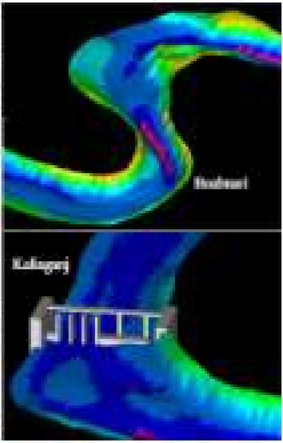
Government of the People's Republic of Bangladesh
Ministry of Water Resources

Bangladesh Water Development Board



CONSULTANCY SERVICES (MATHEMATICAL MODELLING COMPONENT) IN CONNECTION WITH THE PROJECT "FEASIBILITY STUDY FOR SUSTAINABLE RIVER MANAGEMENT IN PANCHAGARH AND THAKURGAON DISTRICTS"

FINAL REPORT

MAY 2024

INSTITUTE OF WATER MODELLING

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EXECUTIVE SUMMARY

Executive Summary

Introduction

Panchagarh and Thakurgaon districts under Rangpur Division, located in the North-Western corner of Bangladesh are characterised by steep catchment slope. Among the 33 rivers flowing through Panchagarh, the Karatoa River is the largest one. Originating from the Jalpaiguri district of India, the river enters Bangladesh through Vojonpur Union, Tetulia and later falls into the Atrai River at Birganj upazila of Dinajpur district. Most of the rivers in Panchagarh district are connected to the Karatoa River. Among the rivers of the district, Talma, Chawai and Dhaimari are transboundary rivers, those originate in India and later fall into the Karatoa River. Bonka and Dahuk are also transboundary rivers, those originate in Bangladesh and later on, enter India. Pathraj is an important river of Panchagarh originates from the lowlands in Boda upazila and later on falls in the Karatoa River. All the rivers experience flood and severe bank erosion due to excessive monsoon rainfall and consequent steep run off. Also, most of these rivers are having morphological changes due to sedimentation resulting changes of river courses and reduced water storage capacity.

Total 13 rivers flow through Thakurgaon district, the rivers are: Tangon, Kulic, Pathraj, Chhoto Dhepa, Shuk, Tirnai, Senua, Chhoto Senua, Vulli, Amon Dhamon, Nona, Lachhi and Nagar Rivers. Among these rivers, Tangon, Kulic and Nagar are transboundary rivers. Originating in Bangladesh, both the Tangon and Kulic Rivers enter India through Bairchuna union of Pirganj Upazila and Baluria union of Haripur upazila of Thakurgaon district.

The characteristics of the rivers of Thakurgaon district are of relatively lower average depth and steeper bed slope. Tangon, Shuk, Lachhi, Nona, Kulic, Pathraj and Vulli rivers are experiencing bank erosion along with sedimentation problem. The water storage capacities of these rivers are decreasing due to sedimentation and thus causing negative impact on the irrigation facilities of the area especially in the dry season. Restoration of the water storage capacity of these rivers have become essential and even should be increased due to growing agricultural and domestic demand.

In view of the above facts, Bangladesh Water Development Board (BWDB) has formulated the study covering all the rivers in Panchagarh and Thakurgaon districts in a holistic approach to devise a sustainable river management plan of the area. The map of the study area is shown in **Figure ES.1**.

This study assessed the hydro-morphological behavior of the study area by using mathematical modelling tool, to devise effective erosion protection plan and increase the water availability of the region. It also analyzed the effectiveness of the plan by simulating the models with and without project conditions in an integrated manner.

Problems in the Study Area

Panchagarh and Thakurgaon districts are characterized by steep catchment slopes. Hence flash flood is a common occurrence in the region. In the recent past, most of the rivers flow has reduced gradually. As the flow of the river got reduced, the regional agriculture, environment and biodiversity have been affected adversely. As the availability of surface water is decreasing, the dependency on the groundwater is increasing. The use of surface water along with lack of groundwater recharge, is decreasing the groundwater level of the region as well.

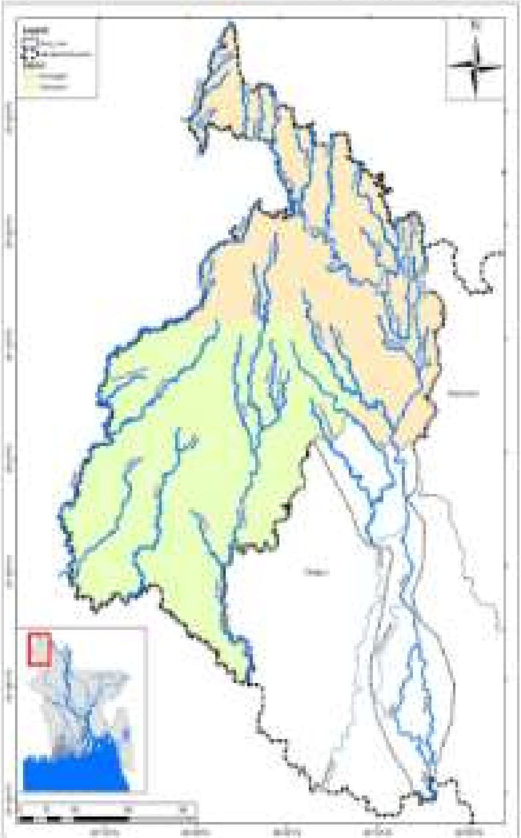

Figure 6.01 Study Area of the project

Under the "Re-excavation program of small rivers, khals and water bodies in 64 District" of the country, lots of rivers in the Panchagarh & Thakurgaon districts have been re-excavated in the last few years. As a result of the re-excavation, the river navigability has got new dimension of life. The canals have been refilled with flowing water and water-holding capacities in small rivers and canals have been increased. Agriculture production is being facilitated by smooth irrigation. The dredging of rivers and canals has reduced waterlogging as well. Along with the improved drainage system, the flooding risk has decreased. Thus, dredging of more rivers could generate similar benefits for those rivers as well in the region.

As mentioned before, the rivers of this region are flashy in nature and possess complex hydrological characteristics than the other rivers of the country. Most of the rivers of the study area originates from India, flows through Bangladesh and subsequently enters India again. As the upstream catchments are hilly areas, the response time of the catchment is very short and sharp rises in the flow hydrographs are often seen whenever rainfall occurs. Besides, the steep riverbed slope means the flood peak takes no time to recede. Hence most of the water drains out quickly. As a result, the water availability during the dry season remains a big problem. BWDB has constructed some Water Control Structures in the Thakurgaon Circle which has been able to retain the surface water and fulfil supplementary irrigation requirements. The water control structures have played an important role in the eco-socio development of the people in the region and the presence of more similar kind of water control structures in Thakurgaon and Panchagarh districts are the demand from the local stakeholders and might be highly beneficial for the people.

Data Collection and Analysis

In order to develop one-dimensional hydrodynamic model and fully dynamic two-dimensional morphological model, extensive data collection, both primary and secondary, were made. The following data were collected:

- Bankline data
- Bathymetry: cross-section data
- Water Level data
- Discharge data
- Bed Material data
- Suspended Sediment data
- Satellite images

Model Development and Applications

Using recent meteorological, hydrometric and hydrographic data collected under this study, one-dimensional and two-dimensional models have been developed.

One-dimensional (1D) hydrodynamic model comprising all the major rivers/khals/channels of the North-West region of Bangladesh has been developed for the study area. With the application of this model, flow distribution through different rivers, channels, khals, etc. in the vicinity of the study area are obtained. This model takes into account rainfall-runoff and flood plain flow. In case of ungauged locations, hydraulic parameters including flows and water levels within the study area and other adjoining rivers are also output of this model. Results of this dedicated 1D model have been used as the boundary conditions of the 2D models developed for the present project.

Several two-dimensional models have been developed using MIKE 21C modelling tool in connection with the present study for the rivers which appears vulnerable to bank erosion. A sample of the developed grid and bathymetry of the 2D models has been shown in **Figure-ES2**. The boundary conditions were taken from the developed 1D Model. The Model has been hydrodynamically calibrated based on the data of that 1D Model as well, while it has been morphologically calibrated based on the measured suspended sediment by IWM in connection of the present project.

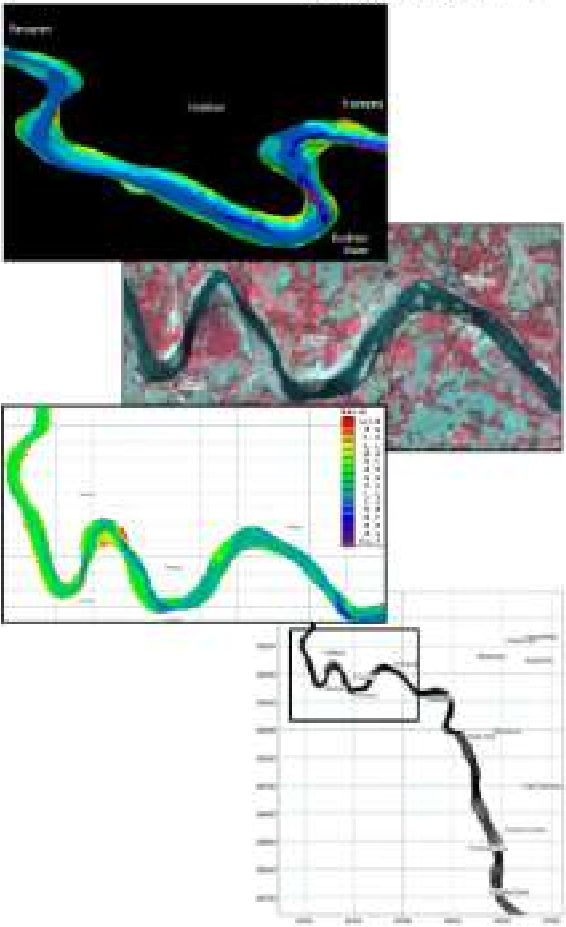

Figure-ES2 Developed 2D Morphological Model of the Karatoa River

The developed two-dimensional model has been used to simulate the morphological changes under present condition and predict the design parameters i.e., design high water level, design discharge, scour levels, scour depth, velocity. The simulated model was also used to predict bank erosion and point out the vulnerable locations within the study area. Morphological model outputs were also used to specify the length of the reach vulnerable due to bank erosion. Finally, models were used to simulate the morphological changes of the river due to the proposed interventions and assess effectiveness of different development options. The outputs of the models aided the planners involved to finalize the intervention for the project.

Proposed Interventions

Considering the Hydro-Morphological scenario and the dynamic nature of the rivers of Panchagarh & Thakurgaon districts, three major intervention components have been proposed from technical point of view. The proposed interventions are:

i. 73.555 km of River Training Works of which 57.310 km is in Panchagarh district and 16.245 km is in Thakurgaon district.
ii. Re-excavation of 37.542 km of river of which 17.542 km is in Panchagarh district and 20.000 km is in Thakurgaon district.

All the recommended interventions, their locations and extents have been shown in **Figure-ES5**.

River Training Works

After conducting detailed satellite image analysis as well as using the state-of-the-art morphological modelling tools, the vulnerable reaches of the study area were identified. After conducting a detailed field visit and with detailed interactions with the officials from BWDB Planning, Design as well as field officials of BWDB and taking their valuable comments and suggestions into consideration, essential 73.555 km River Training Works has been recommended, and designed accordingly. The required length of RTW for each of the rivers have been shown in **Table-ES.1**.

Table-ES.1 Length and number of locations of proposed River Training Works

Sl.	River	District	No.	Length (km)	Priority-1	Priority-2	Priority-3
1	[illegible]	Panchagarh	47	40.885	20.525	[illegible]	[illegible]
2	Chawai	Panchagarh	11	[illegible]	[illegible]	[illegible]	1.610
3	Talma	Panchagarh	9	1.800	[illegible]	0.575	[illegible]
4	Ghoramara	Panchagarh	9	3.940	[illegible]	[illegible]	[illegible]
5	[illegible]	Panchagarh	10	[illegible]	[illegible]	1.590	[illegible]
		Thakurgaon	7	1.835	[illegible]	[illegible]	[illegible]
6	Tangon	Thakurgaon	22	8.460	[illegible]	[illegible]	[illegible]
7	Kulik	Thakurgaon	6	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	Thakurgaon	10	[illegible]	1.710	[illegible]	[illegible]
9	[illegible]	Thakurgaon	1	0.170	[illegible]	[illegible]	0.170
10	[illegible]	Thakurgaon	2	[illegible]	[illegible]	[illegible]	[illegible]
11	Senua	Thakurgaon	1	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	Thakurgaon	3	[illegible]	[illegible]	[illegible]	[illegible]
Total Panchagarh			[illegible]	57.310	33.555	[illegible]	[illegible]
Total Thakurgaon			[illegible]	16.245	[illegible]	[illegible]	[illegible]
Total			138	73.555	37.540	13.280	22.735

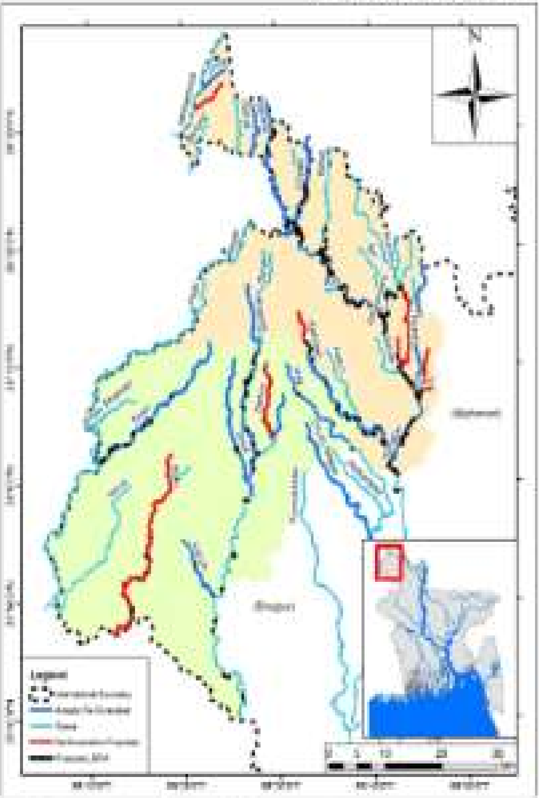

Figure-ES3 Locations of Proposed RTS & river re-excavation

Re-Excavation

Taking into consideration the importance of water storage in the rivers, re-excavation has been proposed for seven rivers in the study area. The rivers which have been proposed for re-excavation along with the proposed re-excavation lengths have been shown in **Table-ES2**.

Table-E33 Proposed re-excavation lengths

Sl	River	District	Length (km)
1	Kulik	Thakurgaon	14.800
2	[illegible]	Panchagarh	3.250
3	[illegible]	Panchagarh	[illegible]
4	[illegible]	Panchagarh	1.800
5	[illegible]	Panchagarh	[illegible]
6	[illegible]	Panchagarh	[illegible]
7	Pathraj	Panchagarh	[illegible]
8	Senua	Thakurgaon	[illegible]
Total Panchagarh			17.042
Total Thakurgaon			[illegible]
Total			**[illegible]**

Combined Water Control Structure

Three Combined water control structures at Kaliaganj, Karatoa; Mohinipur, Tangon and Routnagar, Kulik have been considered in the study. The site map of the tentative location of the combined water control structure at Kaliaganj has been shown in **Figure-E34**. While **Figure-E35** shows the tentative layout of the proposed water control structure at Kaliaganj. Although the combined water control structure over Karatoa river would have some benefits for the now non-functional Boalmari pumphouse, detailed irrigation potential and possible irrigation system of the Karatoa river needs to be assessed properly before construction of the water control structure.

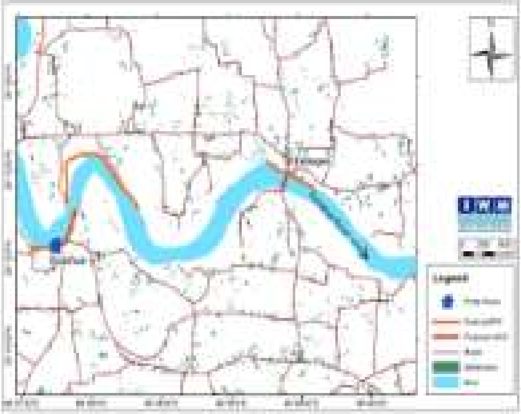

Figure-E34 Tentative Location of the Combined Water Control Structure in Kaliaganj

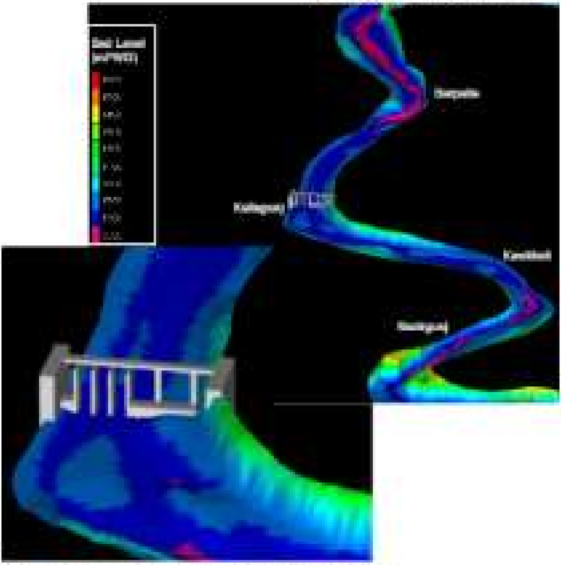

Figure-E.33 Tentative layout of the Water Control Structure at Kaliganj

Sustainable use of river resources

The term "environmental flow requirement" is often described as the "minimum flow" (arbitrarily 10% of the mean annual runoff) in a river, or the "managed flood" and "river flow objective". E-flow is a key contributor to river health, economic development, and poverty alleviation. The outputs from the developed 1D model as well as observed discharge data have been used for calculation of E-flow. However, for determination of E-flow require that flow should not be obstructed / should be undisturbed. The E-flow was taken as an indicator to develop the sustainable river management plan. Dry season water availability of the Karatoa river for the base condition and the proposed water extraction condition vs the environmental flow of the river has been shown in **Figure-E.34**. Based on the analysis, it has been assessed that it is possible to extract 5 cusecs from Ahmed Nagar-1, 4 cusecs from Ahmed Nagar-2, 4 cusecs from Ahmed Nagar-3, 32 cusecs from RB-1 ([illegible]), 64 cusecs from RB-3 ([illegible]) & 64 cusecs from RB-4 ([illegible]) can be extracted from the Karatoa river to ensure "Poor E-Flow" in the Karatoa river.

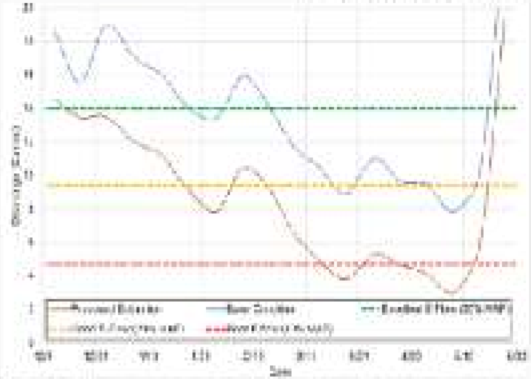

Figure 6.20 Dry season water availability of the [illegible] river for the base condition and the proposed water extraction condition vs the environmental flow of the river

Economic Analysis

The economic indicators are computed for the Project to judge its economic viability. These indicators include Net Present Value (NPV), Benefit Cost Ratio (B/C Ratio) and Economic Internal Rate of Return (EIRR). The analytical results of economic analysis for Priority-1 components of the project are summarized in **Table 6.33**.

Table-6.33 **Results of Base case Economic and Financial Analysis (Lakh BDT)**

Sl no.	Viability Indicator	Result	
		Financial	Economic
1	Capital Cost (Lakh BDT)	[illegible]	[illegible]
2	O&M Cost (Lakh BDT)	1296.41	[illegible]
3	Benefit Cost Ratio (BCR @ 12%)	0.86	1.13
4	Net Present Value (NPV @ 12%) Lakh BDT	-4855.15	5514.14
5	Internal Rate Return (IRR %)	8.90%	12.77%

SUMMARY FINDINGS AND RECOMMENDATIONS

A summary of the study findings has been listed below:

- The study is aimed to make a comprehensive analysis on the rivers of Panchagarh & Thakurgaon districts located in the north-western corner of Bangladesh. Both districts have very steep catchment slopes which results in quick drainage of the water. This results in very high velocity during monsoons, however as the water drains out very quickly, water availability during the lean season also becomes an acute problem in this area.
- With the aid of detailed survey campaign and mathematical modelling technology, the scenarios of different management options of the regions were developed, and

problems were identified. Based on earth observations, reaches vulnerable to erosion were identified and detailed two-dimensional model was used to design the bank protection works of the reaches vulnerable to erosion. A total of 73.555 km of River Training Works of which 57.310 km is in Panchagarh district and 16.245 km is in Thakurgaon district have been proposed to be implemented in 3 phases. The proposed river training works will protect 132.52 ha of lands in Panchagarh district and 46.80 ha of lands of Thakurgaon district. Hence a total of 179.31 ha of land could be protected from riverbank erosion if the proposed Bank Protection Works are constructed.

- A review of the present status of the 60 LLPs (Electric Block) as well as the water availability of the Karatoa river at the LLP block locations have been assessed in this study. Due the Ambari barrage located 22.5km u/s of the Bangladesh-India border on the Karatoa river might be responsible for decreasing water availability in the dry season. It is found that water extraction using the historical pump capacity might not be possible for the LLPs around the Karatoa river without hampering the environmental flow of the river. However, it has been assessed that it is possible to extract 8 cusecs from Ahmed Nagar-1, 4 cusecs from Ahmed Nagar-2, 4 cusecs from Ahmed Nagar-3, 32 cusecs from EB-1 (Boalmari), 64 cusecs from EB-3 (Tepipara) & 64 cusecs from EB-4 (Laxmirharpara), which would allow to irrigate 3841 ha during supplementary irrigation period and 1897 ha during dry season irrigation.
- The local demand of people to construct spurs near Boalmari bazar has also been investigated in the study. However, the challenge in constructing as well as maintaining the spurs is deemed to be too much comparing the benefits it may provide. Hence, it was not recommended to construct the spurs at Boalmari Bazar.
- An alternative of this could be re-excavation of Karatoa river near Boalmari Bazar, however capital dredging is subject to high siltation. It has been estimated that around 70% of re-excavated channel was filled out within one monsoon. While the re-excavation channel was 85% silted up after five seasons. As there is a local demand here to keep the flow northwards for religious reasons, first of all it is important to construct RTW here to stop the flow from going further eastwards and the present practice of yearly excavation may be continued.
- Kulic, Rangapani, Kurum, Dara, Kalidaha, Ronochondi, Pathraj & Sanua rivers were also recommended for re-excavation considering the agricultural potentiality in the region. Re-excavation scenarios were designed in such way that the existing bridges are used as natural humps to store the water behind it. Re-excavation will be carried out to create pockets for water storage regions and the water storage capacity will be increased drastically with the proposed re-excavation scenarios. However, since these rivers are mostly seasonal, they are subject to evaporation & percolation losses, and after considering these losses, most of reservoirs becomes dry by the end of February if no precipitation occurs during the winter seasons. Hence it is not recommended to establish any LLP pump house in these reservoirs. The one reservoir near Umradangi (Kulic River) may have enough water to extract 1 cusec of water which could irrigate 39.42 ha of land during supplementary irrigation period. However, the created reservoirs can be used locally by the people to meet their domestic and agricultural demands. In that case the Kulic River can irrigate 54.83 ha, Rangapani 2.51 ha, Kurum 23.86 ha, Dara 0.20 ha, Kalidaha 13.08 ha, Ronochondi 7.30 ha during supplementary irrigation period. Similar kind of analysis has been carried out for Talma River has well which shows that 16 cusec waters can be withdrawn from the Talma River while still maintaining the E-Flow. This would allow

to irrigate 200 ha during supplementary irrigation period and 50 ha during dry season irrigation using the water of the Talma River.

- To address the issue of water availability in the dry season, two possible combined water control structures were considered in the Karatoa River, with one being in Kalaganj and another one in Laxminarayan. The survey data and model simulation results show that there is enough water available near the BB-4 at Laxminarayan. Hence no water control structure was proposed at Laxminarayan. However, the water depth available near BB-1 at Boalmari was not found to be sufficient under the current condition. Hence, a combined water control structure has been proposed at Kalaganj located 4 km d/s of the BB-1 pump house. The sill level of the structure was fixed using different mathematical model simulations and the structure increased the available water depth near the now non-functional LLP pumphouse at Boalmari bazar. However, comparing to the cost and challenges of construction, the structure does not seem to bear that much benefits. However, a detailed analysis of the irrigational potential of the surrounding area could provide more insights of the surrounding irrigation systems and find out more benefits of the structure. Considering these, Kalaganj water control structure has been placed in lower priority. Re-excavation near the pumphouse could be carried out to ensure required depth for the pump temporarily to make it functional again.
- In Thakurgaon O&M division, DPP has been approved of four water control structures. Two of them are already under construction. The study finds that the structures would have positive impact on the study area, by increasing the water retention and dry season water availability. While the structures do have some benefits during supplementary irrigation period, it would be hard to carry out full-fledged irrigation during boro irrigation with these structures. For example, the dry season flow of the Tangon river would still be a problem for boro season irrigation. But it would be beneficial for supplementary irrigation purposes. For Pathraj river, the created reservoir helps store the water up to May if no water is extracted from it. However, the stored water is not enough for boro season irrigation. But the structure can help provide supplementary irrigation to 42 ha of lands in case of lack of precipitation.
- The effectiveness of the existing water control structures at Basobati, Kaliagaon and Kaspur was evaluated which shows that the weir crest level of the structure is higher than the ground level of the surrounding area. To make the structures more effective, different options were considered and checked. For Basobati structure, re-excavation of the Sanua River afterwards maintaining the water level at 50.15 mMSL (50.61 mPWD) has been proposed. This would allow the structure to store 46087.50 m^3 water upstream of the structure. Similarly, for Kaliagaon & Kaspur structure, it is recommended to maintain the water level at 50.70 mMSL (51.16 mPWD) and 45.30 mMSL (45.76 mPWD) respectively.

The recommendations of the study are described below:

- A total of 73.55km of Bank Protection Works (BPW) at 129 locations among which 57.310km of BPW at 76 locations of Panchagarh district and 16.245 km of BPW at 53 locations of Thakurgaon district have been proposed in 3 phases. In the first phase 31.48km of BPW at Panchagarh district & 5.868 km of BPW at Thakurgaon district has been proposed.
- Re-excavation of 14.60 km of Kulic, 3.35 km of Rangapani, 0.47 km of Kurum, 1.930 km of Dara, 1.765 km of Kalidaha, 3.068 km Ronochondi, 3.80 km of Pathraj river and

0.000 km of Gamua River as per provided design provided along with this report have been proposed.

- Although the water control structure at Kaliaganj, Karatoa river does have benefits, compared to the cost, it is not substantial. However, conducting a detailed analysis of the irrigational potential of the surrounding area could provide more insights of the surrounding irrigation systems and find out more benefits of the structure. Considering these, Kaliaganj water control structure has been placed in lower priority. Re-excavation near the pumphouse could be carried out to ensure required depth for the pump. Considering the significance of northward flow near Boalmari Bazar, the re-excavation of this reach will be required based on requirement under BWDB supervision.
- For effective function of the Balabari water control structure, re-excavation of the Gamua River u/s of the structure and maintaining the water level at 30.15 mMSL (30.51 mPWD) at the structure location is recommended. For the Kaliaganj and Kalapur water control structure, it is recommended to maintain water level 30.70 mMSL (31.10 mPWD) and 40.30 mMSL (40.70 mPWD) respectively.
- **To maintain the "Poor Environmental Flow" of the Karatoa river, maximum 8 cusecs** from Ahmad Nagar-1, 4 cusecs from Ahmad Nagar-2, 4 cusecs from Ahmad Nagar-3, 50 cusecs from BB-1 (Boalmari), 64 cusecs from BB-3 (Taparia) & 64 cusecs from BB-4 (Laxminarayani) can be extracted from the Karatoa River, which would allow to irrigate 3581 ha during supplementary irrigation period and 1097 ha during dry season irrigation. **And to maintain the "E-Flow" of the Talma River maximum 10 cusec of water** can be extracted from the Talma River during dry season. This would allow to irrigate 203 ha during supplementary irrigation period and 80 ha during dry season irrigation using the water of the Talma River.

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ABBREVIATIONS

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
BGB	Border Guard Bangladesh
BPW	Bank Protection Work
BWDB	Bangladesh Water Development Board
CEGIS	Center for Environmental and Geographic Information Services
DPP	Development Project Performa/Proposal
DHI	DHI, Denmark (formerly Danish Hydraulic Institute)
DGPS	Differential Global Positioning System
DFR	Draft Final Report
E-flow	Environmental Flow
EGIS	Environmental and Geographic Information Services
EIA	Environmental Impact Assessment
FAP	Flood Action Plan
GIS	Geographical Information System
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
IWM	Institute of Water Modelling
KM	Kilometer
MIKE 21C	Two-Dimensional Curvilinear Modelling System of DHI
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized difference vegetation index
N/A	Not Available
NWRM	North West Region Model
PWD	Public Works Department
RCP	Representative Concentration Pathway
RTW	River Training Works
SLW	Standard Low Water Level
ToR	Terms of Reference
USGS	United States Geological Survey
WL	Water Level

SECTION ONE

BASIC INFORMATION

1. BASIC INFORMATION

1	Name of the Project	:	Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon Districts
2	(a) Sponsoring Ministry (b) Implementing Agency	: :	Ministry of Water Resources Bangladesh Water Development Board (BWDB)
3	Project Objectives	:	▪ Identify the existing problems related to water resources management and find out no-regret solutions for sustainable development and management of the rivers in Panchagarh and Thakurgaon districts in a holistic approach
4	Estimated Project Cost (Taka in Crore)	:	Total 1679.27 Priority 1 852.76 Priority 2 268.65 Priority 3 557.76
5	Sector & Sub-Sector	:	▪ Water Resources ▪ River Training
6	Project Category (Based on Environmental Conservation Rules 1997)	:	Red Category
7	Project Geographic Location (a) Countrywide (b) Division (c) District	:	 Bangladesh Rangpur Panchagarh, Thakurgaon
8	Project Duration	:	3 Years

SECTION TWO

INTRODUCTION

2 INTRODUCTION

2.1 Background of the Study

Panchagarh and Thakurgaon two districts, under Rangpur Division, located in the North-Western corner of Bangladesh characterized by steep catchment slope.

Panchagarh is the northern most district of Bangladesh and adjacent to Bangladesh India border. There are two beliefs associated with the name of the district. The first is that Panchagarh was named after an area called Pancha Nagari in the kingdom of Pundra Nagar. The second is that it was named for the five forts (or garh) in the region. The forts were Bhitargarh, Hosaingarh, Mirgarh, Rajangarh and Devengarh, hence the name Panchagarh, meaning 'five forts'. During the regime of the British Raj, Panchagarh was a part of the Jalpaiguri district of undivided Bengal. In 1911, Jalpaiguri was fully established as a thana. After the Partition of India and Pakistan in 1947, Panchagarh became a thana under the Thakurgaon mahakuma. On 1 January 1980, it was established as a mahakuma consisting of five thanas. And later, it was established as a district on 1 February 1984.

Among the 33 rivers flowing through Panchagarh, Karatoa River is the largest one. Originating from the Jalpaiguri district of India, the river enters Bangladesh through Vodraswar area of Vojonpur Union under Tetulia upazila of Panchagarh district. Later on, the river falls into Atrai River at Birganj upazila of Dinajpur district. Most of the rivers in Panchagarh district are connected to the Karatoa River. Among the rivers of the district, Talma, Chawai and Ghoramara are transboundary rivers, those originate in India and later fall into the Karatoa River. Barka and Dahuk are also transboundary rivers, those originate in Bangladesh and later on, enter India. Pathraj is an important river of Panchagarh which originates from the Moidon Dighee Beel under Boda upazila and later on falls in the Karatoa River at Sundardighee union in Debiganj upazila. Other rivers of the district are Buri Teesta, Tirnai, Ranochandi, Bering, Pathi, Kurum, Pisani, Chathai, Vulkhal etc. All the rivers experience flood and severe bank erosion due to excessive monsoon rainfall and consequent steep run off. Also, most of these rivers are having morphological changes due to sedimentation resulting changes of river courses and reduced water storage capacity.

These rivers are contributing to different irrigation projects of the area such as Ahmednagar 2.3 Irrigation Project, Talpara Irrigation Project. As a result, sustainable development and management of these rivers has become the key factor for the overall development of the area.

Thakurgaon is located at south-west of Panchagarh, along the Bangladesh-India border at the northern region of Bangladesh. During the British Rule, Thakurgaon was a tehsil (a district sub-division). In 1947 at the time of the Partition of India, Thakurgaon sub-division became part of the newly established Dinajpur District of East Bengal. In 1984 Thakurgaon sub-division was split off from Dinajpur and became a separate district (i.e., Thakurgaon District). Total 13 rivers flow through this district, the rivers are: Tangon, Kulic, Pathraj, Chhoto Dhepa, Shuk, Tirnai, Senua, Chhoto Senua, Yuli, Amon Dhaman, Nona, Lachi and Nagar Rivers.

Among these rivers, Tangon, Kulic and Nagar are transboundary rivers. Originating in Bangladesh, both the Tangon and Kulic Rivers enter India through Bairchuna union of Pirganj Upazila and Baluria union of Haripur upazila of Thakurgaon district. The Nagar River originates in the West Bengal state of India and enters Bangladesh in Panchagarh district. The river flows about 130 km along Bangladesh-India Border in Thakurgaon District, then again enters India. The speciality of Nagar River is that its course, most often indicates the demarcation of Bangladesh-India border.

The characteristics of the rivers of Thakurgaon district are of relatively lower average depth and steeper bed slope. Tangon, Shuk, Lachi, Nona, Nagar, Kulic, Pathraj and Yuli rivers are experiencing bank erosion along with sedimentation problem. The water storage capacities of these rivers are decreasing due to sedimentation and thus causing negative impact on the irrigation facilities of the area especially in the dry season. The Tangon Barrage Irrigation Project, Burifeash Irrigation Project, Vuli Irrigation Project and Rahimanpur FCDI Project are totally dependent on these rivers. Therefore, restoration of the water storage capacity of these rivers have become essential and even should be increased. The existing flood embankment along the left bank of the Nagar River has also been damaged due to lack of maintenance and bank erosion. The embankment is very important as is used by the Border Guard of Bangladesh (BGB) for their regular patrol to safeguard the border. The erosion protection of the rivers along the borders are very important for the sovereignty of the country.

In view of the above facts, Bangladesh Water Development Board (BWDB) has formulated study covering all the rivers in Panchagarh and Thakurgaon district in a holistic approach to device a sustainable river management plan of the area. The map of the study area is shown in **Figure 2.1**.

2.2 Rationale for Mathematical Modelling Study

Assessment for construction of any hydraulic structures on rivers are complex and need comprehensive review of the related aspects in a scientific manner. However, well intended decision-makers need both theoretical and practical frameworks in advance within which, it is possible to consider whether, the project would be totally a successful one or not. The rivers behave in different manners from their usual courses, when they are subjected to any kind of obstruction or intervention like bank protection works, flood control structures, guide bund, abutments etc. During planning & design, implementation and post construction stages of the bank protection and flood control structures, suitable mitigation measures for any adverse situation is required. At the pre-construction phase, it is also necessary to take decision regarding the suitable locations for protection works and with minimal adverse effect on the riverine environment. The analysis and interpretation of model simulated outputs with various interventions would guide the design engineer for safe and economic design of the proposed works.

2.3 Contract Awarding

Institute of Water Modelling (IWM) has been entrusted by Bangladesh Water Development Board (BWDB) to conduct a detailed hydrological and morphological study for the "Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon Districts". In this regard a contract agreement was signed between BWDB and IWM, for this study, on 03rd January 2023.

2.4 Objective

The main objective of the study is to identify all existing problems related to water resources management and find out no-regret solutions for sustainable development and management of the rivers in Panchagarh and Thakurgaon districts in a holistic approach.

The specific objectives of the study are:

- Flood and erosion risk management of rivers within the project area.
- Improvement of water storage capacity of the rivers within the project area.
- Design of proposed interventions.

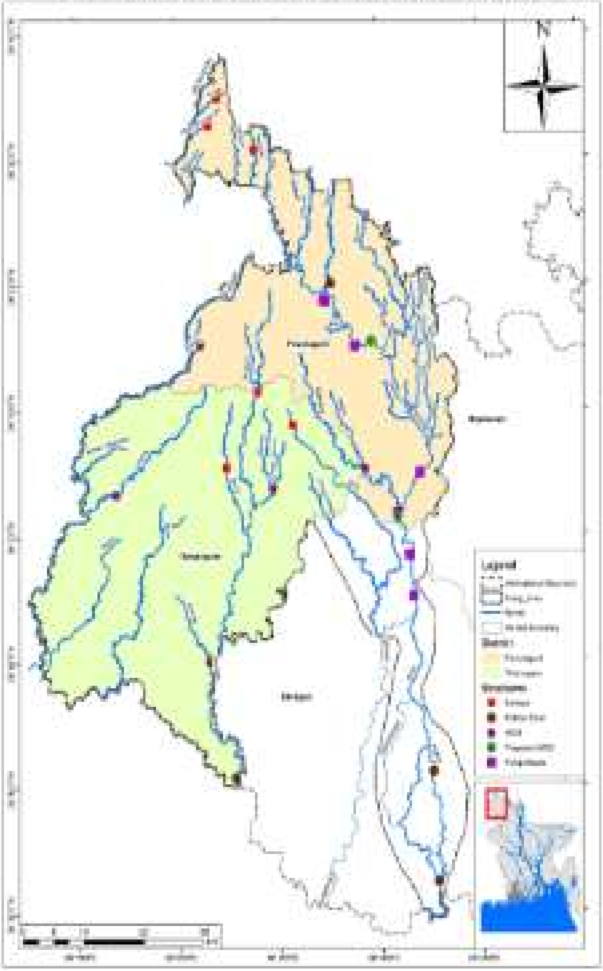

Figure 1-1 Study area map

- Environmental and Social Impact Assessment.
- Assist in preparation of DPP of subsequent investment project.

2.5 Scope of Work

- Collection and review of existing data, maps, information and relevant available study, technical and project reports including study reports/ projects on wetlands in the study sites;
- Bathymetric and cross sectional survey of the selected reaches of the concerned river as per requirement of the morphological study;
- Primary data collection on water level, discharge and sediment concentration, bed material and existing bankline;
- Identification of historical erosion trend and extent of erosion prone/vulnerable locations of the study rivers.
- Determination of Environmental flow of study rivers.
- Propose water level, Bed slope, discharge etc. of the study rivers on the basis of survey and historical data analysis.
- Preparation of Area Elevation Curve for the basin of the study rivers;
- Application of appropriate one-dimensional (1D) and two-dimensional (2D) model for :
  - hydrological, hydraulic and morphological analysis of the study rivers;
  - identification of the vulnerable locations from the base model (without proposed measure condition);
  - assess the river bank protection strategy and test its performance in terms of erosion restrain and sustainability;
  - investigation of alternative options to mitigate the erosion process such as dredging of existing islands/sand bars should be established using model results;
  - analysis of the impact of the existing and proposed interventions on the hydro-morphological aspects of the river;
  - Preparation of flood inundation map showing the extent and depth of inundation;
  - Assessment of long term impacts of surface water retention on groundwater recharge through development of integrated surface water–groundwater interaction model.
  - Calculation of surface water resource and sediment load balance at key locations (with and without proposed measure condition);
- Preparation of detailed engineering design & drawing of proposed interventions (bank protection work, flood embankment re-sectioning and new construction), regulators, drainage canals, water retention structures etc.) and recommendation on hydraulic design parameters of the protective measure(s). Climate Change impact should be incorporated in the design of flood embankment.
- **Necessary soil boring and data analysis (c, Φ, liquid limit, plastic limit etc.) regarding** structures, embankment and protection work (for embankment : 1 boring/km, for protective work : 2 boring/km in which 1 in bank and 1 in L.W.L; for structure : minimum 3 boring)
- Preparation of dredged material management plan in consultation with local stakeholders.
- Plan for afforestation and exploration/development of park/ walkway for recreational purposes along bank protection works;
- Estimation of cost and financial & economic analysis i.e. Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) of proposed intervention;
- Conduction of job training of BWDB officials to share the application process of developed models.
- Arrangement of workshop to disseminate study outputs.
- Submission of reports including above findings.

2.6 Outputs

The followings are the outputs of the study:

- Base map, project map with inventory of existing structures and flood inundation map, Area Elevation Curve.
- Identified critical locations affected by bank erosion and silted reaches within the river requiring protective work for erosion control.
- Recommendation on the dredging, locations and type of water retention structures, bank protective measures to protect vulnerable riverbanks and flood control embankment at selected reaches.
- Analysis of the probability of water reservoir for feeding the study rivers during dry season.
- Water level, bed slope, discharge, environmental flow etc. of the study rivers.
- Maximum depth of scour and flow velocity at or along suggested riverbank protective works.
- Analysis of soil data.
- Monitoring plan to safeguard threatened banks.
- Detailed design and drawings of water retention structures, bank protective works and flood embankment.
- Cost estimate of proposed interventions.
- Adverse impact (if any) on bank erosion and flooding situation or afflux at the upstream or downstream of the study area due to construction of the interventions.
- Recommendation on the impacts of climate change due to implementation of the project.

2.7 Approach and Methodology

To fulfil the objective of the project, specific approach and methodology with the aid of mathematical-morphological modeling supported by primary/secondary data analysis has been adopted.

The hydrology, hydraulics and morphology of the river system of Panchagarh & Thakurgaon has been assessed based on available historical data, and data/information collected from field survey and hydrometric observation. A survey team had been mobilized to the field for conducting the survey soon after commencement of the study. All the collected data has been analyzed for the requirement of determining model inputs and gaining understanding of the existing hydrological, hydraulic and morphological conditions of the study area. A software, namely MIKE EVA (of DHI, Denmark) had been used for statistical analysis of flow discharge and water level data. Planform analysis has been carried out with the help of past series of satellite imageries for better understanding of the river planform dynamics. Based on the field information and secondary data analysis, 33 rivers in Panchagarh and 18 rivers in Thakurgaon were identified. The rivers of Panchagarh and Thakurgaon districts have been shown in **Table 2.1**. The total length of rivers in the Panchagarh and Thakurgaon districts have been identified as 1123 km.

Considering complexity of the entire process, a comprehensive one-dimensional and two-dimensional model has been setup using appropriate suite of modelling tools, namely MIKE 11 and MIKE 21C. Detailed satellite image analysis has been made, that gave the indication of the vulnerability of bank erosion of the rivers of the study area. Detailed two-dimensional morphological models were set up using the surveyed data for the rivers where bank erosion was identified from the data analysis to provide the exact extent of erosion as well as help devise the design parameters for the bank protection works.

Overall approach, which has been followed to achieve the expected outputs, is shown in **Figure 2.2**.

Table 2.1 The Rivers in Panchagarh & Thakurgaon Districts

Sl No.	ID	River	District	Type of River	Length (km)	Max Discharge (Cumec)	Dry Season Flow (90 Day 10th Dependable flow)	Bed Slope (cm/km)
1	-	Aulikhal	Panchagarh	Ephemeral	9.3	19.43	0	37.30
2	-	Alsai Dhepa	Thakurgaon	Ephemeral	19.4	28.05	0	23.77
3	WR87	[illegible]	Panchagarh	Ephemeral	7.5	12.24	0	108.12
4	WR86	Bodha	Panchagarh	Ephemeral	8.5	15.44	0	34.46
5	WR53	Buri Teesta	Panchagarh	Ephemeral	44	68.54	0	33.66
6	WR39	Chawai	Panchagarh	Perennial	55.8	219.83	4.31	17.88
7	WR47	Choto Dhepa	Thakurgaon, Dinajpur	Ephemeral	60.3	196.23	0	11.20
8	WR77	Choto Senua	Thakurgaon	Ephemeral	9.6	51.86	0	78.35
9	WR49	Dahuk	Panchagarh	Perennial	12.75	165.89	0.21	55.57
10	-	Deo	Panchagarh	Ephemeral	3.8	8.22	0	44.38
11	WR27	Ghoramara	Panchagarh	Ephemeral	11.6	108.88	3.05	18.75
12	WR33	Gobra	Panchagarh	Ephemeral	4.7	18.81	0	71.77
13	-	Horai	Panchagarh	Ephemeral	18.7	27.71	0	38.38
14	-	Kalidaha	Panchagarh	Ephemeral	3	21.80	0	25.11
15	WR13	Karatoa-Atrai	Panchagarh, Dinajpur	Perennial	78.11	1351.73	7.41	15.35 (Upto Khansama)
16	-	Kathi	Dinajpur	Ephemeral	25.7	303.20	0	23.38
17	WR23	Kulik	Thakurgaon	Ephemeral	29.8	144.8	0	19.09
18	WR21	Kurum	Panchagarh	Ephemeral	20.4	88.15	0	37.34
19	-	Kuruj	Panchagarh	Ephemeral	16.3	22.27	0	58.47
20	-	Lachhi	Thakurgaon	Ephemeral	15.3	11.39	0	31.45
21	WR60	Mahananda	Panchagarh	Ephemeral	27.8	227.18	0	40.55
22	WR22	Nagar	Panchagarh, Thakurgaon	Perennial	108.2	-	-	31.70
23	WR123	Noha	Thakurgaon	Ephemeral	18	58.88	0	18.00
24	-	Pangga	Panchagarh	Ephemeral	11.8	-	-	-
25	WR71	Pathraj	Panchagarh, Thakurgaon	Perennial	59.7	188.21	0	37.60
26	WR73	Pathi	Panchagarh	Ephemeral	8.5	7.87	0	64.60
27	-	Sui	Panchagarh	Ephemeral	4.5	21.76	0	115.90
28	-	Rangapani	Panchagarh	Ephemeral	7	16.20	0	68.57
29	WR133	[illegible]	Panchagarh	Ephemeral	5.5	7.07	0	79.66
30	-	[illegible]	Panchagarh	Ephemeral	15.5	21.07	0	80.13
31	-	[illegible]	Panchagarh	Ephemeral	2.8	-	0	71.00
32	WR44	Talma	Panchagarh	Ephemeral	13.3	22.34	0	38.66

33	NW113	Senua	Thakurgaon	Ephemeral	20.7	87.20	0	18.20
34	NW115	Shuk	Thakurgaon	Ephemeral	27.7	24.60	0	28.28
35	NW111	Sui	Panchagarh	Ephemeral	13.3	75.50	0	67.20
36	NW21	Talma	Panchagarh	Perennial	27.1	110.70	1.83	16.50
37	NW46	Tangon	Panchagarh, Thakurgaon	Perennial	136	608.77	6.75	25.20
38	NW51	Tirnai	Thakurgaon	Perennial	60.3	88.20	3.4	18.20
39	NW50	Tirnai	Panchagarh	Ephemeral	7.5	38.80	0	24.78
40	NW53	Versha	Panchagarh	Perennial	13.6	38.50	8.65	75.77
41	NW52	Kulik	Panchagarh, Thakurgaon	Ephemeral	20.1	196.77	0	12.75
42	-	Pathraj	Panchagarh	Ephemeral	5.7	100.60	0	

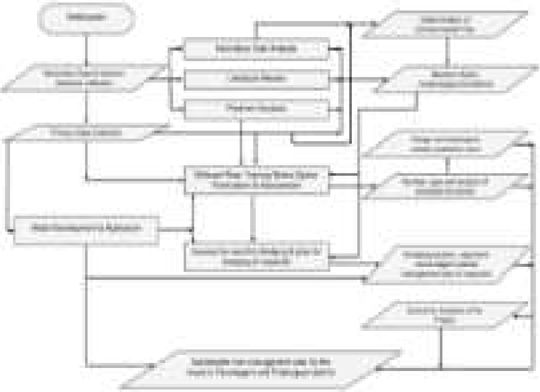
Sustainable river management plan for the rivers in Panchagarh and Thakurgaon districts

Figure 2.2 Flow chart showing Study Approach

2.7.1 Secondary Data Collection

Secondary data were collected from different sources, including BWDB, IWM Archive, USGS, ESA, etc. These data have been analysed to understand the hydrological condition of the study area, to utilize in model set up, and in interpretation of the model results. Inventory of the collected data, which have been used in this study, from secondary sources are listed in **Table 2.3**. While **Figure 2.5** shows the location of the water level and rainfall gauges. The main objectives of secondary data collection from available sources are to acquire knowledge about hydrological and morphological characteristics of the concerned rivers/channels, and to analyse historical data for selecting return periods of required hydrological events.

Table 2.2: Secondary Data Inventory

Data Type	River	Location	Data Coverage	Collected from
Discharge	Karatoa	[illegible]	[illegible]	BWDB, IWM
		Panchagarh	[illegible]	
	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	
	Tangon	Thakurgaon	[illegible]	
	Tangon	[illegible]	[illegible]	
	Nagar	[illegible]	[illegible]	
Water Level	Karatoa	[illegible]	[illegible]	
		Panchagarh	[illegible]	
		Debiganj	[illegible]	
		[illegible]	[illegible]	
		[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible]	
	Tangon	[illegible]	[illegible]	
		Thakurgaon	[illegible]	
		[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]	[illegible]	
	Nagar	[illegible]	[illegible]	
Satellite Image	-	-	[illegible]	USGS, ESA

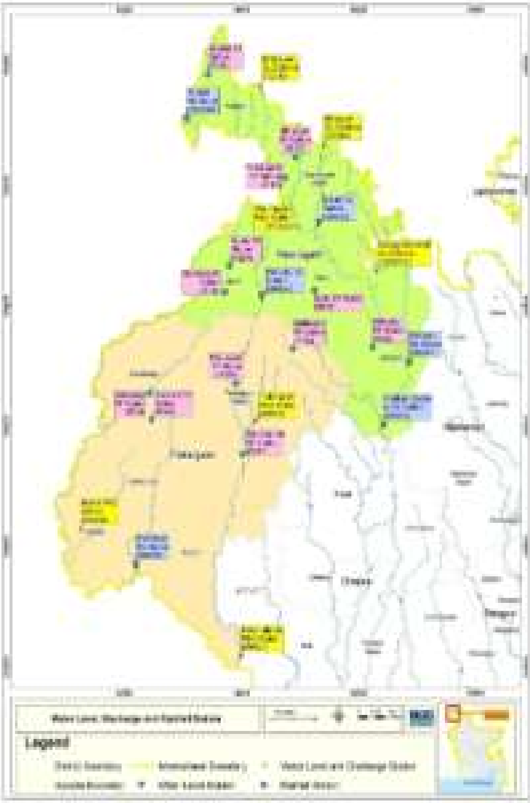

Figure 2.3 BWDB Water Level, Discharge & Rainfall Stations in the study area

2.7.2 Primary Data Collection

The field data campaign of the project was carried out from January 2023 to July 2023. The field data collection includes water level monitoring, flow measurements, bathymetric surveys, cross-section survey, bankline survey, suspended sediment concentration measurement and river bed material sampling. The summary of survey activities is given in

Table 2.3. The Water level gauge locations, discharge measuring location and Sediment sampling location in the study area has been shown in **Figure 2.4**.

Table 2.3: Collected Primary Data

Sl. No.	Item	Unit	Quantity
1	Bathymetric Survey for major rivers	Nos.	4103
2	Cross-section survey		
3	Surface Water Level Measurement (6 locations)	Nos.	6
4	Discharge Measurement	Nos.	52
5	Bed Material Sampling and Analysis	Nos.	20
6	Suspended Sediment Sampling and Analysis	Nos.	105
7	Baseline Survey	km	700

Water Level

Water level has been measured at six locations using manual gauges, with two being at the Karatoa River, one at Talma, Ghoramara, Pathraj and Kulik River from February 2023 to July 2023. The locations of these water level measuring stations are shown in **Figure 2.4**.

Measured water level data has shown in **Figure 2.5**, **Figure 2.6**, **Figure 2.7**, **Figure 2.8** and **Figure 2.9**. **Figure 2.5** shows the water level gauge data of the Karatoa River at Kaliaganj and Laxmirhat. **Figure 2.6**, **Figure 2.7**, **Figure 2.8** and **Figure 2.9** shows the water level gauge data at Talma Bazar (Talma River), Jugighat (Ghoramara River), Bodo (Pathraj River) and Ramsankail (Kulik River).

Discharge

Non-Tidal discharge measurement at 9 locations, a total of 52 non-tidal discharge at 9 locations has been carried out. Although based on ToR, a total of 24 discharge at 6 locations was supposed to be carried out, for collection of dry season as well as monsoon season data. The values of the discharge measurements are shown in **Table 2.4**.

Bed Sediment Sample

20 Bed Sediment sampling has been carried out at different locations of the study area. The details of the bed sediment sampling for the collected samples have been shown in **Table 2.5**.

Suspended Sediment Sample

Suspended Sediment measurement has been carried out during each cycle of the non-tidal discharge measurement. The location of the suspended sediment measurement corresponds to the location of non-tidal discharge measurement location and has been shown in **Figure 2.4**. In total 105 number of suspended sediment samples have been collected in this project and the details of the suspended sediment concentration for the collected samples have been shown in **Table 2.6**.

Bathymetry & Cross-Sectional Survey

Bathymetry data of the rivers in the study area has been collected during January 2023 to August 2023. The topographic survey of the chars in the study area has been carried out as well. The long profile of the surveyed rivers has been shown in **Figure 2.10** to **Figure 2.41**.

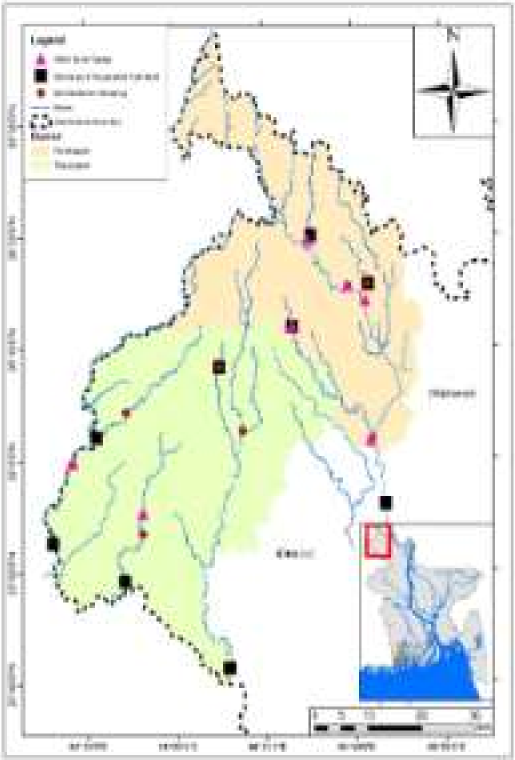

Figure 2.4 Location of Water level gauges, discharge measuring and Sediment sampling in the study area

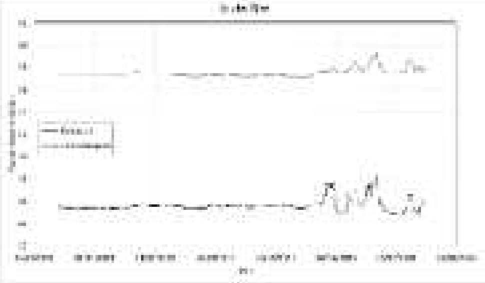

Figure 2.5 Measured Water Level Data for Karatoa River

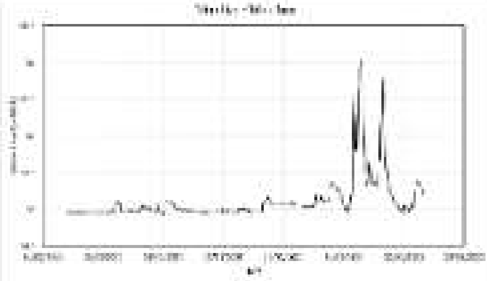

Figure 2.6 Measured Water Level Data for Talma River at Talma Bazar

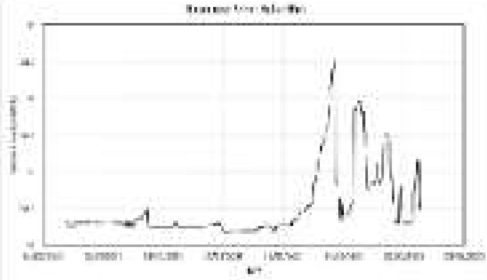

Figure 2.7 Measured Water Level Data for Dhepamara River at Jagdal Ghat

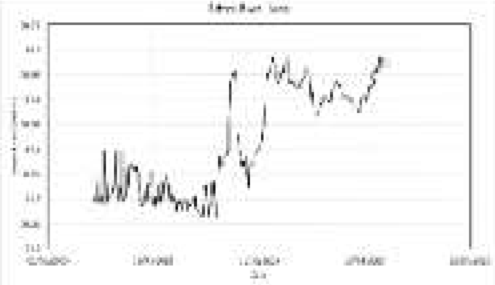

Figure 2.8 Measured Water Level Data for Pathraj River at Boda

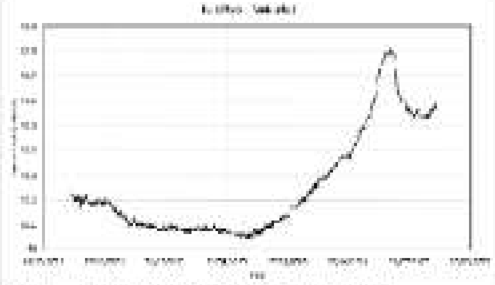

Figure 2.9 Measured Water Level Data for Kulik River at Ranisankail

Table 2.9 Measured Discharge Data

River	Location	Date	Discharge (cumec)	Velocity (m/s)
Atrai	Shamsherpara	20/02/2023	5.950	0.131
		30/03/2023	14.552	0.152
		18/04/2023	13.718	0.147
		14/05/2023	11.409	0.131
		13/06/2023	1.946	0.271
		15/07/2023	185.34	0.204
Tangon	Kantibhita	09/02/2023	2.230	0.151
		29/03/2023	2.481	[illegible]
		17/04/2023	2.447	[illegible]
		16/05/2023	1.215	0.038
		12/06/2023	0.000	0.000
		16/07/2023	121.268	0.145
Nagar	Bodah	08/02/2023	15.827	0.358
		29/03/2023	11.426	0.229
		17/04/2023	15.447	0.281
		16/05/2023	10.211	0.252
		14/06/2023	4.130	0.461
		17/07/2023	64.132	0.463
Kulik	Bhulliganj	08/02/2023	5.128	0.080
		28/03/2023	0.064	0.420
		17/04/2023	0.130	0.028
		16/05/2023	0.000	0.000
		14/06/2023	0.000	0.000
		17/07/2023	6.467	0.261
Talma	Debiganj	07/02/2023	0.000	0.046
		29/03/2023	1.314	0.075
		15/04/2023	4.000	0.100
		14/05/2023	7.230	0.188
		11/06/2023	5.944	0.301
Chhotojamuna	Mallickganj	07/02/2023	4.322	0.150
		28/03/2023	2.204	0.427
		16/04/2023	3.875	0.088
		13/05/2023	2.380	0.308
		11/06/2023	2.807	0.440
		16/07/2023	38.139	0.479
Pathraj	Bhola Bazar	07/02/2023	1.950	0.148
		28/03/2023	0.385	0.024
		16/04/2023	0.394	0.077
		14/05/2023	0.007	0.010
		11/06/2023	0.000	0.000
Tirnoi	Jagdal Bazar	08/02/2023	1.880	0.420
		28/03/2023	0.085	0.51
		17/04/2023	0.157	0.012
		15/05/2023	1.439	0.080
		12/06/2023	0.408	0.138
		17/07/2023	3.378	0.262
Bhulli	Atwari Road	07/02/2023	5.128	0.428
		28/03/2023	1.375	0.805
		16/04/2023	1.875	0.172
		11/05/2023	0.000	0.000
		12/06/2023	0.000	0.000
		17/07/2023	30.05	0.880

Table 2.3 Measured Bed Sediment Sample Data

River	Location	Bank	D50 (mm)	D90 (mm)
Nagar	[illegible]	CL	0.345	0.713
Tangon	Thakurgaon	LB	0.424	0.88
		CL	0.422	0.878
		RB	0.376	0.785
Pathraj	Boda	LB	0.337	0.68
		CL	0.378	0.754
		RB	0.379	0.756
Karatoa	Kaligonj	LB	0.328	0.707
		CL	0.128	0.243
	[illegible]	LB	0.152	0.327
		CL	0.4	0.807
	Chandanbari	LB	0.521	1.059
		CL	0.34	0.652
		RB	0.33	0.768
Tirnai	[illegible]	LB	0.364	0.77
		CL	0.378	0.787
		RB	0.375	0.815
Kulik	[illegible]	LB	0.177	0.457
		CL	0.452	0.88
Bhulli	[illegible]	CL	0.193	0.358

[illegible]

[illegible] [illegible]

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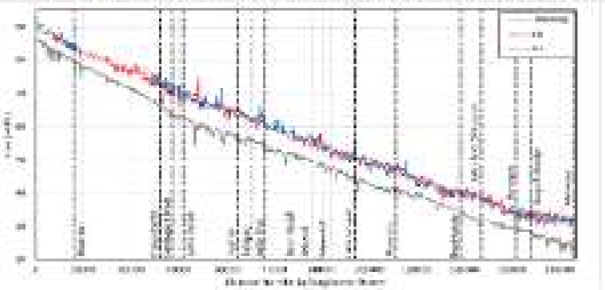

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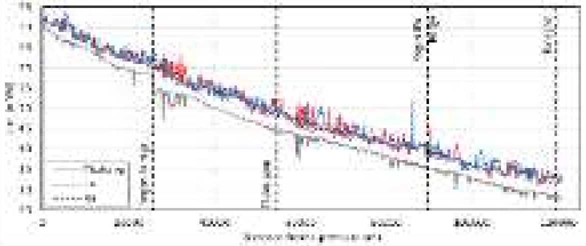

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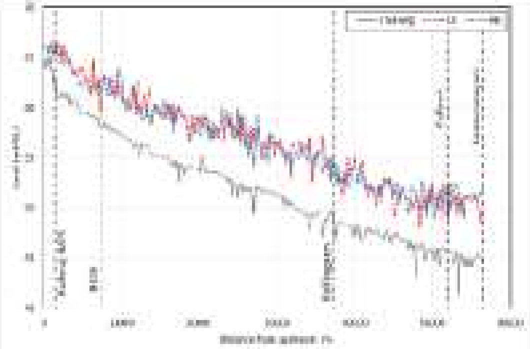

Figure 3.32: Long Profile of Pathraj River

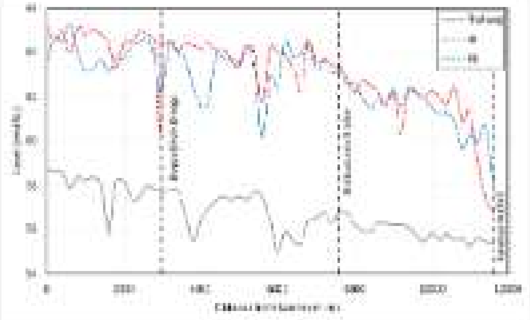

Figure 3.33: Long Profile of [illegible] River

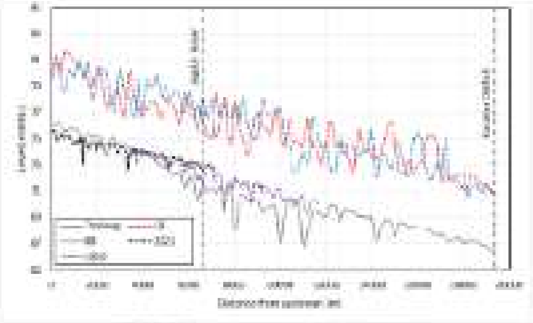

Figure 2.[illegible]: Long Profile of [illegible] River surveyed in [illegible]

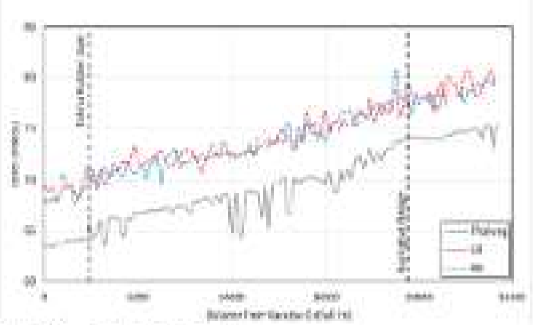

Figure 2.[illegible]: Long Profile of [illegible] River

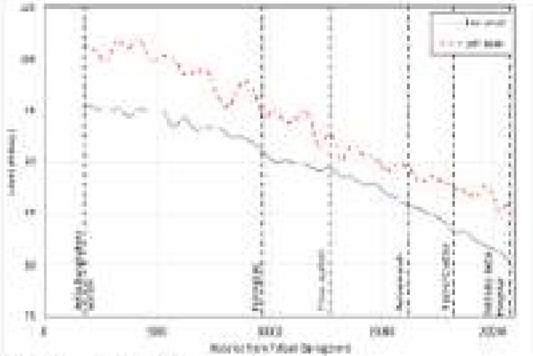

Figure 2.16: Long Profile of Mahananda River

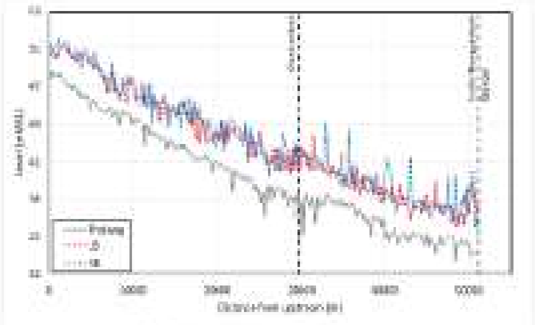

Figure 2.17: Long Profile of Bhulli River

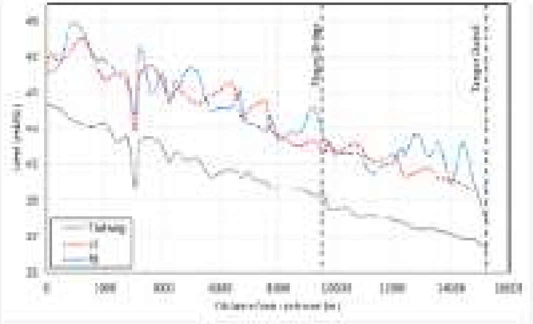

Figure 2.18: Long Profile of Lachhi River

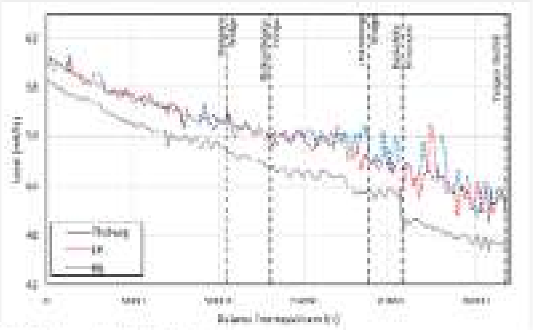

Figure 2.19: Long Profile of Sengua River

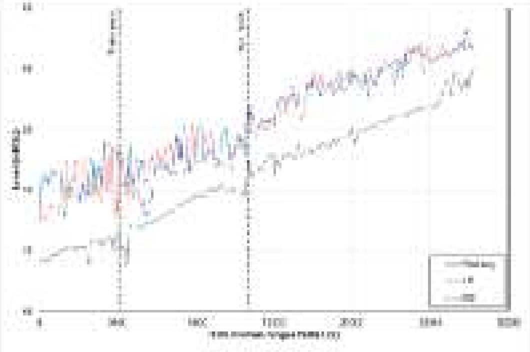

Figure 2.20: Long Profile of [illegible] River

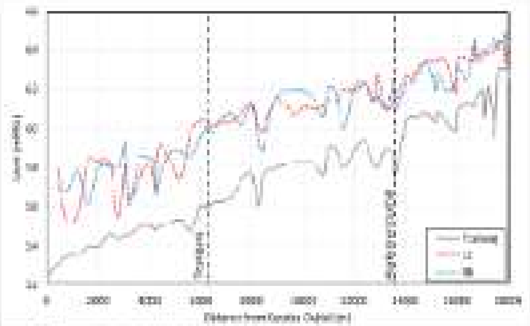

Figure 2.21: Long Profile of [illegible] River

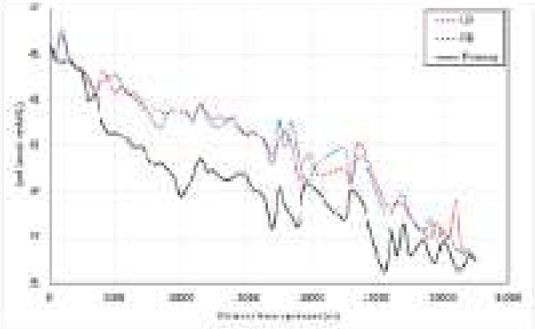

Figure 2.22: Long Profile of Nagar River

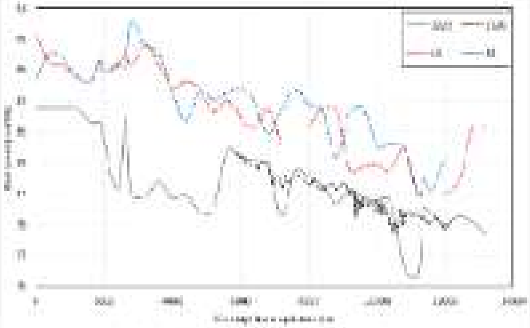

Figure 2.23: Long Profile of [illegible] River Surveyed in 2013 & 2020

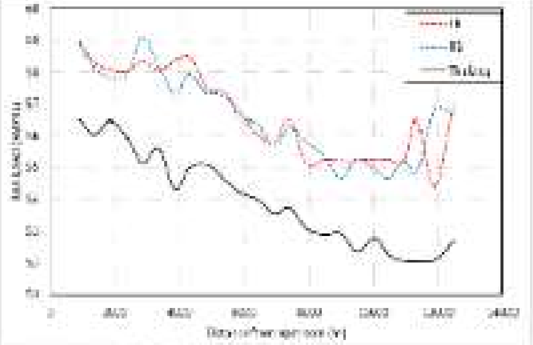

Figure 2.24: Long Profile of [illegible] River

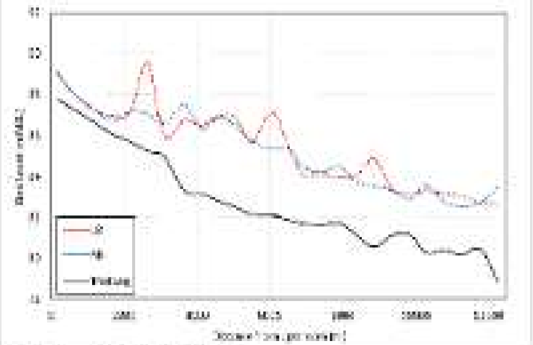

Figure 2.25: Long Profile of [illegible] River

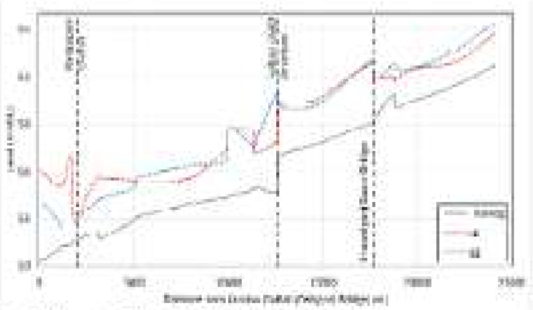

Figure 2.26 Long Profile of Buri Teesta River

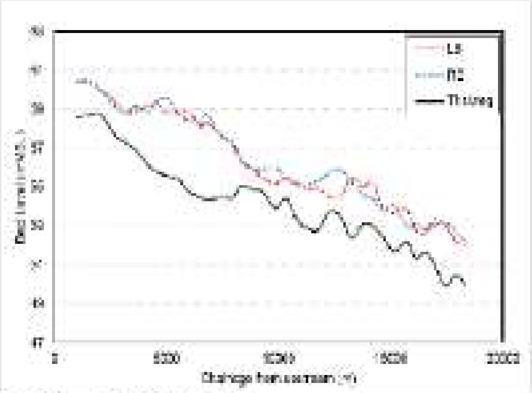

Figure 2.27 Long Profile of Nagor River

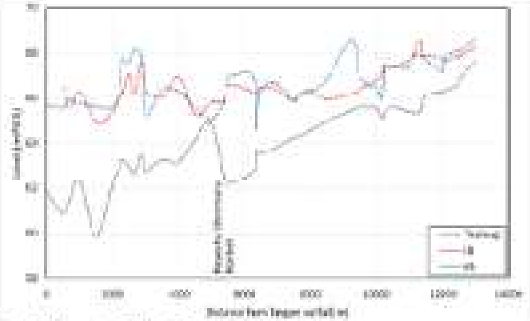

Figure 2.28: Long Profile of [illegible] River

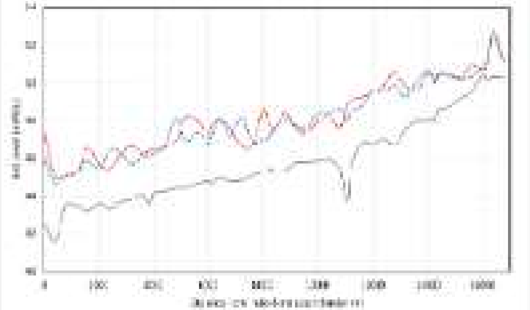

Figure 2.29: Long Profile of [illegible] River

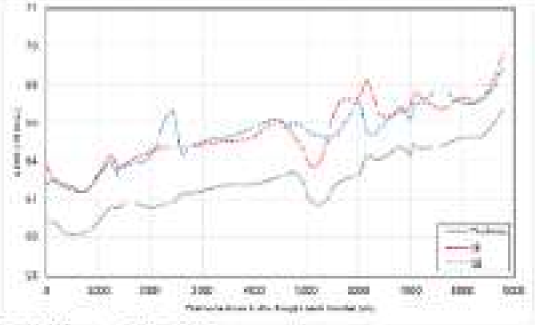

Figure 2.30: Long Profile of [illegible] River

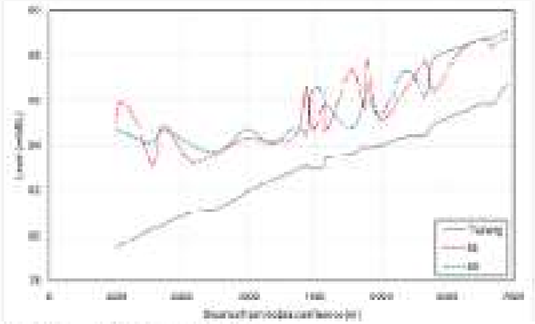

Figure 2.31: Long Profile of [illegible] River

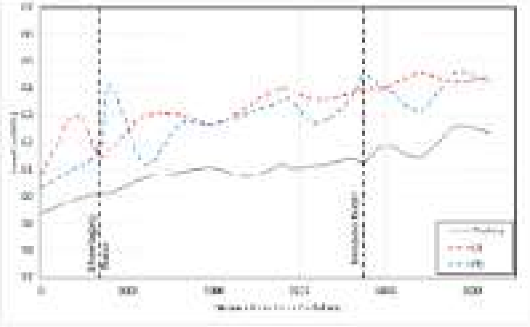

Figure 2.22: Long Profile of [illegible] River

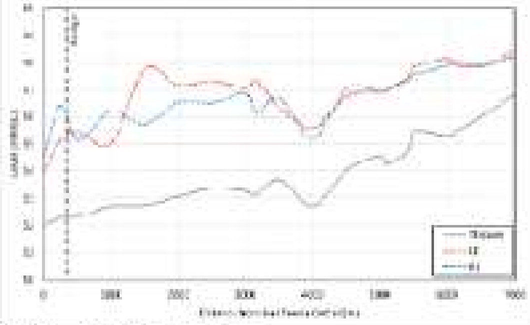

Figure 2.23: Long Profile of [illegible] River

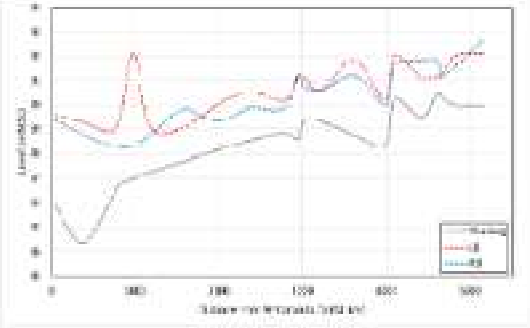

Figure 2.34: Long Profile of [illegible] River

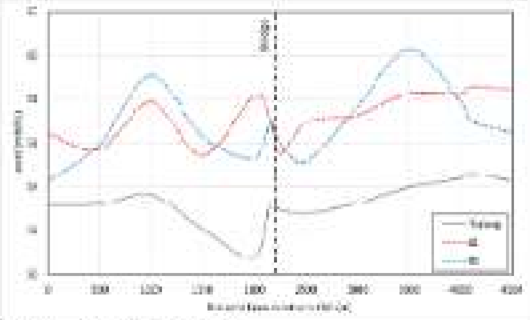

Figure 2.35: Long Profile of [illegible] River

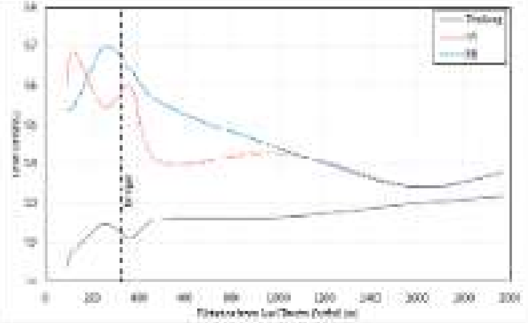

Figure 2.36: Long Profile of [illegible] River

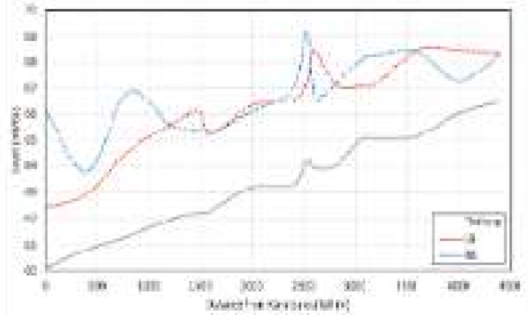

Figure 2.37: Long Profile of [illegible] River

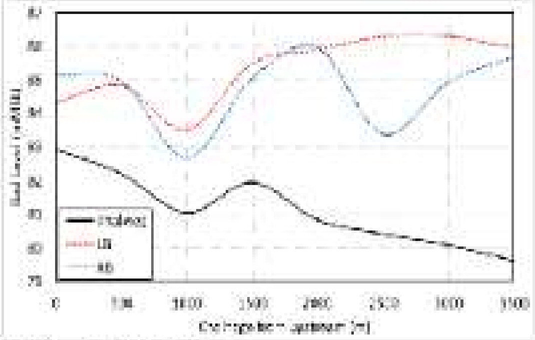

Figure 2.34: Long Profile of [illegible] River

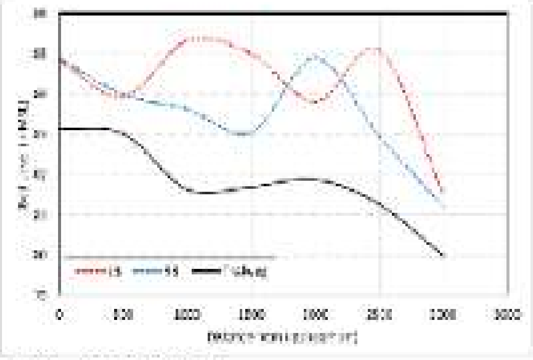

Figure 2.35: Long Profile of [illegible] River

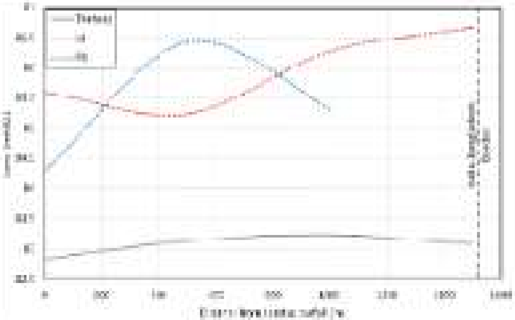

Figure 2.40: Long Profile of Sao River

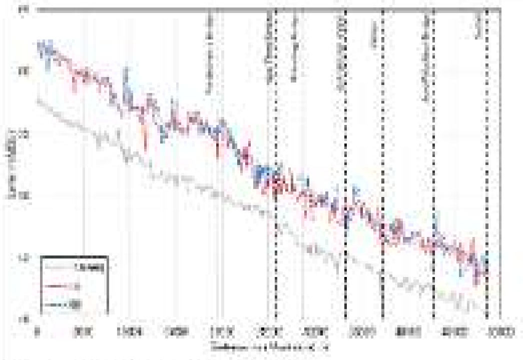

Figure 2.41: Long Profile of Tirnai River (Thakurgaon)

Bench Marks

The list of the bench marks used in the survey has been show in **Table 2.7**.

Table 2.7: Bench Marks and Temporary Bench Marks used for the Survey

SL	ID	Remarks	X	Y	RL
1	BM-715	The pillar is situated in the compound of Amzad Govt. Primary School and south	[illegible]	[illegible]	[illegible]

Sl	ID	Remarks	X	Y	RL
		from Dinajpur-Bogra road, Vill. [illegible], Upazila: Chirirbandar.			
2	SW26 SL-[illegible]	[illegible] ghat	[illegible]	[illegible]	32.[illegible]
3	BM-[illegible]	The pillar is situated in the south-east corner of Md. [illegible]'s rice mill. Vill. [illegible], Upazila: Chirirbandar, District: Dinajpur.	[illegible]	[illegible]	**32.[illegible]**
4	BM-[illegible]	The pillar is situated in the south-east corner of the Rajapukur Girl's Madrasha. It is east side of Dinajpur -Bogra road, Vill. Rajapukur.	[illegible]	[illegible]	34.7[illegible]
5	BM-[illegible]	The pillar is situated in the north-west corner of Chakdaspur (Rajbari) [illegible] Madrasha. It is about 78m south from Dinajpur- Rangpur road, Village Chakdaspur.	[illegible]	[illegible]	[illegible]
6	BM-[illegible]	The Pillar is situated at the south-east corner of [illegible] high school and [illegible] south from Parbatipur - Dinajpur road.	[illegible]	[illegible]	[illegible]
7	SW20 SL-[illegible]	[illegible]	[illegible]	[illegible]	40.[illegible]
8	BM [illegible]	The pillar is situated in north of Khansama College and 450m south from Khansama market. It is north edge of a road and south of Dak- Bungalow.	[illegible]	[illegible]	**47.[illegible]**
9	SW20 SL-[illegible]	Khansama	[illegible]	[illegible]	40.4[illegible]
10	[illegible]	The pillar is situated in the compound of Debiganj Upazila Parishad, Vill. Debiganj, Upazila: Debiganj, Dist. Panchagarh.	[illegible]	[illegible]	**57.[illegible]**
11	SW20 SL-[illegible]	Debiganj	[illegible]	[illegible]	57.[illegible]
12	SW20 SL-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	GTS-[illegible]	The pillar is situated in the south-east corner of playground of [illegible] High School. It is 18m south from east side building. Vill. [illegible].	[illegible]	[illegible]	[illegible]
14	GTS [illegible]	The pillar is situated infront of U.N.O. office at Tetulia. It is south of the Shahid Minar and north bank of a pond. Vill. Tetulia, Upazila: Tetulia, Dist. Panchagarh.	[illegible]	[illegible]	**[illegible]**
15	SW20 SL-[illegible]	[illegible] Tetulia	[illegible]	[illegible]	[illegible]
16	SWM TBM-[illegible]	Kept on the wing wall railing base o/s culvert Vill. [illegible], Ps-[illegible], Dist-Thakurgaon	[illegible]	[illegible]	45.1[illegible]
17	TBM [illegible]-01	Railing Base Top [illegible] P.S.Pirganj,Dis: Thakurgaon	[illegible]	[illegible]	47.[illegible]
18	TBM [illegible]-02	Kept on the wing wall top P.S.Pirganj,Dis: Thakurgaon	[illegible]	[illegible]	47.[illegible]
19	TBM [illegible]-03	Kept on railing base top vill [illegible] P.S.Pirganj,Dis: Thakurgaon	[illegible]	[illegible]	48
20	TBM [illegible]-04	Kept on railing base top vill [illegible] P.S.Pirganj,Dis: Thakurgaon	[illegible]	[illegible]	[illegible]

SL	ID	Remarks	X	Y	RL
21	TBM BG-03	Kept on railing base top vill-Kumargaon P.S-Pirganj,Dist-Thakurgaon	633232	2851463	45.032
22	TBM BG-08	Kept on railing base top vill-Manapara, Kumargaon P.S-Pirganj,Dist-Thakurgaon	634134	2866543	48.181
23	TBM BG-07	Kept on railing base top Khadhan bridge P.S-Pirganj,Dist-Thakurgaon	646413	2833880	63.026
24	TBM HH 27	Kept on wing wall top level n/e corner vill-Sugaon Rail bridge P.S-Pirganj Dist-Thakurgaon	638855	2847757	64.228
25	TBM SB-27	Kept on the railing base top level R/B side vill-Ruinghat P.S-Pirganj Dist-Thakurgaon	643218	2849061	54.148
26	TBM SB-03	Kept on the railing base top level R/B side vill-Paria P.S-Pirganj Dist-Thakurgaon	631737	2858084	43.387
27	TBM A-59	Kept on the railing base top level R/B side vill-Pirganj P.S-Pirganj Dist-Thakurgaon	638887	2858770	49.133
28	TBM SB-03	Kept on the railing base top level R/B side vill-Senua P.S-Pirganj Dist-Thakurgaon	634958	2895229	47.33
29	TBM SB-04	Railing Base Top vill-Senua P.S-Pirganj,Dist-Thakurgaon	635833	2864251	47.86
30	TBM SB-03	Railing Base Top level R/B side vill-Senua Bolaph Post-Pirganj Dist-Thakurgaon	634713	2865542	41.508
31	TBM SB-49	Railing Base Top level R/B side vill-Rani nagar Post-Kulpa Dist-Thakurgaon	642727	2855276	62.207
32	TBM SB-47	Railing Base Top level R/B side vill-Fanbasa Post-Atwari Dist-Panchagarh	641311	2907807	71.85
33	TBM A-3	Kept on the railing base vill-Madhobpur P.S-Ruhia Dist-Thakurgaon	641563	2887736	81.893
34	TBM A-2	Kept on the railing base N/W corner vill-North Kachua P.S-Thakurgaon Sadar Dist-Thakurgaon	643028	2881241	55.535
35	TBM A-1	Kept on the railing base N/W corner vill-Doulatbadpur P.S-Pirganj Dist-Thakurgaon	642532	2844043	33.705
36	TBM DTY-3	Kept on the railing base N/E corner vill-Boikuthoni P.S-Dinar hat Dist-Thakurgaon	644448	2855027	53.038
37	BWDB SW-49	Tangon Barrage R/B Chopatti,Rasnagaon,Ruhia, Thakurgaon	646681	2887755	93.33
38	TBM DTY-08	Kept on the Railing S/E corner bridge,Rankhaga Ruhia, Thakurgaon	648645	2893730	84.428
39	TBM DTY-09	Top on the railing S/E corner Rail Bridge Dhanditola Atoaru, Thakurgaon	643532	2883373	88.048
40	IWM TBM IK-02	kept on the mosque plinth level n/e corner vill-masidpara, po+dist: thakurgaon	632198	2817548	51.100
41	IWM TBM IK-22	kept on the bridge railing base n/e corner vill-kadarhat, po+dist: thakurgaon	633443	2818088	52.478
42	IWM TBM IK-24	kept on the bridge railing base n/e corner vill-kachhia, po+dist: thakurgaon	632647	2818472	52.344
43	IWM TBM IK-25	kept on the plinth level n/e corner vill-kachhia, po+dist: thakurgaon	634008	2819033	51.336

SL	ID	Remarks	X	Y	RL
44	SOB-5124	Kept on the [illegible] college premises, dist- panchagarh	541938	2932245	55.424
45	TBM KH-03	Kept on the railing base of [illegible] bridge s/e corner p/s-atwari, dist- panchagarh	544833	2938284	73.774
46	TBM KH-05-A	Kept on the railing top of [illegible] bridge s/e corner p/s-atwari, dist-panchagarh	544529	2938719	85.158
47	TBM KH-08	Kept on the railing top of bridge s/e corner p/s-atwari, dist-panchagarh	543063	2938717	88.751
48	TBM KH-10	Kept on the railing base of sluice gate s/e corner at [illegible] p/s-atwari, dist- panchagarh	548524	2939381	87.88
49	TBM KH-11	Kept on the plinth level of [illegible] house [illegible] dist-panchagarh	548512	2938929	85.277
50	TBM KH-07	Kept on the railing top of [illegible] sluice gate s/e corner p/s-debiganj, dist- panchagarh	538487	2935181	85.267
51	TBM KH-09	Kept on the railing top of [illegible] bridge s/e corner p/s-debiganj, dist- panchagarh	538813	2934405	86.21
52	TBM KH-08	Kept on the railing base of [illegible] bridge n/e corner p/s-debiganj, dist- panchagarh	534816	2925598	65.467
53	TBM KH-13	Kept on the plinth level of [illegible] house [illegible] dist-panchagarh	438718	2926479	69.787
54	TBM KH-17	Kept on the 776 no pillar top of indian pillar Bangladesh p/s-boda, dist- panchagarh	525562	2919533	55.214
55	SOB BM 1504	[illegible] dist-thakurgaon	525558	2899978	45.547
56	IWM TBM M-02	Kept on the bridge abutment wall top level s/e corner [illegible] bridge, ps- ranisankail, dist- thakurgaon	517233	2884080	48.265
57	IWM TBM M-03	Kept on the plinth level north side house of [illegible] ps- ranisankail, dist- thakurgaon	528516	2890349	43.867
58	IWM TBM M-04	Kept on the [illegible] ps-ranisankail, dist- thakurgaon	528216	2890284	44.308
59	IWM TBM M-05	Kept on the bridge railing base s/e corner [illegible]	526618	2887326	43.706
60	IWM TBM M-06	Kept on the [illegible] wall s/e corner [illegible] ps-ranisankail, dist- thakurgaon	524527	2892039	42.467
61	IWM TBM M-07	Kept on the [illegible] railing top level s/e corner [illegible] ps- ranisankail, dist- thakurgaon	523849	2881789	42.683
62	IWM TBM M-08	Kept on the [illegible] wall of house s/e corner [illegible] ps-ranisankail, dist- thakurgaon	522743	2881611	41.946
63	IWM TBM M-09	Kept on the [illegible] top level north side [illegible]	522441	2888113	42.308
64	IWM TBM M-10	Kept on the plinth level east side house of [illegible] ps-ranisankail, dist- thakurgaon	522539	2218333	42.308
65	IWM TBM M-11	Kept on the [illegible] platform east side [illegible] ps-[illegible], dist- thakurgaon	524614	2218389	40.82

SI	ID	Remarks	X	Y	RL
66	[illegible]	Kept on the [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
67	[illegible]	Kept on the [illegible]	[illegible]	[illegible]	[illegible]
68	[illegible]	Kept on the [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
69	[illegible]	Kept on the [illegible] panchagarh	[illegible]	[illegible]	[illegible]
70	[illegible]	Kept on the [illegible] panchagarh	[illegible]	[illegible]	[illegible]
71	[illegible]	Kept on the [illegible] panchagarh	[illegible]	[illegible]	[illegible]
72	[illegible]	Kept on [illegible] panchagarh	[illegible]	[illegible]	[illegible]
73	[illegible]	Kept on the [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
74	[illegible]	Kept on the [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
75	[illegible]	Kept on the [illegible]	[illegible]	[illegible]	[illegible]
76	[illegible]	Kept on the [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
77	[illegible]	Kept on the [illegible]	[illegible]	[illegible]	[illegible]
78	[illegible]	engraved top of boundary wall [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
79	[illegible]	engraved top of boundary wall [illegible]	[illegible]	[illegible]	[illegible]
80	[illegible]	engraved top of abutment [illegible]	[illegible]	[illegible]	[illegible]
81	[illegible]	engraved top of [illegible]	[illegible]	[illegible]	[illegible]
82	[illegible]	engraved top of [illegible]	[illegible]	[illegible]	[illegible]
83	[illegible]	engraved top of abutment [illegible] thakurgaon	[illegible]	[illegible]	[illegible]
84	[illegible]	engraved top of boundary wall [illegible]	[illegible]	[illegible]	[illegible]
85	[illegible]	situated [illegible] thakurgaon	[illegible]	[illegible]	[illegible]

SI	ID	Remarks	X	Y	RL
86	1998 CFT-26	engraved top of railing base s/e corner of tangon bridge near [illegible], thakurgaon	627732	2856990	64.232
87	1998 CFT-27	engraved top of retaining wall s/e corner road side near [illegible], thakurgaon	627738	2856713	64.636
88	1998 CFT-28	engraved top of railing base s/e corner [illegible] bridge [illegible], thakurgaon	626112	2857352	64.048
89	1998 CFT-29	engraved top of railing base n/e corner [illegible] bridge [illegible], thakurgaon	626147	2855212	56.224
90	1998 CFT-30	engraved top of railing base s/e corner [illegible] para bridge [illegible], thakurgaon	630823	2856507	58.277
91	1998 CFT-31	engraved top of railing base n/e corner [illegible] bridge on tangon river [illegible], thakurgaon	633271	2858508	57.759
92	1998 CFT-31	engraved top of railing base s/e corner [illegible] bridge on tangon river [illegible], thakurgaon	632918	2857151	61.147
93	1998 CFT-32	engraved top of deck level s/e corner bridge on tangon river [illegible], thakurgaon	633049	2857122	58.37
94	1998 CFT-33	engraved top of abutment s/e of damaged cross dam [illegible] field at [illegible]	633897	2852287	56.966
95	1998 CFT-34	engraved top of abutment s/e corner of [illegible] bridge [illegible], thakurgaon	634813	2852749	58.458
96	1998 CFT-35	engraved plinth level n/e corner [illegible] house [illegible], thakurgaon	632058	2854153	58.355
97	1998 CFT-36	engraved top of railing base n/e corner [illegible] on [illegible] road [illegible], thakurgaon	634337	2854638	56.062
98	1999 EWB	kept on the ground plinth top level [illegible] mark [illegible] vill-[illegible], up-[illegible], dist-panchagarh	527898	2894273	73.708
99	1999 J-03	kept on the box culvert wall top level s/e corner vill-[illegible], up-[illegible], dist-thakurgaon	541798	2892339	61.128
100	1999 AH-27	RCC pillar top level vill-[illegible], ps-[illegible], dist-thakurgaon	548013	2866001	48.039
101	1999 MS-29	kept on the railing base top level 2 vent sluice gate n/e corner vill-[illegible], ps-[illegible], dist-thakurgaon	547819	2869437	65.038
102	1999 AH-28	kept on the railing base top level s/e corner vill-[illegible], ps-[illegible], dist-thakurgaon	547819	2869990	65.302
103	1999 AH-27	kept on the railing top level s/e corner vill-[illegible], ps-[illegible], dist-thakurgaon	542208	2893128	63.889
104	1999-15	kept on the railing base top level s/e corner vill-[illegible], ps-[illegible], dist-thakurgaon	542208	2895990	64.234
105	1999 MS-29	kept on the wing wall top level s/e corner vill-[illegible], ps-[illegible], dist-thakurgaon	540248	2899437	43.375
106	1999 J-02	kept on the retaining base top level s/e corner vill-[illegible], ps-[illegible], dist-thakurgaon	545753	2889424	53.862

SI	ID	Remarks	X	Y	RL
107	1200 AN-05	kept on the railing top level n/e corner vill-[illegible], pu-sadar, dist-thakurgaon	540218	2851153	55.244
108	1200 AN-12	kept on the railing base top level n/e corner vill-[illegible], pu-sadar, dist-thakurgaon	541458	2858180	58.262
109	1000 A-01	kept on the railing base top level n/e corner vill-[illegible], pu-sadar, dist-thakurgaon	541707	2861757	58.737
110	1000 SH-01	kept on the railing base top level n/e corner vill-[illegible], pu-sadar, dist-thakurgaon	540618	2859973	59.29
111	1000 A-02	kept on the railing base top level n/e corner vill-[illegible], pu-sadar, dist-thakurgaon	547288	2867152	61.398
112	1000 A-03	kept on the railing base top level n/e corner	543548	2867180	61.082
113	1000 B-04	kept on the railing base top level n/e corner of bridge vill-[illegible], pu-[illegible], dist-panchagarh	570813	2912982	88.068
114	1000 B-05	kept on the railing base top level n/e corner of bridge vill-[illegible], pu-[illegible], dist-panchagarh	571228	2908327	81.108
115	1000 CFH-36	engraved top of railing base n/e corner of [illegible] bridge on [illegible] road pu-baliadangi, dist-thakurgaon	506031	2858658	56.262
116	1000 CFH-37	engraved top of railing base n/e corner of bridge at [illegible] pu-baliadangi, dist-thakurgaon	508028	2858634	65.334
117	1000 CFH-38	engraved top of deck slab n/e corner of box culvert at vill-[illegible], pu-ruhiya, dist-thakurgaon	508418	2858585	61.283
118	1000 CFH-58	engraved top of north side railing 1.7m from n/e corner of bridge vill-[illegible], pu-atwari, dist-panchagarh	521511	2868588	62.032
119	1000 SH-01	top of railing n/e corner of bridge at [illegible] over [illegible] river pu-atwari, dist-thakurgaon	508018	2867913	63.462
120	FM SPS-829	situated in [illegible] colony at ruhiya thakurgaon	500914	2858180	64.302
121	1000 CFH-39	engraved top of deck slab n/e corner of box culvert vill-[illegible], pu-ruhiya, dist-thakurgaon	509418	2858859	61.268
122	1000 CFH-40	engraved top of railing 1.5m n/e corner of bridge at [illegible] pu-baliadangi, dist-thakurgaon	504018	2855228	55.914
123	1000 CFH-41	engraved top of railing n/e corner of bridge at [illegible] pu-baliadangi, dist-thakurgaon	502315	2858354	53.250
124	1000 CFH-22	engraved top of plinth level boundary wall of haripur govt primary school pu-baliadangi, dist-thakurgaon	502018	2858577	58.253
125	1000 CFH-42	engraved top of railing base n/e corner of bridge at [illegible] pu-baliadangi, dist-thakurgaon	502009	2858246	51.071
126	1000 CFH-43	engraved top of name plate haripur gps road pu-baliadangi, dist-thakurgaon	502001	2851882	50.39
127	1200 MC-117A	engraved top of railing base n/e corner of bridge over [illegible] river on [illegible] to [illegible] road pu-baliadangi, dist-thakurgaon	502008	2855082	52.757

SI	ID	Remarks	X	Y	RL
128	SOB GPS-5072	situated corner bangla bari high school compound po-thakurgaon, dist-thakurgaon	370218	2859460	51.951
129	1998 R-11	marked top of railing base n/e corner culvert [illegible] bridge vill-[illegible] po-thakurgaon, dist-thakurgaon	370212	2867121	55.72
130	1998 J-01	marked on railing base n/e corner [illegible] regulator po-thakurgaon, dist-thakurgaon	370813	2856189	49.951
131	1998 J-02	marked on railing base n/e corner [illegible] regulator po-thakurgaon, dist-thakurgaon	370518	2856154	49.138
132	1998 J-01	kept on plinth level of house vill-[illegible]	340219	2850437	56.708
133	1998 A-01	kept on the retaining base top level n/e corner vill-[illegible]	340217	2870534	55.038
134	1998 AA-02	kept on the retaining base top level n/e corner vill-[illegible]	340844	2864880	55.445
135	1998 AA-03	kept on the box culvert railing top level n/e corner vill-[illegible], po-[illegible], dist-thakurgaon	341719	2867433	58.937
136	1998 A-02	kept on the plinth level of house vill-[illegible], po-[illegible], dist-thakurgaon	340215	2858847	56.327
137	1998 R-01	kept on the railing base n/e corner of [illegible] vill-[illegible], dist-panchagarh	354207	2924833	81.037
138	1998 R-02	kept on the railing base n/e corner of bridge vill-[illegible], po-[illegible], panchagarh	353213	2928427	83.808
139	1998 R-03	kept on the railing base n/e corner of bridge vill-[illegible], po-[illegible], panchagarh	352718	2927071	83.788
140	1998 R-10	kept on [illegible] top n/e corner of [illegible] vill-[illegible], po-[illegible], dist-dinajpur	378538	2828282	38.348
141	SOB BM-1938	situated in union land office compound at [illegible], thakurgaon sadar	358443	2862310	56.257
142	SOB BM-8408	situated in playground of [illegible] high school po-[illegible], dist-thakurgaon	363248	2855738	60.072
143	1998 BL-16	marked on the top of [illegible] n/e corner of [illegible] po-[illegible], dist-thakurgaon	350463	2852028	64.666
144	1998 BL-17	marked on the top of railing base n/e corner of [illegible] bridge over [illegible] river po-[illegible], dist-thakurgaon	353211	2854133	66.384
145	1998 DFR-11	engraved top of railing base n/e corner of [illegible] bridge at [illegible] road near [illegible] river po-[illegible], dist-thakurgaon	408717	2848720	44.476
146	1998 DFR-12	engraved top of plinth level boundary wall n/e corner [illegible] primary school po-[illegible], dist-thakurgaon	408248	2854089	47.84
147	1998 DFR-13	engraved top of railing base south side middle of culvert vill-[illegible], po-[illegible], dist-thakurgaon	328538	2854183	51.238
148	1998 DFR-14	engraved top of railing base n/e corner [illegible] bridge po-[illegible], dist-thakurgaon	324307	2859540	52.148

ID	BM	Remarks	X	Y	RL
149	[illegible]	engraved top of boundary wall [illegible] school [illegible]	[illegible]	[illegible]	[illegible]
150	[illegible]	showed [illegible] school [illegible]	[illegible]	[illegible]	[illegible]
151	[illegible]	engraved top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
152	[illegible]	engraved top of [illegible] hospital [illegible]	[illegible]	[illegible]	[illegible]
153	[illegible]	engraved top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
154	[illegible]	engraved top of plinth level [illegible] masjid [illegible]	[illegible]	[illegible]	[illegible]
155	[illegible]	engraved top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
156	[illegible]	engraved top of [illegible] platform [illegible]	[illegible]	[illegible]	[illegible]
157	[illegible]	engraved top of plinth level [illegible] masjid [illegible]	[illegible]	[illegible]	[illegible]
158	[illegible]	on the top of plinth level [illegible] boundary wall [illegible] masjid [illegible]	[illegible]	[illegible]	[illegible]
159	[illegible]	on the top of railing base [illegible]	[illegible]	[illegible]	[illegible]
160	[illegible]	on the top of railing base [illegible] BRIDGE [illegible]	[illegible]	[illegible]	[illegible]
161	[illegible]	on the top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
162	[illegible]	on the top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
163	[illegible]	on the top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
164	[illegible]	on the top of railing base [illegible] bridge [illegible] road	[illegible]	[illegible]	[illegible]
165	[illegible]	on the top of wing wall corner [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
166	[illegible]	showed [illegible] school [illegible]	[illegible]	[illegible]	[illegible]
167	[illegible]	engraved top of [illegible]	[illegible]	[illegible]	[illegible]
168	[illegible]	engraved top of wing wall [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]
169	[illegible]	engraved top of railing base [illegible] bridge [illegible]	[illegible]	[illegible]	[illegible]

SI	ID	Remarks	X	Y	RL
170	TBM SH-20	engraved top of railing base n/e corner of [illegible] Thakurgaon sadar	558117	2875448	52.584
171	TBM SH-09	engraved top of railing base n/e corner of 2 vent culvert vill-[illegible] [illegible], Thakurgaon sadar	557808	2875880	52.322
172	TBM S-01	engraved top of railing n/e corner of [illegible] bridge Thakurgaon sadar	551048	2881012	55.761
173	TBM SH-11	engraved top of railing base n/e corner of [illegible] bridge Thakurgaon sadar	556224	2883949	56.217
174	TBM S-03	on the top of railing base n/e corner of [illegible] 6 vent regulator Thakurgaon sadar	556717	2884815	56.270
175	TBM S-02	on the top of railing n/e corner of bridge vill-[illegible], [illegible], Thakurgaon sadar	555228	2885094	57.367
176	TBM SS-27	on the wing wall top of [illegible] bridge n/e corner of bridge po-[illegible], dist-panchagarh	544008	2851182	66.238
177	TBM SS-23	on the railing base of [illegible] bridge n/e corner	546706	2858307	67.648
178	TBM SS-22	on the railing base of [illegible] bridge n/e corner po-[illegible]	544605	2878294	70.214
179	TBM SS-24	on the railing base of [illegible] bridge n/e corner	544611	2885410	68.334
180	TBM SS-26	on the railing base of bridge n/e corner [illegible]	546012	2894711	69.6
181	TBM SS-25	on the railing base of sluice gate n/e corner at regulator	546520	2903101	83.362
182	TBM SS-28	on the railing top rail bridge n/e corner po-[illegible], dist-panchagarh	546148	2872192	67.435
183	TBM AH-28	kept on the railing base top level n/e corner vill-[illegible], po-[illegible], dist-Thakurgaon	[illegible]	2846094	44.044
184	TBM AH-27	kept on the railing wall top level n/e corner	[illegible]	2857148	44.228
185	TBM AH-29	kept on the box culvert top level n/e corner vill-[illegible], po-[illegible], dist-Thakurgaon	[illegible]	2858138	47.044
186	TBM M-61	bridge vill-[illegible] po-[illegible] dist-Thakurgaon	540118	2870320	46.120
187	TBM-3	[illegible] vill-[illegible], vill-[illegible] [illegible]	542412	2866878	43.264
188	TBM SH-02	railing base n/e corner of [illegible] bridge	541638	2864837	46.328
189	TBM-41	railing base n/e corner of [illegible] bridge	575738	2897188	58.534
190	IWM TBM M-36	kept on the bridge railing base n/e corner vill-[illegible] po-[illegible]	571668	2837142	36.446
191	TBM M-37	kept on the [illegible] bridge n/e corner vill-[illegible], po-[illegible]	470606	2847275	44.34
192	IWM TBM M-35	kept on the bridge railing base n/e corner vill-[illegible] [illegible], po-[illegible] Thakurgaon	530934	2858122	41.887
193	IWM TBM M-27	kept on the bridge railing base n/e corner vill-[illegible], po-[illegible], dist-Thakurgaon	531234	2851145	52.122
194	TBM J2	TBM J2 Marked on railing base SE corner of [illegible] 1 vent regulator at vill [illegible] [illegible] P.S. [illegible] Dist. Thakurgaon	519018	2858116	40.138

Sl	ID	Remarks	X	Y	RL
195	TBM SH 13	TBM SH 13 Engraved top of railing base SE corner of Dumuria bridge over Amarkhana river on ... to ... road, Debiganj Thakurgaon	615417	2884131	40.892
196	TT CH P 2	TT CH P 2 on the top of wooden pillar of bamboo bridge	622531	2882308	44.228
197	TT Ma 07	TT Ma 07 on the top of bamboo peg	628434	2883241	41.803
198	TT Ma 08	TT Ma 08 on the top of bamboo peg	628446	2883308	41.558
199	TBM Ma 03	TBM Ma 03 on the top of railing base SW corner of Bangurgaon bridge over Lachi river, PS: Pirganj Thakurgaon	630088	2883675	46
200	TT Ma 09	TT Ma 09 on the top of the bamboo peg	629928	2883817	42.854
201	TBM Ma 04	TBM Ma 04 on the top of railing base NE corner of Bangurgaon old bridge over Lachi river, PS: Pirganj Thakurgaon	630412	2884123	46.227
202	TBM Sh 04	TBM Sh 04 on the top of railing base SE corner of Bangurgaon new bridge over Lachi river	630013	2884233	47.85
203	TT Sh 11	TT Sh 11 on the top of bamboo peg	633880	2884780	44.875
204	TT Sh 10	TT Sh 10 on the top of bamboo peg	633839	2885111	47.373
205	TBM Sh 03	TBM Sh 03 on the top of railing base SW corner of Shosa nal bridge Pirganj Thakurgaon	634969	2885228	47.82
206	TT Sh 12	TT Sh 12 on the top of bamboo peg	634613	2885441	45.263
207	TBM Sh 05	TBM Sh 05 on the top of railing base SW corner of Bhirui bridge Pirganj Thakurgaon	634771	2886601	41.508
208	TT Sh 13	TT Sh 13 on the top of bamboo peg	634553	2888189	41.111
209	TT Sh 14	TT Sh 14 on the top of bamboo peg	634428	2888423	44.886
210	TBM Ma 05	TBM Ma 05 on the top of railing base SW corner of Uchchagaon bridge Pirganj Thakurgaon	634134	2888845	46.181
211	TT Ma 11	TT Ma 11 on the top of bamboo peg	633928	2887088	47.278
212	TT Ma 10	TT Ma 10 on the top of bamboo peg	633527	2887311	46.773
213	TBM Ma 06	TBM Ma 06 on the top of railing base SW corner of Koyhargaon Bhigaon bridge Pirganj Thakurgaon	633212	2891483	46.862
214	TBM A 01	TBM A 01 on the top of railing base NE corner of Tangon bridge	640816	2887343	56.426
215	TBM CH 03	TBM CH 03 engraved top of wing wall NE corner of Baksa... bridge over Tangon river Thakurgaon sadar	644418	2893637	56.039
216	TBM AT 01	TBM AT 01 on the top of railing base NE corner of Shahid Minar of ... south ... Govt Primary school Thakurgaon sadar PS: Ruhiya	644162	2897120	54.623
217	TBM CH 03	TBM CH 03 engraved top of wing wall NE corner of ... bridge over Tangon river Thakurgaon sadar	644448	2893631	55.039
218	TBM CH 04	TBM CH 04 engraved top of slab SW corner of culvert on irrigation drain at ... PS: Ruhiya Gad Thakurgaon	640318	2893882	52.140
219	TBM Ma 07	TBM Ma 07 engraved top of railing base SE corner of Khochabari bridge over	640429	2893679	52.025

SI	ID	Remarks	X	Y	RL
		Tangon river PS: Ruhiya Dist: Thakurgaon			
220	TBM GTT 04	TBM GTT 04 engraved top of deck slab NW corner of culvert on irrigation drain at Kharibari Hatigara PS: Ruhiya Dist: Thakurgaon	940208	2910983	62.140
221	TBM GTT 05	TBM GTT 05 engraved top of deck slab NW corner of culvert on irrigation drain at Kharibari Hatattpara PS: Ruhiya Dist: Thakurgaon	946246	2904120	63.040
222	TT Ma 12	TT Ma 12 on the top of bullet tree base of Kharibari Hatattpara PS Ruhiya Thakurgaon	946756	2904402	64.608
223	TBM GTT 06	TBM GTT 06 engraved top of boundary wall in front house of Mr. Suman at Vill: Pateldanga PS: Ruhiya Dist: Thakurgaon	956256	2909394	61.084
224	TBM SN 06	TBM SN 06 on the top of railing base SE corner of Pateldanga bridge over Tangon river PS: Ruhiya Dist: Thakurgaon	946747	2909778	61.347
225	TBM GTT 07	TBM GTT 07 on the top of seating bench in front shop of Mr. Akbar Member at Vill: North Ruhiya PS: Ruhiya	947148	2907862	64.198
226	TT AT 02	TT AT 02 on the top of RCC pillar beside road at north Ruhiya PS: Ruhiya DIST: Thakurgaon	941529	2908323	62.735
227	TBM GTT 07	TBM GTT 07 on the top of seating bench in front shop of Mr. Akbar member at Vill: North Ruhiya	947148	2907862	64.198
228	SWGB BM 80	SWGB BM 80 The pillar is situated in Tangon Barrage compound. It is in front of Tangon college	948848	2907750	49.21
229	TT AT 02	TT AT 02 on the top of RCC pillar beside road at north Ruhiya PS: Ruhiya DIST: Thakurgaon	941529	2908323	62.735
230	TBM GTT 08	TBM GTT 08 engraved top of railing SE corner of Ruhiganj bridge. PS: Atwari Dist: Thakurgaon	948016	2908720	64.429
231	TT Ma 13	TT Ma 13 on the top of tree	946837	2911086	63.140
232	TT GTT 23	TT GTT 23 on the top of plinth level SE corner house of Mr. Goni at Vill: Ambardanga PS: Atwari Dist: Panchagarh	947236	2910960	66.402
233	IWM TBM M15	IWM TBM M15 kept on the U wall sluice gate head wall top level NW corner Vill: Jogadpur PS: Haripur Thakurgaon	922016	2894180	38.387
234	IWM TBM M 16	IWM TBM M 16 kept on the RCC seat bench SW corner Vill: Gopalpur PS: Haripur Dist: Thakurgaon	921888	2894037	38.643
235	IWM TBM M 17	IWM TBM M 17 kept on the CC block 1st slab NW corner Vill: Vabuna PS: Haripur Dist: Thakurgaon	921032	2893137	38.83
236	IWM TBM M1	IWM TBM M1 Vill: Gosain Monirpara	928833	2884717	40.778
237	IWM TBM M 18	IWM TBM M 18 kept on the tank pillar top level Vill: Motolbari PS: Ranisankoil Dist: Thakurgaon	928546	2883323	41.237
238	TT 11	TT 11 on head wall culvert SE corner	928763	2886294	41.778
239	TBM	TBM on plinth level	921216	2887033	44.457
240	IWM TBM M 19	IWM TBM M 19 kept on the band tubewell SE corner platform	927232	2887939	44.795

SL	ID	Remarks	X	Y	RL
241	TP 12	TP 12 bamboo cutting	421049	2888338	44.240
242	IWM TBM M 20	IWM TBM M 20 kept on the bridge wing wall railing base SW corner Vill: Mohanpur Up: Ranisankail Dist: Thakurgaon	421085	2889087	47.270
243	IWM TBM M 21	IWM TBM M 21 kept on the bridge wingwall SW corner Vill: Purbo Kalighe PS: Ranisankail Thakurgaon	420772	2888589	46.120
244	IWM TBM M 22	IWM TBM M 22 kept on the culvert railing top level NW corner Vill: Gobindapur PS: Ranisankail Thakurgaon	421315	2875430	46.220
245	TP 13	TP 13 Plinth level NE corner	421453	2875888	45.578
246	IWM TBM M 23	IWM TBM M 23 kept on the wing wall NW corner Vill: Shibrampur PS: Ranisankail Dist: Thakurgaon	420019	2873339	49.564
247	TP 14	TP 14 on the roof top mark	420613	2873391	48.230
248	IWM TBM M 24	IWM TBM M 24 kept on the box culvert railing top level SE corner Vill: Dekut PS: Ranisankail Dist: Thakurgaon	420036	2873420	47.884
249	TP 15	TP 15 on boundary wall	420947	2874073	49.720
250	IWM TBM M 25	IWM TBM M 25 kept on the bridge railing base SW corner Vill: Uttar Bishnupur PS: Ranisankail Dist: Thakurgaon	420019	2874091	50.210
251	IWM TBM M 26	IWM TBM M 26 kept on the box culvert deck level SE corner Vill: Yadav PS: Ranisankail Dist: Thakurgaon	420512	2875273	48.081
252	TP 16	TP 16 culvert NE corner marked	420897	2875743	48.794
253	IWM TBM M 27	IWM TBM M 27 kept on the bridge railing base SW corner Vill: Jamalpur PS: Thakurgaon Dist: Thakurgaon	420741	2876542	50.874
254	IWM TBM M 28	IWM TBM M 28 kept on the bridge railing base NW corner Vill: Rasulpur PS: Thakurgaon Dist: Thakurgaon	420748	2877380	50.708
255	IWM TBM M 29	IWM TBM M 29 kept on the bridge railing base NW corner Vill: Shibnagar PS: Baliadangi Thakurgaon	420758	2878885	51.756

Connections with the existing gauge of BWDB were also carried out to see the difference between the mPWD used in those gauges against the mMSL of SOB. In ideal condition the SOB mMSL should be 0.46 lower than the mPWD. However during the study, it was found that the gauge value of the existing WL gauges were a bit different than that. The connection of the gauge found in the study between gauge mPWD and mMSL has been shown in **Table 3.3**.

Table 3.3: Bench Marks and Temporary Bench Marks used for the Survey

District Name	River	BWDB/SOB ID	Station Name	Remarks
Panchagarh	Dahuk	SW31A	Bhojanpur	SOB=PWD - 0.90m
Panchagarh	Chawai	SW309.1	Chowrangi	SOB=PWD - 0.37m
Panchagarh	Karatoa	SW139	Debiganj	SOB=PWD + 1.18m
Panchagarh	Karatoa	SW140	Panchagarh	SOB=PWD - 0.39m
Panchagarh	Karatoa	SW141	Debiganj	SOB=PWD + 0.18m
Panchagarh	Mohananda	SW220A	Tetulia	SOB=PWD - 3.44m
Panchagarh	Talma	SW233	Talma Outfall	SOB=PWD - 0.474m
Panchagarh	Talma	SW232	Boda	SOB=PWD - 0.46m
Panchagarh	Talma	SW231	Boda	SOB=PWD + 0.5m
Thakurgaon	Kulik	SW175	Bhulliang	SOB=PWD + 1.32m

Thakurgaon	Tangon ([illegible])	SW 2[illegible]	[illegible]	SOB=PWD + 0.43m
Thakurgaon	Tangon	SW 294	Ranigonj	SOB=PWD - 1.07m
Thakurgaon	Tangon	SW 295	Thakurgaon	SOB=PWD - 0.40m

It can be seen from the figure that only Tentulia (Mohananda River), Bhitagarh (Talma River) & Thakurgaon (Tangon River) are gauge mPWD and SOB mMSL were close to the ideal case. As much as 1.80m (1.34+0.46) for Shubang station could be observe from the ideal value of mPWD.

3.7.2 Model Development

Development of 1D Hydrodynamic Model

IWM possesses a one-dimensional (1D) hydrodynamic model comprising of all the major rivers/khals/channels of the North-West region of Bangladesh. For current project, the model has been updated with the cross-sections of 2022 for the rivers in the study area (i.e., Panchagarh, Thakurgaon districts). The network of the one-dimensional model has been displayed in **Figure 3.42**.

With the application of this model, flow distribution through different rivers, channels, khals, etc. in the vicinity of the study area are obtained. This model takes into account rainfall-runoff and flood plain flow. In case of ungauged locations, hydraulic parameters including flows and water levels within the study area and other adjoining rivers are also output of this model. Results of this dedicated 1D model have been used as the boundary conditions of the 2D models developed for the current project.

The updated 1D model has been calibrated for the hydrological event of 2020. The calibration plots of the 1D model for different rivers are shown in **Figure 3.43** to **Figure 3.48**.

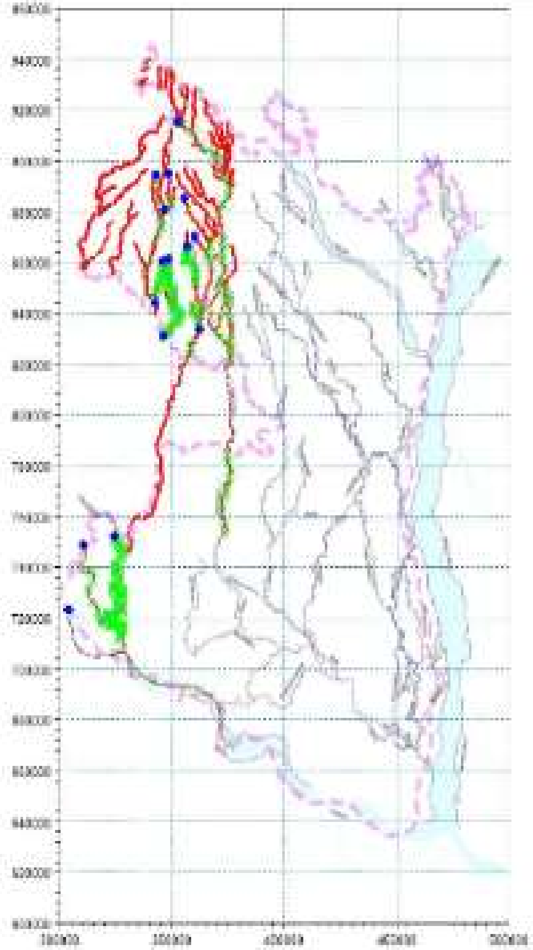

Figure 2.42: Developed 1D Model network for the study

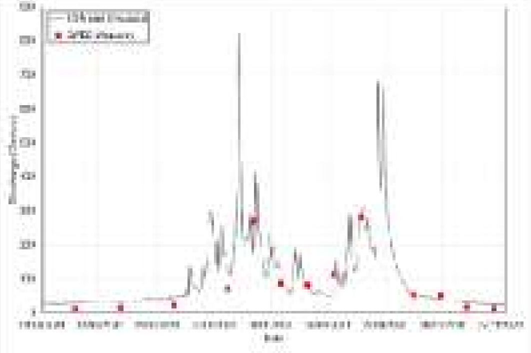

Figure 2.45 1D Discharge Calibration at Panchagarh Station on Karatoa River

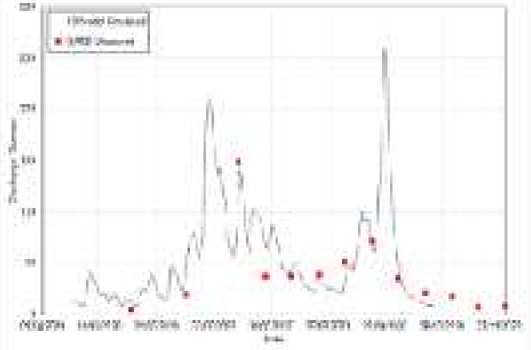

Figure 2.46 1D Discharge Calibration at Thakurgaon station on Tangon River

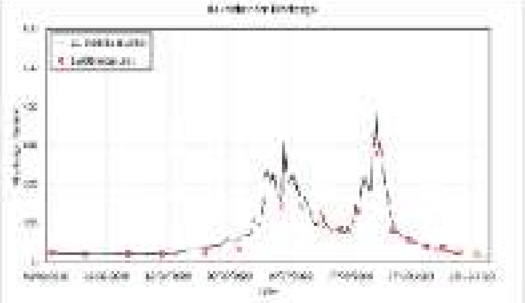

Figure 2.45: 1D Discharge Calibration at Bhushirbandar station on Atrai River

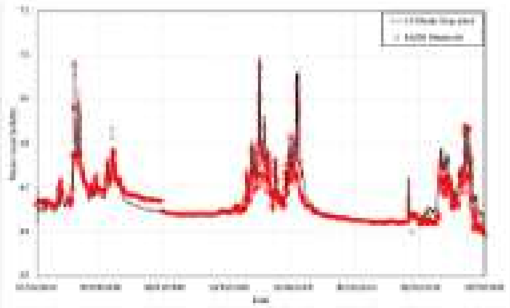

Figure 2.46: 1D Water level Calibration at Panchagarh station on Karatoa River

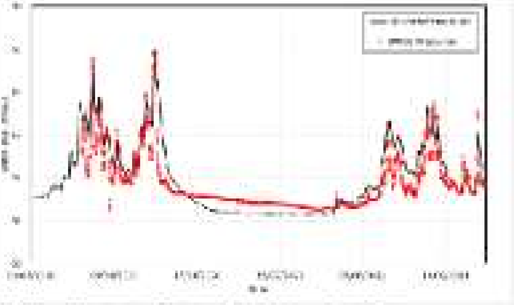

Figure 2.47: 1D water level Calibration at Dargaon station on Atrai River

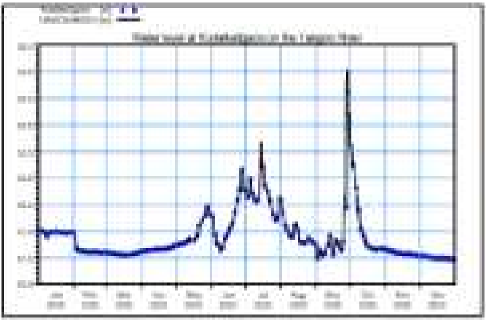

Figure 2.48: 1D water level Calibration at Khalshaligaon station on the Tangon River

Development of 2D Morphological Model

Several two-dimensional models have been developed using MIKE 21C modelling tool in connection with the present study for the rivers which appears vulnerable to bank erosion. The developed grid and bathymetry of the 2D models are shown in **Figure 2.49** to **Figure 2.68**. The boundary conditions were taken from the developed 1D model. The 2D models have been hydrodynamically calibrated based on the data of the developed dedicated 1D model.

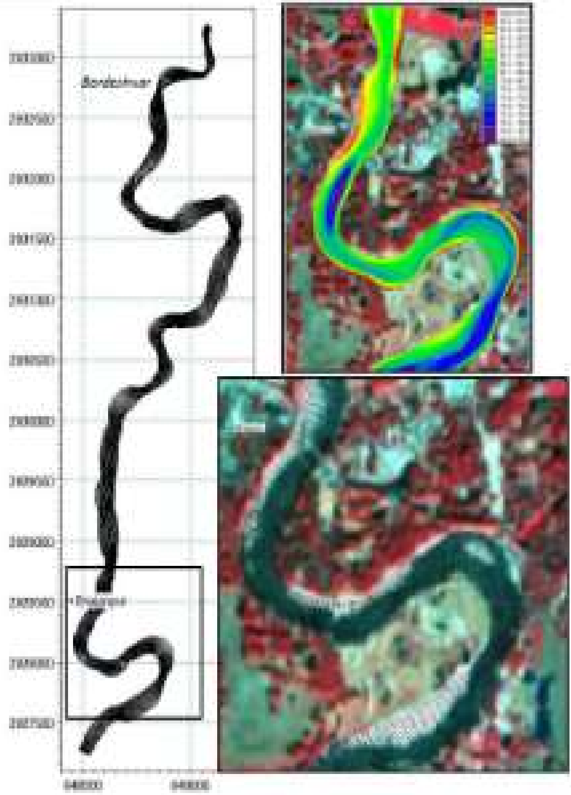

Figure 2.45: Developed Grid and Bathymetry for Karatoa river from Bangladesh-India Border at Bordeshwar to Shaprapur

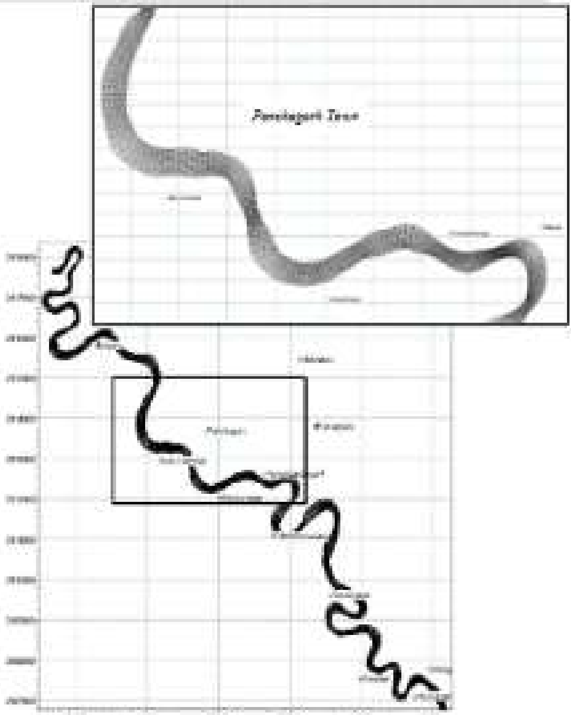

Figure 2.26: Developed Grid for Karatoa river from Bangladesh-India Border at [illegible] to [illegible]

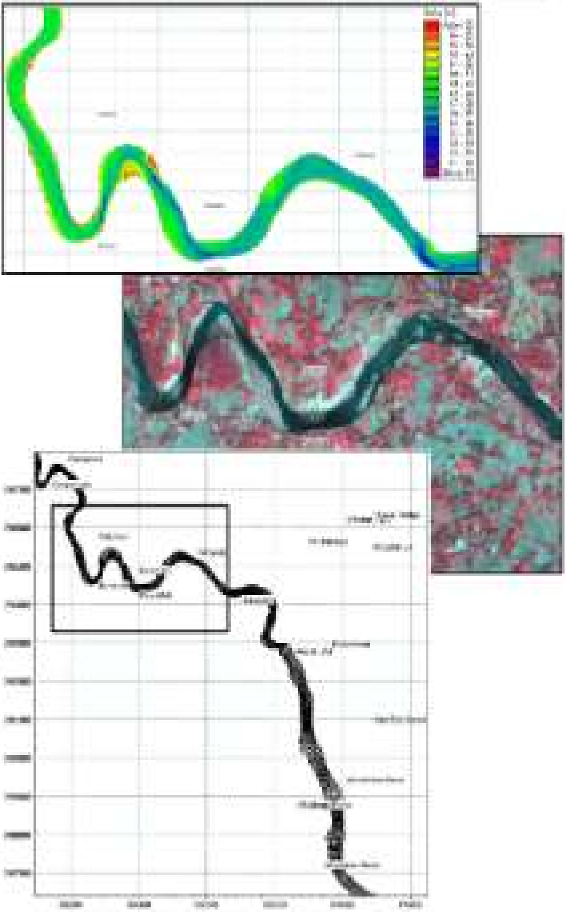

Figure 2.81: Developed Grid and bathymetry for Karatoa river from Shovaganj to Bhojaher Bazar

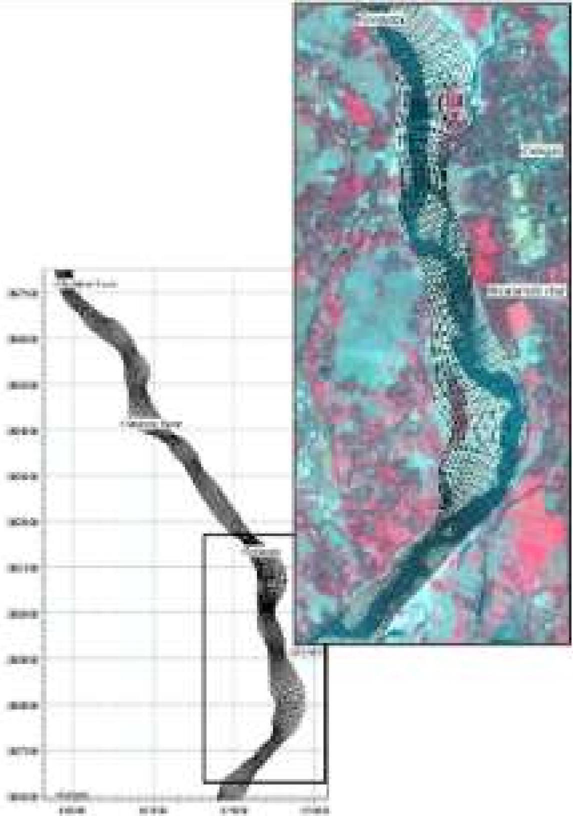

Figure 3.31: Developed Grid for Karatoa river from Bhuapara Bazar to Debiganj

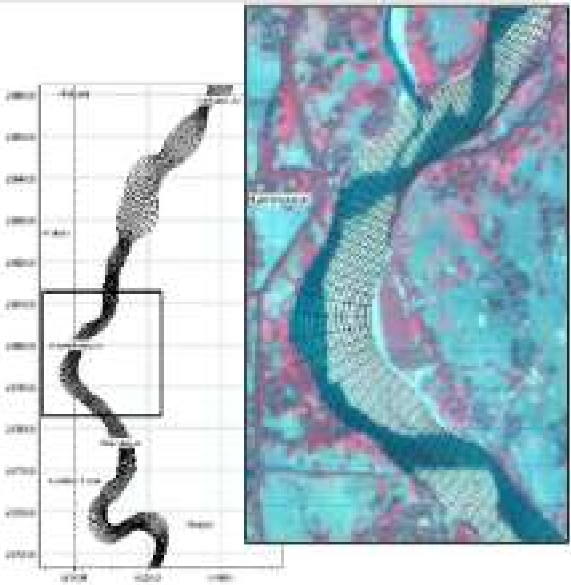

Figure 2.33: Developed Grid for Karatoa River from Tetulia LLP to Laxmirhanpur

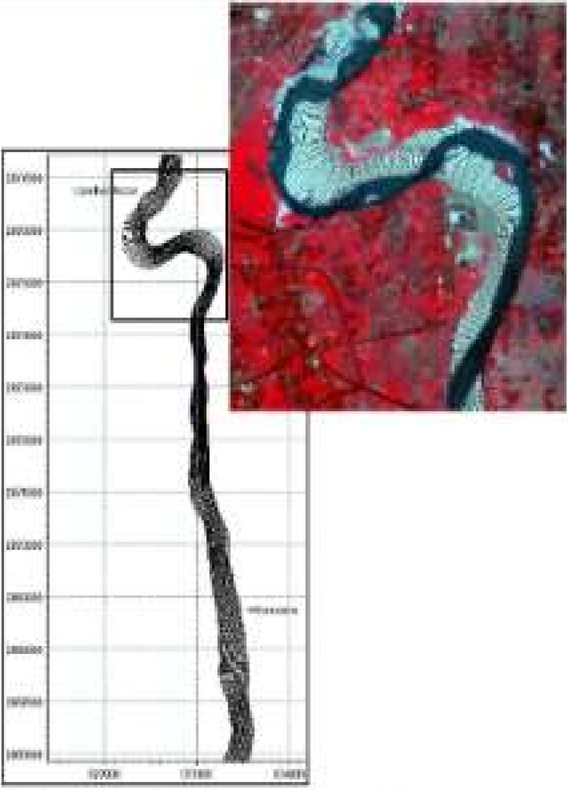

Figure 2.24 Developed Grid for Karatoa river from Bangladesh-India Border at Lochmaripara to Khansama

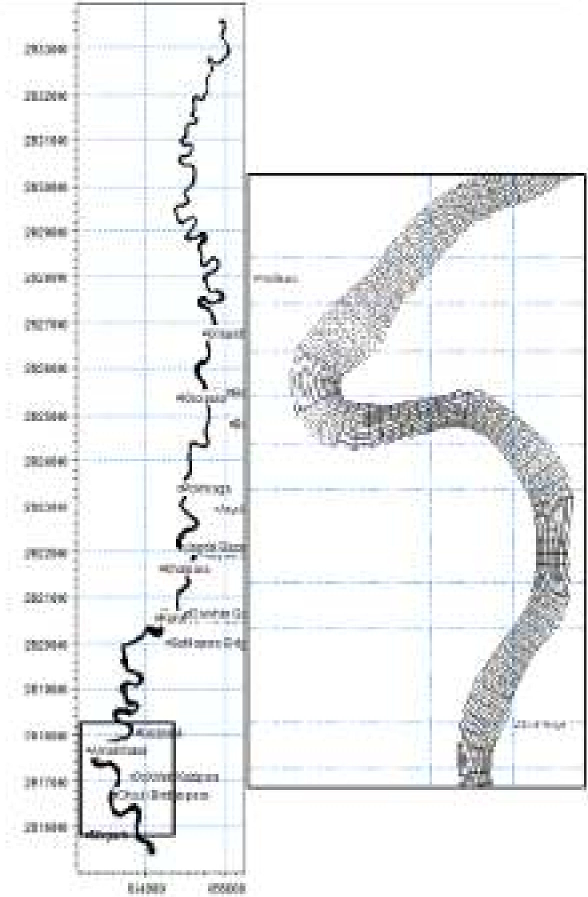

Figure 2.23: Developed Grid for the Chawai river

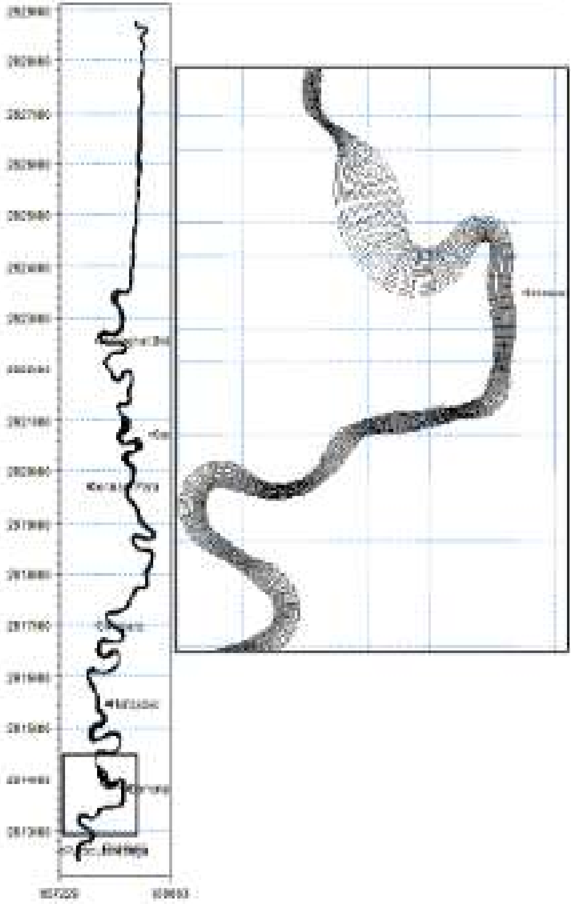

Figure 2.28 Curvilinear Grid for the Talma River

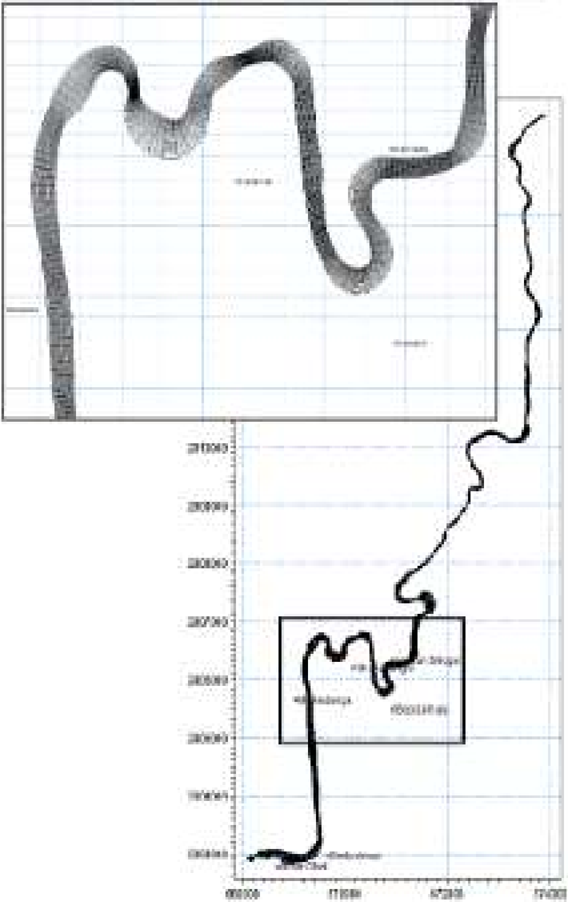

Figure 2.57: Developed Grid for the [illegible] River

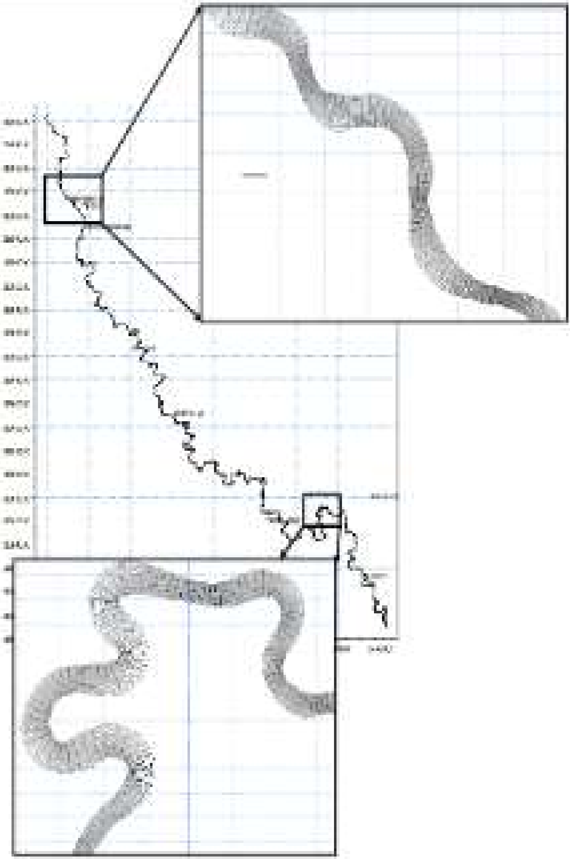

Figure 2.35: Curvilinear Grid for Pathraj River

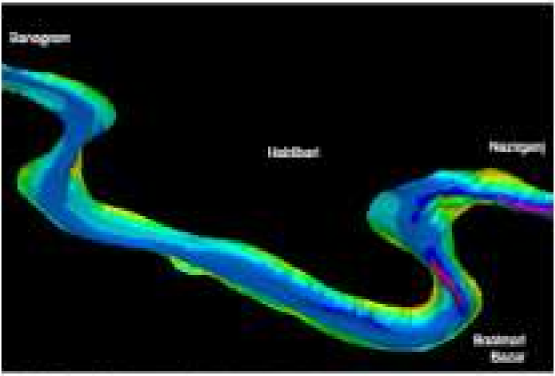

Figure 2.59: Orthogonal view of the developed Morphological Model

The developed 2D model has been calibrated both hydro-dynamically and morphologically for the hydrological event of 2020. The calibration plots of the 2D model for different rivers are shown in **Figure 2.60** to **Figure 2.65**.

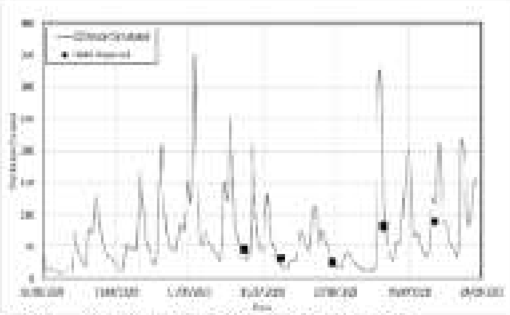

Figure 2.60: 2D Discharge Calibration at Bhajanpur on the Karatoa River

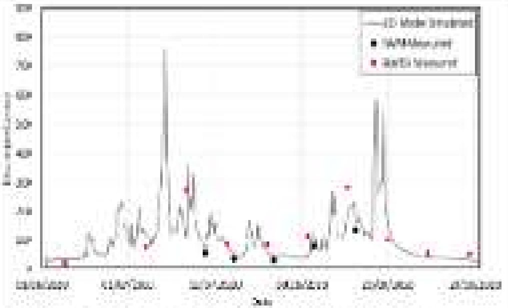

Figure 2.61: 2D Discharge Calibration near Panchagarh on the Karatoa River

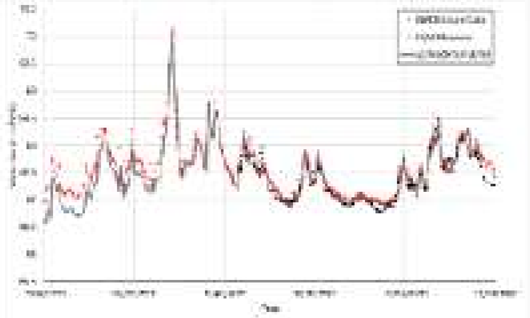

Figure 2.62: 2D Water level Calibration at Panchagarh station on the Karatoa River

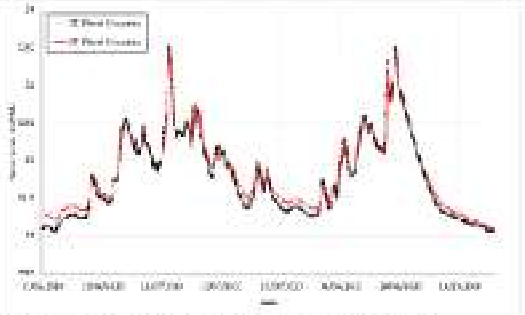

Figure 2.83: 2D water level Calibration at Khansama on the Karatoa/Atrai River

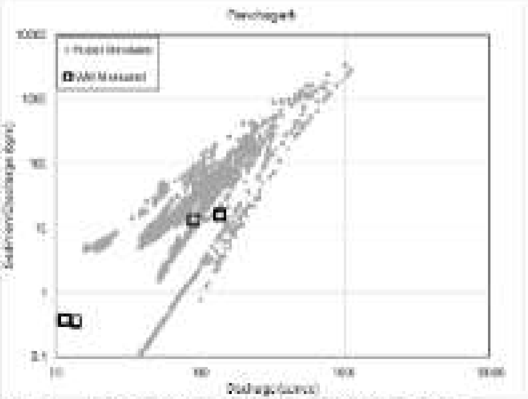

Figure 2.84: 2D Sediment Discharge Calibration at Panchagarh on the Karatoa River

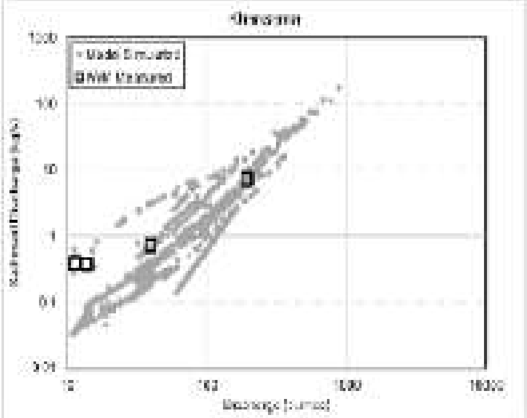

Figure 2.83: 2D Sediment Discharge Calibration at [illegible] on the [illegible] River

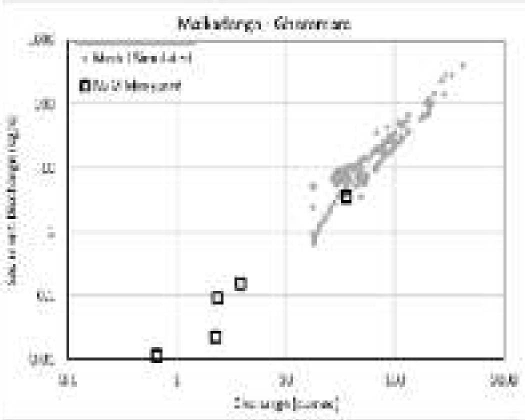

Figure 2.84: 2D Sediment Discharge Calibration at [illegible] on the [illegible] River

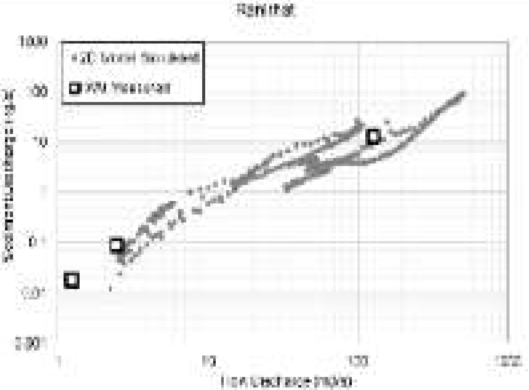

Figure 2.67: 2D Sediment Discharge Calibration at Ranirhat on the Tangon River

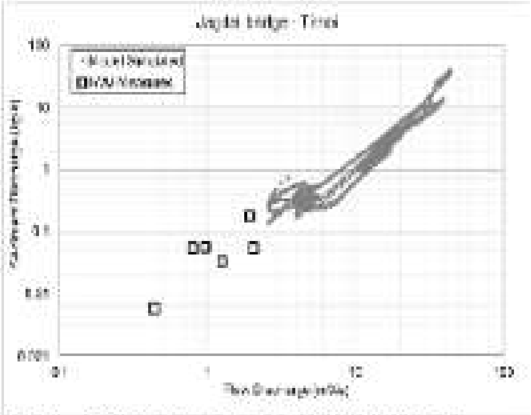

Figure 2.68: 2D Sediment Discharge Calibration at Jagdal Bridge on the Tirnai River

2.8 Structure of the Report

The Inception Report of the study was submitted to the Project Director on 2nd February 2023. A review meeting on Inception Report was held on 22nd February 2023 at Pani Bhaban, chaired by ADG (Planning, Design and Research) of BWDB. A Progress Report was submitted on 15th May 2023 and a meeting on the study progress was held on 8th June 2023 at Pani Bhaban chaired by Chief Engineer (Planning), BWDB. The Draft Final Report was submitted on 26/03/2024. And the meeting of DFR was held on 08/04/2024. The regional workshop was held on 18/05/2024.

This is the Final Report that briefly describes the activities done, survey accomplished, technical analysis and multi-criteria analysis of potential options. It has been developed in the line with the GoB approved prescribed format of the Feasibility Study.

The Final Report consists of twelve chapters and seven appendices, as described below.

Section 1:	focuses on Basic information of the project.
Section 2:	provides the introduction with project background, objectives of the feasibility study, approach and methodology and organization of the study.
Section 3:	assesses the need for public investments and involves problem statement, relevant of the project idea, proposed interventions, stakeholder identification
Section 4:	describes the hydrologic and morphological analysis of the project area, the technical design and cost estimates.
Section 5:	contains environmental sustainability, climate resilience and disaster risk analysis.
Section 6:	describes financial and economic analysis.
Section 7:	describes human resources and administrative support analysis during implementation and post implementation of the project.
Section 8:	describes institutional and legal analysis.
Section 9:	describes uncertainty and sensitivity analysis.
Section 10:	describes option analysis with recommendations and justifications.
Section 11:	presents conclusions and recommendations from this study.
Section 12:	contain references.

Appendix-A:	Tour Reports
Appendix-B:	Workshop Pictures
Appendix-C:	Compliance on Workshop
Appendix-D:	Compliance on DFR Meeting
Appendix-E:	Compliance on ToR
Appendix-F:	Financial and Economic Analysis
Appendix-G:	Terms of Reference (ToR) of the Study

SECTION THREE

MARKET/DEMAND ANALYSIS

3. MARKET/DEMAND ANALYSIS

3.1 Problem Statement

Panchagarh and Thakurgaon districts are located in the north-western tip of Bangladesh. The region is characterized by steep catchment slopes. Hence flash flood is a common occurrence in the region. In the recent past, most of the river's flow has reduced gradually. As the flow of the river got reduced, the regional agriculture, environment and biodiversity have been affected adversely. The navigability of the rivers has also declined drastically. Fish, birds and animals are losing their habitat. And as the availability of surface water is decreasing, the dependency on the groundwater is increasing. The use of surface water along with lack of groundwater recharge, is decreasing the groundwater level of the region as well.

Under the "Re-excavation program of small rivers, khals and water bodies in 64 Districts" of the country, lots of rivers in the Panchagarh & Thakurgaon districts have been re-excavated in the last few years. **Figure 3.1** shows the extents of dredging/re-excavation of the rivers of Panchagarh & Thakurgaon districts. Karatoa, Talma, Pathraj, Dahuk, Versha and Buri Teesta of Panchagarh district and Pathraj, Shuk, Kulik, Lachhi rivers of Thakurgaon district have been dredged/re-excavated in recent times. Moreover, 40 km of Tangon river under Thakurgaon O&M has been dredged. As a result of the re-excavation, the river navigability has got new dimension of life. The canals have been refilled with flowing water and water holding capacities in small rivers and canals have been increased. Agricultural production is being facilitated by smooth irrigation. The dredging of rivers and canals has reduced waterlogging as well. Along with the improved drainage system, the flooding risk has decreased. Dredging of more rivers could generate the similar benefit for those rivers as well in the region.

These rivers are also flashy in nature and possess complex hydrological characteristics than the other rivers of the country. Most of the rivers of the study area originates from India, flows through Bangladesh and subsequently enters India again. As the upstream catchments are hilly areas, the response time of the catchment is very short and sharp rises in the flow hydrographs are often seen whenever rainfall occurs. Besides, the steep riverbed slope means the flood peak takes no time to recess. Hence most of the water drains out quickly. As a result, the water availability during the dry season remains a problem. BWDB has constructed some Water Control Structures in the Thakurgaon Circle which has been able to retain the surface water and fulfil supplementary irrigation requirement. Existing Active Water Control Structure located at Boaldar, Thakurgaon over Senua River is shown in **Figure 3.2**. The water control structure has played an important role in the socio-economic development of the people in the region and the presence of more similar kind of water control structures in Thakurgaon and Panchagarh districts are the demand from the local stakeholders and might be highly beneficial for the people.

Along with decreased water availability during dry season, the flash flood is another persistent problem for the people of Panchagarh and Thakurgaon. Although most of the riverbanks do not overtop during the flood, the very high flow velocity during monsoon along with wave actions causes the riverbank erosion. **Figure 3.3**, **Figure 3.4**, **Figure 3.5** show some of the erosion vulnerable locations of the two districts.

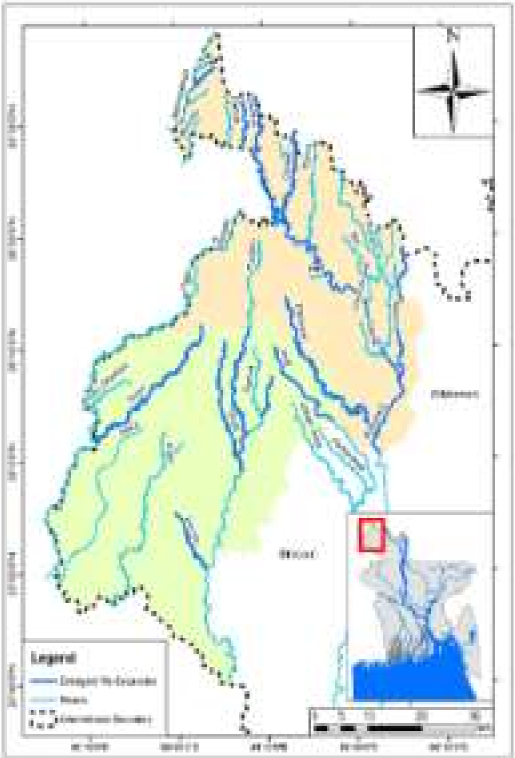

Figure 3.1 Extents of dredging/re-excavation of the rivers of Panchagarh & Thakurgaon districts

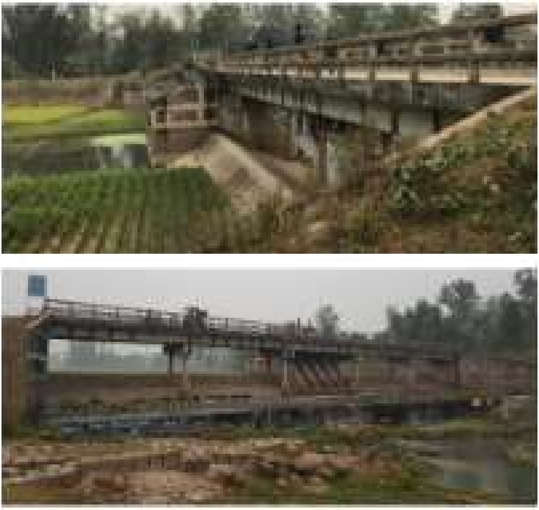

Figure 3.2 Existing Active Water Control Structure located at [illegible], Thakurgaon over Senua River

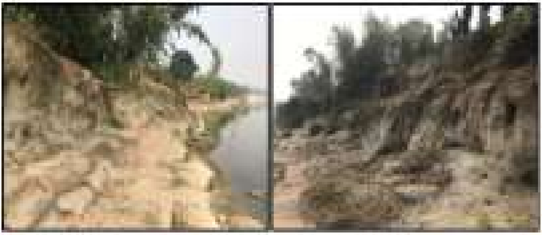

Figure 3.3 Riverbank Erosion of the Karatoa River at Sardarpara, Panchagarh

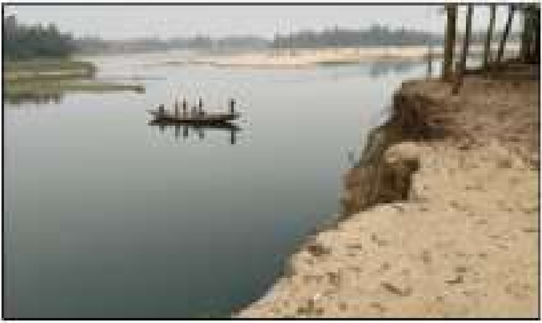

Figure 3.4 Riverbank Erosion of the Karatoa River at Aulia Ghat, Panchagarh

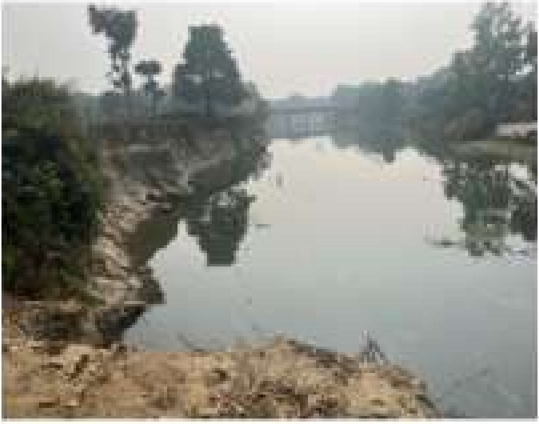

Figure 3.5 Riverbank Erosion of the Talma River at [illegible], Panchagarh

3.3 Relevance of the Project Idea

The study area is characterized by steep catchments and river bed slopes. During monsoon the rivers flow at a very high velocity and results in bank erosion. But the steep slope also results in swift drainage of the incoming water and the rivers dries up very quickly. The project was taken up to assess the water availability and look for option to store water during dry season. Protecting the vulnerable reaches of the river banks remains also another important objective of the project. As a result of a detailed hydro-morphological study and stakeholder consultations, the following benefits of the proposed interventions are identified:

- Keeping important stretches of riverbanks safe from the threat of erosion.
- Increased water availability during dry season.

3.3 Proposed Interventions

Considering the Hydro-Morphological scenario and the dynamic nature of the rivers of Panchagarh & Thakurgaon districts, three major intervention components have been proposed from technical point of view. The proposed interventions are:

i. 73.555 km of River Training Works of which 57.310 km is in Panchagarh district and 16.245 km is in Thakurgaon district.
ii. Re-excavation of 31.842 km of river of which 17.042 km is in Panchagarh district and 14.800 km is in Thakurgaon district.

3.3.1 River Training Works

After conducting detailed satellite image analysis as well as using the state-of-the-art morphological modeling tools, the vulnerable reaches of the study area were identified. After conducting a detailed field visit and with detailed interactions with the officials from BWDB Planning, Design as well as field officials of BWDB and taking their valuable comments and suggestions into consideration, essential 73.555 km River Training Works has been recommended and designed accordingly. The required length of RTW for each of the rivers have been shown in **Table 3.1**.

Table 3.1 Length and number of locations of proposed River Training Works

Sl	River	District	No.	Length (km)	Priority-1	Priority-2	Priority-3
1	Karatoa	Panchagarh	42	[illegible]	[illegible]	[illegible]	[illegible]
2	Chawai	Panchagarh	11	[illegible]	[illegible]	[illegible]	[illegible]
3	Talma	Panchagarh	3	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	Panchagarh	3	[illegible]	[illegible]	[illegible]	[illegible]
5	Pathraj	Panchagarh	11	[illegible]	[illegible]	[illegible]	[illegible]
		Thakurgaon	7	[illegible]	[illegible]	[illegible]	[illegible]
6	Tangon	Thakurgaon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Kulik	Thakurgaon	9	[illegible]	[illegible]	[illegible]	[illegible]
8	Senua	Thakurgaon	12	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	Thakurgaon	1	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	Thakurgaon	2	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	Thakurgaon	1	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	Thakurgaon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Panchagarh			[illegible]	57.310	[illegible]	[illegible]	[illegible]
Total Thakurgaon			[illegible]	16.245	[illegible]	[illegible]	[illegible]
Total			[illegible]	73.555	[illegible]	[illegible]	[illegible]

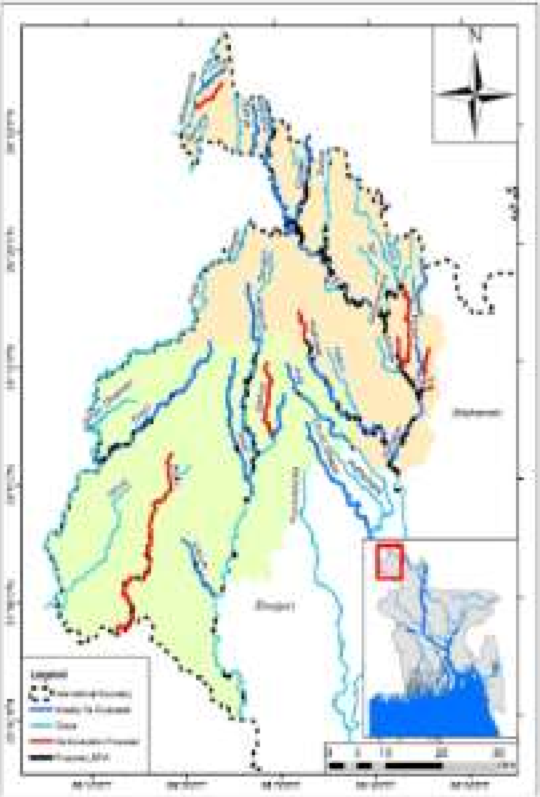

Figure 3.8 Locations of Proposed RTW & River Re-excavation

Table 3.3 Location & Length of the proposed River Training Works

River	Sl	Location	Bank	Upazila	Length (m)	Priority
Karatoa	1	Chilahati	Left	Tentulia	750	2
	2	[illegible]	Left		600	3
	3	Bhajanpur Bridge u/s	Left		400	2
	4		Right		300	4
	5	[illegible]	Left		615	2

River	SL	Location	Bank	Upazila	Length (m)	Priority
	6	Amtola Kachari	Left	Panchagarh Sadar	1500	B
	7	U/S of Chawai Confluence	Left		500	B
	8	Nahkolatanga	Left		1300	A
	9	Fultolichartenga	Left		985	C
	10	Hatkura	Left		1000	C
	11	Satiani – Kadiyatt Para	Right	Boda	1150	C
	12	Sonachandi Sarkerpara	Right		1100	A
	13	Barshimel	Right		800	A
	14	Sikarpur	Right		725	C
	15	Surjattapara	Right		400	C
	16	Banagram	Left		425	B
	17	Baghchitra Kuthepghat	Right		1250	A
	18	Boaman	Right		220	A
	19	Ramganj	Left	Debiganj	800	C
	20	Kamatkhat	Right		1600	C
	21	Dangapara	Right	Boda	800	A
	22	Mara Shasti	Left		1500	B
	23	Antar Tikar	Right		375	A
	24	Sonbazar	Left		1600	A
	25	Dabiganga	Right	Debiganj	313	A
	26	Dabiganga 2	Right		645	B
	27	Fultolibakkar	Left		2520	A
	28	Bhojatbari	Right		2275	A
	29	Telipara	Right		1250	A
	30	Uttarmara	Right		2000	C
	31	Adhikaripara Gunchar ghat	Left		1125	A
	32	Sonapara	Right		1800	C
	33	Debiganj Bridge U/S	Left		800	A
	34	Debiganj Spoda	Left		400	A
	35	Dakshin Hat Sadar Para	Right		575	A
	36	Telipara Lal – Uparhat	Right		800	C
	37	Malkadhanal Mouza	Left		1165	A
	38	Birchaghat-Khan Suhabangha Mouza	Right		725	A
	39	Maltari	Left		825	B
	40	Laxmirhatpara	Right		1125	C
	41	Mohamadpur Mouza	Left		1225	C
	42	Jorpara	Right	Birganj	825	C
Tangon	1	Chaudi Goagara Sudhar Ghat	Right	Thakurgaon Sadar	410	C
	2	Ashannagar	Right		400	C
	3	Khondhat Rokapara	Left		275	A
	4	Khondhat Chowdhury Para	Left		425	B
	5	Dhamrupur Sutradi Para	Right		350	B
	6	Dhimrupur Doulatpara	Left		895	A
	7	Borobasha 1	Left		300	C
	8	Borobasha 2	Right		310	C
	9	Fasabari Rahmanpur	Left		965	C
	10	Dobhita Bodha	Right		300	A
	11	Dagpur	Left		310	C
	12	Akcha	Right		310	C
	13	Hari Dara	Right		275	A
	14	Khadpara	Left		575	A
	15	Bharadpur	Right		300	C
	16	Kachabari	Left	Pirganj	600	B
	17	Mohammadpur mouza bang bridge	Right		425	C
	18	Bonorpara	Right		275	B
	19	Chakbasudebpur mouza	Right		300	B

River	SL	Location	Bank	Upazila	Length (m)	Priority
	20	[illegible]	Right		420	C
	21	Awlabari	Right		375	A
	22	[illegible]	Right		500	A
Pathraj	1	Boda Bridge U/S	Right	Boda	800	A
	2	[illegible]	Left		500	A
	3	Pashchim Para	Left		300	A
	4	[illegible]	Left		150	C
	5	[illegible]	Right	Thakurgaon Sadar	200	A
	6	Sultanpukur	Right		250	C
	7	Jamalpara	Right		200	C
	8	[illegible]	Left		200	B
	9	Bottola 1	Right		300	C
	10	Kathagari	Right		120	A
	11	Kathagari	Left		200	A
	12	[illegible]	Right	Debiganj	340	A
	13	[illegible]	Right		350	A
	14	[illegible]	Right		410	A
	15	Kotbari	Right		180	B
	16	Kotbari Primary School	Right		250	B
	17	Kotbari Bridge U/S	Left		400	B
	18	Kotbari Bazar - Left Bank	Left		320	C
	19	Kotbari High School	Right		650	A
	20	[illegible]	Right		500	B
Chawai	1	[illegible] Bazar	Left	Panchagarh Sadar	400	C
	2	[illegible]	Right		1300	A
	3	U/S of Jagdal Bazar Bridge RB	Right		500	A
	4	Jagdal Bazar	Left		300	A
	5	[illegible]	Left		350	A
	6	[illegible]	Right		400	C
	7	[illegible]	Left		420	B
	8	Amarkhana	Right		420	A
	9	Chawai Bridge	Left		300	B
	10	[illegible]	Right		800	C
	11	[illegible]	Left		1140	A
Tirnai (Thakurgaon)	1	[illegible]	Left	Baliadangi	750	C
	2	[illegible] Para	Right		250	C
	3	Baliadangi Upazila Parishad	Left		675	A
	4	[illegible]	Left		480	C
	5	[illegible]	Right		200	C
	6	[illegible]	Left		120	C
	7	[illegible]	Right		200	C
	8	[illegible] Beel	Right	Ranisankail	500	A
	9	[illegible] Beel Madrasha	Right		440	A
	10	[illegible] Village	Right		200	A
	11	[illegible] Village	Left		475	C
	12	[illegible]	Right		335	C
Kulik	1	[illegible]	Right	Ranisankail	200	A
	2	[illegible]	Left		180	C
	3	[illegible]	Right		150	C
	4	[illegible]	Right	Haripur	250	C
	5	[illegible] Ghat	Right		50	A
	6	[illegible]	Right		100	A
[illegible]	1	[illegible]	Left	Debiganj	510	B
	2	[illegible]	Left		850	A
	3	[illegible]	Left		320	B
	4	[illegible]	Right		540	A
	5	[illegible]	Left		1410	A
Talma	1	[illegible]	Left		875	B

River	Sl	Location	Bank	Upazila	Length (m)	Priority
	2	[illegible]	Left	Panchagarh Sadar	880	A
	3	Banshbari	Left		310	A
	4	Purbo Kotalpara, Purbo Jagadal	Left		240	A
	5	[illegible]	Left		310	C
Shuka	1	Thakurgaon Road Station	Right	Thakurgaon Sadar	400	C
	2	Thakurgaon Road Bazar	Right		200	A
Kulik	1	[illegible] Bazar	Left	Thakurgaon Sadar	110	A
	2	[illegible] Kalimondir	Right		120	A
Senua	1	[illegible]	Left	Thakurgaon Sadar	200	C
[illegible]	1	[illegible]	Left	Pirganj	110	C

3.3.2 River Re-Excavation

Taking into consideration the importance of water storage in the rivers, re-excavation has been proposed for seven rivers in the study area. The rivers which have been proposed for re-excavation along with the proposed re-excavation length has been shown in **Table 3.2**.

Table 3.2 Proposed re-excavation length

Sl	River	District	Length (km)
1	Kulik	Thakurgaon	14.800
2	[illegible]	Panchagarh	3.358
3	[illegible]	Panchagarh	6.470
4	[illegible]	Panchagarh	1.603
5	[illegible]	Panchagarh	1.750
6	[illegible]	Panchagarh	3.058
7	Pathraj	Panchagarh	0.803
8	Senua	Thakurgaon	6.000
Total Panchagarh			17.042
Total Thakurgaon			20.800
Total			37.842

3.4 Stakeholders

Stakeholders are anybody who is both impacted by and has an impact on a system's policies, decisions, or actions. Groups of people, organizations, institutions, and possibly even single person can be a stakeholder. Stakeholders can be divided into primary and secondary stakeholder categories.

3.4.1 Primary Stakeholders

People who would be directly benefited or impacted by this project intervention are considered as primary stakeholder. These include the farmers, fishermen, small business communities as well as the households that may be affected/displaced due to project interventions, women groups, and wage labors. However, local leaders, community members and other local representatives are also consulted during the consultations.

5.4.2 Secondary Stakeholders

This category of stakeholders pertains to those who may not be directly affected but have interests that could contribute to the study, play a role in implementation at some stage, or affect decision-making on Project aspects. In this Project, concerned government departments, and line agencies fall under this category. Secondary stakeholders for the Project include local government institutions (LGI), other government agencies, NGOs and general public at large.

5.4.3 Objectives of the Stakeholder Consultations

The objectives of the stakeholder consultations were:

- Sharing of information with local people and other stakeholders about the goal and objective of the proposed project, and soliciting their views on the project and its potential or perceived impacts;
- Engaging stakeholders for maximization of the project benefits.
- To aware people about the issue that could be created from the proposed project.
- Knowing people's viewpoints, opinions, concerns, and perspectives about the project.
- Collect suggestions (mitigation measures, enhancement measures, contingency measures, compensation measures) to resolve those problems, if any.
- Receiving input on apparent issues in the implementation process, as well as mitigating the negative impacts.

5.4.4 Approach and Methodology

Stakeholder consultation was carried out by CEGIS. A participatory approach was followed for conducting the stakeholder consultation meetings. The CEGIS Team, comprising professionals of all concerned disciplines, used a checklist for the consultation meetings. The issues of the overall project planning for intervention and probable impacts on the socioeconomic, agricultural, hydrological, fisheries, and ecological issues were discussed in detail, including the potential impacts of the interventions on the environmental and social parameters. Institutional issues were also discussed, regarding which the participants provided their opinions and suggestions freely. In this regard, members of District Water Management Committee were also interviewed.

During the consultations, a social scientist of the CEGIS Team collected opinions and comments from different groups of local people. The other members of the multi-disciplinary Team also attended and assisted as necessary. The Team used maps of the project area to show project interventions to the participants of the consultation meetings. The facilitators explained all relevant points and issues in order to enable the participants to comprehend the proposed interventions' activities properly and to receive their respond accordingly. The consultants took utmost care in recording the participants' opinions and views relevant to the study. The local needs and demands were discussed by giving equal opportunity to all participants attending the meetings. During consultation, all relevant issues were discussed in detail.

5.5 Demand Analysis

The summary of the demands based on stakeholder consultations has been presented in **Table 5.4**.

Table 3.4 Summary of Stakeholder Consultations and Opinion of CEGIS

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
01	District Commissioner (DC), Panchagarh	07-03-2021	11:00 A.M.	- Erosion is the big problem for Panchagarh Upazila and thousands of local people are suffering every day. - Another issue is that many rivers are dried up during the winter season.	- Necessary river bank protection works should be undertaken; - The DC welcomed the project and assured for support regarding the project.	- CEGIS agrees to the suggestions and recommends for early implementation of the project.
02	Executive Engineer (XEN), Panchagarh O&M Division, BWDB	28-05-2021	9:30 A.M.	- Issues like river erosion, river drying up during dry season are negatively impacting farmers and locals. People are losing land due to erosion and farmers are unable to use river water for cultivation during dry season. - Sand and stone mining especially from Karatoya, Mahananda and Dahuk river is causing damage to the rivers. Stopping the extracting will have positive impact on Mahananda but it will also cause many people to lose their income sources.	- River wise bank protection works list need to be prepared. - Re-excavation/dredging of rivers is necessary. - Sand and stone mining needs to be stopped. - The people who depend on sand and stone mining should be provided assistance for alternative livelihood source. - BWDB, BADC, BMD, LGED should coordinate while preparing the projects and work in close cooperation. - Integrated approach needs to be adopted for fruitful implementation of the project. - Dependency on surface water should be introduced for	- CEGIS agrees to the suggestions regarding river bank protection works and excavation/ dredging at required sites of the river for the safety of the locals. - Sand and stone mining is badly affecting the river, which needs to be stopped and alternative livelihood for the involved people should also be considered. - The projects formulated by the respective organizations should be at first discussed in the water management **committee** meeting to avoid duplication, consider rationale and transparency of implementation of the project. All the organizations

Sl.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				• BWDB, BADC, BMDA, LGED has their own projects in the river of Panchagarh, which might create conflict among them. • Lack of integration between different organizations for implementation of development work is a major challenge. • Excessive groundwater uses by BADC and BMDA creates problem of water crisis during dry season (especially April-May). • Unplanned structure constructed by LGED seems to be problematic for sustainable river management. • Stone extracting is also a great concern as it hampers the smooth water flow and creates river bank erosion at different locations especially in the	providing irrigation facility. • Before implementation of any project in the river, BWDB should be consulted. • Alternative livelihood should be developed so that stone extracting can be stopped.	should coordinate and work in close cooperation for betterment of the people. • Holistic approach should be followed for implementation of integrated water resources management (IWRM). • According to Govt. declaration, surface water should be given priority to reduce the pressure on groundwater.

SL.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	LGED's Opinion
				Dahuk, Talma, Chawai, Ghoramara, Karatoya, Mahananda River		
03	Assistant Director, Department of Environment (DoE), Panchagarh	25-05-2023	10:30 A.M.	• Auto Unilever Company discharges liquid waste into the Karatoya river directly at Dhakkamara area in Panchagarh Sadar • Kazi & Kazi Tea encroached the Dahuk river at different points. • Illegal encroachment is a major problem in most of the rivers of Panchagarh District.	• Direct discharge of liquid waste into the Karatoya river should be stopped and ETP should be installed without any delay. • Stone lifting and sand extraction should be stopped for the betterment of river management. • Concerned authority should take steps immediately for stopping encroachment of different rivers in Panchagarh District.	• Liquid waste should not be directly discharged into any river and ETP should be installed and properly operated. Concerned authority should monitor this. • Stone and sand extraction should be stopped through ensuring alternative livelihood. • Public awareness needs to be raised for stopping encroachment of the river to keep them lively.
04	Senior Assistant Engineer, LGED, Panchagarh	25-05-2023	12:30 P.M.	• There are many existing structures and project of LGED in the catchments of different rivers under Panchagarh District. Implementation of more new projects in those areas by BWDB can create conflict.	• Both LGED and BWDB needs to cooperate to avoid duplication and conflict.	• Coordination between LGED and BWDB will facilitate successful implementation of the project. • The excavation/dredging of rivers should be conducted under the bridges in consultation with the concerned LGED officials to ensure safety of the bridges.

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
05	Forest Ranger (In-Charge), Bangladesh Forest Department, Panchagarh.	29-05-2023	11:45 PM	- Currently, no development activities are being initiated by BFD within the study area. - There is some vested forest land occupied by the BFD within the study area. Such as, 1. [illegible] Bagan which is covering about 100 to 110 acres in Debiganj Upazila, 2. Moyna Mati Char which is a vested land around the Karatoya River in Debiganj Upazila, 3. Sal forest near Bodeshwari temple in Boda Upazila, 4. Ecopark which is covering about 10 acres in Tetulia Upazila, 5. Mixed forest area of about 112 acres near [illegible] Tea Estate in Tetulia Upazila. - There are two tree nurseries within the study area. One is situated within the Upazila Parishad office	- Mohanagar Dighi is a significant tourist spot within the area. There are different types of migratory birds observed in winter season, which should be taken in to consideration while implementing the project. - River bank erosion also causing destruction of forest land. During field visit, such area should be identified.	- IWM team members followed his suggestions during the field visit.

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				and forest office and another is situated in the Sonarhat Dighi, which is a picnic spot situated in the Panchagarh Sadar Upazila. - The forest area is being encroached and constricted day by day through deforestation by the local inhabitants. - Karatoya river is facing severe bank erosion problem due to sand mining.		
08	Upazila Nirbahi Office (UNO), Panchagarh Sadar, Panchagarh	26-05-2023	12:25 PM	- There are river bank erosions at different locations of the rivers under Sadar Upazila. - For Balu Mahal, Site clearance needs to be taken. - Illegal encroachment in the rivers is a major problem in the area.	- The UNO welcomed the project and suggested for implementation of the river bank protection work. - DC should take necessary steps regarding Balu Mahal issue. - BWDB Executive Engineer has the authority to stop the illegal encroachment.	- Necessary interventions at different locations identified by the technical study team (IWM) based on the model study and situation on the ground should be implemented to prevent river erosion. - Responsible authority may take necessary steps for handling Balu Mahal related issues. - Illegal encroachment should be stopped by the concerned authority.

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
07	Upazila Chairman, Panchagarh Sadar, Panchagarh	26.09.2023	10.30 A.M	• The dredged material was not managed properly while carrying out the dredging under previous projects. • After dredging/re-excavation of the rivers, dredged/re-excavated materials dumped in the river side, which came back in the rivers during monsoon.	• After dredging/re-excavation of the rivers, dredged/re-excavated materials should not be dumped in the river side and should be properly managed under the proposed project. • Public awareness needs to be raised to draw groundwater from deep aquifer. • If there is enough water in the Karatoya River, a water treatment plant could be built to purify water for drinking purpose.	• CEGIS also agrees that a dredged material management plan should be formulated and the dredged/re-excavated materials should be properly managed according to the plan. • Abstraction of groundwater from deep aquifer and construction of water treatment plant to purify water for drinking purpose from Karatoya River may be explored by the concerned organization.
08	Sub Assistant Engineer, DPHE, Panchagarh	26.09.2023	12.45 P.M.	• People draw groundwater from 10-20 feet depth for drinking purpose, which may lead to health hazards.	• Drinking water should be drawn from 30-40 feet depth in order to avoid any health risk.	• CEGIS agrees to the suggestions made by the DPHE official.
09	Executive Engineer, RHD, Panchagarh	26.09.2023	1.00 P.M.	• Sand and stone lifting is one of the main problems for erosion and water quality deterioration of the rivers. Everyday many people are engaged in illegal sand and stone lifting activities.	• These illegal sand and stone lifting should be stopped immediately.	• To protect the rivers from erosion and deterioration of its water quality sand and stone lifting should be stopped but alternative livelihood should be considered for the involved people.

Sl.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
10	Executive Engineer, Barind Multipurpose Development Authority (BMDA), Panchagarh District	23-05-2023	3:00 P.M.	• BMDA re-excavated Pathraj river for about 09 km. • BMDA also re-excavated Talma river from Talma bridge to Mohananda embankment for 33 km in the 2021-22 financial year. • Apart from that, BMDA re-excavated 32 reservoirs at Magura Union Parishad in Panchagarh Sadar Upazila in an area of 5.75 acres and another one has been re-excavated within 02 km of the previous one.	• Flood history must be known before providing technical suggestions. • Catchment area needs to be identified for selecting irrigation potentiality.	• Coordination between BWDB and BMDA is needed to obtain better outcomes after implementation of the project.
11	Sub Assistant Engineer, LGED, Boda, Panchagarh	23-05-2023	11:30 A.M.	• Many parts of Bhulli khal are filled with sand now. • Many people are illegally occupying land next to Bhulli khal by filling it, and encroachment is a significant issue around the khals in the area. • Both Saldanga and [illegible] bridges are in danger only because of sand and	• Address the issue of illegal land occupation, remove encroachments, and proper excavation of Bhulli khal is necessary.	• Re-excavation of Bhulli khal at selected locations suggested by the technical study team should be carried out. • The illegal occupants should be evicted and may be relocated in khas lands, if available. • Coordination between BWDB and LGED is needed to obtain better outcomes after the implementation of the project.

Sl. No.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				stone extraction.		
12	Upazila Nirbahi Officer (UNO), Boda, Panchagarh	23-05-2023	1:45 PM	• The UNO of Boda Upazila mentioned about conflict related to land near the river in few parts of the Upazila. • River bank erosion has been observed on both banks of Karatoya River at Marea Union	• Proper and effective interventions should be implemented to solve river related problems, which will also resolve the conflict. • Necessary steps should be taken without any delay for river bank protection.	• The technical study team (IWM) may suggest necessary interventions to resolve the conflict related to land near the river.
13	Upazila Chairman, Boda, Panchagarh	23-05-2023	1:15 PM	• There is conflicts among people related to land. • Huge amount of water is being used for not only fish sector but also for the agriculture sector.	• Local people welcomed the project and wanted to implement necessary interventions were needed. • Water should be used rationally and conserved through appropriate interventions, so that it remains available for use in the dry season.	• The technical study team may consider necessary interventions for conservation of water so that it remains available for use in the dry season also.
14	Jamadarpara 01 no Banglabandha Union, Tetulia Upazila, Panchagarh	23-05-2023	3:00 pm	• Disposal of dredged/re-excavated material by BWDB on the cultivable lands is a bad system (because it is on both banks of [illegible]	• Dredged material management plan should be formulated in such a way that no cultivable land is affected by disposal of dredged / re-	• The technical study team may consider preparing a dredged/re-excavated material management plan in such a way that no cultivable land is affected by disposal of

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	BWDB's Opinion
				(Tanokagachi) river. There are a huge area of cultivable lands that produces crops round the year. • Proper slope was not maintained during re-excavation of river by BWDB. • There is a barrage (Fulbari barrage) in Indian side of the Mohananda river located at 1.75 km away of Banglabandh-India border. When sudden inflow reaches the barrage, it is released discriminately which badly affects Bangladesh. On the other hand, the flow gets reduced during the dry season. • Tree plantation on private lands done by BWDB creates problem. • During re-excavation of the 'Tirnai' (Tanokagachi) river, huge number of private lands	excavated materials. • Proper side slope should be maintained while carrying out re-excavation/dredging of river. • The issue of sudden release of water through Mohananda river from the Indian barrage and augmentation of the dry season flow may be discussed in the JRC meeting. • A judicious tree plantation plan should be prepared in consultation with DoF and local people, so that no objection would be raised by any part of the society. • Before re-excavation, local Upazila Chairman, Upazila Land Officers, Civil Society Members and Local Stakeholders should be well-informed to avoid any sort of confusion.	dumping the excavated materials. • Proper side slope of re-excavation/dredging of river may be provided while designing the section. • JRC may consider the issue sudden release of water through Mohananda river from the Indian barrage and augmentation of the dry season flow.

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
				have been cut without any prior notice or discussion.		
15	District Fisheries Officer (DFO), Panchagarh	22-08-2023	11:30 A.M	- Limited water availability, coupled with a lack of scientific knowledge, has led to a decline in native species.	- The proposed intervention is well accepted. He assumed that after the development activities, the river system will be alive and also proposed to establish rubber dam, sluice gate in different rivers (Karotoya, Talma, Chawai, Buriteesta etc.) to hold water for various uses like sanctuary establishment, cage culture etc. It will help to regenerate the lost habitat of fish species and will fulfil the local demands. He also suggested that development activities should be done with proper mitigation of negative impacts.	- The technical study team may consider the suggestions for construction of rubber dam, sluice gate in different rivers (Karotoya, Talma, Chawai, Buriteesta etc.) to hold water for various uses. - CEGIS would also provide appropriate EMP to mitigate negative impacts of the intervention suggested by IWM.
16	Upazila Fisheries Officer, Tetulia Upazila Panchagarh (Sadar)	11-09-2023	2:00 pm	- Due to fund crisis, support for fish sanctuary is not possible to be provided in [illegible] River. - Lack of proper management of water control structures of BWDB, fish sanctuary is	- There is good potential for fish sanctuary if sufficient water may be made available in the Mahananda River (Panchagarh) and [illegible] river. - There is scope for fish nursery in the Tetulia Dam. - Fisheries Conservation Act	- The technical study team may consider appropriate interventions to conserve water to enhance fishery resources. - Coordination between BWDB and DOF should be well established to increase fish production.

Sl. No.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				facing problems. • Lack of ownership for ensuring water conservation capacity is a key problem.	should be properly followed and utilized.	
11	Upazila Nirbahi Officer (UNO), Tetulia, Panchagarh	22.06.2023	1:00 P.M.	• Many points of Tetulia are under threat of erosion and every year huge quantity of land is lost. • There is no natural flow in the rivers. • Siltation rate is too high in the rivers. • Lack of regular monitoring against sand extraction. • There is huge demand of sand for government projects. But scope to obtain sand from here is not utilized properly. • River re-excavation should not take huge budget. • Employment of local people is possible. • Lack of sensor-based technology and punch system finger-based attendance is a major	• For immediate response, geo-bags should be dumped. • Local people should be given priority for engagement in the project works. • Natural flow in the rivers need to be ensured for betterment of the environment. • Sustainable solution is urgently needed for stopping high siltation rate. • Extracted sand can be utilized for running development projects of the government at different parts of the country. • Re-excavation of rivers should be completed with least budget. • Local people should be employed for re-excavation related work. • Smart Bangladesh concept should be applied through using latest technology for better and efficient output.	• Immediate response suggested for erosion protection should be taken under consideration. • Local people should be given priority in the project works. • The technical study team may consider the issue for ensuring natural flow of the rivers and sustainable solution for stopping high siltation rate. They also need to assess whether construction of water control structure is needed to be constructed or not in seasonal rivers. • Budget should be rational for re-excavation of rivers. • Respective organization should at first consult with the District Water Resources Management Committee at the planning and implementation

Sl. No.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	BWDB's Opinion
				concern for successful implementation of the project. • There is no online database to monitor annual development program to find out how much are completed and how much are pending. • There is shortage of man-made fish sanctuary which needs to be focused here. • BWDB does not need to take any LLP related project. BADC & BMDA are more than enough to supply irrigation water in rural area. • There are numerous water control structures in seasonal rivers, which seems to be useless. • There is lack of artificial reservoir to use water in the dry season. • Common design should be followed in the upstream	• Man-made fish sanctuary can be explored on pilot basis. • Coordination between BWDB, BADC and BMDA should be maintained. • Construction of new water control structures are not required in seasonal rivers. • Creation of artificial reservoir should be explored. • To execute the project development work in the river through cost-effective approach, District Water Resources Management Committee should be consulted at first.	stage of any project.

Sl. No	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				and maintenance of the bridges located within the Upazila for river bank protection work. - There are many Govt. Organizations who want to work in the rivers. Without taking permission of District Water Resources Management Committee project should not be started.		
19	Upazila Chairman, Tetulia, Panchagarh	01-06-2023	12:15 PM	- The Dahuk River has reached in a critical state as no maintenance efforts have been taken since the project's completion. - There was abundance of fishes especially in Ranachandi river which 5-7 years ago but not observed now-a-days due to lack of sufficient water storage. - There is deficiency in planning for re-excavation related activities.	- A sluice gate is required in the Dahuk river. - Local representatives should be well informed before starting implementation of the project. - O&M activities should be continued properly to obtain long term benefit. - Water storage facility needs to be established for abundance of fishes. - Well-planned re-excavation should be done. - Slope maintenance should be properly done considering sand extraction and stone lifting.	- The individual study team may consider construction of a sluice gate in the Dahuk river. - The local representatives should be well informed regarding implementation of the project for smooth execution of the project. - The individual study team may consider construction of a new water control structure over the Ranachandi river with increased capacity and slope maintenance issue. - Re-excavation should be properly planned for successful implementation.

Sl.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				• Slope maintenance is a challenging issue for the rivers under this upazila as huge amount of sand extraction and stone lifting is going on. • The water control structure over the Ranachandi river is insufficient to pass water.	• A new water control structure over the Ranachandi river with increased capacity needs to be constructed.	
19	Upazila Engineer, Tetulia Upazila, Panchagarh District	11-08-2021	3:00 pm	• Generally, BWDB implements project considering catchment area. From that point of view, there seems to be no problem.	• Projects should be planned based on catchment area.	• Projects should be planned based on catchment area. • Coordination between BWDB and LGED should be well-established to avoid overlapping of any project related activities.
20	Upazila Agriculture Officer (UAO), Tetulia, Panchagarh	11-08-2021	4:00 P.M.	• The canal system connected to the rivers are not sufficient. • The common reach of the Mahananda river has been silted up. Besides, the dry season flow declines sharply, which creates problem for irrigation and other uses. • Sometimes natural water flow is	• More river connected canals need to be excavated. • Joint River Commission (JRC) may discuss with India for the flow augmentation. • If river bank protection works or flood control embankment needs to be constructed, that should be completed in a sustainable way. • Surface water reservoir needs to	• The technical study team may consider excavation of more river connecting canals. • Joint River Commission (JRC) may discuss with India to jointly ascertain the reason for water scarcity in dry season and reach to an agreement for augmenting the dry season flow of the Mahananda river. • JRC Bangladesh may also discuss

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
				obstructed by sediment due to fish farming. The agriculture land is at the risk of collapse due to the river due to stone mining.	be considered for irrigation facility in the dry season.	with India to reach an agreement for carrying out re-excavation/dredging along the common space of the Mahananda river. • The technical study team may study the possibility for creation of surface water reservoir to facilitate irrigation. • Stone extracting should be stopped by the concerned authority.
21	Upazila Chairman, Debiganj, Panchagarh	3-09-2023	1:10 P.M.	• The chairman mentioned erosion is a problem in many points.	• The chairman suggested for implementing required interventions where necessary.	• The technical study team may consider the issue.
22	Upazila Engineer, Debiganj, Panchagarh	3-09-2023	12:30 P.M.	• Some parts of Karatoa river are vulnerable to erosion which needs to be addressed.	• Necessary erosion control interventions should be implemented.	• The technical study team may consider the issue.
23	Upazila Nirbahi Officer (UNO), Atwari, Panchagarh	4-09-2023	4:00 P.M.	• Erosion has caused big damage at many places such as Durgapur Village of Radhanagar Union of Nagor river Atwari Upazila. • Many parts of Atwari Upazila are under grave risk of erosion.	• Proper study should be conducted and required steps should be immediately taken by the responsible organization to combat erosion.	• CEGIS also observed serious erosion at many places of Nagor river. The technical study team may address the issue.
24	Upazila Chairman	4-09-2023	10:30 A.M.	• The part of Nagor river in Atwari is	• Immediate river protection works should be	• CEGIS also agrees to the suggestions for

Sl.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
	Atwari, Panchagarh			causing river erosion. One Eidgah and graveyard is at the risk of erosion. • Pathraj river is also causing river erosion at many places.	undertaken to protect the Eidgah and graveyard from erosion. • Dredging is required in Pathraj River.	considering immediate bank protection works to protect the Eidgah and graveyard from erosion. The technical study team may consider the issue. • Necessary study should be carried out by the technical study team in order to identify the need of dredging in Pathraj river.
23	Upazila Agriculture Officer (UAO), Debiganj, Panchagarh	22.08.2023	10.15 A.M.	• Agriculture land is getting reduced day by day due to increase of rural settlement. • Agriculture land is also reducing due to river erosion. • Some rivers in Debiganj like Kurum, Kalidaha, Dara, Pathraj, Salnei, Tangapani and Vulli have been silted up resulting reduction of their drainage capacity. Drainage congestion occurs during heavy rainfall and damage standing HYV Aman crop. • Some rivers are grabbed by influential	• Land use policy should be practiced in the study area to minimize the tendency of settlement establishment to the cultivable land. • Agricultural land should be protected through river bank protection. • Kurum, Kalidaha, Dara, Pathraj, Salnei, Tangapani and Vulli rivers should be re-excavated/dredged to enhance dry season flow to facilitate irrigation in early dry season by surface water and remove drainage congestion. • Need proper monitoring by BWDB to stop sand bed preparation in the river.	• Land use policy should be practiced in the study area. • Need proper bank protection of the rivers where bank erosion has occurred. The technical study team may address the issue. • Need river dredging/re-excavation and encourage farmers for surface water irrigation in early dry season. • Need proper monitoring by BWDB to stop sand bed preparation in the river. • The technical study team may address the issue of water conservation.

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	IWM's Opinion
				people to make dam/ weir but in the river premises. - Underground water level is going down day by day due to reduced flow of rivers in post monsoon period.	- Need to conserve water through re-excavation of rivers in Debiganj.	
28	Upazila Agriculture Officer (UAO), Atwari, Panchagarh	04.10.2023	10:15 A.M.	- Irrigation crisis is observed in HYV Boro field on both sides of the Pathraj River. - Underground water level is declining day by day during dry season. - Agriculture land/ fields lost by river bank erosion at the concave banks. Some lands are grabbed by the influential people for which the river has become narrow and lost its drainage capacity.	- The rivers need to be re-excavated/dredged to increase flow to facilitate surface irrigation water and remove drainage congestion. - Need river bank protection works at the erosion vulnerable locations.	- The technical study team may address the issue of river dredging/ re-excavation and river bank protection works at the erosion vulnerable locations. - The technical study team may also explore the potential of water conservation through appropriate infrastructures to facilitate irrigation in dry season.

Sl. No.	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
27	CEGIS team at different locations of Kurum, Talma, [illegible], Buri Ghoramara, and [illegible] rivers of Boda and Sadar Panchagarh	07.03.2023	-	- Rivers have been silted up. No surface water in the river during dry season. - Some rivers are grabbed by influential people and make illegal seed bed in the Talma River bed. - About 1.5 km river bank erosion was found at Ghoramara of Ghoramara village.	- Need river excavation for increasing surface water availability in early dry season. - Need proper monitoring by BWDB to stop seed bed preparation in the river. - Need river bank protection works at the erosion vulnerable area.	- The technical study team may address the issue of river re-excavation/dredging and river bank protection at the erosion vulnerable locations. - BWDB and Local administration should aware people of the bad effect of seed bed in the river and sensitize them not to do it.
28	CEGIS team at different locations of Dara, Rangapani, Buri Teesta, Kurum and Kalidaha rivers of Debiganj, Panchagarh	07.03.2023	-	- Some rivers like Dara, Rangapani, Buri Teesta, Kurum and Kalidaha have been silted up and caused reduction of their drainage capacity. Drainage congestion occur during heavy rainfall and drainage standing in T. Aman crop. - Surface water scarcity of the Kalidaha river during dry season.	- The rivers should be re-excavated/dredged to increase water availability to facilitate surface irrigation in early dry season and remove drainage congestion. - Construction of a 06-vent regulator at downstream of Kalidaha river for surface water availability in early Rabi season.	The technical study team may address the issue of river re-excavation/dredging and construction of a 6-vent regulator at the suitable location of Kalidaha river.
29	CEGIS team at different locations of Karatoya, Kurum, Pathraj and [illegible] rivers of Boda Panchagarh	03.03.2023	-	- Some rivers like Karatoya, Kurum, Pathraj and [illegible] have been silted up and caused reduction of	- The rivers should be re-excavated/dredged to increase water availability to facilitate surface irrigation in early dry	- The technical study team may address the issue of river re-excavation/dredging,

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
				their drainage capacity. Drainage congestion occurred during heavy rainfall and damaged standing HYV Aman crop.	season and remove drainage congestion.	
30	CEGIS team at different locations of Pathi, Tangon, Nuvaye and Nagar rivers of Atwari Panchagarh	04.09.2023	–	- Some rivers like Pathi, Tangon, and Nagar have been silted up resulting reduction of their drainage capacity. Drainage congestion occur during heavy rainfall and damage standing HYV Aman crop.	- The rivers should be re-excavated/dredged to increase water availability to facilitate surface irrigation in early dry season and remove drainage congestion.	- The technical study team may address the issue of river re-excavation/dredging.
31	CEGIS team at different locations of Karatoa, Dahuk, and Pathraj rivers of Tetulia and Boda Panchagarh	05.09.2023	–	- Some rivers like Karatoa, Dahuk, and Pathraj have been silted up and resulted reduction of their drainage capacity. Drainage congestion occur during heavy rainfall and damage standing HYV Aman crop.	The rivers should be re-excavated/dredged to increase water availability to facilitate surface irrigation in early dry season and remove drainage congestion.	The technical study team may address the issue of river re-excavation/dredging.
32	CEGIS team at different locations of Karatoa, Talma, and Sui rivers of Debiganj Panchagarh	05.09.2023	–	- The Karatoa, Talma, and Sui rivers have been silted up which has affected conveyance capacity of the rivers causing	- The rivers should be re-excavated/dredged to increase water availability to facilitate surface irrigation in early dry season and	The technical study team may address the issue of river re-excavation/dredging and rehabilitation of the pump house to ensure surface water irrigation in the area.

SL	Stakeholders Locations	Date	Time	Comments on Problems/ Issues	Stakeholders Suggestions	CEGIS's Opinion
				drainage problem when it rains heavily and damaging the HYV Aman crop • Pump houses of Ramdan Hoor at Laxmirampur is not functioning.	remove drainage congestion. • Need rehabilitation of the pump house and ensure surface water irrigation in the area.	

(Reference: ESIA Report, CEGIS)

3.6 Strengths, Weakness, Opportunities, and Threats (SWOT) Analysis

A SWOT analysis is a strategic planning tool to evaluate a project's strengths, weaknesses, opportunities, and threats. It involves specifying the project's objective and identifying the internal and external factors that are favorable and unfavorable to achieving that objective

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During SWOT analysis, strength identified the internal strength of the project. Weakness identified the internal problems and issues of the project. Opportunity identified the external factors that would accelerate the project benefits and Threats identified the unfavorable external factors, which would be hazardous for this project.
As illustrated below, strengths and weaknesses were internal, i.e., projects influenced and manipulated with their strengths and weaknesses. On the other hand, opportunities and threats were external. It meant projects only reacted to opportunities and threats and they did not have any means to influence opportunities and threats.

SWOT analysis has important practical implications. Specifically, with SWOT analysis findings in their hands, the senior-level management identifies and builds upon their strengths, discovers new opportunities, and works on eliminating or minimizing project threats. Accordingly, SWOT can be a powerful aid for senior-level management to develop an appropriate strategy.

After receiving the interventions from the technical study team (IWM), CEGIS conducted the SWOT analysis and find out the strengths, weaknesses, opportunities, and threats due to the interventions in relation to environmental and social contexts.

Table 3.3 SWOT Analysis

Strength	Weakness
• Improved water conservation capacity. • Presence of river bank protection works at several locations in the study area for protection of riparian land from erosion. • Skilled technical professionals under BWDB. • Lots of social amenities, archaeological sites, and health facilities in the project area.	• Lack of sufficient funds for operation and maintenance of project interventions. • Lack of necessary manpower to regularly monitor the condition of the project interventions, in order to undertake the maintenance work at an appropriate time. • Lack of stockpile of geo-bags and CC Blocks near the intervention sites to combat emergency situation.
Opportunity	**Threat**
• Presence of NGO's activities for development of social entrepreneurs. • Possibility for agriculture extension services in the study area. • Improved communication and available transportation facilities. • Improvement of livelihood and increased employment opportunity.	• Failure of recommended material management plan. • Bank erosion at reaches other than protected sites. • Lack of coordination among the GoB organizations for implementing projects in the same river.

(Reference: ESIA Report, CEGIS)

SECTION FOUR

TECHNICAL/TECHNOLOGICAL AND ENGINEERING ANALYSIS

4. TECHNICAL/TECHNOLOGICAL AND ENGINEERING ANALYSIS

4.1 Location

4.1.1 An Overview of the North-West Region

The current study area lies in the North-West Region of Bangladesh (**Figure 4.1**). The North-West Region of Bangladesh is bounded by the Jamuna River in the East, the Ganges to the south, and the international border to the north and west. The region spans between longitudes 88°00' E to 89°50' E and latitudes 23°47' N to 26°45' N. NWRM includes 51 regional rivers with a total length exceeding 2,800 km. An extensive area of depressions or Beels exists in the south-central part of the region. This extensive area is collectively called 'Chalan Beel'. In the monsoon the area acts as a huge flood retention reservoir. The main sources of inflow into the region are runoff from local rainfall, which sometimes can be very intense and spilling from the large bordering rivers, particularly the Jamuna and Teesta.

4.1.2 Geography and Topography of the Study Area

Figure 4.2 shows the Digital Elevation Model (DEM) in and around the study area. The study area is characterized by the steep catchment slope, with the northern tip of the area having RL of 100 mPWD while the southern part of the study area has RL 30mPWD. **Figure 4.3** shows the General Soil Classification in and around the study area. The soil type of the study area is mainly comprised of grey flood plain, Non-Calcareous Brown flood plain and black terai soils. The area-elevation curve of the study area has been shown in **Figure 4.3a**.

4.1.3 The Rivers of Panchagarh-Thakurgaon Districts

The characteristics of the main rivers of the Panchagarh-Thakurgaon districts as well as their bed slope, maximum discharge, 75% dependable flow in dry season has been shown in **Table 4.1**. A short description of the rivers has also been provided below.

Karatoa

Karatoa is a trans-boundary river which rises in the hilly areas of Baikunthapur jungles in the north-west of Jalpaiguri district (West Bengal, India). The river enters Bangladesh through Bhajanpur Union, Tetulia, Panchagarh and subsequently flows southward along with India-Bangladesh border before making its south-eastward journey through Panchagarh. It finally falls into Atrai river in Sarkarpur Union of Dinajpur district. The Karatoa is a meandering perennial river but in the dry season the flow does reduce significantly. The flow of the river varies from 2.36 cumec to 4970 cumec at Bhushirbandar, Dinajpur as mentioned in Bangladesher Nod-Nodi, 2011. The slope of the river is 31 cm per km as mentioned in Bangladesher Nod-Nodi, 2011. The width of the river varies from 35 m to 200 m whereas, the average width is around 135 m. The highest flood level of the Karatoa was found to be 71 mPWD near Panchagarh Town and 54.56 mPWD near Debiganj. The ancient Karatoa was a large river, which received a great volume of water from Teesta River. Since the mainstream of the Teesta was diverted to the east in 1787, the Karatoa has gradually silted up. Ghoramara, Chawai, Chatna, Pathraj, Buri Tista are tributaries of the Karatoa River, while Dhepa is a distributary of the Karatoa River. The river remains navigable throughout the year. This Karatoa River, situated in the Panchagarh district, has been dredged under the 64 zilla project. Analyzing the images of the u/s side of the Karatoa river, a barrage can be near Ambari, 22.5 km u/s of the entry point of the Karatoa river in Bangladesh (**Figure 4.4**). Extensive canal network can be identified on both side of the barrage as well. The barrage is used to divert water from the Karatoa river which might be one of the reasons of declining dry season water in the Karatoa river.

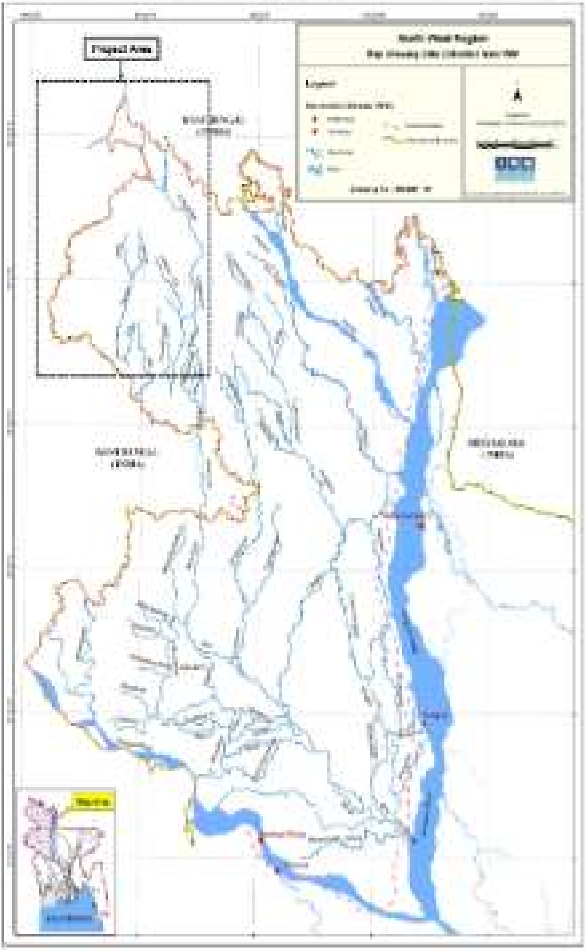

Figure 1.1 North West Region of Bangladesh

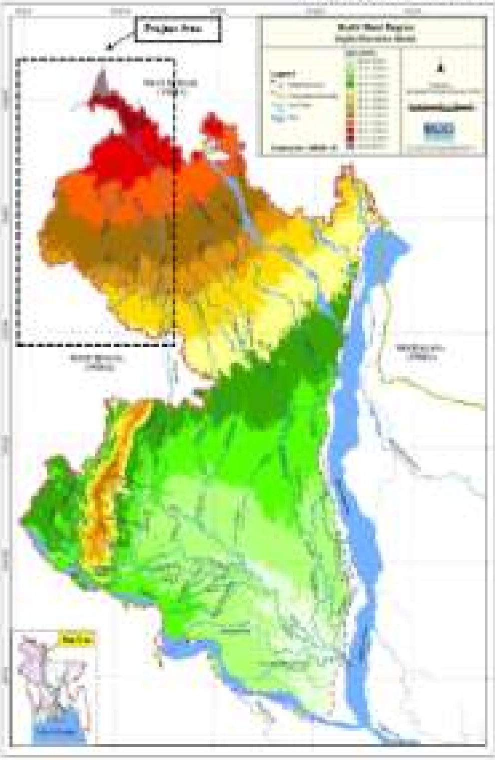

Figure 4.2 Digital Elevation Model of the Study Area

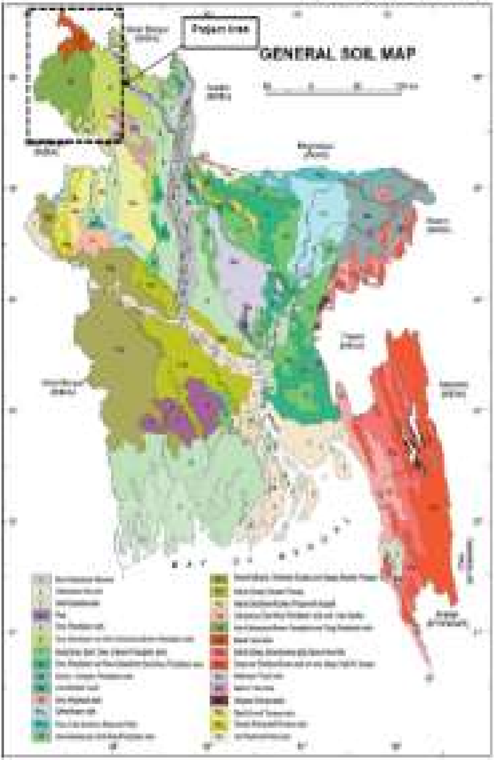

Figure 4.3 General Soil Classification map of Bangladesh (Source: BARC, 2000)

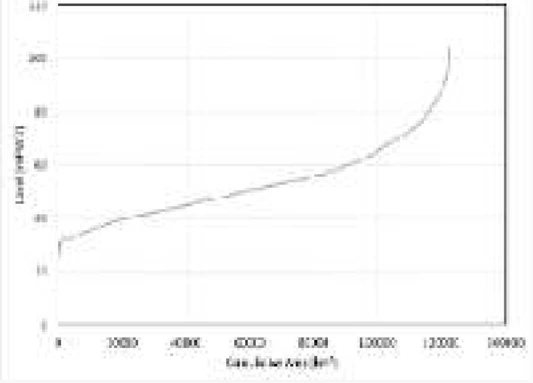

Figure 4.3a Area-Elevation Curve of the Study Area

Talma

Talma is another important river of Panchagarh Sadar Upazila. It originates from Jalpaiguri, India and enters Bangladesh through Amarkhana Union of Panchagarh Sadar Upazila. The length of the river inside Bangladesh is 28 km as mentioned in Banglapedia or Nodi Kosh, 2011. It flows into the Karatoa river in the Kamat Kajal Dighi Union of Panchagarh Sadar Upazila. Talma is a meandering perennial river, but the flow gets reduced drastically during the dry season. The Talma rubber dam at Bamanpara, east of Panchagarh Town is used to store the water and use it for irrigation purposes. Bank erosion was observed on the banks of the ephemeral Talma River.

Ghoramara

Ghoramara river originates from Jalpaiguri, India and enters Bangladesh through Chaklahat Union, Panchagarh. The river is 28km long in Bangladesh and falls into Karatoa river in Marea Bamonhat Union, Boda Upazila, Panchagarh. Kurum and Sui are tributaries of the Ghoramara river. It is a meandering ephemeral river. The width of the river varies from 32m to 122m. Although the flow of the river increases a lot during the monsoon season, flooding does not occur because of it. However, some bank erosion was observed in the Ghoramara river.

Chawai

Chawai is an important river in the Panchagarh district. It is a transboundary river, and it enters Bangladesh 17km north of Panchagarh Town in Satmara Union, Panchagarh. After entering Bangladesh, it flows south and meets with the Karatoa river 4 km upstream of Panchagarh Town. Chawai is a perennial river. The length of the river is 27km. The width of the river varies from 55m to 110m. Although the flow of the river increases a lot during the monsoon season, the presence of high riverbanks keeps the water confined within the river corridor.

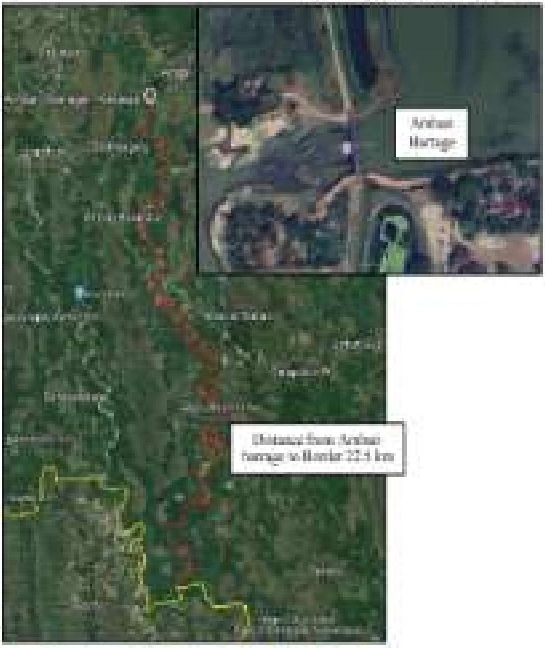

Figure 4.4 Ambari Barrage, India located 22.5km u/s of Bangladesh-India border

Pathraj

Pathraj river originates from the Moydan Dighi Bil of Boda Upazila, Panchagarh. Later it flows through the Debiganj Upazila and falls into the Karatoa river. Pathraj is perennial river. The flow increases a lot during the monsoon season and creates bank erosion in the process. The river is 57 km long and starting from Boda bazar, the whole length has been re-excavated under the 64 zila project. So, only the first 7km of the Pathraj river has not been re-excavated. But for sustainable river management, bank protection works at different vulnerable river reaches will need to be taken.

Satnai

Satnai river originates from the Magura Bil in Sarbanga Union, Debiganj Upazila, Panchagarh. Afterwards it flows south-eastward and falls into the Karatoa River in Debiduba Union, Debiganj Upazila, Panchagarh. Satnai is an ephemeral river. Mainly the river drains the water of the bil during monsoon season. As a result, the flow increases during the monsoon, but it does not cause monsoon flooding. The length of the river is 12 km. The width varies from 15 m to 50 m.

Tangon

Tangon is a transboundary river which originates from the lowlands of Magura Union, Panchagarh. It enters Thakurgaon district through Pirganj Upazila, flows beside the Thakurgaon town and later flows into India. The flow of the Tangon river drops a lot during December and drops further by February. But the monsoon sees a substantial increase in flow and the riverbanks overflow in multiple locations. The river has experienced sedimentation in recent times. Sukh, Senua and Lacchi are tributaries of the Tangon river. The total length of Tangon river is around 123 km (Bangladesh er Nod Nodi, 2011). The width of the river varies from 70m to 250m and the slope of the water surface is around 58 cm/km as mentioned in Bangladesh er Nod Nodi, 2011. Tangon Barrage (**Figure 4.6**) is a water control structure situated over this river. The barrage was constructed in 1985 and has played a critical role for the development of irrigation in the region.

Kulik

Kulik is another trans-boundary river. It originates from the lowlands in Dudaur Union, Baliadangi Upazila, Thakurgaon District, flows south-westward and enters India in Haripur Upazila, Thakurgaon district. Although it is a perennial river, the flow reduces substantially during the dry season. The river has faced aggradation in recent years. The river also has got narrower because of the increase in cultivable lands. The flow of the river is regulated via a regulator. But monsoon flooding can be seen in various locations of the river along with some bank erosions. The length of the river inside Bangladesh is 58 km and the width of the river varies from 25m to 150m as mentioned in Bangladesh er Nod Nodi, 2011.

Nagar

Nagar is a border river that originates from India then flows along the India-Bangladesh border and later goes into India in Haripur Union, Thakurgaon. Pathi, Tirnai are tributaries of the Nagar River. Nagar is perennial river. The flow reduces during February-March months, but the discharge increases during the monsoon season causing riverbank erosion. The length of the river is around 105km and the width varies from 10m to 150m as mentioned in Bangladesh er Nod Nodi, 2011. There are flood embankments on the banks of the river. But a lot of portions of the existing flood embankment seem requiring rehabilitation as well as protection from the river erosion (as shown in **Figure 3.6** and **Figure 3.7**).

Senua

Senua river originates from the lowlands of Debipur Union, Thakurgaon and falls into the Tangon River near Thakurgaon Town. The river mainly discharges the excess water from the basin. The flow of the river gets reduced a lot between December and February. But the discharge increases significantly during the monsoon. The riverbed has experienced sedimentation in recent times and the width of the river has also decreased. The length of the river is around 21 km and the width varies from 10m to 45m as mentioned in Bangladesh er Nod Nodi, 2011. The Baradeshi Combined Water control structure is situated in this river (shown in **Figure 3.3**).

Vulli

Vulli river originates from the lowlands of Debipur Union, Thakurgaon and falls into the Choto Dhepa River in Birganj Upazila, Dinajpur. The river mainly discharges the excess water from the basin. The river completely dries off during the lean season and rice cultivation takes place during the dry months. The length of the river is around 38 km and the width varies from 10m to 40m as mentioned in Bangladesh er Nod Nodi, 2011. The river has been re-excavated recently. The Vulli Sluice Water control structure (**Figure 4.4**) is situated in this river.

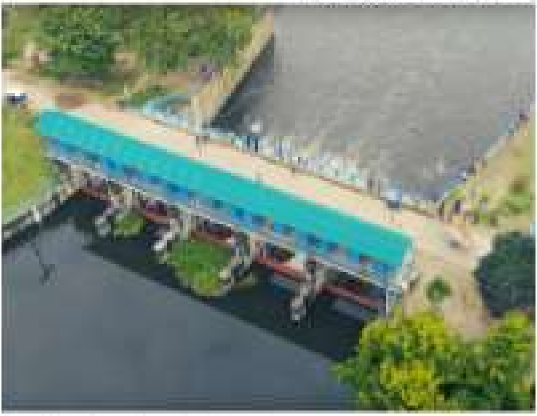

Figure 4.6 Tangon Barrage (Source: Internet)

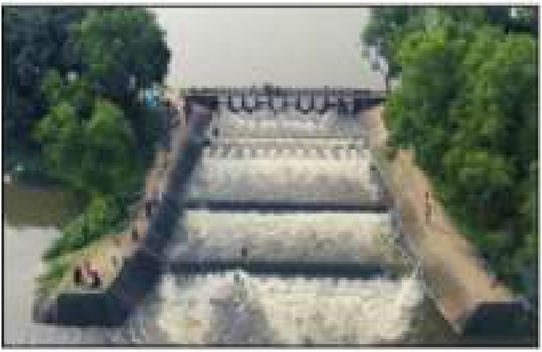

Figure 4.7 Buri Bandh (Source: Internet)

Sukh

Sukh river originates from the lowlands of Akcha Union, Thakurgaon and falls into the Tangon River in Nargun Union, Thakurgaon. The Buri Bandh irrigation project is situated in this river (**Figure 4.7**). The river is an ephemeral river but the flow in the monsoon season increases a bit and bank erosion can be observed in multiple locations. The length of the river is around 21 km and the width varies from 14m to 47m as mentioned in Bangladesh er Nod Nodi, 2011. The river has been re-excavated under the 64 Zila Project.

Figure 4.7 Sluice Gate (Source: Internet)

Nona

Originating from the beel areas of Dhormogarh Union, Ranisankail Upazila Thakurgaon, the Nona River flows southwestward and later enters India in Amgaon Union, Haripur Upazila, Thakurgaon. Beel is present on both banks of the river and thus it becomes very hard to distinguish the bankline of the river from the swelling beels. The riverbed of the Nona River has silted up and the local people use the riverbed for cultivation purposes. The length of the river inside Bangladesh is around 30 km and the width varies from 20m to 260m as mentioned in Bangladesh er Nod Nodi, 2011.

Dahuk

Dahuk is a transboundary river which originates from Jalpaiguri, India and enters Bangladesh in Tirnaihat Union, Tetulia Upazila, Panchagarh. It later flows southeast and re-enters India. Dahuk is a perennial river. Although the flow of the river increases a lot during the monsoon season, the banks of the river generally does not overtop. The riverbed of the Dahuk river is getting silted up and the flow is getting reduced. The length of the river is around 14km and the width varies from 20m to 108m as mentioned in Bangladesh er Nod Nodi, 2011.

Kurum

Originating from Darjeeling, India, Kurum enters Bangladesh through Haribhasa Union, Panchagarh district and falls into Ghoramara river in Boroshoshi Union, Boda Upazila of Panchagarh. It is a meandering river but becomes completely dry during the months of March-April, when the local people use the dried-up riverbed for cultivation purposes. In recent years, the river has experienced a reduction of flow along with siltation of riverbed. The length of the river inside Bangladesh is around 30 km and the width varies from 10m to 75m as mentioned in Bangladesh er Nod Nodi, 2011.

Choto Dhepa

Choto Dhepa River originates from beelands of Auliapur Union, Thakurgaon, flows south-east later to meet with Dhepa River in Dinajpur. The length of Choto Dhepa River in Thakurgaon is 9.60 km. The width of the meandering river varies from 16m to 69m as mentioned in Bangladesh er Nod Nodi, 2011. It is an ephemeral river with the river completely drying up during the lean seasons.

Gobra

The 4km long Gobra river originates from the lowlands of Tetulia Upazila, Panchagarh and is a tributary of the Barong River. It is an ephemeral river. Generally, the flow of the river stays within its banks even during the monsoon season. The flow of the river has reduced a lot in recent times. There is very little to no erosion present at the banks of this river.

Pum:

Pum river originates in the lowlands of Boda Upazila and falls into the Karatoa river near Shuvasthupi, Boda, Panchagarh district. It is an ephemeral river that mainly carries out the rainfall runoff. The total length of the river is around 4.4 km. The existing bed slope of Pum river is found to be very steep (1.43 m/km).

Roseya:

Roseya river originates in the wetlands in Mirzapur Union, Atwari Upazila of Panchagarh. The total length is around 13km and width of the river varies 100m to 3m with the average width of the river is around 10m. The overall bed slope of the Roseya river is around 44cm/km. The Roseya river falls into the Tangon river near the Tangon Barrage.

Rangapani:

Rangapani originates in the lowlands near Mirzaganj Bazar, Debiganj Upazila, Panchagarh and falls into the Buri Teesta River near Debiganj. The total length of the river is around 7 km with the bed slope being 69 cm/km. The first 3 km of the Rangapani river is substantially steeper than the final 3.5 km of the river. The riverbed slope in the upstream part (first 3km) is around 1.38 m/km, while in the downstream part (final 3.5km) the river bed slope is around 47 cm/km.

Alaikumari:

Alaikumari river originates in the lowlands in Boda upazila, Panchagarh and falls into the Kurum River. The average bed slope of the Alaikumari river is around 58 cm/km. The river is an ephemeral river, and the total length of the river is 5.5km. The average width of the river is around 15m.

Kaldaha

Kaldaha river also originates in the lowlands of Boda Upazila, Panchagarh. It mainly drains out the local rainfall runoff and falls into Karatoa river. The total length of the Kaldaha river is 5 km. The width of the river varies from 60m to 20m with the average width being around 35m. The bed slope of the Kaldaha river is relatively flatter compared to the other rivers of the region, with the bed slope being around 25 cm/km.

Kakra

The Kakra river is one of the bi-furcation channels of the Atrai river. The bi-furcation occurs near Jhanjira Bazar, Dinajpur, around 3.3 km downstream of Bhusirbandar. The total length of the Kakra river is around 25.5 km and the average bed slope of the Kakra river is around 23 cm/km. The width of the river varies from 75m to 400m with the average width being around 150m. There is a rubber dam present in the river. The Kakra river meets with the Atrai river again just upstream of Mohonpur rubberdam.

Amon Dhaman

The Amon Dhamon River is a seasonal river which originates in the lowlands of Thakurgaon and falls into the Nagar River. The long profile of the Amon Dhamon River has been shown in Figure 2.25. The slope of the river is around 43.77 cm/km. The width of the river varies from 50m to 5m with the average width being 18m.

Berong

Berong river is one of the trans-boundary rivers originating in the wetlands of Tentulia Upazila of Panchagarh district. The average width of the Berong river varies from 200m to 10m with the average width being 54m. The long profile of the Berong river has been shown in **Figure 2.31**. The measured length of the Berong river was found to be 7.5 km and the average bed slope was found to be 106 cm/km. Berong is seasonal river. The peak discharge of Berong river was found to be 18 cumec from 1D model simulations.

Borka

Borka river originates in the wetlands of Panchagarh and falls into the Chawai river. It is a seasonal river with the total length of the river was found to be 6.5 km. The cross-sectional width of the Borka river varies from 110m to 12m with the average being 46m. The average bed slope of the Borka river was found to be 66 cm/km. The maximum discharge of the Borka river was found to be 19.5 cumec from the 1D model simulations.

Buri Teesta

Buri Teesta river originates in India and enters Bangladesh through Chilahati union, Debiganj upazila, Panchagarh and falls into the Karatoa river near Debiganj town. The river dries up during the dry season, especially downstream the LGED structure at Char Teestapar. The Buri Teesta River is 34km long and the average bedslope was found to be around 51 cm/km. The width of the varies from 130m to 32m with the average width being around 53m. The long profile of the Buri Teesta River has been shown in **Figure 2.28**.

Choto Senua

Choto Senua originates in the lowlands of Thakurgaon. The width of the river varies from 27m to 5 m with the average being 12m. Choto Senua River falls into the Senua River just upstream of the Baliadangi combined water control structure. It is a seasonal river which mainly drains the precipitation of the surrounding area. The total length of the Choto Senua River 5.8km and the average bed slope the river was found to be 75.35 cm/km.

Dara

Dara is a seasonal river which originates in the lowlands of Debiganj, Panchagarh. The total length of the Dara River was found to be 2.18 km with the average bed slope was found to be 94.58 cm/km. The long profile of the river has been shown in **Figure 2.38**. The average width of the Dara River varies from 59m to 8m with the average width being 28m.

Halon

Halon river originates in the lowlands of Panchagarh and falls into the Pathraj river just upstream of the Kaliagaon combined water control structure. The river width varies from 79m to 3m with the average width being 28m. The total length of the river is around 18.75km. The maximum discharge for the Halon river was found to be 37.73 cumec from 1D model simulations. The average bed slope was found to be 30.40 cm/km. The long profile of the river has been shown in **Figure 2.27**.

Kurum

Kurum is a seasonal river which originates in the low lands of Debiganj, Panchagarh and later falls into the Karatoa river. The long profile of the Kurum river has been shown in **Figure 2.21**. The longitudinal bed slope of the river was found to be 36 cm/km. The cross-sectional width varies from 140m to 12m with the average width being 53m.

Laochi

Laochi is a seasonal river which originates in the wetlands of Pirganj, Thakurgaon and later falls into the Tangon river. The long profile of the Laochi river has been shown in **Figure 2.15**. The longitudinal bed slope of the river was found to be 51.5 cm/km. The cross-sectional width varies from 54m to 16m with the average width being 29m. Maximum discharge was found to be around 10 cumec.

Mohananda

Mohananda is a transboundary river. It enters Bangladesh through Tentulia Upazila of Panchagarh, flows along the India-Bangladesh border for 22 km and re-enters India. The Fulbari Barrage located only 1.6 km away from the Bangladesh-India border, diverts the dry season flow of the Mohananda river. The water availability is very low during the lean seasons. However, the flow during the monsoon causes bank erosion. Tirnoi and Ronochondi are two of the tributaries of the Mohananda River. The long profile of the Mohananda River has been shown in **Figure 2.18**. The longitudinal bed slope of the river was found to be 62 cm/km. The cross-sectional width varies from 440m to 170m with the average width being 200m.

Palki

Palki is a seasonal river which originates in the lowlands of Atwari, Panchagarh and later falls into the Nagar River. The long profile of the Palki River has been shown in **Figure 2.30**. The total length of the river was found to 6.8km. The longitudinal bed slope of the river was found to be 67 cm/km. The cross-sectional width varies from 31m to 10m with the average width being 16.6m.

Ronochondi

Ronochondi is a seasonal river which originates in the wetlands of Tentulia, Panchagarh and later falls into the Mohananda River. The long profile of the Ronochondi river has been shown in **Figure 2.34**. The total length of the river was found to 5.0 km. The longitudinal bed slope of the river was found to be 75 cm/km. The cross-sectional width for the high banks and the low banks varies substantially. While the cross-sectional width at the the high banks is around 100m to 170m, the width along the low banks varies from 7m to 10 m.

Sao

Sao is a trans-boundary river that enters Bangladesh in Panchagarh Sadar Upazila and falls into the Karatoa River. The length of the Sao River inside Bangladesh is around 4.58 km. The long profile of the Sao River is shown in **Figure 2.40**. The longitudinal bed slope of the river was found to be 71 cm/km. There is a barrage on the upstream end near Ambari, India. The flow diversion from the barrage reduces the dry season water availability of the river.

Sui

Sui river is a seasonal river which originates in the lowlands of Panchagarh Sadar Upazila and falls into the Ghoramara River. The length of the Sao River is around 13.93 km. The longitudinal bed slope of the river was found to be 67 cm/km. The width of the river varies from 15m to 40m with an average width being 20m.

Tirnai (Panchagarh)

Tirnai (Panchagarh) river is a seasonal river which originates in the wetlands of Tentulia Upazila, Panchagarh and falls into the Mohananda River. The length of the Tirnai (Panchagarh) River is around 7.00 km. The longitudinal bed slope of the river was found to be 84 cm/km. The width of the river varies from 15m to 20m with an average width being 15m.

Tirnai (Thakurgaon)

Tirnai (Thakurgaon) river originates in the lowlands of Ranisankail Upazila, Thakurgaon and falls into the Nagar River. The length of the Tirnai (Thakurgaon) River is around 49.50 km. The longitudinal bed slope of the river was found to be 38 cm/km. The long profile of the Sao River is shown in **Figure 3.41**. The width of the river varies from 15m to 45m with an average width being 35m.

Versha

Versha river originates in the lowlands of Tentulia, Panchagarh and flows into India. The length of the Versha River inside Bangladesh is 12.60 km. The longitudinal bed slope of the river was found to be 71 cm/km. The long profile of the Sao River is shown in **Figure 2.26**. The width of the river varies from 10m to 30m with an average width being 15m.

4.1.4 Climate and Hydrology

The annual average temperature in Panchagarh and Thakurgaon is observed at about a maximum of 36 °C and a minimum of 13.2 °C. The average monthly rainfall in the two districts varies from 3.58 mm/day to 26.26 mm/day. **Table 4.1** shows the average climate information for Panchagarh and Thakurgaon. The temperature data and the precipitation have been shown graphically in **Figure 4.8**, **Figure 4.9**, **Figure 4.10** and **Figure 4.11**.

Table 4.1 Monthly average temperature and precipitation of Panchagarh and Thakurgaon

Location	Parameter	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thakurgaon	Average High Temperature (°C)	23	26	33	36	36	33	33	36	31	32	29	23
	Average Low Temperature (°C)	11	15	16	20	22	27	27	28	25	22	16	14
	Average precipitation (mm)	0.34	0.99	3.00	2.59	7.43	13.54	17.72	14.27	13.64	3.96	0.30	0.18
Panchagarh	Average High Temperature (°C)	20.1	23.6	30.3	33.6	31.1	31.7	31.6	32.1	31.6	30.3	27.4	22.8
	Average Low Temperature (°C)	10.3	12	16.8	21.6	23.4	25.7	26.0	26.1	25	20.7	16.5	11.1
	Average precipitation (mm)	0.69	0.92	0.44	2.16	6.13	11.22	26.24	16.80	13.07	2.86	0.00	0.86

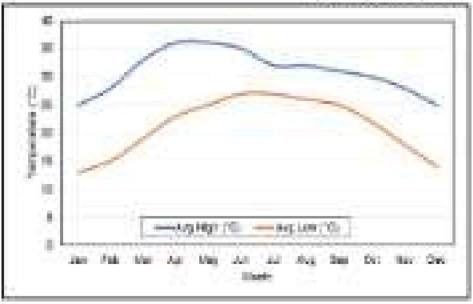

Figure 4.8 Variation of monthly minimum and maximum temperature at Thakurgaon

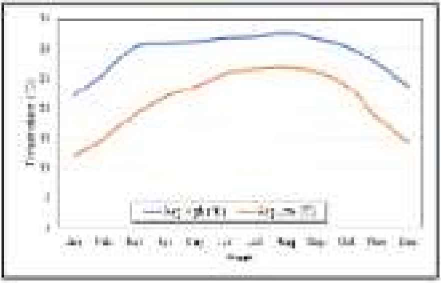

Figure 4.9 Variation of monthly minimum and maximum temperature at Panchagarh

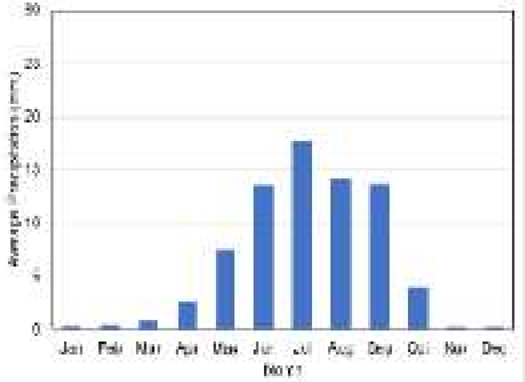

Figure 4.10 Variation of monthly average precipitation at Thakurgaon

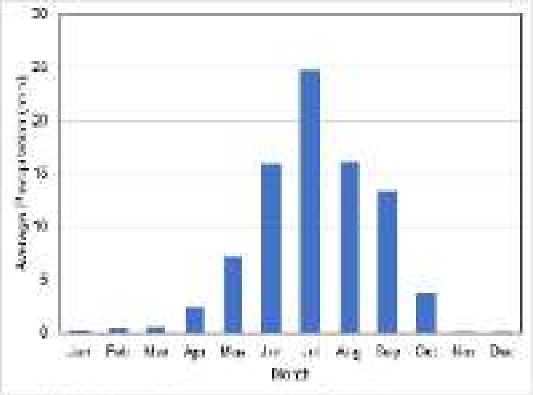

Figure 4.11 Variation of monthly average precipitation at Panchagarh

4.1.5 Hydrological Characteristics

Figure 4.12 displays the locations of available water level and rainfall stations within the study area maintained by BWDB. An analysis on the collected secondary data from BWDB has been carried out in this section, which provided a basic background on the hydrological characteristics of the region.

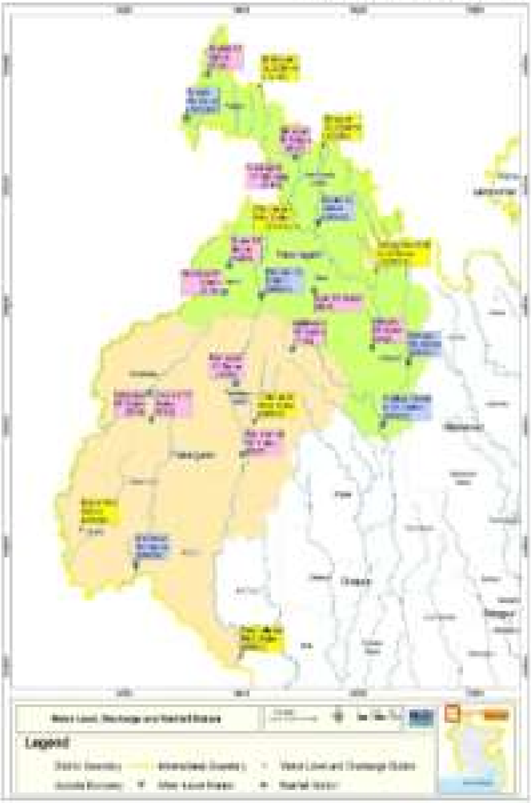

Figure 4.12 BWDB Water Level, Discharge & Rainfall Stations in the study area

Water Level:

Karatoa River:

Karatoa is one of the main rivers of this region. 4 Water Level stations and 2 discharge stations are situated in this river within the study reach, while the Khansama station on this river is located just outside of the study reach. The maximum and minimum water level of this river in the specified gauge stations are shown in **Figure 4.13**, **Figure 4.14**, **Figure 4.15**, **Figure 4.16** and **Figure 4.17**, while the monthly variation of the stations is shown in **Figure 4.18**, **Figure 4.19**, **Figure 4.20**, **Figure 4.21** and **Figure 4.22**. The statistics of water level data on Karatoa River is shown in **Table 4.2**.

Table 4.2 Water Level Statistics for different gauge stations on Karatoa River

Station	Max WL (mPWD)	Min WL (mPWD)	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panchagarh	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

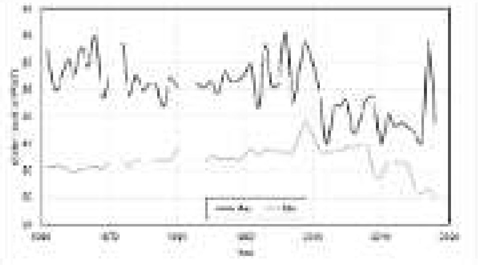

Figure 4.13 Yearly Maximum & Minimum Water Level at [illegible] Station of Karatoa River

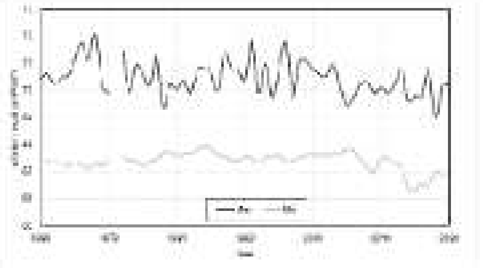

Figure 4.14 Yearly Maximum & Minimum Water Level at Panchagarh Station of Karatoa River

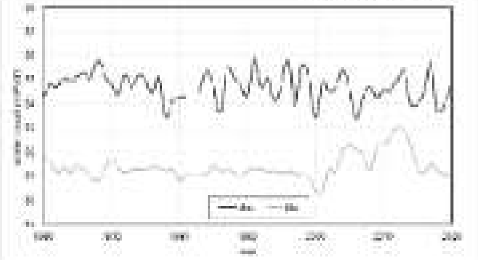

Figure 4.15 Yearly Maximum & Minimum Water Level at Debiganj Station of Karatoa River

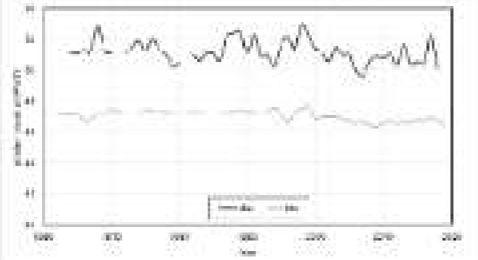

Figure 4.16 Yearly Maximum & Minimum Water Level at Phulbari Outfall Station of Karatoa River

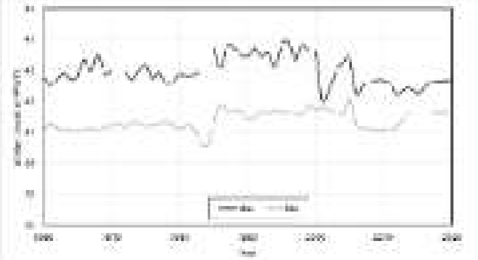

Figure 4.17 Yearly Maximum & Minimum Water Level at Khansama Station of Karatoa River

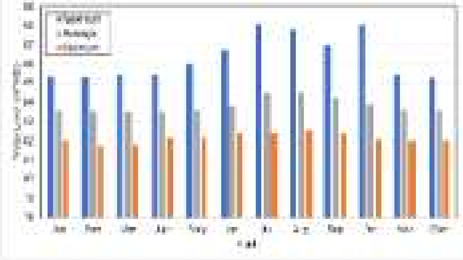

Figure 4.18 Monthly Variation of Maximum, Average & Minimum Water Level at [illegible] Station of Karatoa River

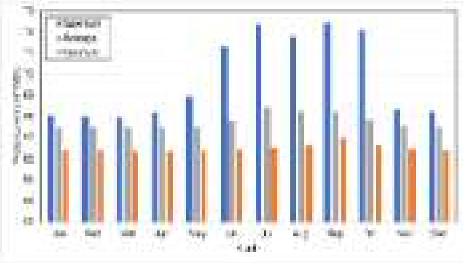

Figure 4.19 Monthly Variation of Maximum, Average & Minimum Water Level at Panchagarh Station of Karatoa River

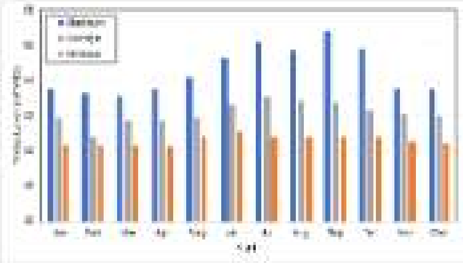

Figure 4.20 Monthly Variation of Maximum, Average & Minimum Water Level at [illegible] Station of Karatoa River

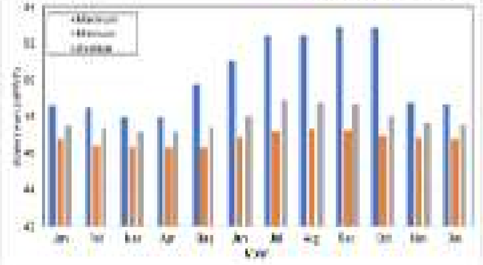

Figure 4.31 Monthly Variation of Maximum, Average & Minimum Water Level at Phulbari Outfall Station of Karatoa River

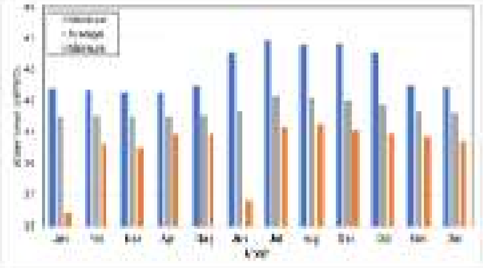

Figure 4.32 Monthly Variation of Maximum, Average & Minimum Water Level at Khansama Station of Karatoa River

Talma River:

Talma River has 2 Water Level stations situated in the river. The maximum and minimum water level of this river in the specified gauge stations are shown in **Figure 4.33** and **Figure 4.34**, while the monthly variation of the stations is shown in **Figure 4.35** and **Figure 4.36**. The statistics of water level data on Talma River has been shown in **Table 4.5**.

Table 4.5 Water Level Statistics for different gauge stations on Talma River

Station	Max WL (mPWD)	Min WL (mPWD)	SHWL (mPWD)	SLWL (mPWD)
[illegible]	76.83	72.93	73.47	72.44
[illegible]	74.34	69.74	71.42	69.56

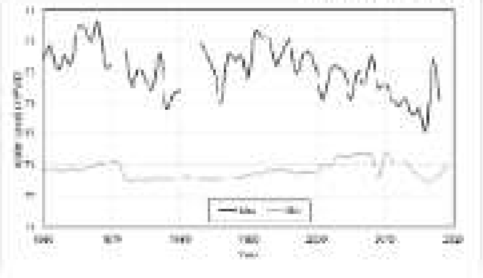

Figure 4.23 Yearly Maximum & Minimum Water Level at [illegible] Station of Talma River

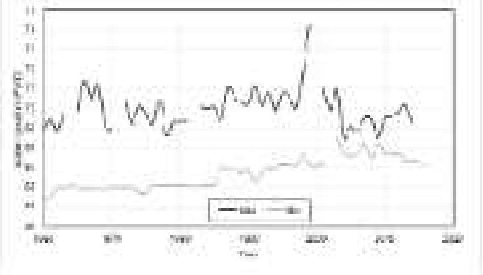

Figure 4.24 Yearly Maximum & Minimum Water Level at [illegible] Station of Talma River

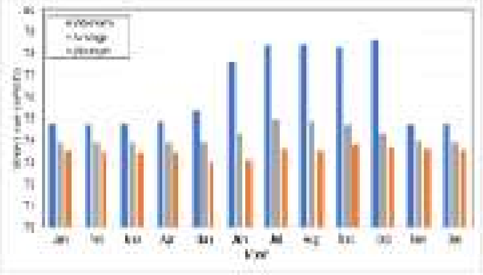

Figure 4.25 Monthly Variation of Maximum, Average & Minimum Water Level at [illegible] Station of Talma River

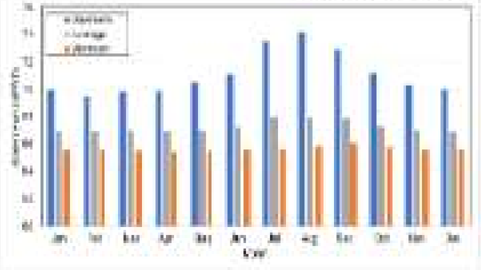

Figure 4.26 Monthly Variation of Maximum, Average & Minimum Water Level at Dinam Station of Talma River

Tangon River:

Water level data from 3 of the gauges situated on the Tangon River has been collected from BWDB. The maximum and minimum water level of this river in the specified gauge stations are shown in **Figure 4.27**, **Figure 4.28** and **Figure 4.29**, while the monthly variation of the stations is shown in **Figure 4.30**, **Figure 4.31** and **Figure 4.32**. The statistics of water level data on Karatoa river has been shown in **Table 4.4**.

Table 4.4 Water Level Statistics for different gauge stations on Tangon River

Station	Max WL (mPWD)	Min WL (mPWD)	RMWL (mPWD)	SLWL (mPWD)
Ranigaon	61.45	55.77	61.22	55.27
Thakurgaon	51.35	46.28	51.14	46.41
Purnabhaban	39.79	33.68	34.87	33.38

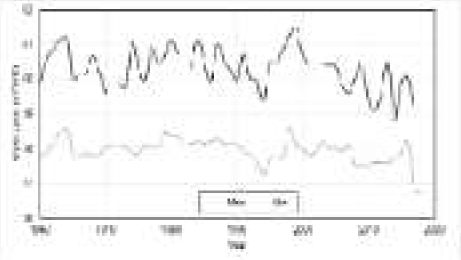

Figure 4.27 Yearly Maximum & Minimum Water Level at Ranigaon Station of Tangon River

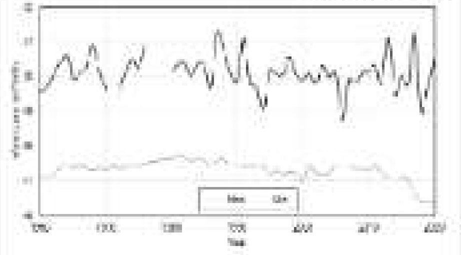

Figure 4.22 Yearly Maximum & Minimum Water Level at Thakurgaon Station of Tangon River

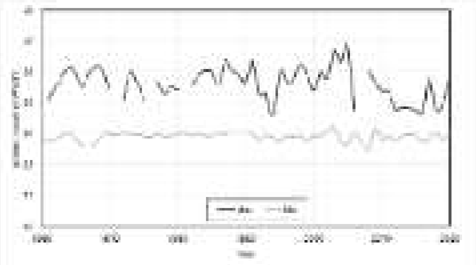

Figure 4.23 Yearly Maximum & Minimum Water Level at Kodalkatigaon Station of Tangon River

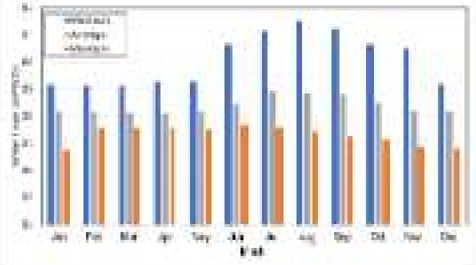

Figure 4.24 Monthly Variation of Maximum, Average & Minimum Water Level at Panchgarh Station of Tangon River

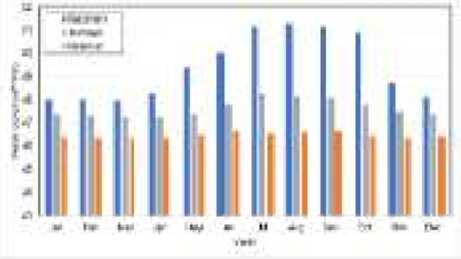

Figure 4.31 Monthly Variation of Maximum, Average & Minimum Water Level at Thakurgaon Station of Tangon River

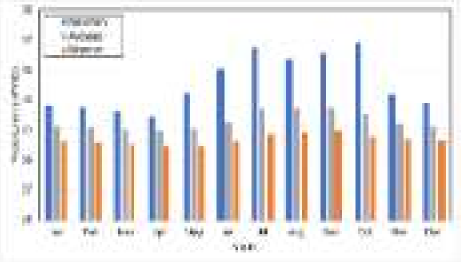

Figure 4.32 Monthly Variation of Maximum, Average & Minimum Water Level at [illegible] Station of Tangon River

Ghoramara River:

One water level measuring gauge station, "Ghoramara Ghat" is situated on the Ghoramara River. The maximum and minimum water level of this river in the specified gauge station are shown in **Figure 4.33**, while the monthly variation of the station is shown in **Figure 4.34**. The statistics of water level data on Ghoramara River has been shown in **Table 4.5**.

Table 4.5 Water Level Statistics for the Ghoramara River

Station	Max WL (mPWD)	Min WL (mPWD)	SHWL (mPWD)	SLWL (mPWD)
Ghoramara Ghat	63.00	54.80	61.52	57.52

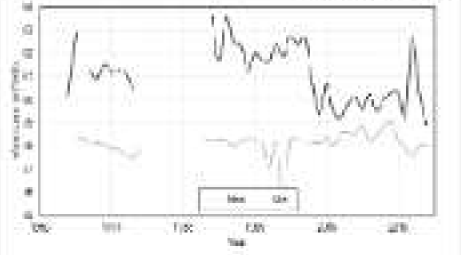

Figure 4.33 Yearly Maximum & Minimum Water Level at Ghoramara Ghat Station of Ghoramara River

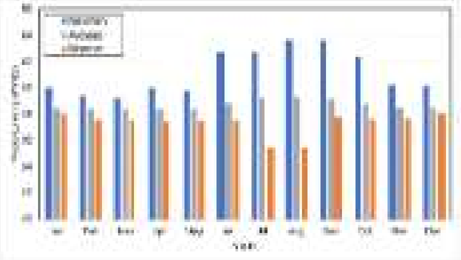

Figure 4.34 Monthly Variation of Maximum, Average & Minimum Water Level at Ghoramara Ghat Station of Ghoramara River

Kulik River:

"Shudang" water level measuring station of BWDB is situated on the Kulik River. The maximum and minimum water level of this river in the specified gauge station are shown in **Figure 4.35**, while the monthly variation of the station is shown in **Figure 4.36**. The statistics of water level data on the Kulik River has been shown in **Table 4.9**.

Table 4.9 Water Level Statistics for the Kulik River

Station	Max WL (mPWD)	Min WL (mPWD)	SHWL (mPWD)	SLWL (mPWD)
[illegible]	40.50	33.26	40.41	35.32

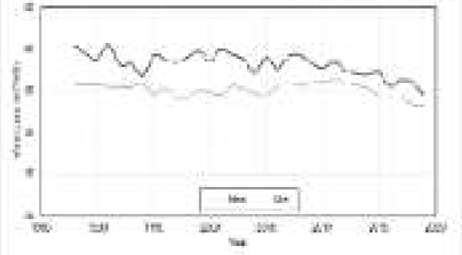

Figure 4.35 Yearly Maximum & Minimum Water Level at Bhulpang Station of Kulic River

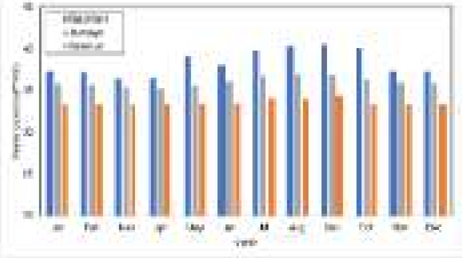

Figure 4.36 Monthly Variation of Maximum, Average & Minimum Water Level at Bhulpang Station of Kulic River

Nagar River:

"Burjub" water level measuring station of BWDB is situated on the border river, Nagar. The maximum and minimum water level of this river in the specified gauge station are shown in **Figure 4.37**, while the monthly variation of the station is shown in **Figure 4.38**. The statistics of water level data on the Nagar River has been shown in **Table 4.7**.

Table 4.7 Water Level Statistics for the Nagar River

Station	Max WL (m PWD)	Min WL (m PWD)	DHWL (m PWD)	DLWL (m PWD)
Burjub	46.47	27.08	43.72	30.48

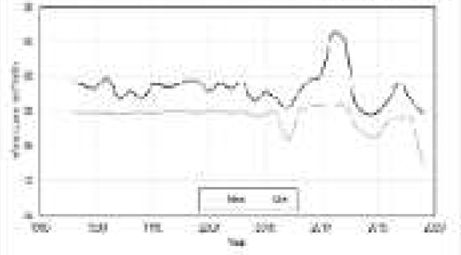

Figure 4.37 Yearly Maximum & Minimum Water Level at Burgun Station of Nagar River

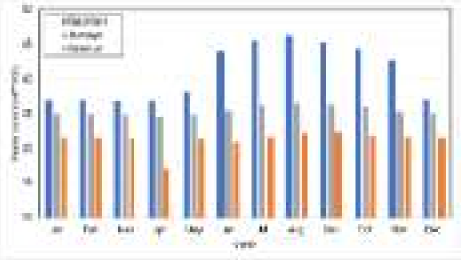

Figure 4.38 Monthly Variation of Maximum, Average & Minimum Water Level at Burgun Station of Nagar River

Discharge:

There are seven discharge measuring stations maintained by BWDB within the study area. The data have been collected from the archive and analysed to get a better understanding of the study area. The maximum observed discharge at different locations of the study area has been shown in **Table 4.5**. The annual maximum discharge of the discharge stations has been plotted in **Figure 4.39** to **Figure 4.45**.

Table 4.5 Maximum Observed Discharge at different locations in the study area

District	River	Station	Max. Discharge (Cumec)	Corresponding Year
Panchagarh	Karatoa	Someswari	172.91	2014
		Panchagarh	461.33	1988
	Talma	Mirzapur	119.20	2000
	Ghoramara	Ghoramara Ghat	409.8	2000
Thakurgaon	Tangon	Thakurgaon	726.1	2013
		Sukhdevpur	288.75	1988
	Nagar	Burgun	866.17	2008

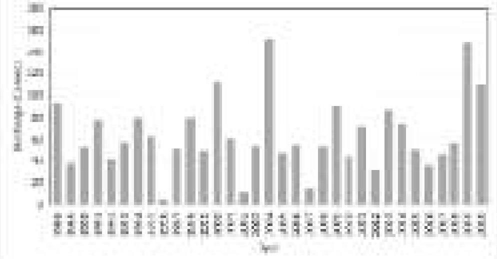

Figure 4.39 Observed Annual Maximum Discharge at [illegible] Station of Karatoa River

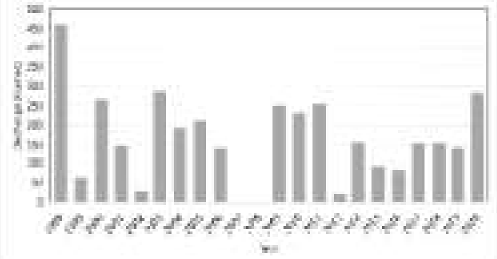

Figure 4.40 Observed Annual Maximum Discharge at Panchagarh Station of Karatoa River

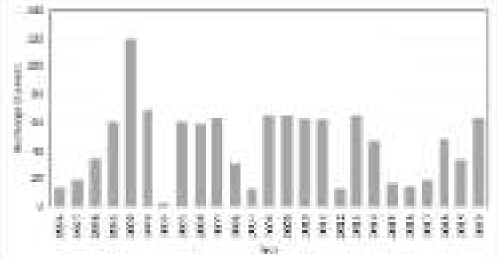

Figure 4.41 Observed Annual Maximum Discharge at [illegible] Station of Talma River

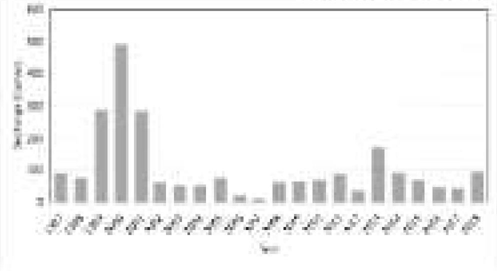

Figure 4.42 Observed Annual Maximum Discharge at [illegible] Station of [illegible] River

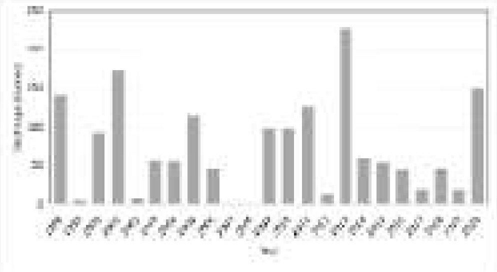

Figure 4.43 Observed Annual Maximum Discharge at Thakurgaon Station of Tangon River

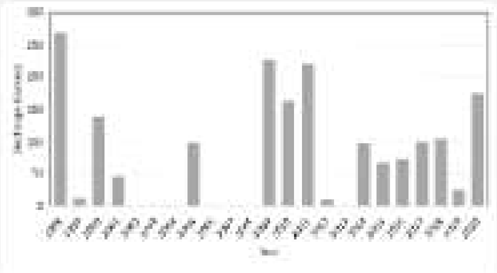

Figure 4.44 Observed Annual Maximum Discharge at [illegible] Station of Tangon River

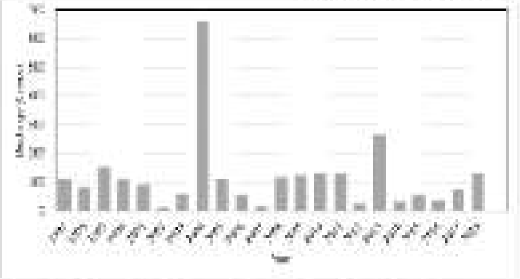

Figure 4.45 Observed Annual Maximum Discharge at Bugun Station of Nagar River

Groundwater level:

An objective statistical method for analyzing trends in the groundwater levels in the study area was developed to identify areas where groundwater abstraction may be unsustainable and areas where more abstraction may be possible. It is important to remember that factors other than groundwater abstraction may lead to rising or falling groundwater trends (e.g. climate variability or land use change). Rainfall and subsequent recharge is the main driver in controlling water tables. Large rainfall events can lead to periods of widespread and prolonged inundation leading to large amounts of recharge to the aquifer. However, it was evident from examining the hydrographs of wells from the two districts that some clear patterns were present. There is a large range of responses evident but most tend towards a greater amplitude in the annual fluctuation. For some sites the annual top up recharge from the monsoon period is sufficient to return the water table close to the surface consistent with the long-term position. This case indicates that recharge has been induced by drawing down water levels and increasing the storage available for recharge to occupy. However, in some wells the annual top up is not sufficient to return the water table fully to its long-term minimum depth which indicates more water is being removed than can be replenished by recharge. The trend analysis aims to identify which sites are stable over the time period and which have falling trends where groundwater depletion is occurring. The method examines the annual maximum and minimum water table depths and classifies them according to the slope (or rate of change) in both.

A trend analysis was carried out for the different wells of the study area. For each well the annual maximum and minimum water table depth readings were extracted and a linear regression performed on each set. The slope of each set was extracted and classified into the trend types. These annual maximums and minimums correlated to the pre-monsoon period and post-monsoon period respectively. The pre-monsoon period represents the time after which irrigation water abstraction for dry season cropping has ceased (typically April/May). In the post-monsoon period water tables are generally much closer to the surface as a result of high rainfall and flooding associated with the wet season. Groundwater use is also minimal in the wet season. The following section describes the trend types and presents an example of each to demonstrate the type behaviors. Following **Table 4.9** lists the trends types identified by the analyses, the parameters used for this classification and a description of the behaviors for each type.

Table 4.3 Different Classes of Groundwater Table Variation

Type	Rate of Variation (Max. depth)	Rate of Variation (Min. depth)	Description
Type-1	falling @ > 0.05 m/yr	falling @ > 0.15 m/yr	These wells have strongly declining levels in both minimum groundwater depths and maximum groundwater depths. There is little or no wet season recovery observed. Note that some of the early stage decline patterns have characteristics of Type 2. In this case abstractions and losses are significantly higher than annual recharge leading to rapid declines in both maximum and minimum depths of the water table.
Type-2	falling @ 0.00 to 0.05 m/yr	falling @ 0.025 to 0.15 m/yr	Groundwater levels where the dry season maximum groundwater depth is declining and the wet season induced recharge 'top-up' appears insufficient to fully restore groundwater levels. This type is characterised by strong declines in the maximum depth of the water table and some decline in the minimum depth. Whilst recharge is being induced by a deeper water table at the end of the dry season abstractions and losses, the monsoon top-up appears insufficient to return the water table to its previous position.
Type-3	falling @ 0.025 to 0.20 m/yr	falling @ 0.025 to rising @ 0.05 m/yr	Groundwater levels where the maximum depth is declining but there is no decline in the minimum depth. The decline in seasonal maximum water table depth reflects increasing abstractions and losses. There is some induced recharge occurring due to increased capacity for recharge during the wet season. The wet season recharge is currently sufficient to make up the dry season deficit.
Type-4	rising @ <0.03 m/yr	falling @ 0.025 to rising @ 0.025 m/yr	Both minimum depth and maximum depth show no trend. These wells have steady groundwater levels which fluctuate seasonally but the wet season recharge is at least sufficient, or more than sufficient, to account for the dry season losses and abstractions.
Type-5	rising @ >0.03 m/yr	rising @ >0.02 m/yr	Both minimum depth and maximum depth show significant rising trends. This can be a sign of suspicious data or caused by some shorter-term climate signal. There are generally few wells of this type in Bangladesh where most water tables have falling or steady hydrographs. Rising trends could indicate the abandonment of production wells nearby, a change in land-use (e.g. urbanisation of previous agricultural land) or some other influence on local groundwater levels. Erroneous data could be the reason some wells of this type are identified as having rising trends.
Type-6	All other rates	All other rates	Both minimum and maximum depth show diverging or converging trends. This type usually indicates suspicious data and should prompt a closer inspection of the data. There is no typical type 6 response as wells of these type are those that do not satisfy the criteria for the other 5 types. Wells of this type should be examined for erroneous data points and cleaned if possible or removed from the analysis if the data are so spurious.

The trend analysis of the groundwater level at different location of Thakurgaon & Panchagarh district has been shown in **Figure 4.46 & Figure 4.47**. The figures clearly indicate that the groundwater level shows a clear sharp decreasing trend in Thakurgaon Sadar, Panchagarh Sadar and Tentulia upazila. The groundwater level in Debiganj shows a lesser depreciation rate comparing to them. And the groundwater level at Baliadangi has remained more or less same in the last decade or so.

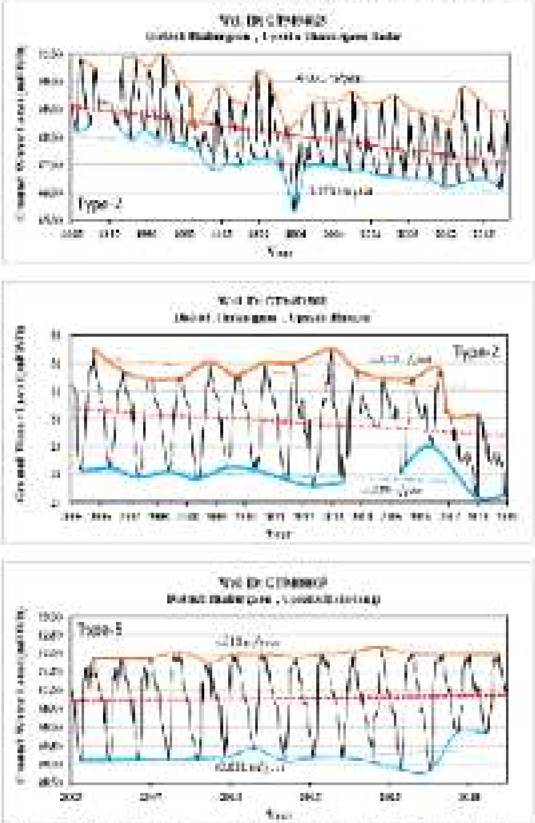

Figure 4.48 Trend Analysis of groundwater level at different location of Thakurgaon district

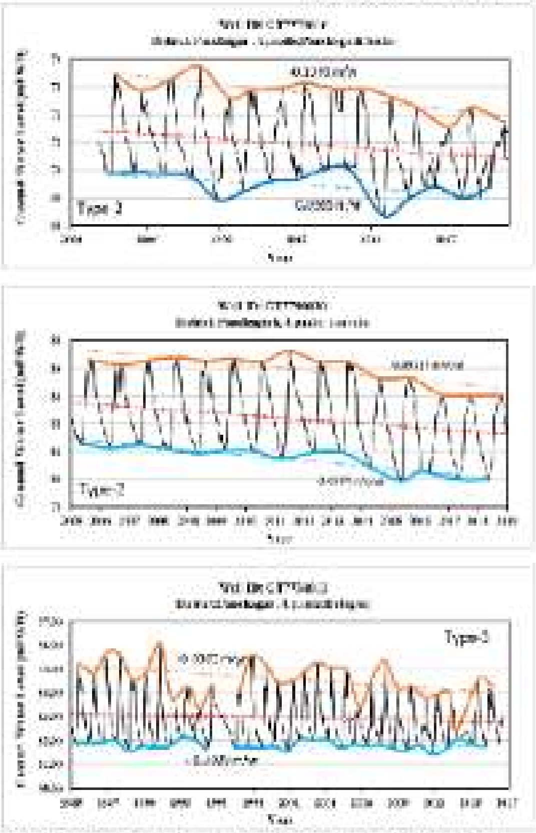

Figure 4.47 Trend Analysis of groundwater level at different location of Panchagarh district

4.1.6 Flood Risk Assessment

The flood extent of the study area based on satellite image analysis has been presented in **Figure 4.48**. The analysis was based on Global Flood Database (GFD), which uses satellite observations of 913 large flood events documented by the Dartmouth Flood Observatory (DFO) from 2000-2018. From the **Figure 4.48**, it is seen that flooding is not a major problem in the study area. Specially the Thakurgaon district mostly remained flood free during 2000-2018. Most of the flood area, in the study area, is located between the banks of Pathraj and Karatoa River. Debiganj and Boda Upazila sees the worst of flooding in the study area according to the satellite image analysis. Some flooding can also be observed at north of the Panchagarh town from Karatoa, Chawai and Talma rivers. Based on the satellite image-based flood risk assessment, around 15,000 hectares of agricultural lands and 830 hectares urban lands in Panchagarh district is under flood risk, while around 6,000 hectares of agricultural lands in Thakurgaon district is under flood risk.

Flood inundation map has been prepared based on the results of the developed 1D model. The map has been shown in **Figure 4.48**.

4.1.7 NDVI Assessment Based on Satellite Image Analysis

The NDVI is one of the most common indices widely applied for monitoring vegetation dynamic at regional and global scales (Yinding et al., 2013; Zhu et al., 2013). This index was introduced by Tucker (1979) and varies between − 1 and 1 in which the values less than zero during indicate no vegetation cover, such as desert, bare earth, cloud, snow, icepack, water body, and glacier, while values more than zero in the growing season describe available vegetation cover. The NDVI was calculated using the following formula:

$$NDVI=\frac{NIR-Red}{NIR+Red}$$

where NIR is near-infrared band (0.851−0.879 µm), and Red is band of Red (0.636−0.673 µm).

Satellite images of dry season (January-April) with cloud cover percentage of less than 1 percent was used for calculation of NDVI values for this analysis. Temporal Changes in NDVI over the last thirty-five years (1988-2022) has been presented in **Figure 4.50**. From the figure it can clearly be seen that the study area of the project, over the years has become greener. It is worth mentioning that the BWDB has completed multiple projects in the study area in this analysis period, such as, Tangon Barrage, Yuli Badh, Burri Badh, Bhasa Dobi combined structure etc., which might have resulted the study area becoming more greener over time. Also lots of plantation has taken place in this region in the mentioned time, which also might have resulted in an increase in NDVI index.

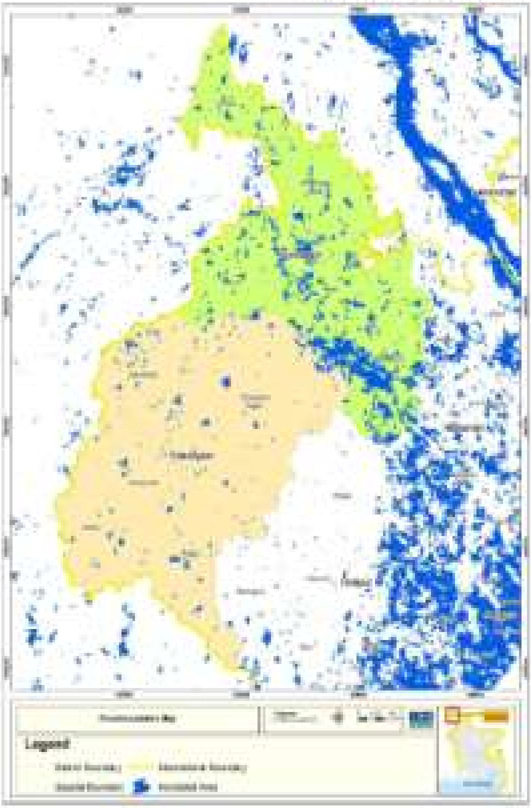

Figure 4.48 Flood Extent of the study area Based on Satellite Image Analysis

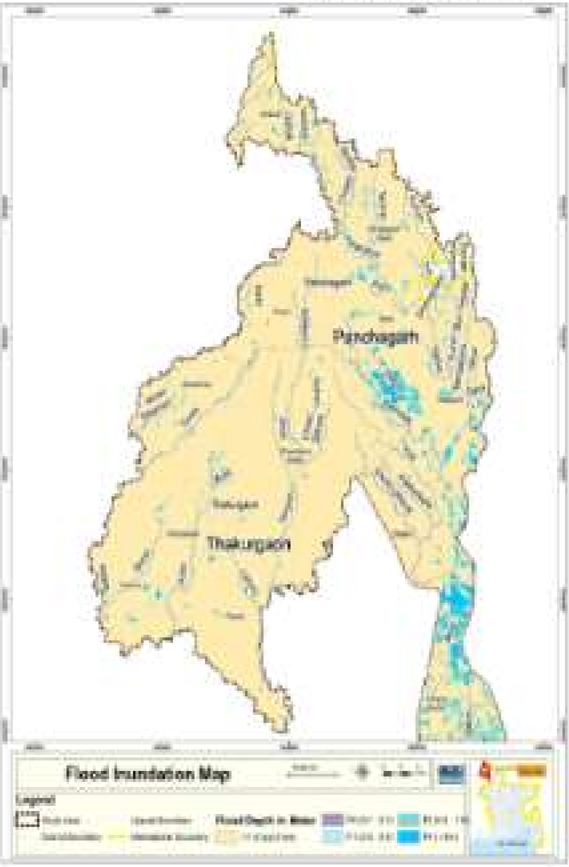

Figure [illegible] Flood Inundation Map Based on developed Mathematical Model

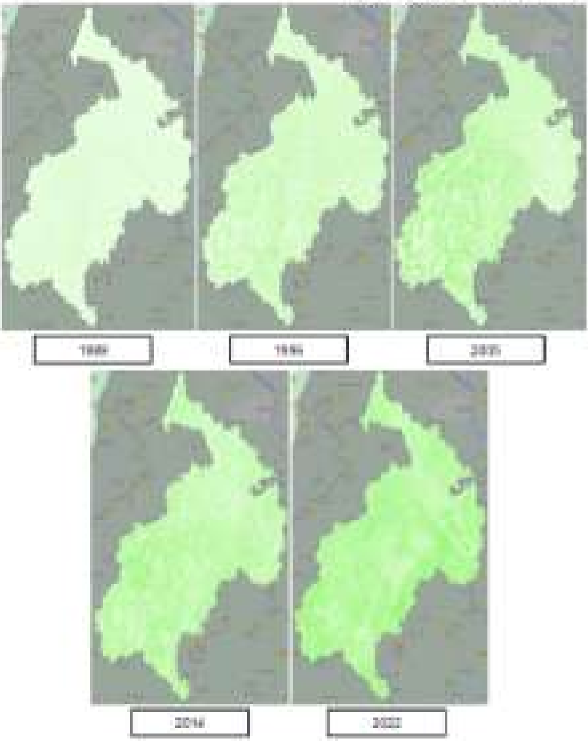

Figure 4.40 Temporal Changes in NDVI over the last thirty-five years

The output of NDVI generated from MODIS satellite has also been presented graphically in **Figure 4.41** to **Figure 4.44**. The graphs also show that the NDVI index is showing an increasing trend in both Panchagarh & Thakurgaon districts.

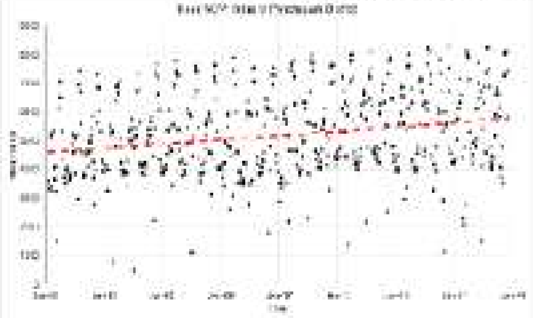

Figure 4.31 Temporal Changes in NDVI at Panchagarh district based on MODIS satellite images

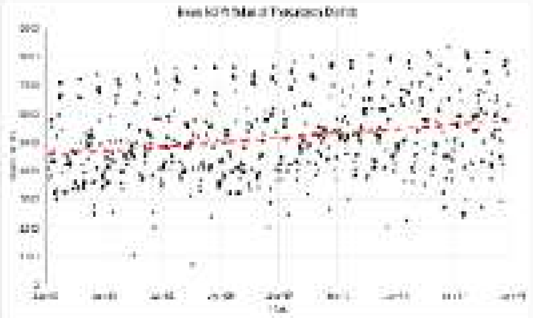

Figure 4.32 Temporal Changes in NDVI at Thakurgaon district based on MODIS satellite images

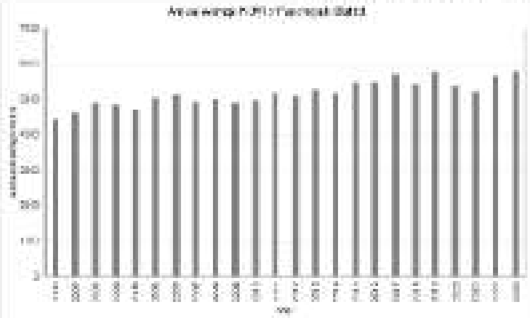

Figure 4.33 Temporal Changes in NDVI at Panchagarh district based on MODIS satellite images

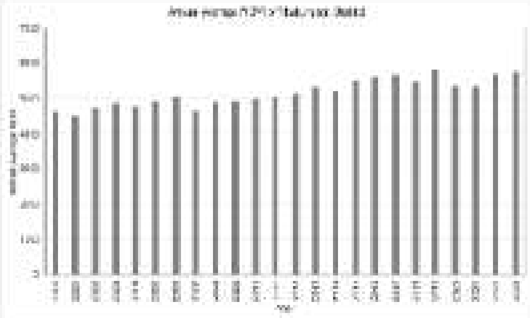

Figure 4.34 Temporal Changes in NDVI at Thakurgaon district based on MODIS satellite images

4.1.6 Planform Analysis:

In order to assess bank erosion, shifting/migration, the banklines of the rivers have been delineated from the available satellite images and plotted using GIS tools. The process was carried out for the major rivers and described in detailed in the following sections.

Karatoa River:

Karatoa River is one of the main rivers in the study area. Out of the five Upazilas of Panchagarh, Karatoa River flows over four of them. The river is characterized by its flashy nature and from satellite image analysis bankline shifting, bank erosion can be seen throughout the Karatoa River. The erosion & sedimentation trend for twenty years from 2004 to 2023 has been shown in **Figure 4.66** to **Figure 4.75**. **Figure 4.66** shows the erosion & sedimentation trend at the Bangladesh-India border near Bardeshwari and Bhajanpur.

Erosion can be seen near Shibchandi and upstream of Bhajanpur. Around 750m reach of left bank of Karatoa River seems vulnerable to bank erosion as per satellite image analysis.

The erosion/sedimentation trend of the reach at downstream of Bhajanpur has been shown in **Figure 4.56**. The most significant erosion in the reach can be seen near the Bhajanpur bridge, where erosion has taken place in the eastern bank. Another erosion spot can be seen just downstream of Bhajanpur bridge, where around 150m stretch of right bank seems vulnerable to bank erosion. The 150m stretch here is very close to the built-up areas of Bhajanpur Bazar. From 2.2 km downstream of the Bhajanpur bridge, Karatoa River becomes the line of demarcation of Bangladesh-India border. The Karatoa River acts as the border of Bangladesh-India up-to Mirgarh, upstream of Panchagarh Town. The erosion & sedimentation trend of the region around Mirgarh has been shown in **Figure 4.57**. From Mirgarh, further downstream erosion can be observed from the figure on the right bank, while sedimentation has occurred in the left bank in this reach. The Mirgarh Guccha Gram is situated in this reach of the river and some erosion can be seen near the Mirgarh Guccha Gram. Around 600m stretch of right bank might need to be protected to stabilize the bank near Mirgarh Guccha Gram.

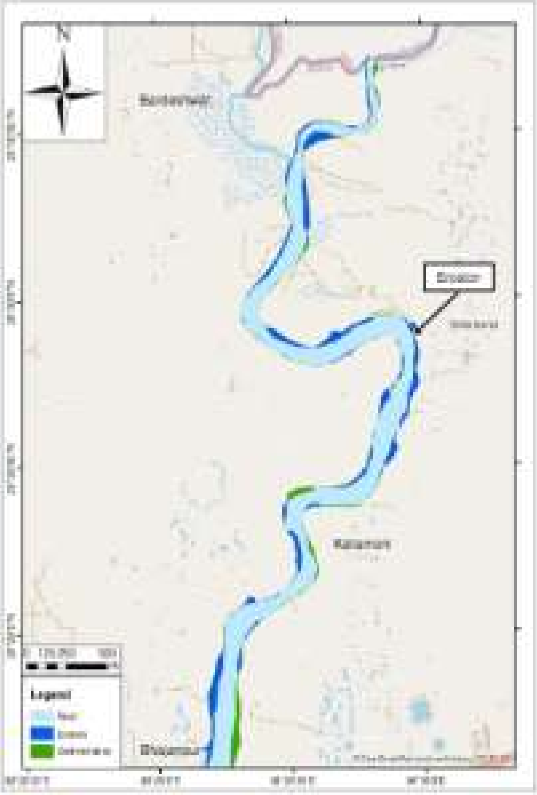

Figure 4.88: Erosion & Sedimentation trend in Karatoa River between Banglabandha and Bhajanpur in Tetulia Upazila, Panchagarh from 2004 to 2023

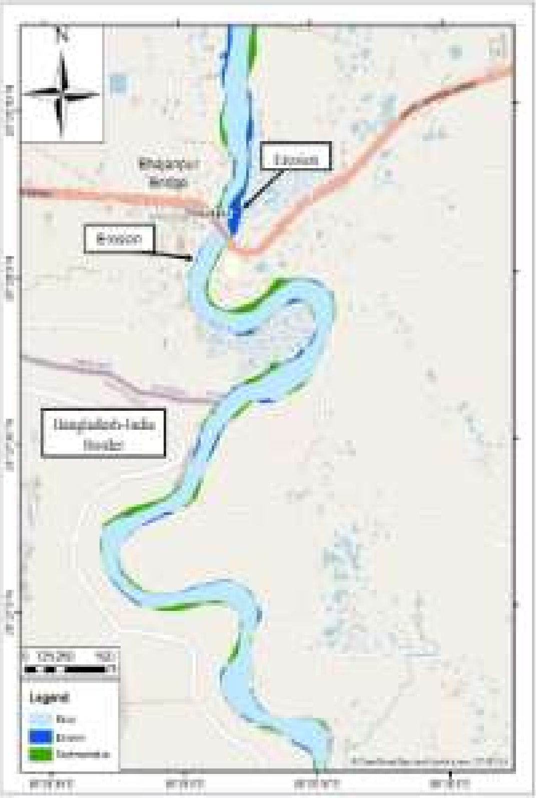

Figure 4.88: Erosion & Sedimentation trend in Karatoa River near Bhajanpur in Tetulia Upazila, Panchagarh from 2004 to 2023

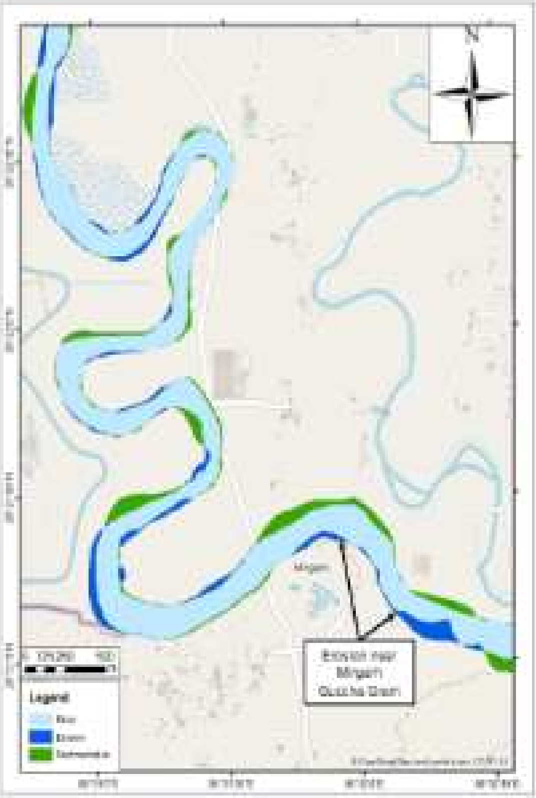

Figure 4.87: Erosion & Sedimentation trend in Karatoa River near Mirgarh in Panchagarh Sadar Upazila from 2004 to 2023

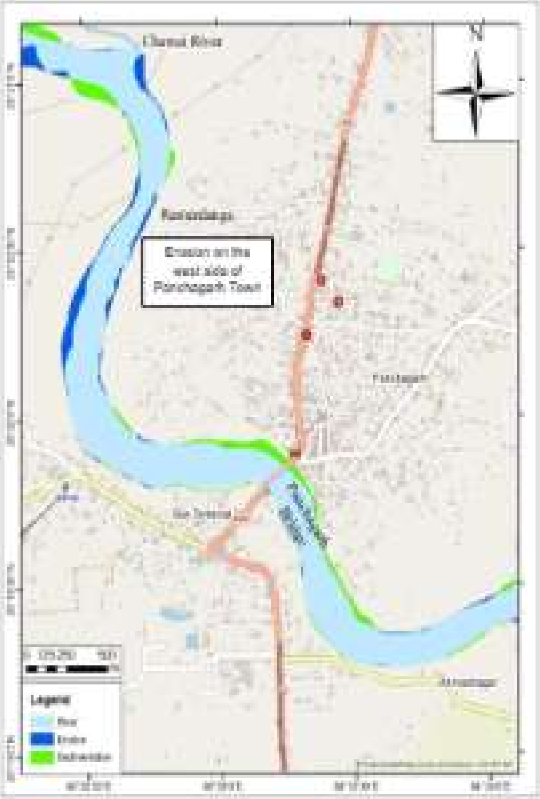

Figure 4.66: Erosion & Sedimentation trend in Karatoa River near Panchagarh Town from 2004 to 2022

Figure 4.66 shows the historical erosion & sedimentation trend of the reach near Panchagarh, which is located downstream of Mirgarh (**Figure 4.67**). The outfall of Chawai River is in this reach of the Karatoa river. Just after the outfall of the Chawai river, bank erosion is observed in the left bank of the Karatoa River, which is situated on the west side of Panchagarh Town. The land here is very valuable, and this reach needs to be put under bank protection works. Based on satellite image analysis, around 1300m stretch of left bank of Karatoa River has been identified as vulnerable to bank erosion near Rahamtanga.

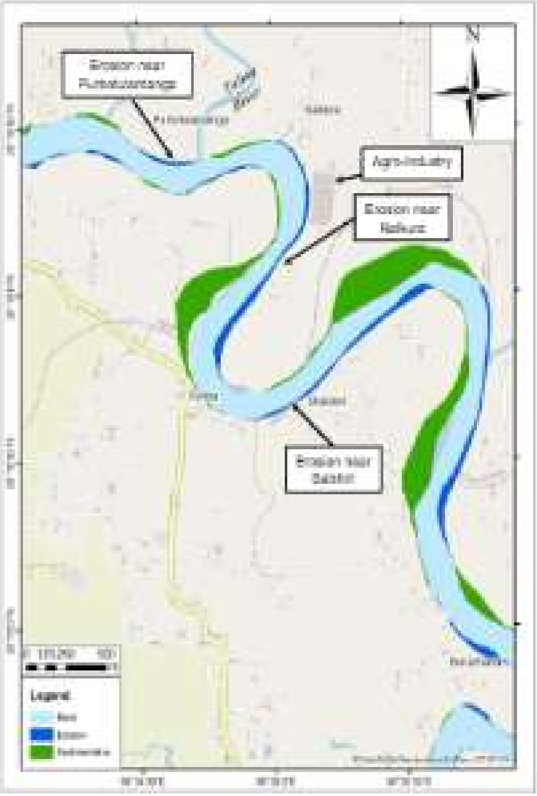

Figure 4.58: Erosion & Sedimentation trend in Karatoa River near Nalkura in Panchagarh Sadar and Boda Upazila, Panchagarh from 2006 to 2022

The historical sedimentation & erosion trend for the Karatoa River, for the reach immediate downstream of Panchagarh Town is shown in **Figure 4.58**. Lots of erosion & Sedimentation can be seen in this reach of the river. Just upstream of the Talma River outfall, erosion is observed near Purbabudastanga. This is a built-up area, and hence river training works might be required to protect this reach from bank erosion. Around 320m stretch of left bank of Karatoa River appears vulnerable to bank erosion based on satellite image analysis. Just downstream of the Tanio River outfall, erosion can be seen along the outer bend at Nakuria. An agro-industry of Nazi Group is situated near the bend and seems vulnerable to bank erosion. Hence this reach might require bank protection works considering the importance of the location. Although erosion can be seen for 1800m reach in this region, around 700m reach of right bank has been identified which might require bank protection works based on satellite image analysis. Further downstream erosion can also be observed on the right bank near Salehit. The area is also built up with Mosque, Schools and lots of residential buildings being present there. Hence the area will also need to put under bank protection works. Bank Protection Works are present in outer bend of the river. However, erosion has occurred right after the protection works has ended in the past few years. BWDB has been carrying out temporary protection measures by dumping geo-bags in this area but considering the importance of this area, permanent Bank Protection Works might be required. From satellite image analysis around 700m reach of right bank of Karatoa River might require BPWs.

The historical sedimentation & erosion trend for the Karatoa River, for the reach immediate downstream of Panchagarh Town is shown in **Figure 4.60**. Sonachandi is a built-up area with mosque, eid gah and lots of residential areas. Sikarpur has schools, mosque along with residential areas. While Bhuvasuan mainly consists of residential infrastructures. Although erosion along the Karatoa River at all the bends of the river can be seen, since these three locations are where the built-up areas are situated, bank protection works at these reaches might be required. Near Sonachandi, erosion can be seen in two separate bends. Near the northern side of Sonachandi, around 850m stretch of right bank of Karatoa River might need BPWs. While in the southern side of Sonachandi, near Sendanmoni around 600m BPWs might be required. Near Sikarpur, around 500m BPWs might be required as per satellite image analysis. Near Bhuvasuan, around 550m of BPWs might also be required.

Figure 4.61 shows the historical erosion & sedimentation from Bhuvasuan to Nazirganj in Boda Upazila, Panchagarh. Once again, erosion can be observed at the bends of the Karatoa River in this reach. But the major built-up area in this reach is Boalmari and Nazirganj. BWDB has constructed a BPW near Boalmari Bazar to protect it from erosion of Karatoa River. However, the length of BPW seems inadequate as erosion can be seen just on the downstream tip of the BPW. The length of the BPW might be required to be increased by 180m to stop further bankline shifting. In the Nazirganj side, erosion can be observed throughout the bend. Some BPWs has been constructed in the region. However, bank erosion can still be seen right from the downstream termination point of the BPW. Another 450m BPW will also be required at Nazirganj according to the satellite image analysis.

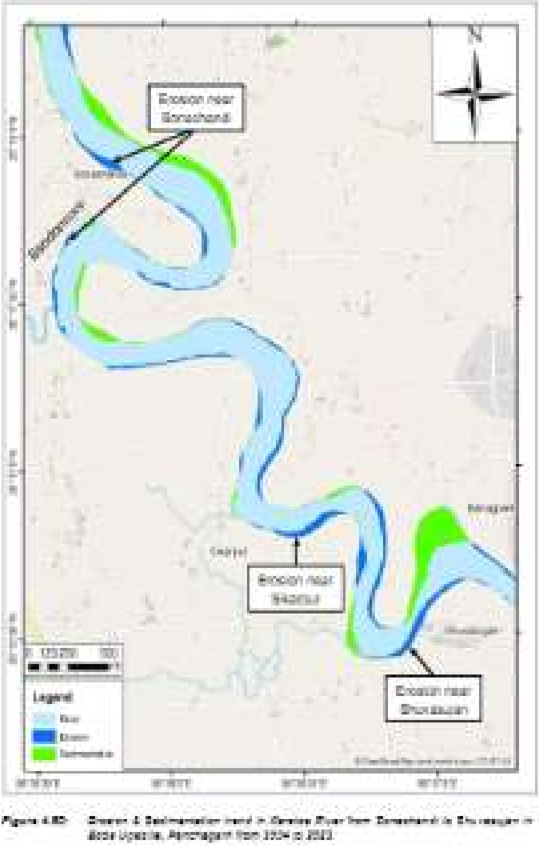

Figure 4.83: Erosion & Sedimentation trend in *Karatoa River* from Sonachandi to Bhuiyapara in Boda Upazila, Panchagarh from 1994 to 2023

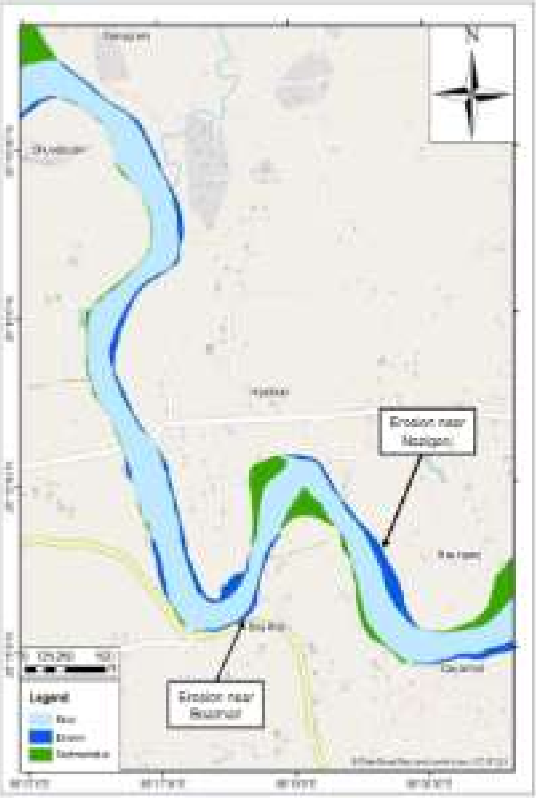

Figure 4.81: Erosion & Sedimentation trend in Karatoa River from [illegible] to [illegible] in Boda Upazila, Panchagarh from 2014 to 2023

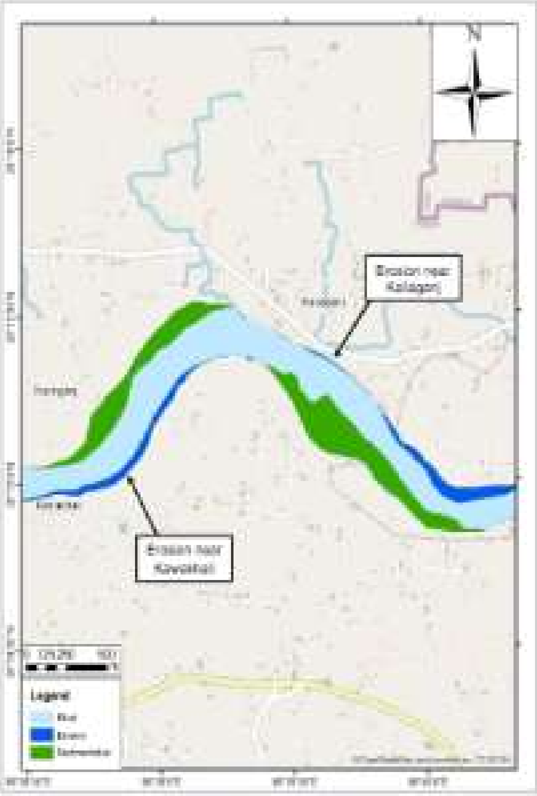

Figure 4.83: Erosion & Sedimentation trend in Karatoa River near Kaliaganj in Boda Upazila, Panchagarh from 2004 to 2023

The historical erosion & sedimentation of Karatoa River near Kaliaganj in Boda Upazila, Panchagarh is shown in **Figure 4.83**. Riverbank erosion can be seen near Kawaahali and Kaliaganj. However, the BWDB has constructed bank protection works near Kaliaganj Bazar ensuring that this reach is protected. The reach near Kawaahali is a built-up area consisting of mosque, shops, and residential areas. 1600m right bank of Karatoa River seems vulnerable as per satellite image analysis.

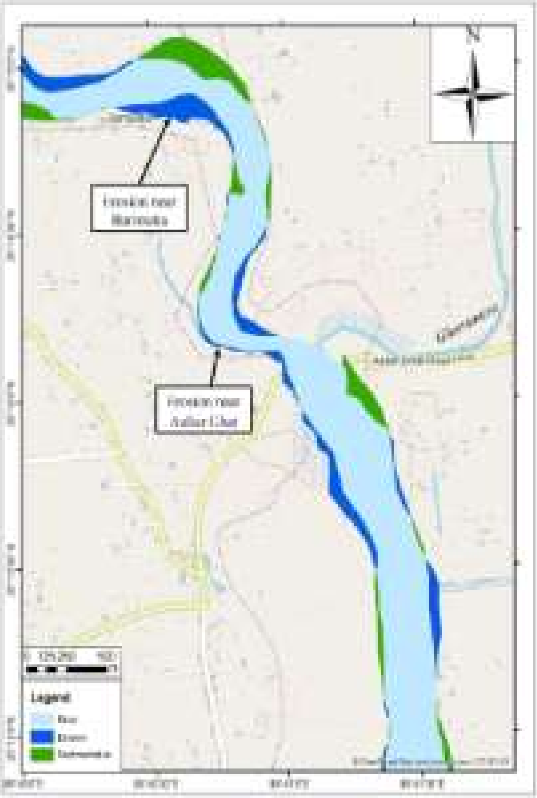

Figure 4.83: Erosion & Sedimentation trend in Karatoa River near Ghoramara outfall in Boda Upazila, Panchagarh from 2014 to 2023

The historical erosion & sedimentation of Karatoa River near Ghoramara outfall in Boda Upazila, Panchagarh is shown in **Figure 4.83**. River bank erosion can be seen near Barnpara and Aulia Ghat. Erosion can be seen near Barnpara, where 800m stretch of right bank of Karatoa River seems vulnerable to bank erosion as per the satellite image analysis. Near Aulia Ghat, around 850m of right bank appears vulnerable due to bank erosion but 520m reach of the bank might require BPW at this location.

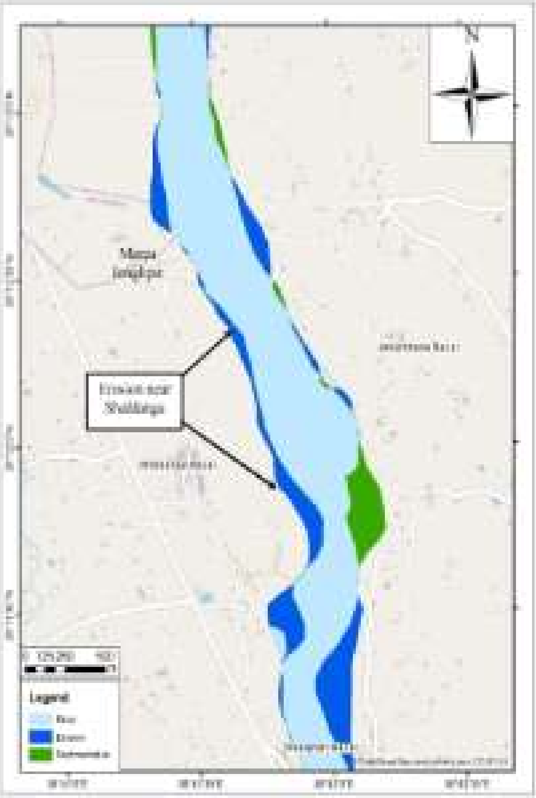

Figure 4.84 Erosion & Sedimentation trend in Karatoa River near Shaldanga Bazar in Debiganj Upazila, Panchagarh from 2004 to 2023

Figure 4.84 shows the historical erosion & sedimentation trend in Karatoa River near Shaldanga Bazar in Debiganj Upazila, Panchagarh. Erosion trend can be seen near the Shaldanga bazar. Sohlanga is an important build-up area in this region with Bazar, Primary School, High School, Mosque and Temple being present along with residential area here. Hence highly valuable land is vulnerable in this reach of the Karatoa River which does require bank protection works. Near Marea Jangipur, Shaldanga around 500m of BPW might be required. Downstream of Shaldanga bazar around 600m of BPW will be required.

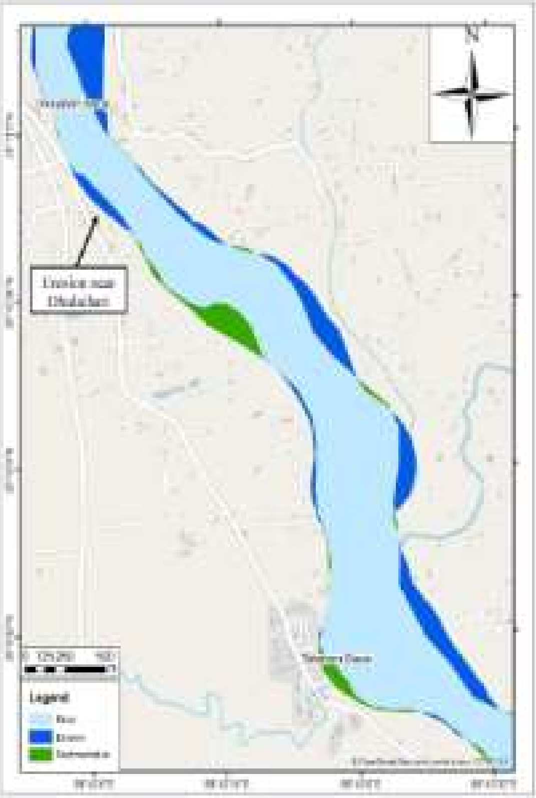

Figure 4.85: Erosion & Sedimentation of Karatoa River near Dhulajhari Bazar in Debiganj Upazila, Panchagarh from 2004 to 2023

The historical erosion & sedimentation trend in Karatoa River from just downstream of Dhulajhari Bazar in Debiganj Upazila, Panchagarh is shown in **Figure 4.85**. Historical erosion trend can be seen just downstream of Dhulajhari bazar. Dhulajhari [illegible], [illegible] remains vulnerable to bank erosion according to the historical bank erosion trend. Around 1200m of right bank might need BPW near Dhulajhari Bazar as per satellite image analysis. Same erosion can be seen on the opposite bank of Dhulajhari bazar as well, but there are only minor residential infrastructures located in the north bank of the Karatoa River.

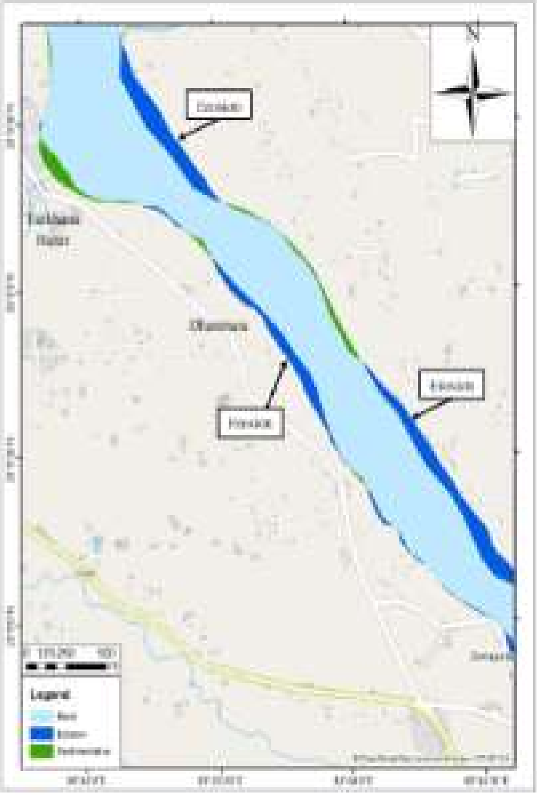

Figure 4.88: Erosion & Sedimentation trend in Karatoa River from Tunirhat Bazar to Sonapara in Debiganj Upazila, Panchagarh from 2004 to 2022

Figure 4.88 shows the historical erosion & sedimentation of Karatoa River from Tunirhat Bazar to Sonapara in Debiganj Upazila, Panchagarh. Erosion can be seen throughout the reach. However, the eroded areas are mostly agricultural lands. Near Dhanmara around

1300m reach of erosion can be observed. On the opposite bank of Tarkhona Bazar, around 1120 m reach of bank appears vulnerable due to bank erosion. While between Tarkhona Bazar and Sonapata, around 1700m stretch of left bank of Karatoa River appears vulnerable due to bank erosion.

The historical erosion & sedimentation of Karatoa River near Debiganj Town, Panchagarh is shown in **Figure 4.87**. Erosion can be seen both upstream and downstream reach of the Debiganj bridge. Erosion can be seen near Sonapata and Moynamotir Char of Debiganj Town. Around 1700m reach of right bank of Karatoa River appears vulnerable due to erosion near Sonapata. While around 1400m stretch of left bank of Karatoa River appears vulnerable due to erosion near Moynamotir Char.

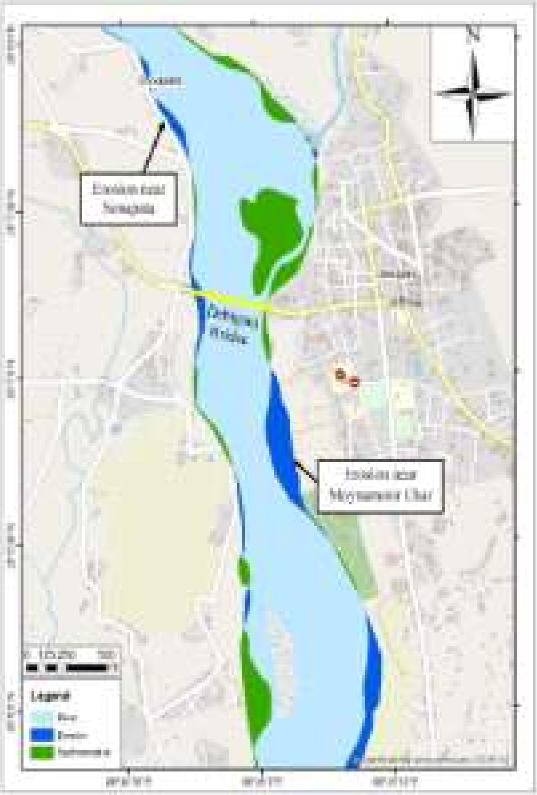

Figure 4.87: Erosion & Sedimentation trend in Karatoa River near Debiganj Town, Panchagarh from 2004 to 2023

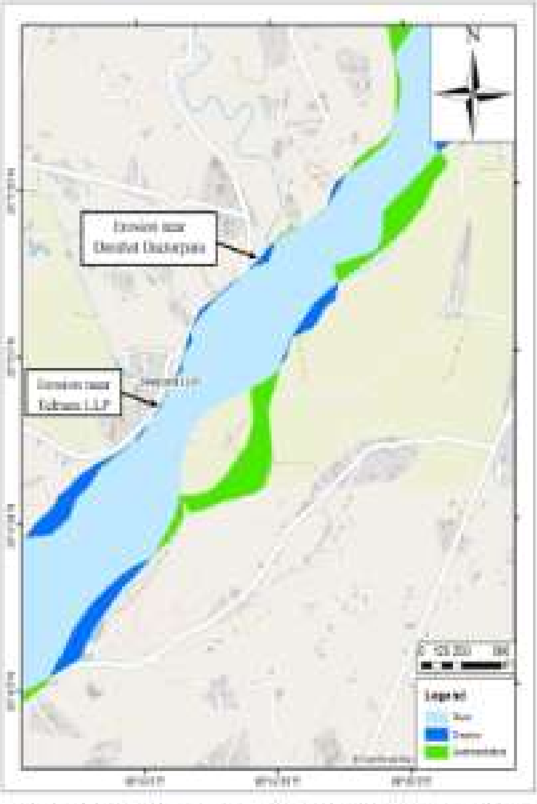

Figure 4.55: Erosion & Sedimentation trend in Karatoa River near Telpara LLP in Debiganj Upazila, Panchagarh from 2014 to 2023

Figure 4.55 shows the historical erosion & sedimentation of Karatoa River near Telpara LLP in Debiganj Upazila, Panchagarh. Some erosion can be seen near the existing Telpara Low Lift Pump and Danshal Dadarpara. Considering the importance of the Telpara LLP, this reach will probably require bank protection works. From image analysis, 400m reach near Danshal Dadarpara and 500m reach near Telpara LLP needs to be protected. Further downstream of Telpara LLP, erosion can be seen but they are mostly in non-built-up areas.

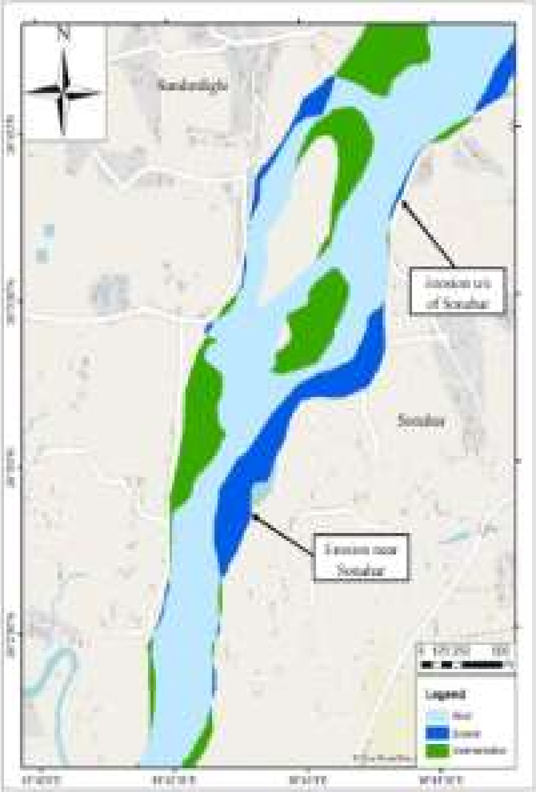

Figure 4.83: Erosion & Sedimentation of Karatoa River from Sundordighi to Sonahar in Debiganj Upazila, Panchagarh from 2014 to 2023

The historical erosion & sedimentation trend in Karatoa River from Sundordighi to Sonahar Debiganj Upazila, Panchagarh is shown in **Figure 4.83**. Erosion can be seen near Sundardighi, where around 1300m stretch of right bank of Karatoa River appears vulnerable due to historical bank erosion. On the left bank, around 800 m appears vulnerable at upstream of Sonahar where erosion has occurred near some residential infrastructures. Near

Bonarhat, erosion can be seen all along the 2100m bend of the river, but this stretch consists mostly of non-built-up areas.

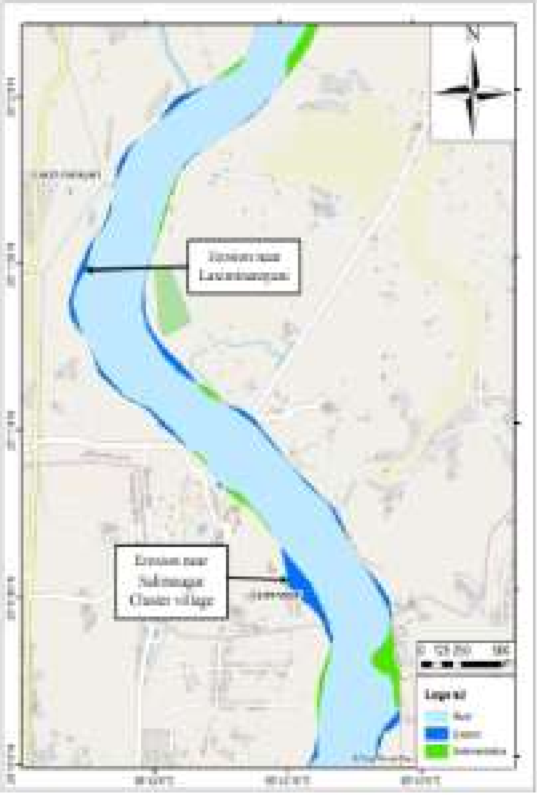
N
Laxmi Narayan
Erosion near Laxminarayan
Erosion near Salimnagar Cluster village
0 125 250 500
Legend
River
Erosion
Sedimentation

Figure 4.70: Erosion & Sedimentation trend in Karatoa River from Laxminarayan to Salimnagar in Debiganj Upazila, Panchagarh from 2004 to 2022

Figure 4.70 shows the historical erosion & sedimentation trend in Karatoa River from Laxminarayan to Salimnagar in Debiganj Upazila, Panchagarh. Erosion can be seen near Laxminarayan, just downstream of the confluence of Pathraj river, where 1220m stretch of right bank of Karatoa River appears vulnerable due to bank erosion. However, considering the built-up areas, around 500m BPW might be required in this region. Erosion can also be seen in the right bank near the Salimnagar cluster village. Around 680m stretch of right bank of Karatoa River might need protection based on satellite image analysis.

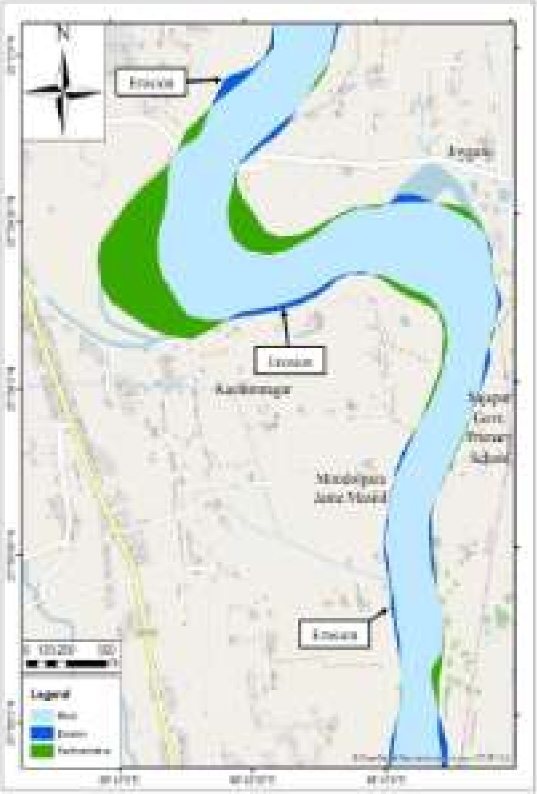

Figure 4.71: Erosion & Sedimentation trend in Karatoa River near Joyganj in Birganj Upazila, Dinajpur from 2004 to 2022

The historical erosion & sedimentation trend in Karatoa River near Joyganj in Birganj Upazila, Dinajpur is shown in **Figure 4.71**. Erosion can be seen throughout the study area.

However, bank erosion has occurred at a stretch of 310m near Kashimnagar near a built-up area and the road near the riverbank has also been eroded away in the past few years. Based on the settlements and road alignment of the area, around 500m BPW might be required at this location. On the other bank, around 1050m of left bank of Karatoa River near Joyganj Bazar appears vulnerable due to bank erosion based on historical image analysis. Erosion can also be seen near Mondolpara Jame Masjid, Kashimnagar, on the right bank of Karatoa River. Around 1400m stretch of right bank appears vulnerable in this reach, however it is mostly on non-built-up areas.

Figure 4.72 shows the historical erosion & sedimentation of Karatoa River from Joyganj to Khansama Bridge in Debiganj & Khansama Upazila, Dinajpur. Although erosion can be seen at multiple locations within this stretch of the river. Near Poschim Basuli, around 2km left bank of the Karatoa River appears vulnerable to bank erosion as observed in historical image analysis. Erosion can also be seen at upstream of Khansama Upazila Fire Service. Although erosion can be seen at more than 820m of the left bank stretch of the Karatoa River, considering the locations of infrastructures near the riverbank, around 260m bank can be categorized as vulnerable in this reach. Erosion can be seen on the right bank of Karatoa River as well, however, they are mostly in non-built-up areas.

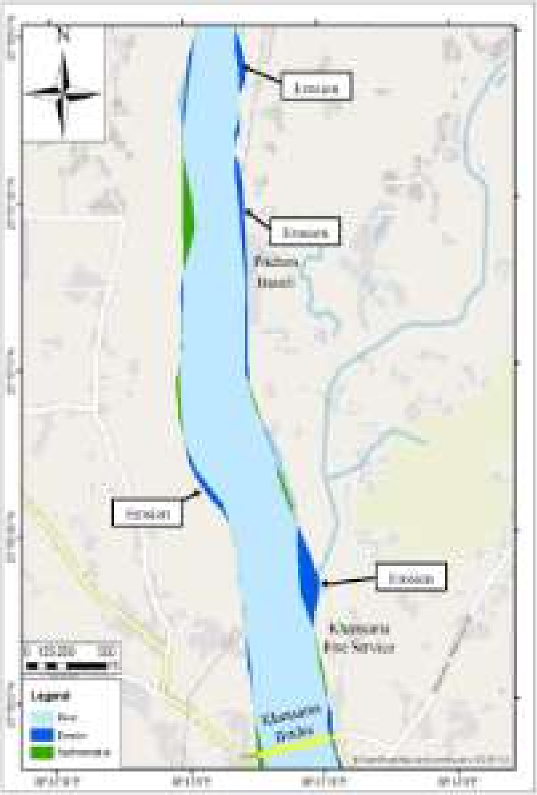

Figure 4.75: Erosion & Sedimentation trend in Karatoa River near Jaygaon in Birganj & Khansama Upazila, Dinajpur from 2004 to 2023

An Upazila wise graph on bank erosion for the last twenty years has been prepared for the Karatoa River which is shown in **Figure 4.76** to **Figure 4.77**.

Figure 4.76 shows the temporal erosion that has taken place in the Karatoa River in Tentulia Upazila, Panchagarh. Here it is evident that the erosion of Karatoa River was higher in the Tentulia Upazila during 2004 to 2009 and 2014 to 2015, when about 3.3 hectors per year land was lost due to erosion. The erosion rate has been reduced during 2009 to 2014, and during the last four years (2019-2023), around 4.85 hectors per year land has been lost due to erosion of Karatoa River in Tentulia Upazila.

The erosion graph for Panchagarh Sadar Upazila has been shown in **Figure 4.74**. The graph shows that the erosion during 2004 to 2009 was around 2.85 hectors per year with around 15 hectors of erosion was observed in Panchagarh Sadar Upazila on the Karatoa Riverbanks. The erosion dropped off during 2009 to 2014 following a similar kind of trend seen in the upstream reach. During 2014 to 2019 the erosion increased slightly but the rate of erosion of Karatoa River has increased substantially during 2019 to 2023 in Panchagarh Sadar Upazila.

Figure 4.75 shows the temporal erosion that has taken place in the Karatoa River in Boda Upazila, Panchagarh. The graph of Boda Upazila shows a clear upward trend with around 60 hectors of land being lost due to the erosion of Karatoa River during 2019 to 2023. Major tributaries like Talma and Ghoramara falls into the Karatoa River within this river reach. As such, different erosion characteristics is observed in this reach, comparing to the upstream reaches of Karatoa River.

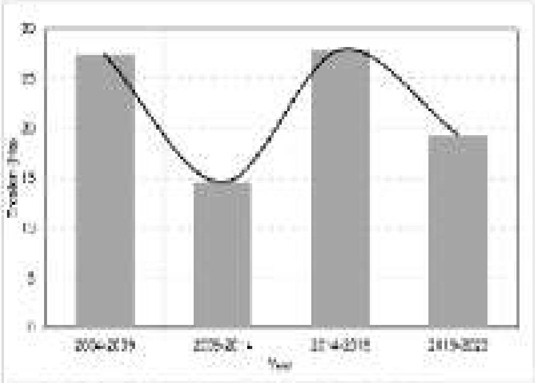

Figure 4.73: Temporal Erosion of Karatoa River in Tentulia Upazila, Panchagarh

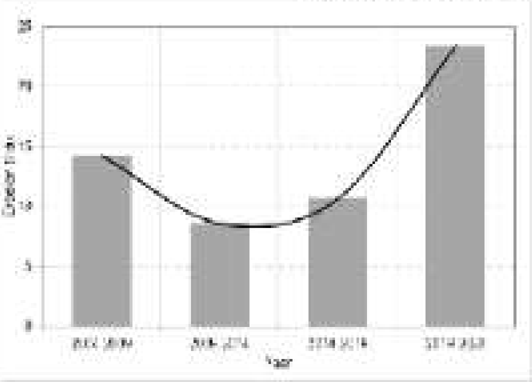

Figure 4.74: Temporal Erosion of Karatoa River in Panchagarh Sadar Upazila

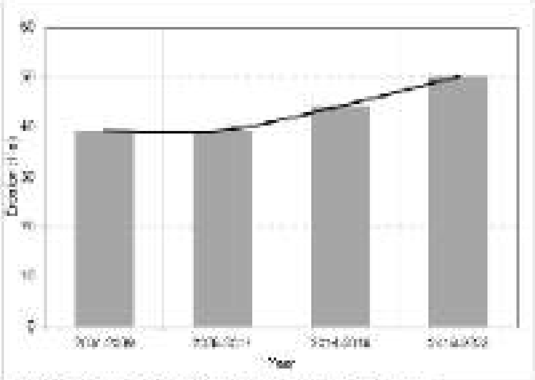

Figure 4.75: Temporal Erosion of Karatoa River in Boda Upazila, Panchagarh

The erosion graph of Karatoa River for Debiganj Upazila, Panchagarh has been shown in **Figure 4.76**. The erosion characteristics of Debiganj Upazila seems similar to that of Boda Upazila. During 2019 to 2023, around 100 hectares of land have been lost due to erosion of Karatoa River at Debiganj Upazila.

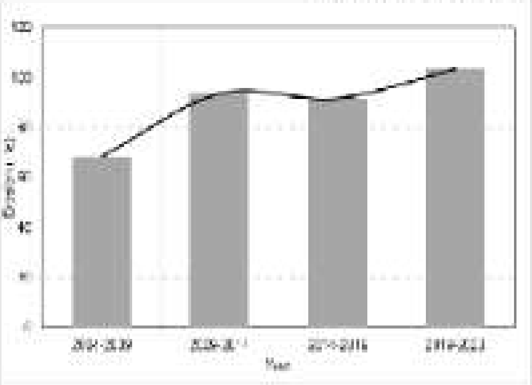

Figure 4.76: Temporal Erosion of Karatoa River in Debiganj Upazila, Panchagarh

The erosion graph of Karatoa River for Khansama & Birganj Upazila, Dinajpur has been shown in **Figure 4.77** and **Figure 4.78**, respectively. Both the graphs show similar kind of results, with erosion being highest during 2014 to 2016, and reduced significantly after that, in the recent years. The pattern of graph for Khansama & Birganj Upazila are similar, but they are totally different from the graph of the upstream reaches of the Karatoa River. Since the Pathraj River falls into the Karatoa River in southern tip of the Debiganj Upazila, further downstream, the characteristics of the river might have been different than that of the upstream reaches.

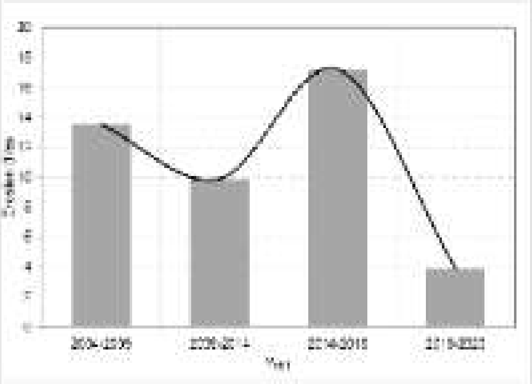

Figure 4.77: Temporal Erosion of Karatoa River in Khansama Upazila, Dinajpur

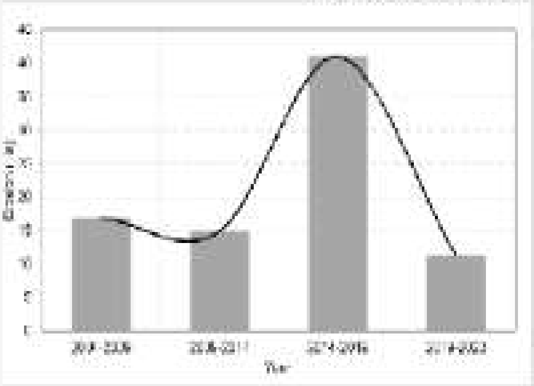

Figure 4.79: Temporal Erosion of Karatoa River in Birganj Upazila, Dinajpur

The summary of all the vulnerable locations of the Karatoa River identified via planform analysis has been presented in tabular format in **Table 4.18**.

Table 4.[illegible] Location and length of vulnerable locations of Karatoa River

River	Location	Upazila	Bank	Vulnerable bank length (m)
Karatoa	[illegible]	Tentulia	Left	700
	Bhajanpur Bridge (Bhajanpur Mouza)		Right	750
	[illegible]	Panchagarh Sadar	Right	800
	[illegible]		Left	1500
	[illegible]		Left	500
	[illegible]		Left	700
	[illegible]	Boda	Right	700
	[illegible]		Right	800
	[illegible]		Right	800
	[illegible]		Right	500
	[illegible]		Right	800
	[illegible] Bazar		Right	150
	[illegible]		Left	400
	[illegible]		Right	1500
	[illegible]		Right	800
	[illegible]		Right	700
	[illegible]	Debiganj	Right	800
	[illegible]		Right	800
	[illegible] Bazar		Right	1200
	[illegible]		Right	700
	[illegible]		Right	1700
	[illegible] Char		Left	1400
	[illegible]		Right	800
	[illegible]		Right	500
	[illegible]		Left	500
	[illegible]		Right	750
	[illegible]		Right	500
	[illegible] cluster village		Right	600
	[illegible]	[illegible]	Right	800
	[illegible]	Khansama	Left	1540
	Khansama Upazila Fire Service		Left	265
Total Length				23985

Talma River

Talma is an important river of Panchagarh district. Like other rivers in Panchagarh, Talma is characterized by its flashy nature. Satellite image analysis shows bankline shifting and bank erosion can be seen along the Talma River. The erosion & sedimentation of Talma River for twelve years from 2011 to 2023 has been shown in **Figure 4.79** to **Figure 4.83**. Where the **Figure 4.79** shows the erosion & sedimentation starting from the Talma Bazar to the outfall of the Talma River, hence the downstream portion of the river. Erosion can be seen on all the outer bend of the Talma River in this stretch of the river. Purba Tulardanga, Purba Hotatpara, Bamonpara and Nalbura are built up areas on the left bank of Talma River and the bank has showed erosion tendency in the historical bankline analysis. Near Purba Tulardanga around 400m reach of Talma River on the right bank appears vulnerable due to bank erosion. Further upstream, near Purba Hotatpara, around 225m BPW might be required. Around 400m left bank reach near Nalbura appears vulnerable due to bank erosion based on historical satellite image analysis. The entire right bank stretching around 700m in length near Bamonpara and Talma rubber dam appears vulnerable to bank erosion.

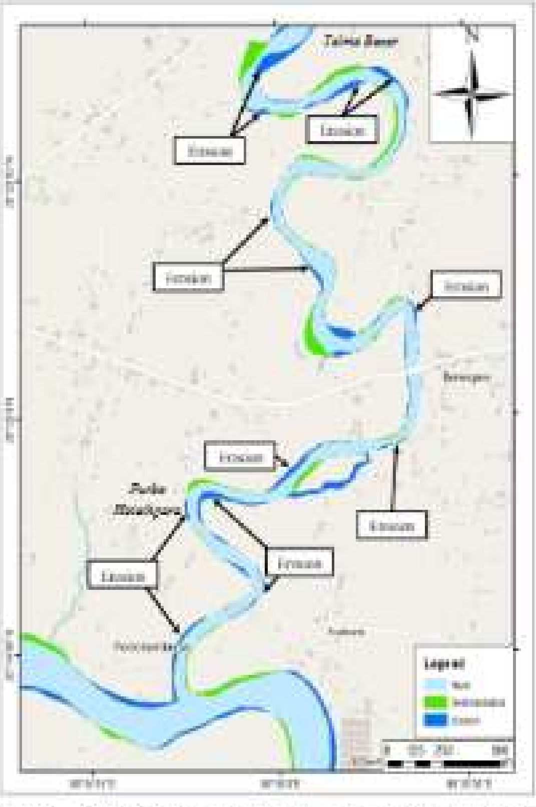

Figure 4.75: Erosion & Sedimentation trend in Talma River from Talma Bazar to outlet in Panchagarh Sadar Upazila from 2011 and 2023

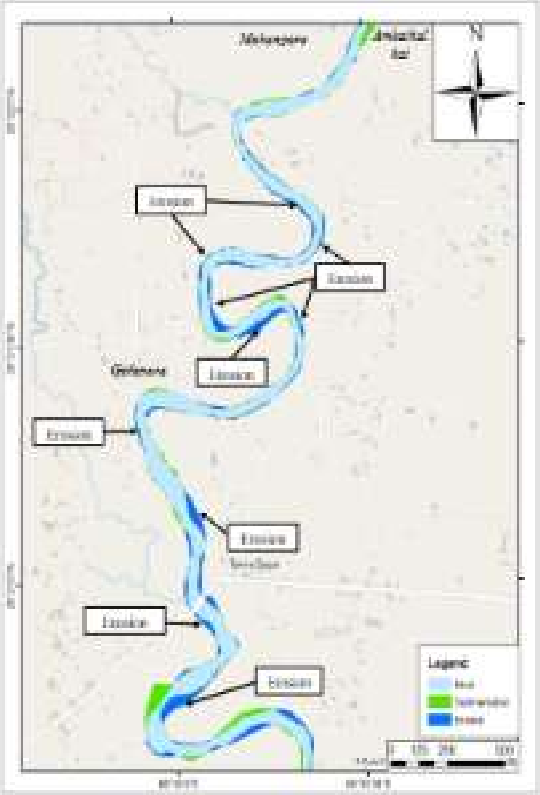

Figure 4.20: Erosion & Sedimentation trend in Talma River from Mahorpara to Talma Bazar in Panchagarh Sadar Upazila from 2011 to 2023

The erosion and sedimentation plot between Mahorpara and Talma Bazar has been shown in **Figure 4.20**. From the figure it can be seen that just downstream of Gobapara, some erosion has taken place on the outer bend of the river. Erosion can also be seen near the Talma Bazar region, which is a built-up area. 250m stretch of left bank upstream of the Talma Bazar bridge may need BPWs based on satellite image analysis.

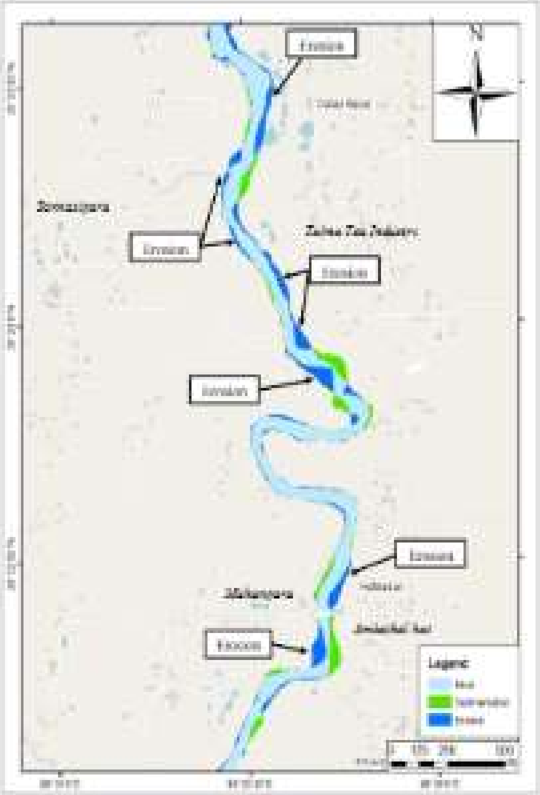

Figure 4.21: Erosion & Sedimentation trend in Talma River from Dabari Bazar to Mahanpara in Panchagarh Sadar Upazila between 2011 and 2023

Figure 4.21 shows the erosion and sedimentation that occurred between Dabari Bazar and Mahanpara. Erosion can be seen just upstream of the bridge connecting Amkathal hat and Mahanpara. As much as 40 to 45 m bank erosion can be seen just upstream of the bridge, putting the left bank near the bridge under vulnerable condition. 450m of left bank starting from the bridge axis appears vulnerable to bank erosion. Further upstream, erosion can be seen on both banks of the river between Sonnaipara and Talma Tea industry. Erosion can also be seen on the left bank near Zia Gari Bazar. However, the erosion prone areas are still situated away from the build-up areas.

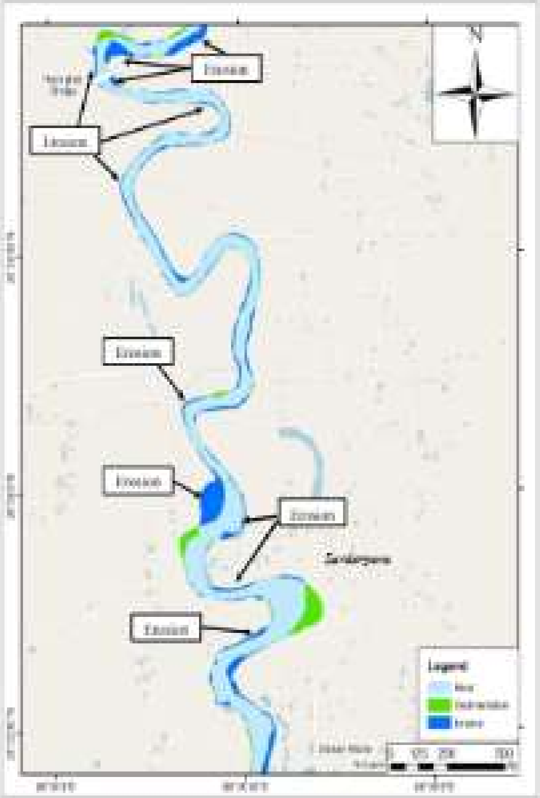

Figure 4.22: Erosion & Sedimentation trend in Talma River from Hazighat Bridge to Zilapir Bazar in Panchagarh Sadar Upazila between 2011 and 2022

The erosion and sedimentation plot between Zilapir Bazar to Hazighat Bridge has been shown in **Figure 4.22**. From the figure it can be seen that, the bank line near Sardarpara has shifted in the last ten years. From Hazighat bridge all the way up to Sardarpara, some erosion deposition can be seen in the Talma River. However, most of the erosion takes place in non-built-up areas.

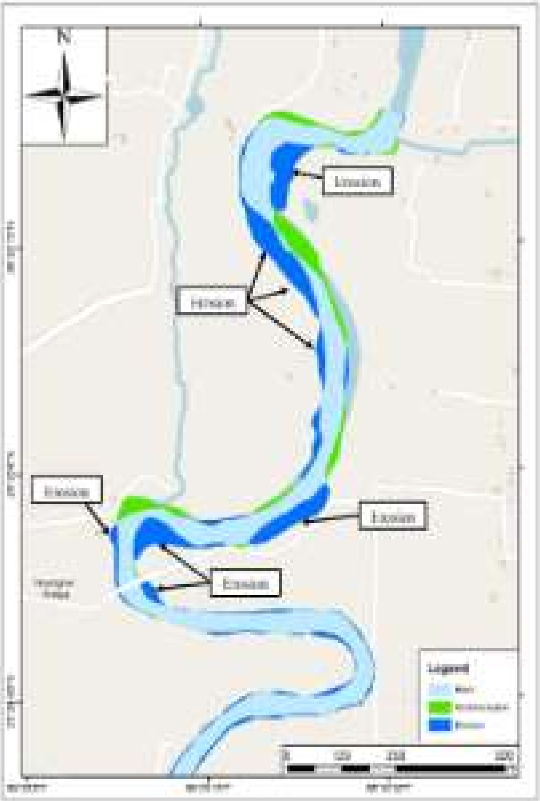

Figure 4.33: Erosion & Sedimentation trend in Talma River upstream of Hazirghat Bridge in Panchagarh Sadar Upazila from 2011 to 2022

Figure 4.33 shows the erosion and sedimentation that occurred at upstream of Hazirghat bridge in Panchagarh Sadar Upazila. Just upstream of the Hazirghat bridge, erosion can be seen on both banks of the Talma River. Erosion and bankline shifting tendency around the vicinity of the Hatirghat bridge is a sign of worry. Near the Hatirghat bridge, on the right bank around 270m bank appears vulnerable. While on the left bank, the bank erosion puts the approach road of the bridge under threat. Around 520m of BPW starting from the bridge axis towards upstream side might be required based on satellite image analysis. Further upstream, the Talma River appears to be very dynamic as erosion and deposition has taken place all throughout the Talma River.

Figure 4.84 shows the temporal erosion that has taken place in the Talma River in the Panchagarh Sadar Upazila. The bar chart of the figure shows cumulative erosion that has taken place in the Talma River between the mentioned year, while the line chart shows the erosion per year for the mentioned period in Talma River. It can be seen from the figure that the erosion per year has stayed between 5 Ha/Year to 7.5 Ha/year in the last twelve years.

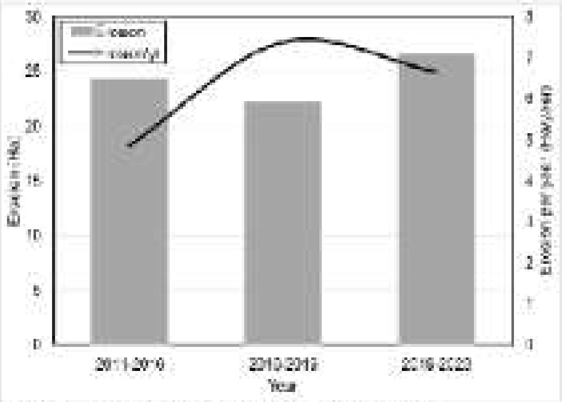

Figure 4.84: Temporal Erosion of Talma River in Panchagarh Sadar Upazila

The **Figure 4.85** was prepared to show the Erosion and Sedimentation side by side for the last twelve years. It can be seen from the Figure that the total sedimented land between 2011 and 2016 was around 11.85 Ha, far less than the total eroded land of 24.33 Ha. However, between 2016 and 2019 more siltation has occurred in Talma River than erosion. While between 2019 and 2023, the scenario has reversed a bit, with more land being eroded than being silted up.

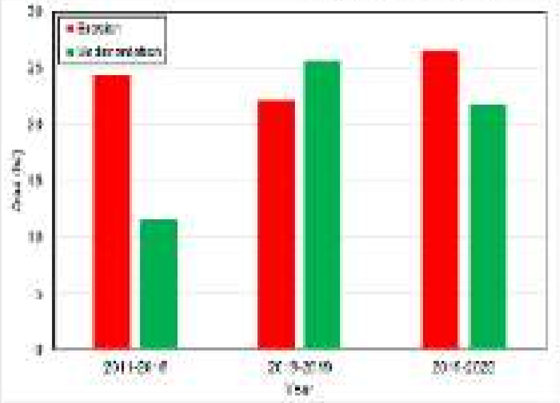

Figure 4.88: Temporal Erosion and Sedimentation of Talma River

Table 4.11 Location and length of vulnerable locations of Talma River

River	Location	Upazila	Bank	Vulnerable bank length (m)
Talma	Dudukumardanga	Panchagarh Sadar	Right	400
	Naduna		Left	400
	Puthur Hoikatpara		Right	225
	Dakhinpara		Left	700
	Talma Bazar		Left	250
	Hatikata		Left	450
	Panchghat Bridge		Right	275
	Panchghat Bridge		Left	525
Total Length				3225

Chawai River:

Chawai River, which originates in India and later falls into the Karatoa River, is another flashy river in Panchagarh. Bankline shifting and bank erosion is also observed in this river. A detailed planform analysis was carried out for this river and the figures are shown between **Figure 4.89** and **Figure 4.90**. The **Figure 4.89** shows the planform changes from Amarkhana to Chawai outfall. Erosion in this reach can also be seen on the right bank of the river near the outfall of the Chawai river. Erosion can also be seen near the bend near Lathuapara. Erosion can be seen on both the left bank and right bank near Lathuapara. On the right bank, around 750m BPW might be required to keep the bend stable near Lathuapara. Erosion can also be seen near the right bank bend, just downstream of Chawai Bridge. Erosion can also be seen on the left bank of the Chawai Bridge. Near the bend of Dakhin Kadpara, erosion could be seen on the right bank of the river. Near Dangapara bend, traces of erosion can be seen on both the left bank and right bank of the river. Around 350m of right bank might need BPW based on the satellite image analysis.

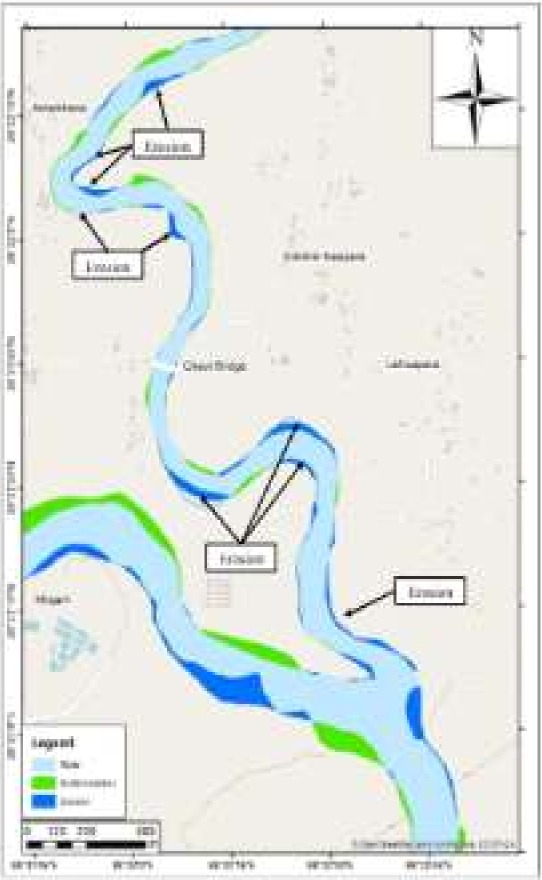

Figure 4.[illegible]: Erosion & Sedimentation trend in Chawai River from Amarkhana to outlet in Panchagarh Sadar Upazila between 2018 and 2023

Figure 4.87 shows the erosion deposition trend from Saldpara to Amarkhana. Erosion can be seen on the right bank. Some traces of erosion can also be seen near the bend at Kazipara, where the erosion occurs very close to the road communication network as well. Considering this, around 750m BPW on the left bank near Kazipara might be required as per satellite image analysis. At further upstream, erosion can also be seen at left bank on the outer bend of Kazipara. Erosion can also be seen on the left bank near the Chawai Bridge at Kazipara. Although further erosion can be seen in other stretches of the river, mostly they are in non-built-up areas.

The erosion & sedimentation trend from Jagdal Bazar Uttar Jame Masjid to Saldpara has been shown in **Figure 4.88**. Jagdal Bazar is an important location in this stretch of Chawai River and erosion can be seen here. Specially near the Jagdal Bazar bridge where erosion can be seen on both banks of the river. Erosion can also be seen upstream of the bridge at both left bank and right bank. On the right bank, near Jagdal bridge, around 750m of BPW might be required. On the left bank, around 523m BPW starting from 50m d/s of the Jagdal bridge, towards upstream direction might be needed. Further downstream, erosion can also be seen near the bend of Jagdal Bazar, where around 430m BPW might be needed. Downstream of the Jagdal bazar, erosion can be seen on the left bank of the river. Erosion on the right bank can also be seen near Khalpara. Near Kalaitra Tea Garden, erosion has occurred very close to the built-up areas and near road infrastructures. Around 356m BPW on the right bank might be needed in this reach of the river.

Figure 4.89 shows the erosion deposition trend from Board Bazar to Jagdal Bazar Uttar Jame Masjid. Erosion can be seen on the right bank near the built-up area of Pirahilage. Around 1150m of right bank will need BPW near Pirahilage based on satellite image analysis. Erosion can also be seen further upstream near Sutarhatti. Near Board Bazar, erosion can be seen near Sallion Tea Factory, which is located very close to the Chawai Riverbank. Around 500m BPW might be needed at this location as per the satellite image analysis. Although erosion can be seen in other places, mostly they are in non-built-up areas.

The erosion and sedimentation plot from Bangladesh-India Border to Board Bazar has been shown in **Figure 4.90**. From the figure it is seen that bank erosion on the right bank, on the opposite bank of the Sallion Tea Factory has put the present village road under threat. Further upstream, in the vicinity of the Omarkhana bridge, erosion can be seen as well.

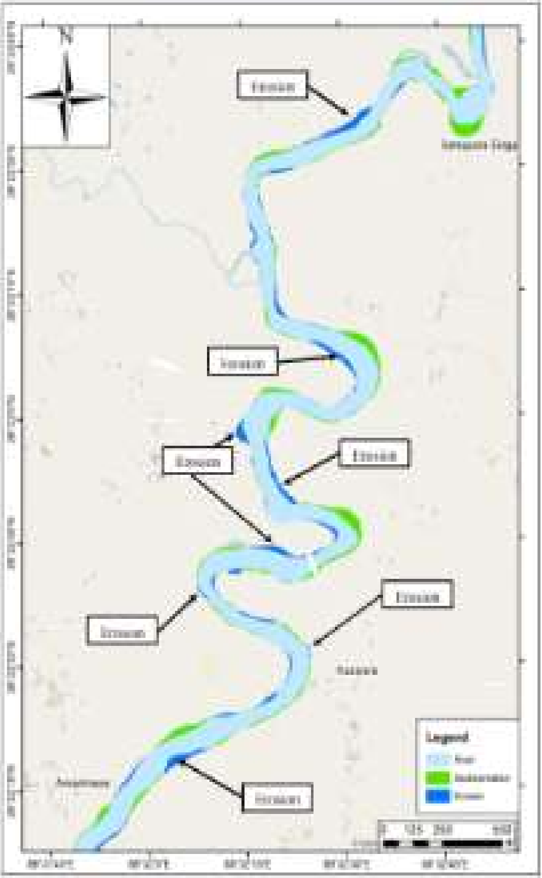

Figure 4.81: Erosion & Sedimentation trend in Chawai River from Sadigara to Amarkhana in Panchagarh Sadar Upazila from 2018 to 2022

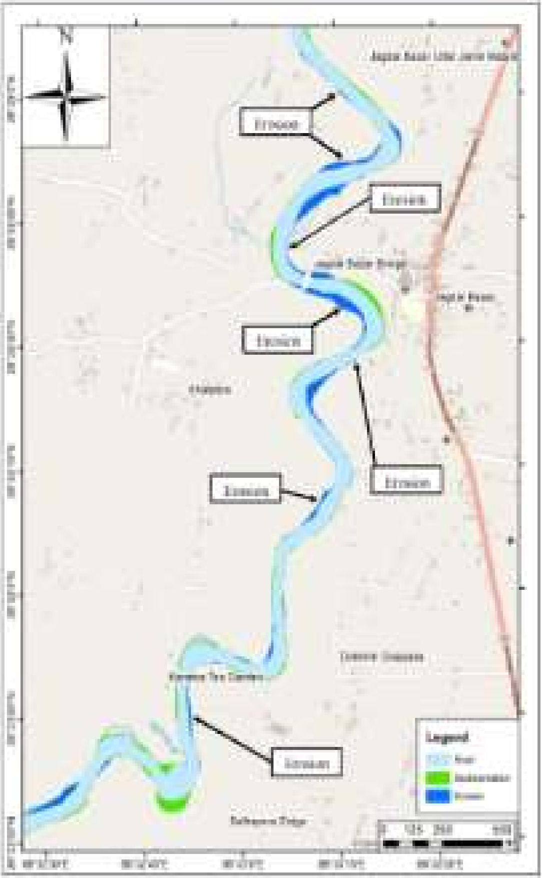

Figure 4.88 Erosion & Sedimentation trend in Chawai River from Jagdal Bazar Uttar Jame Masjid to Baligaon in Panchagarh Sadar Upazila from 2018 to 2022

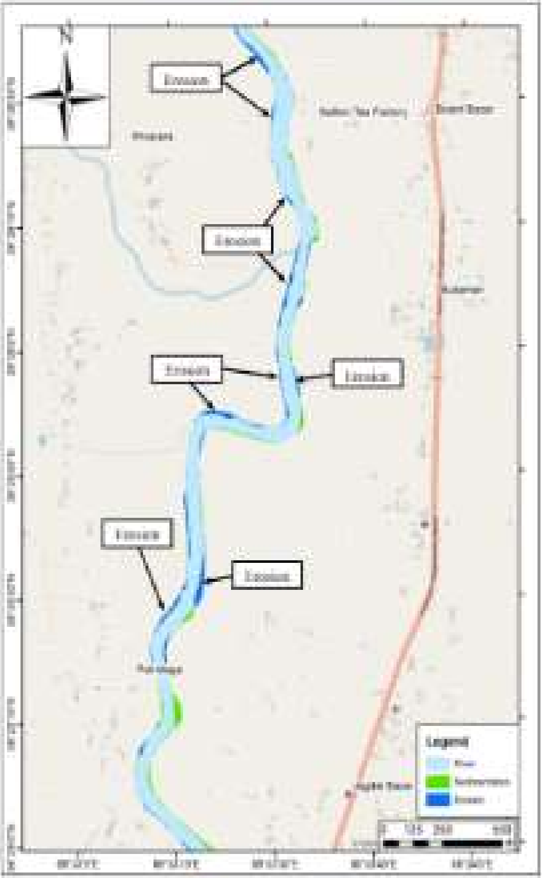

Figure 4.28: Erosion & Sedimentation trend in Chawai River from Board Bazar to Jagdal Bazar (Uttar Jamla Magri) in Panchagarh Sadar Upazila from 2018 to 2023

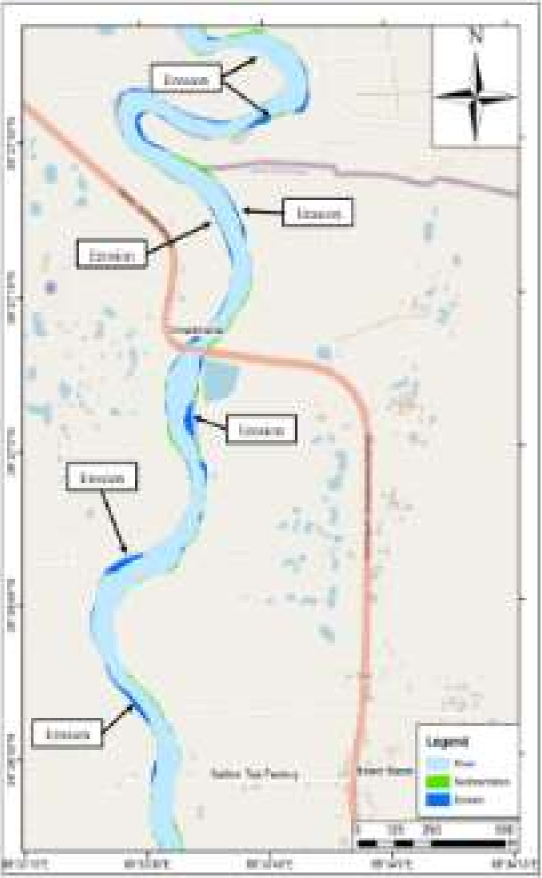

Figure 4.86 Erosion & Sedimentation trend in Chawai River from Bangladesh–India Border to Boda Bazar in Panchagarh Sadar Upazila from 2019 to 2022

The table showing the vulnerable locations of the Chawai river and the required length of BPWs based on satellite image analysis has been presented in **Table 4.12**.

Table 4.12 Location and length of vulnerable locations of Chawai River

River	Location	Upazila	Bank	Vulnerable bank length (m)
Chawai	[illegible]	Panchagarh Sadar	Left	840
	[illegible]		Right	1150
	Jagdal Bazar Bridge		Right	700
	Jagdal Bazar Bridge		Left	520
	Jagdal Bazar		Left	425
	Karatoa Tea Garden		Right	250
	[illegible]		Left	700
	Dangapara		Right	300
	[illegible]		Left	700
Total Length				[illegible]

Pathraj River

Pathraj River which originates in the lowlands in Panchagarh, flows through Panchagarh & Thakurgaon and later falls into the Karatoa River. This is a highly meandering river and bankline shifting and bank erosion can be seen in almost all the bends in this river. A detailed planform analysis was carried out for this river and the figures are shown from **Figure 4.91** to **Figure 4.106**.

Figure 4.91 shows the erosion deposition trend of the Pathraj River between Pulbari High School to the river's outfall at the Karatoa River in Debiganj Upazila. Erosion can be observed near the outfall on the left bank of the river. Erosion can also be observed on the right bank near the Lakshmi Narayan Mamapara. This is a built-up area and around 460m stretch of right bank remains vulnerable to bank erosion here. Further upstream near the Lakshmi Narayan Primary School around 100m of riverbank on the right bank has shown bank erosion in the past 8 years. But more erosion can be seen on the opposite bank i.e., the left bank of the river here. Around 185m of the left bank is vulnerable to erosion. The region also comprises of built-up areas here with plenty of residential houses. Further upstream, just downstream of the BADC LLP Debiganj-2, around 200m of right bank has shown bank erosion in the past 8 years. But mostly it consists of non-built-up areas. Around 500m upstream from the BADC LLP, erosion can be seen on the outer bend i.e., the left. Bank erosion can be seen in about 300m stretch of the left bank of the Pathraj River. A few residential infrastructures can be seen on this bend however, it mostly consists of non-built-up areas.

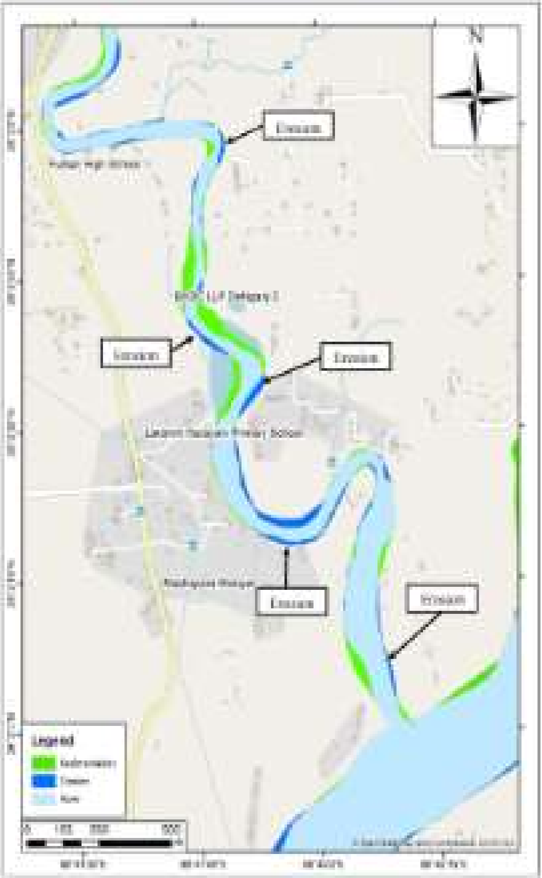

Figure 4.81: Erosion & Sedimentation trend in Pathraj River from Pulban High School to the river's outfall at Karatoa River in Debiganj Upazila from 2018 to 2023

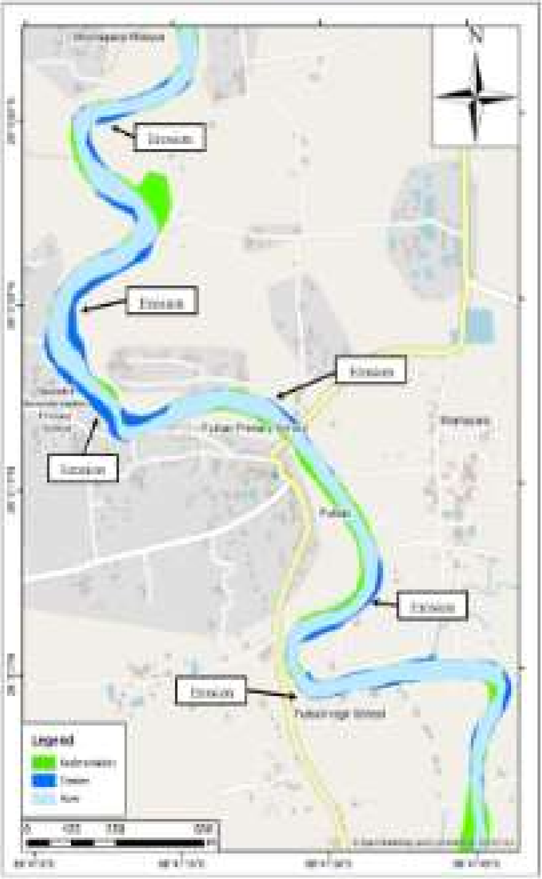

Figure 4.82: Erosion & Sedimentation trend in Pathraj River from Moynaguri Mosque to Fulbari High School in Debiganj Upazila from 2018 to 2023

Erosion and sedimentation near the Fulbari area is shown in **Figure 4.82**. Erosion is observed near the Fulbari High School which is located on the right bank of the Pathraj River. The

Debiganj-Jhalbari-Birganj Road is also located very close to the riverbank here. Around 510m of riverbank is vulnerable in this reach of the river. And the presence of the High School and Upazila Road makes protecting this reach of the Pathraj River very important. 300m upstream of the Fulbari High school, erosion can be seen on the left bank of the river near Shekhpara. Around 360m of the left bank at this reach is vulnerable to bank erosion based on satellite image analysis. A few clusters of residential infrastructure are there in this reach of the river, but mostly it consists of non-built-up areas. Erosion is also seen upstream of the Fulbari bridge, on the left bank of the Pathraj River. This stretch not only is located just upstream of an important bridge, it is also consists of densely populated areas. Hence, the 400m stretch of this right bank will be an important area to protect. And just upstream of this, on the opposite bend, near the Fulbari Primary School, erosion is also seen. This is where the main Fulbari town is located and consists of high value lands. The bank erosion of the 320m of the left bank here needs to be addressed. Between the Fulbari Primary School and the Moynapara Mosque, erosion can be seen on the bends of the Pathraj river. However, these are mostly in non-built-up areas. Erosion at Sasnabin Anondonmadon Primary School is noticeable.

Figure 4.83 shows the erosion sedimentation trend of the Pathraj River from Purbopara Mosque to Moynapara Mosque in Debiganj Upazila, Panchagarh. Between Moynapara Mosque and Hazradanga Primary School, erosion can be seen in mostly non-built-up areas. Further upstream erosion can be seen near the Hazradanga bridge, erosion can be seen on the right bank of the river. Near the Hazradanga Purbopara Mosque, erosion can be seen on the right bank. This 400m stretch of the right bank consists not only of the Hazradanga Purbopara mosque, but also lots of residential infrastructure near the Pathraj Riverbank. Hence protecting this 400m reach of the river looks important. Although erosion can also be seen on the outer bends of Pathraj River upstream of the Purbopara Mosque, this is mostly in the non-built-up areas.

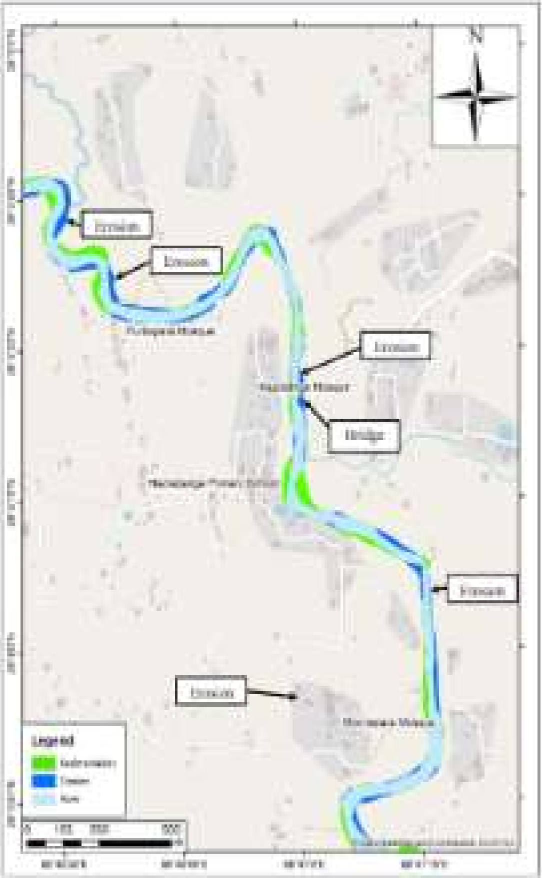

Figure 4.20: Erosion & Sedimentation trend in Pathraj River from Purbopara Mosque to Moynapara Mosque in Debiganj Upazila from 2018 to 2022

Erosion-sedimentation trend from Prodhanpara Mosque to Purbopara Mosque is shown in **Figure 4.84**. This is the highly meander section of the Pathraj River and the river is highly dynamic as well. Erosion can be seen in all the bends of the river with sedimentation occurring in the opposite bank of the river. Most of the erosion falls in the non-built-up areas. However, near the Hazradanga (30 Ghar) Jame Mosjid, erosion can be seen on the right bank of the river, where lots of residential & commercial infrastructures are there. Hence the 400m stretch of right bank near the Hazradanga (30 Ghar) Jame Mosjid might require some bank protection works.

Further upstream, erosion - sedimentation trend from Roth Bazar to Prodhanpara Mosque has been shown in **Figure 4.85**. Like the previous stretch of Pathraj River, erosion can be seen also in the bends of the river in this stretch as well. Erosion site, that needs to be pointed out in this reach is the bend between Agrapara Laxmi Dham, Masterpara and Kismat Bagdoha Primary School. Erosion can be seen in the 270m stretch of the Pathraj River and the presence of Agrapara Laxmi Dham Mondir, Masterpara mosque and Kismat Bagdoha Primary School as well as residential infrastructures very close to the Pathraj River right bank makes this site important. Erosion can also be seen near the Roth bazar bridge area. However built-up areas are not present in that region.

Figure 4.86 shows the erosion & sedimentation trend of the Pathraj River from Motipara Primary School to Roth Bazar. Historical bank erosion can be seen just downstream of the Kalikapur Water Control Structure. Erosion can also be seen on the right bank upstream of the water control structure as well near the Ganga & Gobinda Mondir. Further upstream near the Auliyar Danga, erosion can be seen on the left bank of the river for about 245m river stretch. Erosion can also be seen near the southern bend (Naya Bazar) as well where 115m river stretch has seen erosion on the right bank. Both these erosion prone regions near the Auliyar Danga have residential infrastructures as well as earthen roads nearby. Further upstream, Pathraj River becomes very meandering again near Sinna Kuri Mosque, where erosion can be seen on the other bends of the river. The area has lots of residential infrastructures, earthen roads as well as Motipara Primary school on the southern bend. 250m of reach of right bank near Motipara Primary School and 230m reach of right bank near the Sinna Kuri Mosque might need bank protection works based on the satellite image analysis.

Erosion & sedimentation trend from Pathraj Bridge to Motipara Primary School is shown in **Figure 4.87**. Erosion can be seen on the right bank of the Pathraj River upstream of the Motipara. Erosion can be seen very close to the road present there. Further upstream between Pathraj bridge and Motipara Primary School, erosion can be seen on the bends of the river. However, mostly they have occurred in the non-built-up areas.

Figure 4.88 shows the erosion & sedimentation trend of the Pathraj from Sukhan Pukhari Girls High School to Pathraj Bridge. Around 650m upstream of the Pathraj Bridge, erosion can be seen near built up areas on the right bank. Around 460m stretch of right bank seems vulnerable to bank erosion in this reach of the river. And around 950m upstream of the Pathraj bridge, historical bank erosion can be seen on the left bank of the river. 270m stretch of left bank seems vulnerable to bank erosion in this reach of the river. South-East of Sarobuk, erosion be seen on the left bank of the Pathraj River with 700m of bank remaining vulnerable in this reach. Between Murshidpara and Sarobuk, erosion can be seen on right bank of the Pathraj River where around 250m of bank right bank seems vulnerable to bank erosion, which is close to built-up areas. The dynamism of the Pathraj River can also be seen near Vuiyapara, where a loop cut has formed in the last ten years. Erosion can also be seen near the Sukhan Pukhari Girls High School, where a 200m stretch of right bank seems vulnerable due to bank erosion.

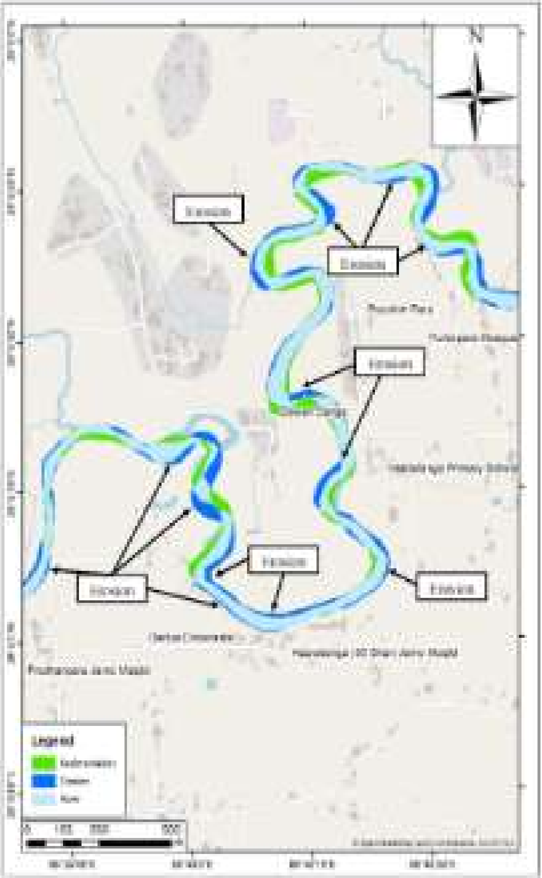

Figure 4.84: Erosion & Sedimentation trend in Karatoya River from Pochampara Mosque to Rustogara Mosque in Debiganj Upazila from 2018 to 2022

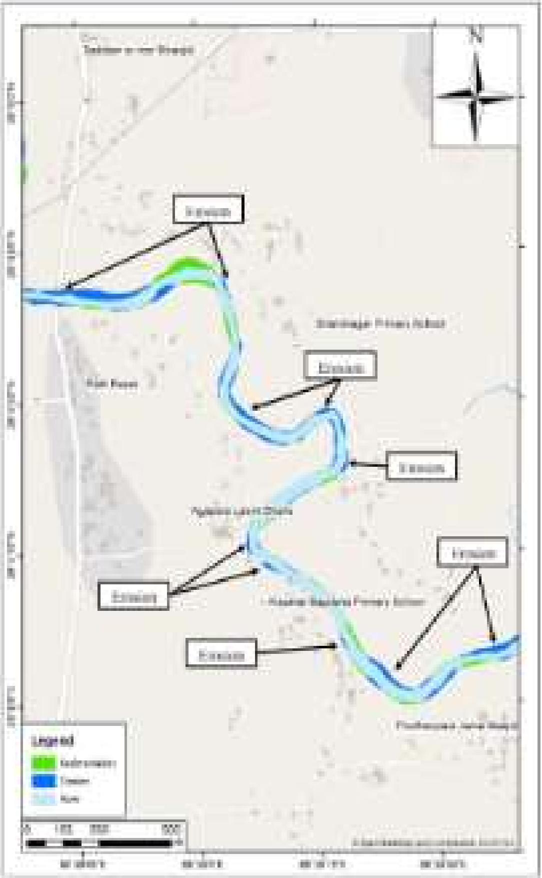

Figure 4.83: Erosion & Sedimentation trend in Pathraj River from Kazi Bazar to Pirohinagore Mosque in Debiganj Upazila from 2018 to 2023

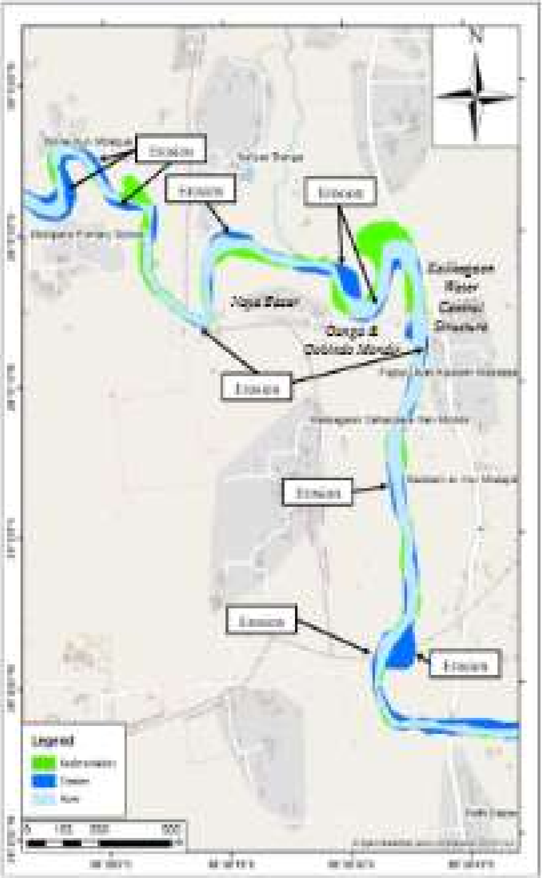

Figure 4.86: Erosion & Sedimentation trend in Parmaj River from Jagdapara Primary School to Rahi Bazar in Stage 2, Thakurgaon Sadar Upazila from 2018 to 2023

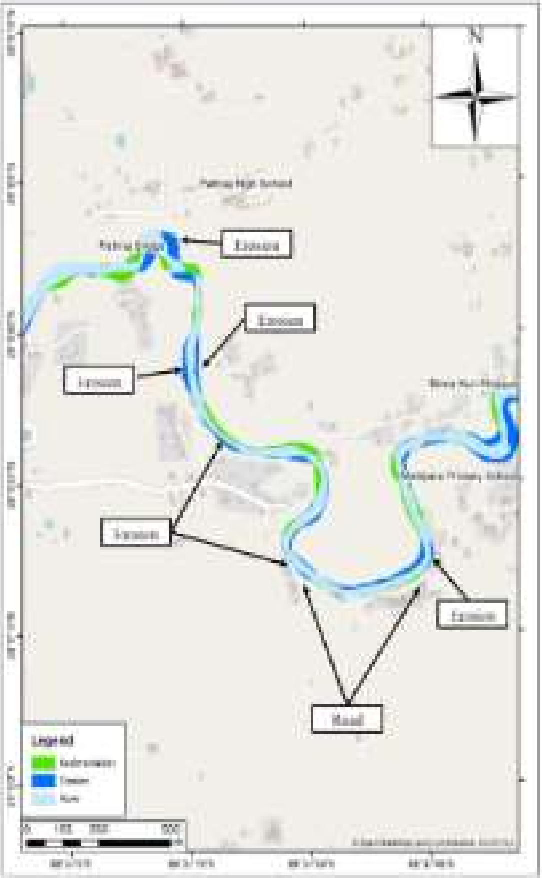

Figure 4.27: Erosion & Sedimentation trend in Pathraj River from Pathraj Bridge to Molipara Primary School in Thakurgaon Sadar Upazila from 2018 to 2022

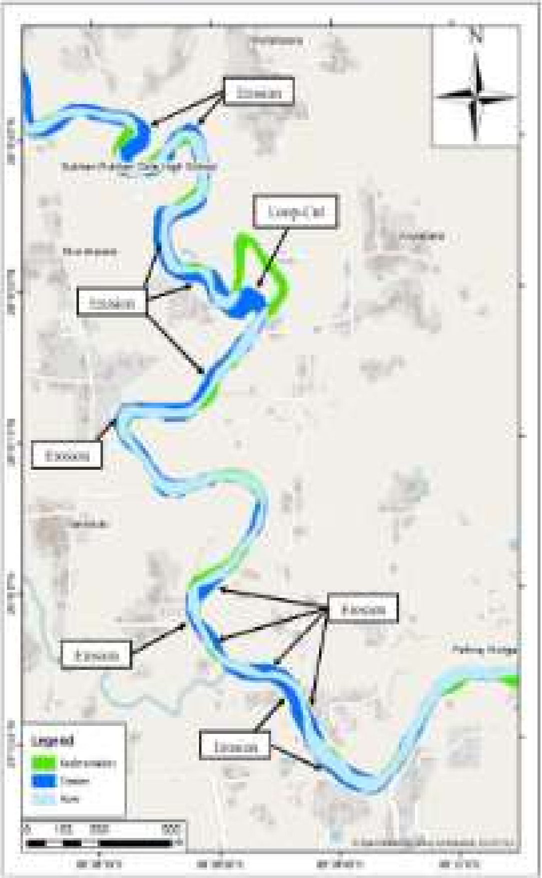

Figure 4.85: Erosion & Sedimentation trend in Pathraj River from Suman Rahman Girls High School to Pathraj Bridge in Thakurgaon Sadar Upazila from 2018 to 2023

Figure 4.99 shows the erosion & sedimentation trend of the Pathraj River from Kismatpara to Sukhan Pukhari Girls High School. Although erosion can be seen all through the river in this reach, most of the erosion occurs in the non-built-up areas. Hence this stretch from Kismatpara to Sukhan Pukhari might not need any bank protection measures.

Erosion & sedimentation trend of the Pathraj River from Fakuapara to Kismatpara is shown in **Figure 4.100**. Erosion can be seen on the right bank of the Pathraj River. Here around 230m stretch of the right bank of the river seems vulnerable to bank erosion. Downstream of Sobdol, another loopcut has formed during the last ten years, which shows dynamism of the Pathraj River in this reach as well. Erosion can also be seen on the right bank near the bridge between Sobdol and Fakuapara. Around 580m upstream of the bridge, erosion can be seen on the left bank. The erosion site here is very close to the road connecting Fakuapara to the bridge, hence this erosion zone might need some close observation. Around 1075m upstream of the bridge, another erosion zone has been identified via image analysis. About 200m stretch of right bank might require bank protection works in this reach of the river.

Figure 4.101 shows the erosion & sedimentation trend of the Pathraj River from Balapara to Fakuapara. Although erosion and sedimentation can be seen all along this reach of the Pathraj River, the erosion near Baitul Miraz Jame Masjid and around 470m upstream of Baitul Miraz Jame Masjid, erosion can be seen occurring close to the built-up areas. Around 230m of the right bank near the Baitul Miraz Jame Masjid and around 110m of the right bank about 870m upstream of the Masjid seems vulnerable from satellite image analysis.

Erosion & sedimentation trend of the Pathraj River from Paramanik Para Primary School to Balapara is shown in **Figure 4.102**. The bends near Sonnar Nagar seems vulnerable to erosion. Around 180m reach of left bank and 170m of left bank reach in two separate bends near Sonnar Nagar seems vulnerable to erosion based on satellite image analysis. Between Sonnar Nagar and Riazul Jannat Mosque near Dakshin Sathkhamar, erosion can be seen occurring near earthen roads. The Pathraj River flows very close to the earthen road for around 430m stretch of right bank in this region. Erosion can be seen at the Riazul Jannat Mosque and Dakshin Sathkhamar as well. Among them near Riazul Jannat Mosque around 200m stretch of right bank of the Pathraj River might need bank protection works considering the proximity of the bank erosion sites to the built-up areas. Further upstream, the bend near the Pramanik Paraom Primary School seems vulnerable to bank erosion. Based on satellite image analysis, around 300m stretch of right bank of Pathraj River in this reach seems vulnerable to bank erosion.

Figure 4.103 shows the erosion & sedimentation trend of the Pathraj River from Boda New Bridge to Pramanik Para Primary School. The southern part of the Boda Town can be seen in this reach. On the southern tip, near Moghalakalia, erosion can be seen from the figure. Around 230m of the left bank of the Pathraj River seems vulnerable to bank erosion near Moghalakalia. Erosion can also be seen on the right bank of Moghalakalia. Around 180m right bank stretch seems vulnerable to bank erosion on the west bank of Moghalakalia. Between Boda Women College and Moghalakalia another 60m stretch of left bank seems vulnerable to bank erosion. Some bank erosion can also be seen on the right bank of Pathraj River near the Boda Thana. Around 120m stretch of right bank seems vulnerable to bank erosion here.

Erosion & sedimentation trend of the Pathraj River near the main Boda Town has been shown in **Figure 4.104**. Near Sathkhamar around 550m stretch of the right bank of Pathraj River, starting from 500m upstream of the New Boda Bridge appears vulnerable. Erosion can also be left bank in two separate reaches, with a combined length of around 230m seems vulnerable based on satellite image analysis.

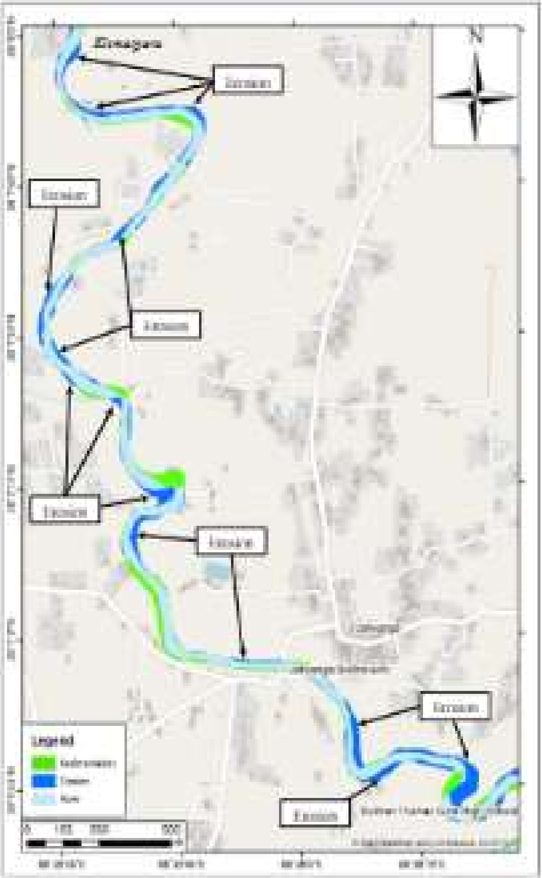

Figure 4.86: Erosion & Sedimentation trend in Pathraj River from Kismatpara to Sukhan Pukhari Girl's High School in Thakurgaon Sadar Upazila from 2018 to 2023

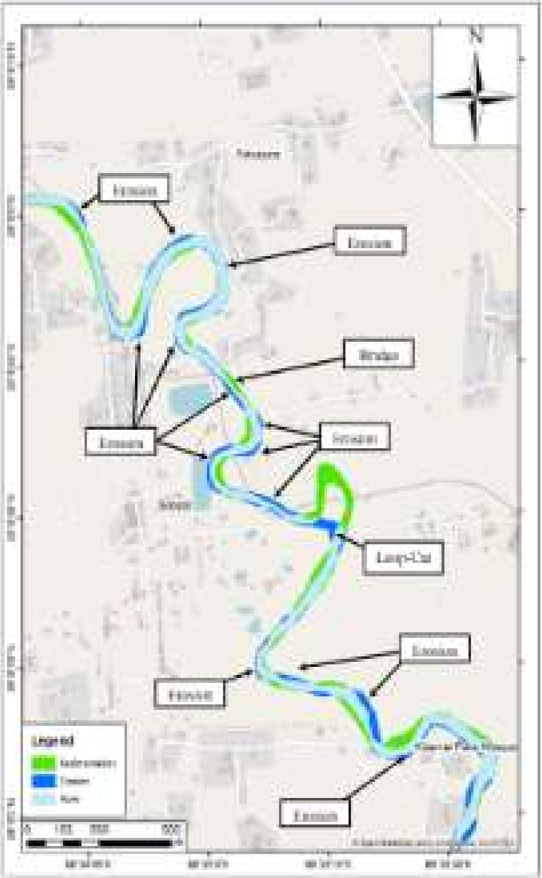

Figure 4.[illegible] Erosion & Sedimentation trend in [illegible] River from [illegible] to [illegible] in Thakurgaon Sadar & [illegible] Upazila from 2015 to 2023

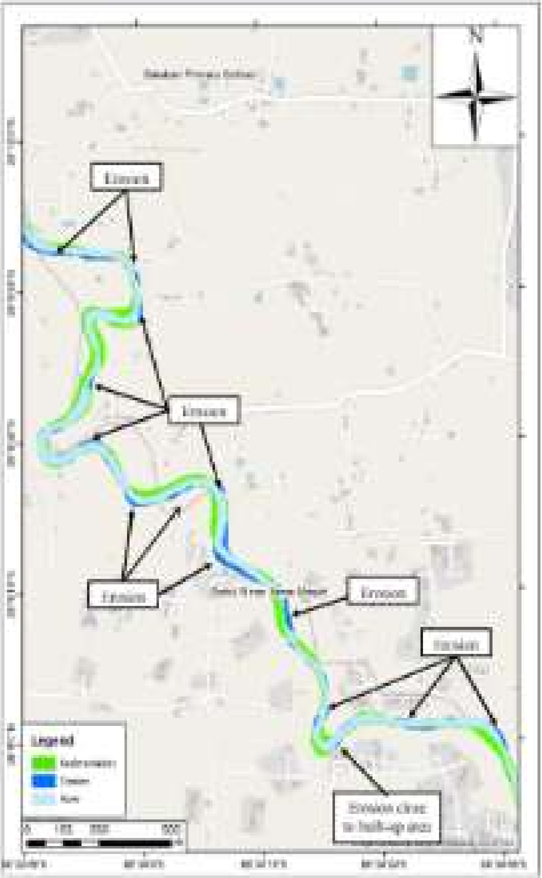

Figure 4.[illegible]: Erosion & Sedimentation trend in Pathraj River from Balaban to Akcahpara in Thakurgaon Sadar & Boda Upazila from 2016 to 2023

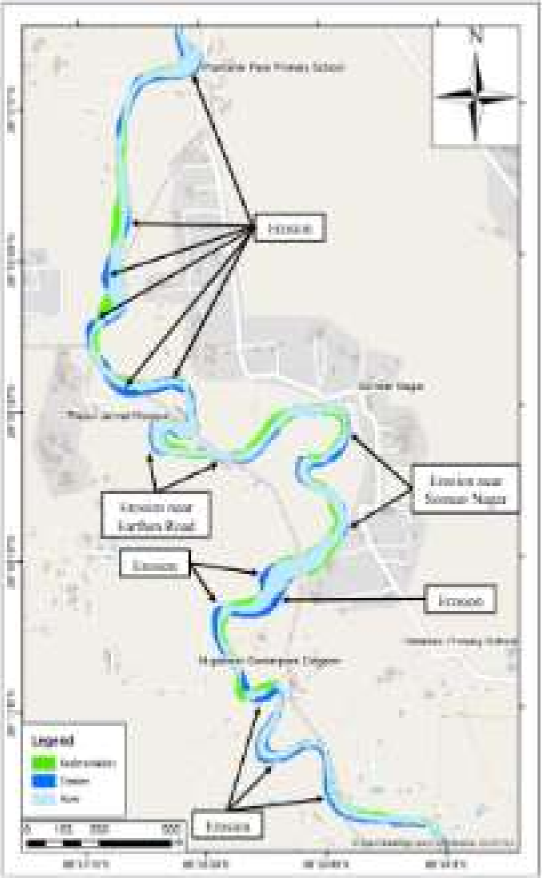
N
Pramanik Para Primary School
Erosion
Erosion near Sonnar Nagar
Erosion near Earthen Road
Erosion
Erosion
Erosion
Legend
Sedimentation
Erosion
River
0 125 250 500

Figure 4.302: Erosion & Sedimentation trend in Palnaj River from Pramanik Para Primary School to Balatari in Thakurgaon Sadar & Baliadangi Upazila from 2018 to 2022

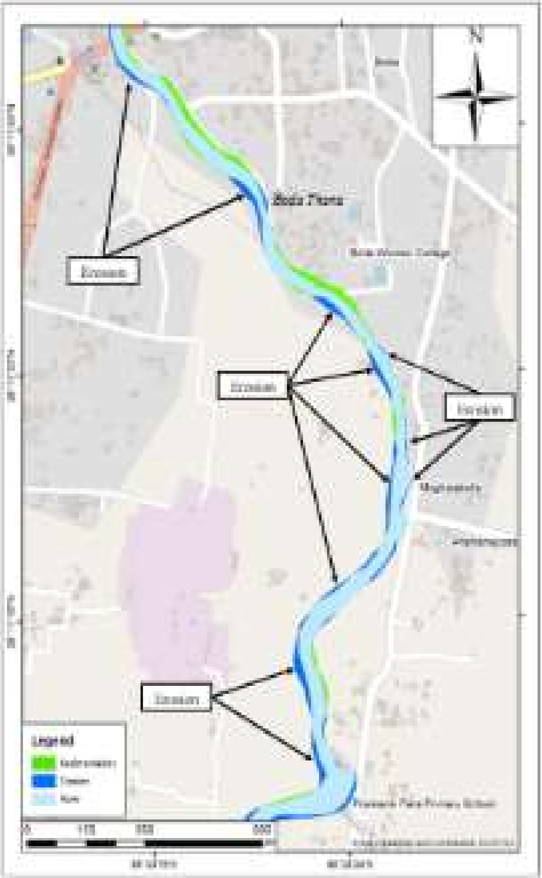

Figure 4.103: Erosion & Sedimentation trend in Pathraj River from Boda New Bridge to Paramanik Para Primary School in Boda Upazila from 2018 to 2022

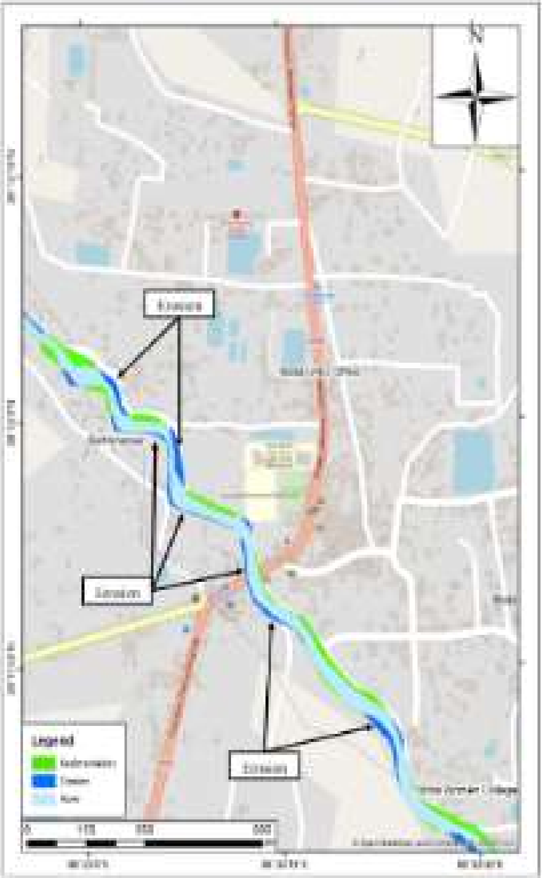

Figure 4.104: Erosion & Sedimentation trend in Pathraj River from Sakhamar to Boda Women College in Boda Upazila from 2016 to 2022

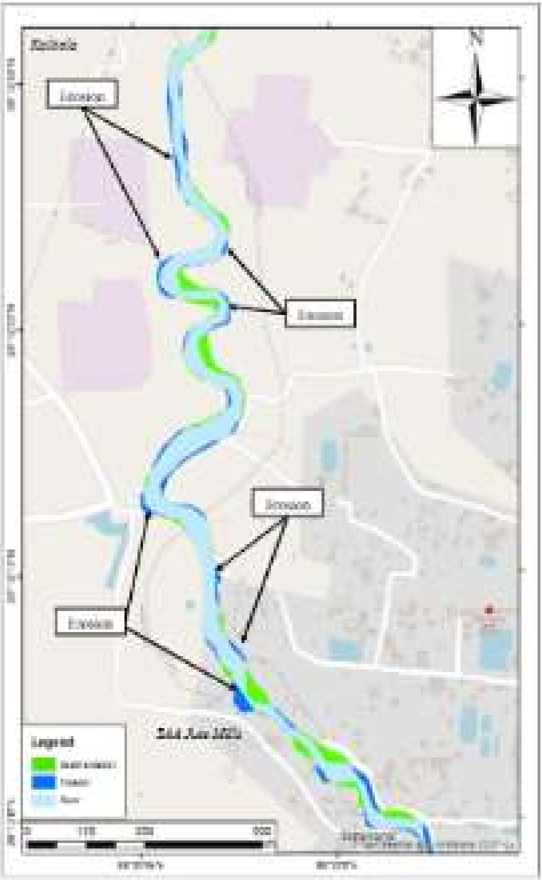

Figure 4.105: Erosion & Sedimentation trend in Pathraj River from Kalibia to Sibnamar in Boda Upazila from 2019 to 2023

Figure 4.105 shows the erosion & sedimentation trend of the Pathraj from Kalibia to Sibnamar. This figure shows the northeastern part of the Boda town up to the source of

Pathraj River. Erosion can be seen near the SAA Jute Mills on the south bank of the Pathraj River. 100m stretch of right bank here appears vulnerable based on satellite image analysis. Erosion can also be seen on couple of spots near the western Boda Town. The cumulative length of bank erosion on the left bank of Pathraj River near the Boda town edges in those two marked locations is 180m. Erosion can also be seen further upstream however these erosion spots are away from the built-up areas.

Pathraj River flows through three Upazila of Panchagarh district and the Thakurgaon Sadar Upazila. The erosion & deposition trend of all the four Upazilas have been shown in **Figure 4.106** to **Figure 4.109**. Temporal Erosion Sedimentation of the Pathraj River in Boda Upazila has been shown in **Figure 4.106**. It can be seen that the erosion for a 3-year period is around 3 Hectors, while the sedimentation is around 4 hectors. Boda Upazila is located in the most upstream reach of the Pathraj River and it can be seen that erosion/deposition trend is almost similar in the last eight years.

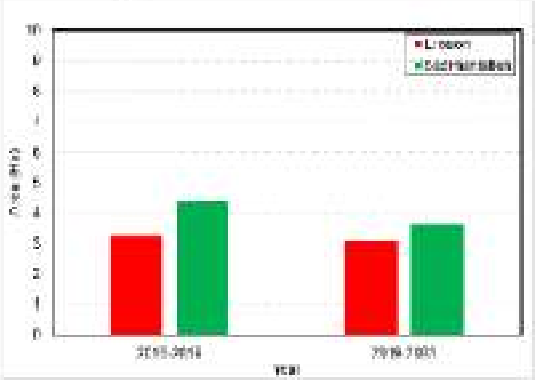

Figure 4.106: Temporal Erosion and Sedimentation of Pathraj River at Boda Upazila

Figure 4.107 shows the temporal erosion and sedimentation of the Atwari Upazila. The amount of erosion and sedimentation is slightly higher in the Atwari Upazila compared to the Boda Upazila. Around 7 hectors of lands have eroded away between 2016 to 2019 and 2019 to 2023. While Atwari Upazila has seen around 6.5 hectors of area eroded between 2016 to 2019 and 2019 to 2023. The temporal erosion and sedimentation of Pathraj River in the Thakurgaon Sadar Upazila has been shown in **Figure 4.108**, which shows a lot more erosion deposition compared to the other two Upazilas. In Thakurgaon Sadar Upazila, around 23.36 Hectors of area was eroded away between 2016 to 2019. The rate of erosion has decreased a bit between 2019 to 2023 as around 18 hectors of land has been eroded away between this time frame. More sedimentation has occurred between 2019 to 2023 in Thakurgaon Sadar Upazila compared to 2016 to 2019. And the temporal erosion and sedimentation of Pathraj River in the Debiganj Upazila, which is the downstream portion of the river, has been shown in **Figure 4.109**. The erosion rate is slightly lower in Debiganj Upazila, compared to Thakurgaon Sadar Upazila but higher than that of the further upstream reaches of the Pathraj River. Slightly more erosion has been observed in the Debiganj Upazila in the recent years (2019 to 2023) comparing to the past years (2016 to 2019).

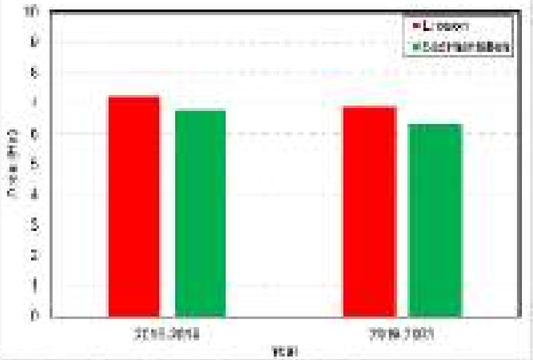

Figure 4.097: Temporal Erosion and Sedimentation of Pathraj River at Atwari Upazila

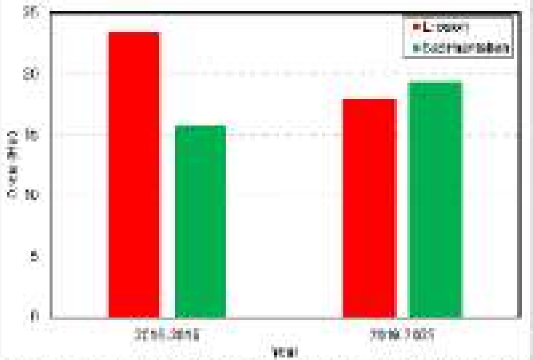

Figure 4.098: Temporal Erosion and Sedimentation of Pathraj River at Thakurgaon Sadar Upazila

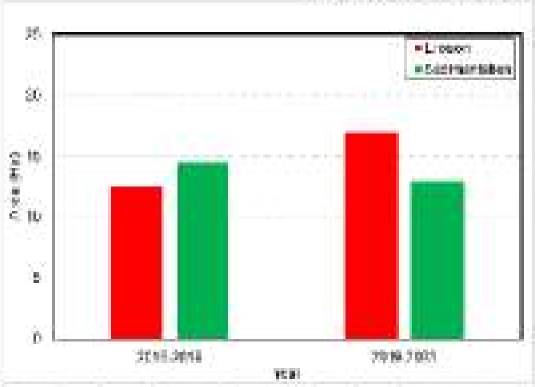

Figure 4.109: Temporal Erosion and Sedimentation of Pathraj River at Debiganj Upazila

A table showing the tentative length of BPW required for the Pathraj river based on the satellite image analysis has been shown in **Table 4.13**. From the table it can be seen that a total of 10170 m of BPW might be required for the Pathraj river, out of which around 7580m is in the Panchagarh district, while 2590m is in the Thakurgaon district.

Ghoramara River

Ghoramara River forms in Panchagarh at the junction of the Kurum and Panga Rivers, then merges with the Karatoa River near Aulaghat. A detailed planform analysis was carried out for this river and the figures are shown from **Figure 4.110** to **Figure 4.112**.

The erosion & sedimentation trend of the Ghoramara River from Chopramara to Aulaghat, outfall at the Karatoa River has been shown in **Figure 4.110**. Erosion and deposition are observed throughout the reach of the river. However, the erosion on the right bank of the Ghoramara River from Bordeshwari to the outfall of the river takes place near built-up areas. River erosion has also taken place very close to a road. Considering the infrastructures located here, around 1050m of BPW might be required in this region.

Figure 4.111 shows the erosion & sedimentation trend of the Ghoramara River from Nazuri Nassabganj Mazar to Chopramara. Erosion is observed near the Maikadanga bridge on both banks of the river. On the right bank, upstream of the Maikadanga bridge towards the Maikadanga BGB camp, the entire 700m reach up to the confluence of Sui and Ghoramara River, appears vulnerable to bank erosion based on satellite image analysis. Starting from 100m downstream of the Maikadanga bridge, all through up to the confluence of the Sui River, this 800m stretch of right bank of the Ghoramara River needs to be put under protection works considering the existence of BGB camp and patrol road of the BGB. Although BWDB has taken up some temporary protection works by dumping geo-bags in this region, permanent BPW might be needed based on the importance of the location. And to address the erosion on the left bank of the Maikadanga bridge, around 300m BPW might be needed. Another erosion spot that needs to be considered in this reach of Ghoramara River is near Nazuri. Around 750m reach of right bank of Ghoramara River appears vulnerable due to bank erosion in this reach of the river.

Table 8.73 Location and length of vulnerable locations of Pathraj River

River	Location	Upazila	Bank	Vulnerable bank length (m)
Pathraj	[illegible]	Debiganj	Right	400
	[illegible] Primary School		Right	325
			Left	[illegible]
	[illegible]		Right	200
	[illegible]		Left	300
	Fulbari High School		Right	[illegible]
	[illegible]		Left	300
	Fulbari Bridge		Left	400
	Fulbari Primary School		Right	325
	[illegible] Mosque		Right	400
	[illegible] Jame Masjid		Right	400
	[illegible]		Right	[illegible]
	[illegible]	Thakurgaon Sadar	Left	[illegible]
	Naya Bazar		Right	775
	[illegible] Mosque		Right	[illegible]
	[illegible] Primary School		Right	225
	500m u/s of Pathraj Bridge		Right	400
	500m d/s of Pathraj Bridge		Left	[illegible]
	[illegible]		Right	100
	[illegible]		Right	200
	[illegible] Girls High School		Right	200
	[illegible] Mosque		Right	225
	[illegible]		Right	300
	[illegible]	Boda	Left	250
	[illegible] Jame Masjid		Right	775
	[illegible] Jame Masjid		Right	250
	[illegible]		Left	300
			Left	175
	[illegible]		Right	450
	[illegible] Mosque		Right	200
	[illegible] Primary School		Left	300
	[illegible]		Left	250
			Right	150
	Boda Women College		Left	80
	Boda Thana		Left	725
	[illegible]		Right	[illegible]
	Near Boda Upazila Parishad		Left	225
	[illegible] Jute Mills		Right	100
	[illegible] part of Boda Town		Left	[illegible]
Total Length in Panchagarh District				[illegible]
Total Length in Thakurgaon District				[illegible]
Total				[illegible]

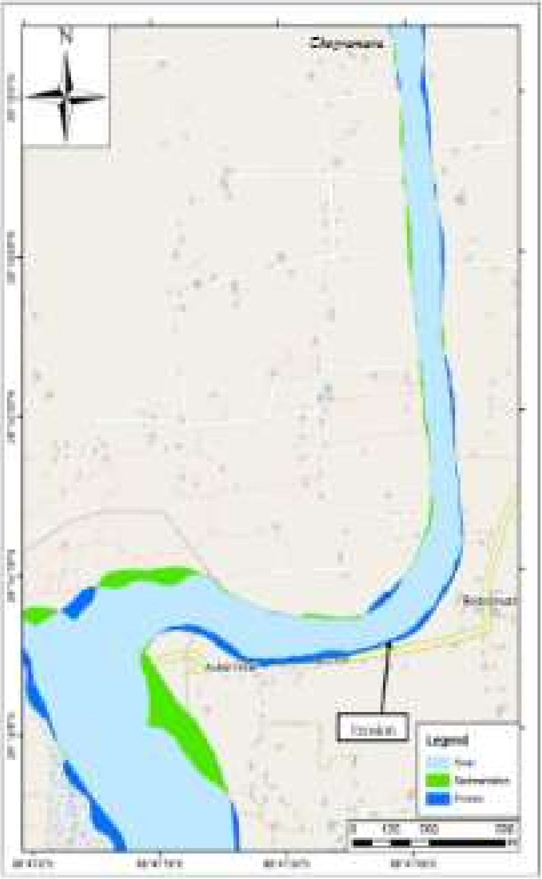

Figure 4.116: Erosion & Sedimentation trend in Shonamati River from Chapramari to Auliar Ghat in Boda Upazila from 2016 to 2020

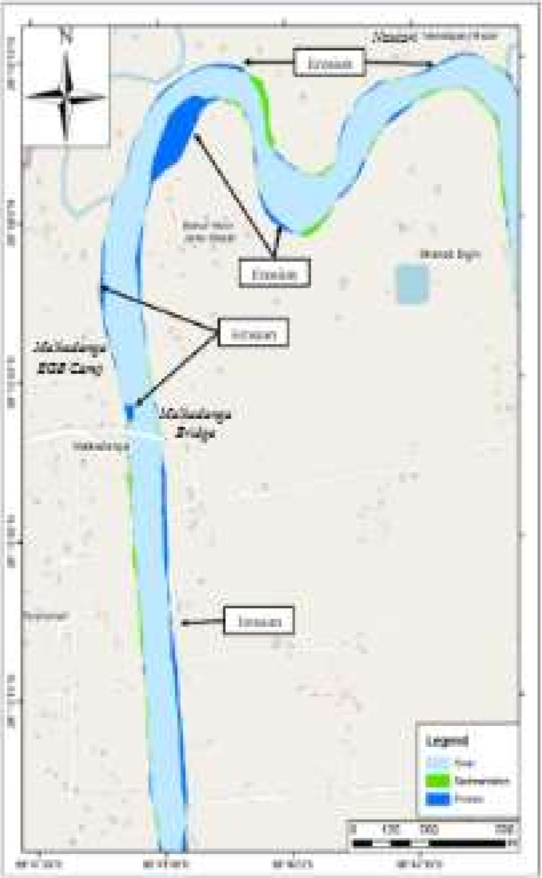

Figure 4.315: Erosion & Sedimentation trend in Bhullamara River from Hazari Newabgonj Mazar to Chapramana in Boda Upazila from 2018 to 2023

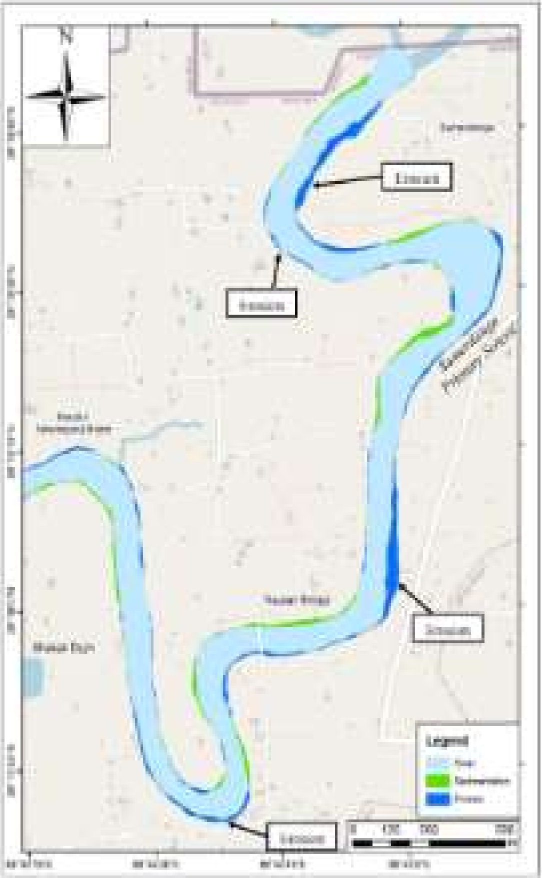

Figure 4.112: Erosion & Sedimentation trend in Ghoramara River from Samantanga to Nautan Nowabganj Mazar in Boda Upazila from 2018 to 2022

The erosion & sedimentation trend of the Ghoramara River from Samantanga to Nautan Nowabganj Mazar has been shown in **Figure 4.112**. Erosion can be seen near the Boghdhula

Bazar for a stretch of 580m on the left bank of Ghoramara River. Considering the presence of Bogdubhula Bazar around 375m stretch of left bank might need BPW based on satellite image analysis. Erosion can also be seen on the left bank (south bank) of the Naudari bridge. All along the left bank from the Naudari bridge towards upstream of the Ghoramara River appears vulnerable to bank erosion. Some residential infrastructures can be seen on the left bank around 500 m upstream of the Naudari bridge. Around 300m of BPW might be required in this stretch of Ghoramara River. And built-up areas are also present near the Samontanga primary school. Around 550m of BPW near Samontanga Primary School might be required based on satellite image analysis.

Figure 4.113 shows the temporal erosion and sedimentation of the Ghoramara River. From the figure it is evident that more lands are being eroded away in Ghoramara River than it is being sedimented. The amount of erosion dropped a bit between 2016 to 2019 compared to that between 2012 to 2016. However, the erosion has increased substantially during the last four years. Both erosion & sedimentation process temporally followed same trend of dropping during 2016 to 2019 and increasing nature during 2019 to 2023.

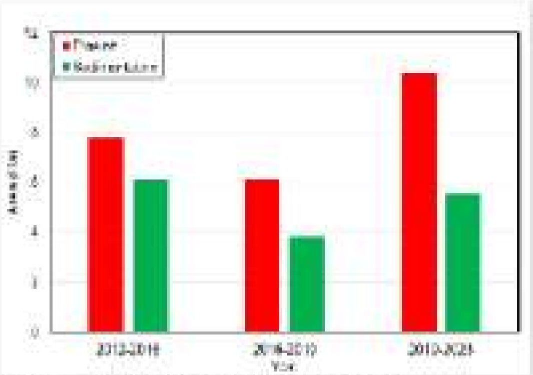

Figure 4.113: Temporal Erosion and Sedimentation of Ghoramara River

The table showing the vulnerable locations of the Ghoramara river and the required length of BPWs based on satellite image analysis has been presented in **Table 4.14**. The total length of BPWs required in Ghoramara river is around 2850m based on satellite image analysis.

Table 4.14: Location and length of vulnerable locations of Ghoramara River

River	Location	Upazila	Bank	Vulnerable Bank length (m)
Ghoramara	Sootarpara	Boda	Left	1000
	Maltadanga Bazar		Right	800
	Maltadanga Bridge		Left	300
	Naudari		Right	750
Total Length				2850

Tangon River:

Tangon River is one of the important rivers of Thakurgaon District. Though this river originates from the Panchagarh, maximum portion of the river passes through Thakurgaon District. The river is very dynamic during monsoon due to its heavy slope. From satellite image analysis bankline shifting, bank erosion can be seen throughout the Tangon River. Erosion can be seen on almost all the outer bend of the Tangon River in this stretch of the river. Bank Protection works at different vulnerable locations of Tangon River have been proposed by IWM study team considering the accumulative analysis of Satellite image, Model simulation, public demand and field investigation. The erosion & sedimentation trend for ten years from 2013 to 2023 has been shown in **Figure 4.114** to **Figure 4.135**.

Chopati Gorgoria Soshan Ghat

To the spiritual point of view this location is very important. From satellite image analysis, erosion has been found near soshan ghat. About 5 to 10m erosion is found near soshan ghat. The Erosion & Sedimentation trend at Chopati Gorgoria Soshan Ghat of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.114**.

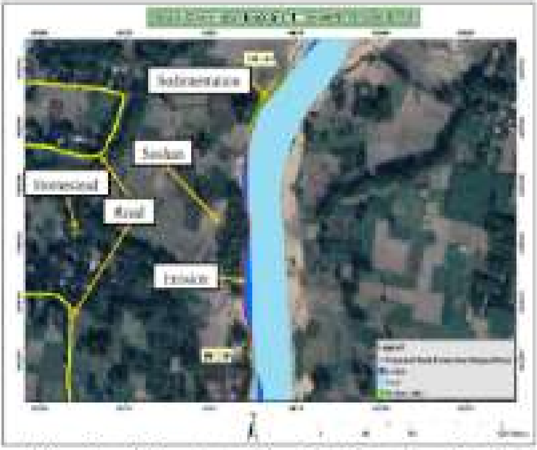

Figure 4.114: Erosion & Sedimentation trend in Tangon River at Chopati Gorgoria Soshan Ghat of Thakurgaon Sadar Upazila from 2013 to 2023

Ashannagar

From satellite image analysis, both erosion and sedimentation has been found near Ashannagar. This area is very important due to having primary school, market and roads. The Erosion & Sedimentation trend at Ashannagar of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.115**.

Khorabari Hotel Para

From satellite image analysis, severe bank erosion has been found near Khorabari Hotel Para. The Erosion & Sedimentation trend at Khorabari Hotel Para of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.116**.

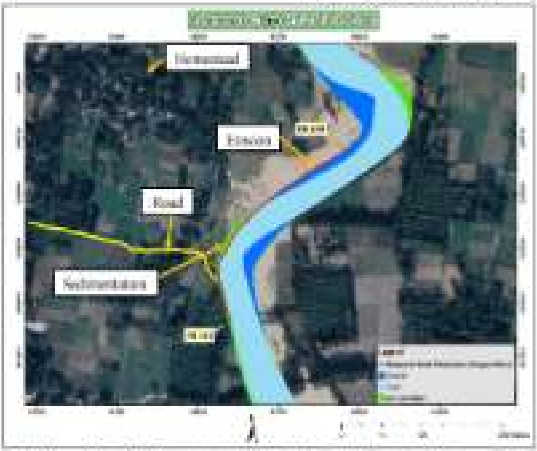

Figure 4.115: Erosion & Sedimentation trend in Tangon River at Akhanagar of Thakurgaon Sadar Upazila from 2013 to 2023

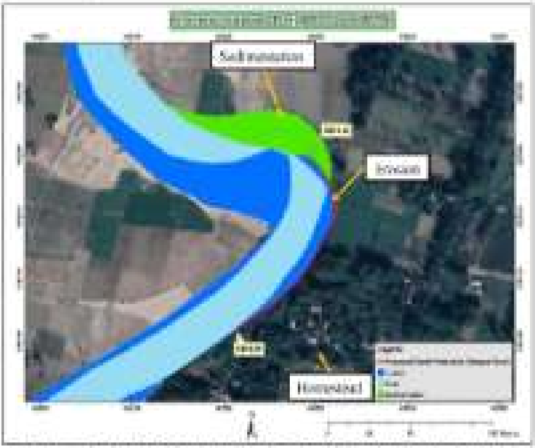

Figure 4.116: Erosion & Sedimentation trend in Tangon River at Khochabari Abadpara of Thakurgaon Sadar Upazila from 2013 to 2023

Khorbari Choukidar Para

From satellite image analysis, bank erosion is very severe at the right bank compared to the Left bank near Khorbari Choukidar Para. The Erosion & Sedimentation trend at Khorbari Choukidar Para of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.117.**

Dhormopur Sonnasi Para

From satellite image analysis, bank erosion is very severe at the left bank compared to the right bank near Dhormopur Sonnasi Para. There is an important local road near the proposed Bank Protection Work. The Erosion & Sedimentation trend at Dhormopur Sonnasi Para of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.118**.

Dhormopur Gucchogram

From satellite image analysis, severe bank erosion has been found near Dhormopur Gucchogram which results in loop cut at the left bank. The river is very dynamic in this area. There is a cluster village at the left bank named Dhormopur 1-2 Guccho Gram. The Erosion & Sedimentation trend at Dhormopur Gucchogram of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.119.**

Bodhasoot 1

From satellite image analysis, bank has been shifted to the right bank near Upper region of Bodhasoot. The Erosion & Sedimentation trend at Upper region of Bodhasoot of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.120**.

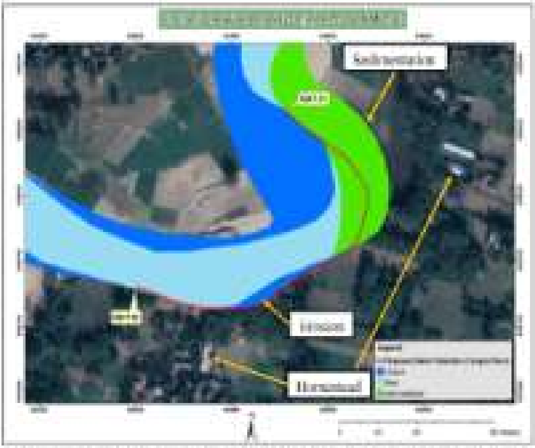

Figure 4.117: Erosion & Sedimentation trend in Tangon River at Khorbari Choukidar Para of Thakurgaon Sadar Upazila from 2013 to 2023

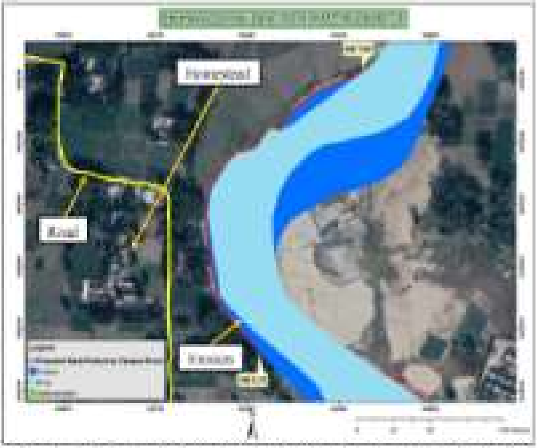

Figure 4.118: Erosion & Sedimentation trend in Tangon River at Dhomopur Sonkar Para of Thakurgaon Sadar Upazila from 2013 to 2023

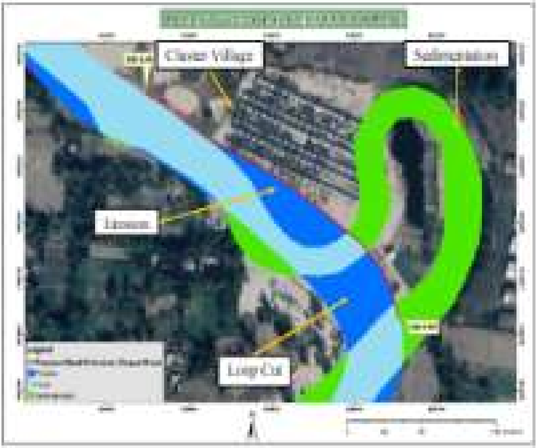

Figure 4.119: Erosion & Sedimentation trend in Tangon River at Dhamnagar Quaziagram of Thakurgaon Sadar Upazila from 2013 to 2023

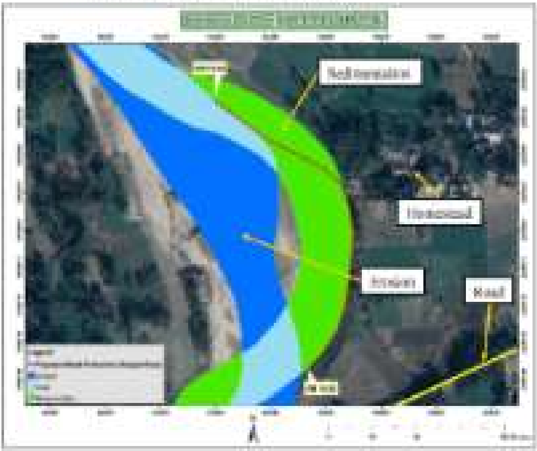

Figure 4.120: Erosion & Sedimentation trend in Tangon River at Bodhasoori (Up) of Thakurgaon Sadar Upazila from 2013 to 2023

Bodhasoori 2

From satellite image analysis, moderate bank erosion is found at both the banks near lower portion of Bodhasoori. There is a bridge named Bodhasoori Bridge which connects LGED road. The Erosion & Sedimentation trend at Upper region of Bodhasoori of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.121**.

Farabari Kalimondir

This location is needed to be protected due to its spiritual point of view. From satellite image analysis, mild erosion has been found near Kalimondir which is situated at the left bank. The Erosion & Sedimentation trend at Farabari Kalimondir of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.122**.

Dokkhin Bolina

From satellite image analysis, bank erosion is found at the right bank compared to the left bank near Dokkhin Bolina. There is a cluster village, an important local road and a Shashan Ghat at the right bank. The Erosion & Sedimentation trend at Dokkhin Bolina of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.123**.

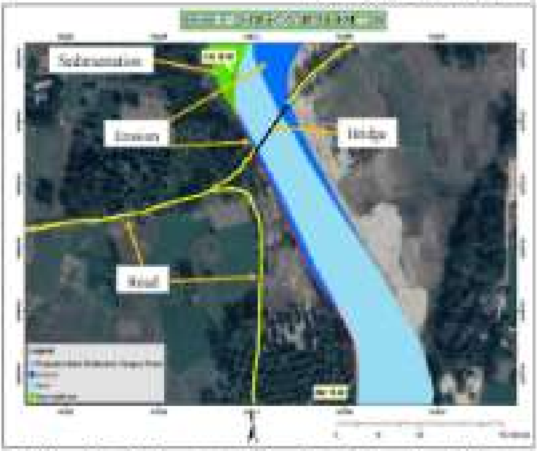

Figure 4.520: Erosion & Sedimentation trend in Tangon River at Bodhasasid (Mouza) of Thakurgaon Sadar Upazila from 2013 to 2023

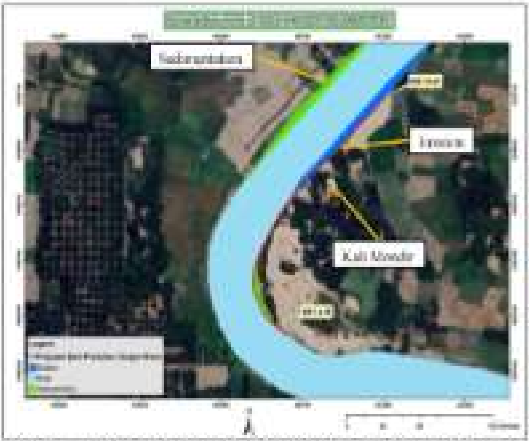

Figure 4.522: Erosion & Sedimentation trend in Tangon River at Sonapari Kalimondir of Thakurgaon Sadar Upazila from 2013 to 2023

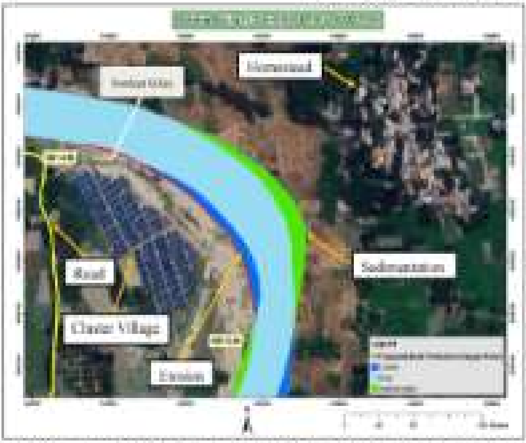

Figure 4.123: Erosion & Sedimentation trend in Tangon River at [illegible] of Thakurgaon Sadar Upazila from 2013 to 2023

Bagpur

From satellite image analysis, bank erosion is found at the left bank compared to the right bank near Bagpur. There is an important local road and a temple named Ganga Mandir at the left bank. The Erosion & Sedimentation trend at Bagpur of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.124**.

Akcha

From satellite image analysis, bank erosion is not much prominent on both banks near Akcha. There is an important upazila road, market, Mosque and homestead at the right bank. The Erosion & Sedimentation trend at Akcha of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.125**.

Hazi Camp

From satellite image analysis, no bank erosion is found at both banks near Hazi Camp. The left Bank of the area is already protected by Bank Protection Works. A Hazi Camp is situated at the right bank. Due to having BPW at the left bank, the right bank has the possibility to erode in the future. The Erosion & Sedimentation trend at Hazi Camp of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.126**.

Shahpara

From satellite image analysis, minor bank erosion is found at the left bank compared to the right bank near Shahpara. The left bank of this area is built-up area and lots of settlements, roads are situated there. The Erosion & Sedimentation trend at Shahpara of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.127**.

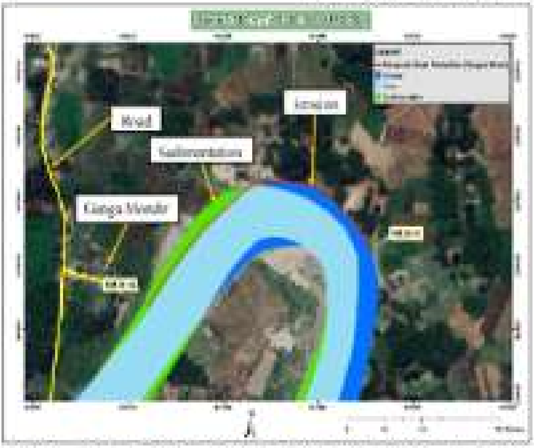

Figure 4.124: Erosion & Sedimentation trend in Tangon River at Begpur of Thakurgaon Sadar Upazila from 2012 to 2022

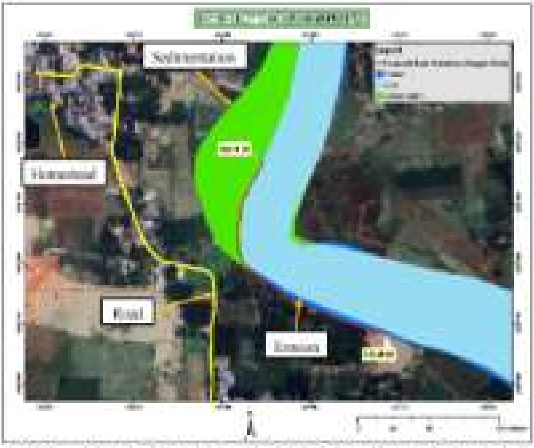

Figure 4.125: Erosion & Sedimentation trend in Tangon River at Akcha of Thakurgaon Sadar Upazila from 2012 to 2022

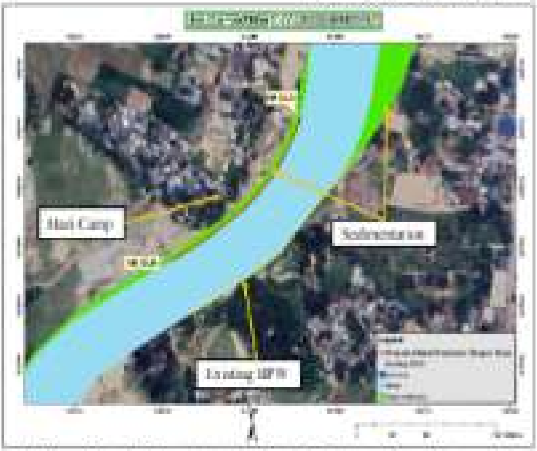

Figure 4.236: Erosion & Sedimentation trend in Tangon River at Hazi Camp of Thakurgaon Sadar Upazila from 2013 to 2023

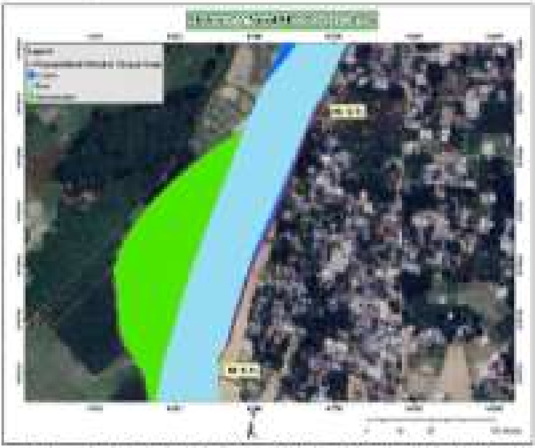

Figure 4.237: Erosion & Sedimentation trend in Tangon River at Shanpara of Thakurgaon Sadar Upazila from 2013 to 2023

Mahegaon:

From satellite image analysis, bank erosion is found at the right bank compared to the left bank near Shahpara. Both left and right bank of this area is non-built-up but there is a connecting road which is partially damaged due to heavy erosion at the right bank. The Erosion & Sedimentation trend at Mahegaon of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.155**.

Kosalondor:

From satellite image analysis, severe bank erosion is found at the right bank compared to the left bank near Kosalondor. Though the erosion at right bank is prominent but this area is non-built-up whereas the left bank is built-up. The Erosion & Sedimentation trend at Kosalondor of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.156**.

Mochobondopur Mochadangi Bridge:

From satellite image analysis, severe bank erosion is found at the right bank near Mochadangi Primary School. The erosion prone area is situated down to the Mochadangi Bridge. There exists an important connecting road near the erosion prone area. The Erosion & Sedimentation trend at Mochadangi of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.157**.

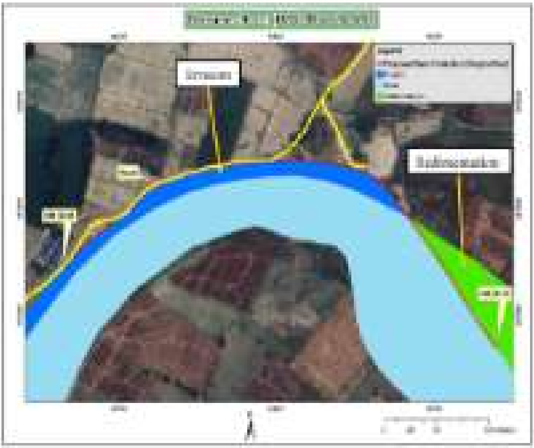

Figure 4.155: Erosion & Sedimentation trend in Tangon River at Mahegaon of Thakurgaon Sadar Upazila from 2013 to 2023

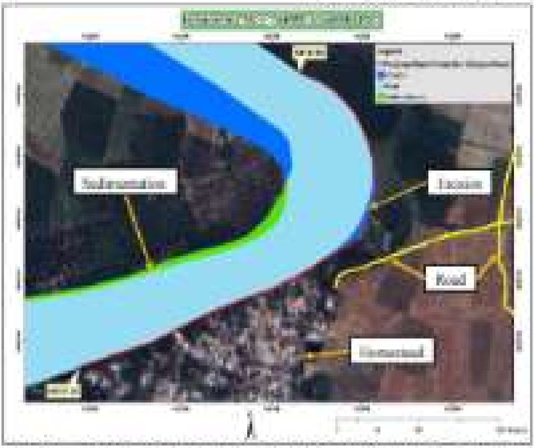

Figure 4-135: Erosion & Sedimentation trend in Tangon River at [illegible] of Pirganj Upazila from 2013 to 2022

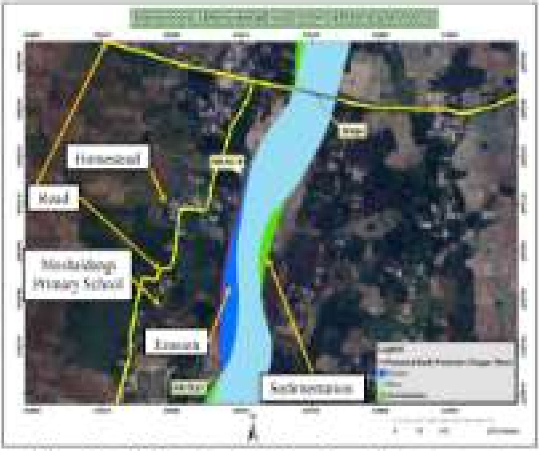

Figure 4-136: Erosion & Sedimentation trend in Tangon River at [illegible] moshaldangi bridge of Pirganj Upazila from 2013 to 2022

Bonsapara

From satellite image analysis, bank erosion is found at both the left and right bank near Bonsapara. There exists a sanctuary named Kodomtola Fisheries Sanctuary at the Right Bank. Moreover, the right bank is built up area having Settlements and connecting roads. The Erosion & Sedimentation trend at Bonsapara of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.131**.

Chattoshoddotpur Noapara

From satellite image analysis, severe bank erosion is found at the left bank compared to the right bank near Noapara. Though the erosion at left bank is prominent but the area is non-built-up whereas the right bank is built-up having Settlements, connecting roads and a khal. The Erosion & Sedimentation trend at Noapara of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.132**.

Kumarpara Soshanghat

To the spiritual point of view this location is very important. From satellite image analysis, erosion has been found near soshan ghat which is situated at the right bank. No bank erosion is found at the left Bank. The Erosion & Sedimentation trend at Kumarpara Soshan Ghat of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.133**.

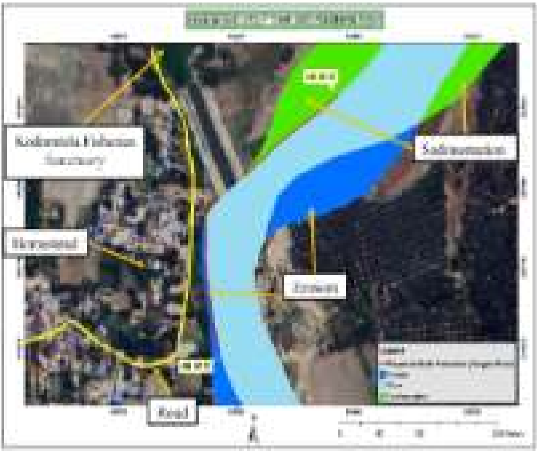

Figure 4.131: Erosion & Sedimentation trend in Tangon River at Bonsapara of Pirganj Upazila from 2013 to 2023

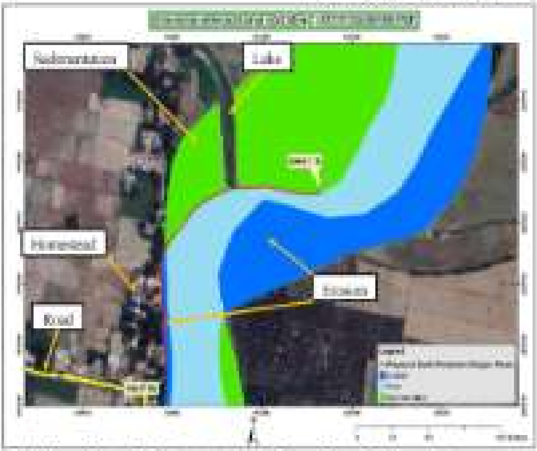

Figure 4.332: Erosion & Sedimentation trend in Tangon River at [illegible] mouza of Pirganj Upazila from 2013 to 2023

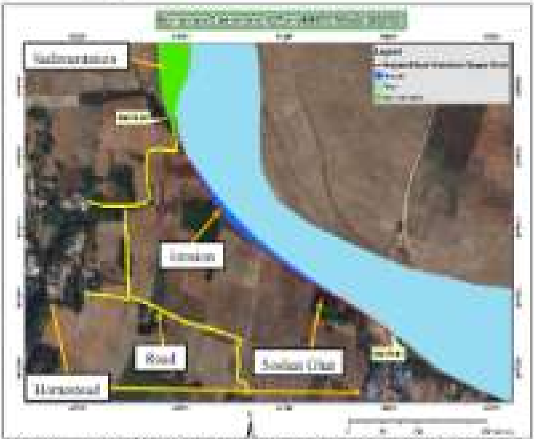

Figure 4.333: Erosion & Sedimentation trend in Tangon River at [illegible] of Pirganj Upazila from 2013 to 2023

Azizabad

From satellite image analysis, bank erosion is found at the right bank near Azizabad. The erosion at right bank is prominent and this area is built-up. There exists an important connecting road near this erosion prone area. The Erosion & Sedimentation trend at Azizabad of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.134**.

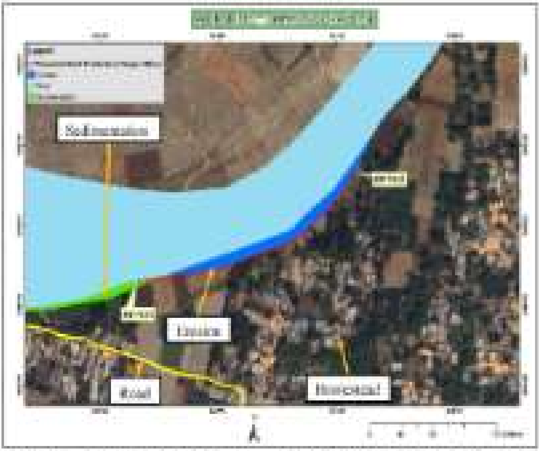

Figure 4.134: Erosion & Sedimentation trend in Tangon River at Azizabad of Pirganj Upazila from 2013 to 2023

Sirol Dangapara

From satellite image analysis, bank erosion is found at the right bank near Sirol Dangapara. The erosion at right bank is prominent and this area is built-up. There exists an important connecting road, a Govt. Primary School and Settlements near this erosion prone area. The Erosion & Sedimentation trend at Sirol Dangapara of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.135**.

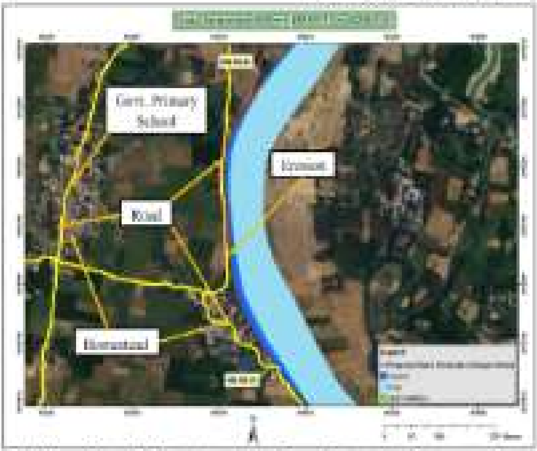

Figure 4.135: Erosion & Sedimentation trend in Tangon River at Shah Dangapara of Pirganj Upazila from 2013 to 2023

Kulik River:

Kulik River originates from the lowlands in Duhosu Union, Baliadangi Upazila, Thakurgaon District, flows south-westward and enters India in Haripur Upazila, Thakurgaon district. During monsoon, flooding can be seen in various locations of the river along with some bank erosions. Satellite image analysis shows bankline shifting and bank erosion can be seen along the Kulik River. Bank Protection works have been proposed at different vulnerable locations of Kulik River considering the accumulative analysis of Satellite image, Model simulation, public demand and field investigation. Planform analysis was carried out for ten years from 2013 to 2023 has been shown in **Figure 4.136** to **Figure 4.141** of this river.

Shoshan Kalimondir:

To the spiritual point of view this location is very important. A Soshan ghat is situated at the right bank. From satellite image analysis, erosion has been found at the left bank whereas sedimentation is found at the right bank. The Erosion & Sedimentation trend at Soshan Kalimondir of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.51**.

Khochabari Eidgaon Field

Erosion & sedimentation trend of the Kulik River near Abad Takiya Eidgaon has been shown in **Figure 4.137**. This area is very important to the people of Muslim religion. Erosion has been found at the left bank based on satellite image analysis. The Eidgaon field is on threatened situation due to bank erosion which is situated at the left bank. The erosion rate is slightly lower at the upper side of Eidgaon but very severe at the lower portion. Sedimentation is found at the right bank in which area is non-built up.

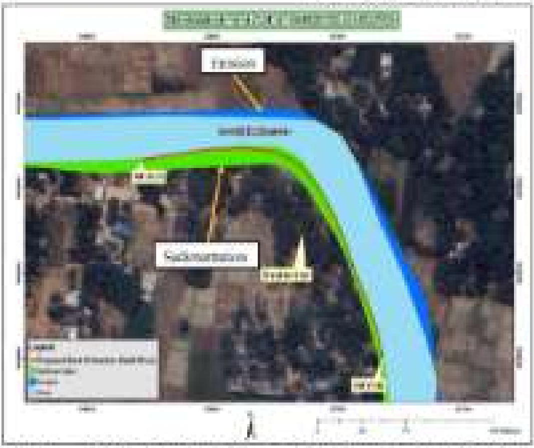

Figure 4.136: Erosion & Sedimentation trend in *Kulik River* at Shaheb Kalimandir of Ranisankail Upazila from 2013 to 2023

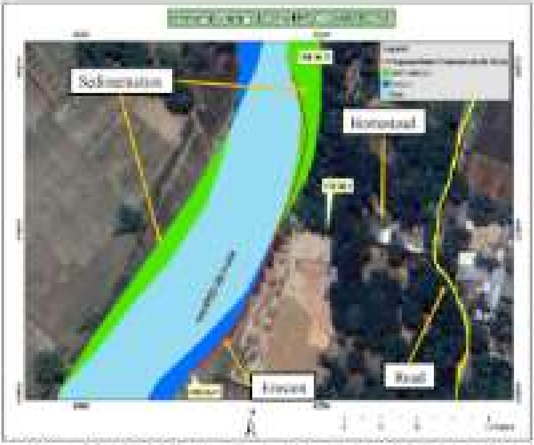

Figure 4.137: Erosion & Sedimentation trend in *Kulik River* at Khanjana Bidgaon Para of Ranisankail Upazila from 2013 to 2023

Omorkadangi

From satellite image analysis, severe bank erosion has been found near Omorkadangi which results in 20-30m bank erosion at the left bank. There is a brick field very close to the left bank which is vulnerable to bank erosion. The Erosion & Sedimentation trend at Omorkadangi of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.138**.

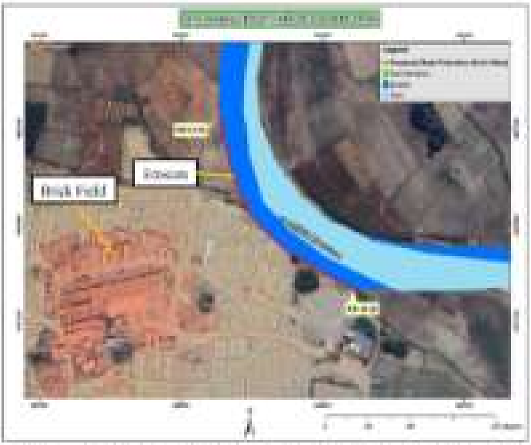

Figure 4.138: Erosion & Sedimentation trend in Kulik River from Omorkadangi of Ranisankail Upazila from 2013 to 2023

Manipur

From satellite image analysis, severe bank erosion is found at the right bank compared to the left bank near Manipur. There is an important road passing near the erosion prone bank. The Erosion & Sedimentation trend at Manipur of Haripur Upazila from 2013 to 2023 has been shown in **Figure 4.139**.

Bhootdang Ghat

From satellite image analysis, minor bank erosion is found at the right bank at Bhootdang Ghat. The right bank of this area is built-up area and lots of settlements, roads and a boat ghat are situated there. Considering the infrastructure located here, around 50m of BPW might be required in the right bank. The Erosion & Sedimentation trend at Bhootdang Ghat of Haripur Upazila from 2013 to 2023 has been shown in **Figure 4.140**.

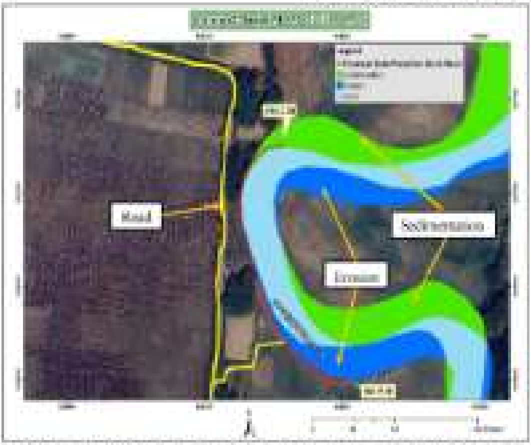

Figure 4.139: Erosion & Sedimentation trend in Kulik River at Mangor of Haripur Upazila from 2013 to 2023

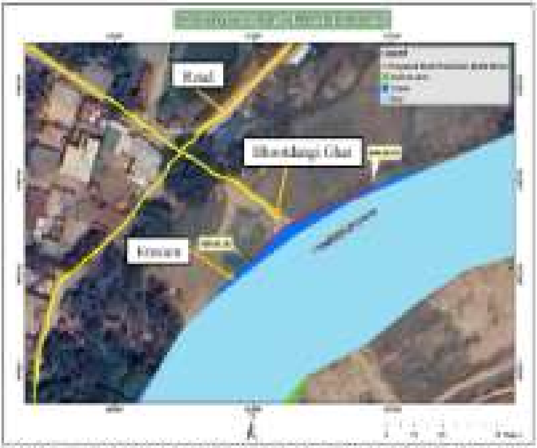

Figure 4.140: Erosion & Sedimentation trend in Kulik River at Bhootdangi Ghat of Haripur Upazila from 2013 to 2023

Bhootdangi

From satellite image analysis, minor bank erosion is found at the right bank at Bhootdangi. On the other hand, sedimentation is found at the left bank. The right bank of this area is built-up area and lots of settlements, bazar and road is situated there. Considering the infrastructure located here, around 100m of BPW might be required in the right bank. The Erosion & Sedimentation trend at Bhootdangi Ghat of Haripur Upazila from 2013 to 2023 has been shown in **Figure 4.141**.

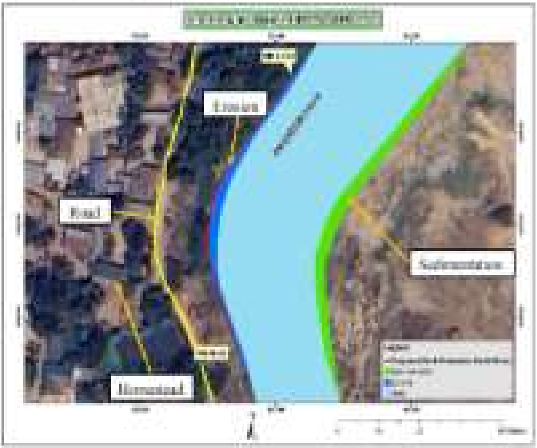

Figure 4.141: Erosion & Sedimentation trend in Kulik River at Bhootdangi of Haripur Upazila from 2013 to 2023

Tirnai River:

The Tirnai river originates in the lower part of the border area of Alowakhowa union of Atwari upazila of Panchagarh district of Bangladesh, crosses Baliadangi upazila of Thakurgaon district and flows up to Kashipur union of Ranisankail upazila before falling into the Nagor River. The flow of water in this river is visible throughout the year compared to other rivers of this area. This is a meandering river and bankline shifting and bank erosion can be seen in almost all the bends in this river. Bank Protection works have been proposed at different vulnerable locations of Tirnai River considering the accumulative analysis of Satellite image, Model simulation, public demand and field investigation. Planform analysis was carried out for ten years from 2013 to 2023 has been shown in **Figure 4.142** to **Figure 4.155** of this river.

Nazir Para

The erosion & sedimentation trend of the Tirnai River near Nazir Para which is situated at the left bank has been shown in **Figure 4.142**. Erosion of 9.10m has been found at the right bank based on satellite image analysis.

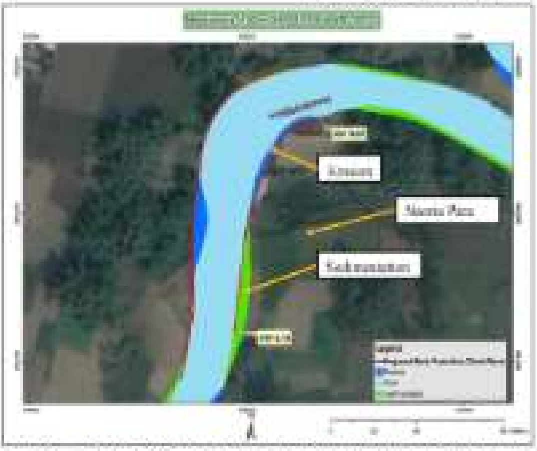

Figure 4.142: Erosion & Sedimentation trend in Tirnai River at Namepara of Baliadangi Upazila from 2013 to 2023

Pontbazit Para

The erosion & sedimentation trend of the Tirnai River near Pontbazit Para which is situated at the right bank has been shown in **Figure 4.143**. Erosion of 5-7m has been found at the left bank based on satellite image analysis.

Baliadangi Upazila Parishad

From satellite image analysis, severe bank erosion is found at both the banks near Baliadangi Upazila Parishad. This area is very important due to having administrative govt. offices of Baliadangi Upazila. The Erosion & Sedimentation trend at Baliadangi Upazila Parishad of Baliadangi Upazila from 2013 to 2023 has been shown in **Figure 4.144**.

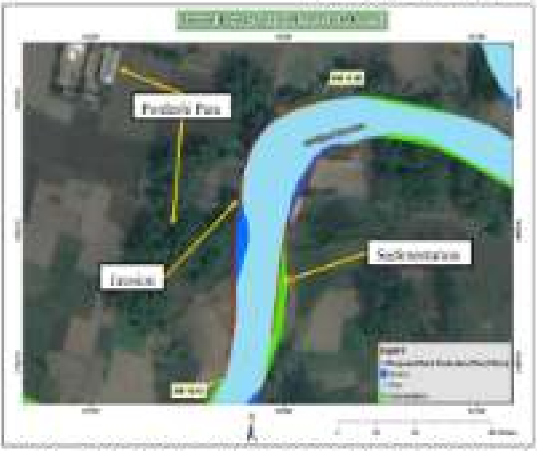

Figure 4.143: Erosion & Sedimentation trend in Tirnai River at Paradesh Para of Baliadangi Upazila from 2013 to 2022

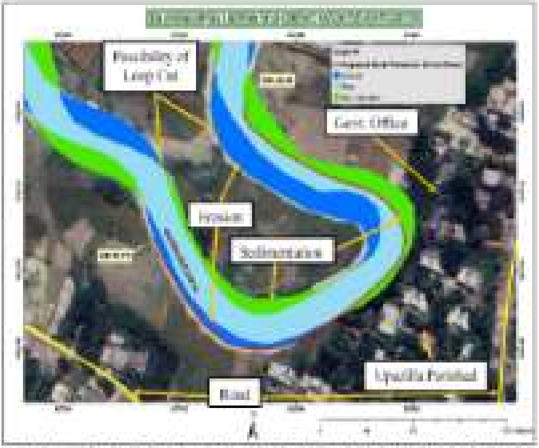

Figure 4.144: Erosion & Sedimentation trend in Tirnai River at Baliadangi Upazila Premises of Baliadangi Upazila from 2013 to 2022

Amtola Poli Bidout

From satellite image analysis, bank erosion is found at both the banks near Amtola Poli Bidout. There is an important Upazila road at the left bank near the proposed Bank Protection Work. Though the erosion at right bank is prominent but this area is non-built-up whereas the left bank is built-up. The Erosion & Sedimentation trend at Baliadangi Upazila Porishod of Baliadangi Upazila from 2013 to 2023 has been shown in **Figure 4.145**.

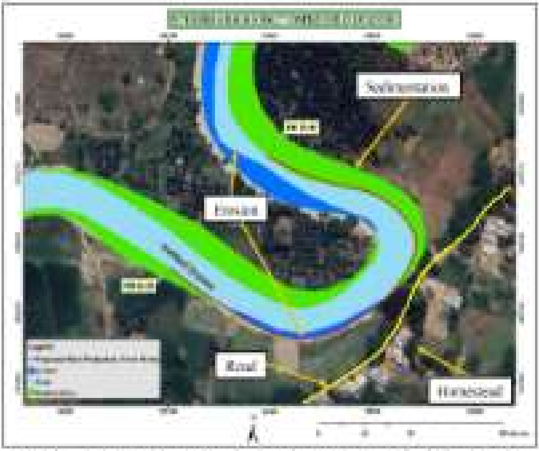

Figure 4.145: Erosion & Sedimentation trend in Tirnai River at Amtola Poli Bidout of Baliadangi Upazila from 2013 to 2023

Kucholdangi

From satellite image analysis, no significant bank erosion is found at both the banks near Kucholdangi. There already exists a 300m Bank protection work just down to the proposed Bank Protection Work. There is an important Upazila road, Mosque, Madrasha and settlements at the right bank near the proposed Bank Protection Work. The Erosion & Sedimentation trend at Kucholdangi of Baliadangi Upazila from 2013 to 2023 has been shown in **Figure 4.146**.

Kasipur

From satellite image analysis, bank erosion is very severe at the left bank compared to the right bank near Kasipur. The proposed BPW at Kasipur is around 200m upstream to the existing Kasipur Water Control Structure. Around 30-35m bank erosion is found at the left bank where bank protective work has been suggested. There is a mango garden near the proposed Bank Protection Work. The Erosion & Sedimentation trend at Kasipur of Baliadangi Upazila from 2013 to 2023 has been shown in **Figure 4.147**.

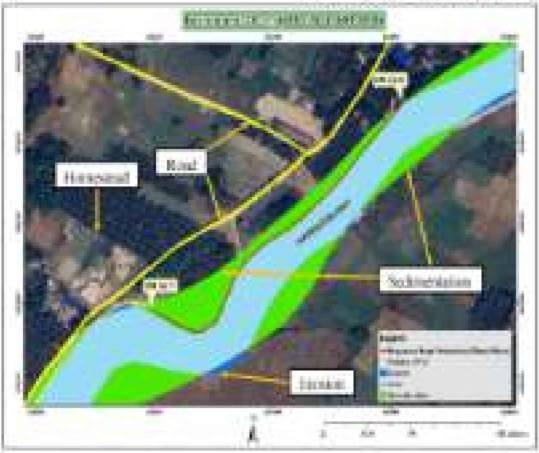

Figure 4.246: Erosion & Sedimentation trend in Tirnai River at Kushaldanga of Baliadangi Upazila from 2013 to 2022

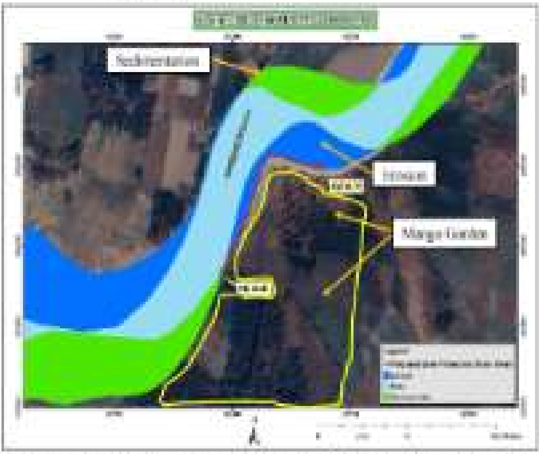

Figure 4.247: Erosion & Sedimentation trend in Tirnai River at Kanpur of Baliadangi Upazila from 2013 to 2022

Kaigpur Water Control Structure

Kaigpur Water Control Structure is one of the important installations by BWDB to retain water of Timai River for irrigation purpose. Excavation of Timai river near this structure was performed during the construction. Bank Protection Work of 60m and 80m length was constructed to protect the upstream of the Water Control Structure. But during monsoon the river overtops the sill level and hits the right bank (Downstream of WCS) with heavy pressure. The erosion rate is increasing, for this reason bank protection work has proposed there. The Erosion & Sedimentation trend at and around Kaigpur Water Control Structure of Baliadangi Upazila from 2013 to 2023 has been shown in **Figure 4.148**.

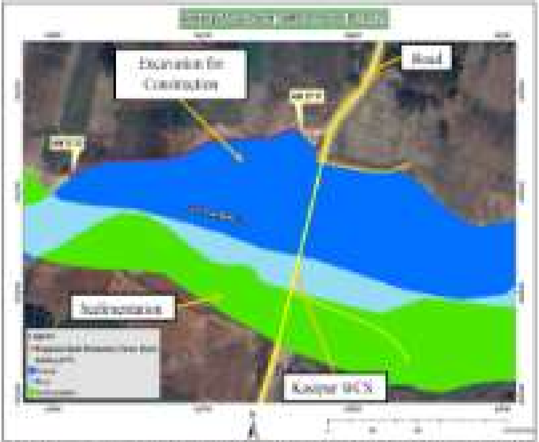

Figure 4.148: Erosion & Sedimentation trend in Timai River at Kaigpur Water Control Structure of Baliadangi Upazila from 2013 to 2023

Boro Polash Bari

From satellite image analysis, severe bank erosion is found at both left and right bank near Boro Polash Bari. Due to erosion channel migration is also observed at the upper portion of the below mentioned reach. Around 500m protection has been suggested to protect the right bank from bank erosion. The right bank is well developed having roads, settlements and bazar. The Erosion & Sedimentation trend at Boro Polash Bari of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.149**.

Boro Polash Bari Madrasha

From satellite image analysis, no significant bank erosion is found at both the banks near Boro Polash Bari Madrasha. Rather deposition is found at Boro Polash Bari Madrasha area. There exists connecting roads, settlements, bazar and a bridge named Boro Polash Bari Bridge. The Erosion & Sedimentation trend at Boro Polash Bari Madrasha of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.150**.

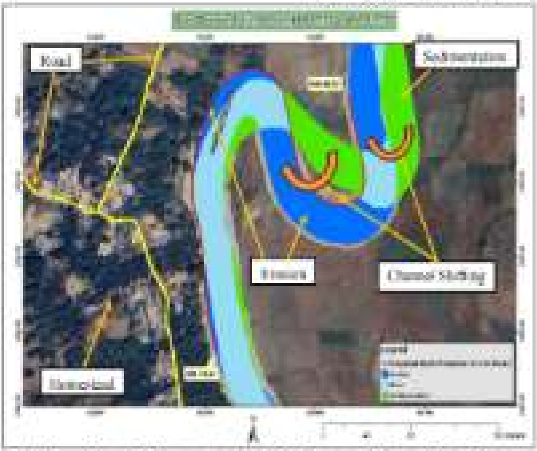

Figure 4.[illegible]: Erosion & Sedimentation trend in Tirnai River at Boro Polash Bari of Panchagarh Upazila from 2013 to 2023

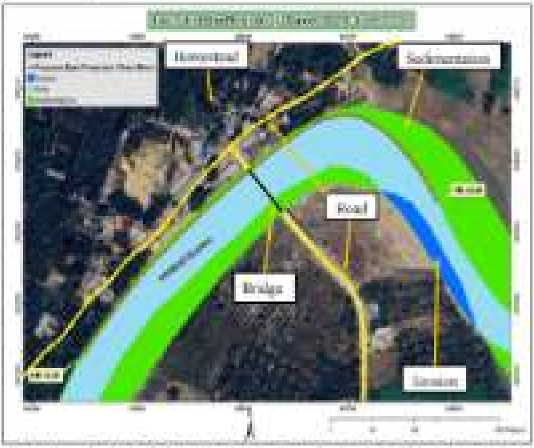

Figure 4.[illegible]: Erosion & Sedimentation trend in Tirnai River at Boro Polash Bari Upstream of Panchagarh Upazila from 2013 to 2023

Babola Village

From satellite image analysis, bank erosion is found at both the left and right bank near Babola Village. Though the erosion at left bank is prominent but this area is non-built-up whereas the right bank is built-up having Settlements, connecting roads, market and mango garden. The Erosion & Sedimentation trend at Babola Village of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.161**.

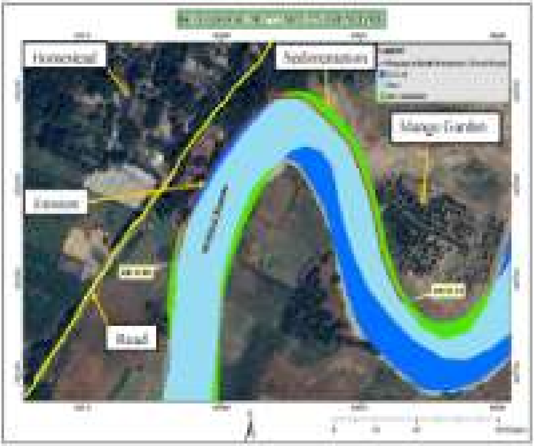

Figure 4.161: Erosion & Sedimentation trend in Tangon River at Babola Village of Ranisankail Upazila from 2013 to 2023

Nodibosti Village

From satellite image analysis, bank erosion is found at both the left and right bank near Nodibosti Village. Though the erosion at right bank is prominent but this area is non-built-up whereas the left bank is built-up having Settlements, connecting road, and mosque. The Erosion & Sedimentation trend at Nodibosti Village of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.162**.

Kashua Pundit Basti

From satellite image analysis, severe bank erosion is found near Kashua Pundit Basti. Due to erosion channel migration is observed and the channel is shifted to left bank. The right bank is well built up, having settlements while the left bank is non-built-up. The Erosion & Sedimentation trend at Kashua Pundit Basti of Ranisankail Upazila from 2013 to 2023 has been shown in **Figure 4.163**.

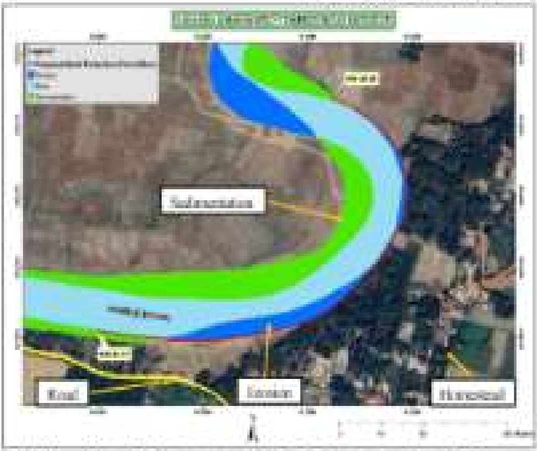

Figure 4.[illegible] Erosion & Sedimentation trend in Tirnai River at [illegible] Village of [illegible] Upazila from 2013 to 2023

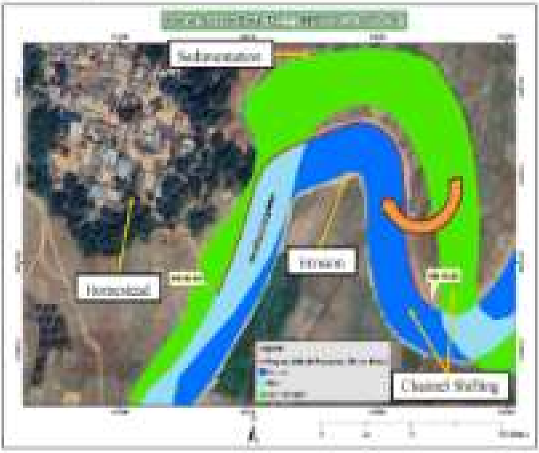

Figure 4.[illegible] Erosion & Sedimentation trend in Tirnai River at [illegible] Village of [illegible] Upazila from 2013 to 2023

Sukh River:

Sukh river originates from the lowlands of Akcha Union, Thakurgaon and falls into the Tangon River in Nargun Union, Thakurgaon. The river is an ephemeral river but the flow in the monsoon season increases a lot and bank erosion can be observed in multiple locations. The river has been re-excavated under the 64 Zilla Project. Bank Protection works have been proposed at two different vulnerable locations of Sukh River considering the accumulative analysis of Satellite image, Model simulation, public demand and field investigation. Thakurgaon road section and bazar area is very close to Thakurgaon Road Railway Station and a zilla road. From image analysis, most erosion is found at both the banks. Though the erosion at left bank is prominent but this area is non-built-up whereas the right bank is built-up having Settlements, Bazar and a Shoshan Ghat. The erosion & sedimentation of Sukh River near Thakurgaon road from 2013 to 2023 has been shown in **Figure 4.154 & Figure 4.155**.

Thakurgaon Road Station

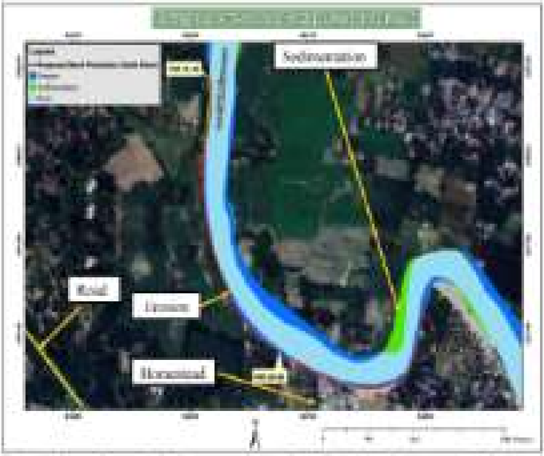

Figure 4.154: Erosion & Sedimentation trend in Sukh River from Thakurgaon Road Station at Thakurgaon Sadar Upazila from 2013 to 2023

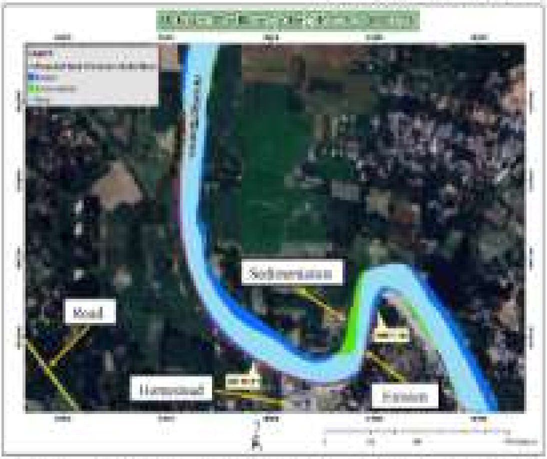

Figure 4.155 Erosion & Sedimentation trend in Sukh River from Thakurgaon Road Bazar of Thakurgaon Sadar Upazila from 2013 to 2023

Vulli River:

Vulli river originates from the lowlands of Gobipur Union, Thakurgaon and falls into the Choto Dhepa River in Birganj Upazila, Dinajpur. The river mainly discharges the excess water from the beel. The river completely dries off during the lean season and rice cultivation takes place during the dry months. The river has been re-excavated recently. The Vulli Bazar Water control structure has been reconstructed to increase water storage during dry season. Bank Protection works have been proposed at two different vulnerable locations of Vulli River considering the accumulative analysis of Satellite image, Model simulation, public demand and field investigation. Planform analysis was carried out for ten years from 2013 to 2023 has been shown in **Figure 4.156** to **4.157** near Vulli Bazar and Gobiya area of this river.

Vulli Bazar

This location is very important because it's very closer to National Highway N-5. From satellite image analysis, erosion has been found at the left bank and the right bank has been accreted to increase navigation. The erosion at left bank is prominent but this area is well built-up having infrastructures like Union Parishad, Govt School, connecting road with National Highway N-5. The Erosion & Sedimentation trend at Vulli Bazar of Pirganj Upazila from 2013 to 2023 has been shown in **Figure 4.156**.

Gobiya Kalimondir

To the spiritual point of view this location is very important. From satellite image analysis, minor erosion has been found near Ma Kali Mondir which is situated at the Right Bank. The Erosion & Sedimentation trend at Gobiya Kalimondir of Thakurgaon Sadar Upazila from 2013 to 2023 has been shown in **Figure 4.157**.

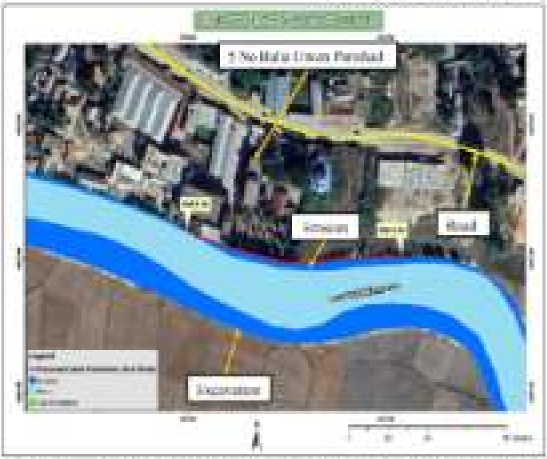

Figure 4.336: Erosion & Sedimentation trend in Kulik River at Kulik Sadar of Thakurgaon Sadar Upazila from 2013 to 2023

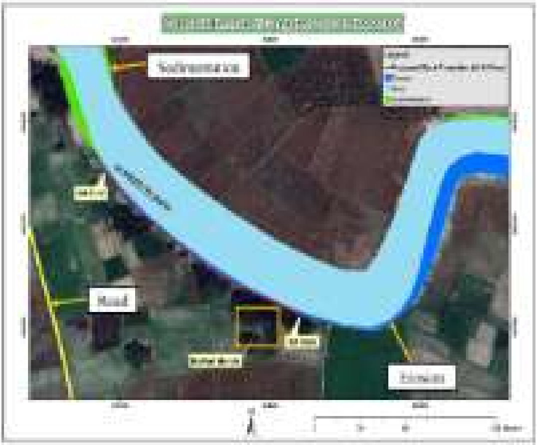

Figure 4.337: Erosion & Sedimentation trend in Kulik River at Gogaya [illegible] of Thakurgaon Sadar Upazila from 2013 to 2023

Senua River:

Senua river originates from the lowlands of Debipur Union, Thakurgaon and falls into the Tangon River near Thakurgaon Town. The river mainly discharges the excess water from the beel. The flow of the river gets reduced a lot between December and February. But the discharge increases significantly during the monsoon. Bank erosion is not very prominent in this river. Downstream of the Senua bridge near Salandar is found comparatively vulnerable to bank erosion. Planform analysis was carried out for ten years from 2013 to 2023 has been shown in **Figure 4.165** near Salandar of this river.

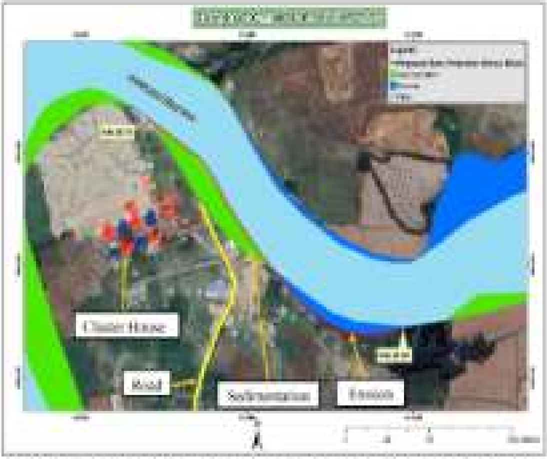

Figure 4.165: Erosion & Sedimentation trend in Senua River at Salandar in Thakurgaon Sadar Upazila from 2013 to 2023

Lacchi River:

Lacchi river originates from the Mohanbhatpur beel of [illegible] Union under Pirganj Upazila, Thakurgaon District. This river falls into Tangon River at Machhlandapur of Pirganj Upazila. The conveyance capacity of this river has been increased significantly after the dredging during 2018-2019 conducted by the BWDB. This river is not much vulnerable to Bank Erosion compared to other rivers of this area. Only one location named Bagungaon is found vulnerable to severe Bank Erosion by image analysis. About 15 to 20m bank erosion has been found here in Bagungaon. Planform analysis was carried out for ten years from 2013 to 2023 has been shown in **Figure 4.166** near Bagungaon of this river.

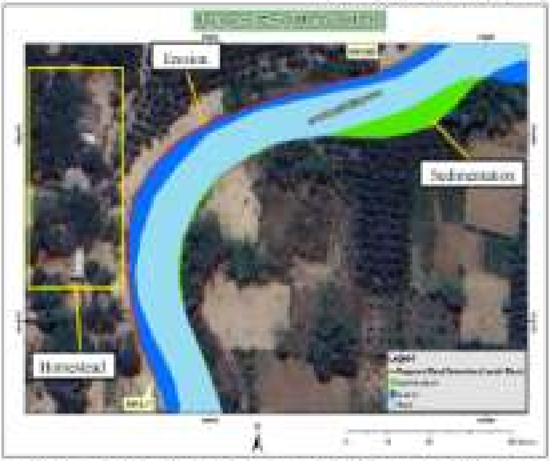

Figure 4.105: Erosion & Sedimentation trend in [illegible] River at [illegible] in [illegible] Upazila from 2013 to 2023

4.1.9 Environmental Flow (E-flow)

The term "environmental flow requirement" is often described as the "minimum flow" (arbitrarily 10% of the mean annual runoff in a river), or the "managed flood" and "river flow objective". E-flow is a key contributor to river health, economic development, and poverty alleviation. E-flow Assessment (EFA) is required for balancing the use (or development) of water from aquatic ecosystems for various purposes whilst protecting (or managing) the aquatic ecosystems so that it can continue to be used by present and future generations. There is no single best way for calculating/quantifying EFA. Each method, approach or framework will thus be suitable only for a set of circumstances.

Different approaches are used worldwide for quantifying environmental flows and can be grouped into four categories which are used for this study for assessment of e-flow. These are:

- Hydrological Method
- Hydraulic Rating Method
- Habitat Simulation Method
- Holistic Method

The outputs from the developed 1D model as well as observed discharge data have been used for calculation of E-flow. Hence, focus has been paid on some of the Hydrological Methods only. However, all these methods require that flow should not be obstructed / should be undisturbed.

The Tennant Method

Also known as Montana Method is one of the oldest methods developed specially for the needs of fish. The Tennant Method is simple as it requires no field work and is based on a single hydrological statistic. The minimum flow requirements for a water course express as a percentage of the mean annual naturalized flow at a specified flow at a specified site. Eight classes of flow classifications were established by Tennant, analyzing a series of field measurements and observations to correlate habitat quality with various percentages of mean annual flow. **Table 4.15 shows Tennant's recommendations for e-flow to support varying qualities of fish habitats based on his observations of flow to best mimic nature's hydrology.** Tennant Method assumes that a portion of mean flow is needed to maintain a healthy stream environment. The method never produces a zero-flow recommendation. The method is not applicable to semi-arid regions. The relationship between flow and the state of the aquatic ecosystem is poorly established and this method is site specific.

Table 4.15 Percentage of mean annual flow required to achieve different objectives based on the Tennant method

Habitat Quality	% Of Mean Annual Flow	
	Low Flow Season	High Flow Season
Flushing or Maximum	200	200
Optimum	60-100	60-100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair	10	30
Poor	10	10
Severe degradation	<10	<10

Flow Duration Curve Analysis

The flow-duration curve (FDC) is a cumulative frequency curve representing the percent of time during which the average discharge equalled or exceeded a particular value at a given location. The FDC may be based on daily, weekly or monthly values of discharge. The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. The basic time unit used in preparing a flow-duration curve will greatly affect its appearance. For most studies, mean daily discharges are used. These will give a steep curve. When the mean flow over a long period is used (such as mean monthly flow), the resulting curve will be flatter due to averaging short-term peaks with intervening smaller flows during a month. Extreme values are averaged out more and more, as the period gets longer. Flow Duration Curve (FDC) is used to derive specific flow percentiles (percentage exceedance values) associated with required suitable river conditions, often in combination with professional judgment, to produce e-flow recommendations. For instance, the Q95 Method is based on the 95% exceedance value on a seasonal FDC. In FDC, naturalized or present-day historical flow records are analyzed over specific durations to produce curves displaying the relationship between the range of discharges and the percentage of time each of them is equalled or exceeded. Usually, 90th percentile flow (Q90) has been set as the minimum e-flow. This is the flow that is exceeded 90% of the time. The 50th percentile usually has been set as high flow month. However, to apply such a FDC technique, hydrological flow data are required.

Constant Yield Method

This method uses a combination of median monthly flow and constant yield statistic to represent the watershed hydrology. This method is suitable for unregulated streams having catchment area greater than 130 km^2 and historic flow records of more than 25 years. In this method, the median monthly flow serves as the datum for evaluating the environmental flow requirement and 100% of the median monthly flow is set as the environmental flow requirement. In Bangladesh, this procedure has been used for assessment of environmental flow requirement for Surma, Kushiyara, Teesta and Gorai River and for the Ganges River (Rahman, 1998) and for the Gorai- Madhumati-Nabaganga-Rupsa River system (IWM, 2017).

Karatoa River:

Environmental flow (E-flow) requirement of Karatoa River at Panchagarh has been assessed by Tennant, Flow Duration Curve (FDC) & Constant Yield Method (CYM). The total requirement has been assessed in terms of considering discharge as the indicator. The comparison of computed E-flow requirements of Karatoa River given in **Table 4.58** below.

Table 4.58 Computed E-flow (cumec) requirements of Karatoa River

Method	Low Flow Season						High Flow Season					
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Tennant	16	14	16	14	14	16	47	94	94	94	47	24
Flow Duration Curve	6	6	4	3	3	3	98	90	75	62	37	20
Constant Yield	13	11	10	8	9	13	98	90	75	62	37	20
E-Flow (cumec)	**16**	**16**	**16**	**14**	**16**	**16**	**47**	**94**	**94**	**94**	**47**	**24**

From this table, it is observed that three different e-flow values have been found for each month for the low flow season using the methods mentioned earlier. And for the high flood season FDC method and Constant Yield Method gives the same result as 50% percent of exceedance used in FDC method gives the same value as the median technique used in Constant Yield Method in high flood season. Environmental flow assessment based on Tennant Method ranges from 14 cumec to 16 cumec for low flow seasons (December to May) and from 24 cumec to 94 cumec for high flow season (June to November). Environmental flow assessment based on Flow Duration Curve Method ranges from 3 cumec to 6 cumec in low flow seasons and from 20 cumec to 98 cumec in the high flow seasons. Environmental flow assessment based on Constant Yield Method ranges from 8 cumec to 13 cumec in low flow seasons and from 20 cumec to 98 cumec in high flow seasons. Considering the values found from analysis, it is evident that e-flow value should be taken such that it satisfies the requirements of all of the methods used. Hence, the values of e-flow of Karatoa river ranges from 14 cumec to 16 cumec for low flow season and from 24 cumec to 94 cumec for high flow season.

The hydrograph of average flood year (mean monthly flow) vs the E-flow requirement is given in **Figure 4.166**.

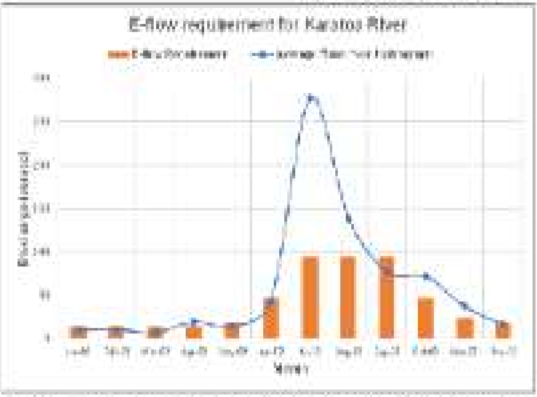

Figure 4.160: Environmental Flow Requirement vs Hydrograph of Average Flood Year for Karatoa River

It can be seen from the table and the figure that generally the Tennant method governs the dry season E-Flow requirements. However, in the calculations previously 30% MAF or Excellent E-Flow condition was considered for the calculations. For Karatoa river, even under base condition with no water extraction scenario, the 10-day 75% dependable flow was found to be lower than the criteria required for "Excellent E-Flow". Hence the criteria for Good E-Flow (20% MAF) and Poor E-Flow (10% MAF) were also brought into the consideration. The 10-day 75% dependable flow of Karatoa river and different E-Flow conditions has been shown graphically in **Figure 4.161**. From the figure, it can be seen that under current condition, the Karatoa river's flow fall below Excellent E-flow but maintains Good E-Flow condition from mid-February to mid-May. For sustainable management of the Karatoa River, it is recommended to ensure at least "Poor E-Flow" (10% MAF) i.e. 4.72 cumec for the Karatoa river at Khansama point. The extraction of the water resources from the Karatoa river has been planned considering this criterion. A detailed analysis of water extraction scenario from the Karatoa river has been shown in **Section 13.3.1**. To maintain the "Poor Environmental Flow" of the Karatoa river, maximum 6 cusecs from Ahmed Nagar-1, 4 cusecs from Ahmed Nagar-2, 4 cusecs from Ahmed Nagar-3, 32 cusecs from SS-1 (Boalmari), 64 cusecs from SS-3 (Tepara) & 64 cusecs from SS-4 (Laxminarayan) can be extracted from the Karatoa River, which would allow to irrigate 3641 ha during supplementary irrigation period and 1307 ha during dry season irrigation.

Talma River:

E-flow analysis was also carried out for Talma River using Tennant method. The E-flow and dry season flow of the Talma River has been shown in **Figure 4.162**. The figure shows that although the flow is below the "Good E-Flow" criteria between mid-January to early-May, "Poor E-Flow" is still present within the Talma River. From the analysis it can be seen that up to 13 cusec waters can be withdrawn from the Talma River while still maintaining the "Poor E-Flow" of the Talma River. This would allow to irrigate 268 ha during supplementary irrigation period and 80 ha during dry season irrigation.

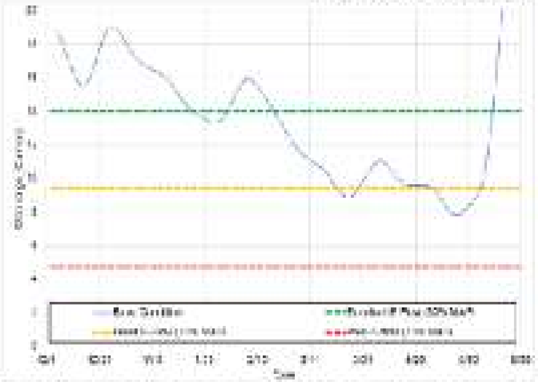

Figure 4.085. 10-day 75% dependable flow of [illegible] River compared against different E-Flow conditions

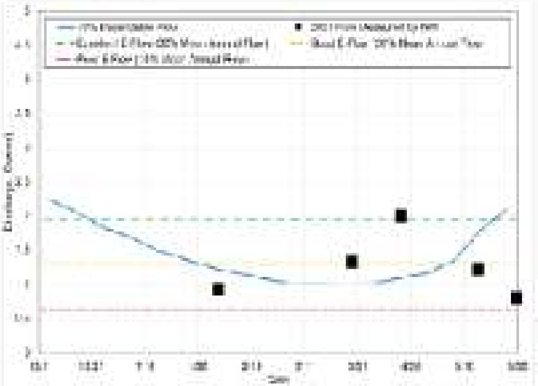

Figure 4.086. 10-day 75% dependable flow of Talma River compared against different E-Flow conditions and 2023 flow measured by IWM

4.1.10 Performance of Existing Water Control Structures

Historically several water control structures were constructed in Panchagarh & Thakurgaon districts. Some of them have been performing satisfactorily while some has become non-function or functioning at a reduced capacity. A list of all the existing structures has been prepared and it has been shown in **Table 4.17**.

Table 4.77: Status of the Water Control Structures in Panchagarh & Thakurgaon Area

Status	Sl No.	Name of the Project	River	Year of Construction	Area (ha)			Remarks
					Gross	Design	Current	
Functional	1	Tangon Barrage	Tangon	1982-1990	9870		4410	Under rehabilitation in Tangon Barrage rehabilitation project.
	2	Buri Badh	Buri	1981-1992			2000	Under rehabilitation in Buri Badh rehabilitation project.
	3	Vulli Badh	Vulli	1991-1997			1800	Under rehabilitation in Vulli Badh rehabilitation project.
	4	[illegible] WCS	Talma	2011-2013			2000	
	5	[illegible] WCS	[illegible]	2015			1500	
	6	[illegible] FCD	Tirnai	-			5630	
	7	[illegible] Barrage	[illegible]	2000-2001			800	
	8	[illegible] WCS	[illegible]	1983-1985		2000	110	Lack of repair & maintenance. Irrigation canal almost unusable. No head regulator. However, emergency repair ongoing in FY 2023-24.
		Total Function Area					18250	
Non-Functional	1	[illegible] Irrigation Project	[illegible]	1980-1983		220		Unusable due to lack of repair & maintenance. Water availability of [illegible] River is very low.
	2	[illegible] FCD Project	Nagor	-		1300		Unusable due to lack of repair & maintenance.
	3	Tirnai, [illegible] & [illegible] Irrigation Project	Tirnai & [illegible] River	1980-1985		600		Not used for a long time, irrigation canal unusable.
	4	[illegible] Irrigation Project	[illegible]	1980-1985		600		Not used for a long time, irrigation canal unusable.
	5	[illegible] Irrigation Project	[illegible]	1980-1987		500		Lack of repair & maintenance for a longtime makes the project unusable.
	6	[illegible] Irrigation Project	[illegible]	1985-1987		500		Lack of repair & maintenance for a longtime makes the project unusable.
		Total Non-Function Area						
Non-Functional but under rehabilitation	1	[illegible] FCD	[illegible]	1984-2001		2500		Being Rehabilitated under Climate Smart Project
Total Non-Functional but under rehabilitation						2500		
[illegible] project of [illegible]	1	[illegible]	[illegible]	1980s		800	-	Non-functional, no pumphouse. Irrigation canals unusable.

Status	Sl. No.	Name of the Project	River	Year of Construction	Area (Ha)			Remarks
					Gross	Design	Current	
	2	[illegible] (SS-2)				700	–	Non-Functional. Pump House situated away for the river. Irrigation canals unusable.
	3	[illegible] (SS-3)				1500	–	Being Rehabilitated under Climate Smart Project.
	4	[illegible] (SS-4)				2000	–	5km canal usable out of 10.25km canals. Rest unusable.
	5	[illegible] (SS-5)				1105	–	1km canal usable out of 4.4km canals. Rest unusable.
	6	Kasipur (SS-6)				1100	–	1.50km canal usable out of 4.10km canals. Rest unusable.
Total						7130		
LGED Rubber Dam	1	Tangon Rubber Dam	Tangon	2008	5000	–	–	Partially functional.
	2	[illegible] Rubber Dam	Tangon	2014	950	–	–	Functional
	3	Tangon River Rubber Dam (Second)	Tangon	2014	850	–	–	Functional
Under Construction BWDB Structures	1	[illegible] WCS	[illegible]	Ongoing	–	–	–	Ongoing Works
	2	[illegible] WCS	[illegible]	Ongoing	–	–	–	Ongoing Works

One of the common problems identified in 3 existing structures at Thakurgaon (Boaldah, Kolkagaon & Kasipur) was that the provided weir level was found to be higher than the existing ground level of the area, meaning that once the gate of the combined water control structure was closed off, it caused inundation in the surrounding low-lying agricultural lands. The existing ground level and the weir level of the structure locations has been shown in Tabular format in **Table 4.58**.

Table 4.58: Weir Crest level and existing ground level of different structure locations

Sl	Location	Weir Level (mMSL)	Average Bank Level (mMSL)
1	Boaldah	51.368	52.15
2	Kolkagaon	51.253	52.73
3	Kasipur	47.006	45.33

A detail analysis on these 3 structures and possible options to solve the problems has been later discussed in **Section 10**.

4.1.11 Irrigation Duty

Table 4.59 shows the crop wise water requirement for the study area.

Table 4.70: Crop-wise Irrigation Water Requirement for the Study Area

[illegible]	[illegible]	[illegible]											
	[illegible]	HYV Boro		Wheat		Maize		[illegible]		[illegible]		[illegible]	
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Considering a pump operation hour of 12 hours and a system efficiency of 60%, the duty during the supplementary irrigation period was found to be 730 ha/cumec and the duty during dry season was calculated as 396 ha/cumec.

4.2 Technical Design

The developed morphological models have been simulated for design flood event to see the planform changes for the rivers in the study area. The locations where model has predicted bank erosion were identified and later based on the settlement information of the identified vulnerable locations, appropriate RTWs were proposed.

4.2.1 River Training Works

The developed morphological models have been simulated for design flood event to see the planform changes for the rivers in the study area. The locations where model has predicted bank erosion were identified and later the based on the settlement information of the identified vulnerable locations, appropriate RTW were proposed.

Karatoa River:

The morphological model simulated bed level changes for the Karatoa river have been shown in **Figure 4.160** to **Figure 4.162**. The model simulated planform change near Shibchar has been shown in **Figure 4.163**. The planform after the design flood event shows bankline movements in multiple locations. The vulnerable locations have been marked with red lines in the Figure. Although the digitalized settlement data, which has been plotted with black polygons in the figure shows the vulnerable locations near Shibchar is the only site which is located near human settlements. Hence 730m SPW has been proposed in this region.

The model simulated planform change near Kaliaman has been shown in **Figure 4.164**. Like previously, the vulnerable locations have been marked with red lines in the Figure. The digitized settlement informations (Plotted with black polygon) shows that the vulnerable site near Kaliaman requires RTWs. Considering the near bank human settlements, 500m SPW near Kaliaman has been proposed.

The **Figure 4.165** shows the planform changes of the Karatoa river near Gorogachi. The bank erosion sites for the design flood event have been marked red in the figure. From the figure it can be seen that the vulnerable locations are far away from the settlement data (marked with black polygon). As a result, no additional RTW has been proposed in this reach.

The model simulated planform change near Bhojanpur has been shown in **Figure 4.166**. Some RTW are present near Bhojanpur and the exiting RTW has been marked with green lines in the figure. The model simulated vulnerable locations based on the model simulated bank erosion has been marked with red lines. Just upstream of Bhajanpur, erosion can be seen on the left bank of the Karatoa river. The model simulated bankline comes very close to the settlements of the Bhajanpur town and hence 400m RTW has been proposed upstream of Bhajanpur. On the right bank, just upstream of the Bhajanpur Bridge, model predicts bank erosion which puts several human settlements into direct threat. Considering the human settlements that is endangered by the vulnerability of the Karatoa bank erosion, 500m RTW has been proposed in this reach. Further downstream, although erosion can be seen on the left bank downstream of Bhajanpur, since no human settlement seemed endangered due to the model predicted bank erosion, no RTW has been proposed in that segment.

The **Figure 4.187** shows the planform changes of the Karatoa River near Mirganj. The existing RTW has been shown in the figure with green polylines. The bank erosion sites for the design flood event have been marked red in the figure. It can be seen from the figure that erosion is predicted by the model just upstream of the existing protection works near Mirganj bazar. The erosion just upstream of the Mirganj BGB camp puts some human settlement in danger in case river bank erosion continues in the near future. However, this area is very close to the India-Bangladesh border and needs to be kept under supervision. However, constructing RTW so close to the border might be challenging. Another erosion location can be seen just downstream of the existing protection works at Mirganj. Although there are no settlements there, the Mirganj Guccho gram is around 300m away from the bankline. But since no settlement lies between the bankline and the Guccho gram, no RTW has been proposed right away. Erosion can also be seen on the left bank just upstream of Chawai confluence. Some settlements are present there near the Chawai confluence at Rajanpur. Although erosion can be seen thorough out the right bank for about 1150m, considering the settlement information, 300m RTW has been proposed in this reach of the river. Erosion also be seen just on the right bank of the Chawai-Karatoa confluence (i.e., opposite bank of the confluence point). However, the region is mostly reminiscence of old Karatoa flow path with a loop-cut detaching the old river flow path. No real settlements can be seen in this region and hence no RTW has been proposed for this erosion zone.

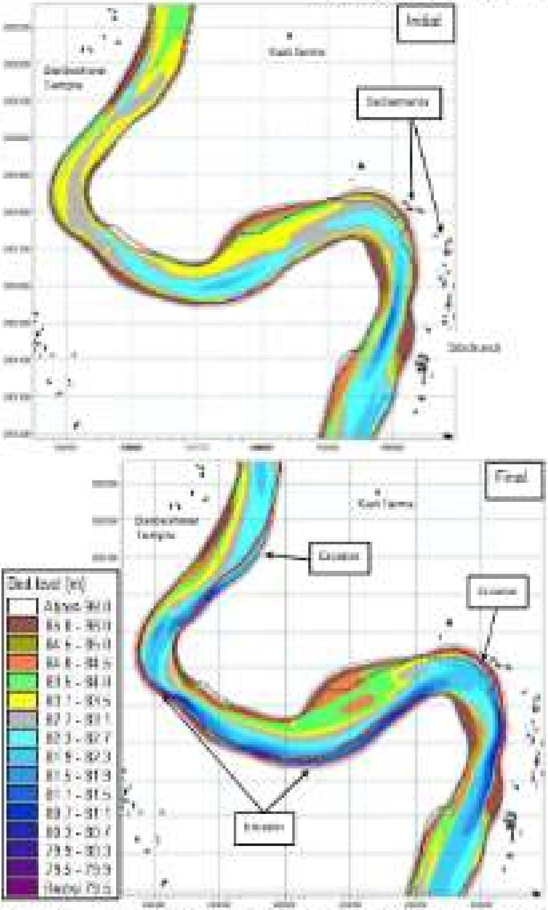


Figure 4.383: Model simulated planform change near Dhibinhat for design flood event of Karatoa River

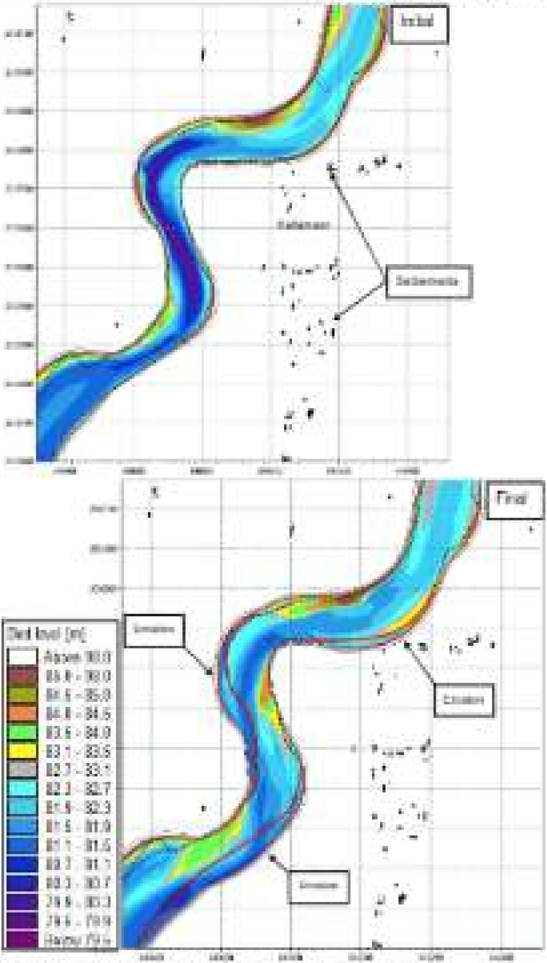


Figure 4.[illegible] Model simulated planform change near [illegible] for design flood event

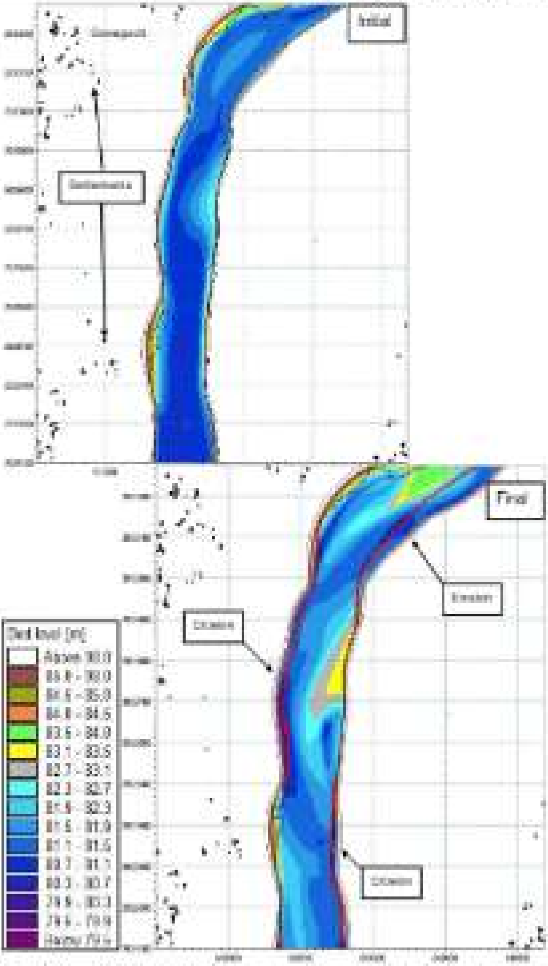


Figure 4.[illegible] Model simulated planform change near [illegible] for design flood event

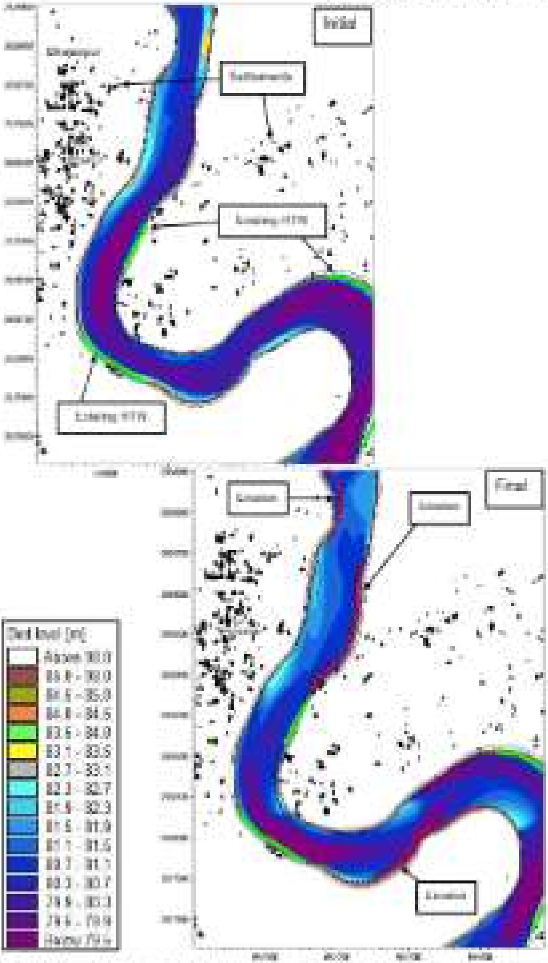
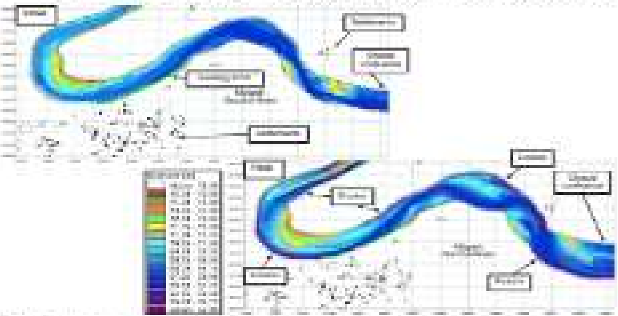


Figure 4.[illegible] Model simulated planform change near Shingapur for design flood event



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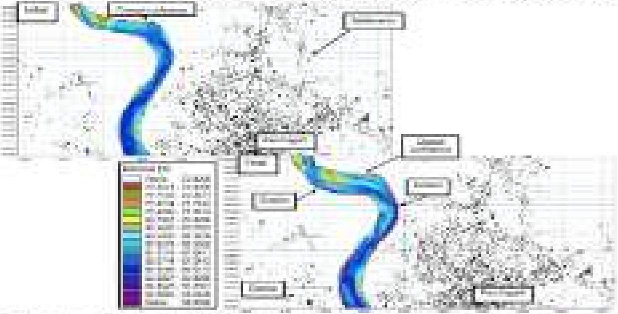

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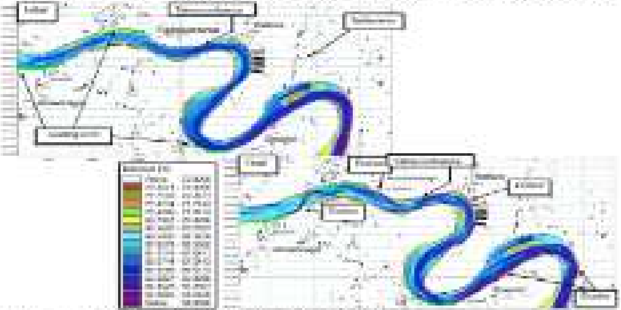
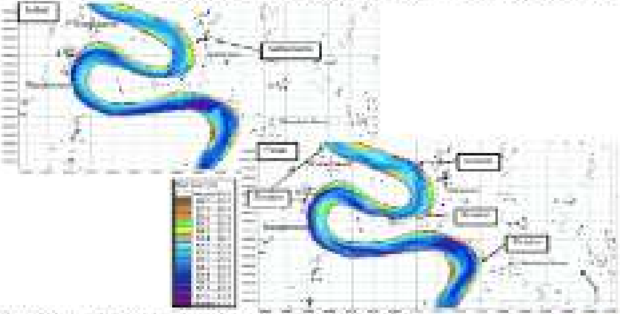
The model simulated planform change near Panchagarh Town has been shown in **Figure 4.168**. The model simulated vulnerable locations based on the model simulated bank erosion has been marked with red lines. Just downstream of the Chawai Confluence, erosion can be seen on the left bank of the Karatoa river near Ramerdanga. The location is just on the western side of the Panchagarh town and the land here has lots of settlements as well as highly valuable. Considering these, 1200m RTW near Ramerdanga has been proposed. Further downstream, on the southern bank of the Karatoa river near the CNB More of Panchagarh Town, erosion can be seen on the right bank as well. The erosion zone is located just upstream of the existing RTW of Panchagarh town. Although erosion can be seen along 1240m of the right bank of Karatoa river, and this area needs to be kept under close supervision.

The model simulated planform change near Natkura has been shown in **Figure 4.169**. Like previously, the vulnerable locations have been marked with red lines in the Figure. And the existing protection near Ahmadnagar, Purbobularidanga and Fulbari has been marked with green line. Erosion can be seen near Ahmadnagar just downstream of the existing protection works. Mostly the erosion zone falls near an open field hence no RTW has been proposed. However, that is not the case near Purbobularidanga, where the erosion occurs near settlements. 581 m RTW has been proposed in this location from the d/s termination of the existing protection works up to the confluence with the Talma River. Erosion also persists downstream of the confluence near Natkura where lots of settlement and infrastructure is present. Considering the settlements near the Natkura region, 1000m RTW has been proposed. Further downstream, erosion can also be seen downstream of the existing RTW near Shalshiri. Lots of settlements including Ahmadiyya Mosque Shalshiri is present here in Shalshiri and the bank erosion puts this entire settlement at risk. 1150m RTW has been proposed near Shalshiri considering these settlements. Further downstream, in the next bend, erosion has occurred in the outer bend of the Karatoa river near Bandarpara. Some settlements are present there. This area needs to be kept under close supervision and if situation deteriorates, 500m of RTW might be needed in the future at Bandarpara.

The **Figure 4.170** shows the planform changes of the Karatoa river near Sonachandi. The bank erosion sites for the design flood event have been marked red in the figure. Erosion can be seen on the right bank near Sonachandi. Lots of settlements are present there as marked with black polygons. 1150m RTW has been proposed on the right bank of Karatoa river near Sonachandi. On the left bank of Sonachandi, erosion can be seen as well but they are away from settlements. However, erosion can be seen on the next outer bend of the Karatoa river near Kathorihari. This area is proposed to be kept under close supervision and 875m of BPW might be needed in the future near Kathorihari on the left bank of Karatoa River. Further downstream, erosion can also be seen on the outer right bank of Karatoa River near Bandarmon. The erosion occurs near the settlements (marked with black polygons) and although erosion can be seen along 1830m reach of the left bank of Karatoa river, considering the available settlement information, 320m of RTW has been proposed near Bandarmon. Erosion can also be seen on the next bend near Chandberi Bazar. Around 1250m of left bank appears vulnerable to bank erosion during design flood event. This area needs to be kept under close supervision and in the future 700m of RTW might be needed in this reach of the Karatoa river.

The model simulated planform change near Sikarpur has been shown in **Figure 4.171**. Like previously, the vulnerable locations have been marked with red lines in the Figure. Erosion can be seen near Sikarpur where the erosion takes place near settlements. Around 725m RTW has been proposed on the right bank near Sikarpur. Erosion can also be seen in the outer left bank just downstream of Sikarpur. Although 850m bank line does appear vulnerable, no real settlements can be seen in this reach. Further downstream erosion can also be seen on the right bank near Shuvasujan where settlements are present. Looking at the model simulated bank line movements, around 500m of RTW has been proposed near Shuvasujan. Just downstream of Shuvasujan, erosion can be seen on the left bank near Boragram. Although erosion can be seen on up to 2150m near Boragram, looking at the settlement information, around 420m of RTW has been proposed in this reach of the river.





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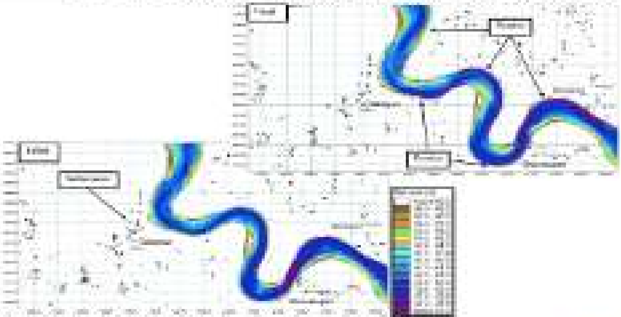

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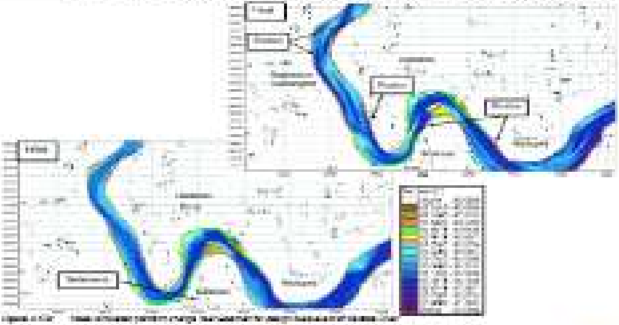

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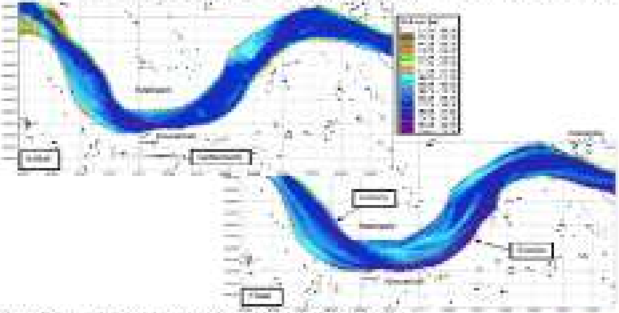
The **Figure 4.172** shows the planform changes of the Karatoa river near Boalmari Bazar. The bank erosion sites for the design flood event have been marked red in the figure. Erosion can be seen on the left bank just upstream of Hoddaton. Erosion can also be seen on the right bank near Baghobila Sosheghat. Some near bank settlements are present there as marked with black polygons. Hence 1200m RTW has been proposed on the right bank of Karatoa river near Baghobila Sosheghat. On the left bank, although erosion can be seen upstream of Boalmari, no major settlement can be seen in this reach hence RTW has not be proposed in this vulnerable reach. Although the channel migrates towards the right bank near Boalmari bazar, the reach is protected with RTW, as marked with green line in **Figure 4.172**. However just downstream of the termination of the RTW, bank erosion can be seen. Hence, it has been proposed to increase the length of the RTW here by another 200m to stop the propagation of erosion. On the opposite bank of Boalmari (i.e., left bank) the reach is protected with RTW. But again, just downstream of the RTW, erosion can be seen near Nazirganj. Around 500m of extension of the existing RTW near Nazirganj has been proposed.

The model simulated planform change near Kawaikhali has been shown in **Figure 4.173**. Like previously, the vulnerable locations have been marked with red lines and green lines shows the existing protection works in the Figure. And the human settlements have been marked with black polygons. From the figure, it is clearly visible that the settlements near Kawaikhali is vulnerable to bank erosion. The design flood event simulations show several of the human settlement under threat to bank erosion. Based on the design flood event simulations, 1400 m RTW has been proposed on the right bank near Kawaikhali. Further downstream, although bankline shifting towards the left bank near Kaliaganj can be seen from the design flood event simulations, the reach is protected with existing BPW near Kaliaganj.

The **Figure 4.174** shows the planform changes of the Karatoa river near Baropatia. The bank erosion sites for the design flood event have been marked red in the figure. Erosion can be seen on the right bank near Baropatia. Lots of settlements are present there as marked with black polygons and from the figure it can be seen that some land might be eroded away at the design flood event. Considering the settlements near Baropatia, 900m RTW on the right bank has been proposed in this reach. Just downstream of Baropatia some near bank settlement seems vulnerable to bank erosion as well. Considering these settlements 1300m of RTW might be required in this reach of the Karatoa river located in Bara Shashi union.

The model simulated planform change near Aulaghat has been shown in **Figure 4.175**. Like previously, the vulnerable locations have been marked with red in the Figure. And the human settlements have been marked with black polygons. From the figure, it is clearly visible that the settlements on the right bank near Aular Ghat, is vulnerable to bank erosion. Based on the outputs of the morphological model, 870m RTW has been proposed on the right bank near Aular Ghat. Further downstream, on the left bank near Bordeshwari, erosion can be seen along 1300m reach of Karatoa river. Based on the settlement information, around 1300m RTW on the left bank has been proposed.

The **Figure 4.176** shows the planform changes of the Karatoa river near Dhuaghat Bazar, where lots of erosion can be seen near the settlements of the bazar region on the right bank. Considering the human settlements and analysing the morphological model results, 2250m RTW on the right bank has been proposed in this reach of the river. On the opposite bank, erosion can be seen near Sikarpur Khomarpara and Daphdigram, where considering the near bank settlements, around 1650m and 950m RTW has been proposed.



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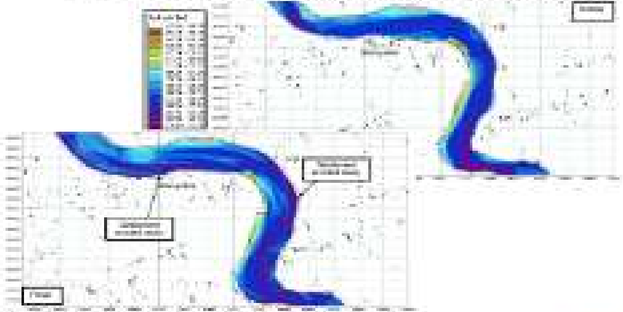

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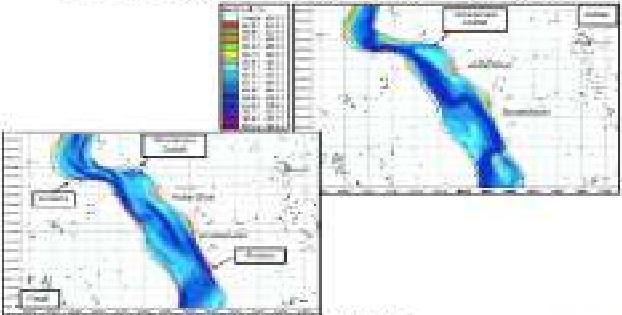

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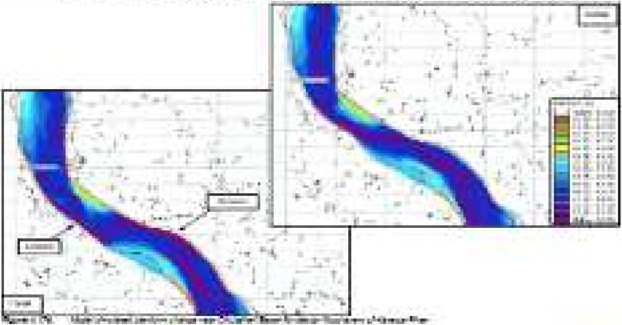

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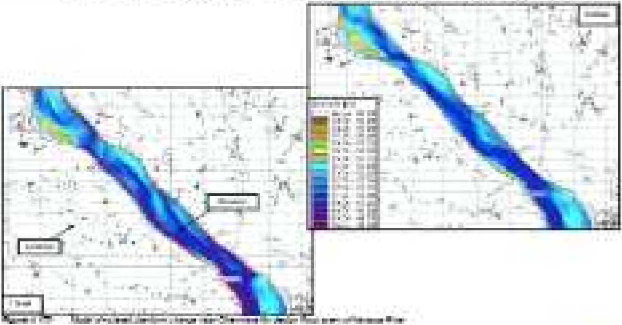

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The model simulated planform change near Dhamnamala has been shown in **Figure 4.177**. Like previously, the vulnerable locations have been marked with red lines. Erosion on the right bank starting just downstream of Tarkahona Bazar up to Sonapota can be seen from model simulations during design flood event simulations. Lots of settlements can be seen along the bank of the river on this reach as well and considering those settlements and extent of bank erosion, 1620m RTW has been proposed in this reach. Erosion can also be seen on the left bank near Sankarpara, Islambad and Adorshopara Guccha gram. Based on model simulation results and settlement information 1325m RTW has been proposed on the left bank of Adorshopara Guccha gram. While, it is recommended to keep Sankarpara and Islambad under close supervision to monitor any erosion that may take place. Erosion can also be seen on the right bank near Sonapota where erosion has occurred near settlements. Assessing the model simulated bank erosion, 1600m of RTW on the right bank has been proposed near Sonapota.

The summary of the proposed RTW has been shown in **Table 4.30**. The priority of each of the location of the proposed RTW has been shown in the table as well. The proposed RTWs has also been shown in **Figure 4.178**. The proposed RTWs will protect a total of 119.28 ha of lands from river bank erosion of Karatoa River.

Table 4.30 Location and length of proposed RTWs of the Karatoa River

SL	Location	Bank	Upazila	Starting Chainage	Length	Priority
1	Sildabari	Left	Tetulia	1500	100	B
2	Kalamari	Left		6000	500	B
3	Bhajanpur Bridge u/s	Left		11350	400	B
4		Right		11500	300	A
5	Shaldanga	Left	Panchagarh Sadar	17500	815	B
6	Amtola Kachari	Left		24500	1000	B
7	U/S of Chawai Confluence	Left		30500	300	B
8	Ramerdanga	Left		35000	1000	A
9	Punkhirdanga	Left		40000	665	C
10	Nalmola	Left		45500	1000	C
11	Sadarl - Sakhiyan Para	Right	Boda	49700	1150	C
12	Sonachandi Sarkarpara	Right		51500	1150	A
13	Bakhimpur	Right		54500	500	A
14	Dhakpur	Right		57350	125	C
15	Sonarkhuli	Right		59000	330	C
16	Barapara	Left		60000	625	B
17	Baghmoira Soshanghat	Right		61700	1200	A
18	Bhobani	Right		64000	300	A
19	Nariganj	Left	Debiganj	65000	600	C
20	Kaiserhat	Right		66800	1400	C
21	Sarupala	Right	Boda	69750	800	A
22	Bara Dhaura	Left		70500	1000	B
23	Kutir Ghat	Right		71800	375	B
24	Bondorkhed	Left		72800	1900	A
25	Debdanga-1	Right	Debiganj	73700	815	A
26	Debdanga-2	Right		75700	665	B
27	Purbo Ghatpur	Left		77200	2125	A
28	Dhulathat	Right		77400	2225	A
29	Tinpara	Right		80050	1225	A
30	Dhamnamala	Right		82800	1620	C
31	Adorshopara Guccha gram	Left		84800	1325	A
32	Sonapota	Right		85450	1600	C
33	Debiganj Bridge U/S	Left		86500	300	A
34	Debiganj Shoshan	Left		87400	400	A
35	Dakshin Uttar Para	Right		88200	575	A
36	Tepara LLP - Bhabahut	Right		87700	800	C
37	Maharaja Mosque	Left		88800	1140	A

Sl	Location	Bank	Upazilla	Starting Chainage	Length	Priority
38	Birthoghat-Arazi Sundardighi Mouza	Right		93800	725	A
39	Madrasi	Left		99600	825	B
40	Laxmirhat	Right		104800	1125	C
41	Mohammadpur Mouza	Left		102000	1200	C
42	Jorpara	Right	Bhojpur	109000	500	C
	Total				40183	

*Chainage starting from Bangladesh-India Border

** Important chainage locations:

Bhajanpur Bridge – 12500m, Chawai Confluence 30000m, Panchagarh Town Bridge – 43200m, Talma Confluence – 48800m, Pum Confluence – 59100m, Bheramara Confluence – 72200m, Kurum Confluence – 81800m, Debiganj Bridge – 87300m, Pathraj Confluence – 100200m, Khansama bridge – 114500m.

In addition to this several locations have been identified as erosion prone and needs to be kept under close supervision. The details of which has been shown in **Table 4.21**.

Table 4.21 Locations that needs to be monitored of the Karatoa River

Sl	Location	Bank	Starting Chainage	Length (m)
1	Hatgacha Bhajanpur	Right	12800	280
2	Natuari Bhajanpur	Left	17780	50.0
3	Amarkhana	Left	14700	60.0
4	LGD Store of Panchagarh	Right	41700	53.0
5	Bandarpara	Left	45800	45.0
6	Kalinerhat	Left	53100	886
7	Dhakabari Bazar	Left	58100	70.0
8	Bashmari Hamid Mela Site	Right	60800	80.0
9	Kaltarpara	Left	67900	1275
10	Islamabad	Left	93800	445
11	Mollikadanga	Left	99600	33.0
Total				7012

The design data of the Karatoa river has been shown in **Table 4.22**.

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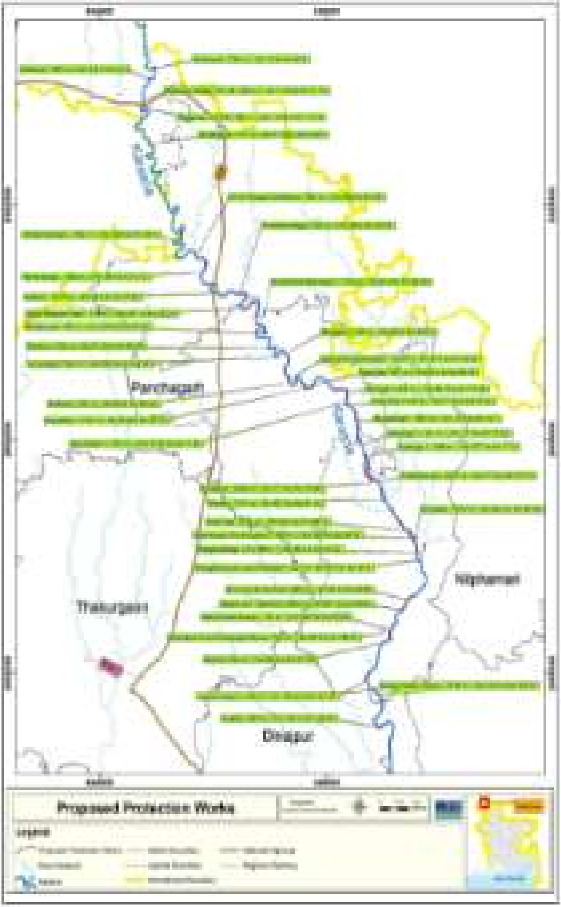

Figure 4.278: Proposed River Training Works on the Karatoa River

Tangon River:

Detailed morphological model has been developed and simulated for the Tangon River and using the simulated bed level change for the design flood event, the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at 22 different locations. The location of the proposed RTWs has been shown graphically in **Figure 4.178**. **Table 4.23** shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 30.31 ha of lands from river bank erosion of Tangon River.

Table 4.23 Location and length of proposed RTWs at the Tangon River

SL.	Name	Starting Chainage (km)	Upazila	Start X	Start Y	Bank	Length (m)	Priority
1	Chapani Ungama Sushan Ghat	11.1	Thakurgaon Sadar	[illegible]	[illegible]	Right	410	C
2	Ashrabnagar	12.88		[illegible]	[illegible]	Right	400	C
3	Shorobari Mulapara	16.07		[illegible]	[illegible]	Left	210	A
4	Shorbari Choukidar Para	16.75		[illegible]	[illegible]	Left	520	B
5	Shormapur Sonnasi Para	17.85		[illegible]	[illegible]	Right	380	B
6	Shormapur Goodhopara	18.18		[illegible]	[illegible]	Left	380	A
7	Bodhapara 1	18.38		[illegible]	[illegible]	Left	300	C
8	Bodhapara 2	20.5		[illegible]	[illegible]	Right	310	C
9	Parabari Sonnasipara	24.07		[illegible]	[illegible]	Left	240	C
10	Gobindo Kotna	24.88		[illegible]	[illegible]	Right	330	A
11	Begpur	25.85		[illegible]	[illegible]	Left	270	C
12	Mohla	35.2		[illegible]	[illegible]	Right	220	C
13	Heli Camp	38.6		[illegible]	[illegible]	Right	270	A
14	Shahpara	40.3		[illegible]	[illegible]	Left	310	A
15	Mohispur	47.1		[illegible]	[illegible]	Right	320	C
16	Kusumbari	61	Pirganj	[illegible]	[illegible]	Left	300	B
17	Mohammadpur Ruistheng Bridge	66.22		[illegible]	[illegible]	Right	400	C
18	Bornopara	74.2		[illegible]	[illegible]	Right	370	B
19	Chakhasauriharpur Kusapara	77.1		[illegible]	[illegible]	Right	330	B
20	Kumarpara Kashiarghat	88		[illegible]	[illegible]	Right	420	C
21	Azadbad	89.6		[illegible]	[illegible]	Right	310	A
22	Saat Dangapara	90.1		[illegible]	[illegible]	Right	305	A
			Total				8460	

Some locations among these 22 might require additional lengths depending on the condition of the field during RTW construction as the planform might change. The locations that need to be kept under close monitoring has been shown in **Table 4.24**. The length of protection in this location might require to be increased by the mentioned amount depending on the situation on the field. So, these locations needs to be kept under close monitoring.

Table 4.34 Locations that needs to be considered of the Tangon River

Sl.	Location Name	Length	Chainage Range	Bank	Remarks
1	Khudobari Hindupara	50	–	Left	270m RTW has been proposed as priority A. But depending on the situation addition 50m RTW might be required.
2	Kasaidobha	450	–	Left	500m RTW has been proposed as priority B. But depending on the situation addition 450m RTW might be required.
3	Fakirhat Kalimondir	65	–	Left	340m RTW has been proposed as a C Priority. But depending on the situation addition 65m RTW might be required.
4	Dhakpara	50	–	Left	170m RTW has been proposed as an "A Priority". But depending on the situation addition 50m RTW might be required.

The design data of the Tangon River has been shown in **Table 4.35**.

[illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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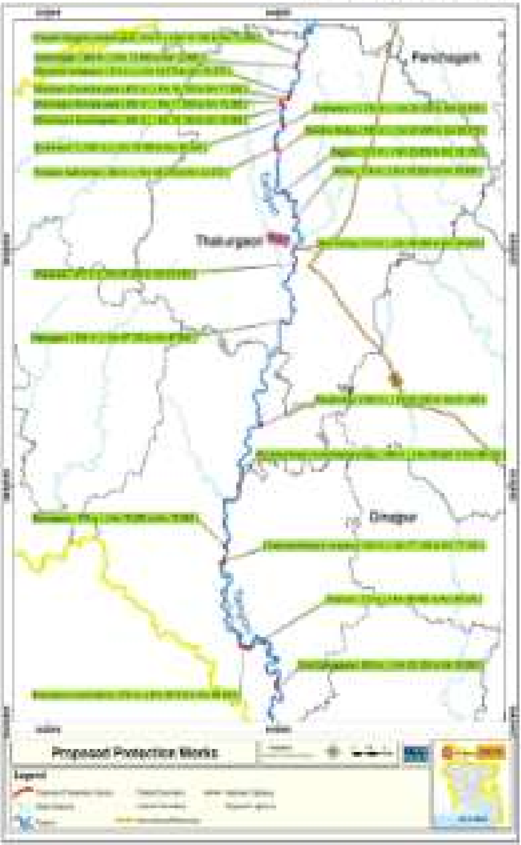

Figure 4-77B: Proposed River Training Works on the Tangon River

Pathraj River:

Similarly, a detailed morphological model has been developed and simulated for the Pathraj River as well and using the simulated bed level change for the design flood event the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at 20 different locations. The location of the proposed RTWs has been shown graphically in **Figure 4.189**. **Table 4.36** shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 15.52 ha of lands from river bank erosion of Pathraj river.

Table 4.36 Location and length of proposed RTWs of the Pathraj River

SL	Name	Starting Chainage (km)	Upazila	Start X	Start Y	Bank	Length (m)	Priority
1	Boda Bridge U/S	3.93	Boda	[illegible]	[illegible]	Right	340	A
2	[illegible]	7.25		[illegible]	[illegible]	Left	320	B
3	Pramanik Para	9.03		[illegible]	[illegible]	Left	300	B
4	[illegible]	10.1		[illegible]	[illegible]	Left	150	C
5	[illegible]	19.4	Thakurgaon Sadar	[illegible]	[illegible]	Right	200	A
6	[illegible]	20.45		[illegible]	[illegible]	Right	250	C
7	Jamalpara	27.80		[illegible]	[illegible]	Right	250	C
8	[illegible]	33.3		[illegible]	[illegible]	Left	250	B
9	[illegible]	32		[illegible]	[illegible]	Right	300	C
10	[illegible]	34		[illegible]	[illegible]	Right	140	B
11	[illegible]	35.6		[illegible]	[illegible]	Left	250	B
12	[illegible]	39.30	Debiganj	[illegible]	[illegible]	Right	350	A
13	[illegible]	42.4		[illegible]	[illegible]	Right	380	A
14	[illegible]	46		[illegible]	[illegible]	Right	510	A
15	Fulbari	46.77		[illegible]	[illegible]	Right	150	B
16	Fulbari Primary School	50.04		[illegible]	[illegible]	Right	250	C
17	Fulbari Bridge U/S	50.29		[illegible]	[illegible]	Left	400	B
18	Fulbari Bazar - Left Bank	50.93		[illegible]	[illegible]	Left	350	C
19	Fulbari High School	51.25		[illegible]	[illegible]	Right	450	A
20	[illegible]	53		[illegible]	[illegible]	Right	500	B
Total							[illegible]	

The design data of the Pathraj river has been shown in **Table 4.37**.

[illegible] [illegible]

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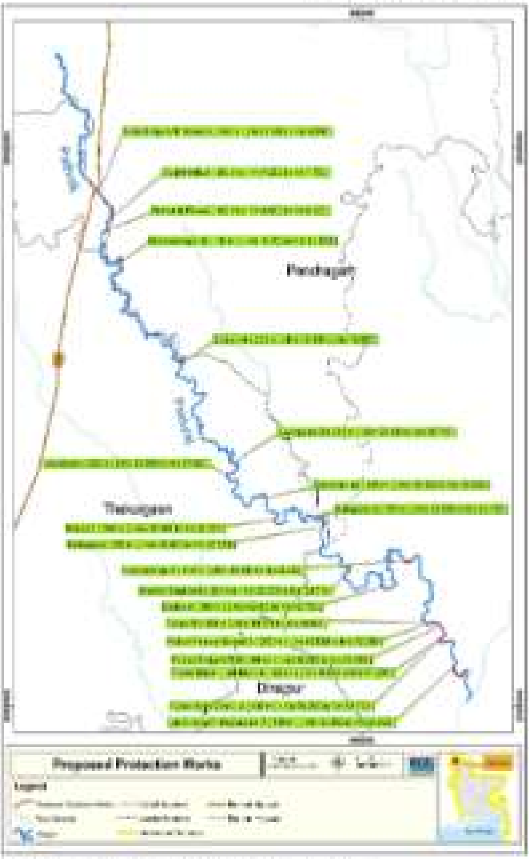

Figure 4.[illegible]: Proposed River Training Works on the [illegible] River

Chawai River:

Detailed morphological model has been developed and simulated for the Chawai River. Using the simulated bed level change for the design flood event, the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at 11 different locations. The location of the proposed RTWs has been shown graphically in **Figure 4.151**. **Table 4.28** shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 5.77 ha of lands from river bank erosion of Chawai River.

Table 4.28 Location and length of proposed RTWs at the Chawai River

ID	Location	Upazila	Bank	Starting Chainage (m)*	Length (m)	Priority
1	Sheikh Bazar	Panchagarh Sadar	Left	1920	430	C
2	Pir bridge		Right	4500	1040	A
3	U/S of Jagdal Bazar Bridge R/B		Right	6020	400	A
4	Jagdal Bazar		Left	6640	300	A
5	Dolapara		Left	7510	280	A
6	Karatoa Tea Garden		Right	8960	280	D
7	Dhakhamari		Left	11,100	200	B
8	Amarkhana		Right	15,100	340	C
9	Chawai Bridge		Left	16800	220	A
10	Aerula		Right	17,034	800	A
11	Lathiapara		Left	17,800	375	A
Total Length					3803	

** Chainage starting from Bangladesh-India Border

** Important chainage locations:

Dhakhinpara Bridge – 440m, Boila confluence – 3600m, Jagdal Bazar Bridge – 6660m, Chawai Bridge – 16625m, Karatoa Outfall – 19200m.

Additional to these proposed RTWs, the locations that needs to be kept under close monitoring has been shown in **Table 4.29**. These locations are not yet on the top priority for RTW but the model simulations did show erosions which may cause some problem in the future. Hence these locations need to be kept under close monitoring for in the future.

Table 4.29 Locations that needs to be monitored at the Chawai River

SL	Location Name	Length	Chainage Range	Bank	River	Remarks
1	Omarkhana	220	KM 0.59 to KM 0.80	Right	Chawai River	Location Prone and 2.0km to the Chawai Bridge
2	U/S of Jagdal Bazar Bridge L/B	410	KM 5.70 to KM 6.17	Left	Chawai River	Sharp bend 250m away from RB
3	Batmara	300	KM 10.70 to KM 11.00	Right	Chawai River	Sharp bend near South Sunnyapara
4	Kalipara-1	320	KM 13.27 to KM 13.58	Left	Chawai River	Sharp bend near a LGED Bridge
5	Kalipara-2	460	KM 14.43 to KM 14.90	Left	Chawai River	Sharp bend near Kalipara Govt. Primary School

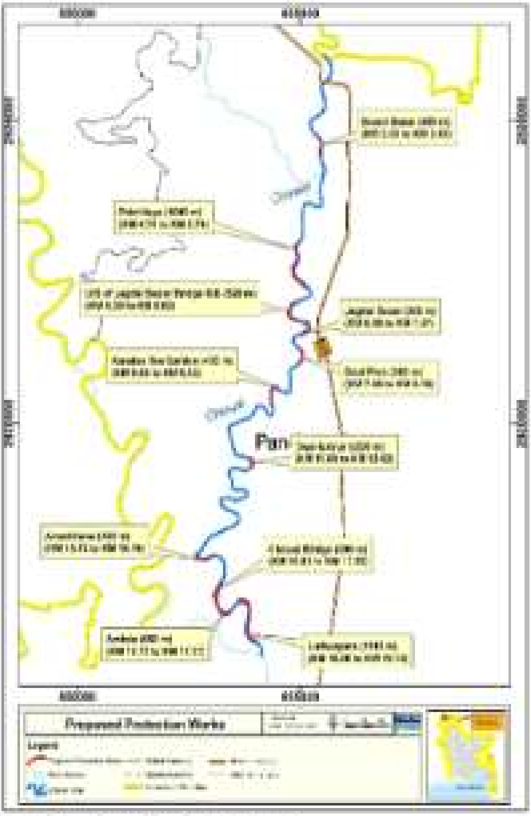

Figure 4.[illegible]: Proposed RTWs on the Chawai River

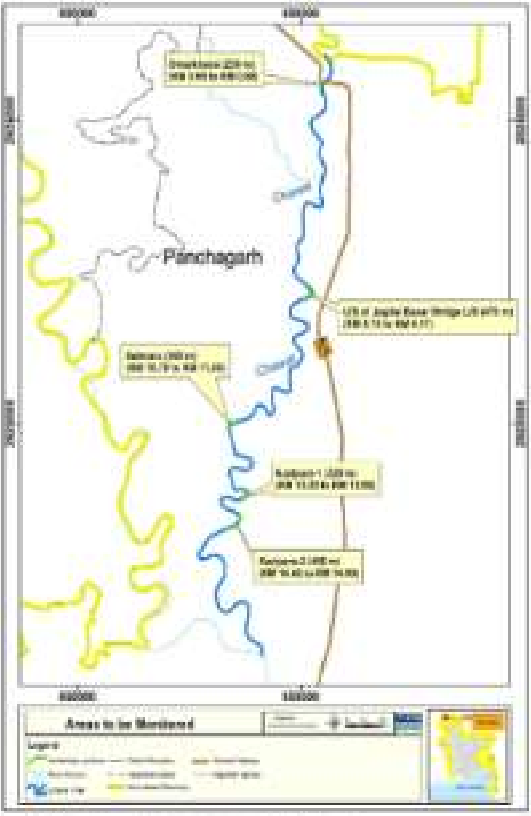

Figure 4.18.1a: Sites requiring close monitoring in Chawai River

Tirnoi River:

Morphological model has been developed and simulated for the Tirnoi River as well. Using the simulated bed level change for the design flood event, the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at

12 different locations. The location of the proposed RTWs has been shown graphically in **Figure 4.103**. **Table 4.20** shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 7.68 ha of lands from river bank erosion of Tirnoi River.

Table 4.20 Location and length of proposed RTWs of the Tirnoi River

Location	Upazila	Bank	Existing Chainage (m)	Length (m)
[illegible]	Tetulia	Left	13000	150
[illegible]		Right	19000	300
[illegible]		Left	20000	410
[illegible]		Left	22640	480
[illegible]		Right	33620	200
[illegible]		Left	35150	150
[illegible]		Right	37175	500
[illegible]		Right	40515	500
[illegible]		Right	42600	440
[illegible] Village		Right	43540	300
[illegible]		Right	46225	300
[illegible] Village		Left	48600	410
Total				3980

The design data of the Tirnoi river has been shown in **Table 4.21**.

[illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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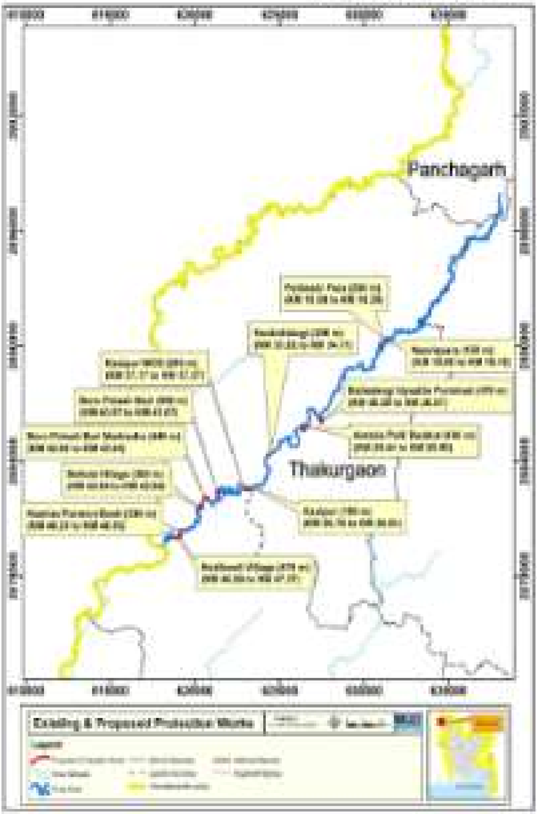


Figure 4.182: Proposed RTWs on the Tirnai River

Ghoramara River:

Based on the results of the morphological models, the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at 5 different locations. The location of the proposed RTWs has been shown graphically in **Figure 4.183**. **Table 4.33** shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 15.10 ha of lands from river bank erosion of Ghoramara river. Additional to these proposed RTWs, the locations that needs to be kept under close monitoring has been shown in **Table 4.33**. These locations are not yet on the top priority for RTW but the model simulations did show erosions which may cause some problem in the future. Hence these locations need to be kept under close monitoring for in the future.

Table 4.32 Location and length of proposed RTWs of the Ghoramara River

Location	Upazila	Bank	Starting Chainage (m)	Length (m)
[illegible]	Debiganj	Left	[illegible]	[illegible]
[illegible]		Left	[illegible]	[illegible]
[illegible]		Left	[illegible]	[illegible]
Mathabanga BGB		Left	[illegible]	[illegible]
[illegible]		Left	[illegible]	[illegible]
Total				[illegible]

Table 4.33 Locations that needs to be monitored of the Ghoramara River

SL.	Location Name	Length	Chainage Range	Bank	River	Remarks
1	Naudari-1	830	KM 4.27 to KM [illegible]	Right	Ghoramara River	Erosion prone Area facing Naudari Nowabganj Market near sharp bend
2	Naudari-2	200	KM 6.18 to KM 6.38	Right	Ghoramara River	Sharp Bend
3	Mathabanga BGB	1050	KM 6.75 to KM 7.80	Right	Ghoramara River	BGB Camp
4	Mathabanga LB	1110	KM 7.26 to KM 8.37	Left	Ghoramara River	Straight portion

Kulic River:

Morphological model has been developed and simulated for the Tangon River and using the simulated bed level change for the design flood event, the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at 6 different locations. The location of the proposed RTWs has been shown graphically in **Figure 4.134**. **Table 4.34** shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 3.47 ha of lands from river bank erosion of Kulic River.

Table 4.34 Location and length of proposed RTWs of the Kulic River

Location	Upazila	Bank	Starting Chainage (m)	Length (m)
[illegible]	Ranisankail	Right	27150	200
[illegible]		Left	31180	180
[illegible]		Right	35370	150
[illegible]	Haripur	Right	45050	200
[illegible]		Right	45130	50
[illegible]		Right	45280	130
Total				910

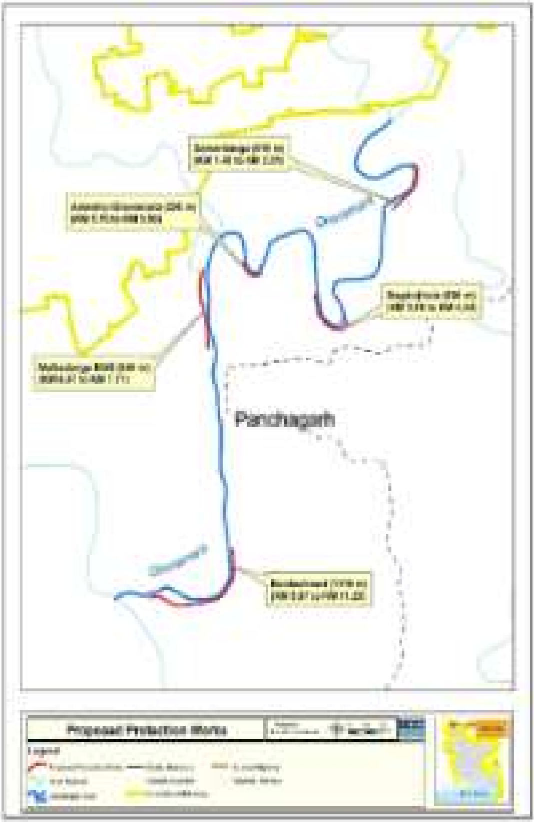


Figure 4.153: Proposed RPWs on the [illegible] River

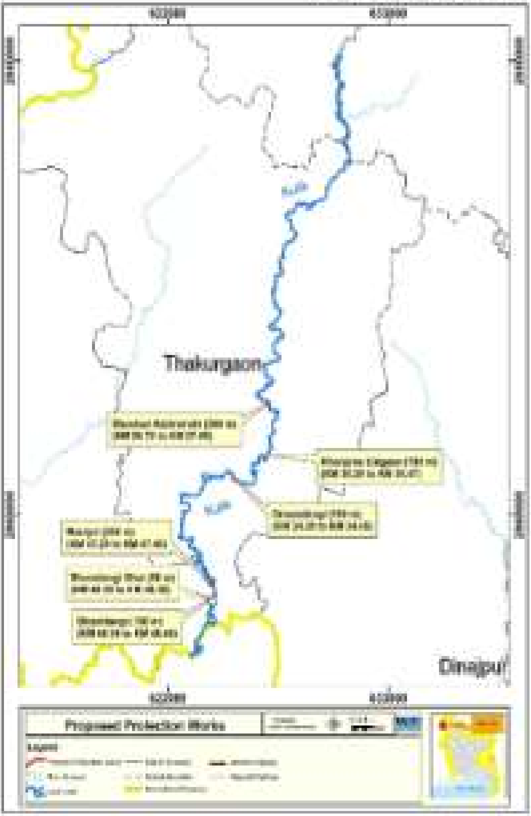


Figure 4.[illegible] Proposed RTWs on the Kulik River

Talma River:

Morphological model has been developed and simulated for the Talma River and using the simulated bed level change for the design flood event, the locations which appears vulnerable due to bank erosion has been identified. Later the vulnerable locations have been assessed in detail with existing settlements information and based on that RTWs has been proposed at 3 different locations. The location of the proposed RTWs has been shown graphically in **Figure**

4.135. Table 4.36 shows the locations and length of the proposed RTWs based on the detailed morphological model analysis. The proposed RTWs will protect 5.83 ha of lands from river bank erosion of Talma River.

Table 4.36 Location and length of proposed RTWs of the Talma River

Sl. No	Location	Upazila	Bank	Starting Chainage (m)	Length (m)	Priority
1	Hafizabad-2	Panchagarh Sadar	Left	15100	300	B
2	Kamatpara		Left	12850	480	A
3	Baraitola		Left	21800	300	A
4	Putia Mondalpara, Putiapara		Left	22600	240	A
5	Pathuapara		Left	23300	300	B
Total					1620	

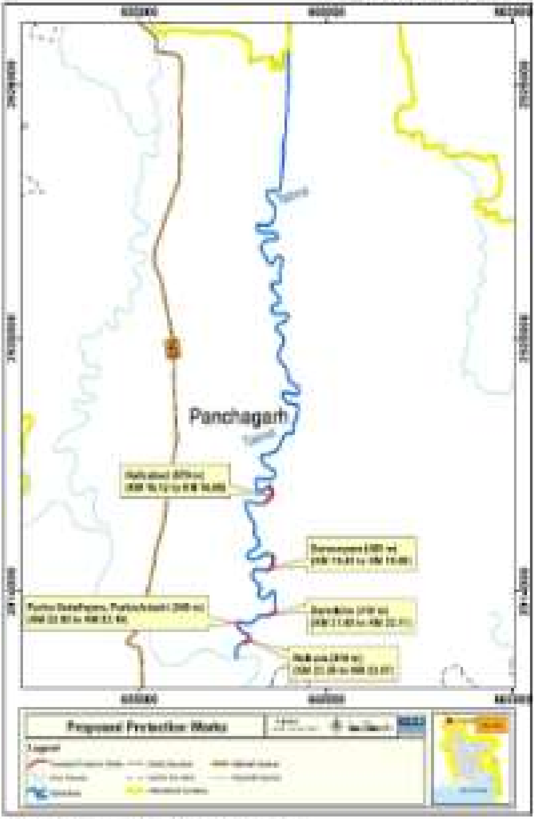


Figure 4.[illegible] Proposed RTWs on the Talma River

Additional to these proposed RTWs, the locations that needs to be kept under close monitoring has been shown in **Table 4.28**. These locations are not yet on the top priority for RTW but the model simulations did show erosions which may cause some problem in the future. Hence these locations need to be kept under close monitoring for in the future.

Table 4.36 Locations that needs to be considered at the Talma River

SL.	Location Name	Length	Chainage Range	Bank	River	Remarks
1	Hanri Ghat	295	KM 6.01 to KM 6.31	Right	Talma River	Sharp bend near a bridge and local town
2	Talma Bazar	285	KM 17.75 to KM 18.04	Left	Talma River	At Talma Bridge & Talma Bazar
3	Talma Bridge	230	KM 17.95 to KM 18.18	Right	Talma River	At Talma Bridge & Rajnagar Girls High School

Mahananda River:

Based on model simulation, vulnerable locations for the Mohananda river have been identified. Total 6.545 km of bank was found to be vulnerable to erosion for the Mohananda river. The details of which has been provided in **Table 4.37**. The location of the vulnerable site has been shown in **Figure 4.158**. However, Mahananda river acts as the border line between Bangladesh-India. Any interventions along this river would require co-ordination between Indian and Bangladesh authorities. Hence vulnerable location has been identified but no interventions has been proposed.

Table 4.37 Location of the vulnerable locations of the Mahananda River

ID	Start Easting (m)	Start Northing (m)	End Easting (m)	End Northing (m)	Length (m)
1	839508.14	2840307.33	838834.80	2840328.58	1273
2	836838.60	2841057.33	837083.81	2841082.78	930
3	836847.03	2840380.17	836854.21	2840117.54	810
4	839827.58	2838142.38	839480.01	2839183.28	880
5	838835.14	2837380.33	833327.18	2836733.82	246
6	835582.25	2836433.44	834180.75	2835842.78	1074
7	837849.41	2833187.86	834878.21	2833283.37	1266
Total					6545

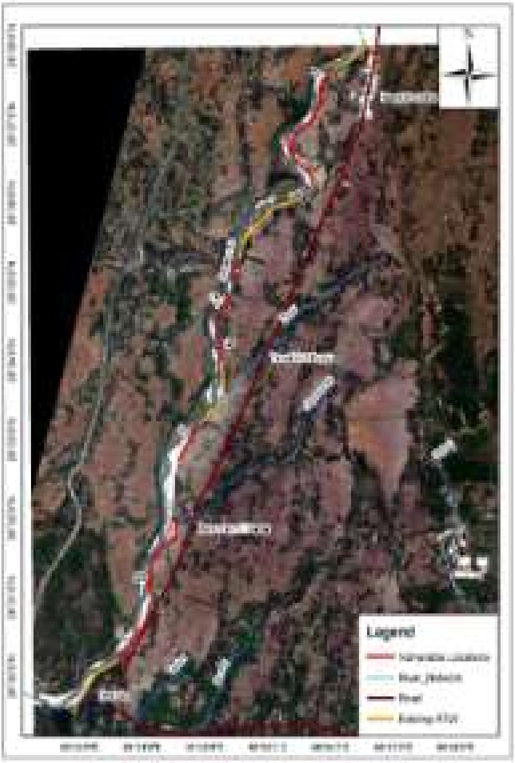


Figure 4.105: Vulnerable locations identified on the Mohananda river based on morphological model simulations

Other Rivers:

Based on model simulation, vulnerable locations for the Shuk, Vulli, Senua and Lacchi rivers have also been determined and after thorough inspection of the settlement information and land use data, RPW in 6 locations in these 4 rivers have been proposed. The details have been shown in **Table 4.33**. The proposed RTWs of these locations will protect 2.79 ha of lands from river bank erosion.

Table 4.28 Location and length of proposed [illegible] of the Shukh, Bhulli, Senua and Lachhi Rivers

River	Location	Upazila	Bank	Starting Chainage (m)	Length (m)
Shukh	Thakurgaon Road Station	Thakurgaon Sadar	Right	23465	600
	Thakurgaon Road Bazar		Right	22965	300
Bhulli	Bhulli Bazar		Left	6325	150
	[illegible]		Right	[illegible]	144
Senua	Salandar		Left	20705	200
Lachhi	[illegible]	Pirganj	Left	6600	170
	Total				1564

4.2.2 River Re-Excavation

ESIA studies which is being carried out by CEGIS has identified agricultural potential for 15 rivers. The list of the 15 rivers has been provided in **Table 4.38**. Among the 15 rivers identified as having agricultural potential, two (Nagor & Mohananda) are border rivers. A river that marks as the international border demarcation line would be difficult to re-excavate. Hence, Nagor & Mohananda rivers have not been recommended for re-excavation.

Five rivers (Buri-Teesta, Chawai, Shuk, Tirnai (Panchagarh), Tirnai (Thakurgaon)) has already been re-excavated under the 64 zila project. Since these rivers has been re-excavated very recently, no additional re-excavation for these rivers has been proposed. However, it is recommended that these rivers are kept in close monitoring to evaluate the re-siltation conditions of the rivers. While, Pathraj & Tangon river has been partially re-excavated under the 64 zila project.

Re-excavation has been proposed for the remaining six rivers, that is Kulik, Rangapani, Kurum, Dara, Kalidaho and Ronochondi. While designing the re-excavation scenarios, importance was given to existing infrastructures located in the river. No re-excavation was recommended near existing bridges and the bridges were used as natural humps to improve water storage capacity of the rivers, that can be used for agricultural & ecological purposes.

Table 4.38 Rivers with agricultural potential (Source: CEGIS) & remarks regarding the re-excavation status

Sl No	River Name	District	Remarks
1	Kulik	Thakurgaon	Re-excavation Recommended
2	Pathraj	Panchagarh, Thakurgaon	Partially re-excavated under 64 zila project. 7 km have not been re-excavated
3	Nagor	Panchagarh, Thakurgaon	Border River
4	Tangon	Panchagarh, Thakurgaon	Partially re-excavated under 64 zila project. 40km have not been re-excavated
5	Rangapani	Panchagarh	Re-excavation Recommended
6	Kurum	Panchagarh	Re-excavation Recommended
7	Buri Teesta	Panchagarh	Re-excavated under 64 zila project
8	Dara	Panchagarh	Re-excavation Recommended
9	Kalidaho	Panchagarh	Re-excavation Recommended
10	Chawai	Panchagarh	Re-excavated under 64 zila project
11	Mohananda	Panchagarh	Border River
12	Ronochondi	Panchagarh	Re-excavation Recommended
13	Shuk	Thakurgaon	Re-excavated under 64 zila project
14	Tirnai (Panchagarh)	Panchagarh	Re-excavated under 64 zila project
15	Tirnai (Thakurgaon)	Thakurgaon	Re-excavated under 64 zila project

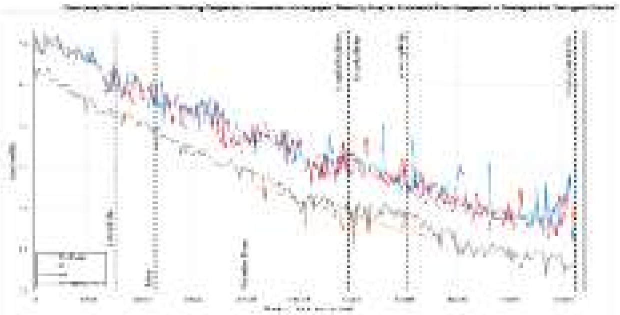
Kulik River

The long profile of the Kulik River along with the developed dredging profile has been shown in **Figure 4.187**. From the figure, it can be seen that the bed slope of the Kulik River has three distinct sections. The first section in the upstream portion up to [illegible] can be characterized with a high slope. While from [illegible] up to India border the bed slope of the Kulik River appears more gentler. The slope for the first 22 km up to [illegible] has been found as 35 cm/km. The second section extends from 22km to 40km chainage which has a slightly milder slope of 20cm/km. While for the last 10 km from 40km chainage up to Indian border, the bed slope was found to be 14 cm/km. When developing the dredging option, this slope calculations were taken into account. It is worth mentioning that the Kulik River is an ephemeral river which originates in the low lands. And re-excavating the first 22km of the river, did not have any significant hydraulic impact on the water availability of the Kulik River

Similarly, re-excavation of the final 10km of the river, only facilitates smooth drainage of the river flow towards India.

When devising the re-excavation plans for the Kulik River, priority was given to the dry season water storage capacity of the river. Re-excavation of the river near existing infrastructures like bridges, is always a difficult task. Hence the existing bridges within the planned re-excavation areas, where left as it is, to act as a natural hump to store water. Considering these fact, re-excavation was planned from 300m downstream of Mohammadpur Bridge (Chainage 20400m). For the next 5km, up to Sundhari Sarkar Para at chainage 25500m, 25 cm/km slope was maintained. For chainage 25500m to 26200m, no re-excavation was proposed to make the existing bed level of the Kulik act like a natural hump. The next re-excavation zone has been proposed between 26200m to 29200m, at a slope of 20 cm/km. This proposed re-excavation zone creates another water storage zone by creating another natural hump by not excavating between the two bridges near Ruhia. Re-excavation has been proposed again starting from 200m downstream of the Rabbashal bridge (29720m) up to 33500m chainage. 20cm/km of bed slope was proposed for the re-excavated sections here, which matches with the original slope of river bed when in the south. From 200m downstream of the Umarkhali Bridge up to 38400 chainage, another re-excavation zone has been proposed having 20cm/km longitudinal bed slope. No re-excavation has been proposed in the last 12.8 km of the Kulik River. The reason of not providing any re-excavation in the final 12.8km is dredging this region only provides smoother drainage for water, rather than storing it.

The model simulation results for the developed dredging option have been shown in **Figure 4.188**. The figure shows the water availability during the driest condition during an average hydrological event for both the base condition as well as the re-excavated condition. It can be seen from the figure clearly that the water storage within the river has increased substantially with the developed re-excavation option. Maximum increase of storage with the re-excavation scenario for each of the Storage zones of Kulik River has been shown in **Table 4.46**. Analyzing the storage capacity of the Kulik River for base and option condition, it can be seen that the water storage in the Kulik River may increase up to 55% due to the re-excavation.



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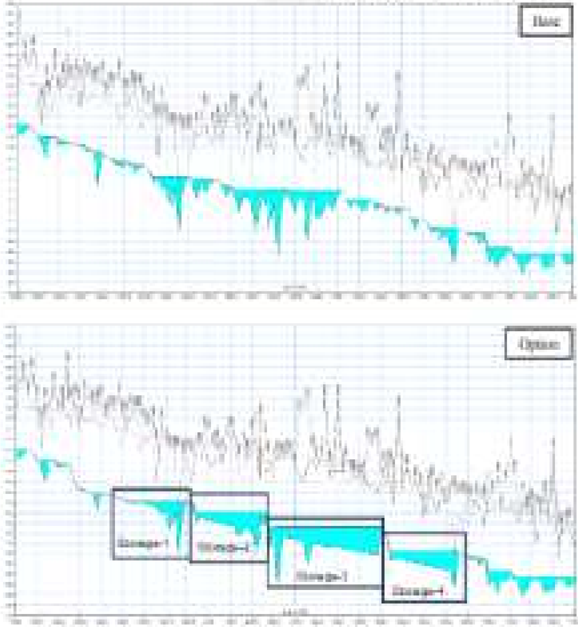

Figure 4.108: Model simulation results for the proposed Dredging Option for the Kulik River during dry season for average hydrological year simulations

Table 4.40: Increase in storage capacity of the Kulik River due to the developed re-excavation scenario

Storage Zone	Base Storage (m³)	Re-excavated Storage (m³)	% Increase
Storage 1	30487.35	32718.83	7.28
Storage 2	13606.9	25052.2	84.09
Storage 3	45453	55126.4	21.28
Storage 4	18851.2	44215.6	134.55
Overall	110317.16	152847.28	38.26

However, the created reservoirs of water storage would be subject to evaporation and percolation losses. Hence not all the water in the created water reservoirs with re-excavation, can be all extracted for other purposes. Considering 5 mm/day of percolation loss and using the evaporation loss data of the Thakurgaon station, a graph was generated to see the available amount of water in the reservoirs for different months for an average hydrological event. The analysis shows that the amount of available water falls drastically by the time of Boro cultivation. Hence it might be very ambitious to plan for using the storage water for cultivation during the dry seasons. However, Storage zone 3 does seem to have enough water storage available to carry out supplementary irrigation. The storage zone 3 extraction points near Umracdang Bridge (25°51'57.32"N, 88°15'13.37"E) could be extracted during supplementary irrigation period up to 1 cusec operating for 12 hours a day. However, for the other storage zones, not so much extractions can be made. For example, after incorporating the evaporation & percolation losses, the maximum possible extraction from Storage Zone 1 is 0.65 cusec, Storage Zone 2 is 0.28 cusec and Storage Zone 4 is 0.06 cusec operating at 12 hours a day. Realistically water extracted from Storage Zone-3 can be used for supplementary irrigation. And considering that 1 cusec extraction for 12 hours can be used to irrigate 28.92 hectors of area considering a duty of 735 Ha/m³.

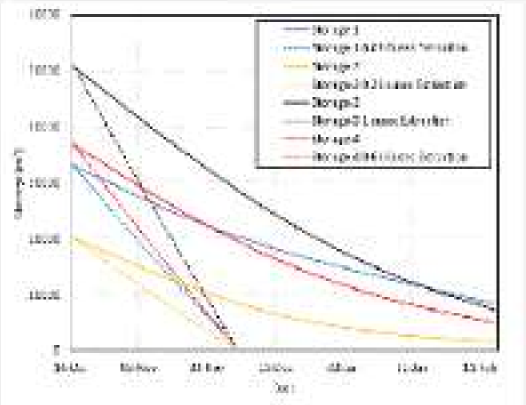

Figure 4.185: Available water at different storage zones with and without water extraction throughout the dry season

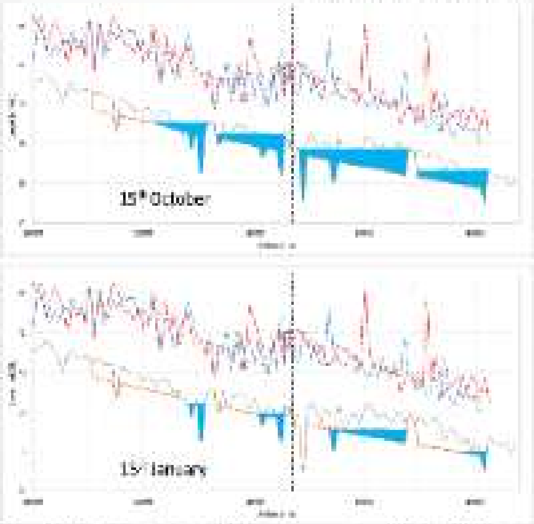

Figure 4.580: Available water within Kulik River after re-excavation in 15th October & 15th January during average hydrological event considering evaporation & percolation losses

The morphological model had also been prepared for the Kulik River to see the morphological response of the Kulik River due to the re-excavation. The re-siltation rate for all the re-excavation zones has been determined using the morphological model and shown in tabular format in **Table 4.41**. From the table, it can be seen that the re-siltation rate in the upstream reaches is higher comparing to the downstream reaches. After 3 years of simulation, the siltation rates for storage zone-1, 2, 3 & 4 was found to be 73.59%, 47.07%, 27.89% and 38.63% respectively. After 3 years it is estimated that around 117184.90 m³ of maintenance re-excavation might be required to reestablish the design water storage capacity.

Table 4.41: Increase in storage capacity of the Kulik River due to the developed re-excavation scenario

Storage Zone	Re-excavated Volume (m³)	Siltation Volume (m³)					
		Year 1		Year 2		Year 3	
		Volume	Silt Rate (%)	Volume	Silt Rate (%)	Volume	Silt Rate (%)
Storage 1	57051.50	13321.83	23.35	34983.42	46.03	39023.53	73.59
Storage 2	29824.28	7808.81	18.45	13809.03	28.75	20087.58	47.07
Storage 3	86465.26	34713.27	11.24	34713.27	18.20	34713.27	27.89
Storage 4	84415.80	24134.55	23.73	24134.55	34.20	24134.55	38.63
Overall	268836.84	79080.34	23.81	88352.47	29.56	117184.90	43.72

The model simulated thalweg after 3 years of model simulation has been shown in **Figure 4.191**. Although the thalweg of the Kulic River changes substantially after simulation of an extreme event the humps still persists in these transition zones. Only the hump of the zone-4 has been somewhat damaged by the passage of an extreme event (2017). Maximum BL change can be seen in the storage zone-1, where by the end of the 3rd year, we see that the thalweg of re-excavated option, becomes almost similar to the initial thalweg (i.e. Base Condition). As we go further downstream, we can lesser movements of the thalweg, with some portion of the dredging channel still remaining after 3 years, albeit with a bit lesser storage capacity.

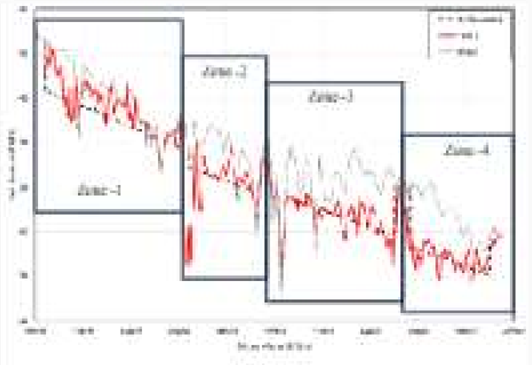

Figure 4.191: Model simulated thalweg for the re-excavated condition after 3 years of model Simulation

A closer inspection of the morphology of the humps indicate that the erosion of the humps generally initiates from the downstream end of the humps. **Figure 4.192** shows the changes of the outputs from the morphological model showing the change of the hump at Umradangi bridge after 3 years due to different scenarios. The figure shows that for created re-excavation profile, immediate upstream and downstream of the humps shows erosion trend. Initially a 300m stretch of the river was kept as a hump, but after 3 years, the hump reduced to only a tip of less than 50 m which looked vulnerable to being washed out as well (red line). Placing geobags, on the upstream side of the hump does increase the stability of the hump on the upstream side of the hump. However still erosion can be still seen on the downstream part of the hump (blue line). The sharp drop on the downstream end of the hump prompts higher velocity, resulting in higher stream-power of the Kulic River. Rather than protecting from this stream power, this stream power could be used to prompt a self-excavation of the Kulic River itself. Morphological model simulations were carried out creating a milder profile on the downstream end of the hump and the results are shown in **Figure 4.192**. 1:100 slope was used on the downstream end of the Umradangi hump. From the results it can be seen that the stream-power of the Kulic River has automatically re-excavated the provided milder slope of the humps of the river. Like previously, it can be seen that without providing geo-bags on the upstream side of the hump, generates erosion of the hump from the upstream end as well. But placing geo-bags on the upstream side of the hump, creates a more sustainable hump section, which lasts for more than 3 years.

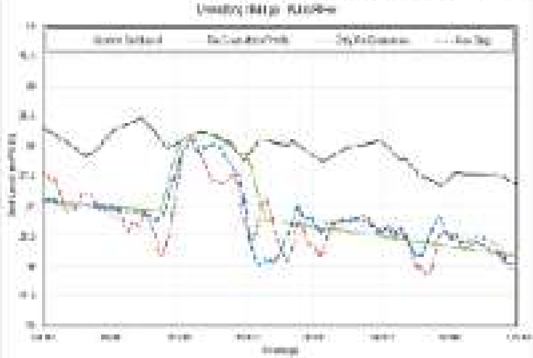

Figure 4.182: Morphological change of the hump at Umedabad bridge after 3 years due to different scenario.

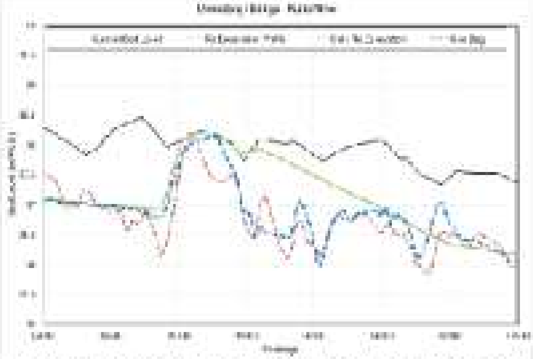

Figure 4.183: Morphological change of the hump at Umedabad bridge after 3 years due to different scenario after considering a milder d/s hump profile.

Rangapani River:

The long profile of Rangapani River along with the developed re-excavation profile has been shown in **Figure 4.184**. The long profile of Rangapani river shows two distinct sections, from downstream end, the first five kilometer of the Rangapani river is characterized by slightly milder slope comparing to the further upstream portion. It was found that the first five kilometer have a longitudinal bed slope of 42 cm/km. While further upstream the longitudinal bed slope of Rangapani river was found to be 1.48 m/km. Hence it was not deemed suitable to store water in the first few kilometers of the river. Two distinct sections were identified for storage based on the long profile and the presence of infrastructure. The storage zone-1 uses the Rangapani Bridge (333m upstream of river outfall) on Bhowaliganj-Debiganj road as a natural storage. 5m bed width and a side slope of 1:2 for the re-excavation of storage zone-1. Re-excavated cross-section super-imposed on existing cross-section of storage zone-1 has been shown in **Figure 4.195**. The second storage zone used the Tahsaltali bridge as a natural hump to store water between 3150m to 4063m chainages. 5m bed width and a side slope of 1:2 for the re-excavation of storage zone-2. Re-excavated cross-section super-imposed on existing cross-section of storage zone-2 has been shown in **Figure 4.196**. The created reservoir will be subject to evaporation & percolation losses and the available water in the storage zones at the end of October and at the end of January has been shown in **Figure 4.197**. The temporal available water at different storage zones after evaporation & percolation has been shown in **Figure 4.198** where it can be seen that the created storage dries up by the end of February. The figure also shows the maximum amount of water that can be extracted from the created storage during the supplementary irrigation period. And it can be seen that the maximum amount of water that can be extracted from the storage zone -1 and storage zone -2 is 0.1 cusec and 0.02 cusec respectively for 12 hours, corresponding to a total of 2.5 ha irrigable lands in the supplementary irrigation period. Hence establishing an LLP pump house is not recommended for the small amount of available water. The morphological model simulations shows that the re-excavation channels were subject to 11% re-siltation yearly.

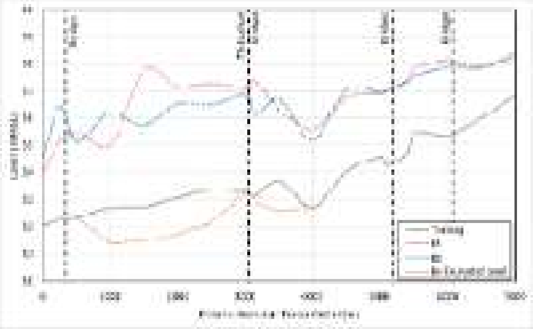

Figure 4.194: Proposed Re-Excavation Option for the Rangapani River

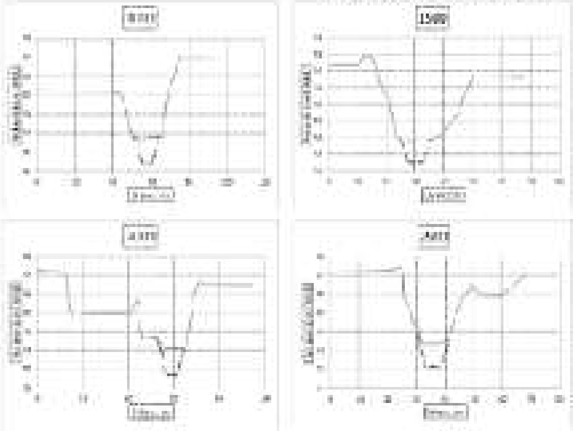

Figure 4.203: Proposed Re-excavation Option for the Rangapani River alongside zone-I

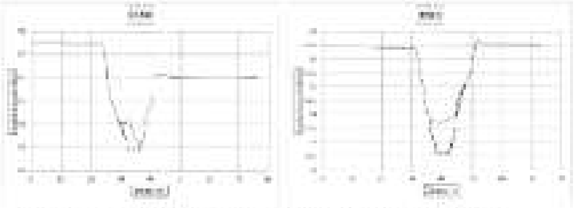

Figure 4.204: Proposed Re-excavation Option for the Rangapani River alongside zone-II

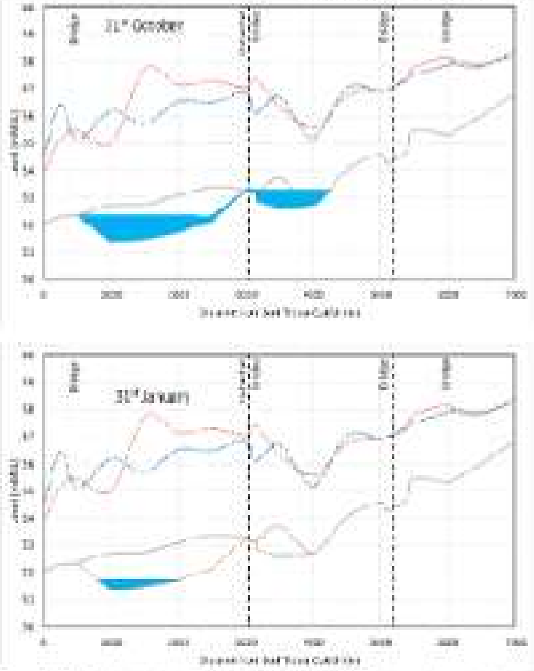

Figure 4.[illegible]: Available water in the storage areas at the end of October and January in a typical dry season

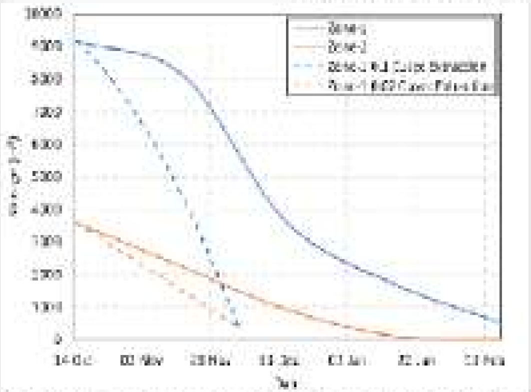

Figure 4.198: Temporal available water at different storage zones after evaporation & percolation losses

Dara River:

The long profile of Dara River along with the developed re-excavation profile has been shown in **Figure 4.199**. From the Buri Teesta outfall, up to the Bhawanipur-Debiganj bridge, Dara River shows very high bed slope. However upstream of the bridge, the existing bed slope is significantly milder (37 cm/km). For water store capacity, the Dara River on the upstream direction from the bridge has been recommended for re-excavation with the bridge acting as a natural hump to store water. 8m bed width and a side slope of 1:2 for the re-excavation on storage zone-2. Re-excavated cross-section super-imposed on existing cross-section of the storage zone has been shown in **Figure 4.200**. The available water in the storage zones at the end of October and December in a typical dry season for Dara River has been shown in **Figure 4.201**. From the figure it can be seen that the created storage through re-excavation can store water upto end of December. So, the proposed re-excavation can store water for two additional months. However, the created storage is not big enough to be used effectively for agricultural development. The morphological model simulations shows that the re-excavation is subject to 18% re-siltation on the first year.

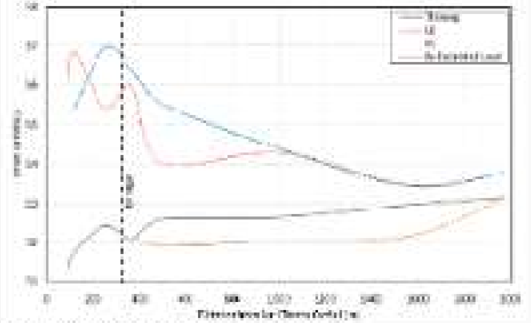

Figure 4.208: Proposed Re-Excavation Option for the [illegible] River

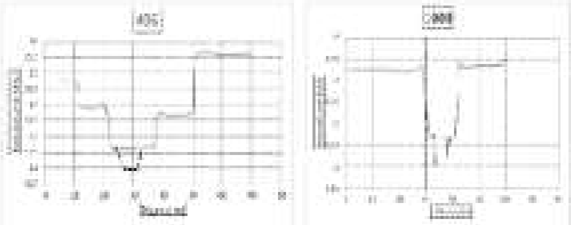

Figure 4.209: Proposed Re-Excavation Option for the [illegible] River storage zone

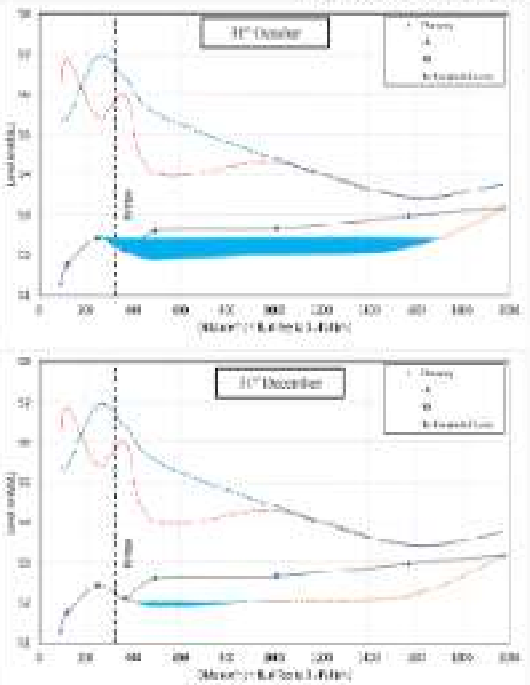

Figure 4.281: Available water in the storage zones at the end of October and December in a typical dry season for Dara River

Kalidaha River

The long profile of Kalidaha River along with the developed re-excavation profile has been shown in **Figure 4.282**. The overall bed slope of the Kalidaha river was found to be around 35 cm/km. However, near the Karatoa confluence, the river does seem to have big scour holes. Between the Chaturadangi bridge and Baudadanga bridge, the river bed slope is around 67 cm/km and this area was identified as potential water storage zone. Hence the proposed re-excavation zone for storage is between the two bridges located on the Kalidaha river, the Chaturadangi bridge and Baudadanga bridge. The proposed re-excavation bed width was proposed to be 12 m with a longitudinal bed slope of 67cm/km. The side slope of the proposed re-excavation was 1:2. Re-excavated cross-section super-imposed on existing cross-section of the storage zone has been shown in **Figure 4.283**. The water storage capacity of the Kalidaha river between the Chaturadanga bridge and Baudadanga bridge may increase by around 1000%.

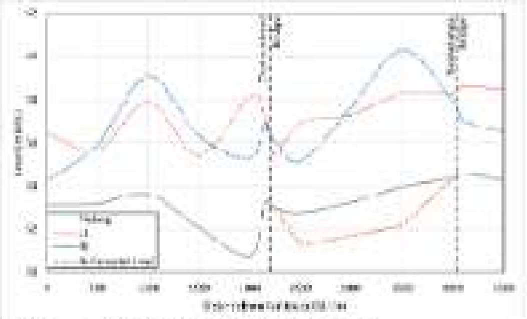

Figure 4.282: Proposed Re-excavation Option for the Kalidaha River

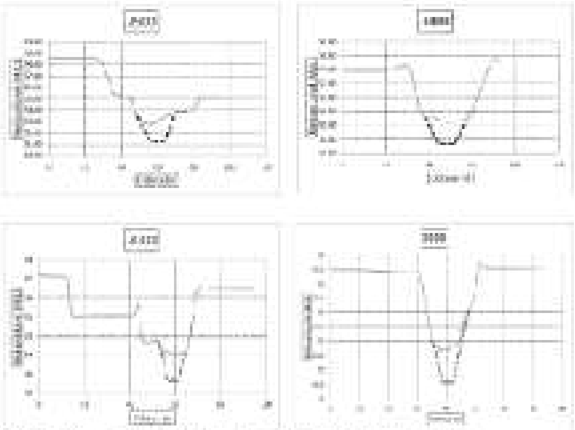

Figure 4.283: Proposed Re-excavation Option for the Kalidaha River storage zone

However, the reservoir created via the re-excavation scenario will be subject to evaporation and percolation losses and incorporating these losses, it can be seen that the water in the created reservoir would be present till April if no extraction from the reservoir is carried out. The available water in the storage zone at the end of October and end of April in a typical dry season for Kalidaha River has been shown in **Figure 4.284**.

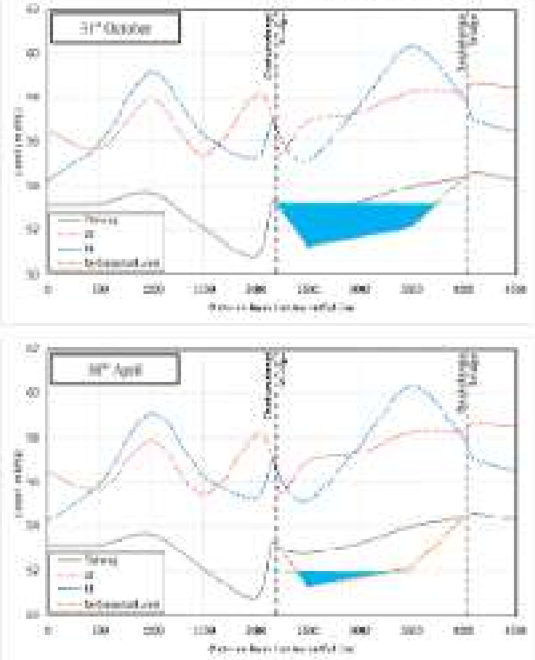

Figure 4.386: Available water in the storage zone at the end of October and April in a typical dry season for Kalidaha River

The temporal available water in the storage zone after evaporation & percolation losses has been shown in **Figure 4.386**. It can be seen that the storage zone still has enough water until April in a typical dry event, if no water is extracted from that reservoir. However, water extraction is carried out from the reservoir, maximum of 0.62 cusec of water can be extracted 12 hours daily from the reservoir, to meet the demand of supplementary irrigation. If that extraction is carried out then, 13 ha of lands can be brough under supplementary irrigation. However, it is not recommended to establish an LLP irrigation scheme since around only 0.65 cusec of water can be extracted for 12 hours daily.

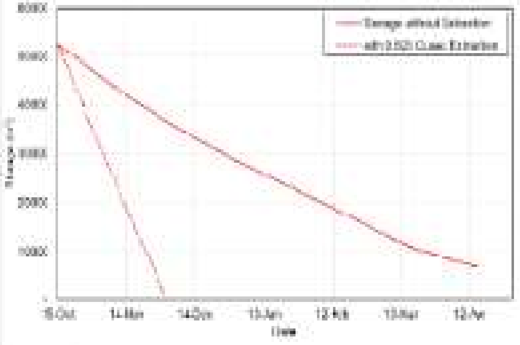

Figure 4.205: Temporal available water for the storage zone of Karatoa River after evaporation & percolation losses and with 2.628 cusec extraction

Ronochondi River:

The long profile of Ronochondi River along with the developed re-excavation profile has been shown in **Figure 4.206**. Three specific storage zone has been created u/s of Bonmrid structure (Storage-1), between Bonmrid structure and the bridge at 3000 chainage (Storage-2) and upstream of Ronochondi Bazar bridge (Storage-3).

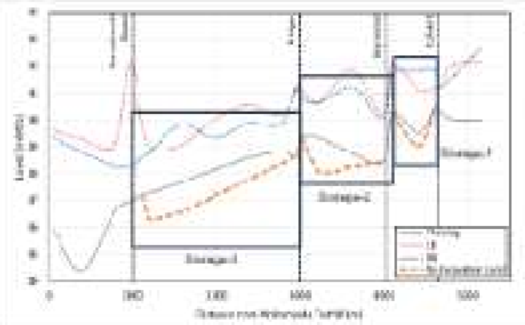

Figure 4.206: Proposed Re-Excavation Option for the Ronochondi River

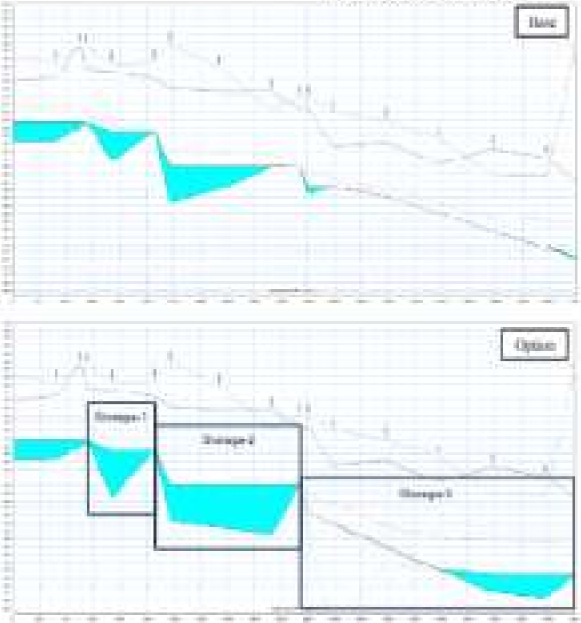

Figure 4.207: Model simulation results for the proposed Re-Excavation Option for the Ronochondi River during dry season for average hydrological year simulations

The model simulated water availability at all the storage for the re-excavation option model has been during dry season for average hydrological year simulation has been shown in **Figure 4.207**. The increase in water storage capacity of the Ronochondi river at different storage zones has been shown in **Table 4.42**. From the table it can be seen that the water storage capacity of the Ronochondi River increases by 281% for the proposed re-excavation scenario.

Table 4.42: Increase in storage capacity of the Ronochondi River due to the developed re-excavation scenario

Storage Zone	Base Storage (m³)	Re-excavated Storage (m³)	% Increase
Storage 1	1222.73	1808.08	47.9%
Storage 2	1979.93	6675.13	237.10
Storage 3	144.72	3462.55	2270.27
Overall	3346.73	12267.13	281.32

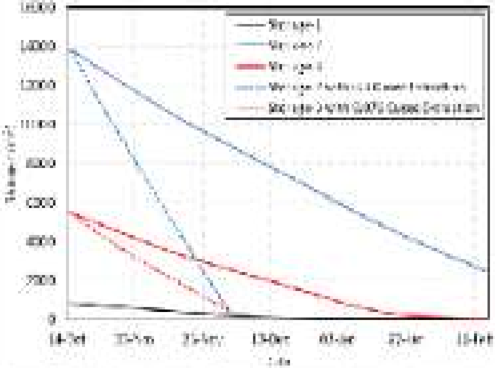

Figure 4.208: Available water at different storage zones with and without water extraction throughout the dry season for Rohochonda River

The developed reservoirs with re-excavation are subject to evaporation and percolation losses. Considering these losses possible extraction for each of the storage zones has been calculated. It has been found that Storage zone 1 (U/S of Bommlot structure) would dry out within January of an average hydrological year. From Storage zone-2, 0.3 cusec of water can be extracted 12 hours daily to fulfil the supplementary agricultural irrigation requirements. Considering the duty of 738 ha/m^3/s for supplementary irrigation, the extracted water can help irrigate 6.28 ha of lands. Similarly, around 0.075 cusec water can be extracted 12 hours daily from storage zone 3, which can provide supplementary irrigation to 1.58 ha of land. In total the, re-excavated water storage should be able to provide supplementary irrigation to 7.86 ha of land. However, it is not recommended to establish an LLP pump house in Rohochonda river since it would not be able to provide too much benefit compared to the cost. However local people can still utilise the water for their needs.

Kurun River:

The long profile of Kurun River along with the developed re-excavation profile has been shown in **Figure 4.209**. Five separate pockets of water storage zones have been created with this re-excavation option to store water in this seasonal river. However, the stored water is subject to evaporation & percolation losses, which has been portrayed in **Figure 4.210**, which shows that zone 1, 2, 3 & 4 becomes almost empty by the end of February of an average dry event. Only some water can be seen to be remaining in Zone 5. The amount of water stored after evaporation & percolation losses in the Kurun river for different storage zone has been shown in **Figure 4.211**. And it can also be seen from the figure that only in zone-5, some water can be extracted for supplementary irrigation. And from the zone-5, 0.58 cusec of water can be extracted for 12 hours daily. This amount of extraction can help to irrigate around 12 ha of land during supplementary irrigation period. However, again, it is not recommended to establish an LLP pump house in Kurun river since it would not be able to provide too much benefit compared to the cost. However local people can still utilise the water for their needs.

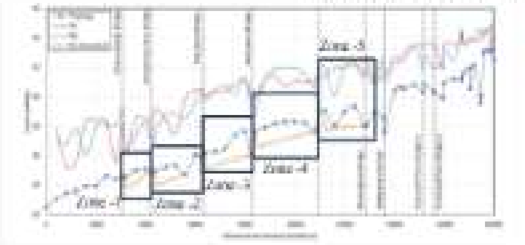

Figure 4.209: Proposed Re-Excavation Option for the Kurum River

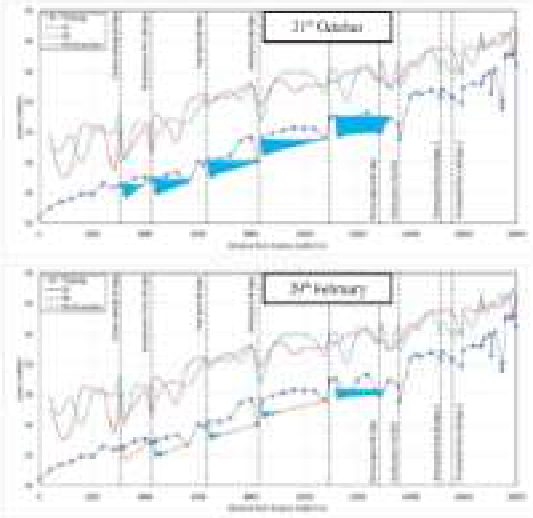

Figure 4.210: Available water in the storage zone at the end of October and February in a typical dry season for Kurum River

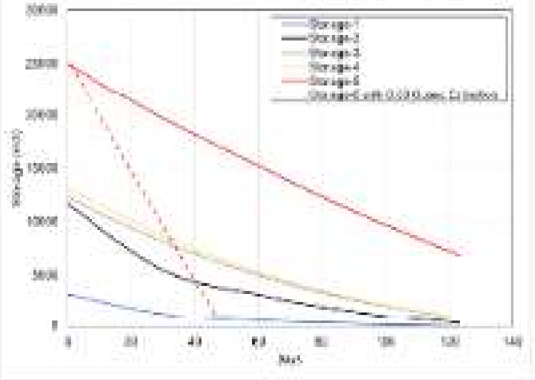

Figure 4.311: Available water at different storage zones with and without water extraction throughout the dry season for Kurum River.

Pathraj River:

Under the 64 zila project, the Pathraj river starting from Boda bridge upto the outfall has been re-excavated. Only the first 7 km of the Pathraj River has not been re-excavated. The partially functional water control structure of the Pathraj river is situated in this reach. The long profile in this reach has been shown in **Figure 4.313**. In the long profile it can be seen that the area just upstream of the Pathraj WCS, appears to be silted up. To increase the water retention capacity of the water control structure, re-excavation of 800m of the river starting from 200 to 1000 chainage has been proposed to be re-excavated.

Senua River:

As mentioned previously in **Section 4.1.10**, the sill level of the Basadebi structure was found to be higher than the ground level of the adjacent area. Multiple analysis was carried out to address the issue which are shown in detail in **Section 10.2**. Re-excavation of the Senua River was deemed to be the most effective option for solution for the problem. 6 km of re-excavation of the Senua River was proposed to increase the storage capacity of the river. The re-excavation profile has been shown in **Figure 4.312**. From the figure it can be seen that re-excavation has been proposed from Boikunthopur Bridge to Basadebi structure with Chandlong Bridge acting as an intermediate hump. On the d/s side of the Boikunthopur Bridge, milder slope of 1:100 has been provided as it was found previously that milder slope of the d/s side of a hump promotes self-excavation of the channel. 16 cm/km longitudinal slope was provided for the bottom level of the re-excavation channel. The re-excavation along with the Basadebi combined water control structure (WL maintained at 50.15 mMSL) would allow to store 48,000 m^3 of water in the created reservoir.

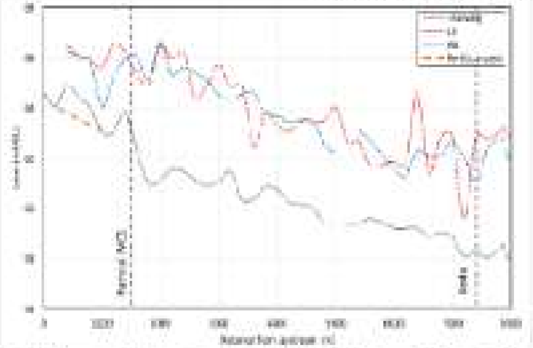

Figure 4.312: Long Profile at the upstream reach of Dahuk River & proposed Re-Excavation Option

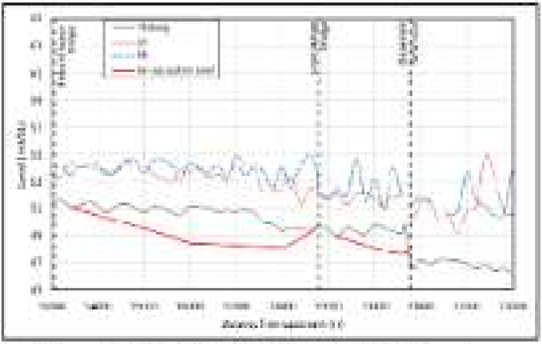

Figure 4.313: Long Profile near the proposed re-excavation reach of the Sanua River

Figure 4.308 shows the available water in the storage zone at the end of October and April in a typical dry season for Sanua River if no water is withdrawn from the reservoir. It can be seen that the reservoir can store water up to end of April if no water is withdrawn from it. However, if 1 cusec water is withdrawn from the reservoir during Boro season, the reservoir can supply for 34 days before drying out. But the structure has more use in case of supplementary irrigation. With 1 cusec pump, the reservoir can supply for 46 days and 2 cusec pumps being able to support supplementary irrigation for 23 days. With the average annual consecutive non-rainfall days being around 18 days, it can be assumed that 2 cusecs of water can be withdrawn from the reservoir during supplementary irrigation period covering 42 ha of area during supplementary irrigation period.

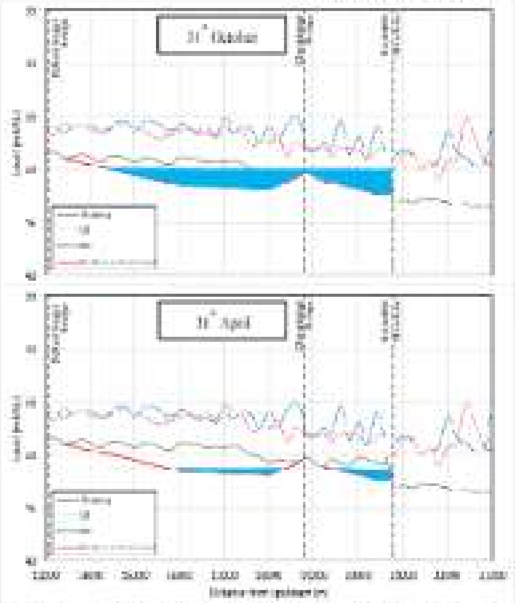

Figure 4.214: Available water in the storage zone at the end of October and April in a typical dry season for Sanua River (the water is [illegible])

It is estimated that the re-excavation would generate around 196,000 m³ re-excavation materials. As shown later in **Section 10.2** & **Figure 10.14**, the land level upstream of the Basadebi structure is around 1.5m lower than the weir crest level. The re-excavated material can be used to elevate the land level of this region to ensure that this land does not get inundated if water stored up to weir crest level. **Figure 4.215** shows the possible Re-excavated material deposition site u/s of Basadebi Combined Water Control Structure. Two distinct locations have been shown in the Figure, Zone A and Zone B which has an area of 2.81 ha and 3.71 ha respectively. If on an average 0.7403m (29.1 inch) re-excavated earth is deposited at this location, in total 48,300 m³ of re-excavated material can be managed in these two locations.

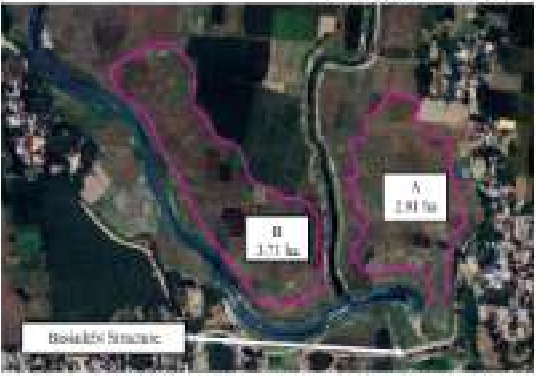

Figure 4.215: Possible Re-excavated material deposition site u/s of Boaladabi Combined Water Control Structure.

The re-excavated material can be deposited in both the storage zone to ensure that the land stays inundation free due to the structure. Possible Re-excavated material deposition site between Charadangi Bridge and Boikunthopur Bridge has been shown in **Figure 4.216**. The zone identified as C, D, E and F are lands which are generally inundated during the flash floods as a result of higher rainfall but mostly stays inundation free. Further downstream near the Boikunthopur Bridge, the existing ground level is relatively higher comparing to the HFL of the study area. Hence for re-excavation material management the lands closer to the Charadangi Bridge is more suitable. The area of zone C, D, E and F is 13.75 ha, 10.46 ha, 3.30 ha and 2.18 ha respectively. Hence the total area is 37.70 ha in those zones. If 0.2136m (8 inch) deposition is carried out throughout the show regions 77,816 m^3 of re-excavated earth can be managed in these locations.

To manage this re-excavated earth following this method, total 44.31 ha land would be required. However, if more than 8 inch of earth is deposited in zone C, D, E & F then the required land can be decreased as well. In case the land used for managing the re-excavated earth, crop compensation of 1.20 lac taka per ha of land used per year. Hence for 44.31 ha of lands around 53.17 lac taka has to kept for crop compensation purpose. It is recommended to keep the crop compensation for 3 years in the DPP depending on the situation of the field. Hence around 1.60 Crore Taka has to be kept in the DPP for crop compensation due to re-excavated earth management.

Another alternative approach could be constructing a dike along the bank of the river where re-excavation has been carried out. Since the region is subject to flash floods, the constructed dike would also have a positive impact in maintaining the water within the banks. It is also worth mentioning the surrounding lands does get inundated when the gates of the Boaladabi structures are closed. Hence constructing a dike could also keep the water out of these low-lying areas.

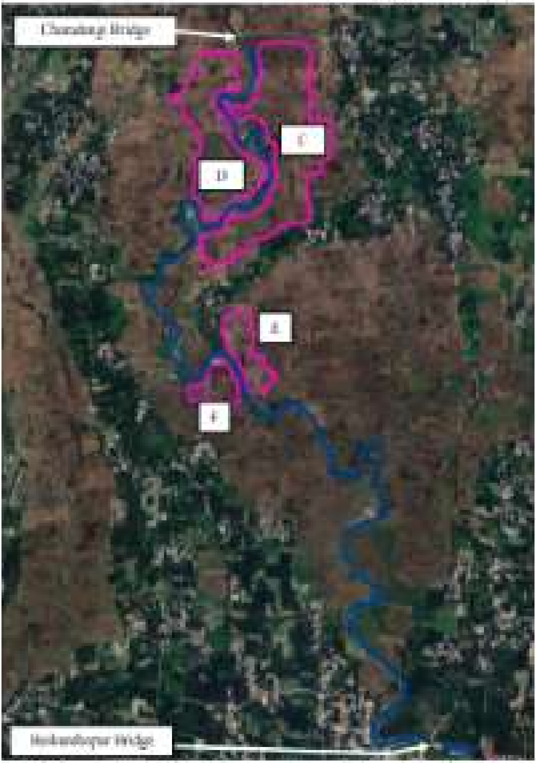

Figure 4.218: Possible Re-excavated material deposition site between Chandang Bridge and Mukundapur Bridge

4.2.3 Combined Water Control Structure at Kaliganj

It can be seen from the mathematical model simulations that the available water depth near the now non-functional Boalmari (Electric Block -1) pump house is not sufficient if that pump house has to be revitalised. Historically 16 pumps of 4 cusec each (64 cusec total) operated in the Boalmari pump house providing irrigation to 680 hectares of irrigable lands. Looking at the water availability of the Karatoa river at Boalmari Bazar, 64 cusecs of water can be extracted from the Boalmari point of Karatoa, however the available water depth needs to be increased if that is to happen. To increase the water depth, it was assessed that a combined water control structure would be required. In this respect the planform of the Karatoa River was assessed downstream of the Boalmari pumphouse and the historical planform change has been shown in **Figure 4.217**.

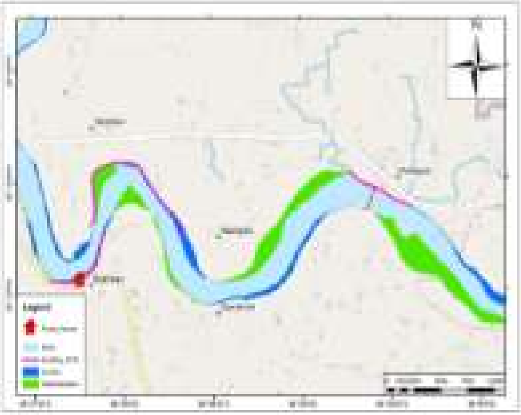

Figure 4.217: Historical planform changes of the Karatoa river downstream of Boalmari Bazar

Looking at **Figure 4.217**, it can be seen that between Boalmari and Koliaganj , the bankline of the Karatoa river is unstable, with lots of historical bank erosion present there. The site near Koliaganj is one of the stable reaches there. The presence of river training works on the left bank near Koliaganj have stabilized the bankline of Karatoa River in this reach. Considering this, a combined water control structure has been proposed at this location.

Sill Level

One of the major challenges in designing the combined water control structure is setting the sill level of the structure. Multiple trials were carried out to set the sill level of the structure. Setting the sill level too high, increases the highest flood level of the influence zone due to the afflux generated by the water control structure. While too low sill level might not head up the water surface as needed to maintain the water depth required at the Boalmari pump house. After testing the models with multiple sill levels, finally a sill level of 38.5 mPWD was set for the combined water control structure, which ensures a water depth of 1.05m near the Boalmari pump house for 90% dependable flow conditions. The Flood inundation map for the combined water control structure with 38.5 mPWD sill level has been shown in **Figure 4.218**.

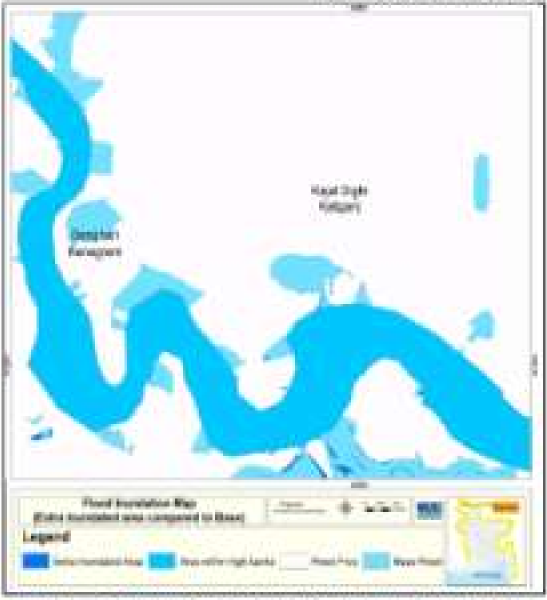

Figure 4.218: Flood inundation map during peak flood near the proposed combined water control structure for sill level of 56.0 mPWD

Figure 4.219 on the other hand shows the inundation during dry season when the gate of the combined water control structure is closed off. It is important for the weir crest level of the proposed structure to be below the existing ground level of the adjacent area to prevent flooding due to the gate closure. In the case of the proposed combined water control structure at Kaliaganj, the sill level of 56.0 mPWD (55.54 mMSL) was found to be below the existing ground level of the adjacent area and it did not cause any flooding of the lands around the structure as shown from **Figure 4.219**.

Figure 4.220 shows difference in the velocity due to the proposed combined water control structure, which shows around 0.58 m/s increase in velocity just after the weir portion of the structure. Further downstream, near the d/s termination of the Kaliaganj BPW, the velocity has increased by 0.18 m/s and similar story can be seen near Barpatia where the velocity increased by around 0.33 m/s. The influence of the weir can be seen almost as far as Autaghat (4200m d/s from the structure), after which the velocity becomes similar to that of base condition.

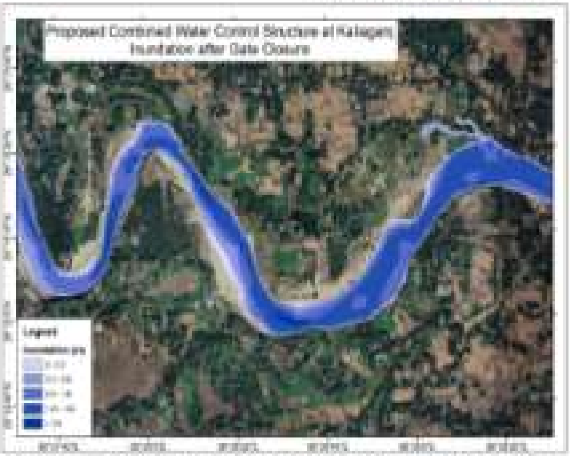
Proposed Combined Water Control Structure at Kaligonj
Inundation after Gate Closure
Legend
Inundation (m)

Figure 4.219: Inundation map for the proposed combined water control structure for sill level of 55.5mPWD after gate closure during dry season.

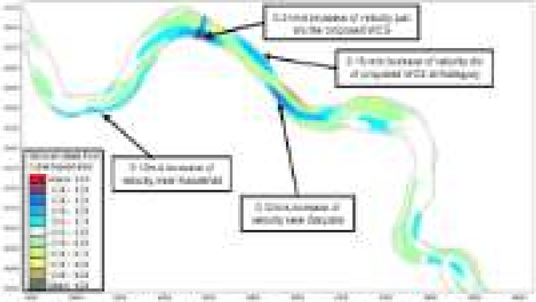

Figure 4.220: Difference in the velocity due to different the proposed combined water control structure.

Afflux

The maximum afflux during the design flood event (2017) was found to be 0.15m for the proposed combined water control structure with sill level of 55.5mPWD. Around 5 cm of afflux can be seen around 8km u/s of the proposed water control structure near Boalmari Bazar. The afflux reduces further towards upstream with around 1 cm afflux occurring around 8km u/s of the proposed water control structure. The simulated maximum water surface elevation during design flood event (2017) for the base and proposed WCS option has been shown in **Figure 4.221**.

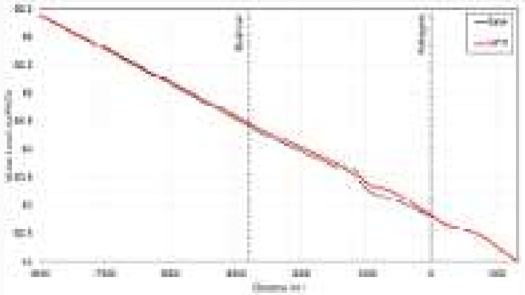

Figure 4.221: Simulated maximum water surface elevation during design flood event (2017) for base condition and WCS option

Siltation due to the proposed Water Control Structure

The placement of a cross structure in the river would not only increase the water head during dry season, but also invite sedimentation u/s side of the proposed structure. The simulated long profile for the siltation that occurred due to the proposed water control structure with 58.5m sill level has been analysed. The morphological model has been simulated for 3 years and the thalweg near the proposed water control structure has been shown in **Figure 4.222**. It can be seen from the figure that after 3 years of model simulations, the model simulated bed level changes showing an erosion tendency, with around 1m excess erosion occurring due to the WCS just downstream of the structure. Further upstream a steady deposition trend can be seen with some spikes of erosion near the bends.

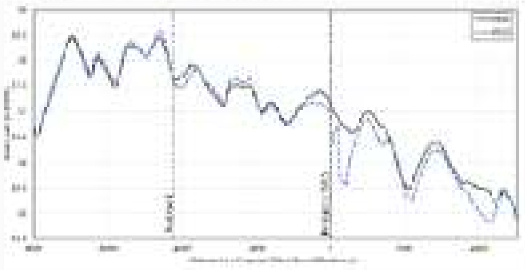

Figure 4.222: Simulated thalweg after 3 year of morphological model simulation for base condition and WCS option

To quantify the deposition in the Karatoa river due to the construction of the WCS, the storage capacity of the Karatoa river in the u/s side of the proposed WCS has been assessed and presented graphically in **Figure 4.233**. During the normal flood years (Year 1 and Year 3) the average reduction of storage capacity due to sedimentation is around 7500 m³. However, it can be seen that during the extreme flood event (Year 2), the storage capacity reduced by around 43,000 m³, indicating the high morphological activity during the extreme flood events. Over the period of 3 years, the storage capacity of the Karatoa river reduced by 58,000 m³.

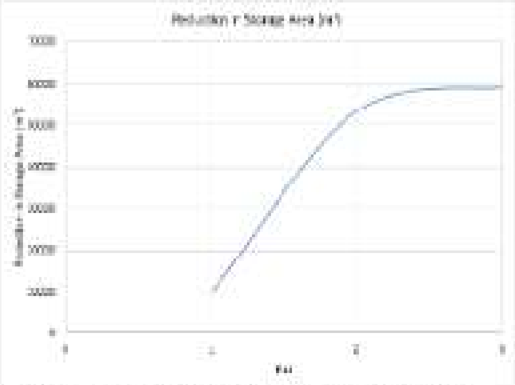

Figure 4.233: Reduction in storage area due to sedimentation for the Proposed WCS

Irrigable Area

The water can be withdrawn with historical capacity of the Boalmari pump house (16 pumps with 4 cusec each, total 64 cusec). Considering an efficiency of 0.83 with the pumps operating for 12 hours, it was determined that the duty for supplementary irrigation period was 733 ha/m³/s and for dry season 264 ha/m³/s. So, with 64 cusecs of water extraction the Boalmari pump house would be able to irrigate 665 ha during supplementary irrigation period and 237 ha dry irrigation period.

Potential Low-cost Alternative

Comparing to the cost of the water control structure, the benefits are not that substantial for the Kaliaganj combined water control structure. A more detailed analysis of the agricultural potential for the Kaliaganj combined water control structure needs to be carried out to see if the structure can provide more benefits other than just the Boalmari pumphouse. There could be potential low-cost alternatives like re-excavating a channel to divert water and provide the necessary water depth near the pumps. A similar situation is present near the Ahmednagar pumphouse, where the re-excavated channel provides the necessary water depth as shown in **Figure 4.234**. Similar thing can be carried out near the Boalmari pump house to keep it operational with periodic re-excavation.

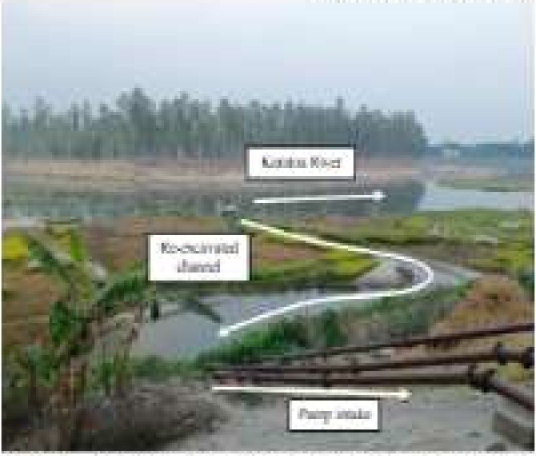

Figure 4.224: Re-excavation channel to carry out pump operation at Ahmednagar Pump House

Considering this the construction of the water control structure at Kaliganj has been considered as priority 3, in the phasing for sustainable river management.

4.3.4 Combined Water Control Structure at Machhintopur, Tangon River

The historical planform changes downstream from Thakurgaon has been shown in **Figure 4.225**. From the figure it can be seen that the Ramdara khal meets with the Tangon river just 1400m downstream of the Tangon bridge at Thakurgaon. From the field visit, it was seen that Ramdara khal discharges the wastewater from Thakurgaon city area. So, water retention downstream of the Ramdara khal would require treatment of the water hence is not recommended. Hence any water control structure near the Thakurgaon city, has to be constructed upstream of Ramdara khal. Just upstream of the Ramdara khal, near Machhintopur (shown in white box), on the right bank the land is relatively more open i.e. less built-up area. To store water near Thakurgaon city, this site near Machhintopur seems more appropriate. Although some erosion can be seen at this site, hence river training works will be required at this site.

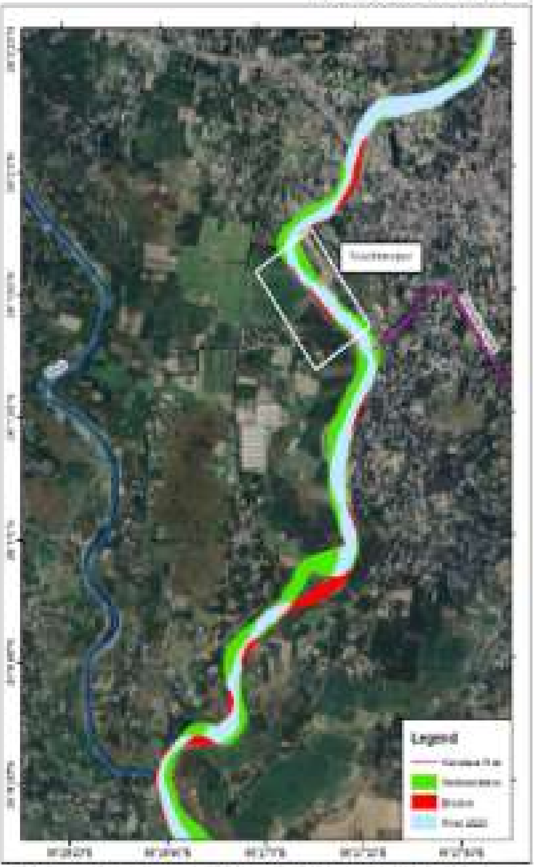

Figure 4.222: Historical planform changes of the Tangon River downstream of Thakurgaon

From the long profile of the Tangon River near the proposed Water Control Structure near Nischintapur has been shown in **Figure 4.226**. The sill level of the proposed water control structure has been set at 47.34 mMSL (47.30 mPWD). It can be seen from the long profile that the sill level of the weir is located below that bank level of the adjacent regions. The effect of the structure could also be observed in the Senua River, especially downstream of its

Bastobidi structure. The long profile of Sanua River & created backwater profile due to the proposed WCS near Nischintapur has been shown in **Figure 4.227**. It can be seen from the Figure that water would be stored in up to 5 km of the Sanua River, and the reservoir would be able to store rainwater in the monsoon season. The soil bearing capacity at the proposed structure location is shown in **Figure 4.228**.

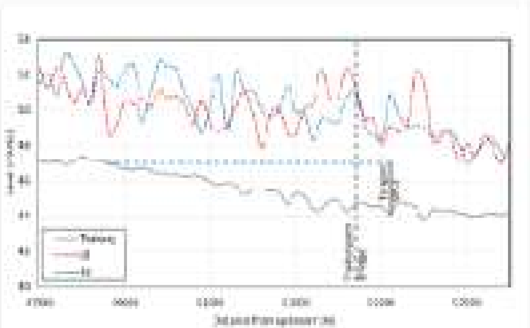

Figure 4.226: The long profile of Tangon River near the proposed WCS near Nischintapur

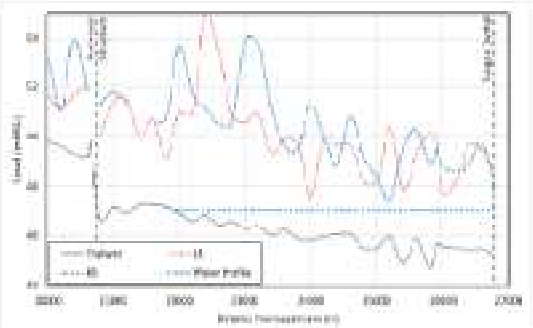

Figure 4.227: The long profile of Sanua River & created backwater profile due to the proposed WCS near Nischintapur

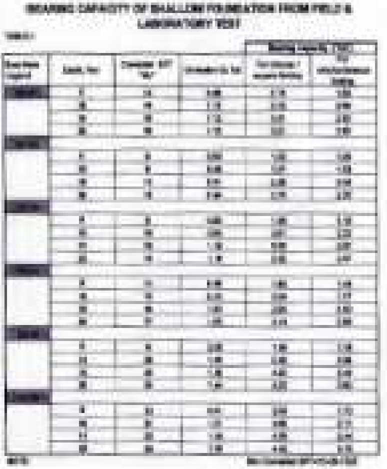

Figure 4.228 Soil Bearing Capacity of Shallow Foundation from field & laboratory test

Afflux

Figure 4.229 showcases the model simulated maximum and minimum water level of the Tangon River near Thakurgaon. The Maximum afflux during the design flood event (2017) was found to be 0.10m for the proposed combined water control structure with sill level of 47.64 mMSL (47.30 mPWD). Influence of afflux during monsoon can be seen as much as 6.5km. During the dry season the water control structure can increase the depth by as much as 2.20m near the water control structure location. And the under the influence of the WCS, water level increases for as much as 5.15 km in the dry season.

Possible Irrigable Area

It is estimated that the WCS structure would create a reservoir of 42,000 m³ in the Tangon river. In addition to that it is estimated that 35,000 m³ of water can be stored in the Senua River due to the effects of the Nischintopur Water Control Structure. So, a total of 77,000 m³ more water can be stored within the river comparing to base condition. Which means that during supplementary irrigation period, in case of lack of rainfall, 2 cusec of pump (operating for 10 hours) can provide supplementary irrigation for 16 days. If 3 cusec pump (operating for 10 hours) is used, the stored water can provide irrigation for 22 days. So, during supplementary irrigation period up to 66 ha of lands can be irrigated using the stored water in case of lack of rainfall.

The main idea of constructing the water control structure would be to store excess incoming water during the floods, for the dry season that is to follow. If water can be stored then the total available water could be increased for irrigation purposes. Although the basic criteria for calculating the E-Flow of a river is to have the river free of interventions, just to check the current condition of the Tangon river near Thakurgaon, E-Flow based on Tennant method was calculated for Thakurgaon station, Tangon. The calculated E-Flow vs 75% dependable flow of the Tangon river has been compared and shown in **Figure 4.229**. It can be seen from the figure that the current flow of the Tangon river at Thakurgaon is below the 10% Mean Annual Flow i.e. "Poor E-Flow" condition between mid-February to mid-May. To ensure long term sustainability of the Tangon River, it is imperative to maintain at least 10% of Mean Annual Flow throughout the year. Although there should be enough water available in the Tangon river to withdraw at least 1 cusec water from the created reservoir, it would be hard to justify extraction of more water during boro season from the Tangon river without affecting the long-term sustainability of the Tangon river.

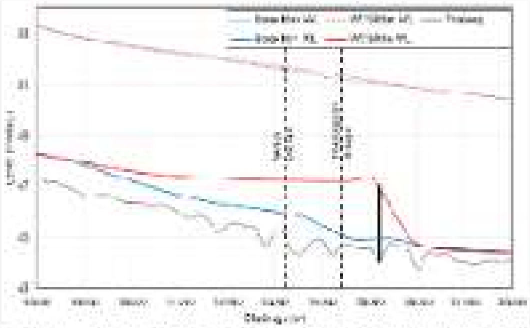

Figure 4.228 Maximum and Minimum Water Level of Tangon River near Thakurgaon due to the proposed Water Control Structure at Thakurgaon

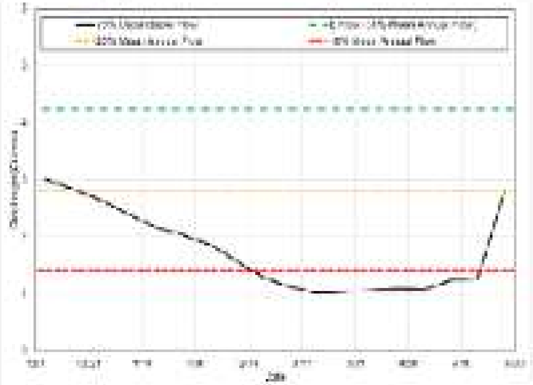

Figure 4.229 75% Dependable flow of Tangon River vs Calculated E-Flow based on Tennant's method

4.2.6 Combined Water Control Structure at Rauthnagar, Kulic River

The long profile of the Kulic River has already been shown in **Figure 4.194**. It can be seen from the Figure that the slope of the Kulic River becomes milder after 40 km. The erosion-sedimentation trend of the Kulic River u/s of 40km has been shown in **Figure 4.251**. From the figure it can be seen that the Kulic River is quite dynamic in this stretch of Kulic River. Only near Rauthnagar, it can be seen the river is a bit stable (marked with white box), comparing to the stretch u/s & d/s. Further downstream from Rauthnagar, the planform again becomes more dynamic as shown in **Figure 4.252**. Old loop-cuts channels are also very prominent d/s of Rauthnagar, indicating the morpho-dynamism of this reach of the river. Also, between 2023 and 2010, it can be seen clearly that the river has shifted in almost every bend.

The long profile of the Kulic River near the proposed Water Control Structure near Rauthnagar has been shown in **Figure 4.253**. From the long profile, another issue arises when looking at the bank level of the area just downstream of the proposed water control structure near Rauthnagar. Since there are lots of remanence of old loop-cuts in this reach of the river, the bank level also is not that high comparing to that of the further u/s. Since the difference between the thalweg of the river and the bank level of the corresponding section is very low, the sill level of any structure further downstream of Rauthnagar would require to be lower as well. And a low sill level would also mean lower storage of water in the reservoir. Hence the most suitable location for constructing the water control structure would be near Rauthnagar. Another potential site for constructing the water control structure would be near [illegible] gauge at 40280 chainage.

Looking at the bank level of the adjacent lands, the sill level of the proposed water control structure has been set at 47.04 mMSL (47.50 mPWD). Drawing a backwater line based on that, it can be seen that some inundation can occur near 41.4 km chainage of the river, just upstream of the Rauthnagar-Rasurpur connecting road crossing point. From the available data, how much area is likely to be inundated has been shown in **Figure 4.254**. From the figure it can be seen that around 0.491 ha can be inundated. Since this area would also be re-excavated, this 0.491ha of land could also be used for re-excavation material management location. If up to 2m of soil is deposited here, around 10,000 m^3 of re-excavated soil could be managed at this location. The soil bearing capacity at the proposed structure location is shown in **Figure 4.255**.

Possible Irrigable Area

Combined with the proposed re-excavation, the Rauthnagar WCS can actually store 77,000 m^3 of water within the Kulic River. If no water is extracted, the reservoir can store the water till May. For supplementary irrigation period, 2 cusec waters (operating for 18 hours) can be extracted from the reservoir for 30 days, in case of lack of rainfall. However, when considering for dry season irrigation, the created storage would be subject to evaporation and percolation losses. It is estimated that, after incorporating those losses, 30,000 m^3 of water would remain in the reservoir at the beginning of January. If this water is used during the boro irrigation period 1 cusec pump (operating for 18 hours) would empty the reservoir in 16 days. To cover the whole boro season around 0.25 cusec water can be extracted from the reservoir. Hence as an initial estimate, the proposed water control structure at Rauthnagar can help to irrigate 42 ha of lands during the supplementary irrigation period however only 2 ha during boro irrigation period.

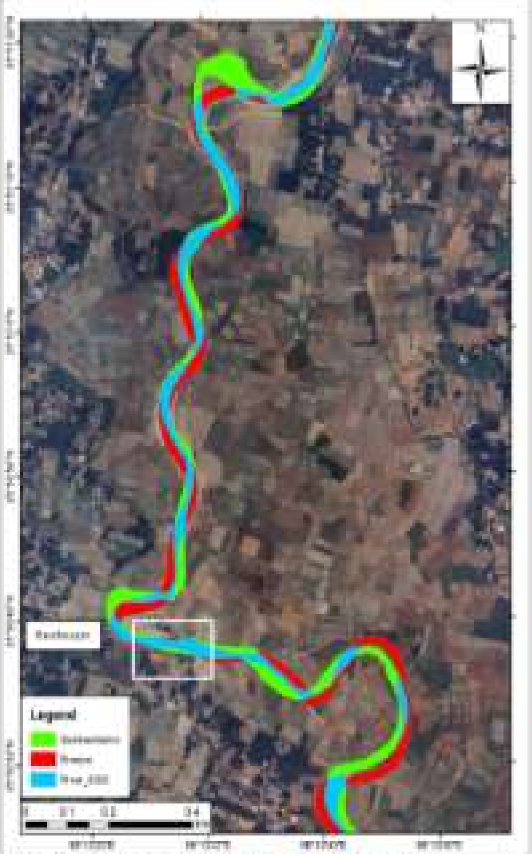

Figure 4.2[illegible]: Historical planform changes of the [illegible] River near [illegible]

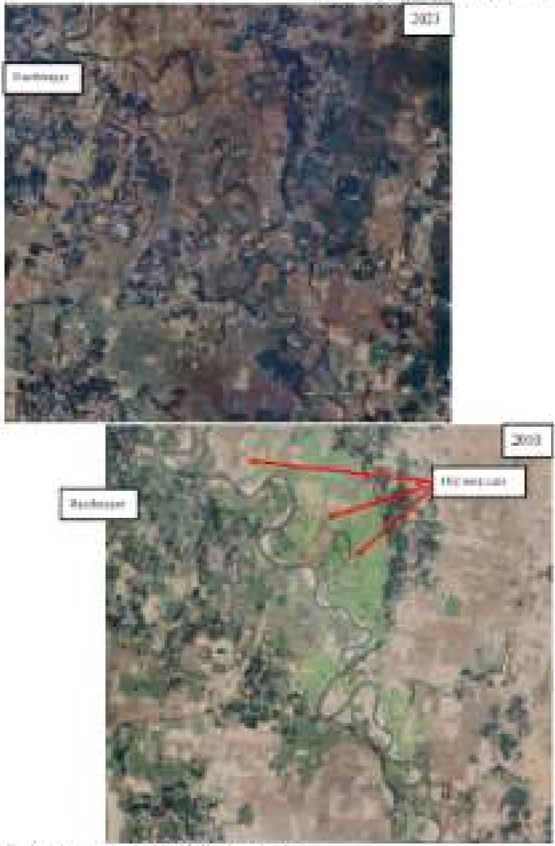

Figure 4.[illegible] Planform change d/s of [illegible]

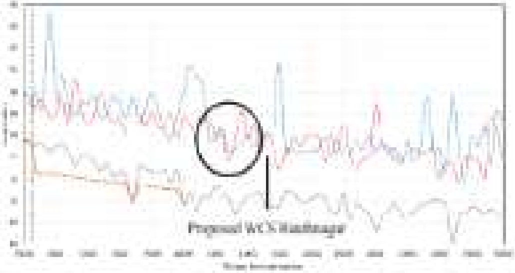

Figure 4.233: Long-profile of the Kulik River near the proposed WCS at [illegible]

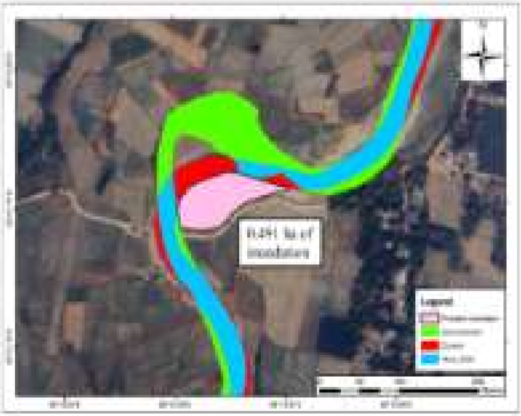

Figure 4.234: Long-profile of the Kulik River near the proposed WCS at [illegible]

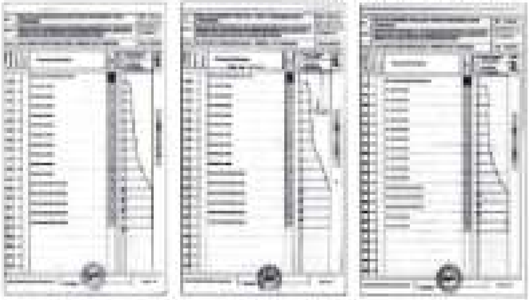

Figure 4.239: Field bore log at the proposed structure location at [illegible]

4.3 Cost Estimates

The estimated cost of the proposed project has been shown in **Table 4.43 & Table 4.44**.

Table 4.43: Estimated cost for the proposed river training work

Sl	River	District	No.	Length (km)	Probable Cost (Lakh Taka)
1	Karatoa	Panchagarh	42	40.38	77203
2	Chawai	Panchagarh	11	6.27	8336
3	Talma	Panchagarh	5	7.66	2780
4	Ghoramara	Panchagarh	4	3.835	5753
5	Pathraj	Panchagarh	13	5.12	1930
		Thakurgaon	7	1.50	2235
6	Tangon	Thakurgaon	22	8.48	12650
7	Kulik	Thakurgaon	5	3.505	1322
8	Tirnai	Thakurgaon	12	3.880	3728
9	Lacchi	Thakurgaon	1	0.12	128
10	Nagor	Thakurgaon	2	0.286	868
11	Senua	Thakurgaon	1	0.2	250
12	Shuk	Thakurgaon	2	0.7	1050
Total Panchagarh			75	62.213	118468
Total Thakurgaon			52	18.283	23880
Total			126	81.544	142348

Table 4.49 Estimated cost for the proposed river re-excavation

Sl	River	District	Re-Excavation Length (km)	Probable Cost (Lakh Taka)
1	Tulik	Thakurgaon	14.000	481.334
2	Rangapani	Panchagarh	1.366	45.187
3	Karun	Panchagarh	8.415	145.723
4	Dala	Panchagarh	1.003	8.463
5	Nabialha	Panchagarh	1.755	57.600
6	Ranchimoat	Panchagarh	3.258	83.594
7	Pathraj	Panchagarh	0.803	15.600
8	Senua	Thakurgaon	8.005	278.700
Panchagarh			17.240	355.859
Thakurgaon			22.005	832.234
Total			37.245	984.585

SECTION FIVE

ENVIRONMENTAL SUSTAINABILITY, CLIMATE RESILIENCE AND DISASTER RISK ANALYSIS

5. ENVIRONMENTAL SUSTAINABILITY, CLIMATE RESILIENCE AND DISASTER RISK ANALYSIS

CEGIS has carried out the detailed ESIA Study of this project. The main findings from their report have been compiled in this chapter.

5.1 Environmental, Climate Change and Disaster Risk Analysis

Environmental impacts, disaster and climate change impacts and possible compensations for ecological damages etc. has been specified. Potential Environmental and social impacts and counter measures to be undertaken has also been stated briefly in this section.

The hazard assessment has been carried out to identify the potential hazard associated with or inherent in the design process and to identify possible measures to avoid/mitigate the hazard along with the safety plan for minimizing the risk. The assessment process involved the following steps:

- Identification of potential hazard
- Identification of causes and consequences
- Risk management

The study area mainly consists of the Karatoa River, Atrai River, Tangon River etc. Increasing temperature and decreasing rainfall leading to increased droughts is exerting adverse effects on the area. The basic hazard related information and their causes and consequences has been collected during the field visit and available secondary data sources (BMD, BWDB, BBA, DRIP portal etc.). Based on the information from field and secondary sources, the possible impacts of climate change and natural disasters on the proposed project and appropriate risk reduction measures has been identified and presented in the following **Table 5.1**.

Table 5.1 Assessment of Potential Disaster Impact

Sl. No.	Natural Disaster	Potential Impact	Disaster Risk Reduction/management
1	Flood	The study area is located in the north-western region of Bangladesh, which is prone to monsoon floods. Though, the study area lies within the north-western region, the relative flood hazard risk is medium level in the study area due to their high elevation and low drainage density (Nasir et al., 2021). In future, due to climate change induced increase in rainfall in upstream areas, risk of flood might increase in the area.	a) Emergency lighting facilities b) Emergency fuel supply c) Elevated seed bed d) Proper distribution of drinking water and relief goods e) Enhanced Flood Warning and Propagation system f) Coordinated Emergency Response and Rescue and Recovery during and post flood period g) Establishing infrastructures considering characteristics of flood on that area h) Providing assistance in re-establishing infrastructures (houses, roads etc.) i) Enhanced flood protection over historically highest inundated areas j) Plinth level of the infrastructures above historically highest inundation depths. k) Elevated platforms for keeping livestock safe.

Sl. No.	Natural Disaster	Potential Impact	Disaster Risk Reduction/management
			l) Deliver aquatic fish ponds. m) Research based fisheries system. n) Emergency medical facilities with free distribution of drugs. o) Capacity building among affected people for switching to alternate profession. p) Increased carrying capacity and drainage of canals and rivers by dredging. q) Appropriate flood protection (Embankment, Flood bypass) and drainage schemes. r) Establishment of mobile sanitation facilities. s) Strengthened Early-warning systems. t) Dissemination of flood forecasting news at the root level over digital platforms.
2	Erosion	The Karatoa river is a major river flowing through the study area. Historic data depicts that erosion rate in Karatoa river in recent years is around 200 Ha. Overall vulnerable river bank is around 23 kms. In the Talma River, the vulnerable river bank is around 3.2 km. Similarly, for the Chawai, Pathraj and Ghoramara rivers, the vulnerable bank area is 5.3, 10, 2.85 km respectively. Erosion is posing threat to the local population.	a) Emergency evacuation facilities. b) Maintain appropriate and adequate set back distance for preparation of lands for agriculture. c) Proper distribution of drinking water and relief goods. d) Enhanced erosion protection (structural) over typical erosion prone areas. e) Establishing infrastructures considering characteristics of erosion and vulnerability on that area. f) Portable housing construction. g) Providing assistance or compensation in resettlement and rehabilitation of infrastructures (houses, roads etc.). h) Maintain appropriate and adequate set back distance for livestock grazing. i) Emergency medical facilities with free distribution of drugs. j) Capacity building among affected people for switching to alternate profession. k) Increased carrying capacity and drainage of canals and rivers by dredging. l) Establishment of mobile sanitation facilities. m) Strengthened Early-warning systems. n) Awareness building program regarding erosion vulnerability and infrastructure building them.

Sl. No.	Natural Disaster	Potential Impact	Disaster Risk Reduction/management
			z) Dissemination of erosion forecasting news at the root level over digital platforms.
3	Drought	The north-west region of Bangladesh is the most drought-prone region of the country including the study area, since it is located in this region. The lack of rainfall and excessive-high temperature of this region contributes to severe droughts in this region. The analysis of temperature and rainfall data of the last 30 years (1991 to 2021) revealed that the annual maximum temperature, annual minimum temperature and the annual average temperature of the study area have an increasing trend. On the other hand, the annual rainfall has a decreasing trend. This is a major factor behind the rise in heat, water scarcity and occurrence of droughts in the study area. Dehydration during droughts can be particularly dangerous for vulnerable populations, such as children and elderly. Prolonged drought conditions can cause significant depression, stress and anxiety among communities, particularly those who rely on agriculture and water-dependent livelihoods.	a) Strengthening field bunds to conserve more rain water. b) Adopting drought-resistant crops. c) Adopting water-efficient irrigation system. d) Minimizing wastage of water during crop production. e) Emergency irrigation facilities for the farmers. f) Increase ponds/reservoirs for holding rain water. g) Enhance public awareness by arranging Training Programs, Workshops, and Group Discussions at the root level for rain water harvesting and efficient use of water. h) Proper distribution of drinking water and relief goods. i) Enhance preparation for historically highest drought affected areas. j) Coordinated Emergency Response and Rescue and Recovery during and post drought period. k) Drought proofing in various sectors in earthen infrastructures. l) Adopting water-efficient livestock rearing and farming system. m) Adopting livestock breeds requiring minimum water. n) Adopting small scale livestock feed production program. o) Usage of stored fodder for livestock during drought. p) Emergency livestock feed supply during post-disaster period. q) Emergency medical facilities with free distribution of drugs. r) Capacity building among affected people for switching to alternate profession. s) Strengthened Early warning Drought monitoring system. t) Dissemination of drought forecasting news at the root level over digital platforms.

(Reference: EIA Report, CEGIS)

5.1.1 Existing Disaster Profile at the Project Location

The information tabulated below (**Table 5.2**) was gathered from the Disaster and Climate Risk Information Platform (DRIP) web tool. In DRIP database, all data related to natural disaster vulnerability are represented at the district level aggregation. The DRIP web tool represents hazard, exposure and risk level on a scale of 1 to 5 where the levels are very low, low, medium, high, and very high.

Table 5.2 Existing Disaster Profile of the Project Location

Disaster	Hazard Level	Exposure Level	Vulnerability Level	Risk Level
Erosion	Very Low	Medium	Very Low	Very Low
Flood	Medium	High	Very Low	Medium
Drought, Flash Flood	Low	Low	Very Low	Very Low

(Reference: ESIA Report, CEGIS)

5.1.2 Trend analysis of recent climate

Meteorological or microclimatic data of the study area has been collected from the nearest station of BMD. Historical records of meteorological parameters i.e., precipitation, temperature etc. has been collected from the respective agencies. Besides, water level has also been analysed based on data availability from BWDB and CEGIS archive. Based on the data, trend of recent climate has been analysed for understanding the pattern of climate in the study area.

Rainfall

The monthly maximum and average rainfall data of the last 31 years (1991-2022) of Dinajpur station was collected, analysed, and shown in **Figure 6.1**. The analysis of data shows that the monthly maximum rainfall varies from 44 mm to 1196 mm and the monthly average rainfall varies from 6.67 mm to 414.5 mm. The maximum rainfall is received in July and the minimum rainfall is received in December. Seasonal analysis of monthly maximum rainfall is shown in **Table 6.2**. The area received the maximum monthly rainfall of 1196 mm in July 1987. The historical maximum annual rainfall of this station was recorded as 3179 mm in 1987 and minimum was 821.4 mm in 2016 and the average annual rainfall is 1684.72 mm. The trend of annual total rainfall is shown in **Figure 6.2**. A decreasing trend can be observed from here.

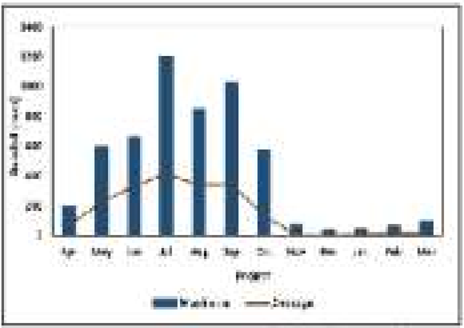

Figure 6.1: Monthly Maximum and Average Rainfall at Dinajpur BMD Station

(Reference: ESIA Report, CEGIS)

Table 5.3 Seasonal Analysis of Monthly Maximum Rainfall at Dinajpur BMD Station

Season	Monthly Maximum Rainfall (mm)
Winter	44-87.5
Pre-monsoon	152-485
Monsoon	505-1,126
Post Monsoon	14-558

(Reference: ESIA Report, CEGIS)

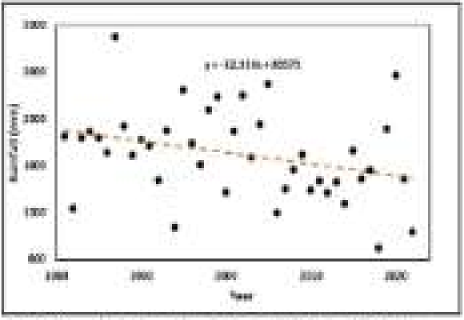

Figure 5.2: Annual Rainfall Trend at Dinajpur BMD Station (1981-2022)

(Reference: ESIA Report, CEGIS)

__Temperature__

The monthly temperature data of the last 31 years (1991-2022) from Dinajpur station shows that the maximum temperature varies from 22.55°C to 32.59°C and June is the warmest month, while the minimum temperature varies from of 10.40°C to 26.46°C and January is the coldest month. Seasonal temperature variation analysis is shown in **Table 5.4**. From the table it can be observed that the variation in minimum temperature is greater than the variation in maximum temperature in case of pre-monsoon and post-monsoon. The monthly average of maximum and minimum temperature of Dinajpur station are shown in **Figure 5.3**. The average annual temperature varies from 24.65°C in 1992 to 25.81°C in 2018. The annual average trends for average, maximum and minimum temperatures are shown in **Figure 5.4**, **Figure 5.5** and **Figure 5.6** respectively. Increasing temperature trends are observed from the figures. The maximum temperature trend is increasing at higher rate, which implies that, summer is getting hotter.

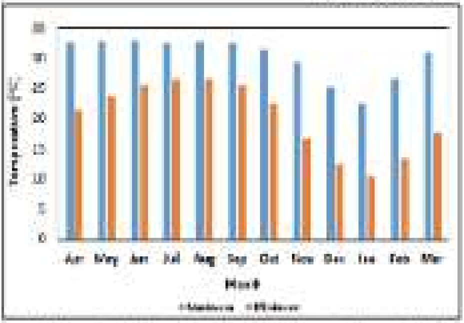

Figure 3.3: Monthly Maximum and Minimum Temperature at Dinajpur BMD Station (1991-2022)
(Reference: CDSA Report, CEGIS)

Table 3.4 Seasonal Analysis of Maximum and Minimum Average Temperature at Dinajpur BMD Station

Season	Maximum Avg. Temperature (°C)	Minimum Avg. Temperature (°C)
Winter	22.50-26.74	10.48-13.33
Pre-Monsoon	30.80-32.53	17.54-23.83
Monsoon	32.33-32.81	25.58-26.49
Post Monsoon	29.23-31.43	16.77-22.37

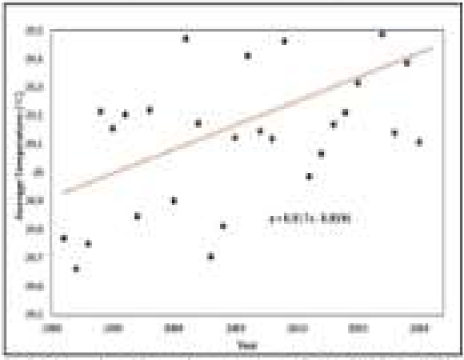

Figure 3.4: Annual Average Temperature trend at Dinajpur BMD Station (1991-2022)
(Reference: CDSA Report, CEGIS)

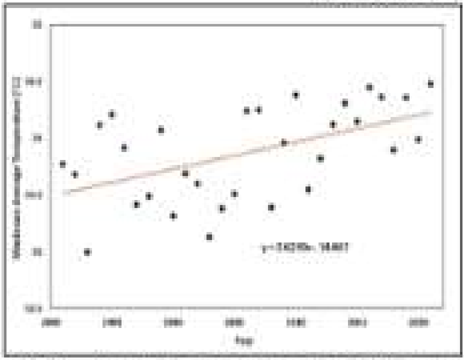

Figure 5.5: Annual Maximum Temperature Trend at Dinajpur BMD Station (1991-2022)

(Reference: CSA Report, CEGIS)

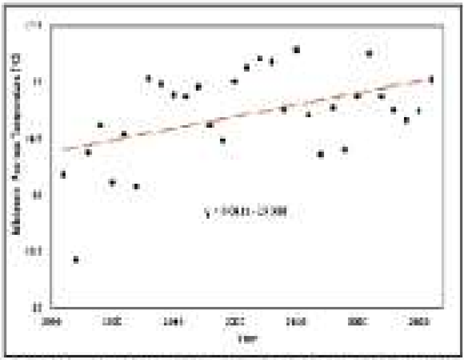

Figure 5.6: Annual Minimum Temperature Trend at Dinajpur BMD Station (1991-2022)

(Reference: CSA Report, CEGIS)

Wind Speed

The analysis of maximum and average monthly wind speed data collected from BMD station at Dinajpur for the last 31 years (1991-2022) is shown in **Figure 5.7**. The maximum wind speed varies from 14.82 km/h in November to 64.82 km/h in May. The monthly average varies from 0.70 km/h in November to 14.23 km/h in March. So, the area faces Kalboishakhi storms during March - May.

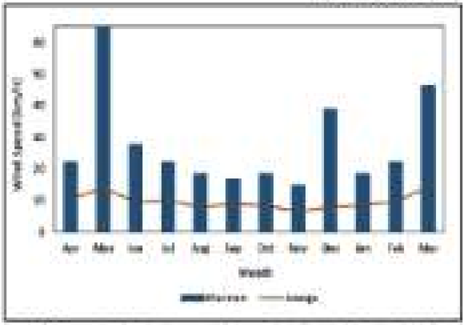

Figure 5.7: Monthly Maximum and Average Wind Speed at Dinajpur BMD Station (1991-2022)
(Reference: ESIA Report, CEGIS)

Relative Humidity
The analysis of average monthly relative humidity data collected from BMD station at Dinajpur for the last 31 years (1991-2022) is shown in **Figure 5.8**. The average monthly humidity varies from 69.2% in March to 85.8% in September. So, the pre-monsoon season has the lowest relative humidity and the monsoon season has the highest. The average monthly relative humidity has a decreasing trend as observed from the graph.

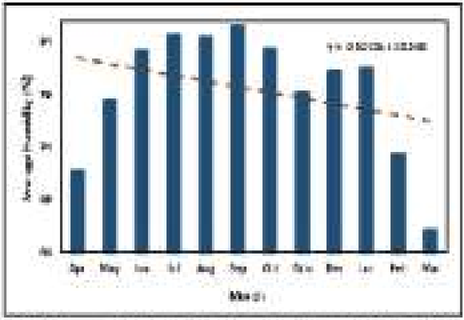

Figure 5.8: Monthly Average Relative Humidity at Dinajpur BMD Station (1991-2022)
(Reference: ESIA Report, CEGIS)

Evaporation
The analysis of maximum and average monthly evaporation data collected from BMD station at Dinajpur for the last 31 years (1991-2022) is shown in **Figure 5.9**. The maximum evaporation varies from 4.5 mm/day in December to 15.4 mm/day in April. The monthly average varies from 3.0 mm/day in December to 7.7 mm/day in April. So, the pre-monsoon season has the highest evaporation rate and the dry period has the lowest.

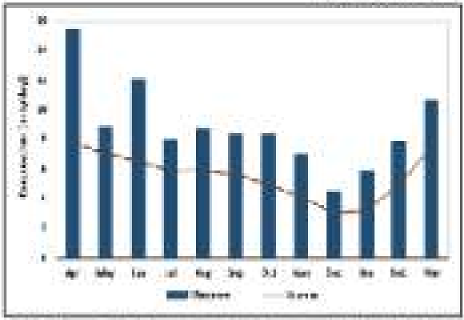

Figure 5.9: Monthly Maximum and Average Evaporation at Dinajpur BMD Station (1991-2020)

(Reference: IZDM Report, CEGIS)

Water Level

Roeshanpur station

Water level analysis of the Dahuk River at Roeshanpur station has been conducted for the year 1991-2021 (**Figure 5.10**). The maximum water level varies from 90.08 mPWD in March to 90.99 mPWD in October. The minimum water level varies from 88.7 mPWD in March to 88.92 mPWD in September. The average water level varies from 89.33 mPWD in March to 89.83 mPWD in July. The highest maximum water level is observed in October, while the lowest minimum water level is observed in March. It is observed that the water level rises in monsoon and the highest is recorded in October, then it starts decreasing and reaches its lowest in March.

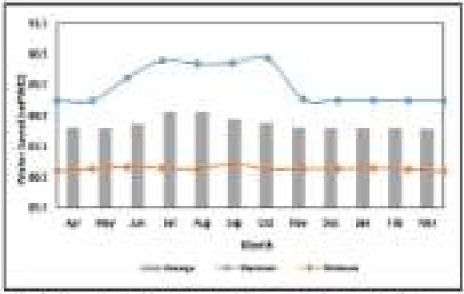

Figure 5.10: Variation of Water Level at Roeshanpur Station (1991-2021)

(Reference: IZDM Report, CEGIS)

[illegible] station

Water level analysis of the Karatoya River at [illegible] station has been conducted for the year 1991-2021 (**Figure 5.11**). The maximum water level varies from 85.28 mPWD in December to 88.11 mPWD in July. The minimum water level varies from 81.76 mPWD in February to 82.38 mPWD in July. The average water level varies from 83.37 mPWD in March to 84.36 mPWD in August. The highest maximum water level is observed in July, while the lowest minimum water level is observed in February. It is observed that the water level is the highest in September, and reaches its lowest in February. It starts rising again since onset of monsoon.

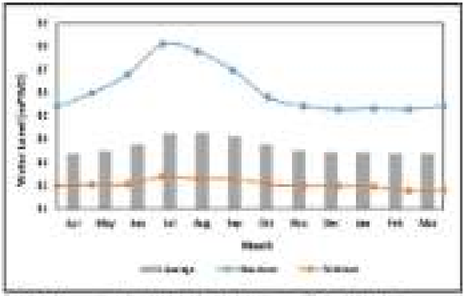

Figure 6.11: Variation of Water Level at [illegible] Station (1991-2021)

(Reference: CSA Report, CEGIS)

Panchagarh station

Water level analysis of the Karatoya River at Panchagarh station has been conducted for the year 1991-2021 (**Figure 6.12**). The maximum water level varies from 67.88 mPWD in February to 71.87 mPWD in September. The minimum water level varies from 65.41 mPWD in August to 66.3 mPWD in September. The average water level varies from 67.32 mPWD in March to 68.28 mPWD in July. The highest water level is observed in September, while the lowest is observed in August. It starts rising again since onset of monsoon.

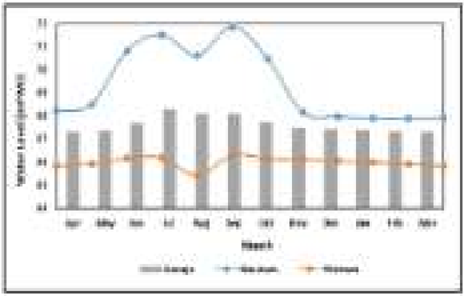

Figure 6.12: Variation of Water Level at Panchagarh Station (1991-2021)

(Reference: CSA Report, CEGIS)

SECTION SIX

COST-BENEFIT ANALYSIS

6. COST-BENEFIT ANALYSIS

6.1 Economic Analysis

The economic analysis also appraises the benefit of an investment, but the concept of the economic benefit is different from the financial benefit. The economic analysis measures the effects on the national economy whereas the financial analysis assesses the financial profitability of the Project operating entity. The effect of the Project on the national economy is indicated by the Economic Internal Rate of Return (EIRR).

Project Economic Assessment provides a tool to support investment decision on the part of the Government. Sensitivities and switching value of the base case results of the economic analysis assessed and discussed against possible risks.

6.1.1 Methodology

Economic assessment refers to valuing and comparing costs and benefits of investment package at economic prices. Investment costs and O&M costs of the project are incurred over a period of time and benefits are derived as a consequence of project interventions over the project life. Usually, the costs and benefits are expressed in financial prices. But financial price is the market price involving a number of imperfections like distortions in demand and supply or monopolies in the market. To reflect economic values of costs and benefits, the financial prices of tangible items have been adjusted using Conversion Factors to eliminate transfer payments and distortions.

In this assessment, financial and economic values are being computed which are being processed and analysed using standard procedures.

6.1.2 Decision Criteria

NPV: The most basic economic criterion for accepting a project is the Net Present Value (NPV) as reflected in the net cash flow become positive.

EIRR: The other economic decision-making criterion is the Economic Internal Rate of Return (EIRR). EIRR is that discount rate which, when applied to the stream of incremental benefits and costs as reflected in the net cash flow of the project produces a zero net present value. It is the maximum (real, non-inflationary) annual rate of interest that the project could pay for the resources used, if the project is to recover all costs.

For any project to be economically feasible, the EIRR must be equal to or greater than the opportunity cost of capital in Bangladesh. Besides, Benefit-Cost Ratios (Economic & Financial) have to be worked out.

6.1.3 Direct, Indirect and Associated Cost and Benefit Components

Estimation of Project Costs

Costs considered are capital and operation and maintenance. Capital cost includes pre-construction, construction, engineering & administration costs. Annual O&M cost is considered after project completion. All costs are presented in terms of present worth at year 0 of project life. It is assumed, for analytical purpose, that all project costs are to be incurred at the start of the year and all benefits to be accrued at the end of each year. The corresponding economic prices were worked out following FAP Guidelines for Project Assessment. Details related investment and O&M cost have been given in Appendix-F1 to Appendix-F28.

Capital Costs

The Consultant Engineers and the subject specialists have prepared cost estimates of the project based on field visits and field surveys. Total Financial Investment cost of the Priority-1, Priority-2 and Priority-3 are estimated as BDT 55,273.88, 36,683.25 and 33,775.50 lakh respectively. Financial Costs used in the analysis are given in Table 6.1, and detailed in Appendix-F1 to F20.

Table 6.1 Project Summary Financial Investment Cost (BDT, Lakh)

Expenditure Accounts by Components - Base Costs	Priority-1		Priority-2		Priority-3		Total
	Panchagarh	Thakurgaon	Panchagarh	Thakurgaon	Panchagarh	Thakurgaon	
I. Investment Costs							
A. Protective Works							
1. Karatoa River	[illegible]	-	[illegible]		[illegible]	-	[illegible]
2. Chawai River	[illegible]		[illegible]		[illegible]		[illegible]
3. Talma River	[illegible]		[illegible]				[illegible]
4. [illegible] River	[illegible]		[illegible]				[illegible]
5. Pathraj River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. Tangon River	-	[illegible]		[illegible]		[illegible]	[illegible]
7. Kulik River	-	[illegible]				[illegible]	[illegible]
8. [illegible] River	-	[illegible]				[illegible]	[illegible]
9. [illegible] River	-	-				[illegible]	[illegible]
10. [illegible] River	-	[illegible]					[illegible]
11. Senua River	-	-				[illegible]	[illegible]
12. Bhulli River	-	[illegible]				[illegible]	[illegible]
Subtotal Protective Works	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. Re-Excavation							
1. [illegible] River re-excavation	[illegible]						[illegible]
2. [illegible] River re-excavation	[illegible]						[illegible]
3. [illegible] River re-excavation	[illegible]						[illegible]
4. [illegible] River re-excavation	[illegible]						[illegible]
5. [illegible] River re-excavation	-					-	
6. Pathraj River re-excavation	[illegible]						[illegible]
7. Kulik River re-excavation	-	[illegible]				-	[illegible]
8. [illegible] River re-excavation	-	[illegible]				-	[illegible]
Subtotal Re-Excavation	[illegible]	[illegible]				-	[illegible]
C. TAP cost	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D. Survey & Investigation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E. Project Management Support	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total BASELINE COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical Contingencies	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Price Contingencies							
Inflation							
Local	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foreign	-	-	-	-	-	-	-
Subtotal Inflation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Devaluation	-	-	-	-	-	-	-
Subtotal Price Contingencies	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total PROJECT COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Priority wise total	55,273.88		36,683.25		33,775.50		[illegible]

Source: Consultant's Estimates

Total investment cost of the project at financial price and economic prices are estimated. The year wise Financial and Economic Costs used in the analysis are given in **Error! Reference source not found.** and detailed in **Appendix-F1** to **Appendix-F19**.

Table 8.2 Year wise Financial and Economic Investment Cost (Lakh taka)

Year	Project-1				Project-2				Project-3			
	Panchagarh		Thakurgaon		Panchagarh		Thakurgaon		Panchagarh		Thakurgaon	
	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic
1	[illegible]	[illegible]	[illegible]	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Project O&M Costs

Annual Operation and Maintenance (O&M) costs of the project facilities have been estimated based on the civil works cost. The detailed financial and economic annual O&M cost are given in Appendix- N21.

Project Beneficiaries

The whole population of the project area will be the beneficiaries. All of them will be benefited directly indirectly by implementing the dredging and Construction of New Regulator Works. Working communities will be the most benefited groups. day labour and households living on project area will be the other beneficiaries groups.

Project Economic Benefits

The Economic benefits of the project have been identified and quantified as far as possible for economic analysis. The objective of establishing the river re-excavation and River Bank Protective works.

Therefore, the benefits of the re-excavation and River Bank Protective works could be listed as follows:

Agriculture Benefits

- Cropping intensity will same and yields will be increased of agricultural crops due to proposed intervention
- Net benefits on agriculture have been considered for analysis. Other direct and indirect benefits of the project were ignored and not accounted for analysis although such sectors would enhance potential tangible benefits as a direct impact of the project. The proposed works are for the development Panchagarh and Thakurgaon project.
- The net benefit derived from the difference between the gross product and the production cost. Net Incremental Benefit, which represent the surplus of the net benefit in post-project condition over that of pre-project condition BDT 8,500 lakh and 8,406 lakh are financial and economic respectively. Details of the pre-project and post project agricultural production and costs of productions have been given in Appendix-F22 to Appendix-F68.

Fisheries Benefits

Fishery is one of the fastest growing sub-sectors in the food production context of Bangladesh. This is the reason why the benefit of this sub-sector has been considered with great importance in the sub-project. The implications of the climate change to fisheries are extremely significant not only for the livelihood of the majority of the population in the sub project who depend on agricultural output and system but also it would create a great threat to their own food security. Some of the main benefits of the river bank protection to the local communities are the availability of water and the development of fisheries sub-sector. Implementation of the project will protect the culture of fisheries and may motivate people to adopt improved fish culture practices. In order to have the potential benefits, it is necessary to provide all kinds of support services to the people for instance supplying of good quality of fish seeds and other logistic supports of modern aquaculture. The annual Fisheries benefits are estimated as Taka 43.83 BDT in lakh, detailed given in Appendix- N69.

Immovable and Movable Properties is expected to be saved

Immovable and Movable Properties to be saved after implementation of the project which have been calculated on market price resulting of Panchagarh value estimated Taka 14604.84 Lakh and Thakurgaon value Taka 4672.63 lakh over the period of Twenty (20) years and Yearly Panchagarh value estimated Taka 730.24 Lakh and Thakurgaon value Taka 233.63 lakh. (Appendix – N70 to N71).

Employment Generation

Employment Opportunity for Local People will be generated. Employment will be generated in 2 phases, i.e., during infrastructure development and Operation & Maintenance activities. After implementation of the project, employment opportunities will be created yearly in O&M BDT 514.16 Lakh. Whereas during infra-structure development, the employment opportunities will be generated by BDT 21423.52 lakh, Appendix- N72

Induced Benefit

- Employment Opportunity of Local People

Non quantified benefits

A number of potential benefits, both, quantifiable and non- quantifiable, have not been quantified, as dependable data for making reasonable estimates are not available. Some of these non-quantified benefits have profound socio-economic implications for poverty reduction such as income generation of the local people.

8.1.4 Assumptions for Economic Analysis

For the present study, the following general assumptions have been adopted:

- All costs, benefits and revenues are expressed as on June, 2024 prices.
- Financial costs have been estimated based on schedule of rate of Thakurgaon O&M Circle.
- The implementation period of this project is five years covering all the interventions proposed within the project.
- The project life for economic analysis is assumed to be 30 years.
- The real opportunity cost of the capital investment adopted in this analysis is assumed as 12% per annum, which represents the social opportunity cost of capital (SOCC) for Bangladesh.
- A Standard Conversion Factor of 0.838 and other specific conversion factors used in the study have been developed in the recent studies.
- The foreign exchange rates used for the analysis is US$ 1 = BDT 117.00
- The Shadow Exchange Rate Factor (SERF) used for analysis is 1.0128

- Physical contingencies are included at lump-sum on base cost for all civil works and development programmes; and
- Local inflation rate has been considered lump-sum.

6.1.3 Key Indicators

The economic indicators are computed for the Project to judge its economic viability. These indicators include Net Present Value (NPV), Benefit Cost Ratio (B/C Ratio) and Economic Internal Rate of Return (EIRR).

The analytical results of economic analysis are summarized in **Table 6.3**. Details of analytical computations are presented in Appendix-F73 to N77.

Table 6.3 Results of Base case Economic Analysis (Lakh BDT)

Sl no.	Viability Indicator	Result	
		Proposed	Alternative
1	Capital Cost (Lakh BDT)	[illegible]	[illegible]
2	O&M Cost (Lakh BDT)	1265.41	1524.88
3	Benefit Cost Ratio (BCR) @ 12%)	0.88	1.10
4	Net Present Value (NPV @ 12%) Lakh BDT	[illegible]	[illegible]
5	Internal Rate Return (IRR %)	8.88%	13.77%

The results indicate that the Project is economically viable, as it secures a rate of return that exceeds 12%, i.e. the opportunity cost of capital, presently used by all sectors of the economy in Bangladesh.

6.2 Conclusion

In accordance with the analysis stated above, the engineering interventions are technically feasible and conducive to the project objectives. The main benefit of the project is to the dredging and construction of regulator. The relevant economic information has been shown in Appendix-C. The Internal Rate of Return (IRR) of economic has been calculated which are found to be 13.77%. A sensitivity and switching value analysis have been carried out assuming 10% increase in investment cost, 10% decrease in benefit. However sensitivity analysis has been also carried out with costs being increased by 10% together with benefits being decreased by 10% which eventually indicates that the EIRR in most of the cases is better to opportunity cost of capital 12%.

In conclusion, the analysis of the interventions and impact is that project is technically feasible, economically viable, socially acceptable and environmental-friendly. Considering the **importance of peoples livelihood and self**-sustainable, this project is being recommended for implementation.

SECTION SEVEN

HUMAN RESOURCES AND ADMINISTRATIVE SUPPORT ANALYSIS (DURING IMPLEMENTATION AND POST IMPLEMENTATION OF THE PROJECT)

7. HUMAN RESOURCES AND ADMINISTRATIVE SUPPORT ANALYSIS (DURING IMPLEMENTATION AND POST IMPLEMENTATION OF THE PROJECT)

Panchagarh and Thakurgaon O&M Divisions, BWDB has its functional and institutional capabilities to implement this project and to continue functioning of the project output under its regular establishment. Investment in this project will come from the government and after implementation all expenditures will be incurred by existing institutional and financial resources now available in the framework.

7.1 Existing Set up of Panchagarh & Thakurgaon BWDB

The existing set up of Panchagarh & Thakurgaon O&M BWDB has been showed in **Table 7.1** and **Table 7.2** respectively.

Table 7.1 **Existing Set up of Panchagarh BWDB**

Sl. No	Designation	No. of Post	Currently Working	Vacant Post	Comments
1	2	3	4	5	6
1	Executive Engineer	1	1	0	
2	Sub-Divisional Engineer	3	0	3	
3	Assistant Engineer	1	1	0	
4	Sub Assistant Engineer	2	2	0	
5	Work Assistant	3	3	0	

Table 7.2 **Existing Set up of Thakurgaon BWDB**

Sl. No	Designation	No. of Post	Currently Working	Vacant Post	Comments
1	2	3	4	5	6
1	Executive Engineer	1	1	0	
2	Sub-Divisional Engineer	2	2	0	
3	Sub-Divisional Engineer (Mechanical)	1	1	0	
3	Assistant Engineer	3	3	0	
4	Sub Assistant Engineer	6	6	0	
5	Sub Assistant Engineer (Mechanical)	4	4	0	
6	Surveyor	3	3	0	
7	Work Assistant	8	8	0	

7.2 Workforce During Project Timeline

For implementation of the project, some additional technical personnel will be required to be engaged and/or the vacant posts required to be filled up. Civil engineers and engineers having knowledge of morphology and re-excavation will be responsible for planning, design and implementation of the activities recommended. Work assistant would be required for supervision of the project works, while surveyor would be required to conduct regular survey during project implementation. Additional support staff like Office Assistant, Assistant Clerk, Peon and Guard would be required for smooth functioning of the project activities.

BWDB has the personnel resources to engage managerial workforce required for the implementation of the project. The officials will be appointed from within BWDB for implementation of the project in addition to their own duties.

7.3 Continuation of Project Output

After implementation of the project all outputs will be handed over to the existing setup of BWDB Panchagarh, Thakurgaon and Dinajpur O&M Divisions based on their jurisdiction area. Regular monitoring of the river movement as well as predicted scour at and around the proposed structures with regular survey is recommended, this work which will require outsourcing.

7.4 Capacity Development Training for BWDB Officials

A capacity building training for BWDB Officials was arranged by IWM. The methodology followed during the study, the survey methods as well as the development and usage of the models has been demonstrated in the training sessions. Some pictures of the training session are shown in **Figure 7.1** to **Figure 7.3**.

Figure 7.1: Capacity Development Training for the BWDB Professionals

Figure 7.2: Capacity Development Training for the BWDB Professionals

Figure 7.3: Capacity Development Training for the BWDB Professionals

7.6 Project implementation period

The project is proposed to be implemented in 5 consecutive years.

SECTION EIGHT

INSTITUTIONAL AND LEGAL ANALYSIS

8. INSTITUTIONAL AND LEGAL ANALYSIS

8.1 Legal Boundary and Institutional Capacity

Bangladesh Water Development Board (BWDB) is a government agency, responsible for administering the flow of all rivers, waterways and ground water bodies through management and development of the water resources in the country. This responsibility has been bestowed on BWDB through the BWDB Act of 2000. It is also responsible to undertake programmed relating to water resources sector including project formulation, implementation, operation, maintenance and evaluation in line with the National Water Policy and the National Water Plan.

The activities of BWDB are divided into two inter-related groups: Structure related functions and non-structure oriented supportive activities. The structure-oriented functions of the BWDB are:

(1) Development and control of rivers, river basins and construction of reservoirs, barrages, embankments, regulators and other structures for flood control, drainage and irrigation system development and drought prevention;
(2) Re-excavation of water ways, canals, water bodies etc. for the improvement of water flow or to divert its course with a view to easing irrigation, fisheries, shipping, afforestation, wild life preservation and environment development;
(3) Protection, recovery and reclamation of land and management of river estuaries;
(4) Protection of river banks, towns, markets and places of historical and national importance from river erosion;
(5) Construction and protection of coastal embankments;
(6) Prevention of infiltration of saline water and desertification and
(7) Harvesting of rain water for irrigation, environment protection and drinking purpose.

BWDB has zonal field offices, headed by one Chief Engineer with full fledge office and staffs at site. Under zonal Chief Engineers, there are Superintending Engineers with full fledge office (Circle) and staffs at site. Under Superintending Engineers, there are Divisional offices, headed by the Executive Engineers. He possesses full fledge office and staffs as per BWDB organogram and field at site. In the present case, the Superintending Engineer of Thakurgaon Circle office and the Executive Engineer of Thakurgaon O&M office are both fielded at Thakurgaon town. While the Executive Engineer of Panchagarh O&M office is fielded at Panchagarh town.

Separate projects are being proposed to be implemented by Thakurgaon, Panchagarh and Dinajpur O & M Divisions of BWDB, headed by Executive Engineer of their respective divisional office. BWDB is capable of implementation of such type of project through its existing manpower. The Executive Engineer with the help of Sub Divisional Engineer will prepare the tender document. After following procurement rule, the tender would be floated and contractor would be selected as per Procurement rule. The proposed work would be implemented by contractor through proper engineering supervision by their respective O & M Division of BWDB.

After implementation of the project, operation and maintenance under the regular establishment will be carried out through the existing set up. It can be done by adjusting the present set up of respective O & M Divisions of BWDB.

SECTION NINE

RISK (UNCERTAINTY) AND SENSITIVITY ANALYSIS

9. RISK (UNCERTAINTY) AND SENSITIVITY ANALYSIS

9.1 Major Risks, Their Impacts and Possible Mitigation Measures

The economic analysis of projects is generally based on uncertain future events and imperfect data. Moreover, certain risks are inherent in project planning and implementation. The project risks may arise due to the following reasons:

- Delay in project implementation due to lack of fund
- Lack of O&M after project implementation

The above project risks are crucial to derive targeted benefit of the project. If the project implementation is delayed the cost will be increased. The O&M of any project is the corner stone of total investment cost. The full benefit of the project will be accrued after implementation and if the provision of annual O&M is not kept later on, the benefit of the project will wither away yielding negative impact on EIRR. This will lead project investment to a meaningless exercise. Therefore, the planners and policy makers must ensure O&M activities before the project implementation takes off.

In this context, fund must be released timely in order to ensure timely project commencement and implementation so that project costs do not increase. It is very important to devise an O&M plan and make provision for the fund for O&M costs before implementation of the project.

9.2 Sensitivity and Switching Value Analysis

The economic analysis of projects is generally based on uncertain future events and imperfect data. Also, certain risks are inherent in project planning and implementation. So, a sensitivity analysis, Sensitivity Indicator and Switching Values of the project EIRR has been conducted for the Project, based on variations in the level of costs and benefits, due to various uncertainties and risks involved in the project investment. By switching values, it can be indicated that EIRR will remain same for the opportunity cost of capital (12%) if the cost increases up to the indicated percent in the **Error! Not a valid bookmark self-reference.** and EIRR will remain same for the opportunity cost of capital (12%) if the benefit decreases up to the indicated percent in the Table 9.1 Sensitivity and Switching Value Indicator The findings of sensitivity analysis and Switching Values are summarized in Table 9.1 Sensitivity and Switching Value Indicator. Details of analytical computations are presented in Appendix-A42 to A44.

Table 9.1 Sensitivity and Switching Value Indicator

Sl No.	Description	Variation	EIRR	NPV (Lakh Taka)	Sensitivity Indicator (SI)	Switching Values (SV) %
	Base Case	–	13.77%	5424.1	–	–
1	Investment Cost Increased by +10%	10%	12.18%	300.2	8.91	11.22
2	O & M Cost Increased by +10%	10%	13.61%	5119.3	0.98	102.21
3	Total project Cost Increased by +10%	10%	12.04%	150.1	9.73	10.28
4	Agriculture Benefits decreased by -10%	-10%	13.64%	6326.2	0.83	120.48
5	Fisheries benefits decreased by -10%	-10%	12.26%	1180.1	8.52	11.74
6	Total benefit decreased by -10%	-10%	11.87%	-405.3	10.73	9.32
7	Total Cost increased by +10% and Total Benefit decreased by -10%	20%	10.37%	-5621.8	20.45	4.89

SECTION TEN

ALTERNATIVE/ OPTIONS ANALYSIS

10. ALTERNATIVE/ OPTIONS ANALYSIS

Reconnaissance surveys, field surveys, field visits as well as meetings with officials from Planning-3, Design-6, Thakurgaon O&M and Panchagarh O&M Field Offices of BWDB as well as interactions with ESIA Study team were carried out to assess the condition of the study area, identify the problems, understand the morpho-dynamics of the region and develop potential options for sustainable river management of the Panchagarh & Thakurgaon districts. In option formulation relevant past reports and literature were thoroughly reviewed specially to understand the recommendations provided in those studies and their effectiveness.

10.1 Criteria for Suitability

A set of selection criteria has been devised to rank the potential options to make the selection most acceptable to achieve the objective effectively. The selection criteria are based on the hydrology and morphology of rivers of the Panchagarh & Thakurgaon districts and its adjacent areas, and all the options need to be accepted from ESIA point of view also. The criterion for selecting the most suitable option includes the following:

- Near bank Flow velocity
- Scour level
- Change in water storage capacity
- Increase in Probable Irrigable area
- Highest Flood Level
- Economically viable
- Social acceptance
- Acceptability from Environmental impact point of view

10.2 Potential Alternatives of Karatoa River

Based on the knowledge gathered, six potential interventions have been considered for the Karatoa River. The possible interventions include:

i. 40.58km of River Training Works
ii. 1 weir + regulator combined water control structure (WCS) at Kaliaganj
iii. 1 weir + regulator combined water control structure (WCS) at Laxminarayan
iv. Different water extraction scenarios at Ahmednagar 1, 2, 3 as well as EB-1, EB-2 and EB-3.
v. 2 Groynes, near Boalmari Bazar
vi. Excavation near Boalmari Bazar

The possible interventions are shown in **Figure 10.1**. These possible options have been analysed in detail considering five different option scenarios, which are:

Option A:	40.58km of River Training Works.
Option B:	River Training Works plus water withdrawal Ahmednagar 1, 2 & 3 as well as EB-1, EB-2 and EB-3 withdrawal at design capacity.
Option C:	River Training Works plus Ahmednagar 1, 2, 3 withdrawals at 12 Cusec and EB-1, EB-2 and EB-3 withdrawal at design capacity.
Option D:	Ahmednagar 1 withdrawal at 8 Cusec, Ahmednagar 2, 3 withdrawals at 4 Cusec and EB-1, EB-2 and EB-3 withdrawal at design capacity.
Option E:	River Training Works plus Ahmednagar 1 withdrawal at 8 Cusec, Ahmednagar 2, 3 withdrawals at 4 Cusec and EB-1, EB-2 and EB-3 withdrawal at design capacity plus WCS at Kaliaganj at 53.5mPWD.

Option F:	River Training Works plus Ahmednagar 1 withdrawal at 0 Cusec, Ahmednagar 2, 3 withdrawals at 4 Cusec and BB-1, BB-2 and BB-3 withdrawal at design capacity WCS at Kaliganj at 60mPWD.
Option G:	River Training Works plus Ahmednagar 1 withdrawal at 0 Cusec, Ahmednagar 2, 3 withdrawals at 4 Cusec and BB-1, BB-2 and BB-3 withdrawal at design capacity WCS at Kaliganj at 58.0 mPWD & WCS at Laxmirhat.
Option H:	River Training Works plus 2 spurs at Boalmari Bazar.
Option I:	River Training Works plus excavation at Boalmari Bazar.

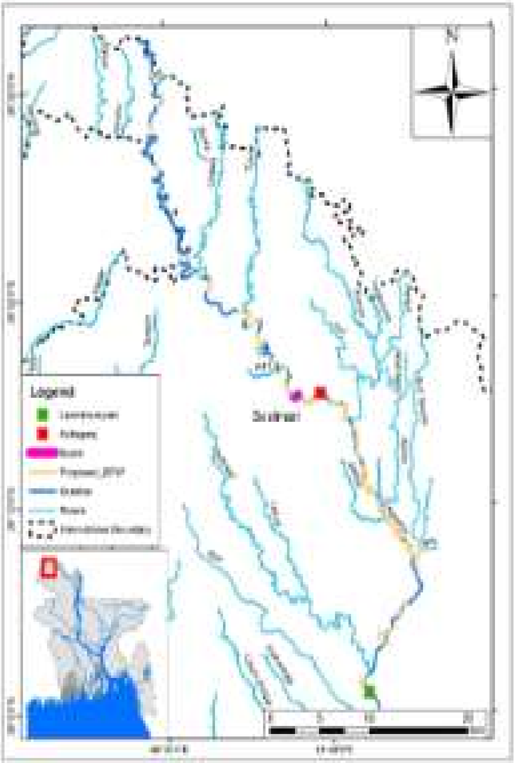

Figure 10.1: Possible interventions of the Karatoa river

The Options are shown in Tabular format in **Table 10.1**.

Table 10.1 Potential alternative options for Karatoa River

Intervention Type	Option No.								
	A	B	C	D	E	F	G	H	I
E-FW	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ahmednagar 1, 2 & 3 as well as EB-1, EB-3 and EB-4 withdrawals at design capacity		✓							
Ahmednagar 1, 2, 3 withdrawal at 12 Cusec and EB-1, EB-3 and EB-4 withdrawal at design capacity			✓						
Ahmednagar 1 withdrawal at 5 Cusec, Ahmednagar 2, 3 withdrawals at 4 Cusec and EB-1, EB-3 and EB-4 withdrawal at design capacity				✓	✓	✓	✓	✓	✓
WCS at Nalagaon at 20.34 PWD					✓		✓		
WCS at Nalagaon at 20m PWD						✓			
WCS at Laxminarayan							✓		
Spur at Goalhari Gadai								✓	
Reexcavation at Goalhari Gadai									✓

10.2.1 Evaluating different Water Extraction scenarios of Karatoa River

The 63 LLPs were installed along the Karatoa river in six blocks under the scheme "63 Electrical Low Lift Pump Station" and put into operation in mid-sixties. Since its operation, the schemes provided desired benefit to the target area. During the liberation war in 1971, pumps, motors and transformers were damaged. Afterwards, change of the river course, irregular supply of electricity, non-availability of adequate fund for repair and maintenance etc. caused abandoning some of the Low Lift Pumps of the above blocks. In addition to the existing 63 LLPs, three more LLP stations at Ahmed Nagar (1, 2 and 3) were added which according to its design could irrigate 524 ha of land. Considering these LLPs located in the Karatoa river, different water extraction scenarios were developed (Option B, Option C and Option D). Among the options, Option B considers water extraction at design capacity for Ahmed Nagar -1, 2 & 3 (20 cusecs, 15 cusecs, 15 cusecs) and historical water extraction capacity at EB-1 (32 cusec), EB-3 (64 cusec) and EB-4 (64 cusec). Using this extraction scenario, the model simulated discharge d/s of Laxminarayan falls below 14 cumec, the calculated e-flow of the Karatoa river. Keeping this in mind another scenario test (Option C) was carried out, where instead of the 20 cusecs, 15 cusecs, 15 cusecs extraction at Ahmed Nagar -1, 2 & 3, 12 cusecs at each of the location was extracted. Even for this scenario, the available flow d/s of Laxminarayan is found very close to the calculated E-Flow. Hence the Option C water extraction also could not be recommended. For Option D, it has been proposed that 5 cusecs, 4 cusecs, 4 cusecs water to be extracted from the Karatoa river at Ahmed Nagar -1, 2 & 3, while historical capacity of the EB-1, EB-3 and EB-4 is maintained. Considering this option it could be seen that E-Flow could be ensured downstream of Laxminarayan (EB-4). The available water at different locations for different options has been shown in tabular format in **Table 10.2**. Also, the available water at different locations of Karatoa River for different options has been shown graphically in **Figure 10.2**. The Dry season water availability of the Karatoa river for the base condition and the proposed water extraction condition vs the environmental flow of the river has been shown in **Figure 10.5**. The figure indicates that for the proposed water extraction scenario, 10% of mean annual flow (i.e. Poor E-flow) could be ensured. It can also be seen from the figure that the Karatoa river is really water stressed between March and May. And anymore than the proposed water extraction in the Karatoa river would take the flow below the 10% mean annual flow and be harmful for the overall health and sustainability of the river.

Table 10.3: Available water at different locations of Karatoa River for different Options

Details	Location						
	Ahmed Nagar 1	Ahmed Nagar 2	Ahmed Nagar 3	[illegible]	[illegible]	[illegible]	[illegible]
Design Command Area (ha)	204	152	152	960	-	1503	2009
Historical Outlet (Cusec)	-	-	-	32	-	64	64
Proposed Water Extraction (Cusec)	6	4	4	32	-	66	66
Supplementary Command Area (ha)	125.08	83.70	83.70	669.64	-	1338.2	1338.2
Dry Season Command Area (ha)	46.18	32.13	32.13	257.57	-	514.63	514.63
Base Discharge without any withdrawal (Cumec)	19.88	19.88	19.88	20.08	20.33	20.33	20.34
E-Flow	14						
Discharge – Option B (Criterion of Design Condition)	19.38	18.92	18.49	17.61	17.61	15.81	13.80
Discharge – Option C	19.84	19.84	19.32	18.21	18.21	16.21	14.22
Discharge – Option D (Proposed Water Extraction)	19.81	19.81	19.72	18.64	18.64	16.84	14.89

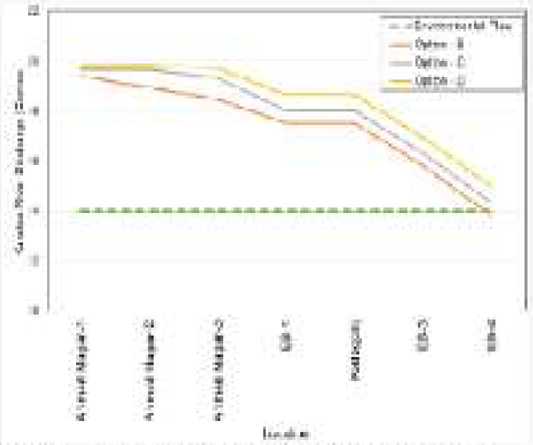

Figure 10.3: Available water at different locations of Karatoa River for different Options

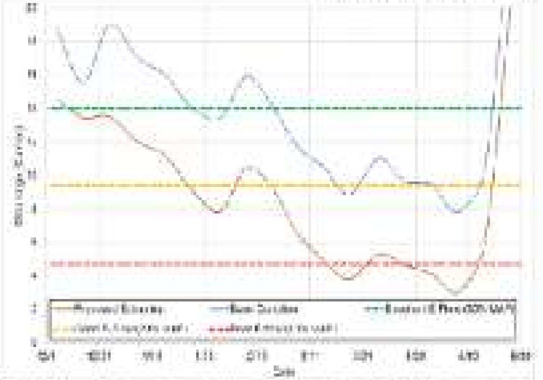

Figure 10.3: Dry season water availability at the Betna river for the base condition and the proposed water extraction condition vs the environmental flow of the river

10.2.2 Setting the Sill Level for Combined Water Control Structure at Kaliganj

Setting the sill level of a combined water control structure is a challenging task. Two different options have been considered for this purpose, 1 with 59.5 mPWD sill level (Option E) another with 60mPWD (Option F). The change in velocity from base condition for Option-E and Option-F has been shown in **Figure 10.4**. With 60mPWD sill level, the velocity just downstream of the WCS has increased as much as 0.06 m/s whereas it increased by 0.04 m/s in the Option-E (59.5mPWD sill level). Moreover around 0.04 to 0.05 m/s increase in velocity can be seen near Kawachar, d/s of Kaliganj and Bornata.

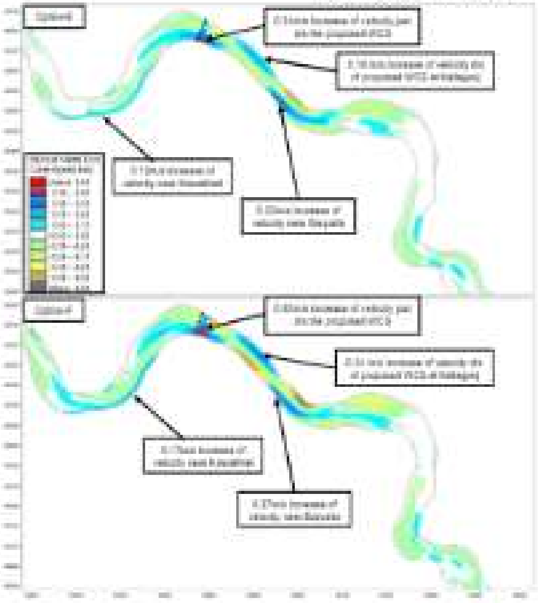

Figure 13.4: Difference in the velocity from base condition due to Option-E and Option-F

The model simulated bed level change after 5 years in the vicinity of the proposed water control structure has been shown in **Figure 13.5**. And with the 60mPWD sill level, the morphology of the river becomes dynamic. Just around the proposed WCS, more than 2m drop forms with Option-F, while the drop is around 1.5m with Option-E. Moreover, erosion tendency has increased near Boolmari, Kowahati, Barpara with Option-F. Considering the adverse effects vs the added benefits, the sill level of 60mPWD does not seem to have much added benefits compared to the adverse effects.

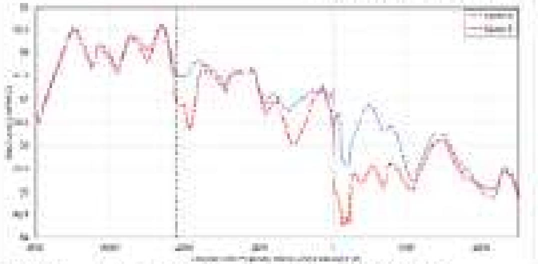

Figure 10.8 Model simulated bed level after 3 years for Option-E and Option-F

The model simulated maximum afflux for Option-F was found to be 7 cm higher than the maximum afflux for Option-E which is a cause of concern as well. The maximum afflux for both Option-E and Option-F has been shown in **Table 10.3**.

Table 10.3 Afflux of Karatoa River for different Options

Option	Max Afflux (cm)
Option-E (35.5m RWL weir)	16
Option-F (36.0m RWL weir)	23

The morphological model was also used to see the reduction in storage area for Option-E and Option-F. The result has been presented in a graph in **Figure 10.9**. It can be seen that over 3 years, for Option-E the storage capacity reduces by 2.80% while for Option-F, it gets reduced by 4.30%. Around 43,000 m^3 of added siltation occurs due to the increase of sill level by 0.5m.

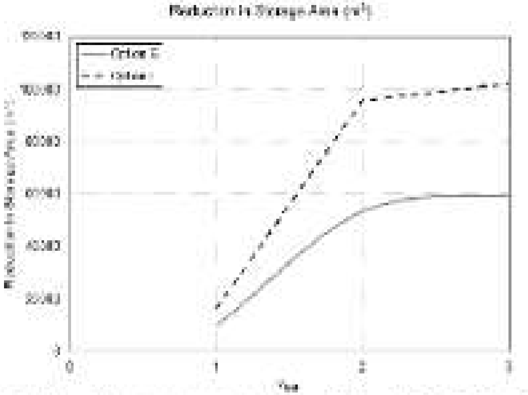

Figure 10.9 Model simulated reduction in storage area after 3 years for Option-E and Option-F

One of the major challenges during setting the sill level of the structures is to check whether any water spills on the bank when the gate is closed during dry season. Along with afflux check, probable breaching locations due to the gate closure was identified with Option-E and Option-F. Weir height was compared against the bank levels at 200m intervals to produce **Figure 10.7**. It can be seen from the figure that the Option-F would breaching at 2 different locations on the upstream side of the proposed structure at Noongonj and Kasakhali. Hence the sill level of 60mPWD might be too high for the proposed structure location as it would cause flooding in the nearby lands.

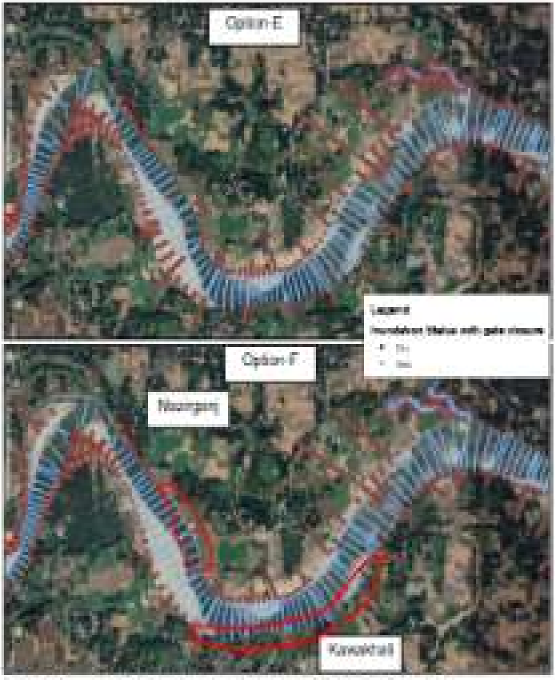

Figure 10.7: Probable breach location identification for Option-E and Option-F

The minimum water depth at different locations of Karatoa river for different options has been shown in **Table 10.4**. With the proposed water extraction as well as under no water extraction situation, the available water depth near ES-1 (Boalmari) is around 0.3m. However, with the Kalaganj combined water control structure with a sill level of 59.5 mPWD, the minimum water depth near ES-1 increased by 80%. The minimum water depth near Kalaganj for Option-A, Option-D and Option-E has been shown as a bar chart in **Figure 10.8** as well.

Table 10.4 Minimum water depth at different locations of Karatoa River for different Options

Details	Location					
	Ahmed Nagar-1	Ahmed Nagar-2	Ahmed Nagar-3	EB-1	EB-3	EB-4
Option-A (No withdrawal)	1.042	1.014	1.353	0.904	1.288	1.812
Option-D (Proposed Water Extraction)	1.035	1.008	1.278	0.87	1.234	1.758
Option-E (Proposed Water Extraction + Kaliaganj WCS at 58.50 mPWD)	1.035	1.008	1.278	1.601	1.228	1.758

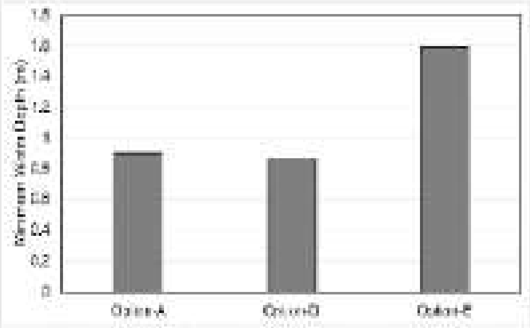

Figure 10.8 Minimum Water Depth near Kaliaganj for Option-A, Option-D and Option-E

10.2.3 Combined Water Control Structure at Laxminarayan

As per the local demand, a combined water control structure at Laxminarayan has been considered during option formulation for the study. However, from Table 10.4, it can be seen that with Option-A, D and E, the minimum water depth near the EB-4 Laxminarayan was around 1.750m. Since the available minimum water depth was found to be sufficient for water extraction at design capacity of the Laxminarayan pumphouse. Hence it was deemed that providing another combined water control structure near Laxminarayan would not have any substantial added benefits.

10.2.4 Spur at Boalmari Bazar

The Baruni Festival is held near Boalmari Bazar and is a spot of great significance for the people of Hindu religion of the region. The spot is significant because the Karatoa river flows northward near the Boalmari bend. However, in recent times, the bank erosion just downstream of the existing protection works at Boalmari Bazar has moved the flow slightly eastward. Considering the spiritual significance of northward flow in this region, the festival committee regularly re-excavates the Karatoa river. However, under the study it was tested whether a permanent solution like spurs can deflect flow northwards at Boalmari bazar continuously. In this regard, 2 spurs with a length of 20m at 75 m was introduced into the model. The developed option has been shown in **Figure 10.9**. Another three-dimensional view of the proposed spur option has been shown in **Figure 10.10**. The developed two-dimensional model was tested to see the response of the river. The changes of the bed level due to the spur option (Option-H) has been shown **In Figure 10.11**. It can be seen from the figure that the presence of these 3 spurs increases the scour level in front of the spur. The maximum scour depth in front of the spur, increased by 7% comparing to the base condition. Moreover, the maximum velocity also increases due to the presence of the spur. The difference in velocity between the base and the spur option (Option-H) has been shown in **Figure 10.12**. From the Option-H, the maximum velocity was found to be 2.85 m/s for the design flood event, which was found to be around 2.72 m/s. Hence the velocity increased by 4.77% from the Option-H condition. The flow vectors on the peak of third year on model simulations for both the base and spur condition have been shown in **Figure 10.13**. It can be seen from the figure that the 20m spurs do move the flow vector more towards northward, however the spurs do not seem to have too many added benefits when the cost & difficulty of construction & maintenance is being considered. Considering these facts, the spur option (Option-H) has not been recommended.

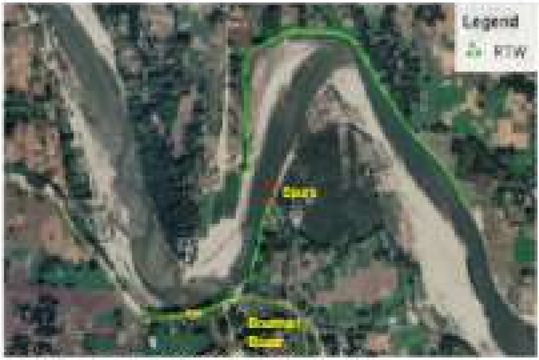

Figure 10.8: Option H (Developed Spur Option for Boalmari Bazar)

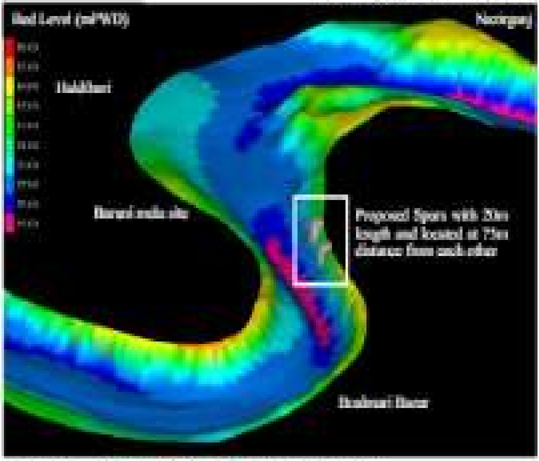
Bed Level (mPWD)
Nongaon
Haldibari
Barund nala ghat
Proposed Spurs with 20m length and located at 75m distance from each other
Boalmari Beur

Figure 16.18: Option III (Proposed Spur Option for Boalmari Beula)

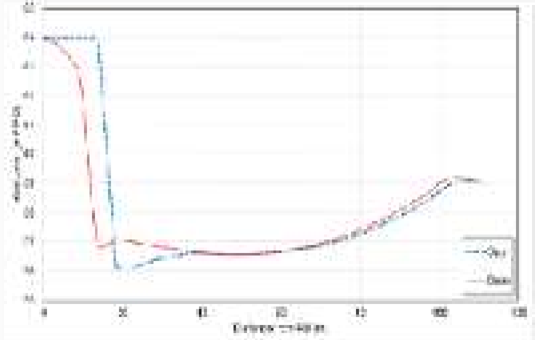

Figure 16.19: Model simulated bed level for the Spur (Option-III) & Base Condition

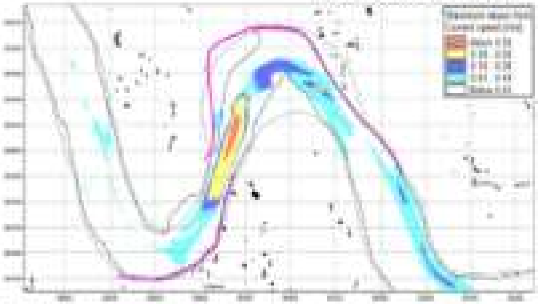

Figure 18.12: Increase in velocity from base condition due to the Spur

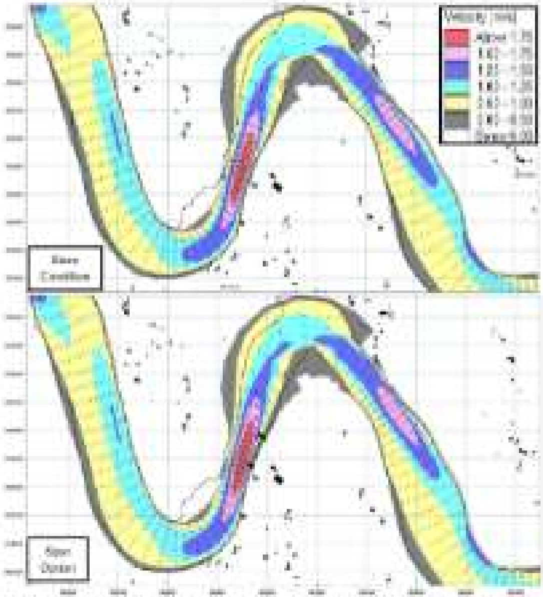

Figure 18.13: Model Simulated peak velocity on the third year for both base and Spur Option Condition

10.2.6 River Excavation of Boalmari Bazar

As described in Section 10.2.4, there is a huge demand from the local people to keep the river flow northwards. An alternative to Option-H, could be to have an excavation near Boalmari Bazar. A re-excavation scenario was generated where a capital dredging was incorporated into the developed model to see its responses. The morphological model simulations do show that the capital dredging channel is subject to siltation. The model was simulated for 5 years and shows the siltation rates after year 1, 2, 3, 4, 5 was 75%, 78%, 88%, 88.5% and 89% respectively. Hence the sedimentation rate of the re-excavation channel was found to be very high. Although the flow did divert more northwards because of the re-excavation, however after the first season, the flow became very much similar to the scenario with no re-excavation. The re-siltation rates for different years for the re-excavation channel has been presented in **Figure 10.14**. To keep the flow northwards, first of all the BPW has to be extended in Boalmari Bazar, then regular river re-excavation will be necessary.

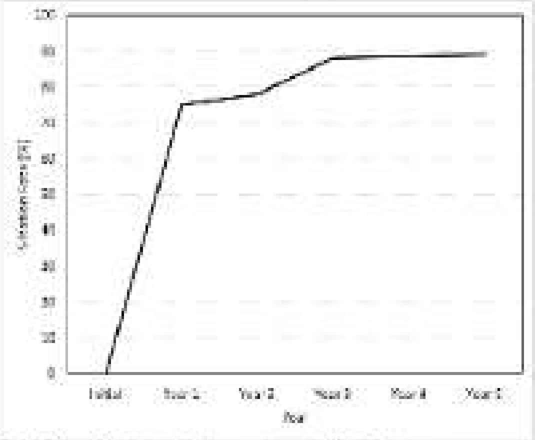

Figure 10.14: Re-siltation rate for the re-excavation channel for different years

10.3 Potential Alternatives of Basiadebi Combined Water Control Structure

During the field visit, it was recorded that the gate of the Basiadebi Combined Water Control Structure could not be properly operated as the local stakeholders claimed that it caused inundation when the gates of the structures were closed. The structure shown in **Figure 10.15**, was designed to store water and use it during dry season. During a detailed analysis it was found that the weir level of the structure (51.368 mMSL) was higher than the average bank level of the surrounding area upstream of the structure (50.15 mMSL). As a result, the surrounding area were getting inundated if the gates of the structure were closed. The probable inundation map due this scenario was prepared based on the collected data (**Figure 10.16**). It is estimated that 4.80 ha area can get inundated due to this scenario when the gates of the structures are closed off to store water.

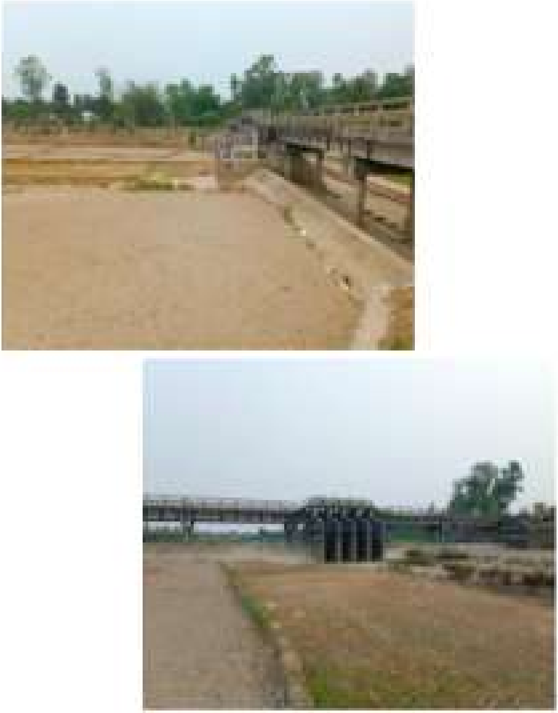

Figure 10.15: Combined Water Control Structure at Baliadangi on Senua River

Four different options have been considered to solve this issue. The first option considered was to carry out land acquisition of the created reservoir. The second option considers construction of a submersible dike along the banks of the river which prevents the land from inundation when the gates of the structures are closed off. However, this option would require regulators as well to prevent water logging. Moreover, the submersible dikes would require regular maintenance as well. The third option would be to maintain the water level at the average bank level of the surrounding regions. This option would require closure of the gate when certain water level is reached to prevent the surrounding areas from inundating. The fourth option, considers re-excavation of the Senua River on the upstream part of the Baliadangi combined water control structure. The water level at the Baliadangi structure would be maintained at the bank level (i.e. 50.13 mMSL) at the structure location in this option. The outcomes of the three options compared have been shown in **Table 10.6**.

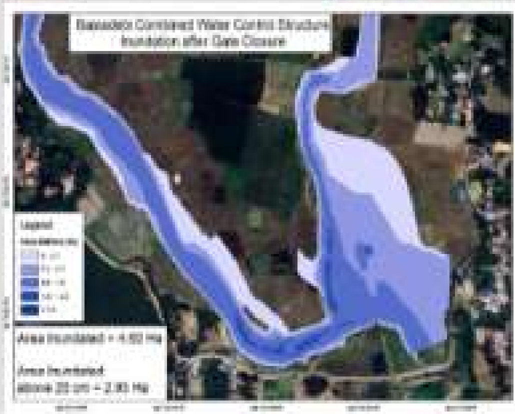

Figure 13.18: Area inundated after gate closure of Balasdabi Combined Water Control Structure on Senua River

Table 13.8: Different Options assessed for Balasdabi combined water control structure

Structure	Item	Option-A	Option-B	Option-C	Option-D
		U/S Gate Closed	Dike + Regulator	Keep 5% @ Bank	Re-excavation & Keep 5% @ Bank
Balasdabi	Closing Weir Level (mPWD)	61.388			
	Bank Level (mPWD)	60.75			
	Area of Inundation (ha)	4.61	0	0	0
	Storage Volume (m³)	61204.83	38132.08	8464.58	48387.13
	Dike Length (m)	0	1937	0	0
	Regulator (nos)	0	2	0	0
	Land Acquisition (ha)	4.61	0.472	0	0
	Cost (Lakh Taka)	1709.73	401.47	0	215.68
	Number of Days with 1 Cusec Pump	39 Days	37 Days	6 Days	34 Days

Since the Balasdabi combined water control structure is located near the Thakurgaon City, the mouza rates of this region is relatively high. Considering the mouza rate of 30,000 BDT per decimal for Salandar Mouza and 3 times the cost for land acquisition, the cost of 4.61 ha land acquisition comes closer to 1709.73 lakh BDT. This would allow the structure to maintain its full reservoir capacity. It is estimated that the option-B, constructing submergible dikes of 1937m plus 2 regulators, would cost around 401.47 lakh BDT, which is substantially lower than Option-A. For Option-C, the stored water is deemed to be very low even though the option does not involve any investment. The Option-D which creates a reservoir on the u/s side of the structure is able to store more water than Option-B. It can also be seen that Option-D can store 79% of water comparing to the Option-A with around 8 times less investment. Considering this information, it can be said that Option-D, i.e. 5 km re-excavation of the Senua River, on the u/s side of the Boaladabi structure and afterwards maintaining the water level at 50.15 mMSL (50.61 mPWD).

10.4 Potential Alternatives of Kalkagaon Combined Water Control Structure

During the field visit, it was recorded that the gate of the Boaladabi Combined Water Control Structure could not be properly operated as the local stakeholders claimed that it caused inundation when the gates of the structures were closed. The structure shown in **Figure 10.17**, was designed to store water and use it during dry season. During a detailed analysis it was found that the weir level of the structure (51.303 mMSL) was higher than the average bank level of the surrounding area upstream of the structure (50.70 mMSL). As a result, the surrounding area were getting inundated if the gates of the structure were closed. The probable inundation map due this scenario was prepared based on the collected data (**Figure 10.18**). It is estimated that 1.38 ha area can get inundated due to this scenario when the gates of the structures are closed off to store water.

Three different options have been considered to solve this issue. The first option considered was to carry out land acquisition of the created reservoir. The second option considers construction of a submergible dike along the banks of the river which prevents the land from inundation when the gates of the structures are closed off. However, this option would require regulators as well to prevent water logging. Moreover, the submergible dikes would require regular maintenance as well. The third option would be to maintain the water level at the average bank level of the surrounding regions. This option would require closure of the gate when certain water level is reached to prevent the surrounding areas from inundating. The outcomes of the three options compared have been shown in **Table 10.8**.

Table 10.8 Different Options assessed for Kalkagaon combined water control structure

Structure	Item	Option-A	Option-B	Option-C
		LA + Gate Closed	Dike + Regulator	Keep WL @ Bank
Kalkagaon	Existing Weir Level (mMSL)	51.303		
	Bank Level (mMSL)	50.70		
	Area of Inundation (ha)	1.38	0	0
	Storage Volume (m³)	60582.79	60358.57	27319.41
	Dike Length (m)	0	1506	0
	Regulator (nos)	0	2	0
	Land Acquisition (ha)	1.38	0.41	0
	Cost (Lakh Taka)	87.80	139.13	0.00
	Number of Days with 1 Cusec Flow	40 Days	35 Days	23 Days

With Option-A and Option B, the created storage does not seem substantially larger comparing to the Option-C. And since, Option-C does not require any investments or land acquisition, the Option-C that is to maintain the water level at 50.70 mMSL (51.16 mPWD) at the structure gate location, would be best possible solution for this structure.

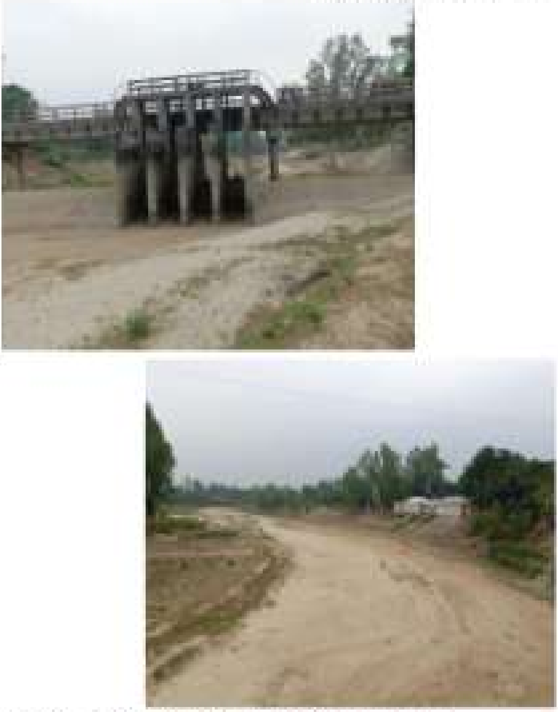

Figure 10.10: Combined Water Control Structure at [illegible] on Pathraj River

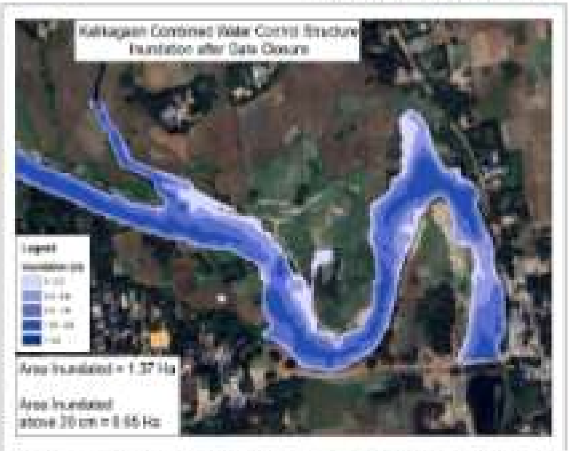
Kalikagaon Combined Water Control Structure
Inundation after Gate Closure
Legend
Area Inundated = 1.37 Ha
Area Inundated above 20 cm = 0.65 Ha

Figure 10.18: Area inundated after gate closure at Kalikagaon Combined Water Control Structure on Pathraj River

10.5 Potential Alternatives of Kasipur Combined Water Control Structure

During the field visit, it was recorded that the gate of the Kasipur Combined Water Control Structure could not be properly operated as the local stakeholders claimed that it caused inundation when the gates of the structures were closed. The structure shown in **Figure 10.19**, was designed to store water and use it during lean season. During a detailed analysis it was found that the weir level of the structure (47.086 mMSL) was higher than the average bank level of the surrounding area upstream of the structure (46.3 mMSL). As a result, the surrounding area were getting inundated if the gates of the structure were closed. The probable inundation map due this scenario was prepared based on the collected data (**Figure 10.20**). It is estimated that 0.81 ha area can get inundated due to this scenario when the gates of the structures are closed off to store water. However, since Tirnoi is a perennial river, flow occurs throughout the year and proper management of the gate could be carried out and water could be stored at an optimal level.

However, like previous cases, three different options have been considered to solve this issue. The first option considered was to carry out land acquisition of the created reservoir. The second option considers construction of a submergible dike along the banks of the river which prevents the land from inundation when the gates of the structures are closed off. However, this option would require regulators as well to prevent water logging. Moreover, the submergible dikes would require regular maintenance as well. The third option would be to maintain the water level at the average bank level of the surrounding regions. This option would require closure of the gate when certain water level is reached to prevent the surrounding areas from inundating. The outcomes of the three options compared have been shown in **Table 10.7**.

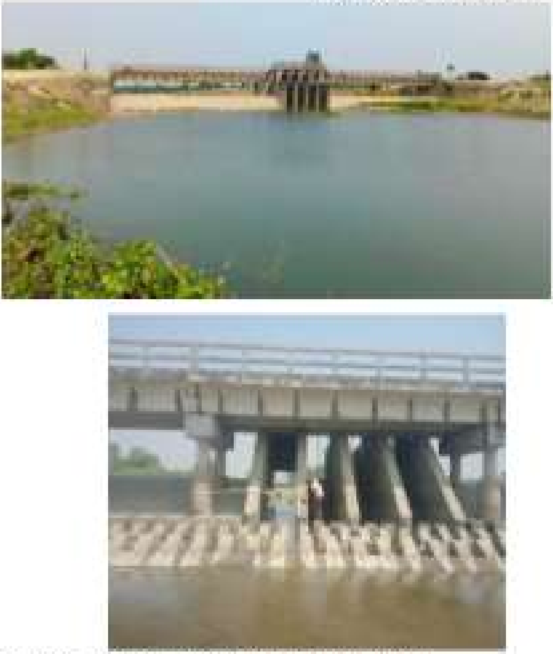

Figure 14.18: Combined Water Control Structure at [illegible] on Tirnai River

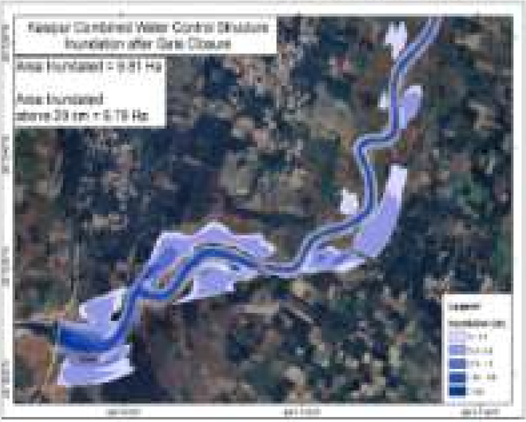

Figure 10.26: Area inundated after gate closure at Kaspur Combined Water Control Structure on Tirnai River

Table 10.7 Different Options assessed for Kaspur combined water control structure

Structure	Item	Option-A	Option-B	Option-C
		LA + Gate Closed	Dike + Regulator	Keep WL @ Bank
Kaspur	Existing Bank Level (mMSL)	47.009		
	Sill Level (mMSL)	45.3		
	Area of Inundation (ha)	9.81	0	0
	Additional Storage Volume (m³)	95274.81	46150.36	0
	Dike Length (m)	0	3700	0
	Regulator (nos)	0	8	0
	Land Acquisition (ha)	9.81	1.24	0
	Cost (Lakh Taka)	557.57	390.81	6.00
	Number of Days with 1 Cusec Flowing	All Options should be able to fulfil 1 Cusec operation for Boro Season		

Option A and Option B would be able to create additional storage volume. However, even by maintaining the water level at the existing ground level, the created storage can be used for boro season irrigation. Considering this, Option-C, that is to maintain the water level at 45.33 mMSL (45.76 mPWD) at the reservoir with gate operation is proposed for the Kaspur combined water control structure.

10.6 Potential Alternatives of River Re-excavation

Tradition way of re-excavation was not deemed necessary for the rivers of Panchagarh & Thakurgaon. The rivers of this region are very steep hence as a result, rainfall-runoff of the river moves very fast towards the downstream. As a result, the water level of the river rises and falls very fast and most of time the river stays dry. As a result, tradition way of re-excavation, only prompts smoother drainage of the river and does not aid in water storage. To by-pass this problem, stepped re-excavation with intermediate humps acting as check structure has been proposed in this study. However, then the immediate problem that arises is the sustainability of these humps and its performance against traditional water control structures. As a pilot case, sustainability of the Umredang bridge hump on the Kulik River has been checked for different options. **Figure 10.21** shows the morphological changes of the Umredang Bridge hump for the different hump option. Three different options have been simulated at the location with the first one is being just stepped re-excavation with intermediate humps (Option-A). Second one being placing geo-bag just upstream of the hump (Option-B) and the last one considering a water control structure at the hump location (Option-C). From the figure it can be seen that for the first option, that is just re-excavation, erosion occurs both u/s side and the d/s side of the hump. As a result, most of the hump gets almost washed away. However, if geo-bags are provided u/s side of the hump, it can be seen that the erosion stops on the u/s side of the hump. But erosion can still be seen on the d/s side of the hump. A Water control structure constructed on the hump would protect the hump however similar kind of profile d/s side of the hump can be seen as well. One thing is prominent from the figure that on the downstream side of the hump, stream power of the river causes erosion i.e. self-excavation of the river itself.

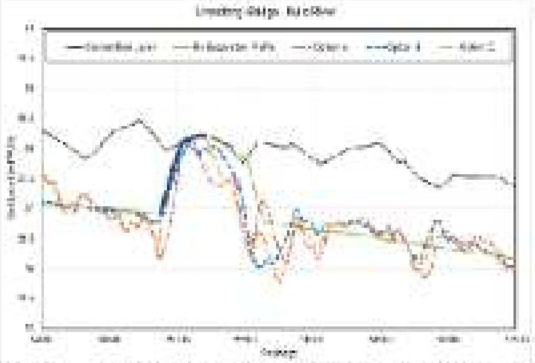

Figure 10.21: Morphological changes of the Umredang Bridge hump for the different hump option

To increase the longevity of the humps and promote self-excavation of the river, slightly milder slope of cutting has been tested with morphological model and the result has been presented in **Figure 10.22**. Considering 1:100 slope on the downstream side of the hump, it can be seen that even after providing this milder slope, for only re-excavation (Option-D), erosion once again can be seen on the u/s & d/s side of the hump. If Geo-bags are provided on the u/s side of the hump (Option-E), erosion stops on the u/s side of the hump but on the d/s side of the hump erosion still persists. This also indicates that using river stream power, natural re-excavation is also possible, reducing the need of re-excavation cost. The condition of the hump also seems more stable after 3 years when milder slope is provided comparing Option-B. The last option considers placing of geo-bags all along the milder slope (Option-F) which does prevent erosion of the hump considerably. However, placing geo-bags along this big stretch of dry river which would be exposed to the weather for majority of the year does not seem practical or sustainable hence Option-F is not recommended.

A summary of all the options considered for re-excavation are:

Option-A:	Re-excavation with intermediate humps
Option-B:	Option-A + Geo-bags placed just upstream of the humps
Option-C:	Option-A + Water Control Structure
Option-D:	Re-excavation with intermediate humps but 1:100 slope provided on the d/s part of the hump
Option-E:	Option-D + Geo-bags placed just upstream of the hump
Option-F:	Option-D + Geo-bags placed both u/s and d/s of the hump

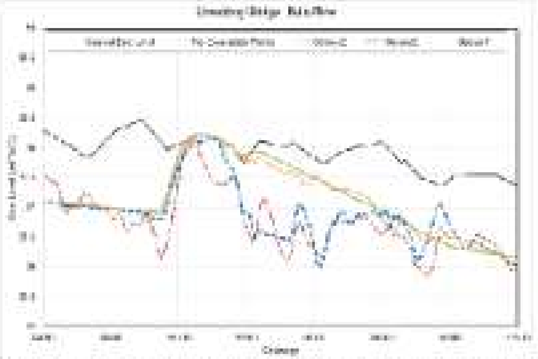

Figure 10.22: Morphological changes of the [illegible] Bridge Hump for the different hump option after considering mild d/s slope

The cost comparison of different options has been shown in **Table 10.8**. Comparing the benefits and cost, it can be seen that Option-E would be the most practical and cost-effective option among these. Option-C which is the water control structure, would cost 25 times more than the Option-E would generate similar kind of benefits. The Option-E would be a nature-based solution to store water in the study area.

Table 10.8: **Cost Comparison of different Options considered for re-excavation**

Item	Option					
	A	B	C	D	E	F
Capital Cost (Lakh Taka)	132.57	134.83	3258.37	103.90	124.36	335.80
5-year Maintenance Re-excavation cost (Lakh Taka)	51.46	56.59	33.46	41.21	34.09	21.92
Capital +Maintenance Cost (Lakh Taka)	184.03	191.43	3292.37	145.11	158.46	357.71

SECTION ELEVEN

CONCLUSIONS AND RECOMMENDATION

11. CONCLUSIONS AND RECOMMENDATION

The study is aimed to make a comprehensive analysis on the rivers of Panchagarh & Thakurgaon districts located in the north-western corner of Bangladesh. Both districts have very steep catchment slopes which results in quick drainage of the water. This results in very high velocity during monsoons, however as the water drains out very quickly, water availability during the lean season also becomes an acute problem in this area.

With the aid of detailed survey campaign and mathematical modelling technology, the scenarios of different management options of the regions were developed, and problems were identified. Based on such observations, reaches vulnerable to erosion were identified and detailed two-dimensional model was used to design the bank protection works of the reaches vulnerable to erosion. A total of 73.005 km of River Training Works of which 57.315 km is in Panchagarh district and 15.240 km is in Thakurgaon district have been proposed. The proposed river training works will protect 132.52 ha of lands in Panchagarh district and 46.80 ha of lands of Thakurgaon district. Hence a total of 179.31 ha of land could be protected from riverbank erosion if the proposed Bank Protection Works are constructed.

A review of the present status of the 80 LLPs (Electric Block) as well as the water availability of the Karatoa river at the LLP block locations have been assessed in this study. Due the Amtali barrage located 22 Km u/s of the Bangladesh-India border on the Karatoa river might be responsible for decreasing water availability in the dry season. It is found that water extraction using the historical pump capacity might not be possible for the LLPs around the Karatoa river without hampering the environmental flow of the river. However, it has been assessed that it is possible to extract 6 cusecs from Ahmed Nagar-1, 4 cusecs from Ahmed Nagar-2, 4 cusecs from Ahmed Nagar-3, 32 cusecs from BB-1 (Boalmari), 64 cusecs from BB-3 (Telpara) & 64 cusec from BB-4 (Laxmirpara), which would allow to irrigate 3641 ha during supplementary irrigation period and 1397 ha during dry season irrigation. Similar kind of analysis has been carried out for Talma River has well which shows that 10 cusec waters can be withdrawn from the Talma River while still maintaining the E-Flow. This would allow to irrigate 200 ha during supplementary irrigation period and 80 ha during dry season irrigation using the water of the Talma River.

The local demand of people to construct spurs near Boalmari bazar has also been investigated in the study. However, the challenge in constructing as well as maintaining the spurs is deemed to be too much comparing the benefits it may provide. Hence, it was not recommended to construct the spurs at Boalmari Bazar. An alternative of this could be re-excavation of Karatoa river near Boalmari Bazar, however capital dredging is subject to high siltation. It has been estimated that around 75% of re-excavated channel was filled out within one monsoon. While the re-excavation channel was 90% silted up after three seasons. As there is a local demand here to keep the flow northwards for religious reasons, first of all it is important to construct RTW here to stop the flow from going further eastwards and the present practice of yearly excavation may be continued.

Among all the rivers, Kulik, Rangapani, Kurum, Dara, Kaldoha, Ranochondi, Sanua & Pathraj rivers were also recommended for re-excavation considering the agricultural potentiality in the region. Most of these rivers were seasonal rivers, carrying the storm water of the surrounding catchments. Re-excavation scenarios were designed in such way that the existing bridges are used as natural humps to store the water behind it. Re-excavation will be carried out to create pockets for water storage regions and the water storage capacity will be increased drastically with the proposed re-excavation scenarios. The maximum storage capacity of Kulik River increased by 38.28%, Rangapani 737%, Kurum 288%, Dara 1708%, Kaldoha 1606%, Ranochondi 181%. Re-excavation of the u/s side of the Pathraj WCS increased the storage capacity by 132%. However, since these rivers are mostly seasonal, they are subject to evaporation & percolation losses, and after considering these losses, most of reservoirs becomes dry by the end of February if no precipitation occurs during the winter seasons. Hence it is not recommended to establish any LLP pump house in these reservoirs. The site reservoir near Umradangi (Kulic River) may have enough water to extract 1 cusec of water which could irrigate 20.00 ha of land during supplementary irrigation period. However, the created reservoirs can be used locally by the people to meet their domestic and agricultural demands. In that case the Kulic River can irrigate 54.83 ha, Rangapani 2.01 ha, Kurum 23.99 ha, Dara 0.20 ha, Kalisona 13.89 ha, Ronochondi 7.50 ha during supplementary irrigation period.

To address the issue of water availability in the dry season, two possible combined water control structures were considered in the Karatoa River, with one being in Kaliaganj and another one in Laxminarayan. The survey data and model simulation results show that there is enough water available near the BB-4 at Laxminarayan. Hence no water control structure was proposed at Laxminarayan. However, the water depth available near BB-1 at Boalmari was not found to be sufficient under the current condition. Hence, a combined water control structure has been proposed at Kaliaganj located 4 km d/s of the BB-1 pump house. The crest level of the structure was fixed using different mathematical model simulations and the structure increased the available water depth near the now non-functional LLP pumphouse at Boalmari bazar. However, comparing to the cost and challenges of construction, the structure does not seem to bear that much benefits. However, a detailed analysis of the irrigational potential of the surrounding area could provide more insights of the surrounding irrigation systems and find out more benefits of the structure. Considering these, Kaliaganj water control structure has been placed in lower priority. Re-excavation near the pumphouse could be carried out to ensure required depth for the pump temporarily to make it functional again.

In Thakurgaon O&M division, DPP has been approved of four water control structures. Two of them are already under construction. The study finds that the structures would have positive impact on the study area, by increasing the water retention and dry season water availability. While the structures do have some benefits during supplementary irrigation period, it would be hard to carry out full-fledged irrigation during boro monsoon with these structures. For example, the dry season flow of the Tangon river would still be a problem for boro season irrigation. But it would be beneficial for supplementary irrigation purposes. For Pathraj river, the created reservoir helps store the water up to May if no water is extracted from it. However, the stored water is not enough for boro season irrigation. But the structure can help provide supplementary irrigation to 40 ha of lands in case of lack of precipitation.

The effectiveness of the existing water control structures at Basabari, Kalikagaon and Kalopur was evaluated which shows that the weir crest level of the structure is higher than the ground level of the surrounding area. To make the structures more effective, different options were considered and checked. For Basabari structure, re-excavation of the Senua River afterwards maintaining the water level at 50.15 mMSL (50.61 mPWD) has been proposed. This would allow the structure to store 48087.10 m^3 water upstream of the structure. Similarly, for Kalikagaon & Kalopur structure, it is mentioned to maintain water level 30.70 mMSL (31.16 mPWD) and 40.30 mMSL (40.76 mPWD) respectively.

11.1 Recommendation

The recommendations of the study are as follows:

- A total of 73.555km of Bank Protection Works (BPW) at 129 locations among which 57.310 km of BPW at 76 locations of Panchagarh district and 16.245 km of BPW at 53 locations of Thakurgaon district have been proposed in 3 phases. In the first phase 31.05km of BPW at Panchagarh district & 5.865 km of BPW at Thakurgaon district has been proposed.
- Re-excavation of 14.40 km of Kulic, 3.38 km of Rangapani, 4.47km of Kurum, 1.636km of Dara, 1.755km of Kalisona, 3.058km Ronochondi, 0.80 km of Pathraj river and

0.000km of Sanua River as per provided design provided along with this report have been proposed.

- Although the water control structure at Kaliaganj, Karatoa river does have benefits, compared to the cost, it is not substantial. However, conducting a detailed analysis of the irrigational potential of the surrounding area could provide more insights of the surrounding irrigation systems and find out more benefits of the structure. Considering those, Kaliaganj water control structure has been placed in lower priority. Re-excavation near the pumphouse could be carried out to ensure required depth for the pump. Considering the significance of northward flow near Bhoiman bazar, the re-excavation of this reach will be required based on requirement under BWDB supervision.
- For effective function of the Bakabadi water control structure, re-excavation of the Sanua River u/s of the structure and maintaining the water level at 50.15 mMSL (50.61 mPWD) at the structure location is recommended. For the Kaliaganj and Kaspur water control structures, it is recommended to maintain water level 50.70 mMSL (51.15 mPWD) and 45.30 mMSL (45.76 mPWD) respectively.
- **To maintain the "Environmental Flow" of the Karatoa river, maximum 8 cusecs from** Ahmad Nagar-1, 4 cusecs from Ahmad Nagar-2, 4 cusecs from Ahmad Nagar-3, 32 cusecs from BB-1 (Boaimari), 64 cusecs from BB-3 (Tepria) & 64 cusecs from BB-4 (Laxminarayan) can be extracted from the Karatoa River, which would allow to irrigate 3641 ha during supplementary irrigation period and 1397 ha during dry season irrigation. **And to maintain the "E-Flow" of the Talma River maximum 10 cusec of water** can be extracted from the Talma River during dry season. This would allow to irrigate 203 ha during supplementary irrigation period and 80 ha during dry season irrigation using the water of the Talma River.

SECTION TWELVE

REFERENCES

12. REFERENCES

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Appendix-A: Tour Reports

Tour Report - 01

in connection with

Consultancy Services (Mathematical Modelling Component) in connection with the project "Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon District"

Participants from IWM:

- Mr. Md. Saim Bhuiyan (SMB), Consultant, IWM
- Mr. Imran Khan (IMK), Associate Specialist, IWM
- Mr. Md. Salman Arfin (SAN), Junior Engineer, IWM

Participants from BWDB:

- Mr. Md. Mukleshur Rahman, Superintending Engineer (Civil), Thakurgaon O & M Circle, BWDB, Thakurgaon
- Mr. Muhammad Abu Saeed, Project Director & Executive Engineer, Directorate of Planning-2, BWDB, Dhaka
- Mr. Rabiul Islam, Executive Engineer, Thakurgaon O & M Division, BWDB, Thakurgaon
- Mr. Md. Hafizul Haque, Executive Engineer, Panchagarh O & M Division, BWDB, Panchagarh
- Mr. Md. Rakibul Islam, Assistant Engineer, BWDB, Thakurgaon
- Mr. Shanu Joy Das, Sub-Divisional Engineer, BWDB, Thakurgaon

Purpose and approach:

- Meet with the BWDB field officials, understand the demands of the projects, problems of the regions and possible objectives.
- To visit the vulnerable locations along the Karatoa, Tangon, Talma, Upper Nagor and the Ghoramara River under Panchagarh and Thakurgaon District.
- Visit the possible location of water retention structure in the Karatoa and Bulic River

Prior to commencement of modeling component of the study, a reconnaissance survey visit was undertaken in the study area to understand the existing situation, extent of vulnerability and to collect general information on the behavior of the rivers of Panchagarh and Thakurgaon through field inspection and taking opinion from local stakeholders at and around the vulnerable locations within the study reach.

IWM modeling study team and the BWDB field officials of Thakurgaon O & M circle, Superintending Engineer (Civil), Directorate of Planning-2, Thakurgaon O & M Division and Panchagarh O & M Division.

BWDB met together before departing for site visit finalize the plan of action of the site visit. The team visit focused on the followings:

- River channel regime (to observe, whether the river has a wide flood plain or it is with little or no flood plain)
- River channel flow pattern (if it is sinuous, whether the channel migration is active)
- River channel stability (steepness of banks, evidence of bank erosion, vegetation on the bank, erosion pockets and embayment in the bank etc.)
- Type of material forming the bank
- Debris marks on trees or banks, which is indicative to the probable water level of recent floods

- Watermarks on walls, jetties, and piers which, indicate record high-water levels
- Information on existing Bank Protection Works
- Probable structures for improving irrigation of the study area
- Best suited structures for controlling irrigation water of this study area

Details of Tour activities:

13 December 2022

The IWM Modelling study team left Dhaka for Thakurgaon, BWDB office at 06:00 am. The team reached Thakurgaon in the afternoon around 01:30 pm. A discussion meeting took place between the IWM visiting team, BWDB Directorate of Planning-2 and local field officials namely, Mr. Md. Mustafizur Rahman (Superintending Engineer of Thakurgaon O & M Circle), Muhammad Abu Saeed (Executive Engineer, Directorate of Planning-2), Mr. Rabiul Islam (Executive Engineer of Thakurgaon O & M Division) and Mr. Md. Hafizul Haque (Executive Engineer of Panchagarh O & M Division) discussed some salient features of the study. The team as well as BWDB officials decided to start their observation that day. As per discussion and plan the combined team of IWM and BWDB Panchagarh field officials went out to cover vulnerable areas of Karatoa River near Aulia ghat and one of the structures (Low Lifting Pump) installed by BWDB at Boalmari Bazar. The field visit of day-1 ended at 5 pm.

14 December 2022

The IWM team together with the BWDB officials of Panchagarh O & M Division met, planned, and started the journey to inspect a few more vulnerable locations of the Karatoya River, the Talma River and the Ghoramara River at 9 am. The team visited the vulnerable locations at Ahmadiyya Mosque Shalmari, Araji Sikarpur Sarkar Para Mosque, Mirgor Guccho Gram, Koliaganj ghat of the Karatoya River, at Jamidarpara (Bamanpara) of the Talma River and at Mahadanga of the Ghoramara River. Having a short discussion about these locations with the Executive Engineer of Panchagarh O & M Division, the team moved forward for inspecting the vulnerable locations of the rivers of Thakurgaon district with the BWDB officials of Thakurgaon O & M Division. The team observed the Bochaganj Weir plus Regulator structure installed by BWDB for Bochaganj Irrigation Project at Ranungaon over Sonrai River and Pipe Outlet structure over Tangon River at Bhulli Bazar. On the way, necessary questionnaires regarding river hydrology i.e., maximum historical water level, extent of flooding, and or if the banks erode were shared with the local stakeholders. After that, the team left for BWDB Thakurgaon office from the site at 5 pm.

15 December 2022

The IWM team together with the BWDB officials of Thakurgaon O & M Division started the site visiting continuation for the Upper Nagor and the Kulic River at 9:00 am. The team observed the vulnerable locations at Dhormogher (Brahail Khamar) of the Upper Nagor River and at Sonshara Sarkar Para of the Kulic River. After the site visit of the Upper Nagor and the Kulic rivers the team closed the programme for the time being and returned to BWDB, Thakurgaon office at 1:15 pm. After taking lunch, the team left for Dhaka at 1:30 PM.

Field Observations:

Karatoa River

- The river is very dynamic and vulnerable to erosion. Severe erosion was found near Aulia Ghat, Ahmadiyya Mosque at Shalshiri, Sahebpara.
- A non-functionable low lift pump was found damaged at Boalmari Bazar. BWDB officials of Panchagarh Division suggested to make this pump functionable for irrigation purpose.
- An Embankment is proposed by BWDB to protect the Mirgor Bucchu Gram from flooding during flash flood.
- For improving irrigation and connectivity, tentative water control structure at Kalapani Ghat was observed by the study team. IWM will evaluate this tentative structure.

Talma River

- The team observed bank erosion at Bamonpara.

Ghoramara River

- Riverbank erosion was found at Malkadanga.
- The team also found Dumped Geo-Bags at Malkadanga.

Senua River

- Existing Water Control Structure (Senua Dam Irrigation Project) which is established by BWDB at Borunagaon was observed by the study team.

Tangon River

- The study team observed the Pipe Outlet Structure at Bodolia.

Upper Nagar River

- The team observed bank erosion at Dhormogar. This area is near to Bangladesh-India international border. So, this area is needed to be addressed very soon.
- The team also found protective works at some portions of Dhormogar.

Kulik River

- Tentative Water Control Structure at Sondhani Sarkar Para was observed by the study team.

Some photographs, taken during the field visit, are given.

Karatoya River

Photo A1 Riverbank Erosion at Auliar Ghat (Karatoya- Ghoramara River Confluence)

Photo A2 Non-functional Low Lift Pump at Boalmari Bazar

Photo A3 Riverbank Erosion near Ahmadiyya Mosque at Sharatin

Photo A4 Riverbank Erosion at Sarkarpara

Photo A5 Proposed Embankment near Mogor Buccho Gram

Photo A6 Tentative Water Control Structure location at Kalaganj Ghat

Talma River

Photo A7 Riverbank Erosion at [illegible]

Ghoramara River

Photo A8 Riverbank Erosion at [illegible]

Photo A9 Existing Dumped Geo-Bags at [illegible]

Senua River

Photo A10 Existing Water Control Structure ([illegible] Irrigation Project) at [illegible]

Tangon River

Photo A11 Pipe Outlet Structure at [illegible]

Upper Nagar River

Photo A12 Riverbank Erosion at [illegible]

Photo A13 Existing Protective Works at Dharmaghat

Kulik River

Photo A14 Tentative location of the proposed Water Control Structure at Sonatikar Sarkar Para over the Kulik River

Photo A15 Discussion with local stakeholders while collecting information of the Kulik River at Sanchan Senior Park

Tour Report - 02

in connection with

Consultancy Services (Mathematical Modelling Component) in connection with the project "Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon District"

Participants from IWM:

- Mr. Md. Saim Bhuiyan (SMB), Consultant, IWM
- Mr. Imran Khan (IMK), Associate Specialist, IWM

Participants from BWDB:

- Mr. Muhammad Abu Saeed, Project Director & Executive Engineer, Directorate of Planning-2, BWDB, Dhaka
- Md. Rakibul Hasan, Executive Engineer, Dinajpur O & M Division, BWDB, Dinajpur
- Md. Golam Zakaria, Executive Engineer, Thakurgaon O & M Division, BWDB, Thakurgaon
- Mr. Ashutosh Barman, Executive Engineer, Panchagarh O & M Division, BWDB, Panchagarh
- Mr. Rahsan Jony, Sub-Divisional Engineer, BWDB, Dinajpur
- Md. Nakibuzzaman Khan, Sub-Divisional Engineer, BWDB, Dinajpur
- Mr. Md. Rakibul Islam, Assistant Engineer, BWDB, Thakurgaon

Purpose and approach:

- Meet with the BWDB field officials, understand the demands of the projects, problems of the regions and possible objectives.
- Identify the rivers on the field.
- To visit the vulnerable locations along the Karatoa, Atrai and Kalna under Panchagarh, Thakurgaon and Dinajpur District.

The field visit was undertaken to communicate with field Officials of BWDB, brief them about the progress of the study. The study team visited the BWDB Dinajpur O&M Division and met with the Executive Engineer. The team discussed about the potential vulnerable locations of the Karatoa-Atrai river in Dinajpur district. The team also met with Executive Engineer of Thakurgaon and Panchagarh O&M divisions to not only visit the vulnerable sites of the district and identify the rivers on the field.

The team visit focused on the followings:

- River channel regime (to observe, whether the river has a wide flood plain or it is with little or no flood plain)
- River channel flow pattern (if it is sinuous, whether the channel migration is active)
- River channel stability (steepness of banks, evidence of bank erosion, vegetation on the bank, erosion pockets and embayment in the bank etc.)
- Type of material forming the bank
- Debris marks on trees or banks, which is indicative to the probable water level of recent floods
- Watermarks on walls, jetties, and piers which, indicate recent high-water levels
- Information on existing Bank Protection Works.

Details of Tour activities:

30 March 2023

The IWM Modelling study team left Dhaka for Dinajpur, BWDB office at 06:30 am. The team reached Dinajpur around 10:30 AM. A discussion meeting took place between the IWM visiting team, BWDB Directorate of Planning-2 and local field officials namely, Muhammad Abu Saeed (Executive Engineer, Directorate of Planning-2), Mr. Md. Rashid Hasan Executive Engineer of Dinajpur O & M Division), Mr. Md. Nasiruzzaman Khan (Sub-Divisional Engineer, Dinajpur O & M Division) and Mr. Rehan Jany (Sub-Divisional Engineer, Dinajpur O & M Division) discussed some salient features of the study. the team as well as BWDB officials decided to start their observation that day. The visited some vulnerable sites on the banks of Karatoa-Atrai rivers near Golchar, Joshna Bazar and Kashim Nagar. The field visit of day-1 at Dinajpur district ended at 4 pm and the team proceeded towards Thakurgaon. The team halted for the night at Thakurgaon.

31 March 2023

The team met with the Mr. Md. Golam Zakaria (Executive Engineer of Thakurgaon O & M Division) and Mr. Md. Rokibul Islam (Assistant Engineer, Dinajpur O & M Division) in the morning and visited the Tangon Barrage site. Later the team met with Mr. Abdullah Barman (Executive Engineer of Panchagarh, O & M Division) near Boda Upazila and proceeded to visit Boalmari Bazar on the banks of Karatoa river. After lunch the team visited a control structure on the Buri Teesta River. The team later moved eastward to identify the Rangapani river and the Deek River on the field. The field visit concluded the field visit near Debiganj at 4 PM and left for Dhaka.

Field Observations:

Karatoa-Atrai River:

- The river is very dynamic and vulnerable to erosion. Erosion was found near Golchar (Photo A16, Photo A17), Joshna Bazar (Photo A18), Kashimpur (Photo A19 and Photo A20) and Boalmari (Photo A24 and Photo A25).
- Near Boalmari, erosion was observed at the termination point of existing BPW. The local stakeholders said that the northward flow of the Karatoa River is very important for religious purposes and erosion of the Karatoa river makes it vulnerable. Considering the religious importance, BPW might be needed here.

Tangon River

- The study team visited the Tangon Barrage (Photo A21, A22 and A23). The Executive Engineer said that the there are problems regarding the reservoir capacity of the Barrage as the barrage reservoir inundates public lands. Hence, the gate of the barrage has to be opened quickly to avoid the backlash of the people. He requested the study team to assess the land acquisition potential for increasing the Tangon barrage reservoir.

Buri Teesta River

- A combined water structure over the Buri Teesta River (Photo A26 & A27) was visited by the team. The structure present here mostly blocked off the natural drainage of the river. The sill level of the regulator seemed higher than the bed level upstream of the structure. While Weir portion of the structure completely blocked off the river. The river downstream of the structure seemed to have dried out as a result.

Dara River

- The location and flow path of the Dara River was identified.

Rangapani River

- The location and flow path of the Rangapani River was identified.

Some photographs, taken during the field visit, are given:

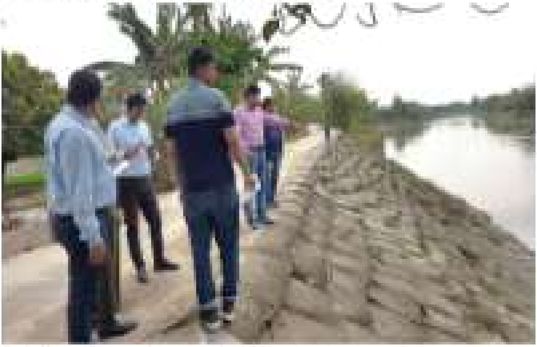

Photo A16 Riverbank Erosion near [illegible]. The reach is being protected with temporary bank protection works.

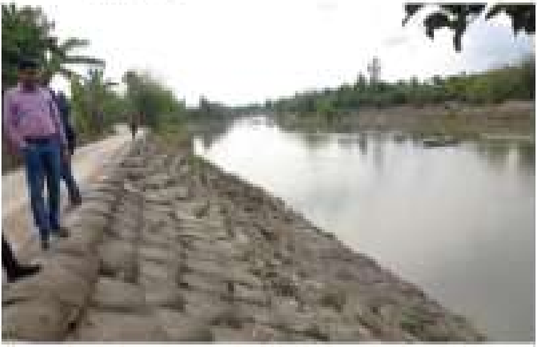

Photo A17 Riverbank Erosion near [illegible], [illegible]. The reach is being protected with temporary bank protection works.

Photo A18 Riverbank Erosion near [illegible], Dinajpur Sadar

Photo A19 Riverbank Erosion near [illegible], Birganj

Photo 4.20 Riverbank Erosion near Kashimpur, Biganj

Photo 4.21 Sluice Gate Structure of Tangon Barrage

Photo A22 Sluice Gate Structure of Tangon Barrage

Photo A23 Tangon Barrage

Photo A.24 Drain near Goalman Bazar where erosion is occurring

Photo A.25 Stakeholder consultation near Goalman Bazar

Photo A26 Water Control Structure on Buri Teesta River constructed by LGED

Photo A27 Water Control Structure on Buri Teesta River constructed by LGED

Tour Report 03

in connection with

Consultancy Services (Mathematical Modelling Component) in connection with the project "Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon District"

Participants from IWM:

- Mr. Md. Alim-Uz-Zaman (AUZ), Associate Specialist, IWM
- Mr. Md. Salman Arifin (SAN), Junior Engineer, IWM

Participants from BWDB:

- Mr. Krishnakamal Chandra Sarkar, Superintending Engineer (Civil), Thakurgaon O & M Circle, BWDB, Thakurgaon
- Mr. Ashutosh Barman, Executive Engineer, Panchagarh O & M Division, BWDB, Panchagarh
- Mr. Md. Golam Zakaria, Executive Engineer, Thakurgaon O & M Division, BWDB, Thakurgaon
- Mr. Md. Shamsul Haque, Executive Engineer, Thakurgaon Mechanical Division, BWDB, Thakurgaon
- Mr. Md. Rafiul Bari, Deputy Chief Extension Officer, BWDB, Thakurgaon
- Mr. Md. Mostul Islam Rony, Sub-Divisional Engineer, BWDB, Thakurgaon
- Mr. Bhanu Joy Das, Sub-Divisional Engineer, BWDB, Thakurgaon
- Mr. Md. Rokibul Islam, Sub-Divisional Engineer, BWDB, Thakurgaon
- Mr. Md. Rashedul Islam, Sub-Divisional Engineer, BWDB, Panchagarh
- Mr. Bipon Shaha, Sub-Divisional Engineer, BWDB, Panchagarh

Purpose and approach:

To visit the model identified vulnerable locations of the rivers under Panchagarh and Thakurgaon District and to take the feedback from the BWDB field officials of Thakurgaon O & M circle, Superintending Engineer (Civil), Planning-2 Directorate, Thakurgaon O & M Division and Panchagarh O & M Division.

Details of Tour activities:

17 December 2023:

The IWM Modelling study team left Dhaka for Panchagarh, BWDB office at 08:00 pm of 16th December and reached the Panchagarh BWDB office around 12:30 pm of 17th December. A discussion meeting took place between the IWM visiting team and local field officials of Panchagarh O & M Division namely, Mr. Ashutosh Barman (Executive Engineer), Mr. Md. Rashedul Islam (Sub-Divisional Engineer), Mr. Bipon Shaha (Sub-Divisional Engineer) discussed some salient features of the study and checked the model identified vulnerable locations of the rivers of Panchagarh District by the supervision of Mr. Ashutosh Barman.

18 December 2023:

The IWM team together with the BWDB officials of Panchagarh O & M Division met, planned, and started the journey to inspect the vulnerable locations of the Mahananda, Karatoya and the Chawai River at 8 am by a hired vehicle. The team visited the vulnerable locations at Bangabandha, Sardar Para, Tetulia Eid Gah River Side and Tetulia Purahon Bazar of the Mahananda River, at Upstream of Bhojanpur Bridge, [illegible], [illegible] Para at Amarkhana of the Karatoa River and at the downstream of the Chawai Bridge of the Chawai River. On the way, necessary questionnaires regarding river hydrology i.e., maximum historical water level, extent of flooding, and whether the banks erode were shared with the local stakeholders. After that, the team set for Panchagarh from the site at 5 pm.

18 December 2023

A meeting was held between the IWM visiting team and local field officials with the supervision of Mr. Krishnakanta Chandra Sarkar (Superintending Engineer of Thakurgaon O & M Circle) at BWDB Thakurgaon Office. In this meeting BWDB field officials namely Mr. Ashutosh Barman (Executive Engineer of Panchagarh O & M Division), Mr. Md. Shamsul Haque, (Executive Engineer of Thakurgaon Mechanical Division), Mr. Md. Golam Zakaria (Executive Engineer of Thakurgaon O & M Division), Mr. Md. Rafiul Bari (Deputy Chief Extension Officer of Thakurgaon), Mr. Md. Mojiul Islam Rony (Sub-Divisional Engineer of Thakurgaon O & M Division), Mr. Md. Rokibul Islam (Sub-Divisional Engineer of Thakurgaon O & M Division), Mr. Md. Rashedul Islam (Sub-Divisional Engineer of Panchagarh O & M Division) and Mr. Bipon Shaha (Sub-Divisional Engineer of Panchagarh O & M Division) were present. The agenda of the meeting was to verify the model identified vulnerable locations, proposed water retention structures and expressed their opinion on the study. After having lunch, the team left for Dhaka at 3:30 PM.

Field Observations:

Mahananda River

Photo A18 Partially damaged protective works at Bangabandha

Photo A22 Riverbank Erosion at Sardar Para

Photo A23 Discussion with Local People

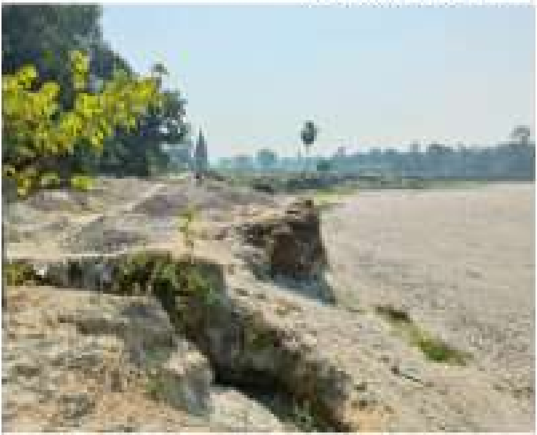

Photo A31 Unprotected Purnoba Bank Erosion at Teulia

Karatoya River

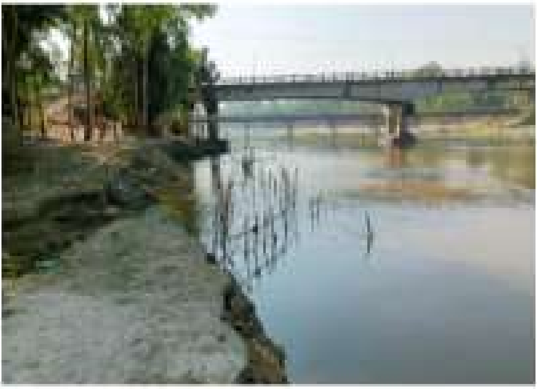

Photo A32 Riverbank Erosion at the upstream of Bhajanpur Bridge

Photo A33 Riverbank Erosion at Debiganj

Photo A34 Under Constructed Building Solar Panel at Amarkhana

Chawai River

Photo A22 Riverbank Erosion at the downstream of Chawai Bridge

Discussion Meeting at Thakurgaon

Photo A23 Discussion with Field Office

Tour Report-04

in connection with

Consultancy Services (Mathematical Modelling Component) in connection with the project "Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon District"

Participants from IWM:

- Mr. Imran Khan (IMK), Associate Specialist, IWM

Participants from BWDB:

- Mr. Krishnakamal Chandra Sarker, Superintending Engineer (Civil), Thakurgaon O & M Circle, BWDB, Thakurgaon
- Ms. Farzana Ahmed, Executive Engineer & Project Director, BWDB
- Mr. Ashuddin Barman, Executive Engineer, Panchagarh O & M Division, BWDB, Panchagarh
- Mr. Md. Golam Zakaria, Executive Engineer, Thakurgaon O & M Division, BWDB, Thakurgaon
- Dr. Faria Fahim Bashor, Executive Engineer, Directorate of Planning-I, BWDB
- Mr. Md. Rafiul Bari, Deputy Chief Extension Officer, BWDB, Thakurgaon
- Mr. Md. Rokibul Islam, Sub-Divisional Engineer, BWDB, Thakurgaon
- Mr. Md. Rashedul Islam, Sub-Divisional Engineer, BWDB, Panchagarh

Participants from CEGIS:

- Mr. Sanjib Sarkar, Research Consultant, CEGIS

Purpose and approach:

To interact with the field officials to assess the situation post-workshop and visit the model proposed water control structure locations.

Field Pictures:

Photo A37 Discussion with Field officials

Photo A38 Meeting with Field officials

Photo A39 Meeting with Field officials

Photo A40 Meeting with Field officials

Photo A41 Field visit at Nashimnagar

Photo A42 Field visit at Nashimnagar, Tangon River near proposed Water Control Structure

Photo A43 Under construction Water Control Structure at [illegible], Tulai River

Photo A44 Under construction Water Control Structure at Balia, Shuk River

Appendix-B: Workshop Pictures

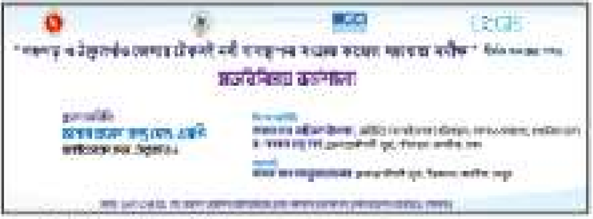

Photo B1 Workshop Banner

Photo B2 Workshop Picture

Photo B3 Workshop Picture

Photo B4 Workshop Picture

Photo 83 Workshop Picture

Photo 84 Workshop Picture

Photo B7 Workshop Picture

Photo B8 Workshop Picture

Appendix-C: Compliance on Workshop

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Appendix-D: Compliance on DFR Meeting

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Appendix-E: Compliance on ToR

Compliance on the Outputs:

Expected Outputs	Comments	Relevant Chapter/Section in Report
Base map, project map with inventory of existing structures and flood inundation map, flood Elevation Curve.	The base map & project map with inventory of the structures has been provided in Figure 2.1 & Section 4.1.10. Flood risk assessment and flood inundation has been discussed in detail in Section 4.1.9. The area-elevation curve of the study area has been provided in Figure 4.8.	Figure 2.1, Figure 4.8, Figure 4.40, Figure 4.48a & Table 4.18
Identified critical locations affected by bank erosion and silted reaches within the river requiring protective work for erosion control.	The critical locations affected by bank erosion has been identified from satellite images in Section 4.1.8. The engineering measures requirement assessment for bank erosion and silted up reaches has been mentioned in Section 4.2.1 & Section 4.2.2.	Section 4.1.8, Section 4.2.1 & Section 4.2.2
Recommendation on the dredging locations and type of water retention structures, bank protective measures in project considering standards and flood control embankment at selected reaches.	Detailed alternative analysis for different options has been carried out in Section 10. Final engineering interventions, the protection works, re-excavation and Water Control Structure design process has been described in Section 4.2.1, Section 4.2.2, Section 4.2.3, Section 4.2.4 & Section 4.2.5.	Section 4.2.1 to Section 4.2.5
Analysis of the probability of water reservoir for feeding the study rivers during dry season.	Normal river re-excavation in the steep gradient, without intermittent bunds acting as check structure, will not bring any major benefits. Re-excavation which has been proposed under the study, would prioritize water retention with least amount of investment in nature friendly way. Moreover, 3 water control structure has been proposed which would retain water in the study area.	Section 4.2.2, Section 4.2.3, Section 4.2.4 & Section 4.2.5
Water level, bed slope, discharge, environmental flow etc. of the study rivers.	Bed Slope, discharge has been provided in Table 2.1. The Environmental flow analysis has been shown in Section 4.1.8. Water Level at the proposed WCS locations has been provided in Section 4.2.1 in Tabular format (Table 4.18a, Table 4.19a, Table 20a, Table 4.22a)	Table 2.1, Section 4.1.8, Section 4.2.1, Table 4.18a, Table 4.19a, Table 21a, Table 4.22a
Maximum depth of scour and flow velocity at or along suggested riverbank protective works.	Maximum depth of scour and flow velocity has been provided in Section 4.2.1 in Tabular format (Table 4.18a, Table 4.19a, Table 20a, Table 4.22a)	Section 4.2.1, Table 4.18a, Table 4.19a, Table 20a, Table 4.22a
Analysis of soil data.	Provided in Section 4.2.4, Section 4.2.5	Section 4.2.4, Section 4.2.5
Monitoring plan for safeguard structures/banks.	Monitoring plan has been provided along with the respective drawing of the river training works.	Volume-2 Drawing
Detailed design and drawings of water retention structures, bank protective works and flood embankment.	Detailed drawing has been submitted in Volume-2.	Volume-2 Drawing
Cost estimate of proposed interventions.	Cost Estimates has been provided in Section 4.3.	Section 4.3
Adverse impact (if any) on bank erosion and flooding situation or effect at the upstream or downstream of the study area due to construction of the interventions.	Detailed analysis has been carried out in Section 4.2 addressing the probable impact of the proposed interventions.	Section 4.2
Recommendation on the impacts of climate change due to implementation of the project.	Climate change impacts has been shown in Section 5 of the report.	Section 5

Compliance on Scope of Works:

Scope of Works	Relevant Chapter/Section/Appendix
Collection and review of existing data, maps, information and relevant available study (technical and project reports including study reports/ projects on erosion) in the study area.	Section 2.7.1, 2.7.2, 4.1.3, 4.1.5
Bathymetric and cross-sectional survey of the selected reaches of the concerned river as per requirement of the morphological study.	Section 2.7.2
Primary data collection on water level, discharge and sediment concentration, bed material and existing bankline.	Section 2.7.2
Identification of historical erosion trend and extent of erosion prone/vulnerable locations of the study rivers.	Section 4.1.6, 4.2.1
Determination of Environmental flow of study rivers.	Section 4.1.8
Propose water level (Bed slope, discharge etc.) of the study rivers on the basis of survey and historical data analysis.	Table 2.1
Preparation of Area Elevation Curve for the basin of the study rivers.	Section 4.1.4, Figure 4.4
Application of appropriate one-dimensional (1D) and two-dimensional (2D) model for:	
hydrological, hydraulic and morphological analysis of the study rivers;	Section 4.2.1, 4.2.2, 4.2.3
identification of the vulnerable locations from the base model (without proposed measure condition);	Section 4.2.1
assess the river bank protection strategy and test its performance in terms of erosion control and sustainability;	Section 4.2.1
investigation of alternative options to mitigate the erosion process such as changing of existing island/shoal/ bars should be established using model results;	Section 4.2.2, 15.2.4 15.2.5
analysis of the impact of the existing and proposed interventions on the hydro-morphological aspects of the river.	Chapter 6
Preparation of flood inundation map showing the extent and depth of inundation;	Section 4.1.9
Assessment of long-term impacts of surface water retention on groundwater recharge through development of integrated surface water- groundwater interaction model.	Section 4.2.7 – Section 4.2.8
Calculation of surface water resource and sediment load balance at key locations (with and without proposed measure condition).	Section 4.2.3, Section 15.2
Preparation of detailed engineering design & drawing of proposed interventions (bank protection work, flood embankment (re-sectioning and new construction), regulators, drainage canals, water retention structures etc.) and recommendation on hydraulic design parameters of the protective measure(s). Climate Change impact should be incorporated in the design of flood embankment.	Volume 2
Necessary soil boring and data analysis (c, Φ, liquid limit, plastic limit etc.)	Section 15.2, Figure 4.185, Figure 4.187
Preparation of strategic river/area management plan in consultation with local stakeholders.	Volume 3
Estimation of cost and financial & economic analysis i.e. Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) of proposed intervention.	Chapter 9
Conduction of job training of BWDB officials to share the application process of developed models.	Section 7.4
Arrangement of workshop to disseminate study outputs.	Appendix-E
Submission of reports including above findings.	All the reports have been submitted.

Appendix-F: Financial and Economic Analysis

Appendix-F1: Financial Expenditure Amounts by Components - Base Costs (Lakh BDT)

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Total BASE COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical Contingencies	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Price Contingencies							
Inflation							
Local	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foreign							
Subtotal Inflation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Devaluation							
Subtotal Price Contingencies	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total PROJECT COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Taxes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foreign Exchange	-	-	-	-	-	-	-

Appendix-F?: Financial DPP Cost (Lakh BDT)

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Appendix-F1: Economic Expenditure Accounts by Components - Base Costs (Lakh BDT)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Total
I. Investment Costs							
A. Protective Works							
1. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Protective Works	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. Re-Excavation							
1. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Re-Excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C. Staff cost	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D. Survey & Investigation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E. Project Management Support	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total BASELINE COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical Contingencies	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Price Contingencies							
Inflation							
Local	-	-	-	-	-	-	-
Foreign	-	-	-	-	-	-	-
Subtotal Inflation							
Devaluation	-	-	-	-	-	-	-
Subtotal Price Contingencies	-	-	-	-	-	-	-
Total PROJECT COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Taxes	-	-	-	-	-	-	-
Foreign Exchange	-	-	-	-	-	-	-

Appendix-F4: Economic DPP Cost (Lakh BDT)

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[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]										
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]

Appendix F17 Expenditure Accounts by Years -- Base Costs Priority-1 (Panchagarh and Thakurgaon) (Lakh BDT)

Bangladesh

Feasibility study of Panchagarh and Thakurgaon

Expenditure Accounts by Years -- Base

	Base Cost (BDT Lakh)					
	Year1	Year2	Year3	Year4	Year5	Total
I. Investment Costs						
A. Protective Works						
[illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. Mahananda River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. Tangon River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. Kulik River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9. [illegible] River	-	-	-	-	-	-
10. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11. [illegible] River	-	-	-	-	-	-
12. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Protective Works	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. Re-Excavation						
1. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible] River re-excavation	-	-	-	-	-	-
6. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. Kulik River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Re-Excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C. O&M cost	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D. Survey & Investigation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E. Project Management Support	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total BASELINE COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical Contingencies	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Price Contingencies						
Inflation						
Local	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foreign	-	-	-	-	-	-
Subtotal Inflation	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Devaluation	-	-	-	-	-	-
Subtotal Price Contingencies	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total PROJECT COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Taxes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foreign Exchange	-	-	-	-	-	-

[illegible]

[illegible]

[illegible]

Appendix-F19: Detailed Economic Investment Cost Priority-1 (Panchagarh and Thakurgaon) (Lakh BDT)

Bangladesh
Feasibility study of Panchagarh and Thakurgaon
Expenditure Accounts by Years -- Base Economic Costs

	Base Cost (BDT Lakh)					
	Year1	Year2	Year3	Year4	Year5	Total
I. Investment Costs						
A. Protective Works						
1. [illegible] River	4,085.14	8,158.30	13,279.43	13,279.43	4,085.14	[illegible]
2. [illegible] River	636.07	1,258.14	1,987.29	1,987.29	636.07	[illegible]
3. Talma River	122.17	210.80	586.52	586.52	122.17	[illegible]
4. [illegible] River	511.38	1,030.33	1,563.79	1,563.79	511.38	[illegible]
5. Pathraj River	516.86	1,036.17	1,554.36	1,554.36	516.86	[illegible]
6. Tangon River	560.62	880.67	1,369.30	1,369.30	560.62	[illegible]
7. [illegible] River	56.38	116.77	171.85	171.85	56.38	[illegible]
8. [illegible] River	245.77	488.69	738.22	738.22	245.77	[illegible]
9. [illegible] River	-	-	-	-	-	-
10. [illegible] River	20.80	71.80	107.90	107.90	20.80	[illegible]
11. [illegible] River	-	-	-	-	-	-
12. [illegible] River	40.80	81.52	121.90	121.90	40.80	[illegible]
Subtotal Protective Works	6,733.13	13,308.30	20,204.36	20,204.36	6,733.13	[illegible]
B. Re-Excavation						
1. [illegible] River re-excavation	8.71	17.63	23.39	23.39	8.71	[illegible]
2. [illegible] River re-excavation	11.75	23.40	35.52	35.52	11.75	[illegible]
3. [illegible] River re-excavation	0.88	1.75	1.07	1.07	0.88	[illegible]
4. [illegible] River re-excavation	4.22	8.88	13.09	13.09	4.22	[illegible]
5. [illegible] River re-excavation	-	-	-	-	-	-
6. Pathraj River re-excavation	1.34	2.68	4.03	4.03	1.34	[illegible]
7. [illegible] River re-excavation	30.21	70.44	100.32	100.32	30.21	[illegible]
8. [illegible] River re-excavation	17.28	34.80	51.80	51.80	17.28	[illegible]
Subtotal Re-Excavation	74.38	159.23	237.35	237.35	74.38	[illegible]
C. EMP cost	8.86	17.31	26.27	26.27	8.86	[illegible]
D. Survey & Investigation	2.76	5.36	8.27	8.27	2.76	[illegible]
E. Project Management Support	13.00	21.00	27.00	27.00	13.00	[illegible]
Total BASELINE COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical Contingencies	127.21	271.14	411.82	411.82	127.21	[illegible]
Price Contingencies						
Inflation						
Local	-	-	-	-	-	-
Foreign	-	-	-	-	-	-
Subtotal Inflation	-	-	-	-	-	-
Devaluation	-	-	-	-	-	-
Subtotal Price Contingencies	-	-	-	-	-	-
Total PROJECT COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Taxes	-	-	-	-	-	-
Foreign Exchange	-	-	-	-	-	-

Appendix-F30: Economic Base Cost DPP Priority-1 (Panchagarh and Thakurgaon) (Lakh BDT)

Bangladesh
Feasibility study of Panchagarh and Thakurgaon District
Expenditure Accounts by Years -- Totals (Lakh)
Economic Costs

	Economic Costs (BDT Lakh)					
	Year1	Year2	Year3	Year4	Year5	Total
I. Investment Costs						
A. Protective Works						
1. Karatoa River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Chawai River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. Talma River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. Tangon River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9. [illegible] River	-	-	-	-	-	-
10. Kulik River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11. [illegible] River	-	-	-	-	-	-
12. [illegible] River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Protective Works	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. Re-Excavation						
1. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible] River re-excavation	-	-	-	-	-	-
6. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. [illegible] River re-excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Re-Excavation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C. EMP cost	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E. Project Management Support	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total PROJECT COSTS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix E11: Yearly O & M Cost (Lakh BDT)

Items	Investment Cost	% of O&M	O&M Cost (Financial)	C.F.	O&M Cost (Economic)
A. Priority 1					
a. River Bank Protection	[illegible]	1.5%	[illegible]	[illegible]	[illegible]
b. Re-excavation	[illegible]	1.5%	[illegible]	[illegible]	[illegible]
Sub total of Priority 1	[illegible]		[illegible]		[illegible]
B. Priority 2					
a. River Bank Protection	[illegible]	1.5%	[illegible]	[illegible]	[illegible]
b. Re-excavation	[illegible]	1.5%	[illegible]	[illegible]	[illegible]
Sub total of Priority 2	[illegible]		[illegible]		[illegible]
C. Priority 3					
a. River Bank Protection	[illegible]	1.5%	[illegible]	[illegible]	[illegible]
b. Re-excavation	[illegible]	1.5%	[illegible]	[illegible]	[illegible]
Sub total of Priority 3	[illegible]		[illegible]		[illegible]
Total			[illegible]	[illegible]	[illegible]

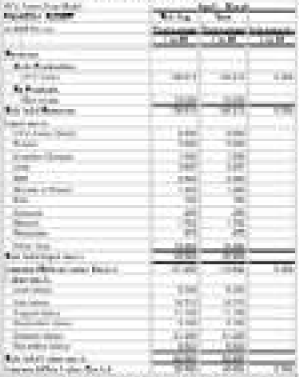
Appendix-F22: Per ha. HYV Aus Crop Model
(YIELDS AND INPUTS)

Appendix-F23: Per ha. HYV Aus Crop Model
(FINANCIAL BUDGET)

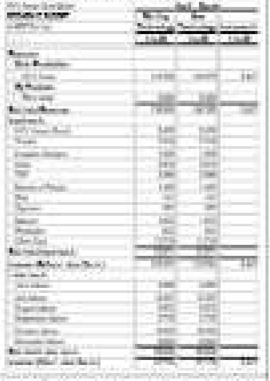
Appendix-F24: Per ha. HYV Aus Crop Model
(Economic BUDGET)

Appendix-F25: Per ha. HYV Aman Crop Model
(YIELDS AND INPUTS)

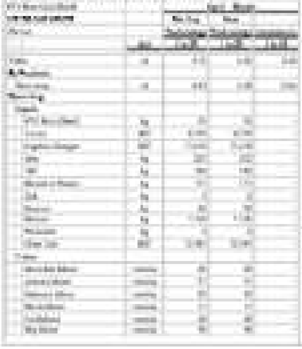
Appendix-F26: Per ha. HYV Aman Crop Model (FINANCIAL BUDGET)



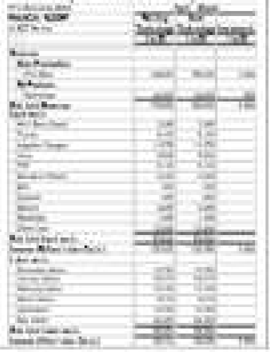
Appendix-F27: Per ha. HYV Aman Crop Model (ECONOMIC BUDGET)



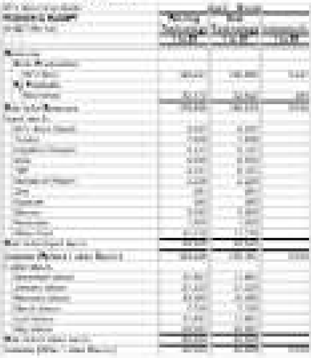
Appendix-F28: Per ha. HYV Boro Crop Model (YIELDS AND INPUTS)



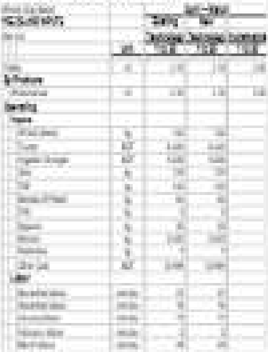
Appendix-F29: Per ha. HYV Boro Crop Model (FINANCIAL BUDGET)



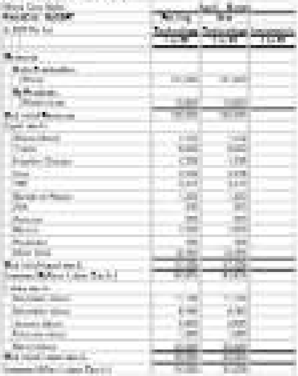
Appendix-F30: Per ha. HYV Boro Crop Model (ECONOMIC BUDGET)



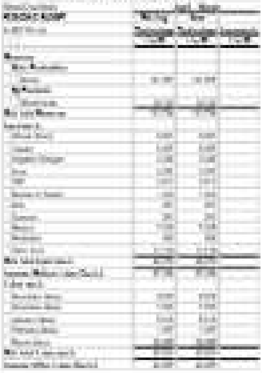
Appendix-F31: Per ha. Per ha. Wheat Crop Model (YIELDS AND INPUTS)



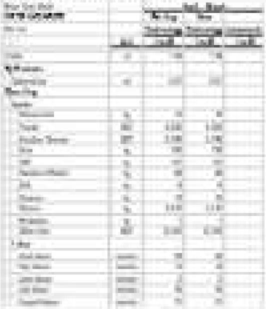
Appendix-F32: Per ha. Wheat Crop Model (FINANCIAL BUDGET)



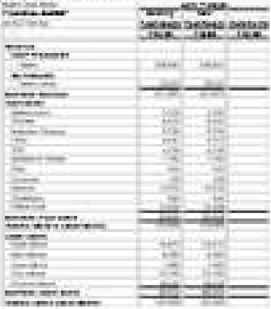
Appendix-F33: Per ha. Wheat Crop Model (ECONOMIC BUDGET)



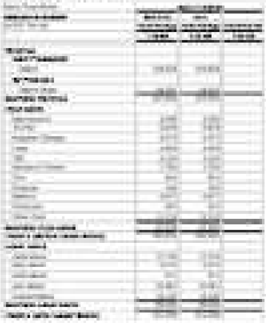
Appendix-F84: Per ha. Per ha. Maize Crop Model (YIELDS AND INPUTS)



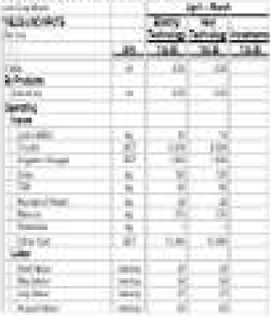
Appendix-F85: Per ha. Maize Crop Model (FINANCIAL BUDGET)



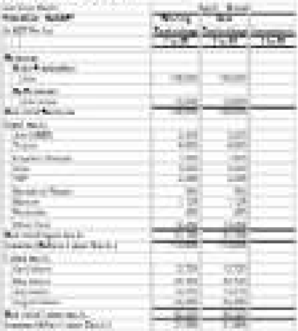
Appendix-F86: Per ha. Maize Crop Model (ECONOMIC BUDGET)



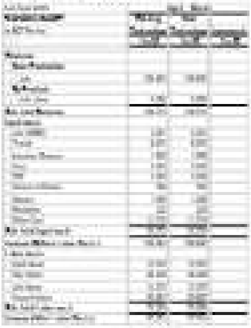
Appendix-F87: Per ha. Per ha. Jute Crop Model (YIELDS AND INPUTS)



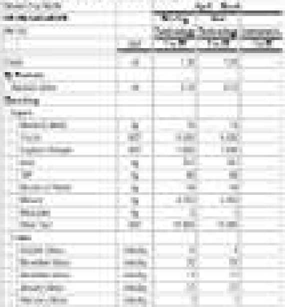
Appendix-F58: Per ha. Jute Crop Model (FINANCIAL BUDGET)



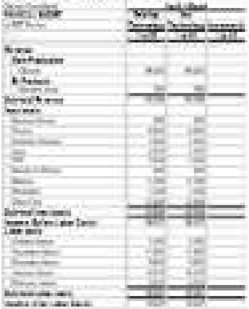
Appendix-F59: Per ha. Jute Crop Model (ECONOMIC BUDGET)



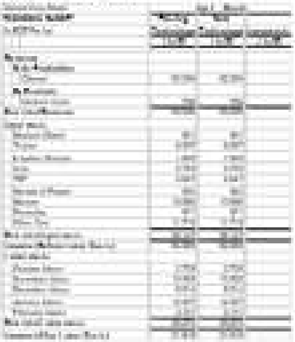
Appendix-F60: Per ha. Per ha. Oilseed Crop Model (YIELDS AND INPUTS)



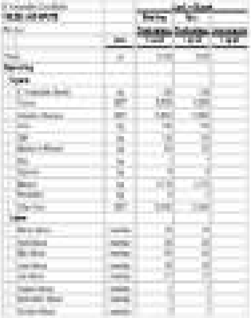
Appendix-F61: Per ha. Oilseed Crop Model (FINANCIAL BUDGET)



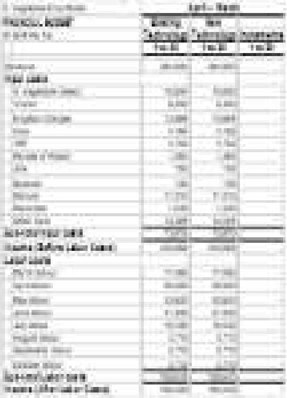
Appendix-F42: Per ha. Oilseed Crop Model (ECONOMIC BUDGET)



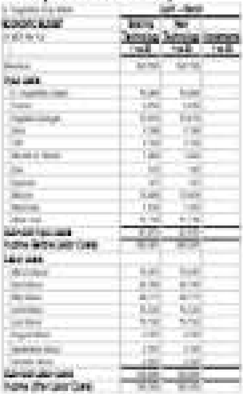
Appendix-F43: Per ha. Per ha. S. Vegetable Crop Model (YIELDS AND INPUTS)



Appendix-F44: Per ha. S. Vegetable Crop Model (FINANCIAL BUDGET)



Appendix-F45: Per ha. S. Vegetable Crop Model (ECONOMIC BUDGET)



Appendix-F46: Per ha. Per ha. W. Vegetable Crop Model (YIELDS AND INPUTS)

[illegible]

Appendix-F47: Per ha. W. Vegetable Crop Model (FINANCIAL BUDGET)

[illegible]

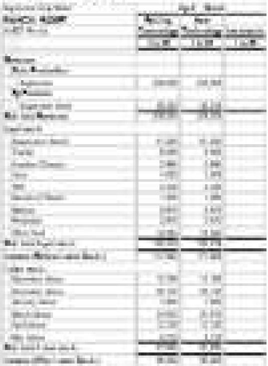
Appendix-F48: Per ha. W. Vegetable Crop Model (ECONOMIC BUDGET)

[illegible]

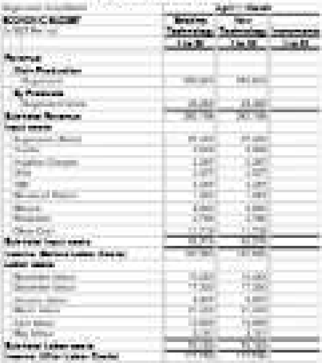
Appendix-F49: Per ha. Sugarcane Crop Model (YIELDS AND INPUTS)

[illegible]

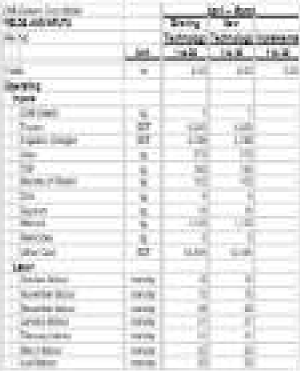
Appendix-F50: Per ha. Sugarcane Crop Model (FINANCIAL BUDGET)



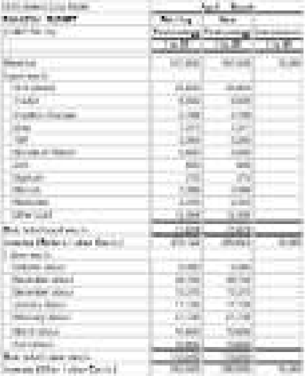
Appendix-F51: Per ha. Sugarcane Crop Model (ECONOMIC BUDGET)



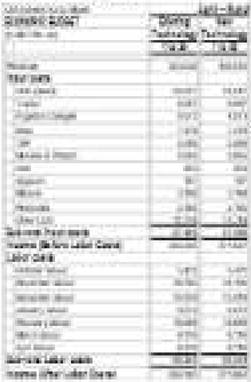
Appendix-F52: Per ha. Per ha. Chili Crop Model (YIELDS AND INPUTS)



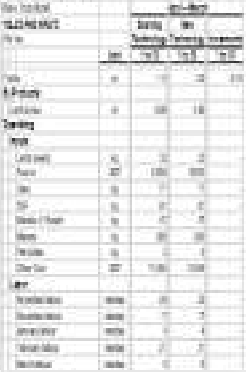
Appendix-F53: Per ha. Chili Crop Model (FINANCIAL BUDGET)



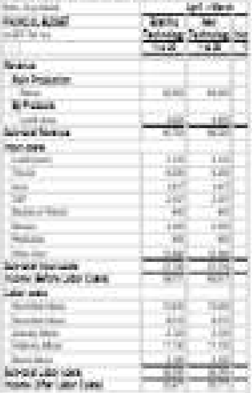
Appendix-F54: Per ha. Chili Crop Model (ECONOMIC BUDGET)



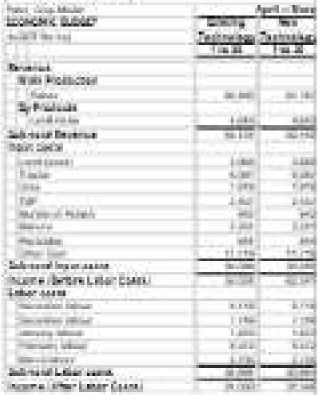
Appendix-F55: Per ha. Pulse Crop Model (YIELDS AND INPUTS)



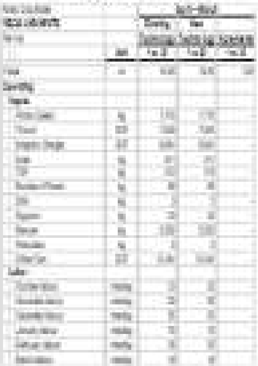
Appendix-F56: Per ha. Pulse Crop Model (FINANCIAL BUDGET)



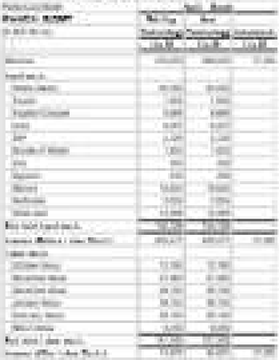
Appendix-F57: Per ha. Pulse Crop Model (ECONOMIC BUDGET)



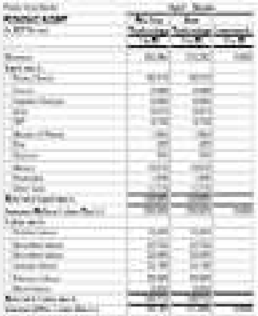
Appendix-P58: Per ha. Potato Crop Model (YIELDS AND INPUTS)



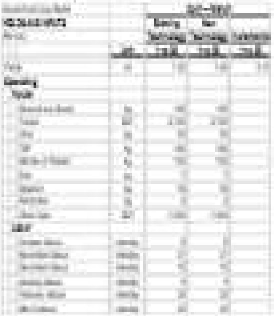
Appendix-P59: Per ha. Potato Crop Model (FINANCIAL BUDGET)



Appendix-P60: Per ha. Potato Crop Model (ECONOMIC BUDGET)



Appendix-P61: Per ha. Ground nut Crop Model (YIELDS AND INPUTS)



Appendix-R62: Per ha. Ground nut Crop Model (FINANCIAL BUDGET)

Ground nut Cultivation	2007 - 2012		
FINANCIAL BUDGET	Existing	New	
In BDT Per ha	Technology	Technology	Increment
	Per ha	Per ha	Per ha
Revenue	[illegible]	[illegible]	[illegible]
Input costs			
Ground nut Seed	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	-
Urea	[illegible]	[illegible]	-
TSP	[illegible]	[illegible]	
Muriate of Potash	[illegible]	[illegible]	-
Zinc	[illegible]	[illegible]	-
Gypsum	[illegible]	[illegible]	-
Pesticides	[illegible]	[illegible]	-
Other Cost	[illegible]	[illegible]	-
Sub-total Input costs	[illegible]	[illegible]	
Income Before Labor Costs	[illegible]	[illegible]	[illegible]
Labor costs			
October labour	[illegible]	[illegible]	
November labour	[illegible]	[illegible]	-
December labour	[illegible]	[illegible]	-
January labour	[illegible]	[illegible]	-
February labour	[illegible]	[illegible]	-
March labour	[illegible]	[illegible]	-
Sub-total Labor costs	[illegible]	[illegible]	
Income after Labor Costs	[illegible]	[illegible]	[illegible]

Appendix-R63: Per ha. Ground nut Crop Model (ECONOMIC BUDGET)

Ground nut Cultivation	2007 - 2012		
ECONOMIC BUDGET	Existing	New	
In BDT Per ha	Technology	Technology	Increment
	Per ha	Per ha	Per ha
Revenue	[illegible]	[illegible]	[illegible]
Input costs			
Ground nut Seed	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
Urea	[illegible]	[illegible]	
TSP	[illegible]	[illegible]	
Muriate of Potash	[illegible]	[illegible]	
Zinc	[illegible]	[illegible]	
Gypsum	[illegible]	[illegible]	
Pesticides	[illegible]	[illegible]	
Other Cost	[illegible]	[illegible]	
Sub-total Input costs	[illegible]	[illegible]	
Income Before Labor Costs	[illegible]	[illegible]	[illegible]
Labor costs			
October labour	[illegible]	[illegible]	
November labour	[illegible]	[illegible]	
December labour	[illegible]	[illegible]	
January labour	[illegible]	[illegible]	
February labour	[illegible]	[illegible]	
March labour	[illegible]	[illegible]	
Sub-total Labor costs	[illegible]	[illegible]	
Income after Labor Costs	[illegible]	[illegible]	[illegible]

Appendix-F94: Cropping Pattern

Panchagarh-Thakurgaon Priority Subproject Model
CROPPING PATTERNS
(in Units)

		April - March		
		Without Project	With Project	Incremental
	Units	Yr 20	Yr 20	Yr 20
Cropping Intensity	Percent	211.00	211.00	0.00
Cropping Pattern				
Existing Technology				
HYV Aus	ha	1,435	–	-1,435
HYV Aman	ha	18,602	–	-18,602
HYV Boro	ha	16,358	–	-16,358
Wheat	ha	753	–	-753
Maize	ha	11,888	–	-11,888
Jute	ha	3,877	–	-3,877
S. Vegetable	ha	3,183	–	-3,183
W. Vegetable	ha	8,750	–	-8,750
Sugarcane	ha	798	–	-798
Oilseed	ha	3,158	–	-3,158
Pulse (Lab-D)	ha	798	–	-798
Potato	ha	4,225	–	-4,225
Chilli (Green)	ha	1,348	–	-1,348
Ground nut	ha	1,583	–	-1,583
Subtotal Existing Technology		103,383	–	-103,383
New Technology				
HYV Aus	ha	–	1,411	1,411
HYV Aman	ha	–	19,138	19,138
HYV Boro	ha	–	16,557	16,557
Wheat	ha	–	753	753
Maize	ha	–	11,888	11,888
Jute	ha	–	3,807	3,807
S. Vegetable	ha	–	3,023	3,023
W. Vegetable	ha	–	8,780	8,780
Sugarcane	ha	–	803	803
Oilseed	ha	–	3,158	3,158
Pulse (Lab-D)	ha	–	792	792
Potato	ha	–	1,207	1,207
Chilli (Green)	ha	–	1,338	1,338
Ground nut	ha	–	1,559	1,559
Subtotal New Technology		–	[illegible]	[illegible]
Total Cropped Area		103,383	[illegible]	[illegible]

Appendix P65: Production and Inputs

[illegible] PRODUCTION AND INPUTS (Details) (in Units)	Unit	Without Project Year 20	April – March With Project Year 20	Increment Year 20
Main Production				
HYV Aus	mt	[illegible]	[illegible]	[illegible]
HYV Aman	mt	[illegible]	[illegible]	[illegible]
HYV Boro	mt	[illegible]	[illegible]	[illegible]
Total Paddy production	mt	[illegible]	[illegible]	[illegible]
Wheat	mt	[illegible]	[illegible]	[illegible]
Maize	mt	[illegible]	[illegible]	[illegible]
Jute	mt	[illegible]	[illegible]	[illegible]
Oilseeds	mt	[illegible]	[illegible]	[illegible]
Potato	mt	[illegible]	[illegible]	[illegible]
Pulses	mt	[illegible]	[illegible]	[illegible]
S.Vegetable	mt	[illegible]	[illegible]	[illegible]
W.Vegetable	mt	[illegible]	[illegible]	[illegible]
Chili	mt	[illegible]	[illegible]	[illegible]
Sugarcane	mt	[illegible]	[illegible]	[illegible]
Groundnut	mt	[illegible]	[illegible]	[illegible]
By-Products				
Rice straw	mt	[illegible]	[illegible]	[illegible]
Jute sticks	mt	[illegible]	[illegible]	[illegible]
Lentil straw	mt	[illegible]	[illegible]	[illegible]
Mustard straw	mt	[illegible]	[illegible]	[illegible]
Wheat straw	mt	[illegible]	[illegible]	[illegible]
Maize straw	mt	[illegible]	[illegible]	[illegible]
Sugarcane straw	mt	[illegible]	[illegible]	[illegible]
Operating				
Purchased Inputs				
HYV Aus (Seed)	kg	[illegible]	[illegible]	[illegible]
HYV Aman (Seed)	kg	[illegible]	[illegible]	[illegible]
HYV Boro (Seed)	kg	[illegible]	[illegible]	[illegible]
Wheat (Seed)	kg	[illegible]	[illegible]	[illegible]
Maize (seed)	kg	[illegible]	[illegible]	[illegible]
Jute (Seed)	kg	[illegible]	[illegible]	[illegible]
Mustard (Seed)	kg	[illegible]	[illegible]	[illegible]
Lentil (Seed)	kg	[illegible]	[illegible]	[illegible]
Potato (Seed)	kg	[illegible]	[illegible]	[illegible]
S. Vegetable (Seed)	kg	[illegible]	[illegible]	[illegible]
W. Vegetable (Seed)	kg	[illegible]	[illegible]	[illegible]
Chili (Seed)	kg	[illegible]	[illegible]	[illegible]
Sugarcane (Seed)	kg	[illegible]	[illegible]	[illegible]
Groundnut (Seed)	kg	[illegible]	[illegible]	[illegible]
Urea	kg	[illegible]	[illegible]	[illegible]
Muriate of Potash	kg	[illegible]	[illegible]	[illegible]
TSP	kg	[illegible]	[illegible]	[illegible]
DAP	kg	[illegible]	[illegible]	[illegible]
Gypsum	kg	[illegible]	[illegible]	[illegible]
Manure	kg	[illegible]	[illegible]	[illegible]
Pesticides	kg	[illegible]	[illegible]	[illegible]
Tractor	BDT	[illegible]	[illegible]	[illegible]
Irrigation charges	BDT	[illegible]	[illegible]	[illegible]
Other Cost	BDT	[illegible]	[illegible]	[illegible]
Labor				
April labour	manday	[illegible]	[illegible]	[illegible]
May labour	manday	[illegible]	[illegible]	[illegible]
June labour	manday	[illegible]	[illegible]	[illegible]
July labour	manday	[illegible]	[illegible]	[illegible]
August labour	manday	[illegible]	[illegible]	[illegible]
September labour	manday	[illegible]	[illegible]	[illegible]
October labour	manday	[illegible]	[illegible]	[illegible]
November labour	manday	[illegible]	[illegible]	[illegible]
December labour	manday	[illegible]	[illegible]	[illegible]
January labour	manday	[illegible]	[illegible]	[illegible]
February labour	manday	[illegible]	[illegible]	[illegible]
March labour	manday	[illegible]	[illegible]	[illegible]

Appendix P[illegible]: Financial Agriculture Crop Benefits (Tk in lac)

[illegible]				April - March					
[illegible]	Without Project			With Project			Incremental		
Main Production	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Subtotal Main Production	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
By Products									
Gross Value Of Production	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Production Cost									
Purchased Inputs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sub-Total Purchased Inputs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sub-Total Production Cost	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OUTFLOWS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cash Flow Before Financing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net Financing									
Cash Flow After Financing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Change in Net Worth									
Sub-Total Change in Net Worth	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Farm Family Benefits After Financing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Appendix-P07: Economic Agriculture Crop Benefits (Tk in lac)

Panchagarh Thakurgaon (Mainly 1) Subsystem 1a **ECONOMIC BUDGET (AGGREGATED)** (In 2007 Lakh)	April – March		
	Without Project	With Project	Increments
	1 to 30	1 to 30	1 to 30
Main Production			
HYV Aus	1,696	1,807	111
HYV Aman	42,548	47,200	4,652
HYV Boro	28,402	30,482	2,080
Wheat	848	852	4
Maize	29,573	29,635	62
Jute	7,446	7,480	34
Oilseed	2,396	2,472	76
Potato	14,420	15,008	588
Pulses	550	566	16
S. vegetables	14,696	14,741	45
W. vegetables	27,268	27,290	22
Chili	6,333	6,650	317
Sugarcane	2,649	2,756	107
Ground nut	4,242	4,563	321
Sub-total Main Production	[illegible]	[illegible]	[illegible]
By Product			
Straw	14,408	14,569	161
Gross Value Of Production	[illegible]	[illegible]	[illegible]
Production Cost			
Purchased Inputs			
HYV Aus (Seed)	30	30	0
HYV Aman (Seed)	1,358	1,360	2
HYV Boro (Seed)	408	408	0
Wheat (Seed)	50	50	0
Maize(seed)	402	403	1
Jute (SEED)	530	532	1
Mustard (Seed)	28	28	0
Lentil (seed)	27	28	1
Potato (Seed)	2,330	2,342	12
S. Vegetable (Seed)	677	678	2
W. Vegetable (Seed)	1,530	1,532	2
Chilli (Seed)	275	276	0
Sugarcane (Seed)	459	480	21
Groundnut (Seed)	308	300	-8
Urea	3,480	3,511	30
Muriate of Potash	2,649	2,655	6
TSP	4,519	4,557	38
Zinc	299	300	1
Gypsum	246	247	1
Manure	4,653	4,674	21
Pesticides	1,364	1,370	6
Tractor	7,960	8,000	40
Irrigation	3,452	3,476	24
Other Cost	[illegible]	[illegible]	[illegible]
Sub-Total Purchased Inputs	[illegible]	[illegible]	[illegible]
Labor			
Farm Labour	[illegible]	[illegible]	[illegible]
Sub-Total Production Cost	[illegible]	[illegible]	[illegible]
OUTFLOWS	[illegible]	[illegible]	[illegible]
Cash Flow	[illegible]	[illegible]	[illegible]

Source: [illegible]

Appendix-P88: Financial and Economic prices of Agricultural Output and Input (Tk)

Items	Unit	Financial	CF	Economic
Outputs				
Rice				
HYV Aus	mt	30,450	1.0000	30,579
HYV Aman	mt	31,200	1.0000	31,174
HYV Boro	mt	31,200	1.0000	31,174
Other outputs				
Wheat	mt	49,000	1.0000	499.38
Maize	mt	28,000	0.908	25,264
Jute	mt	34,000	0.908	30,832
Oilseed	mt	82,000	0.908	78,578
Potato	mt	21,000	0.908	19,069
Pulses	mt	16,000	0.908	14,784
S.Vegetable	mt	32,000	0.908	29,078
W.Vegetable	mt	28,000	0.908	25,264
Onion	mt	48,000	0.908	43,146
Chili	mt	90,000	0.908	81,882
Sugarcane	mt	8,000	1.0134	8,107
Garlic	mt	82,000	0.908	78,578
Pumpkin	mt	15,000	0.908	14,078
Groundnut	mt	87,000	0.908	30940
Straw				
Rice straw	mt	10,000	0.908	9080
Jute straw	mt	5,000	0.908	4540
Lentil straw	mt	5,000	0.908	4540
Mustard straw	mt	5,000	0.908	4540
Wheat straw	mt	6,000	0.908	5448
Maize straw	mt	3,000	0.908	2811
Sugarcane straw	mt	7,000	0.908	3556
Input				
Seeds				
Rice Seed	kg	48	0.908	43.6
HYV Aus (Seed)	kg	50	0.908	45.75
HYV Aman (Seed)	kg	50	0.908	45.75
HYV Boro (Seed)	kg	60	0.908	45.75
Wheat (Seed)	kg	61	0.908	57.24
Maize(seed)	kg	70	0.908	70.55
Jute (SEED)	kg	240	0.908	220.12
Mustard (Seed)	kg	59	0.908	48.11
Pulses (Seed)	kg	100	0.908	88.19
Potato (Seed)	kg	22	0.908	21.24
S. Vegetable (Seed)	kg	18,000	0.908	16341
W. Vegetable (Seed)	kg	17,000	0.908	15556
Onion (Seed)	kg	7,000	0.908	6356
Chili (Seed)	kg	20,000	0.908	10072.3
Sugarcane (Seed)	kg	3	0.908	1.543
Garlic (Seed)	kg	100	0.908	118.21
Ground nut (Seed)	kg	70	0.908	78.58
Fertilizer				
Urea	kg	47	1.0000	27.0278
Muriate of Potash	kg	38	1.0000	20.291
TSP	kg	27	1.0000	27.0984
Zinc	kg	150	0.908	145.7
Gypsum	kg	15	0.908	11.07
Manure	kg	3	0.908	2.812
Pesticides	kg	450	0.908	408.7
Labor	manday	220	0.80	182.8

Appendix-F69: Fisheries Benefits (Lakh BDT)

[illegible]		Future-without Project	Future-with Project	Impact
A. Panchagarh - Thakurgaon Fish production				
a. Fish production (M.T)				
	1. Fisheries	[illegible]	[illegible]	[illegible]
	2. Aquaculture	[illegible]	[illegible]	[illegible]
Subtotal of (a)		561	[illegible]	28
b. Price (tk/ton)		200000	200000	200000
c. Gross value (Lakh taka)		[illegible]	[illegible]	[illegible]
d. Production cost@40% (Lakh taka)		[illegible]	[illegible]	[illegible]
e. Net Benefits (Lakh taka)		[illegible]	[illegible]	[illegible]

Source: CEGIS Report

Appendix-F70: River Bank Protection Benefits (Panchagarh) Lakh BDT

Sl No.	Name of Properties	Unit	No/ Quantity	Unit Value	Total price	Damage (%)	Total Savings
1	Agri land	ha	[illegible]	45.62	[illegible]	100%	[illegible]
2	Rural Settlement	ha	[illegible]	45.62	[illegible]	100%	[illegible]
3	Forest	ha	[illegible]	45.62	[illegible]	100%	[illegible]
4	Road	km	[illegible]	45.62	1764.34	100%	1764.34
5	Industry	Nos	2	300.00	600.00	80%	480.00
6	Govt. Buildings	Nos	1	200.00	200.00	80%	160.00
7	Schools/Colleges	nos	15	200.00	3000.00	80%	2400.00
8	Mosque/Eidgah	nos	14	150.00	2100.00	80%	1680.00
9	Mandir/Shasan	nos	3	150.00	450.00	80%	360.00
10	Graveyard	nos	2	100.00	200.00	100%	200.00
11	Urban Area	ha	1.2	247.10	296.52	100%	296.52
	Total Savings						14804.84
20 years Return period: Per year savings							740.24

Appendix-F71: River Bank Protection Benefits (Thakurgaon) Lakh BDT

Sl No.	Name of Properties	Unit	No/Quantity	Unit Value	Total price	Damage (%)	Total Savings
1	Agri land	ha	[illegible]	45.62	[illegible]	100%	[illegible]
2	Rural Settlement	ha	[illegible]	45.62	[illegible]	100%	[illegible]
3	Forest	ha	[illegible]	45.62	[illegible]	100%	[illegible]
4	Road	km	[illegible]	45.62	[illegible]	100%	[illegible]
5	Industry	Nos	[illegible]	300.00	0.00	80%	0.00
6	Govt. Buildings	Nos	2	200.00	400.00	80%	320.00
7	Schools/Colleges	nos	2	200.00	400.00	80%	320.00
8	Mosque/Eidgah	nos	6	150.00	900.00	80%	720.00
9	Mandir/Shasan	nos	4	150.00	600.00	80%	480.00
10	Graveyard	nos	[illegible]	100.00	0.00	100%	0.00
11	Urban Area	ha	[illegible]	247.10	[illegible]	100%	[illegible]
	Total Savings						[illegible]
20 years Return period: Per year savings							[illegible]

Appendix-F73: Employment Generation Lakh BDT

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							
						[illegible]						[illegible]	
						[illegible]	[illegible]					[illegible]	[illegible]
							Y-1	Y-2	Y-3	Y-4	Y-5		
[illegible]													
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]													
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]													
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Appendix [illegible]: Base case Financial Internal Rate of Return (FIRR) (Lakh BDT)

Year	Cost			Benefits						Cash flow
	Investment Cost	O & M	Total Cost	River bank protection		Agriculture	Fisheries	Employment	Total Benefits	
				[illegible]	[illegible]					
1	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
2	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
3	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
4	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
5	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
6		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NPV @12%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All calculations are based on project period of 30 years

FIRR ([illegible])	[illegible]
Benefit Cost Ratio	[illegible]
NPV @12% ([illegible])	[illegible]

Appendix F7.4 Base case Economic Internal Rate of Return (EIRR) (Lakh BDT)

Year	Cost			Benefits						Cash Flow
	Investment Cost	O & M	Total Cost	River bank protection		Agriculture	Fisheries	Employment	Total Benefits	
				Panchagarh	Thakurgaon					
1	4947.38	0.00	4947.38	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
2	19892.38	0.00	19892.38	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
3	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
4	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
5	4947.38	0.00	4947.38	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
6		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
7		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
8		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
9		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
10		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
11		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
12		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
13		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
14		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
15		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
16		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
17		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
18		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
19		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
20		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
21		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
22		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
23		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
24		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
25		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
26		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
27		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
28		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
29		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
30		1524.86	1524.86	730.24	233.42	8480.88	43.60	314.16	10019.42	8494.77
NPV @12%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All calculations are based on project period of 30 years

EIRR base case	14.77%
Benefit Cost Ratio	[illegible]
NPV @12% (Lakh Taka)	[illegible]

Appendix-F75: Sensitivity EIRR (Total project Cost increased by + 10%) Lakh BDT

Year	Cost			Benefits						Cash flow
	Investment Cost	O & M	Total Cost	River bank protection		Agriculture	Fisheries	Employment	Total Benefits	
				Panchagarh	Thakurgaon					
1	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
2	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
3	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
4	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
5	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
6	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All calculations are based on project period of 30 years

EIRR sensitivity case	[illegible]
Benefit Cost Ratio	[illegible]

Appendix F7.6: Sensitivity EIRR (Total project Benefits decreased by : 10%) Lakh BDT

Year	Cost			Benefits						Cash Flow
	Investment Cost	O & M	Total Cost	River bank protection		Agriculture	Fisheries	Employment	Total Benefits	
				Panchagarh	Thakurgaon					
1	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
2	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
3	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
4	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
5	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
6	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NPV @12%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All calculations are based on project period of 30 years

EIRR Sensitivity Case	[illegible]
Benefit Cost Ratio	[illegible]

Appendix-F[illegible]: Sensitivity EIRR (Both Total cost increased by +10% and Total benefits decreased by -10%) Lakh BDT

Year	Cost			Benefits						Cash Flow
	Investment Cost	O & M	Total Cost	River bank protection		Agriculture	Fisheries	Employment	Total Benefits	
				Panchagarh	Thakurgaon					
1	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
2	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
3	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
4	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
5	[illegible]	0.00	[illegible]	0.00	0.00	0.00	0.00	[illegible]	[illegible]	[illegible]
6	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NPV @12%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

All calculations are based on project period of 30 years

EIRR Sensitivity case	[illegible]
Benefit Cost Ratio	[illegible]

Appendix-F8: Estimation of Standard Conversion Factor (SCF)

SCF = [illegible]

[illegible]

[illegible]

Items	2011-12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8 years average
1. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. Import Duty	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8. Export Duty	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9. [illegible]	0	0	0	0	0	0	0	0	0
10. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12. SCF [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: [illegible]

Appendix-F[illegible]: [illegible]

[illegible]			[illegible]				[illegible]	
	[illegible]			[illegible]	[illegible]			[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]							
[illegible]	[illegible]							
[illegible]	[illegible]							

[illegible]

Appendix-G: Terms of Reference (ToR)

Section 6

Terms of Reference (TOR)

for Procurement of Consultancy Services (Mathematical Modelling Component)
in connection with the project
"Feasibility Study for Sustainable River Management in Panchagarh and Thakurgaon Districts."

1.1 Background

- **Rivers of Panchagarh District:** Panchagarh is the northern most district of Bangladesh and adjacent to the Bangladesh-India border. About 33 rivers flow through this district in which Karatoa river is the major one. Originating from the Jalpaiguri district of India, the river enters Bangladesh at Vadeswari area of [illegible] Union under Tetulia upazila of Panchagarh district. Later on, the river falls into the Atrai river in Birganj upazila of Dinajpur District. Most of the rivers in Panchagarh district are connected to the Karatoa river. Among the rivers of the district, Talma, Chawai and Ghoramara are three transboundary rivers those originate in India and later on falls into the Karatoa river. Other two transboundary rivers of the district are Buria and Dahuk river, both of these rivers originate in Bangladesh and later on, enter India. Pathraj is another important river of Panchagarh which originates from the [illegible] Dighee Beel under Boda upazila and later on falls in the Karatoa river at [illegible] union in Debiganj upazila. Other rivers of the district are Buri Teesta, Tirnai, [illegible], [illegible], [illegible], Kurum, [illegible], Chawai, [illegible] etc. All of these rivers are experiencing flood and severe bank erosion due to excessive monsoon rainfall. Also, most of these rivers are having morphological changes due to sedimentation which results change of river courses and reduced water storage capacity.

  These rivers are contributing in different irrigation projects of the area such as [illegible] Irrigation Project, Talma Irrigation Project. Therefore, sustainable development and management of these rivers is the key factor of overall development of the area.

- **Rivers of Thakurgaon District:** Thakurgaon district is located along Bangladesh-India border in the northern region of Bangladesh. Total 11 rivers flow through this district, the rivers are: Tangon, Kulik, [illegible], Chhoto [illegible], [illegible], Tirnai, [illegible], Chhoto [illegible], Vulli, [illegible], [illegible], Lachhi and Nagar river.

  Among the rivers, Tangon, Kulik and Nagar are transboundary rivers. Originating in Bangladesh, both the Tangon and Kulik river enters India respectively through

Bairchuna union of Pirganj Upazila and [illegible] union of Haripur upazila of Thakurgaon district. The Nagar river originates in the West Bengal state of India and enters into Bangladesh in Panchagarh District. The river flows about 130 km along Bangladesh-India border in Thakurgaon District, then again enters into India. The speciality of the Nagar river is most often its course indicates the Bangladesh-India border.

The characteristics of the rivers of Thakurgaon district are relatively lower average depth and steeper bed slope. Tangon, Shuk, Lachhi, Sena, Nagar, Kulik, Pathraj and Vulli rivers are experiencing bank erosion along with sedimentation problem. The water storage capacity of these rivers are decreasing due to sedimentation which causes negative impact on the irrigation facilities of the area specially in the dry season. The Tangon Barrage Irrigation Project, Buriboth Irrigation Project, Vulli Irrigation Project and [illegible] project are totally dependent on these rivers. Therefore, water storage capacity of these rivers should also be increased. The existing flood embankment along the left bank of the Nagar river is also damaged due to lack of maintenance and bank erosion. The embankment is very important because it is used by the Border Guard of Bangladesh (BGB) for their regular patrol to safeguard the border. Also, erosion protection of rivers along the borders are very important for the sovereignty of the country.

In view of the above, Bangladesh Water Development Board (BWDB) has formulated the proposal to study all the rivers in Panchagarh and Thakurgaon district in a holistic approach to devise a sustainable river management plan of the area.

1.2 Objective of the Study

The main objective of the study is to identify all existing problems related to water resources management and find out [illegible] solutions for sustainable development and management of the rivers in Panchagarh and Thakurgaon district in a holistic approach.

The specific objectives of the study are:

- Flood and erosion risk management of rivers within the project area
- Improvement of water storage capacity of the rivers within the project area
- Design of proposed interventions
- Environmental and Social Impact Assessment
- Preparation of DPP of the subsequent investment project

1.5 Scope of Works

- Collection and review of existing data, maps, information and relevant available study, technical and project reports including study reports/ projects on wetlands in the study area;
- Bathymetric and cross sectional survey of the selected reaches of the concerned rivers as per requirement of the morphological study;
- Primary data collection on water level, discharge and sediment concentration, bed material and existing bank line;
- Identification of the historical erosion trends and extent of erosion prone/ vulnerable locations at the study rivers;
- Determination of Environmental flow of study rivers;
- Propose water level, bed slope, discharge etc. of the study rivers on the basis of survey and historical data analysis;
- Preparation of Area Elevation Curve for the basin of the study rivers;
- Application of appropriate one-dimensional (1D) and two dimensional (2D) model for:
    - hydrological, hydraulic and morphological analysis of the study rivers;
    - identification of the vulnerable locations from the base model (without proposed measures condition);
    - assess the river bank protection strategy and to test its performance in terms of erosion mitigation and sustainability;
    - investigation of alternative options to mitigate the erosion process such as dredging of existing [illegible] bars should be established using model results;
    - analysis of the impact of the existing and proposed interventions on the hydro-morphological aspects of the river;
    - Preparation of flood inundation map showing extent and depth of inundation;
    - Assessment of long term impact of surface water resources on groundwater recharge through the development of integrated surface water - groundwater interaction model;
    - Calculation of surface water resources and sediment load balance at key locations (with and without proposed measure conditions);
- Preparation of detailed map showing design & drawing of proposed interventions (bank protection work, flood embankment (re-sectioning and new construction), regulators,

drainage canals, water retention structures etc.) and recommendation on hydraulic design parameters of the protective measure(s). Climate change impact should be incorporated in the design of flood embankment;

- Necessary soil boring and sieve analysis i.e. D_{50}, liquid limit, plasticity limit etc. regarding structures, embankment and protective work (for embankment: 1 boring/km, for protective work: 2 boring/km in which 1 in bank and 1 in L.W.L, for structure minimum 2 boring);
- Preparation of dredged material management plan in consultation with local stakeholders;
- Plan for afforestation and tourism development/development of park/ walkways for recreational purposes along bank protection works;
- Estimation of cost and financial & economic analysis i.e. Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) of proposed interventions;
- Conduction of on the job training of BWDB officials to make the application process of developed models;
- Arrangement of workshop to disseminate study outputs;
- Submission of reports including above findings;

1.4 Expected Output

The outputs of the study that are to be provided are as follows:

- Base map, project map with inventory of existing structures and flood inundation map, Area Elevation Curve;
- Identified critical locations affected by bank erosion and other reaches within the river requiring protective work for erosion control;
- Recommendation on the dredging, location and type of water retention structures, bank protective measures to protect vulnerable river banks and flood control embankment at selected reaches;
- Analysis of the probability of water reserve for feeding the study river during dry season;
- Water level, bed slope, discharge, current/sediment flow etc. of the study rivers;
- Maximum depth of scour and flow velocity at or along suggested river bank protective works;
- Analysis of soil data;
- Monitoring plan to safeguard the eroded river banks;

- Detailed design and drawings of water regulatory structures, bank protective works and flood embankments;
- Cost estimate of proposed interventions;
- Adverse impacts (if any) on bank erosion and flooding situation or other at the upstream or downstream of the study area due to construction of the interventions;
- Recommendation on the impacts of climate change due to implementation of the project.

1.3 Duration of the Service and Reporting

The Mathematical Modelling Component of the study shall be carried out within a period of 08 (Eight) months within the project period from the date of commencement set forth in the agreement. The following are the reporting schedule for submission of the study reports to other parties where necessary).

Sl. No.	Report	No of copies	Schedule (with reference to consultancy period)
1.	Inception Report	20 copies	At the end of 1st month
2	Draft Final Report with detailed design. * Detailed design should be submitted with DFR duly vetted by concerned Design office of BWDB	20 copies	At the end of 7th month
3	Final Report	20 copies	Within 15 days of 8th month from the date of commencement of the study. Incorporating all comments and suggestions received from different concerned offices.

All models developed/ updated under this project, hard and soft copies of the reports, data, cross sections, shp files, documents, etc. and all other relevant information have to be submitted with Final Report. All the reports should be submitted in book binding format with name of the project on the front side cover of All printed & colored reports.

The Project Director will represent BWDB and receive all the deliverables mentioned above. Review meetings with participation of concerned Planning, Design and Field level officials of BWDB will be held on Inception and Draft Final Reports.

1.6 Dissemination of Study Results

The findings of the study should be presented in workshops to be held after submission of the Draft Final Report (DFR). Field workshop shall be arranged to share the study results with the local stakeholders before finalization of the study report. Consultants responsible for Mathematical Modelling Component of the study will arrange the field workshop in close consultation with the Project Director, BWDB, Dhaka and will make arrangement to share the results of all components of the study.

The findings and recommendations of the study should be mentioned and acceptable feedbacks from the participants would be incorporated, as required, in the Final Report.

1.7 Duties and responsibilities

BWDB's responsibilities

The Consultant will work under the direct supervision of the Project Director, BWDB, Dhaka. BWDB will ensure that the objectives of the study as detailed in the ToR would be achieved within agreed time schedule and that the contents of the report are acceptable to BWDB. BWDB will direct the planning process and work program and supervise the study and monitor progress according to the objectives set in ToR.

The hydrology department of BWDB shall assist the Project Team as required, particularly with regard to the hydrological aspect of the study. It shall also ensure the involvement of respective design and field offices in survey works, field data collection and modelling activities. The concerned Design Circle of BWDB shall provide guidance in the design of major structures as required. The design office will vet the drawings prepared by the consultants so that the drawings can be used in the preparation of DPP. Field survey and field data collection will be done by the respective Consultants in close consultation with the concerned Field Executive Engineer under the guidance of the Superintending Engineer, Thakurgaon O&M Circle, BWDB, Thakurgaon.

The Project Director, BWDB, Dhaka will arrange regular meetings between the consultants and BWDB professionals to discuss technical and project management issues. Any unresolved issues either technical or otherwise should be consulted with the high officials of BWDB (Chief Engineer (Civil) Planning, concerned Zonal Chief Engineer, Chief Engineer, Hydrology, Chief Engineer, Design) or other GoB agencies as required.

BWDB should provide or make available the following data, services and facilities to the consultants as per existing rules of BWDB.

a. Available hydrological, morphological, meteorological data and records on concerned rivers.
b. Available relevant contour maps and previous study reports.
c. Any other support, available with BWDB, to help the consultants to carry out the data collection program as per ToR.

Any unresolved issues either technical or otherwise shall be taken up with BWDB senior technical personnel and will be met amicably.

Consultant's responsibilities

The consultants should carry out the services as detailed in "Objectives, Scope of Works, Expected outputs and ToR" in the best interest of the Government with reasonable care, skill and diligence with sound engineering, administrative and financial practices. The Consultants will be responsible to BWDB for discharge of responsibilities. All the primary and secondary data, developed and updated models, maps, consultation information, notes on the interviews and other relevant audio and video clips collected during the evaluation process would be handed over under the rights of BWDB. In response to this, the consultant should:

- Make available all developed/updated models, primary and secondary data and/or set of information (including audio-visual recordings) to BWDB as and when required. Data and information should be submitted to BWDB both in hard and soft copies.
- Make necessary arrangement for site investigation, environmental and social survey & data collection as required for performance of the assigned task and evaluation thereby.
- Provide all support for the effective delivery of the services as stipulated in the objectives, scope of works, expected outputs and ToR.
- All types of technical support (i.e. preparation of maps etc.) necessity of BWDB and any other information related to the task the consultant is assigned with should be provided to BWDB.

- Consult regularly with the concerned design circle of BWDB during field survey and design preparation.

- All the stakeholder consultation sessions should be recorded for future documentation. Video recording would be done and the clips should be handed over BWDB. Discussions would be introduced with necessary introductory information and mobile phone number duly incorporated in the reports. Discussion points should be focused properly and addressed accordingly.

- Provide necessary assistance during DPP preparation of the subsequent implementation project.

- Consultants responsible for Mathematical Modelling Component will share all data collected under the project with the Consultants of ESIA Component. Consultants of each component of the study will share data and information collected under the project and co-ordinate each other for the best outcome and smooth running of the project.

1.8 Key Personnel

The proposed study may require **42 man-months** of local professional input. The estimated consultants staffing requirements are as shown below:

Sl. No.	Professional	Nos.	Man-Month
1	Team Leader	1	6
2	Hydrologist	1	2
3	GIS Expert	1	2
4	Survey Specialist	1	3
5	Hydrodynamic Modeller	1	3
6	Irrigation System Specialist	1	2
7	Dredging and Dredged Material Management Specialist	1	1
8	Morphological Modelling Specialist	1	4
9	Sr. Design Engineer (Civil)	1	2
10	Design Engineer (Civil)	1	4
11	Economist	2	2
12	Data Analyst	2	11
Total		14	42

1.9 Task and Qualifications of the Key Professionals

Discipline	Qualifications and Tasks
Team Leader	*Qualifications* He/ She should have Masters' Degree in Civil Engineering/ Water Resources Engineering. Preference will be given to higher degree. He/She should have at least 15 years' professional experience in civil engineering and water resources engineering with minimum 10 years' experience in the relevant management, including leading and managing a multidisciplinary consultancy team for drainage management, water resources planning, drainage structure design, disaster management, river hydraulics, bank protection works and river morphology particularly in Bangladesh. Previous experience in a similar work will be preferred. *Tasks:* His/Her major responsibilities shall include but not necessarily be limited to the following: • Take full responsibility for all aspects of planning, liaison and reporting of the study; • Guide and supervise the survey, modelling and design activities; • Coordinate the study activities; • Take necessary steps to collect existing data from external sources if available and required; • Arrange discussion meeting with BWDB personnel to disseminate the study results; • Attend meeting as and when required by the designated responsibility of BWDB; • Take responsibility for the quality of the model upgrading and development of tools; • Analyse and interpret the mathematical modelling results for technical and commercial justification; • Maintain liaison with BWDB and other relevant agencies;

Discipline	Qualification and Tasks
	• Execute necessary investigations and studies related to this study. • Quality control of the analysis of erosion, river characterization and drainage condition and modelling. • Carry out overall co-ordination and top supervision of the different study activities and maintain close liaison with the client. • Preparation of cost estimates for the project. • Participate in training and technology transfer. • Preparation of all reports as needed under the contract. • Attending meetings as and when required. • Disseminate monitoring results to all stakeholders.
Hydrologist	Qualification Minimum Master's degree in Civil /Water Resources Engineering/Hydrology or equivalent. He/she should have 10 years of experience on hydrological analysis and hydrological modelling. Tasks His/her major responsibilities shall include but not necessarily be limited to the following: • Review of the river system and available data. • Development of hydrological and hydrodynamic model for river systems. • Simulate hydrological and hydrodynamic conditions of rivers. • Establish design parameters from simulation results. • Analyse simulation results. • Contribute in preparing the reports of the study and workshop materials.
GIS Expert	Qualification: Minimum Bachelor's degree in Civil Engineering/Water Resources Engineering/Urban and Rural Planning/Hydrology/Geography. He/she should have at least 7 years experience in producing GIS coverage,

Discipline	Qualifications and Tasks
	Contour map, Digital Elevation Model of water areas. **Tasks** His/her major responsibilities shall include but not necessarily be limited to the following: • Make GIS layer for location, river, road, settlements and other different features; • GIS analysis of river bank locations in GIS layer; • Prepare study area map based on recent satellite imagery; • Prepare GIS based maps for erosion and depositions and digitize river bank line from historical satellite imagery; • Preparation of ArcView based contour maps of basins, different maps of basin/bed topography; • Identify the important features such as existing embankment, khals, bill, wetland, regulators, bridges of the proposed area and presentation the map showing all the features; • Assist the study team in conducting mitigation analysis; • Preparing cross-checks in connection with the reports.
Survey Specialist	**Qualification** Minimum B. Sc. degree in Civil Engineering/Water Resources Engineering. He/she should have 10 years of experience in state of the art Survey Techniques. *Tasks* His/her major responsibilities shall include but not necessarily be limited to the following: ▪ Formulate realistic field data collection plan & schedule; ▪ Lead and supervise the field data collection team with necessary safety measures; ▪ Conduct surveys, cross-sections of canals, drainage channels and other water bodies as requirement; ▪ Maintain close and proactive co-ordination with the field officials of BWDB and the local people; ▪ Participate in the survey work to be conducted for field data collection.

Discipline	Qualification and Tasks
	- Inform the status and progress of the data collection activities regularly to the BWDB and other concerned. - Responsible for timely completion of data acquisition in accordance with the specification mentioned in the ToR. - Share all survey data with the Client for preserving them in BWDB. - Assist in the preparation of Reports.
Hydrodynamic Modeller	**Qualification** Minimum master's degree in civil engineering/Water resources Engineering/Hydraulic Engineering. He/she should have 10 years working experience in the field of river hydraulics, river engineering and morphology with mathematical modeling of river hydraulics. Previous experience in similar environment will be preferred. **Tasks** His/her major responsibilities shall include but not necessarily be limited to the following: - Establish the baseline hydraulic condition of the study area. - Setup calibration and verification of 1D and 2D hydraulic model according to the necessity of the project. - Review and identify the need of updating and upgrading the available models. - Re-calibrate and validate the available models according to the necessity. - Assessment of the existing hydrodynamic conditions. - Simulation of different options for protection measures. - Interpret model results. - Interpret model results in accordance with the requirements. - Participation in meetings with BWDB as and when required. - Find the hydraulic design parameters for the proposed protective works.

Discipline	Qualifications and Tasks
	• Preparation of different reports as required for the proposed study.
Irrigation System Specialist	Qualification: Minimum Master's degree in Civil Engineering/Water Resources Engineering/Agricultural Engineering. He/she should have at least 15 years of experience in the field of irrigation related project. Tasks: His/her major responsibilities shall include but not necessarily be limited to the following: • Carry out irrigation related data collection; • Considering the water availability and physical constraints, suggest future cropping pattern; • Assessment of total irrigation requirement; • Assessment of appropriate irrigation method; • Contribute in report writing and review milestone report.
Dredging and Dredged Material Management Specialist	Qualification: Minimum Master's Degree in Civil Engineering/Water Resources Engineering. He/she should have 10 years working experience in the field of dredging and management of dredged material, bank protection works, river hydraulics, sediment transportation and river morphology etc. **Tasks:** His/her major responsibilities shall include but not necessarily be limited to: • Formulate alternative options/measures to be recommended for river training works and dredging; • Comparison of all options and find out suitable solutions; • Evaluate the effectiveness of different options as well as dredging; • Participate in the internal/external/technical meeting with the client

Discipline	Qualifications and Tasks
	as and when required. • Prioritization and selection of cost effective re-excavation works; • Identify lands and also owners of the land suitable for dumping of excavated earth; • Protection and dredging management plan and management of dredged earth material; • Preparation of different reports as required for the proposed study.
Morphological Modelling Specialist	Qualification: Minimum Master's Degree in Civil Engineering/Water Resource Engineering. He/she should have at least 12 years working experience in the field of bank protection works, river hydraulics, sediment transportation and river morphology together with morphological modelling of rivers. Previous experience in similar environment will be preferred. Tasks: His/her major responsibilities shall include but not necessarily be limited to: • Detailed analysis of time series satellite images and bathymetric/ hydrographic charts and other surveyed data to ascertain riverline movement, erosion-deposition pattern and sediment transport characteristics; • Detailed analysis of time series satellite images and bathymetric/ hydrographic charts and other surveyed data to ascertain riverline movement, erosion-deposition pattern and sediment transport characteristics; • Analyse and interpret historical data as well as surveyed data of the rivers; • Analyse the overall (past) and (present) morphological characteristics of the river and identification of erosion vulnerable area; • Assess the need of river training work; • Simulate different options for river training works; • Simulate different options for different dredging alignment; • Participation in meetings with BWDB as and when required.

Discipline	Qualifications and Tasks
	• Prepare reports in a standard format acceptable to BWDB. • Collect and incorporate comments on final report. • Assist the team leader in coordinating the study. • Prepare workshop materials and to assist the workshop convention.
Senior Design Engineer (Civil)	Qualification: Minimum of Bachelor's degree in civil engineering/Water Resources Engineering, preferably a postgraduate degree in relevant field. He/she should have at least 12 years' professional experience in hydraulic structure design and bank protection work design. Previous experience in designing bank protective works using the result of mathematical model output is preferred. Tasks: His/her major responsibilities shall include but not necessarily be limited to the following: • Establish the criteria for hydraulic design of the proposed protective works using different design guidelines. • Evaluation and design of the alternative structures recommended for the river training works. • Designing of protection work, different drainage structures, and road and embankment. • Preparation of cost estimate of the structures on the basis of current annual schedule of rates including annual expenditure schedules. • Comparison of the alternatives and find out the suitable solution. • Development design specifications and drawing. • Find out cost estimate of different protective measures. • Participation in meetings with BWDB as and when required. • Preparation of different reports as required for the proposed study. • Assist the team leader in coordinating the study.

Discipline	Qualifications and Tasks
Design Engineer (Civil)	Qualification: Minimum of bachelor's degree in civil engineering/Water Resources Engineering, preferably a postgraduate degree in relevant field. He/she should have at least 10 years' professional experience in water sector, hydraulic structure design and bank protection work design. Previous experience in designing bank protection works using the result of mathematical model output is preferred. Tasks: His/her major responsibilities shall include but not necessarily be limited to the following: • Assist in designing of protection work, different drainage structures, culvert and cross embankments; • Assist in preparation of cost estimate of the structures on the basis of recent annual schedule of rates including annual expenditure schedules • Assist in developing design specifications and drawing; • Cost estimate of different protective measures; • Participation in meetings with BWDB as and when required; • Preparation of different reports as required for the proposed study; • Assist the Senior Design Engineer in coordinating the study
Economist	Qualification: S/he should have at least Master Degree in Economics with minimum 10 years' experience in economic appraisal of water resources sector projects. A significant portion of this experience may also include natural resources management, physical and monetary valuation of possible environmental impacts. The Economist will assist the study mainly in appraisal of project worthiness in terms of economic viability.

Discipline	Qualifications and Tasks
	Tasks: • Estimation of benefits; the benefits will include profits from extra agriculture production as a result from project interventions e.g. irrigation development, higher cropping intensities and use of high yielding varieties, recreational facilities, environmental improvement. • Elaboration of the feasibility level cost estimates, contingency reserves, detailed price escalation estimates on the expected implementation schedule, administration costs and tax and duties shown as separate line items and the method of calculation of these costs; • Calculate projects BCR, IRR, NPV etc. for assessing the projects worthiness. • Assessment of costs arising out of mitigation measures (or external disbenefits); • Preparation of expenditure schedule. • Assist the Team Leader in preparation of project report containing all the requirements of BWDB for the feasibility study.
Data Analyst	*Qualification:* Masters or Bachelor's degree in Civil Engineering/ Water Resources Engineering. He/she should have at least 5 years' experience in analysis of different types of data including sediment, discharge, water level, flow velocity etc. Previous experience in similar assignment will be preferred. *Tasks:* His/her major responsibilities shall include but not necessarily be limited to the following: • Responsible for the collection of field data and data from different organizations. • Ensure data quality and prepare data needed for hydrological and morphological modelling and analysis.

Discipline	Qualifications and Tasks
	- Provided necessary support with data for what task required for performance by the Study Team; - Analysis of all the surveyed data; - Assist the study team for the preparation of different reports.

INSTITUTE OF WATER MODELLING

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