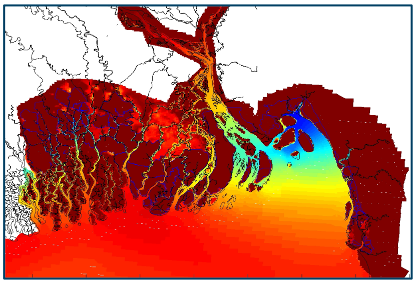
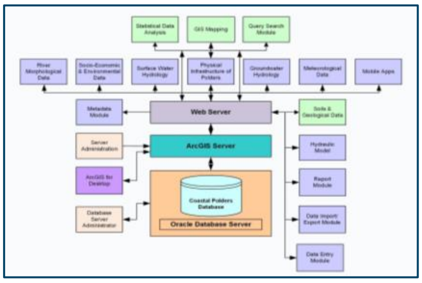
Ministry of Water Resources

Bangladesh Water Development Board

Coastal Embankment Improvement Project, Phase-I (CEIP-I)

Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics)





QUARTERLY PROGRESS REPORT-4

November 2019

Bangladesh Water Development Board
Coastal Embankment Improvement Project, Phase-I (CEIP-I)
Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone
Office: Flat #3/B, House #4, Road #23/A, Block# B, Banani, Dhaka 1213, BANGLADESH
Phone +880 1307 693299

Memo No. CEIP/LTMRA/1119/44 Date: 7 November 2019

Project Management Unit
Coastal Embankment Improvement Project, Phase-I (CEIP-I)
House No.15, 4tn Floor, Road
No.24(CNW) Gulshan, Dhaka-1212

Att: Engr. Md. Habibur Rahman, Chief Engineer & Project Director

Dear Sir,

Submission of Fourth Quarterly Progress Report (first Submission)

The submission of the Fourth Quarterly Report was held back until we concluded our discussions with the PMU and the World Bank regarding our maintaining reference to the original list of Project Deliverables as stated in the Terms of Reference. We have now reached agreement and the new list of deliverables depicted as Tables 1-2 and 1-3 in the Fourth Quarterly Progress Report are closely based on the TOR – but each item on this list is also related to one or more activities described in the Progress Report.

We have made many of the changes in response to the observations we received form you after the submission of QPR-3. The most important among these was the inclusion of an Executive Summary.

The preparation of the chart showing a graphical representation of progress is under preparation. The Capacity Building Action Plan is also under preparation. We will submit a final version of QPR-4 including these two items within two weeks.

Owing to the delay in finalising the Deliverables, we could not deliver QPR-4 as earlier promised. We apologise for the delay, but we hope the first submission (3 copies) will help you to initiate the review of the report.

Thank you,

Yours sincerely,

Dr Ranjit Galappatti
DHI Team Leader

Copies:

1. Engr. Md. Mahfuzur Rahman, Director General, BWDB
2. Mr. A. M. Aminul Haque, Additional Director General (Planning), BWDB
3. Dr Kim Wium Olesen, Project Manager
4. Dr Alessio Giardino, Deltares Manager
5. Mr Zahirul Haque Khan, Deputy Team Leaders

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QUARTERLY PROGRESS REPORT-4

October 2019

Contents

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ADCP- Acoustic Doppler Current Profiler

BDP2100- Bangladesh Delta Plan 2100

BIWTA- Bangladesh Inland Water Transport Authority

BMD- Bangladesh Meteorological Department

BoB - Bay of Bengal

BWDB- Bangladesh Water Development Board

CBA- Coast Benefit Analysis

CCP- Chittagong Coastal Plain

CDMP-Comprehensive Disaster Management Program

CDSP- Char Development Settlement Project

CEA- Cost Effectiveness Analysis

CEGIS- Centre for Environmental and Geographic Information Services

CEIP- Coastal Embankment Improvement Project

CEP- Coastal Embankment Project

CERP-Coastal Embankment Rehabilitation Project

CPA- Chittagong Port Authority

CPP-Cyclone Protection Project

CSPS-Cyclone Shelter Preparatory Study

DDM- Department of Disaster Management

DEM- Digital Elevation Model

DOE- Department of Environment

EDP- Estuary Development Program

FAP- Flood Action Plan

FM- Flexible Mesh

GBM- Ganges Brahmaputra Meghna

GCM- General Circulation Model

GIS- Geographical Information System

GNSS- Global Navigation Satellite System

GPS- Global Positioning System

GTPE- Ganges Tidal Plain East

GTPW- Ganges Tidal Plain West

HD- Hydrodynamic

InSAR- Interferometric Synthetic Aperture Radar

IPCC- Intergovernmental Panel for Climate Change

IPSWAM- Integrated Planning for Sustainable Water Management

IWM- Institute of Water Modelling

LCC- Life Cycle Costs

LGED- Local Government Engineering Department

LGI- local Government Institute

LRP- Land Reclamation Project

MCA- Multi Criteria Analysis

MES- Meghna Estuary Study

MoWR- Ministry of Water Resources

MPA- Mongla Port Authority

NAM - Nedbor Afstromnings Model

PPMM- Participatory Polder Management Model

RCP- Representative Concentration Pathways

RSET-MH- Rod surface elevation table – marker horizon

RTK- Real-Time Kinematic

SET-MH- Surface Elevation Tables – Marker Horizons

SLR- Sea Level Rise

SOB- Survey of Bangladesh

SSC- Suspended Sediment Concentration

SWRM- South West Region Model

TBM- Temporary Bench Mark

ToR- Terms of Reference

WARPO- Water Resources Planning Organization

WL - Water Level

Executive Summary

ES-1 INTRODUCTION

After the feasibility study of the first phase CEIP-1, it was recommended that certain gaps in our knowledge of the delta should be addressed by the research study which was to be known as the Long-Term Monitoring, Research and Analysis of Bangladesh Coastal Zone.

After a long gestation period, the study was initiated on 15 October 2018 and the Inception Phase was completed in January 2019. The Inception Report was treated as the first Quarterly Progress Report (QPR-1). The Second Quarterly Progress Report which was submitted in April 2019 covered the period 1 January 2019 to 31 March 2019. The Third Quarterly Progress Report (QPR-3) covers the period 1 April 2019 to 30 June 2019. This is the Fourth Quarterly Progress Report describing the progress made between 1 July 2019 to 30 September 2019.

The Work Plan proposed in the Inception Report has been amended slightly to respond to exigencies of carrying out the work with a very large team of experts, both local and foreign.

ES-2 DEVELOPMENT OF INPUT DATASETS FOR MODELLING PHYSICAL PROCESSES

The Data Collection programme is proceeding as planned, with some delays in initiating the field programmes conducted by University of Colorado and Columbia University. These delays have now been caught up. The large Surveys comprising several large field campaigns mounted by IWM are all on schedule.

The joint measurement programmes carried out with BWDB (Hydrology) ate Bahadurbad has led to greater understanding and interaction regarding the interpretation of historical data and the sharing in of techniques and methodology.

As per ToR the model input datasets have been shared (in both soft and hard form) with the project office.

ES-3 DATABASE FOR THE COASTAL ZONE

The Database Design Report has been submitted. The Database itself is now active and receiving data. Protocols for updating and accessing the database are being discussed.

Data Collection and Database updating status is reported in the QPR-4

ES-4 MODELLING LONG TERM PROCESSESS

Modelling is the largest component of this study and the variety and extents of modelling work undertaken can be seen in the table ES-1 below. All the models listed below are already under development. The hydrodynamic modelling stage is well advanced and the development of the morphological models has also been initiated in the models where the field sediment data have already been processed.

The modelling progress made so far is described in Chapter 4 of QPR-4.

Table ES-1: Models currently under development

	Modelling Activity	Sub description	Scale
A	GBM Basin Model	Hydrotrend	Macro
B	Macro scale River Model	Delft3D Main River system (2D)	Macro
C	Macro scale River Model	Delft3D Main River system (1D)	Macro
D	Pussur Sibsa	Delft3D: Modelling of long term Morphology	Meso
E	Baleswar-Bishkhali Model	Delft3D: Modelling of long term Morphology	Meso
F	Lower Meghna	Delft3D: Modelling of long term Morphology	Meso
G	Sangu	Delft3D: Modelling of long term Morphology	Meso
H	Pussur Sibsa	MIKE 21C: Modelling of bank erosion process	Meso
I	Baleswar	MIKE 21C: Modelling of bank erosion process	Meso
J	Bishkali	MIKE 21C: Modelling of bank erosion process	Meso
K	Lower Meghna	MIKE 21FM: Modelling of bank erosion process	Meso
L	Sangu	MIKE 21C: Modelling of bank erosion process	Meso
M	Pussur-Sibsa fine sediment model- ext	Delft3D Fine Sediment (2D/3D)	Meso
N	Pilot TRM Model for Polder 24	MIKE 11, MIKE 21 AND MIKE FLOOD	Micro
O	Storm Surge Model	Generating Synthetic Storm Events	Bay of Bengal
P	Storm Surge Model	MIKE 21FM & CYLONE MODEL	Bay of Bengal
Q	Salinity Model	Delft3D Salinity (2D/3D)	Total Coast

ES-5 POLDER RECONSTRUCTION PROGRAMME

After the Selection of 5 Polders for Pilot Study have been approved by the PMU, the selected polders have been taken up for study. This has involved adjusting the extent of meso scale models simulating long term morphology to allow for testing drainage capacity during the design process.

A Strategic Approach towards devising a Polder Reconstruction Programme was decided and a Road Map was devised towards a reaching a viable Reconstruction Plan based on an extended multicriteria analysis.

ES-6 INVESTMENT PLAN FOR ENTIRE CEIP

Work on the investment plan will commence in 2020 after the MCA is finalized

ES-7 DESIGN PARAMETERS, CONSTRUCTION MANAGEMENT & MONITORING PLAN

This work will commence in mid-2020 when the design approach is finalized

ES-8 CAPACITY BUILDING

Training Courses and Study Tours have been undertaken and are described in Chapter 8

ES-9 TRANSPARENCY AND ACCOUNTABILITY

The detailed proceedings of the Stakeholder Workshops held at Barisal on 30 March 2019 and at Khulna on 27 April 2019 are published in Bangla and in English in the month of September 2019 and submitted to PD’s Office.

The following Reports have been submitted by the project up to the end of the 4th Quarter

1. Inception Report, submitted on 20 January 2019

2. 2nd Quarterly Progress Report, submitted on 07 April 2019

3. 1st Interim Literature Review Report, submitted on 24 June 2019

4. 3rd Quarterly Progress Report, submitted on 06 August 2019

5. Database Design Report, submitted on 11 September 2019

6. Report on Regional Stakeholder's Consultation Workshop, Barisal (Both English and Bengali versions), submitted on 24 September 2019

7. Report on Regional Stakeholder's Consultation Workshop, Khulna (Both English and Bengali versions), submitted on 24 September 2019

8. Report on Boundary Data for Models at various scales, submitted on 25 September 2019

9. Report on GIS Database Maps, Submitted on 25 September 2019

10. Report on Data Reports, Inventory, Quality checks, Submitted on 29 September 2019.

1 INTRODUCTION

The coastal zone of Bangladesh spans over 710 km of coastline and is subject to multiple threats. Sixty- two percent of the coastal land has an elevation less than 3 meters above mean see level. The coastal lands, being subject to regular flooding by saline water during high tides, could not be used for normal agricultural production in a country with a very high demand for land. The Coastal Embankment Project)CEP(was initiated in the 1950s and 1960s to build polders surrounded by embankments preventing the spilling of saline water onto the land at high tides. These embankments were built along the larger rivers and across the smaller rivers and creeks which then formed the drainage system within each polder and connected to the peripheral rivers via appropriately sized flap gate regulators, that open at low tide to let the drainage water out.

The Coastal Embankment Project made possible the reclamation of large tracts of land for agriculture from 1960 onwards. Polder building proceeded continuously until today. We now have 1.2 million hectares reclaimed in 139 active polders in the coastal zone of Bangladesh.

In over half century of its existence, a number of challenges have surfaced that threaten the long-term safety and even the very existence of the polder system as a viable and sustainable resource. These are:

- The interference with natural tidal regime created severe siltation problems in some rivers resulting in severe drainage congestion in some polders.
- Sea level rise and changes in precipitation and water discharge due to climate change
- Threats of damming and diversion to the delivery of river sediments from upstream
- Subsidence of lands)except where it has been allowed to be rebuilt by tidal flooding(and structures founded on existing land
- Increasing vulnerability to cyclones and storm surges

The damage caused by Cyclones Sidr and Aila in 2007 and 2009 led to a major new investment of World Bank funds called the Coastal Embankment Improvement Project through which the coastal embankment system was to be improved and made much more climate resilient, over several phases of construction. After the feasibility study of the first phase CEIP-1, it was recommended that certain gaps in our knowledge of the delta should be addressed by the research study which was to be known as the **Long-Term Monitoring, Research and Analysis of Bangladesh Coastal Zone.**

After a very long gestation period, the study was initiated on 15 October 2018 and the Inception Phase was completed in January 2019. The Inception Report was treated as the first Quarterly Progress Report (QPR-1). The Second Quarterly Progress Report which was submitted in April 2019 covered the period 1 January 2019 to 31 March 2019. This Third Quarterly Progress Report (QPR-3) covers the period 1 April 2019 to 30 June 2019. This is the Fourth Quarterly Progress Report describing the progress made between 1 July 2019 to 30 September 2019.

1.1 Work Plan

The Inception Report (DHI, 2019) gave a detailed description of the work to be carried out by this project. Table 1.1 shows the full schedule of activities to be carried out during the 30 months of the project. This work plan was shown in the Inception Report published in December 2018. However, some adjustments have had to be made due to contingencies and developments in the field. The new work plan, which still includes the original deliverables as well as additional outputs, has been rescheduled as shown in Table 1.2. As far as this report is concerned the activities carried out during the 4th Quarter (1 July to 31 September) are described in detail.

Table 1-1: Full Activity Schedule

Activity Schedule

Component	Component NAME	Sub Activity	2018			2019												2020												2121			
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
C-1	Inception	Inception Report & Workshop																															
C-2	Literature Review and Lessons Learned	Detailed Leterature Review							X																		X						
		Lessons learnt							X																								
C-3	Develop Datasets for model input	Data Coverage and Collection																															
		National Polder Database											X																				
Component - 4	Modelling Long-term Processes in the Coastal Zone	Macro-scale Modelling																						D			X						
		Meso-scale Modelling																						D			X						
		Micro-scale Modelling																						D			X						
		Subsidence																					1	1			2						2
		Meteorology																															
		Salinity, Water Levels, Storm Surges																						D			X						
C-5	Polder Reconstruction Programme	Phased Zonal Programme																						D						F			
		Coherence & Delta Overview																									F						
C-6	Design Parameters Construction, Management & and Monitoring	Updating Parameters and Specifications								P																							F
		Polder management, stakeholder participation								P																							F
		Performance Monitoring System								P																							P
C-7	Investment Plan for Entire CEIP	Plan Preparation																															F
C-8	Capacity Building	In-houseTraining Programmes																															
		External Training Programmes																															
C-9	Transparency & Accountability	Outreach Programme																															
		Communication Activities																															
		Communication Activities																															

X	Reporting (usually final)
F	Reporting (Final)
D	Reporting (Draft)
1	First
2	Second

quarterly progress

quarterly progress -2

quarterly progress - 3

quarterly progress - 4

quarterly progress

quarterly progress

quarterly progress

quarterly progress

quarterly progress

1.2 List of Project Milestones and Deliverables

A large number of outputs have been listed in the ToR as deliverables during the 30 months duration of this project. In order to rationalise the work programme, we have subdivided the activities into intermediate activities. Tables 1.2 and 1.3 lists deliverables in two parts. Table 1.2 lists the all the deliverables other than those directly related to modelling activities. This table is shown in two parts Table 1.2a and 1.2b.

The modelling activities are listed separately in Tables 1.3a, 1.3b and 13c.

The deliverables are numbered and listed in the same order as they are found in the Terms of Reference. However, the order of model development and execution is different to that anticipated during the writing of the TOR and this is reflected in the timing of a number of sub-deliveries which has impacted both the timing of the related models and the polder development and management plans.

Table 1-2a: Milestones and Deliverables other than Modelling Activities Part 1

Output No	TOR Reference	TOR Deliverables	Description	Programme Item (s)	Schedule in Inception Report	Adjusted delivery date (if any)	Deliverable Status	Comment
D-1	D-1	Inception Workshop	Inception	Inception Workshop	0-3		√	Delivered
		Inception Report (Workplan etc		Inception Report (Workplan etc			√	
D-2	D-2	Literature Inventory & Interim Review 1	Literature	Literature Inventory & Interim Review 1	0-6		√	Delivered
		Literature Inventory & Interim Review 2		Literature Inventory & Interim Review 2	7-24			Due Dec 2019 rec. contributions
		Literature Review & Lessons Learnt		Literature Review & Lessons Learnt	12	24		Due in 9th Qtr end
D-3	D-3: 1, 2	1) Soft and hard copies of map of the location of all the current field measurement stations, by tape, stored in Database of BWDB, Map showing the location of primary BM with values 2) Raw datasets of all type of data. Including meta-data. Stored in Database of BWDB	Data Collection, Analysis and Documentation in GIS Database	Data Report, Inventory & Quality Checks (Includes field Data collection and monitoring programmes)	3-9		√	This item refers to progress on field activities up to August 2019
	D-3: 3	Completed and validated dataset including meta-data, stored in Database of BWDB		Databased Design Report	3-9		√	Delivered Month 11
	D-3: 4	GIS based National Coastal Polder Database/ Management Information System/ Database		GIS Based Maps	3-9		√	Delivered Data Report & CD
	D-3: 4	GIS based National Coastal Polder Database/ Management Information System/ Database		GIS Based Database/ MIS system/ Sharepoint	3-9	24		Data entry in progress
	D-3: 5	Boundary conditions and data for calibration and validation of models		Supply of Model Boundary Data	3-9		√	continuing to end of 5th Quarter
	D-3: 6	Monitoring results on sedimentation rate in rivers and floodplain		Monitoring Results on Sedimentation rate in rivers				
	D-3: 7	Annual and seasonal sediment load of major rivers and to Bay of Bengal		Annual & Seasonal Sediment load of Major rivers & to Bay of Bengal				
	D-3: 8	Technical memorandum describing the validation and completion procedures that have been udes by the consultant for all type of data; for reproducibility purposes and to be stored in Database of BWDB		Technical Report of Data analysis & Validation	10-12			Under processing by Survey & Modelling Teams
	D-3: 9	Memorandum with recommendations to improve the data collection, processing, validation and dissemination within the GoB		technical Report on improving Data collection	10-12			Awaitng completiong of consultation with BWDB
D-4			Mathematical Modelling	Complex programme of modelling, is dealt with in a separate Table				
D-5	D-5A:1	Technical Report on Long Term Polder Improvement measures and Polder Development Plan	Polder Development Plan	Polder Development Plan I	30	24		Update Polder Inventory, Characterisitcs, (incl land use, population, economic activity, … Problems requiring solutions Ongoing (include 17 Polders)
	D-5A:2	Design of polder improvement measures of 17 polders under CEIP-I with consideration of existing improvements. Draft report focusing on initial 4 Polders to be optimised. Final report, 17 polders		(incl) Improvements to 17 Polders	21-30	24		Included in above plan

Table 1-2b: Milestones and Deliverables other than Modelling Activities Part 2

D-5A: 3	Report for each of the 3-5 polders with a description of ; Present situation, boundary conditions (scenarios), Matching with polder options, Establish design, Including management plan, Costs and benefits. Draft report focusing on initial 4 Polders to be optimised. Final Report, 17 Polders.	Polder Development Plan	Feasibility Report on each of 3-5 Polders	10 to 14	18		Study has commenced
D-5A: 1	Technical Report on Long Term Polder Improvement measures and Polder Development Plan		Polder Development Plan II	30	18-28		Completion of new MCA, Identifaction of interventions etc Analysis and more consultations
D-5A: 1	Technical Report on Long Term Polder Improvement measures and Polder Development Plan		Polder Development Plan III	30	20-30		Preparation of Development plan
D-5A: 3	Report for each of the 3-5 polders with a description of ; Present situation, boundary conditions (scenarios), Matching with polder options, Establish design, Including management plan, Costs and benefits. Draft report focusing on initial 4 Polders to be optimised. Final report, 17 Polders		Draft Report on 3-5 Polders	4-21	21		Awaiting study results
			Final Report on 17 polders	21-30	24		Include within Development Plan
D-5B	Report describing the Interdependencies and relations between the processes and parameters, consequences for the boundary conditions and recommendations for future action plan/ research		Coherence with respect to Oveall Delta	24			Awaiting results of other studies
			Environmental Assessment of Proposed Interventions	new item	20-26		Environmental Assessment of Proposed Interventions
			Cost Benefit Analysis	new item	20-26		Cost Benefit Analysis
D-6.1	Report with updated set of design parameters and specifications for construction/ reconstruction of the polders as well as associated appurtenant structures	Updated Parameters	Updated Design Parameters & Specifications	30			rescheduled
	Detailed delivery plan to be developed during the inception phase		Detailed Delivery Plan	6			
D-6.2	Report on Management plans for the polders	Polder Management	Polder Management Plan	30	26		
	Detailed delivery plan to be developed during the inception phase		Detailed Delivery Plan	6			
D-6.3	Report on participatory monitoring mechanism with goals and targets		Performance Monitoring Mechanisms	24-30			
	Detailed delivery plan to be developed during the inception phase		Detailed Delivery Plan	30			
D-7	An investment plan describing a phaased polder improvement roadmap and required budget An investment plan for long term management of the polders, including the expansion of monitoring An execution plan including financing and fundraising strategies and plan and technical collaboration plan	Investment Plan and Fund Raising	Investment Plan fo Enitire CEIP	24-30			Awaiting initiation
				none			On going
	Action Plan for Capacity Building	Capacity Building and Technical Sustainability	Action Plan for Capacity building	6			Under preparation
	On the job technical training in country		In-country on-the- job Training	0 - 24	3-27		Requires more BWDB participstion
D-8	Report on: results of the on the job training, list of participants		Training Report with list of trainees	27			
	International Workshop		International Worlshop	27			
	Teach the teacher, Teaching at the universities		Cirriculum Development		24-27		Appoint Curriculum Development Committee
D-9.1	Workshops	Outreach programme	Workshops	12,16,24,27		√ (3, 6, 7)	3 workshops to date; Reports submitted
	Workshop Report		Workshops Report			√ (4, 11, 11)	

Table 1-3a: Milestones and Deliverables of Modelling and Related Activities Part 1

TOR Reference	TOR Deliverables	Scale	Model	Description & One Report each			Delivery Dates	Special Comments (pl see below)
D-4A-1: 1	The software newly developed under this project with all source code and accompanying technical document with detailed explanation of the methodology and assumptions			Source code of any new software, etc.			Not relevant	**A**
D-4A-1: 2	Geospatial datasets of main sources and deposits of sediment at present, including full meta-data a restored and archived in Database of BWDB	**Macro**	GBM Basin Model	Model Set up Calibration & Validation	**a**	D4A-1 Describes all these activities . Deliverable between Aug 19 and Oct 20	Dec-19	
		Macro	Macro scale River Model	Model Set up Calibration & Validation	**a**		Dec-19	
		Macro	Macro scale River Model	Model Set up Calibration & Validation	**a**		Dec-19	
		Macro	GBM Basin Model Applications	Climate Change Simulations	**b**		7th Quarter	
		Macro	Macro scale River Model Applications	Climate Change Simulations	**b**		7th Quarter	
		Macro	Macro scale River Model Applications	Climate Change Simulations	**b**		7th Quarter	
		Macro	Sediment Budget Analyses	Long Term Sediment Balances in Delta			Dec-19	
D-4A-1: 3, 4	Geospatial datasets of main sources and deposits of sediment for 100 years from present, including full meta-data are published and archived in Database of BWDB. Technical reports		**FINAL REPORT ON MORPHOLOGICAL TRENDS**		**A**	Jan-20	Oct-20	
			SPECIAL REPORT ON SEDIMENT RECIRCULATION IN THE DELTA		**B**	Jan-20	Oct-20	
			Long Term Morphology Modelling					
D-4A-2: 1, 2	Report on upgrade and update of present meso scale model including detailed explanation of the methodology and assumptions. Geospatial datasets of erosion and sedimentation in the coastal zone at present for various seasons and circumstances in relevant. These geospatial datasets should include full meta-data and be stored and archived in Database of BWDB	**Meso**	Pussur Sibsa	Model Set up Calibration & Validation	**a**	Jan-20	Dec-19	
		Meso	Baleswar-Bishkhali Model	Model Set up Calibration & Validation	**a**		Dec-19	
		Meso	Lower Meghna	Model Set up Calibration & Validation	**a**		Dec-19	
		Meso	Sangu	Model Set up Calibration & Validation	**a**		Dec-19	
D-4A-2: 3	Geospatial datasets of erosion and sedimentation in the coastal zone for possible scenarios 25, 50 and 100 years from now, for various reasons and circumstances if relevant. These geosparial datasets should incldue full meta-data and be stored and archived in Database of BWDB	**Meso**	Pussur Sibsa	Long Term Morphology Applications	**b**	Oct-20	6th Quarter	
		Meso	Baleswar-Bishkhali Model	Long Term Morphology Applications	**b**		6th Quarter	
		Meso	Lower Meghna	Long Term Morphology Applications	**b**		6th Quarter	
		Meso	Sangu	Long Term Morphology Applications	**b**		6th Quarter	
D-4A-2: 4	Technical report (one report for 4A-1 and 4A-2)		**FINAL REPORT ON ESTUARINE MORPHOLOGY**		**C**		Nov-20	
			Bank Erosion on Meso Scale					
D-4A-2: 1, 2	Report on upgrade and update of present meso scale model including detailed explanation of the methodology and assumptions. Geospatial datasets of erosion and sedimentation in the coastal zone at present for various seasons and circumstances in relevant. These geospatial datasets should include full meta-data and be stored and archived in Database of BWDB	**Meso**	Pussur	Model Set up Calibration & Validation	**a**	ec-19 to Feb -	Apr-20	**B**
		Meso	Sibsa	Model Set up Calibration & Validation	**a**		Apr-20	
		Meso	Baleswar	Model Set up Calibration & Validation	**a**		Apr-20	
		Meso	Bishkali	Model Set up Calibration & Validation	**a**		Apr-20	
		Meso	Lower Meghna	Model Set up Calibration & Validation	**a**		Apr-20	
		Meso	Sangu	Model Set up Calibration & Validation	**a**		Apr-20	
D-4A-2: 3	Geospatial datasets of erosion and sedimentation in the coastal zone for possible scenarios 25, 50 and 100 years from now, for various reasons and circumstances if relevant. These geosparial datasets should incldue full meta-data and be stored and archived in Database of BWDB	**Meso**	Pussur	Erosion Prediction Report	**b**	Apr-21	Dec-20	
		Meso	Sibsa	Erosion Prediction Report	**b**		Dec-20	
		Meso	Baleswar	Erosion Prediction Report	**b**		Dec-20	
		Meso	Bishkali	Erosion Prediction Report	**b**		Dec-20	
		Meso	Lower Meghna	Erosion Prediction Report	**b**		Dec-20	
		Meso	Sangu	Erosion Prediction Report	**b**		Dec-20	
D-4A-2: 4	Technical report (one report for 4A-1 and 4A-2)	**Meso**	**FINAL REPORT ON BANK EROSION MODELLING**		**D**	Apr-21	Dec-20	

Table 1-3b: Milestones and Deliverables of Modelling and Related Activities Part 2

			Other special purpose models					
		Meso	Pussur-Sibsa fine sediment model- ext	Pussur Sibsa Fine Sediment Model	E	Various dates given	Jan-20	
D-4D-3: 1, 2, 3, 4, 5	Geospatial datasets of High Water, Low Water and maximum salt intrusion in all river branches for average tide in the wet and dry season at present and at 25, 50 and 100 years from now, including full meta-data stored and archived in database of BWDB. Geospatial datasets of groundwater salinity at 3 relevant levels (in the upper shallow, lower shallow and deeper aquifers, to be deignated by BWDB) at present and at 25, 50 and 100 years from now, including full metadata and stored and archived in Database of BWDB. Tidal and salinity curves for key locations in the coastal zone (about 20, to be designated by BWDB) in the wet and dry season at present, and at 25, 50 and 100 years from now. Exceedance frequency curves for water levels in the same 20 stations at present, and at 25, 50 and 100 years from now.	**Bay of Bengal**	Storm Surge Model	Analysis of Synthetic Cyclone Events & Selection of events	G1		Dec-19	
		Bay of Bengal	Storm Surge Model	Storm Surge Modelling			Dec-20	
		Bay of Bengal	Wave Propagation Model	Wave Modelling			Dec-20	
		Bay of Bengal	Salinity Model	Salinity Modelling	I		2020 end	
D-4A-3: 1, 2, 3	The model setup developed will be updated under this project with all accompanying technical document with detailed explanation of the methodology and assumptions. A report that describes the pros and cons of the different methodologies to prevent water-logging within the polder and sedimentation of tidal river system including polder-subsidence. The report will include meta-data on the models used and measurements, recommendations for polder design including drainage and long term management plan, and recommendations for pilot area/ polder to implement the ideas, such as but not limited to location, methods and measurements. Recommended plan to manage sediment at the downstream stretch of the tidal river and in the polder.	**Micro**	Pilot TRM Model for Polders 24 etc	TRM Model for Polder 24	F		Feb-20	
		Micro	5 or more polder models	Drainage Model Reports	H	Oct-19 to July-20	await conceptual designs selections 2020	**C**
			METEOROLOGY (these are covered under other modelling and data topics)					
			SUBSIDENCE					
D-4B: 1, 2,3	Geospatial datasets of total subsidence at present and for 25, 50 and 100 years from now, including full metadata and stored in Database of BWDB and Estimate the annual rate of subsidence. Detailed Technical Report with description and explanation of geospatial analysis of the total subsidence in the four regions of the polder area of the coastal zone at present and for 25, 50 and 100 years from present, including description of the causes of subsidence, full metadata and stored in Databse of BWDB. Report on the total subsidence in specific polders (designated by BWDB) in 25, 50 and 100 years from now when no sediment is supplied to the polder, including the amount of sediment needed to counteract this subsidence.		Field Campaigns (several)	Continuous GPS & Surface Elevation Tables, Borehole sampling, luminescence testing etc				
			Subsidence Geospatial Datasets	Report		Apri to Oct 2020		
			Detailed Technical Reports on Subsidence and Flood Plain Sedimentation			Oct-20		

Table 1-3c: Milestones and Deliverables of Modelling and Related Activities Part 3

			METEOROLOGY (these are covered under other modelling and data topics)				
D-4C: 1, 2	Technical Report describing current trends and future scenarios in rainfall in the polder area of coastal zone for four coastal regions (including estimation of rainfall distribution over the year) and cyclone frequency and intensity for the next 25, 50 amd 100 years from now, including meta-data of the datasets used for the trend analyses and store and archived in Database of BWDB. The Research Team shall include a description of the statistical and downscaling methods used for reproducibility reasons. Geospatial Dataset and archived in Database of BWDB.		Technical reports & Database				
			CLIMATE CHANGE EFFECTS			Oct-20	
			Clinmate Change & Preciptation,			Oct-20	
D-4D: 1, 2, 3	Geospatial datasets of High Water, Low Water and maximum salt intrusion in all river branches for average tide in the wet and dry season at present and at 25, 50 and 100 years from now, including full meta-data stored and archived in database of BWDB. Geospatial datasets of groundwater salinity at 3 relevant levels (in the upper shallow, lower shallow and deeper aquifers, to be deignated by BWDB) at present and at 25, 50 and 100 years from now, including full metadata and stored and archived in Database of BWDB. Tidal and salinity curves for key locations in the coastal zone (about 20, to be designated by BWDB) in the wet and dry season at present, and at 25, 50 and 100 years from now.		Salinity intrusion & Groundwater Salinity			Oct-20 Oct-20	
D-4D: 4, 5	Exceedance frequency curves for water levels in the same 20 stations at present, and at 25, 50 and 100 years from now. Define extreme water levels in the polder of coastal zone at 25, 50 and 100 years from now, due to cyclonic storm surges.		Extreme Storm Surges			Oct-20	
D-4D: 6	Technical Report with description and explanation of the geospatial datasets of surface and ground water salinity, and the tidal salinity and water level curves, including description of relevant seasonal variations, used models, indication of more and less likely scenarios and full metadata. The Research Team shall also discuss the effect of at least two relevant options of redistribution of river water in the South West delta on salt intrusion.		**Detailed Technical Reports on Climate Change Effects**			Nov-20	

Special Comments:

A: This project has never intended to develop new modelling software tailor-made for its work. It uses only a variety of tried, tested and widely recognised modelling software modules to create calibrated and validated models of very complex processes taking place in this active Delta Region. However, all the models developed by the project (together with the relevant software licences) would be transferred to the BWDB with adequate documentation and training to enable the work to be continued after the project is concluded.

B: It should be noted that there are two sets of Meso Scale models covering nearly identical river reached but investigating different phenomena on different time scales, both sets providing important inputs to the planning and design teams.

C. The micro scale modelling will be used in modelling drainage processes and TRM processes. The extent of applications of micro scale modelling will depend on the nimber of polders that are taken up or detailed study.

1.3 First Activities of the Fourth Quarter (Components 2 and 3)

Component No 1 (Inception Phase) has been completed during the first Quarter. The Work Plan proposed and approved in the Inception Report will provide broad guidance for the later activities.

Component No 2 (Literature Review) is the first activity listed for the post inception period. Much progress was achieved in this activity, keeping in mind the need to keep up with the outputs from new field campaigns, other related studies and projects, which will continue to provide additional knowledge and insights. The first Interim Literature Review was published in the month of April 2019. This report was published as Appendix A of the previous Progress Report (QPR-3)..

A new Chapter on Coastal Biodiversity has been added to the latest version of the Literature Review.

It is anticipated that the next interim Review will be prepared in December 2019. It is intended that a section on “Lessons Learnt” will be included in the Second Interim Literature Review and in subsequent reports.

The major activities undertaken during the previous and current quarter are Data Collection as inputs for Modelling (Component 3). This is described in Chapter 2.

The data collection effort has already begun to culminate in the development of a major Database designed for use in managing the Coastal Zone of Bangladesh. This is described in Chapter 3.

Progress in the development and application of the several types of models used in this study are described in Chapter 4.

Progress in the selection of the Selection of Pilot Polders for Conceptual Designs and the Road Map for formulating the Polder Reconstruction Programme Polders are covered on Chapter 5.DEVELOPMENT OF INPUT DATASETS FOR MODELLING PHYSICAL PROCESSES

2 DEVELOPMENT OF INPUT DATASETS FOR MODELLING PHYSICAL PROCESSES

2.1 Collecting Existing Data

IWM already has a very comprehensive database comprising hydrometric, meteorological and morphological and environmental data collected over many decades all over the territory of Bangladesh and the adjacent ocean. These data have the advantage of having been used many times over in a large model studies which have also established the quality of the data through repeated verification.

The present study requires the addition of socio-economic data and its subdivision in to a polder-wise demarcated body of data. The availability of data is described in the Inception Report and is too large to be included in this progress report. The reader is directed to the Inception report for an outline of availability. Appendix A of the Second Quarter Progress Review Report gives a list of available data.

2.2 Field Surveys carried out by IWM

2.2.1 Mobilization

The survey team was mobilized on 05 February 2019. A team of 12 personnel comprising the IWM survey Expert, experienced hydrographic surveyor and land surveyors has been deployed for conducting the planned data collection campaign as per specification.

2.2.2 Summary of Field Survey Activities

The whole survey team has been spilt into four groups. Out of these two groups comprising specialised hydrographic surveyors and land surveyors for conducting bathymetry survey, monitoring section, discharge observation and other hydrological observation. Whereas, other two groups comprising experience in BM Fly and salinity data collection has been engaged for water level gauge installation and Salinity data collection.

The progress of survey activities are shown in Table 2-1 to Table 2-7.

The survey methodology employed by IWM survey teams is described in details in the Second Quarterly Progress Report

Table 2-1: Progress of Bathymetric Survey.

SL	River Name	Description/ Specification	Duration of survey	Unit	Target		Progress upto 30th June 2019	Progress in between 01-July to 30-Sep 2019	Cumulative Progress up to Sep-2019	Remarks
					TOR	Modified				
1	Shibsa	From Haborkhali to Akrampoint 70 Km length(out of this 50 km @ 1000m interval & 20km @ 500 m interval	18-23/03/2019	Km-transect	0	168	168	0	168	As per consultation with client, expatriate and national consultants-bathymetry survey of Sibsha, Pusur, Baleswar and Bishkhali river has been added.
2	Pussur	From Rupsha to Outerbar of 133 km length @ 1000m interval	12-24/03/2019	Km-transect	0	353	353	0	353	
3	Baleswar	From Hularhat to outfall of 82 km length @ 1000m Interval	01-10/03/2019	Km-transect	0	196	196	0	196	
4	Bishkhali	From Gabkhan khal to Badurtala of 92 Km length @ 1000m interval	28-31/03/2019	Km-transect	0	97	97	0	97	
5	Lower Meghna	From Chandpur to Tajumuddin of 100 km @ 1000m interval	26/03/19-09/04/19	Km-transect	1306	1068	1068	0	1068	
Total				Km-transect	**1306**	**1882**	**1882**	**0**	**1882**	
SL	River Name	escription/Specificatio	Duration of survey	Unit	Target		Progress upto 30th June 2019			Remarks
					TOR	Modified				
1	Sangu River	95Km @ 500m interval		Nos.	141	141	0	141	141	At 500m interval for 70 km, a total of 141 transects

Table 2-2: Progress of discharge observation

SL no.	Location/ River Name	Target (Number)		Progress upto June 2019	Progress in between July to	Cumulative Progress upto Sep-2019	Remarks
		TOR	Modified				
A	3 main rivers						
1	Bahadurabad, Brahmaputra	18	48	4	6	10	As per post inception consultation (Twice a months for 2 years)
2	Hardinge Bridge, Ganges	18	48	3	7	10	
3	Bhairab Bazar, Upper Meghna	18	48	6	7	13	
	Total of A	54	144	13	20	33	
B	Lower Meghna						
4	Chandpur, Lower Meghna	3	5	2	3	5	2 spring+ 1 neap during monsoon and 2 nos. 1 Spring +1 Neap for dry season
C	5 nos. Tidal rivers						
5	U/S of Mongla port, Pusur	44	8	3	3	6	For each location 8 measurement: 1 spring in every two months and -1 neap in every six months for the periods of one year.
6	Nalian, Shibsha		8	3	3	6	
7	Charduani, Baleswar		8	3	3	6	
8	Bhandaria, Baleswar		8	3	3	6	
9	Polder-17/2, Gangril		8	1	5	6	
	Total of C	44	40	13	17	30	
D	Additional 3 tidal River						
10	Dasmina, Tetulia	0	2	0	2	2	2 nos. measurement during June-Oct-19, 1 Spring+ 1 Neap
11	Kakchira, Bishkhali	0	3	3	0	3	Total 3 nos. -1 spring in dry season and 1-Neap+1-Spring for monsoon
12	Taliar dwip,Shangu	0	2	0	1	1	2 nos. measurement during June-Oct-19, 1 Spring+ 1 Neap
	Total of D	0	7	3	3	6	

Table 2-3: Progress of suspended sediment sampling for total concentration

<table>
<tr><th rowspan="2">SL no.</th><th rowspan="2">Location/ River Name</th><th colspan="2">Discharge observation</th><th colspan="4">Suspended Sediment Sampling for Total concentration</th></tr>
<tr><th>As per TOR</th><th>Modified</th><th>As per TOR</th><th>Progress upto June-2019</th><th>Progress in between July to Sep-2019</th><th>Cumulative Progress upto Sep-2019</th></tr>
<tr><td>A</td><td>3 main rivers</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td>Bahadurabad, Brahmaputra</td><td>18</td><td>48</td><td rowspan="3">1056</td><td rowspan="3">340</td><td rowspan="3">469</td><td rowspan="3">809</td></tr>
<tr><td>2</td><td>Hardinge Bridge, Ganges</td><td>18</td><td>48</td></tr>
<tr><td>3</td><td>Bhairab Bazar, Upper Meghna</td><td>18</td><td>48</td></tr>
<tr><td>B</td><td colspan="7">Lower Meghna</td></tr>
<tr><td>4</td><td>Chandpur, Lower Meghna</td><td>3</td><td>5</td><td>234</td><td>95</td><td>54</td><td>149</td></tr>
<tr><td>C</td><td colspan="3">5 nos. Tidal rivers surrounding</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>U/S of Mongla port, Pusur</td><td rowspan="5">44</td><td rowspan="5">40</td><td rowspan="5">3432</td><td rowspan="5">812</td><td rowspan="5">896</td><td rowspan="5">1708</td></tr>
<tr><td>6</td><td>Nalian, Shibsha</td></tr>
<tr><td>7</td><td>Charduani, Baleswar</td></tr>
<tr><td>8</td><td>Bhandaria, Baleswar</td></tr>
<tr><td>9</td><td>Polder-17/2, Gangril</td></tr>
<tr><td>D</td><td colspan="7">Additional 3 tidal River (as per modified plan)</td></tr>
<tr><td>10</td><td>Dasmina, Tetulia</td><td>0</td><td>2</td><td rowspan="3">0</td><td rowspan="3">51</td><td rowspan="3">397</td><td rowspan="3">448</td></tr>
<tr><td>11</td><td>Kakchira, Bishkhali</td><td>0</td><td>3</td></tr>
<tr><td>12</td><td>Taliar dwip,Shangu</td><td>0</td><td>2</td></tr>
</table>

Table 2-4: Progress of suspended sediment and bed sampling for grain size distribution

<table>
<tr><th rowspan="2">SL no.</th><th rowspan="2">Item</th><th colspan="4">Sediment Sampling</th><th rowspan="2">Remarks</th></tr>
<tr><th>As per TOR</th><th>Progress upto June-2019</th><th>Progress in between July to Sep-2019</th><th>Achieved upto August-2019</th></tr>
<tr><td>1</td><td>Suspended Sediment sampling</td><td>33</td><td>0</td><td>10</td><td>10</td><td>suspended Sediment sampling during discharge observation (1 sample of minimum 40 liter volume during each observation) for 11 locations in 3 times</td></tr>
<tr><td>2</td><td>Collection of Bed Sample</td><td>55</td><td>60</td><td>3</td><td>63</td><td>Collection of five bed samples from each river discharge observation</td></tr>
</table>

Table 2-5: Progress of water level data collection

SL. No.	Name of Location/River	Postion in UTM		Installation Date	Modified Target (statⁿ-month)	Progress up to June-2019 (statn-month)	Progress in between July to Sep-2019 (statn-month)	Cumulative Progress up to Sep 2019 (statn-month)	Status
		UTM_X	UTM_Y						
1	Dularshar, outfall of Rabnabad Channel	216528	2421048	18-Feb-19	12	4	3	7	Continue
2	Taltoli, outfall of Biskhali /Baleswar	193946	2426687	17-Feb-19	12	4	3	7	Continue
3	Kaikhali, Ichamoti	713469	2456684	15-Feb-19	12	4	3	7	Continue
4	Chandpur, Lower Meghna	258997	2570810	1-Feb-19	4	4.5		2	
5	Dasmina(Hajir hat), Tetulia	252198	2465785	8-Apr-19	4	2.5	2	4.5	Closed at 22/08/2019
6	Joymuni, Pusur	771508	2474265	14-Mar-19	4	3	2	5	Closed at 28/08/2019
7	Nalian, Shibsha	750574	2485746	15-Mar-19	4	3	2	5	Closed at 22/08/2019
8	Charduani, Baleswar	800698	2449693	31-Mar-19	4	2	2	4	Closed at 22/08/2019
Total					56	27		41.5	

Table 2-6: Progress of Monitoring Sections

SL no.	River name	Left bankPosition in UTM		Target as per TOR (event)	Progress up to June-2019	Progress in between July to Sep 2019	Cumulative Progress up to Sep-2019	Remarks
		Easting (m)	Northing (m)					
1	Pusur	762273	2501059	4	2	0	2	Next data collection will be done on Feb-2019 & May-2019
		765884	2494718					
2	Sibsha	751161	2487806	4	2	0	2	so
		751557	2482153					
3	Kobadak	734559	2474997	4	2	0	2	so
		735522	2468624					
4	Chunkuri	759390	2500705	4	2	0	2	so
		758092	2498287					
5	Badurgacha	753417	2504229	4	2	0	2	so
		749232	2499644					
6	Dhaki	755788	2498307	4	2	0	2	so
		751834	2493821					
7	Gangril	739773	2522911	4	2	0	2	so
		746214	2515543					
8	Gashikhali	772383	2496263	4	2	0	2	so
		769190	2489629					
9	Andharmanik	206871	2432616	4	2	0	2	so
		214473	2433381					
10	Galachipa	233074	2451448	4	2	0	2	so
		232892	2462016					
11	Baleswar	808406	2488650	4	2	0	2	so
		796650	2467005					
12	Lower Meghna	259138	2565429	4	2	0	2	so
		261237	2543677					
13	Shangu			4	1	0	1	so
Total				52	25	0	25	

Table 2-7: Progress of Salinity Data Collection

Stat^n ID	Station Name	River_Name	Easting (m)	Northing (m)	Start date	Progress up to June-2019	Progress in between July to Sep-2019	Cumulative Progress upto Sep-2019
1	Bashantapur	Isamoti	706840	2486285	12-Feb-19	4.50	3	7.5
2	Kaikhali	Modan Gauga	714395	2455144	13-Feb-19	4.50	3	7.5
3	Kobadak	Kobadak	738053	2459252	15-Mar-19	3.50	3	6.5
4	Nalian	Shibsha	749190	2486655	13-Feb-19	4.50	3	7.5
5	Gangrail	shundor mohc	746284	2509461	10-Mar-19	3.50	3	6.5
6	Khulna	Rupsha	764985	2523883	8-Mar-19	3.50	3	6.5
7	Bardia/ Nabaganga	Noboganga	773750	2555764	19-Feb-19	4.50	3	7.5
8	Chapailghat	Modhumati	786778	2544530	13-Feb-19	4.50	3	7.5
9	Patgati	Modhumati	797052	2533438	16-Mar-19	3.50	3	6.5
10	Mongla	MonglaNala	767846	2487421	10-Mar-19	3.50	3	6.5
11	Joymoni	Pussur	770059	2478036	9-Mar-19	3.50	3	6.5
12	Gasiakhali	Gasiakhali	796021	2484687	22-Mar-19	3.50	3	6.5
13	Char Doani	Baleswar	800083	2449931	13-Feb-19	4.50	3	7.5
14	Bishkhali DS	Bishkhali Rive	808483	2439742	6-Mar-19	4.00	3	7.0
15	Hiron Point	Pusur	756533	2412633	10-Mar-19	3.50	3	6.5
16	Mohipur	Shibbaria Khal	200814	2419537	25-Feb-19	4.00	3	7.0
17	Khepupara Kolapara	Adhanmanik	214449	2431880	13-Feb-19	4.50	3	7.5
18	Madhupara	Andharmanik	222130	2433381	13-Feb-19	4.50	3	7.5
19	Amtali	Burisuar	213580	2450306	5-Mar-19	4.00	3	7.0
20	Patuakhali	Buriswar	217267	2473096	15-Mar-19	3.50	3	6.5
21	Burhanuddin	Tetulia	257606	2494785	3-Mar-19	4.00	3	7.0
22	Daulatkhan	Meghna	264409	2504558	13-Feb-19	4.50	3	7.5
23	Hilsha	Ganeshpura	255886	2524418	13-Feb-19	4.50	3	7.5
24	Moju Chowdurir Hat	Lower Meghn	271573	2524453	13-Feb-19	4.50	3	7.5
25	Ramgati	Lower Meghn	296451	2496925	2-Mar-19	4.00	3	7.0
26	Char Elahi	Outfall of Noakhali	316468	2512380	13-Feb-19	4.50	3	7.5
27	Musapur	Little Feni outfall	334907	2517844	1-Mar-19	4.00	3	7.0
28	Kalurghat Bridge	Karnafuly	379618	2469046	27-Feb-19	4.00	3	7.0
29	Patenga	Karnafuly	378241	2459360	13-Feb-19	4.50	3	7.5
30	Sangu Outfall	Sangu	380988	2449507	28-Feb-19	4.00	3	7.0
Total (station-month)						122	90	212.0

2.2.3 Field visit to BWDB measuement programme at Bahadurabad

A Joint monitoring team from Long Term Monitoring and BWDB consisted of 4 members jointly visited discharge observation and sediment sampling from 18/08/19 to 20/08/19 at Bahadurabad. Following is the list of the monitoring team:

a) Mohammad Ali, Executive Engineer, PMU, CEIP-1, BWDB

b) Tarek Bin Hossain, Sediment Management Specialist, Long Term Monitoring, Consultant

c) Pankaj Kumar Maitra, Survey and Monitoring Specialist, Long Term Monitoring, Consultant

d) Mohammad Ziaur Rahman, Coastal and Estuarine Morphological Modelling Specialist, Long Term Monitoring, Consultant

During the field visit, the team inspected the discharge observation and sediment sampling by IWM and BWDB. IWM also conducting turbidity observation together with sediment sampling. BWDB measurement team at Bahadurabad also participated the survey activity conducted by IWM team. At the end of the measurement IWM team explained to BWDB field team the methodology needed to correct the positioning errors that could be introduced in instances when the ADCP bottom tracking feature is affected by the movement of the layer sediment on the bed. Regarding sediment sampling and output of BWDB, the monitoring team recommended to make an interaction meeting with the concerned authorities of BWDB for better understating and make consistent of the all output as these sediment data would be very useful for this research work under this project.

Figure 2-1: Discharge observation by IWM Team

Figure 2-2: Collection of suspended sediment

2.3 Field Surveys carried out by US University Teams

2.3.1 GPS and SET-MH Field Work (16 July to 9 August 2019)

Participants:

International

IK-9	Michael S. Steckler, LDEO, Columbia University steckler@ldeo.columbia.edu
INK-14	Christopher Small, LDEO, Columbia University csmall@columbia.edu
INK-25	Carol A. Wilson, Louisiana State University carolw@lsu.edu

We were also accompanied by John Galetzka, engineer from UNAVCO as expert on GPS installations

National

NNK-12	Salam Sikder, IWM
NNK-26	Shaikh Nahiduzzaman, IWM

In addition, 6 Dhaka University students participated in the fieldwork: Sharmin Akter, Md. Samiul Alim, Md. Mesbah Uddin Bhuiyan, Md. Masud Rana, Sanju Singha, Md. Ashraf Uddin.

For the final leg of the field work Alamgir Hosain and Md. Hasnat Jaman of Barisal University also participated.

Figure 2-3: From left to right: Sharmin Akter, Carol Wilson, Mesbah Uddin Bhuiyan, Samiul Alim, Sanju Singha, Salam Sikder, Shaikh Nahiduzzaman, John Galetzka, Barkat Sikder, Ashraf Uddin, Masud Rana

Fieldwork was conducted from the *M/V Bawali* from 18 until 27 July, and subsequently using two vans from 28 July until 4 August. Continuous GPS and Surface Elevation Tables with Marker Horizons (SET-MH) were co-located and installed at multiple sites in SW Bangladesh to measure sedimentation, subsidence, and elevation changes (Fig 2-4). Upazilla maps of primary schools and land change maps were used to locate sites for equipment, in conjunction with discussions with local farmers and officials. Field installations were very labor intensive, thus necessitated many participants.

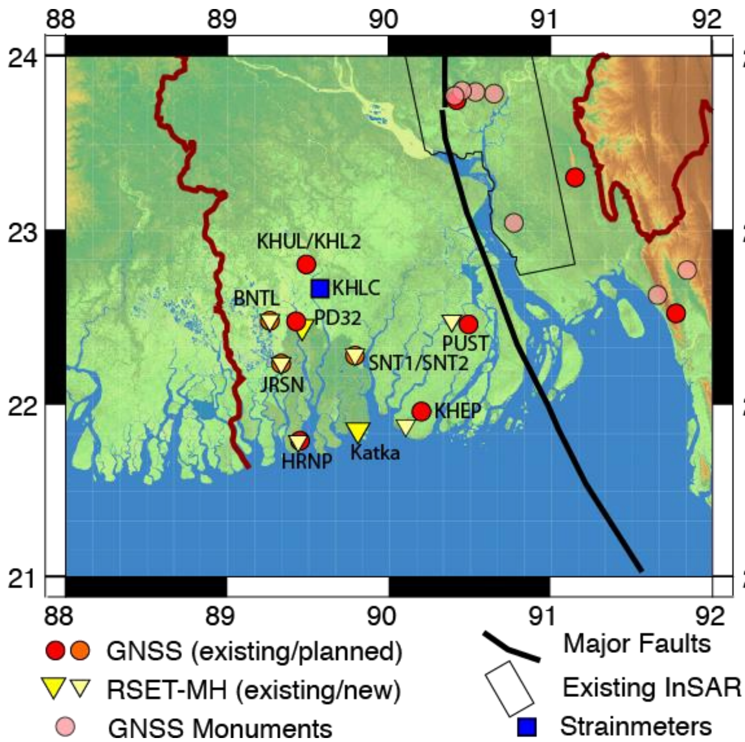


Figure 2-4: Map of GPS and SET sites installed, upgraded or serviced.

For the GPS, 4 new sites were scouted and installed at Sonatola (SNT1, SNT2), Jorshing (JRSN) and Baintola (BNTL), and 5 sites had systems upgrades and/or repairs: Patuakhali (PUST), Khepupara (KHEP), Hiron Point (HRNP), Polder 32 (PD32), and Khulna University (KHL2) [see Fig 2-4]. All GPS sites were successfully installed/upgraded, and data from existing sites was collected. In addition, cellular modems for data transmittal were upgraded/added to all GPS sites except HRNP (although a cellular tower has been installed near the site, coverage is only 2G and does not support data communications). Computer hard drives for older PUST and KHUL GPS were located, but still require data download.

At Sonatola, two GPS antennas and receivers were installed. One was installed on the roof of a reinforced concrete column of a primary school (SNT1), similar to other continuous installations in Bangladesh (Fig. 2-5). The other was installed on a rod (Fig. 2-6) identical to the nearby RSET (SNT2). This will enable direct measurement of any subsidence occurring beneath the bottom of the 80’ long rod.

In addition, we were able to install campaign GPS monuments on the Hiron Point (Fig. 2-7) and Khepupara tide gauges, and two at Barisal University. These campaigns monuments will allow subsequent monitoring of subsidence. Measurements at the two tide gauges will also be able to help assess the stability of the stability of the tide gauges. At Khepupara, the tide gauge location has been shifted multiple times and corresponds to changes in rates of apparent relative sea level rise at the tide gauge.

Figure 2-5: John Galetzka on roof of primary school at Jorshing with GPS antenna.

Figure 2-6: GPS mounted on rod identical to that of RSET, visible in next field. A tripod was added for stability, but bracing has a cylinder that allows free motion of the rod to measure deep subsidence.

New SET-MH pairs (one inside polder and one outside the polder) were scouted and installed at PUST, KHEP, SNT, HRNP, JRSN, BNTL for a total of 12 new sites (see Fig 2-4, also Table 2-8). Because of the season, it was impossible to install marker horizons (MH) at the 12 SET sites (as it was the monsoon season, the land area was under rice paddy cultivation). Initial measurements were made at Katka (Fig. 2-8). For these measurements, two Dhaka University students were trained (Sharmin Akter, Md. Masud Rana) as well as IWM participants Salam Sikder and Shaikh Nahiduzzaman. In order to make future measurements (furthering capacity building and training), students Akter and Rana will participate in a second training opportunity in October 2019, where they will finish their training for taking SET-MH measurements, and learn how to make MH installations (during the dry season; planned spring 2020).

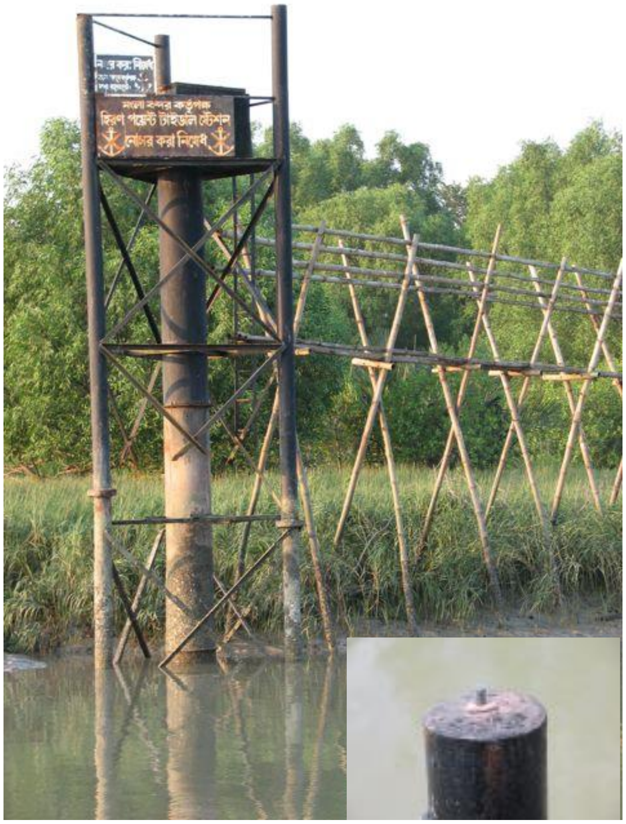


Figure 2-7: Tide gauge at Hiron Point. Monument pin (inset was installed on far cement-filled support column.

Figure 2-8: Carol Wilson measuring the height of one of the fingers on an RSET arm at Katka. Carol and Sharmin are on board to avoid touching the measurement area around the RSET.

The land cover survey and soil sampling campaign was conducted in parallel with the GPS and SET installations. Crop photos were collected from the vehicles along transits of opportunity. This reduced scheduling complexity with the other teams and was actually complementary to surveys conducted in earlier years because most of the new stations are in areas not previously surveyed by our team. A total of 8622 geolocated field photos were collected. In several locations where fallow soil was observed (e.g. Sonatola, Jorshing), walking transects were conducted and soil samples were collected for calibration of satellite substrate fraction and soil moisture content. Farmers were interviewed at all soil sample collection sites to determine the reason(s) why the fields were not under cultivation. As expected, the frequency of fallow fields was considerably less than what has been observed on winter (Jan.-Mar.) surveys in the same area. On the polders surrounding the Sundarban, almost all fields showed early stage khareef rice crops, while further north, jute crops were also observed. During the time in the field, one partial cloud-free Sentinel 2 image and two partial cloud-free Landsat 8 images were acquired. Referencing the land cover observed in the field to the reflectance measured on these images will provide constraints on the extent of monsoon crops under cultivation.

Figure 2-9: Fallow fields and farmers (and Chris Small) in Sonatola on 19.07.2019 and in Jorshing (South) on 24.07.2019.

The compaction meter site (KHLC) in Bhanderkote was also visited during this field campaign. An upgraded computer system for the site was to be delivered to the host family, however it was discovered upon arrival that the compaction meter (KHLC) was destroyed by river erosion after dredging operations were conducted in 2015.

General comments

Local farmers and school officials were extremely helpful in providing permission and donating land for the equipment installations. In at least one case, a planned local embankment will be adjusted to leave the RSET open to the river. In addition, local inhabitants were generally supportive of the work we are doing and were very interested in hearing about our results as they develop when we revisit the sites. They expressed they have no confidence that they will be informed of results from any official channels.

Delays in clearing equipment from customs in a timely manner continued to be an issue. It caused delays in the start of the fieldwork by at least 2 days. Due to the much faster installation of the SET rods with the gasoline-powered hammer drill and the teams' dedication to hard work and efficiency, however, we were able to make up the lost time.

The SET will provide direct measurements of elevation changes. When combined with the MH measurements of sedimentation rate, the system provides an estimate of the shallow subsidence above the base of the driven rod (80 ft. or less). The GPS provides a measurement of the total subsidence of the antenna. Thus when combined with the SET-MH, they are capable of separating the shallow and deep components of subsidence. At Sonatola, we installed two GPS, one on a rod identical to the SET (SNT2) and one on a building roof, similar to other GPS in Bangladesh (SNT1). The two GPS will enable us to examine and differences due to the monument, e.g., seasonal clay expansion/contraction.

SET-MH measurements must be made seasonally, at the end of the monsoon season (recommended October-November) and at the end of the dry season (March-end April). GPS stations are downloaded weekly via cellular data connection, except for HRNP which requires manual downoad, however the GPS stations should be visually inspected each time the SETs are measured OR at least annually. Inspection of the GPS stations must include:

1) Check for and report vandalism, damage or excessive wear to cabling, geodetic monument, GPS antenna, antenna radome, solar panels, and equipment case.
2) Making sure area around solar panels and equipment enclosure are clean and free of vegetation, debris, animal waste, furniture.
3) Clean solar panel of dust, mildew, paint if necessary.
4) Check interior of equipment enclosure for insects, water accumulation or excessive dust. Avoid tripping circuit breakers!
5) At departure take digital photos of station and equipment enclosure exterior and interior and send to John Galetzka and Mike Steckler.

Shortcomings in the support you received from the Project Office

While IWM personnel were extremely helpful for the success of the fieldwork during the first part of the mission in which they participated (on boat). In contrast, the expected participants from BWDB for the second part of the field work (via land transit by van) never showed up. This diminishes the capacity building planned for this project. Other than the 2 students from Dhaka University who have received training, it remains unclear which Bangladeshi counterparts are responsible for this work, i.e., who exactly will oversee the maintenance and measurement of this equipment (particularly the SET-MH) moving forward.

Table 2-8: RSET installations

SITE NAME	Polder #	RSET #	Inside/Outside polder/ Sundarbans	Latitude	Longitude	# of rods	Date Installed
SNT	35/1	4A	inside	22.25558	89.80568	20	7/19/2019
SNT2	35/1	4B	inside (topped with GPS)	22.25558	89.80554	20	7/20/2019
SNT	35/1	4C	outside	22.24856	89.80091	16	7/20/2019
KATKA	-	RSET-9	Sundarbans creek bank				July 2018
KATKA	-	RSET-10	Sundarbans interior	21.86299	89.77925		July 2018
HRNP	-	RSET-11	Sundarbans interior	21.81892	89.45645	20	7/22/2019
HRNP	-	RSET-12	Sundarbans creek bank	21.81837	89.45693	19	7/22/2019
JRSN	14/1	RSET-13	outside	22.25625	89.33666	19	7/24/2019
JRSN	14/1	RSET-14	inside	22.24707	89.34361	20	7/24/2019
BNTL	7/2	RSET-15	inside	22.49778	89.23315	19	7/25/2019
BNTL	7/2	RSET-16	outside	22.49842	89.25224	16	7/25/2019
KHEP	48	RSET-17	outside	21.85825	90.13931	16	7/30/2019
KHEP	48	RSET-18	inside	21.85625	90.13587	14	7/31/2019
PUST	43/2	RSET-19	outside	22.42121	90.45151	20	8/2/2019
PUST	43/2	RSET-20	inside	22.42038	90.44697	17	8/3/2019

Table 2-9: GPS Installations

SITE NAME	Polder #	Location Description	Latitude	Longitude	Date Installed
SNT1	35/1	Sonatola primary school	22.2522	89.8050	7/20/2019
SNT2	35/1	Field near SET	22.2556	89.8056	7/20/2019
JRSN	14/1	Jorshing primary School	22.4982	89.2301	7/24/2019
BNTL	7/2	Baintala primary school	22.2480	89.3444	7/25/2019
HRNP		Forest ranger station	21.81642	89.45940	10/21/2012
PD32	32	Gunari High school	22.50460	89.43589	10/20/2012
KHL2		Khulna University	22.80217	89.53273	2/06/2014
PUST	43/2	Patuakhali Science and Technology University	22.46513	90.38339	5/24/2003
KHEP	48	Khepupara weather radar station (Met Dept)	21.98668	90.21968	10/19/2012

Figure 2-10: Additional Photographs


ALAMGIR

2.3.2 Core Drilling and Analysis leading to determining Sediment Budget

<u>SEDIMENT BUDGET</u>

Data compilation and analysis has been ongoing in support of the macro-scale delta modelling. A full delta sediment budget is being developed, with initial results provide here. Figure 2-11 shows the GIS-based sediment budget template, dividing the delta into physiographic regions, for which sediment volumes and grain size distributions are determined for each. Results are summarized in Table 2-10 and show that similar volumes of sediment are stored in the Jamuna, Ganges, and Meghna valleys and the offshore basin. In collaboration with GPS stations and SET stations, we will explore whether subsidence rates are higher where Holocene sediments are thicker, by potentially enhancing compaction or preserving thicker mud sections also prone to compaction.

The sediment budget work is also calculating overall sediment budgets (Table 2-11). Initial results show that average storage rates are 1 billion tonnes per year, similar to modern discharge rates. However, the storage has been time variable, with much higher rates in early Holocene and lower than average rates in the last 8000 years. These periods provide useful comparisons for future delta response to possibly increased rates of sediment supply due to enhanced monsoon strength, or conversely its response to reduced sediment load due to damming and water diversions.

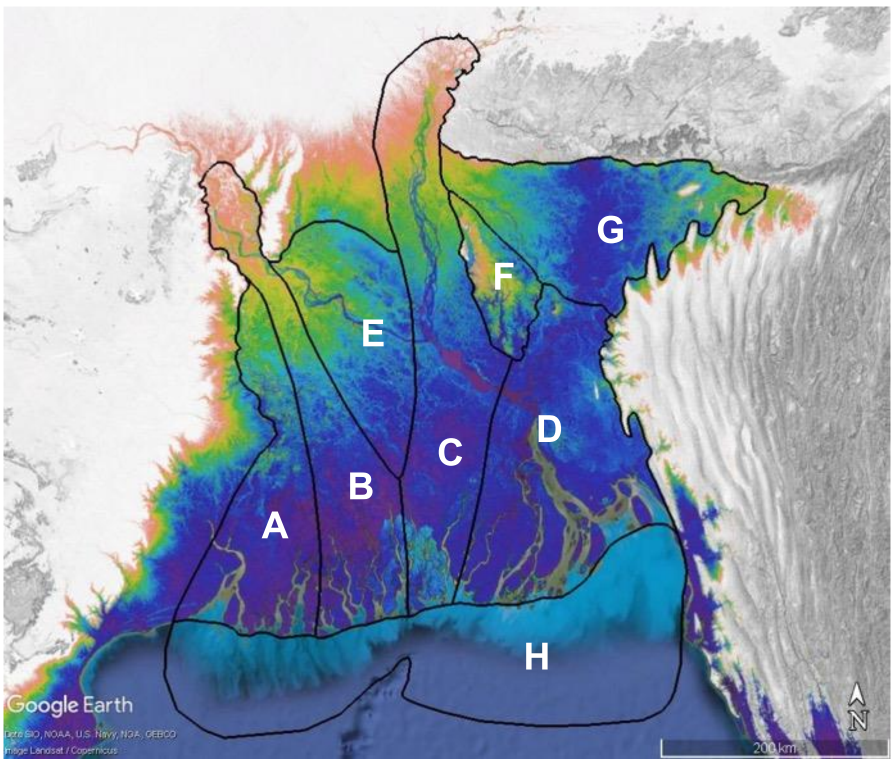


Figure 2-11: Digital Elevation Map overlain by physiographic regions used to determine sediment mass balance. Core data from each region are used to determine sediment volume, mass, and grain-size distribution. Physiographic regions include: A. West Bengal, B. Ganges valley, C. Brahmaputra valley, D. Meghna valley, E. Barind interfluve, F. Madhupur terrace, G. Sylhet basin, H. Offshore.

Table 2-10: Summary of Holocene sediment mass balance for each physiographic region

Physiographic Region	Area (km^2)	Volume (km^3)	Mean thickness (m)
River Valleys			
Jamuna Valley	2.70×10^4	1.70×10^3	62.9
Ganges Valley	1.80×10^4	1.10×10^3	61.1
Meghna Valley	2.71×10^4	1.51×10^3	55.9
Interfluves and Terraces			
Barind Interfluve	1.42×10^4	0.35×10^3	24.4
Madhupur Terrace	0.47×10^4	0.02×10^3	4.3
West Bengal	1.69×10^4	0.39×10^3	22.9
Basins			
Sylhet Basin	1.91×10^4	0.71×10^3	37.0
Offshore	4.16×10^4	1.62×10^3	38.8

Table 2-11: Summary of river sediment storage in Bengal Basin over the Holocene

Time (yrs BP)	Volume (km^3)	Storage ($t \cdot yr^{-1}$)
12,000 to present	7.63×10^3	1.00×10^9
8,000 to present	4.39×10^3	0.82×10^9
12,000 to 8,000	3.24×10^3	1.37×10^9

CORE DRILLING

The core drilling team was organized by Dhaka University, headed by Md. Saddam Hossain and Md. Abir Delwaruzzaman, plus a local drilling crew and assistant geologists. The team conducted preliminary drilling in Satkhira District from July 29 to August 2, 2019. Results from the drilling show contrasting stratigraphy, with some sites having nearly complete sand deposits and others dominated by mud (Figure 2-12). The abundance of wood and shell fragments suggest that this region has been tidal estuarine throughout the Holocene. Several cores also reached the Pleistocene boundary, helping to demarcate the edges of the Ganges valley. Samples from these cores will be shipped to the U.S. for detailed analyses of grain size, geochemistry, and radiocarbon dating. More drilling is planned for end of 2019 and beginning 2020.

Figure 2-12: Field lithologs from initial drill cores and map of locations. collected west-east across the lower delta plain. Pictures show Dr. Chamberlain collecting luminescence samples by hand coring (left) and from local outcrops (right).

depth (m)	H001	H008	H014	H020	H028	H035
2	Mud	**Mud**	Mud	Mud	Mud	**Mud**
3	Mud	Mud	**Mud**	**Mud**	Mud	Mud
5	**Mud**	Mud	Mud	**Mud**	Mud	Mud
6	**Mud**	Mud	Mud	**Mud**	**Mud**	Mud
8	**Mud**	**Mud**	Mud	Mud	**VF-F Sand**	**Mud**
9	**Mud**	**Mud**	Mud	Mud	**VF-F Sand**	**Mud**
11	VF-F Sand	**Mud**	Mud	VF-F Sand	**Mud**	**Mud**
12	VF-F Sand	**Mud**	**Mud**	VF-F Sand	Mud	Mud
14	VF-F Sand	**Mud**	VF-F Sand	VF-F Sand	Mud	Mud
15	VF-F Sand	**Mud**	VF-F Sand	VF-F Sand	VF-F Sand	Mud
17	**VF-F Sand**	Mud	VF-F Sand	VF-F Sand	VF-F Sand	**Mud**
18	VF-F Sand	**Mud**	VF-F Sand	VF-F Sand	VF-F Sand	**Mud**
20	VF-F Sand	Mud	VF-F Sand	VF-F Sand	Mud	**VF-F Sand**
21	**VF-F Sand**	Mud	VF-F Sand	VF-F Sand	Mud	**VF-F Sand**
23	**VF-F Sand**	Mud	**Mud**	VF-F Sand	**Mud**	**VF-F Sand**
24	VF-F Sand	Mud	**Mud**	VF-F Sand	Mud	**VF-F Sand**
26	VF-F Sand	Mud	**Mud**	VF-F Sand	**Mud**	**VF-F Sand**
27	VF-F Sand	Mud	Mud	VF-F Sand	Mud	**VF-F Sand**
29	VF-F Sand	Mud	Mud	VF-F Sand	Mud	**VF-F Sand**
30	VF-F Sand	**Mud**	Mud	**VF-F Sand**	**VF-F Sand**	**Mud**
32	VF-F Sand	VF-F Sand	**Mud**	VF-F Sand	**VF-F Sand**	**Mud**
34	VF-F Sand	VF-F Sand	Mud	**VF-F Sand**	**VF-F Sand**	**Mud**
35	VF-F Sand	Mud	**Mud**	VF-F Sand	**VF-F Sand**	Mud
37	VF-F Sand	**Mud**	Mud	VF-F Sand	**VF-F Sand**	**Mud**
38	VF-F Sand	Mud	**Mud**	VF-F Sand	**VF-F Sand**	**Mud**
40	VF-F Sand	Mud	Mud	VF-F Sand	**VF-F Sand**	Mud
41	**VF-F Sand**	Mud	Mud	**VF-F Sand**	**VF-F Sand**	**Mud**
43	VF-F Sand	**Mud**	Mud	VF-F Sand	VF-F Sand	**Mud**
44	VF-F Sand	Mud	**Mud**	VF-F Sand	VF-F Sand	**Mud**
46	VF-F Sand	Mud	**Mud**	VF-F Sand	VF-F Sand	**Mud**
47	VF-F Sand	***MUD***	Mud	VF-F Sand	**VF-F Sand**	**Mud**
49	VF-F Sand	Mud	Mud	VF-F Sand	VF-F Sand	Mud
50	VF-F Sand	VF-F Sand	Mud	**VF-F Sand**	VF-F Sand	**Mud**
51	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	**Mud**
52	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	**Mud**
53	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	F-M Sand	**Mud**
55	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	F-M Sand	**Mud**
56	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	F-M Sand	**Mud**
58	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	F-M Sand	**Mud**
59	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	VF-F Sand	Mud
61	VF-F Sand	F-M Sand	VF-F Sand	VF-F Sand	F-M Sand	Mud
63	VF-F Sand	F-M Sand	VF-F Sand	VF-F Sand	F-M Sand	**Mud**
64	VF-F Sand	F-M Sand	VF-F Sand	VF-F Sand	F-M Sand	Mud
66	VF-F Sand	VF-F Sand	VF-F Sand	Mud	F-M Sand	VF-F Sand
67	VF-F Sand	VF-F Sand		VF-F Sand	F-M Sand	VF-F Sand
69	VF-F Sand	**VF-F Sand**		VF-F Sand	VF-F Sand	VF-F Sand
70	VF-F Sand	VF-F Sand		VF-F Sand	**Mud**	VF-F Sand
71	VF-F Sand	Mud		VF-F Sand	**Mud**	VF-F Sand
73	VF-F Sand	Mud		VF-F Sand	VF-F Sand	VF-F Sand
75	VF-F Sand	Mud		VF-F Sand	F-M Sand	VF-F Sand
76	Mud	Mud		Mud	F-M Sand	VF-F Sand
78	VF-F Sand			Mud	Mud	VF-F Sand
79	VF-F Sand			Mud	Mud	VF-F Sand
81	Mud			Mud	Mud	VF-F Sand
82	Mud			Mud	Mud	F-M Sand
84				Mud	Mud	F-M Sand
85				Mud		F-M Sand
87				Mud		F-M Sand
88				Mud		F-M Sand
90				Mud		F-M Sand
91				Mud		

KEY

Mud	clay and silt
Mud	mud with organics
VF-F Sand	very fine to fine sand
F-M Sand	fine to medium sand

BOLD = wood or plant fragments
BLUE = shell
ORANGE = oxidized
Pleistocene boundary

LUMINESCENCE DATING

Elizabeth Chamberlain has collected field samples for luminescence dating at 11 sites (Figure. 2-13). The sampling has been focused on addressing the activity of Ganges distributaries, such as the Gorai and Madhumati channels. Chamberlain is currently prepping the samples, which involves careful separation of the 10-20 µm silt fraction from the full sample. Dr. Chamberlain will conducted the final luminescence dating using the OSL lab at Wageningen University in the Netherlands, where we have access to state-of-art instrumentation needed for measuring luminescence. Initial results should be available in Spring 2020.

Figure 2-13: Map of luminescence dating sites (upper panel; yellow and green symbols), collected west-east across the lower delta plain. Pictures show Dr. Chamberlain collecting luminescence samples by hand coring (left) and from local outcrops (right).

2.4 Submission of Reports related to Development of Input Datasets

The acquisition of new as well as existing data was a major task for providing boundary and calibration data for developing a large variety of models for use by this project. The types and formats of these data are model-dependent. This requirement keeps growing as different models are developed for different project needs.

The Terms of Reference requires that these datasets were to be provided in the form of a report titled "Supply of Boundary Data for Models at Various Scales Datasets for Model Calibration". This has already been submitted to the PD's office.

Two other reports as mentioned below are also submitted to PD's office on 29 September 2019.

1. Supply of GIS Based Maps
2. Data Reports, Inventory, Quality Checks

:

3 DATABASE FOR THE COASTAL ZONE

3.1 Introduction

This report is prepared based on the work progress for developing Interactive Geodatabase for Costal Zone (IGDCZ) Web GIS application until the 4th quarter of the project.

As per the Terms of Reference, the objectives of Componenet-3 of the project are:

- To collect all input datasets, undertake Quality Assurance/Quality Checking 9QA/QC) and update/modify datasets as necessary for use in the modelling of the physical processes in the coaster zone of Bangladesh
- To improve the process of data collection, QA/QC and data dissemination and sharing among the government agencies

In order to meet the objectives, the tasks and activities mentioned in the ToR have been reviewed and analyzed, and a set of relevant datasets with their respective sources have been identified during inception period of the project. These datasets are being collected from secondary principal sources and from the field survey by the project. A suitable IT platform has been selected to develop a Web GIS based Database Application to disseminate the Coastal Polder Database.

The datasets include in the database will be comprehensive, consistence, reliable and complete according to the sources, methods of data collection and processing. The final database will be open for further updating by the privileged users (relevant BWDB engineers). Most of the data are spatial, geo-referenced with real-world situation in GIS, and the non-spatial data (tabular data) are maintained in tabular forms in the database.

3.2 Data Collection

Data Collection is an ongoing process. From the initiation of the project the relevant data are being collected from the principal sources, such as, BWDB, WARPO, BMD, GSB, BBS, IWM, SoB and some other organizations.

3.2.1 Database Development

A geodatabase design and structuring has been done in Oracle Database system using Spatial database engine (SDE) schema. The processed data are being gradually uploaded into the Oracle database. A database design report has been prepared and submitted to the Project Authority. During the progression of the data layers development, sometimes it requires to adjust or add of some table columns in the database. The database is fully secured, and password protected.

3.2.2 Data Collection and updating status

Following table illustrates the current progress of the development of Coastal Polder database.

Table 3-1: The current progress of the development of Coastal Polder database

Sl No	Dataset	Data Source	Data Collection	Published in Website	Remarks
1	Polder General Information	Long Term Project	Yes	Yes	There are 137 numbers of Polder boundaries received from the project, remaining 2 polder boundary information need to collected
2	General Administrative Boundaries (Division, District, Upazila and Union)	IWM & SoB	Yes	Yes	
3	General Administrative Headquarters (District, Upazila and Union)	IWM & SoB	Yes	Yes	
4	River Network (wide and narrow)	IWM & SoB	Yes	Yes	
5	Canals and Khals	Survey of Bangladesh	Yes	Yes	
6	Wetlands	Survey of Bangladesh	Yes	Yes	Wetlands in dry season
7	Ponds	Survey of Bangladesh	Yes	Yes	Ponds in dry season
8	Topographical land Height-Digital Elevation Model (DEM)	CEIP project, FINNMap and National DEM Data	Yes	Yes	13 numbers of polder data from CEIP projects
9	Embankment	CEIP Project	Yes	Yes	91 numbers of Polders
10	Embankment Cross Section	CEIP Project	YS	Yes	Received data for 17 numbers of polders
11	Bathymetry	IWM	Yes	Yes	
12	Cana Cross Section	IWM	Yes	No	Received data for 17 numbers of polders
12	Hydraulic Structure	BWDB Structure Inventory Survey	Yes	Yes	
13	Settlement	Sentinel-II Satellite Image, December, 2018	Yes	Yes	

Sl No	Dataset	Data Source	Data Collection	Published in Website	Remarks
14	Polder Population	BBS, 2011 census	Yes	Yes	Population in 2011 of each polder was estimated from the population density in each union based on union settlement area. Population.
15	Road Network	RHD and Survey of Bangladesh	Yes	Yes	
16	Bridges and Culverts	Survey of Bangladesh	Yes	Yes	
17	Physiographical Units with Forests areas	AEZ Map from BARC	Yes	Yes	
18	Water Level Gauge Station	BWDB	Yes	Yes	
19	Surface Water Observation Station	BWDB	Yes	Yes	
20	Surface Water Level Timeseries data	BWDB	Yes	Yes	Data up to the year of 2012
21	River discharge Observation Station	BWDB	Yes	Yes	
22	River discharge Timeseries data	BWDB	Yes	Yes	Data up to the year of 2012
23	Rainfall Observation Station	BWDB & BMD	Yes	Yes	
24	Rainfall Time Series Data	BWDB & BMD	Yes	Yes	Data up to the year of 2012
25	Salinity Raster Surface	CPWF Project	Yes	Yes	
26	Temperature Observation Station	BWDB	Yes	Yes	
27	Daily Maximum Time Series data	BWDB	Yes	Yes	Data up to the year of 2012
28	Daily Minimum Time Series data	BWDB	Yes	Yes	Data up to the year of 2012
29	Humidity observation Station	BWDB	Yes	Yes	
30	Relative Humidity Time Series Data	BMD	Yes	Yes	Data up to the year of 2012
31	Groundwater Monitoring Station	BWDB	Yes	Yes	
32	Groundwater Table Timeseries	BWDB	Yes	Yes	Data up to the year of 2012

Sl No	Dataset	Data Source	Data Collection	Published in Website	Remarks
33	Borehole Lithology	BWDB	Yes	Yes	Data up to the year of 2012
34	Cyclone Track	CEIP Project	Yes	Yes	
35	Groundwater Pump Test data, and well characteristics	Long-term Project	No	No	Long term project will provide data
36	Bio-Diversity	Long-term Project	Yes	No	Data is under process
37	Land use	Satellite Image	No	No	
38	Agricultural Map	Satellite Image	No	No	
39	Land Subsidence	Long-term Project	No	No	Long term project will provide data
40	Erosion & Accession	Satellite Image	No	No	
41	Cyclone Shelter	Survey of Bangladesh	Yes	No	
42	Groundwater Quality (Arsenic)	British Geological Survey (BGS), 1998	Yes	No	
43	Soil Distribution	BARC	No	No	
44	Geological Map on Compaction	Geological Survey of Bangladesh (GSB)			
45	Relative Mean Sea levels	5th Assessment Report, IPCC	No	No	
46	Precipitation projections	5th Assessment Report, IPCC	No	No	
47	Sediment data	Long term project	No	No	

3.3 Web GIS based Application Development

A Web GIS based database application entitled “Interactive Geodatabase for Coastal Zone (IGDCZ)” is under development stage. A demo application of IGDCZ has been developed and presented before the Project Authority during previous quarters of the project. The development of full-scale of IGDCZ application is underway. The URL of this application is: www.geo.iwmbd.com:3010\igdcz\

3.4 Software and Hardware Platform

Currently, the database and the web GIS based application is being developed with the IWM software and hardware resources with selected platforms by the Project Technical Committee. The development platforms are fully compatible with the Software and hardware installed with BWDB Headquarter. BWDB has a licensed ESRI ArcGIS Server running in a central GIS server and similarly, for database a central Oracle 12c database server is installed. After completion of the development of IGDCZ and Web GIS based Application, the developed system will be deployed into the central GIS and Oracle Database at BWDB Headquarter. The software and Hardware platforms are:

Table 3-2: Software Platform

Sl. No	Items	Software Description
1	GIS Server	ESRI ArcGIS Server Enterprise Edition
2	Database Server	Oracle 11g Database
3	Backend and Front end tools	Laravel Framework, Java Script, ArcGIS API, Json, Bootstrap, CSS, HTM
4	Web Server	Microsoft IIS/Apache

Table 3-3: Hardware Platform

Sl. No	Items	Software Description
1	Web Server	Standard high-speed Server Computer
2	Database Server	Standard high-speed Server Computer
3	GIS Server	Standard high-speed Server Computer

3.5 User Security

The database and web GIS based application software are secured with user authenticated and password. The final version of the Database application will have a User Administration module through which the System Manager/Database Administrator can provide privileges and permission to the different levels of users in BWDB and relevant agencies and projects.

3.6 Activity in the Next Quarter

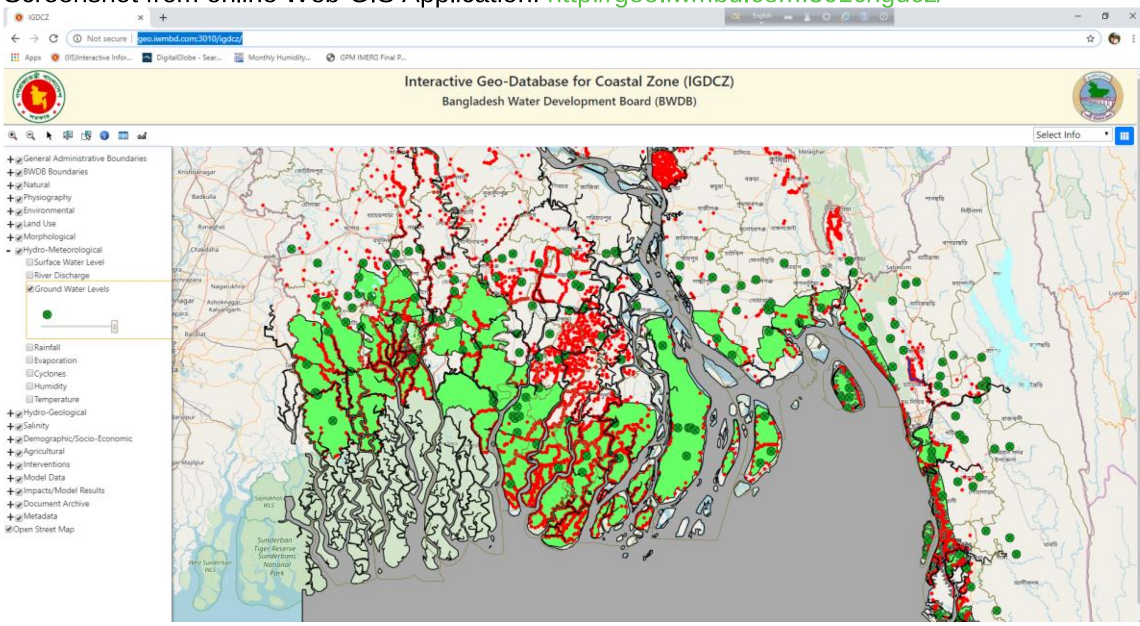
The IGDCZ database is under development stage, the respective datasets are being collected, processed and uploaded into the Geodatabase. The plan for the next quarter is to update the polder database with the following datasets:

- Land use focusing on agricultural including historical and temporal distribution of land use classification with fresh water demand of all types land use categories using Remote Sensing Techniques as indicated in the ToR.
- Erosion and Accession feature layers using Remote Sensing Techniques
- Update the database with Hydrometeorological time series data
- Update the database with Canal Cross Section data
- Other layers as available.

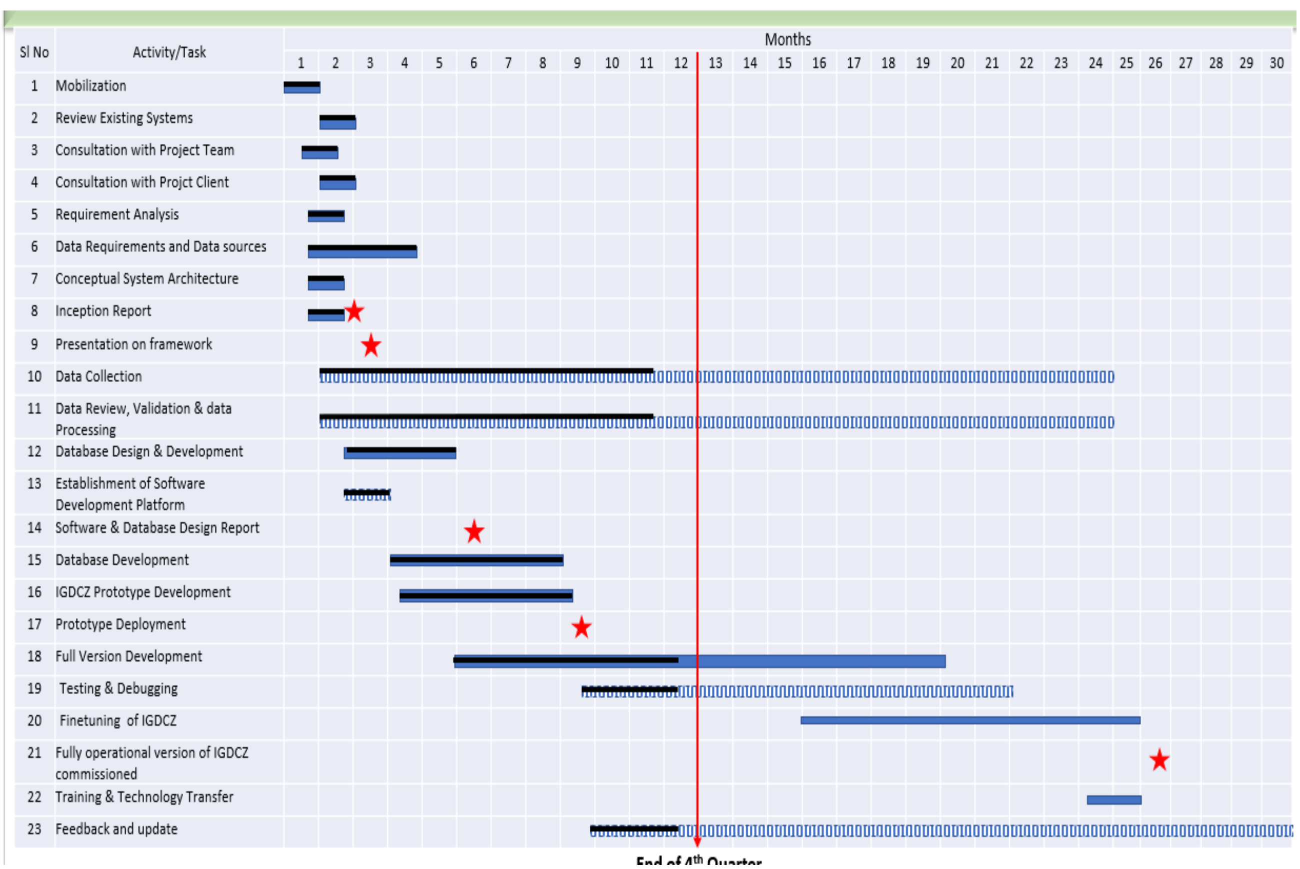
The development tasks of Web GIS based IGDCZ Application will be continued in the next quarter.

3.7 Sample Web-GIS Interface of IGDCZ Application

Screenshot from online Web-GIS Application: http://geo.iwmbd.com:3010/igdcz/



3.8 Workplan



4 MODELLING LONG TERM PROCESSESS

4.1 Introduction

A very large proportion of the work carried out by the consultant on this project comprises the development and application of many types of mathematical models for predicting the long-term processes (evolution) of the conditions in the Bengal Delta. The evolution of the Bengal Delta under the disturbances imposed upon it by natural processes and by human interventions occur at many different length and time scales.

There are many different types of models, using a variety of formulations and many versions of standard software being used in this study. Table 4.1 lists the Models that are under development by the project team.

Table 4-1: Models currently under development

	Modelling Activity	Sub description	Scale
A	GBM Basin Model	Hydrotrend	Macro
B	Macro scale River Model	Delft3D Main River system (2D)	Macro
C	Macro scale River Model	Delft3D Main River system (1D)	Macro
D	Pussur Sibsa	Delft3D: Modelling of long term Morphology	Meso
E	Baleswar-Bishkhali Model	Delft3D: Modelling of long term Morphology	Meso
F	Lower Meghna	Delft3D: Modelling of long term Morphology	Meso
G	Sangu	Delft3D: Modelling of long term Morphology	Meso
H	Pussur Sibsa	MIKE 21C: Modelling of bank erosion process	Meso
I	Baleswar	MIKE 21C: Modelling of bank erosion process	Meso
J	Bishkali	MIKE 21C: Modelling of bank erosion process	Meso
K	Lower Meghna	MIKE 21FM: Modelling of bank erosion process	Meso
L	Sangu	MIKE 21C: Modelling of bank erosion process	Meso
M	Pussur-Sibsa fine sediment model- ext	Delft3D Fine Sediment (2D/3D)	Meso
N	Pilot TRM Model for Polder 24	MIKE 11, MIKE 21 AND MIKE FLOOD	Micro
O	Storm Surge Model	Generating Synthetic Storm Events	Bay of Bengal
P	Storm Surge Model	MIKE 21FM & CYCLONE MODEL	Bay of Bengal
Q	Salinity Model	Delft3D Salinity (2D/3D)	Total Coast

All the models are not at equally advanced stages of development.

4.2 Climate Change Scenarios

4.2.1 Regional sea level rise projections

IPCC 5th Assessment Report (CMIP 5 results)

The IPCC AR5 published regional sea level projections computed from the CMIP5 model output (Chapter 13: “Supplementary material” (Church et al.,2013a)). Those regional estimates of sea level rise (Relative sea surface height) were retrieved form the Integrated Climate Data Center (ICDC) of the University of Hamburg, Germany. All these estimates do not include subsidence.

For the case of Bangladesh, the closest locations with available data near the coast were selected (see **Error! Reference source not found.** – 5 coastal locations) in order to obtain the regional sea level p rojections for future time horizons and their associated uncertainties (see Table 4.2 for detailed information about 5 closest locations, and **Error! Reference source not found.** and **Error! Reference source not fo und.** for the mean values of all 5 locations).

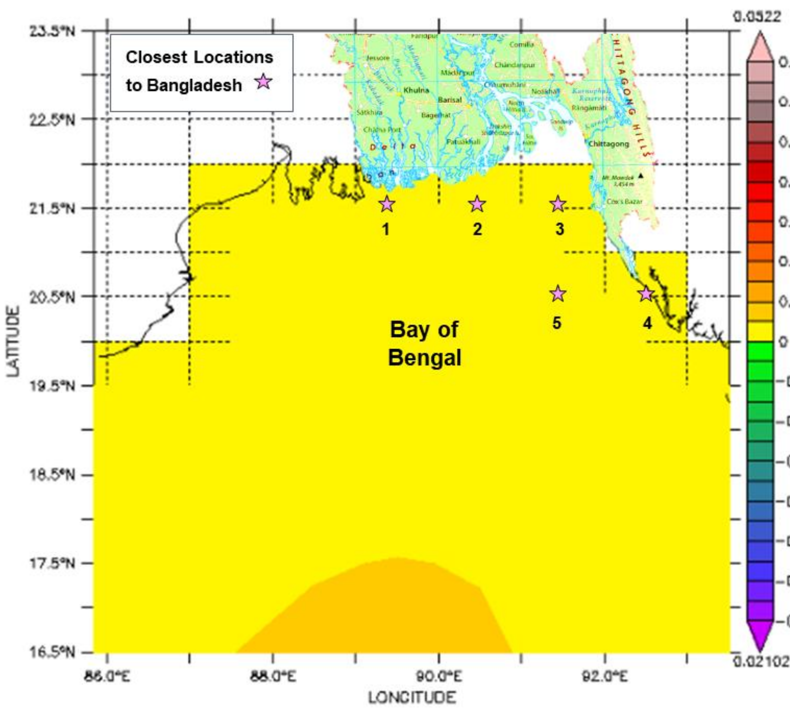


Figure 4-1: Example of SLR data viewer for the year 2007, RCP 4.5 Scenario. Stars within the Bay of Bengal represent the closest coordinates to Bangladesh with available SLR data. Source: Live access Server[1]- Integrated Climate Data Center, University of Hamburg, Germany.

Table 4.2. Total SLR time series for different locations in the Bay of Bengal (relative to 1986 – 2005 MSL) under different RCP scenarios. Red line and blue line represent the mean ensemble sea surface height of RCP scenario 4.5 and 8.5 respectively. Red and blue shaded area correspond to the confidence intervals (5% and 95% uncertainty) of each RCP scenario. Source: IPCC AR5 2013, (ICDC, icdc.cen.uni-hamburg.de)

[1] Integrated Climate Data Center – Live Access Server: http://icdc.cen.uni-hamburg.de/1/daten/ocean/ar5-slr.html

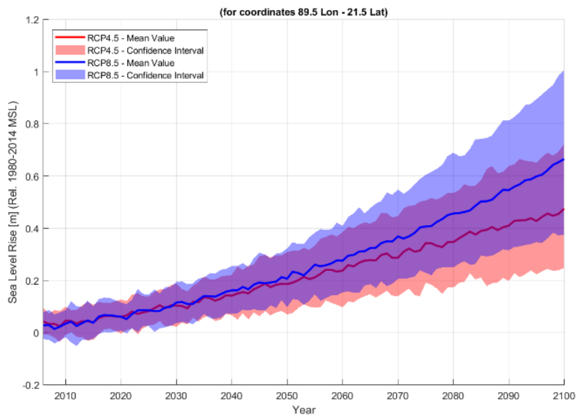


Figure 4-2: Total SLR time series for Location 1 (Bangladesh)

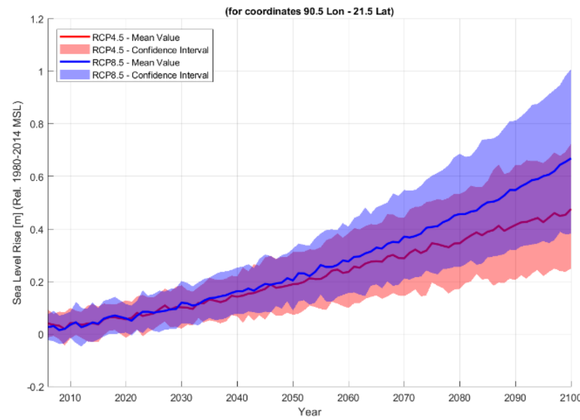


Figure 4-3: Total SLR time series for Location 2 (Bangladesh)

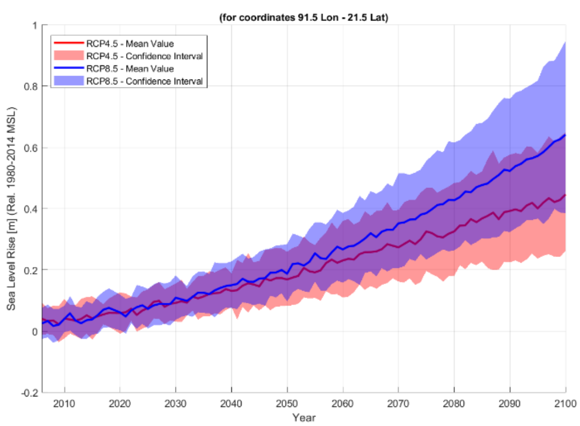


Figure 4-4: Total SLR time series for Location 3 (Bangladesh)

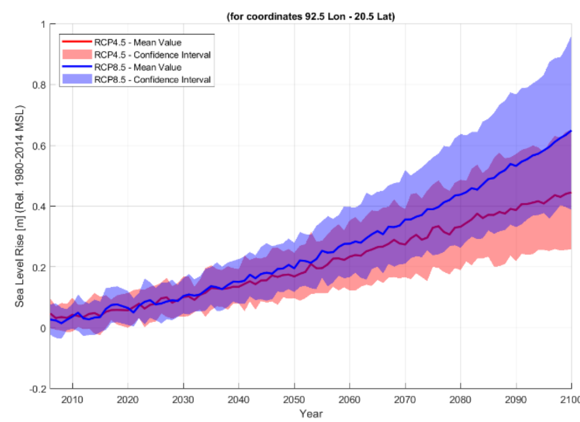


Figure 4-5: Total SLR time series for Location 4 (Bangladesh)

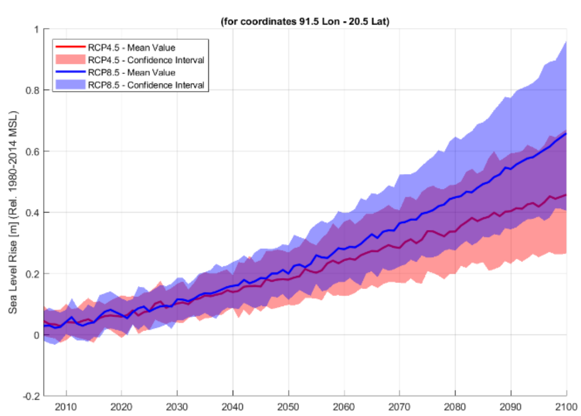


Figure 4-6: Total SLR time series for Location 5 (Bangladesh)

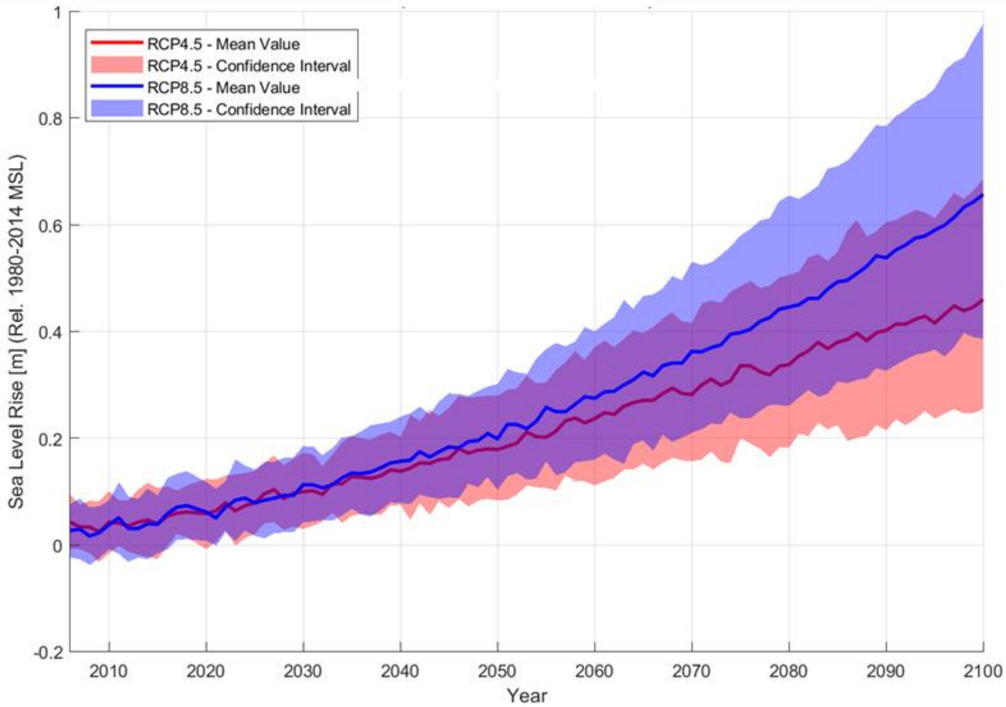


Figure 4-7: Total SLR (Mean of the five locations nearest to the Bangladesh coast) (relative to 1986 – 2005 MSL) under different RCP scenarios. Red line and blue line represent the mean ensemble sea surface height of RCP scenario 4.5 and 8.5 respectively. Red and blue shaded area correspond to the confidence intervals (5% and 95% uncertainty) of each RCP scenario. Source: IPCC AR5 2013, (ICDC, icdc.cen.uni-hamburg.de)

Table 4-3: Total regional SLR projections (Mean of the five locations nearest to the Bangladesh coast and relative to 1986 – 2005 MSL) for the 21st century and associated uncertainties (5 and 95%) under different RCP scenarios. Source: IPCC AR5 2013, (ICDC, icdc.cen.uni-hamburg.de)

Time Horizon	Total Sea Level Rise by Scenario [m] (Rel. to 1986 to 2005) (Value in brackets represent the range 5-95% uncertainties and bold number represents the mean)	
	RCP 4.5	**RCP 8.5**
2010	**0.025** [-0.031 to 0.082]	**0.023** [-0.025 to 0.072]
2020	**0.059** [-0.007 to 0.125]	**0.062** [0.008 to 0.118]
2030	**0.100** [0.030 to 0.173]	**0.113** [0.042 to 0.186]
2040	**0.138** [0.076 to 0.203]	**0.157** [0.079 to 0.240]
2050	**0.179** [0.084 to 0.279]	**0.199** [0.104 to 0.301]
2060	**0.237** [0.111 to 0.370]	**0.275** [0.161 to 0.400]
2070	**0.282** [0.157 to 0.416]	**0.363** [0.211 to 0.531]
2080	**0.338** [0.183 to 0.506]	**0.446** [0.261 to 0.655]
2090	**0.402** [0.216 to 0.605]	**0.538** [0.327 to 0.785]
2100	**0.460** [0.256 to 0.684]	**0.657** [0.387 to 0.977]

The regional projections presented above do not account for local subsidence and therefore, an adjustment is needed to account for vertical land motion (VLM).

4.3 Macro Scale Models: GBM Basin wide Applications

Table 4-4: Macro Scale Modelling

D-4A-1		**Modelling of the long-term physical processes; Morphology on a macro scale**
	1a	Basin scale modelling (HydroTrend) Products: HydroTrend model, report, data upstream boundary conditions
	1b	MIKE Basin Model of GBM Basin Products: Upstream Boundary Conditions for multiple Scenarios
	1c	Macro scale river modelling (Reinier, Wang) Products: Delft3D-FM 1D model, report, data water/sediment budget
	1d	Macro scale coastal modelling (Dano) Products: Delft3D-FM 2D model, report, data long-term erosion/sedimentation
	2	**Geospatial datasets of main sources and deposits of sediment at present (reference modelling results), including full meta-data restored and archived in Database of BWDB**
	3	**Geospatial datasets of main sources and deposits of sediment for 100 years from present (scenario modelling results), including full meta-data are published on archived in Database of BWDB**
	4	**Technical Report (one report for 4A-1 and 4A-2)** [2)+C44]

4.3.1 The Hydrotrend model

The Hydrotrend model is a model applied to the entire GBM Basin. (see Figure 4.8). This is the key that controls all the inputs to the GBM Delta.

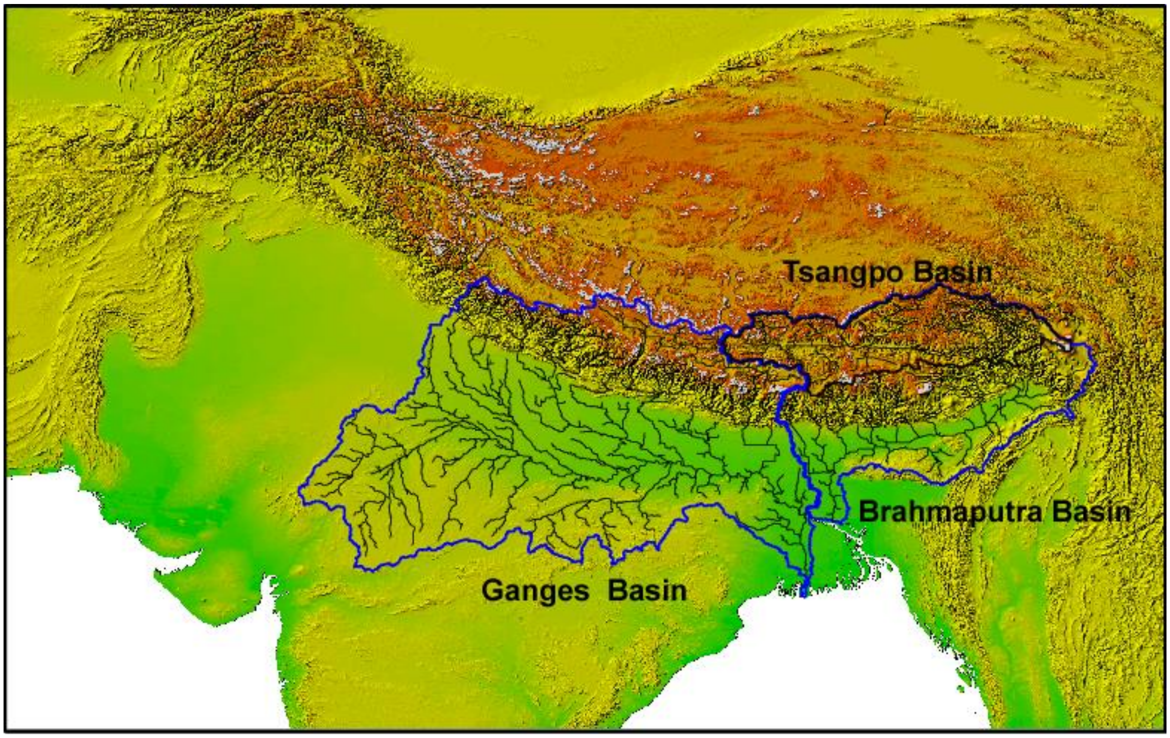


Figure 4-8: Map showing the Ganges and Brahmaputra basins

A list of input data types such as terrain (eg DEM), land use, precipitation, erosion properties etc.

The main input file (HYDRO.IN) which contains: project title, input–output directory, simulation length, yearly and monthly climate statistics (such as precipitation observed in the basin, average temperature at downstream of the basin, lapse rate etc.), glacier parameters, groundwater parameters and parameters that describe the possible river distributaries;

Hypsometric Input file (HYDRO0.HYPS) which is analysis of the Digital Elevation Model (DEM) of the basin;

Another optional input file (HYDRO.CLIMATE) can be used which contains sequential climate input instead of the statistical realizations of the climate otherwise defined in HYDRO.IN. The sequential climate input minimum–maximum time step ranges from 1-hour to 1-day.

Scenarios we plan to use in the model

- Future with climate change;
- Future with implementation of Indian River Linking Project (IRLP);
- Future with both climate change and implementation of IRLP

Model outputs (eg water and sediment at Hardinge, Bahadurabad etc)

- The outfall of the model domain is at Farakka (not Hardinge bridge) in the Ganges and Bahadurabad in the Brahmaputra River. The model will provide the following outputs for base and future scenarios:
- Water discharge, discharge velocity, width and depth at the river mouth;
- Bed load and the suspended sediment concentrations for each grain size.

4.3.2 Macro Scale Models: Large Rivers System

The macro-scale models will be developed for the major river systems of Bangladesh. These models are divided into two modelling approaches:

1) River branch modelling approach (1D)

- To derive a sediment budget for the Bangladesh Ganges-Brahmaputra-Meghna (GBM) delta
- To assess the effects of changing boundary conditions (climate change, upstream damming) on the sediment budget
- To derive boundary conditions for smaller scale (i.e. meso scale) sub-models

2) Coastal modelling approach (2D)

- Large-scale tidal propagation and flow distribution
- To study coastal hydrodynamics and sediment transport pathways
- Sand and fine sediment distribution
- Pathways for fine sediment
- Morphology of major channels on decadal scales
- To forecast long-term morphological changes for different scenarios
- To derive boundary conditions for meso-scale models

Both the River branch (1D) modelling and Coastal modelling (2D) will be developed using Delft3DFM modelling system.

1) **1D Ganges-Brahmaputra-Meghna macro scale model**

<u>Model Setup</u>

Schematization of the major river branches in a network for the Delft3D-FM 1D model is shown in Figure 4-9.

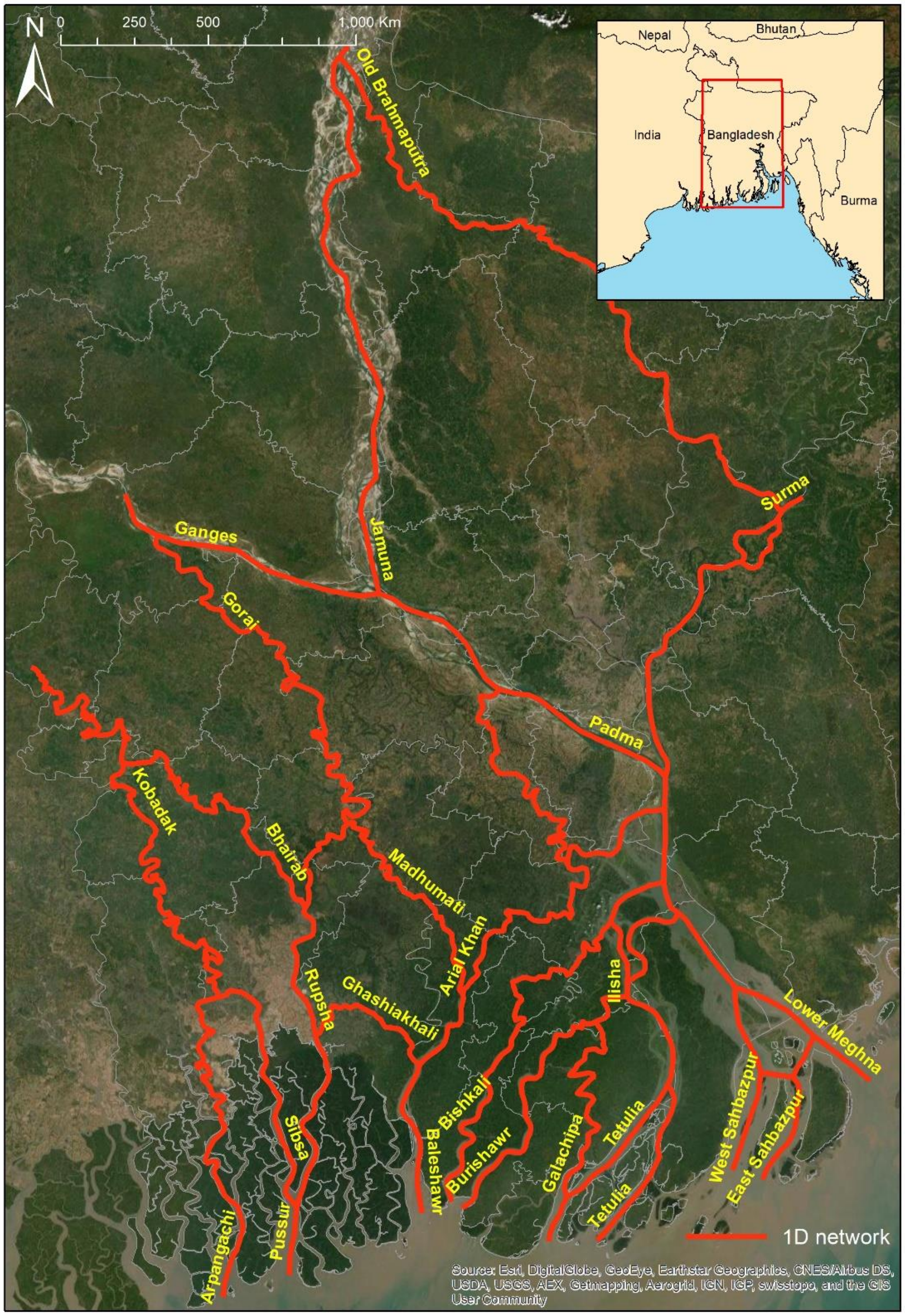
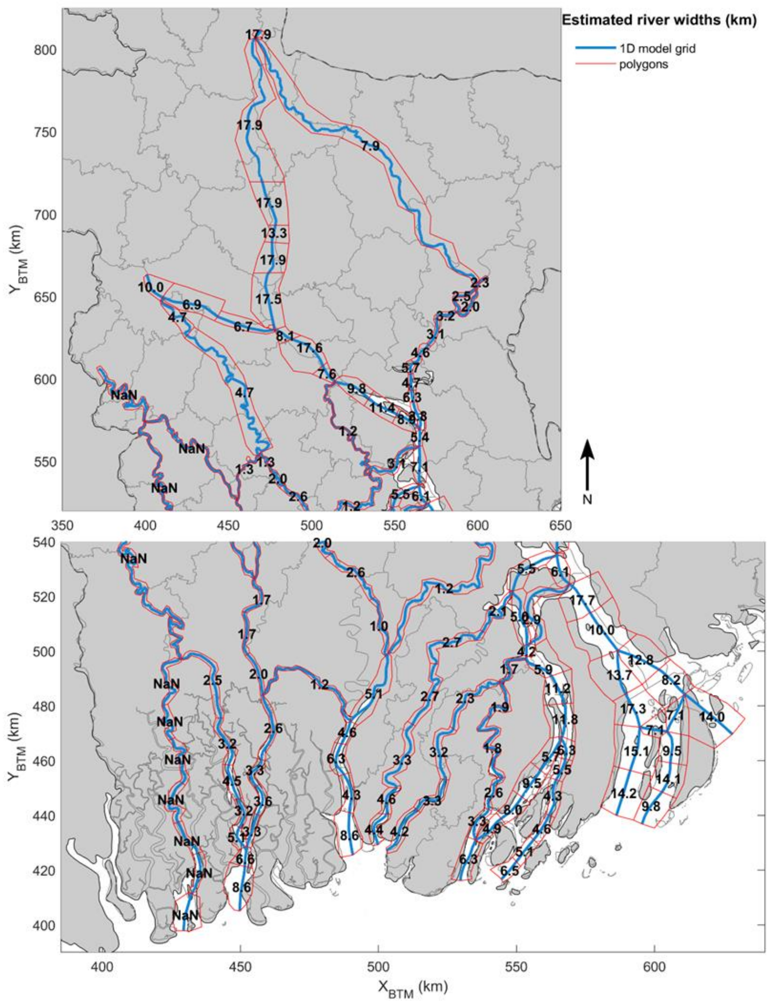
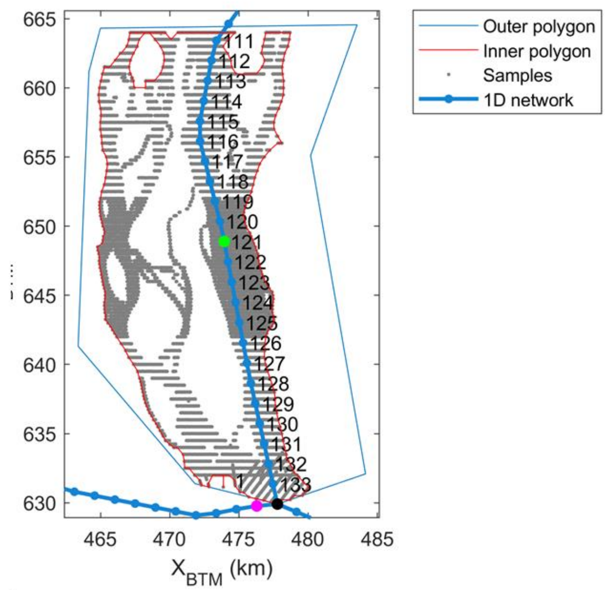


Figure 4-9: Schematization of the major river branches in a network for the Delft3D-FM 1D model.

Schematizing profiles from observations (hybrid approach)





Example of methodology to derive an area and river length based on a tightly data-fitting polygon (red), which is found by the definition of manually defined outer polygons (blue)/

Figure 4-10: Map of the GBM delta with the model network (blue), the topo-bathymetric observations (gray dots), the estimated river widths (black numbers), and the polygons (red) defining subareas of the river branches for schematization of the cross-sectional profiles.

Boundary conditions

Upstream

The upstream open model boundaries are situated at the three major rivers (from west to east) Ganges, Brahmaputra, and Surma (Figure 4-9). Due to the availability of long-term discharge and suspended sediment concentrations (SSC) observations at Hardinge Bridge (Ganges), Bahadurabad (Brahmaputra), and Bhairab Bazar (Surma) the open boundaries are situated exactly at these locations (and not at Bangladesh' national border). At the upstream boundaries the model is forced by measured time series of discharge and suspended sediment concentrations (Figure 4-11).

Downstream

The downstream boundary conditions are imposed at the seaward boundaries of the estuaries (Figure 4-9). The boundary conditions consist of astronomical tidal constituents, prescribing the amplitude and phase of the tidally induced water level fluctuations. The constituents are derived from the MIKE21 Bay of Bengal model (Figure 4-12) and include all tidal constituents identified by the model.

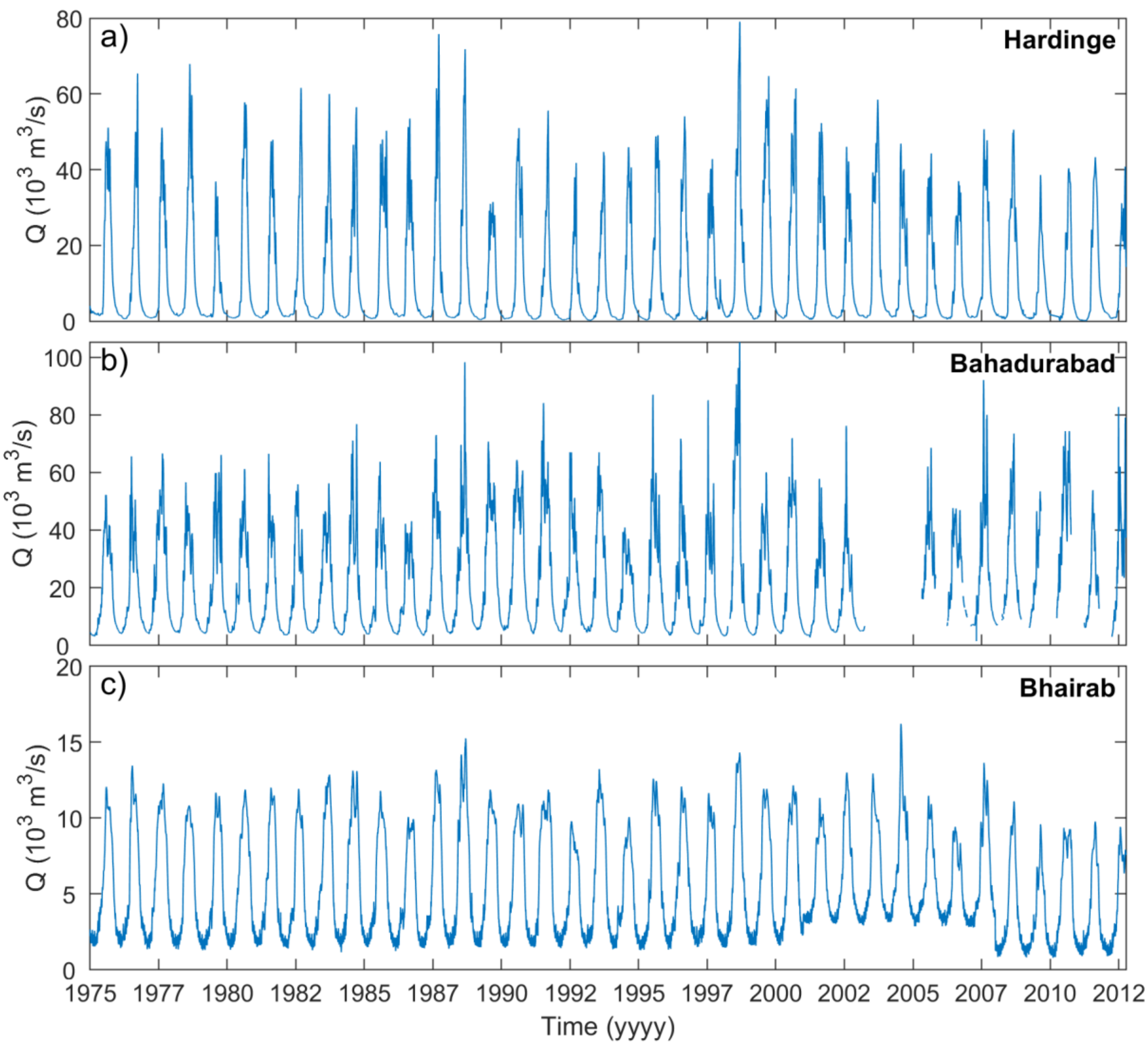


Figure 4-11: Timeseries of discharge from 1975 up till 2012 at the three locations used to force the model at the upstream boundaries.

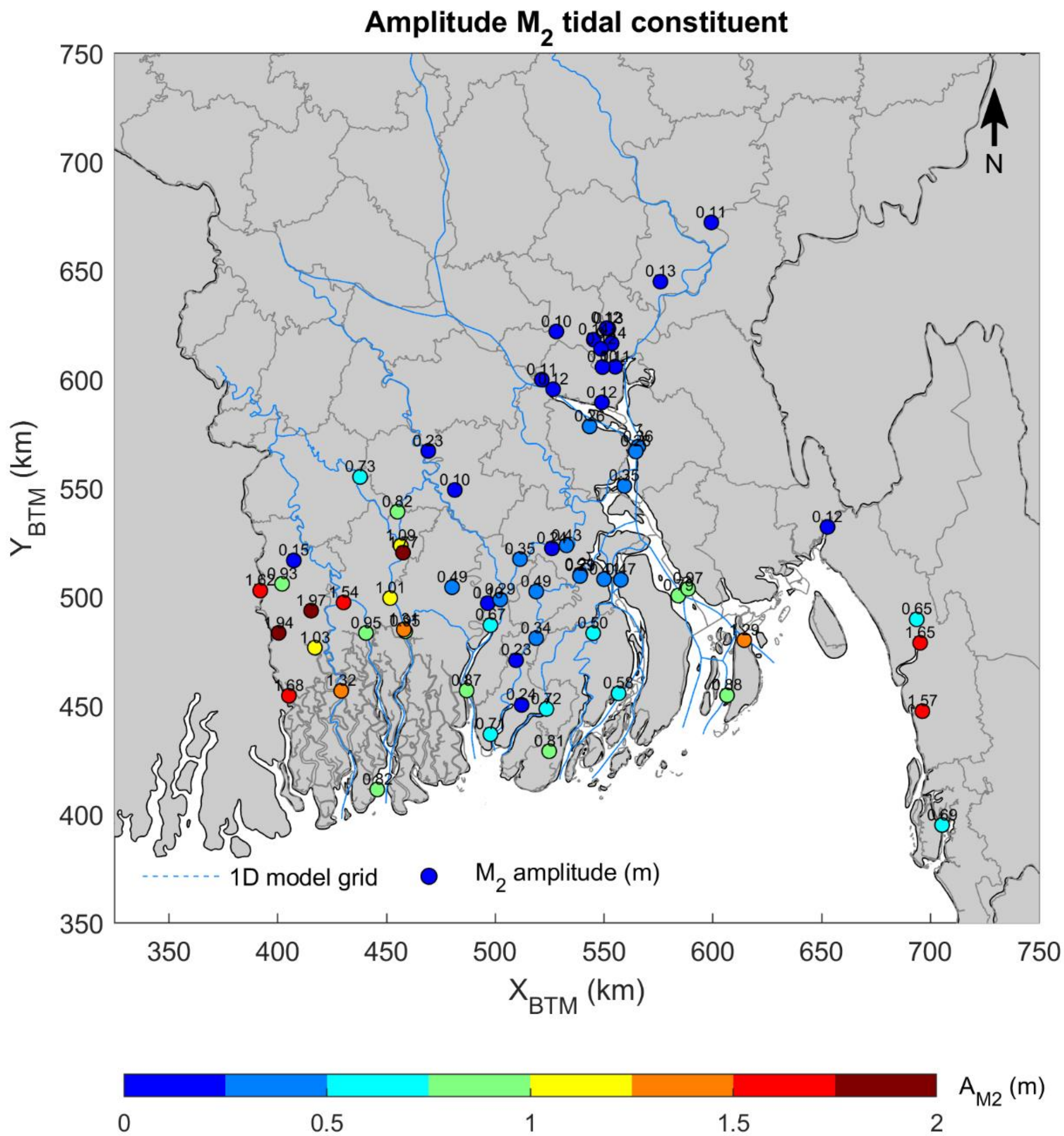


Figure 4-12: Amplitude of the M_2 tidal component based on water level observations.

2) Coastal modelling approach (2D)

The 2D coastal model domain will cover the whole coastal area including the river and land area. The resolution varies from 8km to 500m. Figure 4-13 shows the model domain.

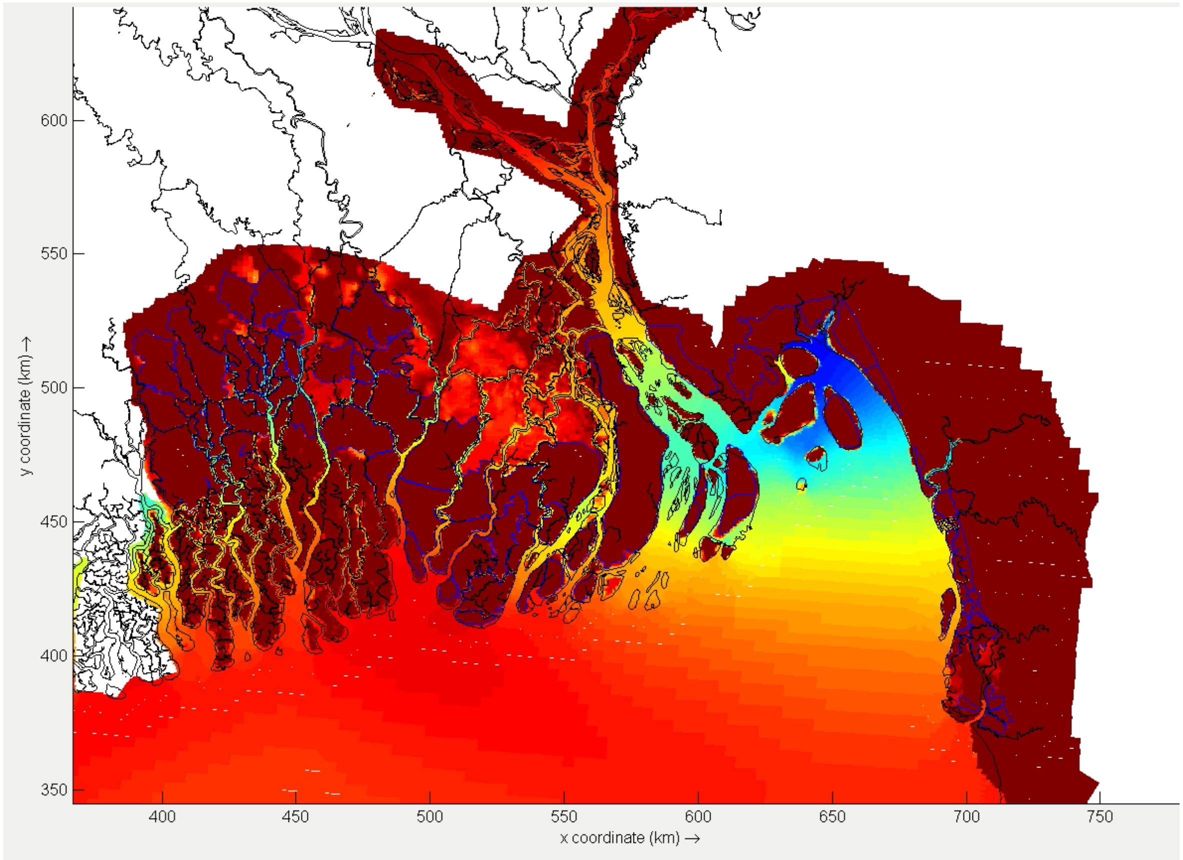


Figure 4-13: Two-dimensional coastal model domain for the coastal area of Bangladesh

4.4 Meso Scale Models for Long Term Morphology

Table 4-5: Meso Scale Modelling for Long Term Morphology

D-4A-2		**Modelling of the long-term physical processes; Morphology on a meso scale**
	1a	Pussur-Sibsa (Delft3D-FM & Delft3D 4)
	1b	Baleshwar (Delft3D-FM)
	1c	Lower Meghna (Delft3D-FM)
	1d	Chittagong (Delft3D-FM)
	2	Geospatial datasets of erosion and sedimentation in the coastal zone stored and archived in Data base
	3	Geospatial datasets of erosion and sedimentation in the coastal zone for possible scenarios 25, 50 and 100 years from now stored and archived in Data base
	4	Technical Report (one report for 4A-1 and 4A-2)

4.4.1 Pussur-Sibsa River system for meso scale modelling for long term morphology

The Delft3D FM sediment transport model calculates transport rates on a flexible mesh (unstructured grid) covering the area of interest on the basis of the hydrodynamic data obtained from a simulation with the Hydrodynamic Module (HD) together with information about the characteristics of the bed material. That is why a well calibrated and validated hydrodynamic model is needed to develop a reliable sediment transport model. Hydrodynamic model calibration has already been done for 2011 both dry and monsoon season for the Pussur-Sibsa river system. The locations of the field data are shown in Figure 4.14.

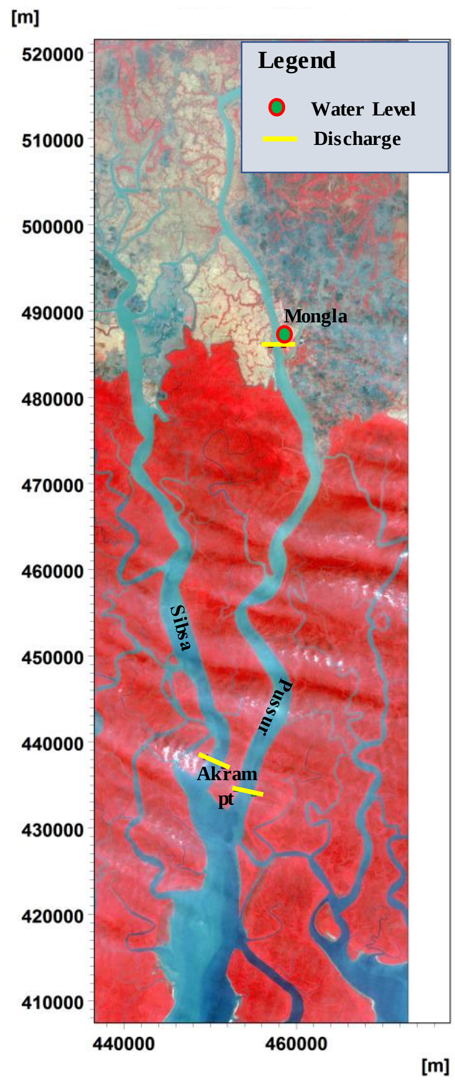


Figure 4-14: Field data collection map for 2011

Figure 4.15 and Figure 4.16 show the discharge calibration at Mongla Port in Pussur river and Akram Point in Sibsa river respectively during monsoon season. The computed discharge is well calibrated with measurement.

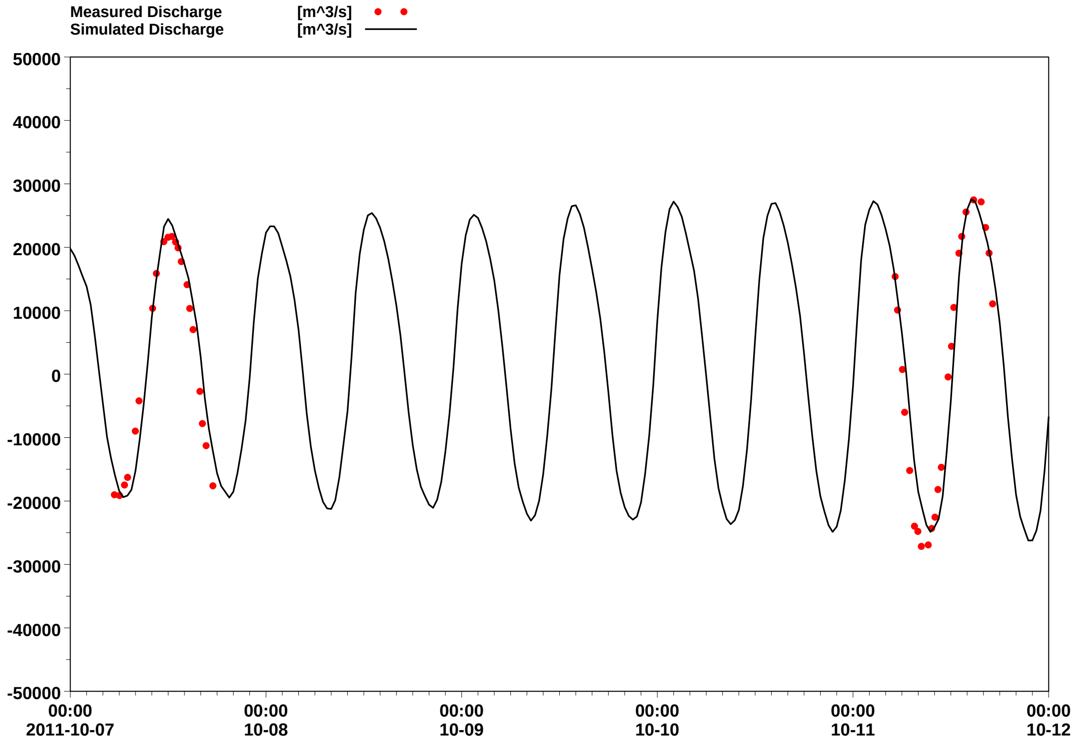


Figure 4-15: Discharge calibration at Akram Point in Pussur river during monsoon

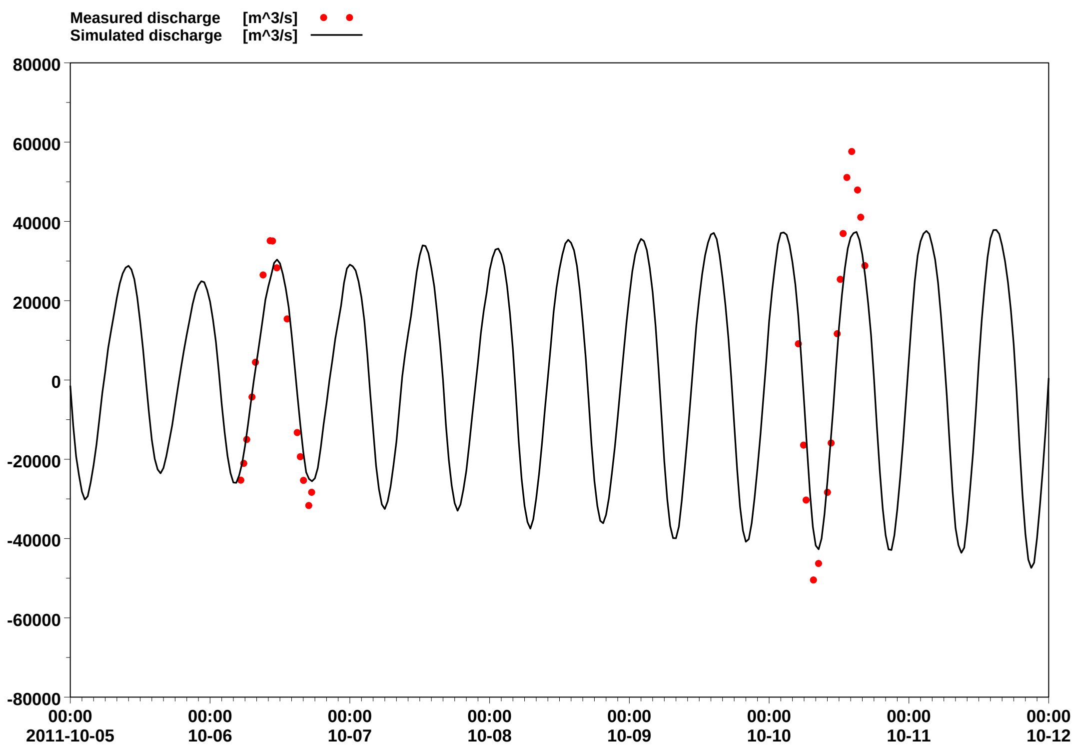


Figure 4-16: Discharge calibration at Akram Point in Sibsa river during monsoon

4.4.2 Baleswar River system for meso scale modelling for long term morphology

The long term meso scale model development has already started by Delft3D FM modelling system. The Baleswar-Bishkhali river system is modelled in one numerical grid, combining both river systems in a single model. The recent 2019 bathymetry data for the main river channel was interpolated on the unstructured curvilinear grid system. Figure 4.17 shows the grid and bathymetry of the Baleswar-Bishkhali river system for 2019.

The new model incorporates Bishkhali River with Baleswar river system. Bathymetry has been updated with 2019 surveyed data. The grid size varies between 1600m to 100m. The Baleswar-Bishkhali river system model has two upstream boundary, three downstream boundary and several source points representing side channels. Upstream boundary and sources were collected from calibrated and validated South West Regional Model for year 2015. The three southern boundaries have been generated from the Bay of Bengal Model for the year 2015.

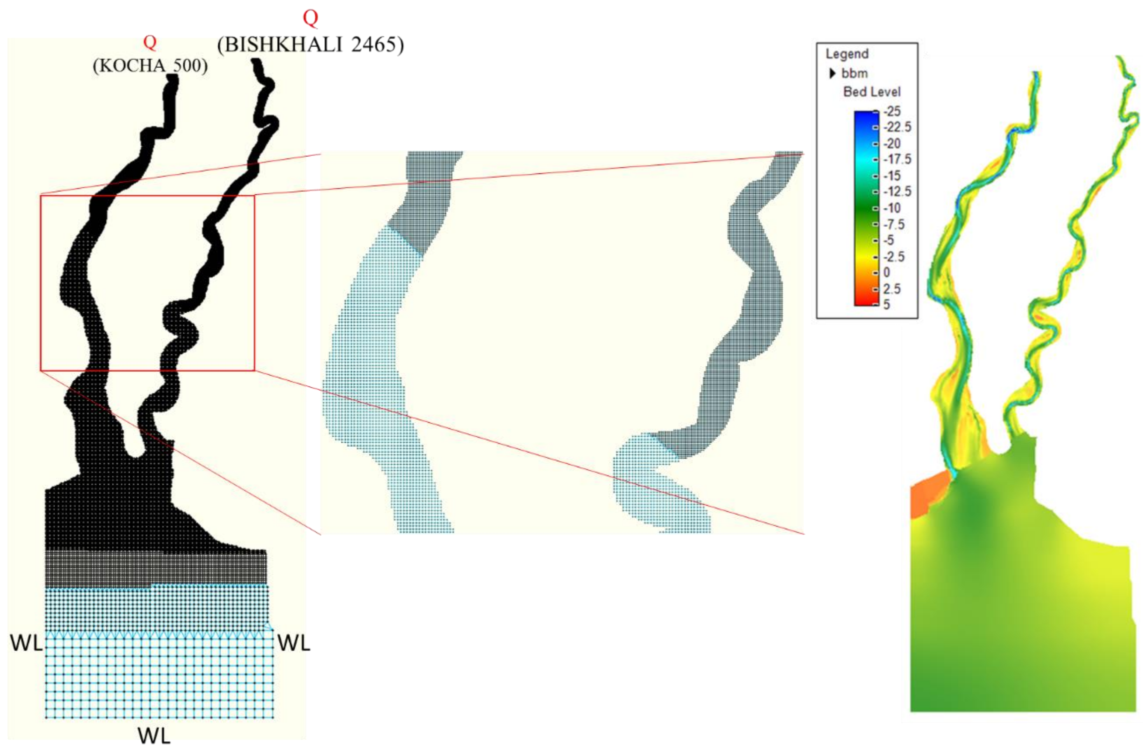


Figure 4-17: Computational mesh/grid (left panel) for Baleswar-Bishkhali river system and interpolated bathymetry (right panel) for 2019.

Hydrodynamic model will be calibrated and validated with measure data of year 2011 and 2015. Water Level calibration shows good correlation with measured and simulated water level data. The calibration plot for the year 2015 has been shown in Figure 4.18. Further improvement of hydrodynamic model calibration and validation are in progress.

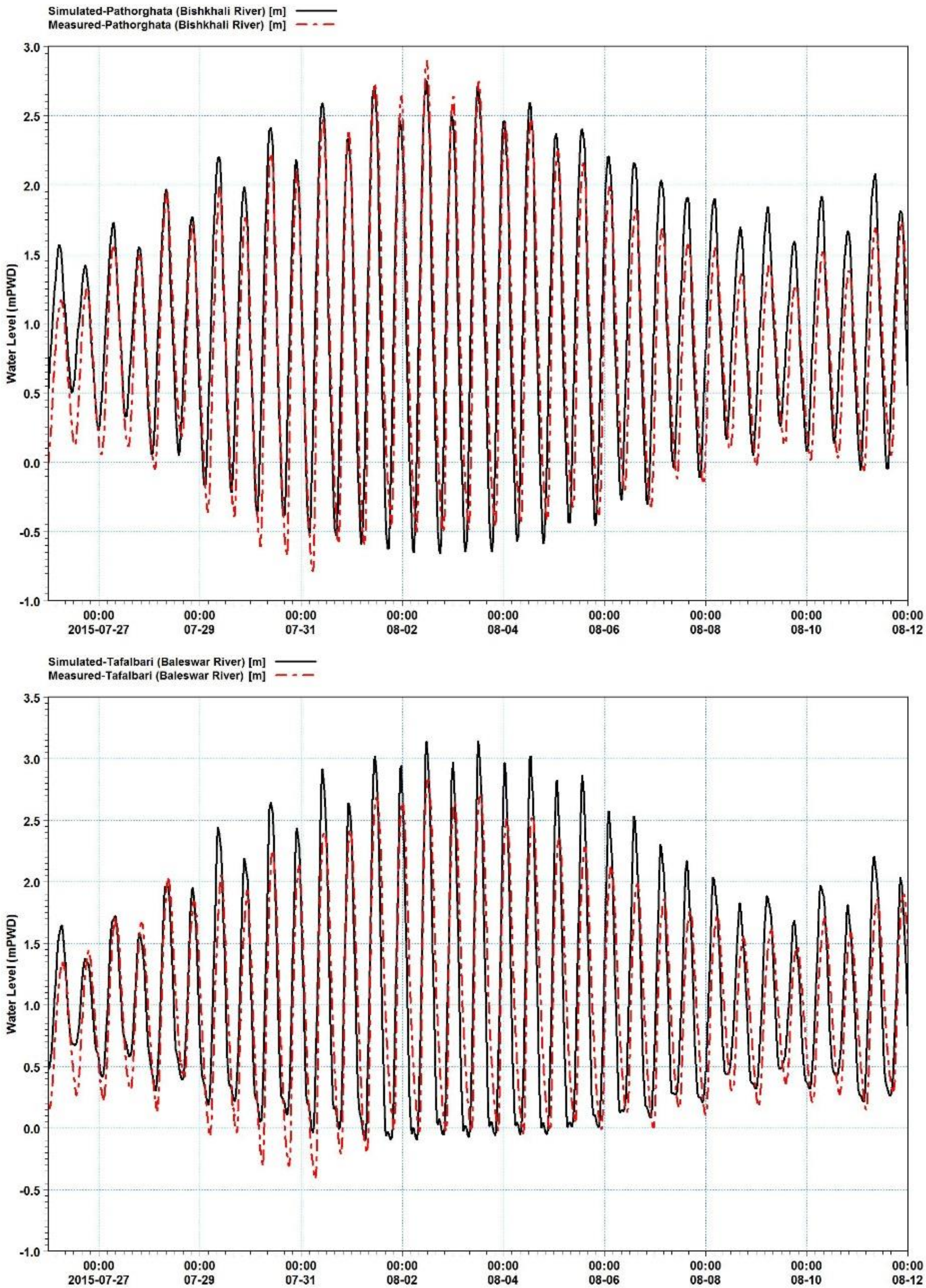


Figure 4-18: Water Level Calibration at Pathorghata (upper panel) and Tafalbari (bottom panel) for 2015

4.4.3 Lower Meghna-Tentulia River system for meso scale modelling for long term morphology

The long term meso scale model development for Lower Meghna-Tentulia river has already started by Delft3D FM modelling system. The available 2009 bathymetry data for the main river channel was interpolated on the unstructured curvilinear grid system. The grid size varies between 1600m to 200m. Figure 4.19 shows the grid and bathymetry of the Lower Meghna-Tentulia river system for 2009. The bathymetry of the model will be further updated with the 2019 survey data.

The Lower Meghna-Tentulia river system model has two upstream boundary and one downstream boundary. Three open boundaries are defined in the model, two in the north: one in the Padma River at Baruria and another one in the Upper Meghna River at Bhairab Bazar; and one in the south in the Norther Bay of Bengal (21º 30′ north latitude). The northern boundaries at Baruria in the Padam river and Bhairab Bazar in the Upper Meghna river have been defined by daily rated discharge time series for the year 2009. The southern boundary has been generated from the Bay of Bengal Model.

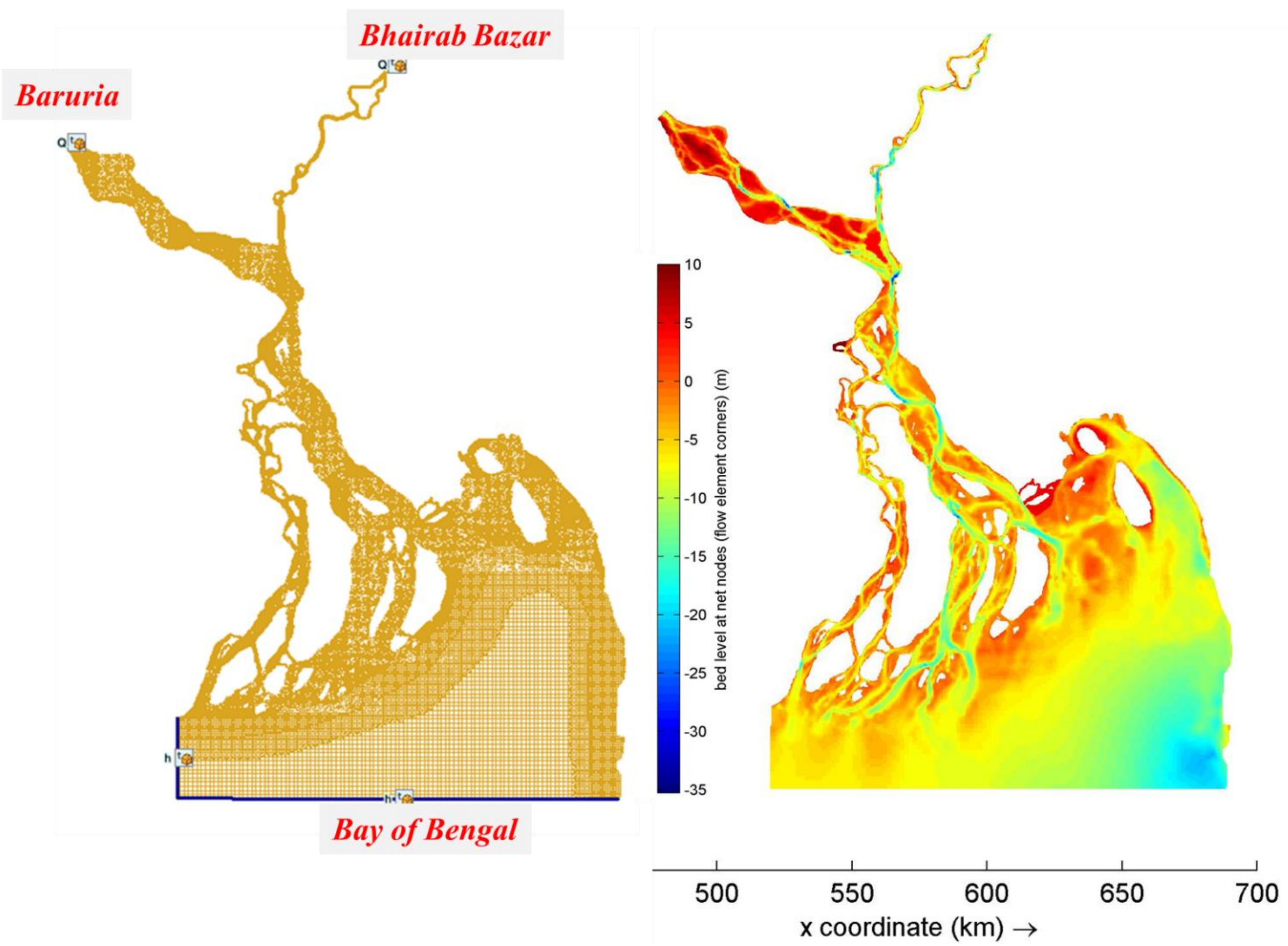


Figure 4-19: Computational mesh/grid (left panel) and interpolated (right panel) for 2009 in the Lower Meghna-Tentulia river system.

4.5 Meso Scale Models for Bank Erosion

Table 4-6: Meso Scale Modelling for Bank Erosion Prediction

		Modelling of Bank Erosion Processes; Morphology on a Meso scale
D-4A-3	1	Several models setup & developed to study bank erosion processes - to model recent occurrences and to hindcast erosion of a medium term time scale. Identify three or four key vulnerable sites A, B, C for detailed study
	2a	Site A: Tagetted field investigations, model schematisation & set up, simulations for hindcasting and forecasting & risk assessemt, testing preventive measures and other proactive interventions
	2b	Site B: Tagetted field investigations, model schematisation & set up, simulations for hindcasting and forecasting & risk assessemt, testing preventive measures and other proactive interventions
	2c	Site C: casting and forecasting & risk assessemt, testing preventive measures and other proactive interventions
	¨3	Report on Erosion Guidelines and Recommendations, early warning methodology & Erosion Management Strategy

4.5.1 Selection of Baleswar River for pilot bank erosion model study

The preliminary model has been developing by MIKE21C modelling system. The Baleswar model has one upstream boundary, one downstream boundary and several source points representing side channels. Upstream boundary and sources were collected from calibrated and validated South West Regional Model for 2011 and 2015. The water level of Haringhata was corelated from Hiron Point used as downstream boundary for the year 2011. Measured Water level data Fakirghat was used and downstream water level boundary for the year 2015.

The side channels are important to include in the hydrodynamic model, as the flow exchanges with these side channels are not insignificant. Without the side channels it becomes difficult to get the correct discharges in the Baleswar model.

With the side channels added, the MIKE 21C model becomes very similar to the MIKE 11 SWRM model, with the exception that the MIKE 21C model does not include floodplain. The MIKE 11 model appears to include some floodplain, but most of the floodplain around Baleswar is today polder, so one should not expect any floodplain influence, except in the downstream end (Sundarbans). This opens up for the possibility that the MIKE 21C model will not calibrate using the same parameters as MIKE 11. The Baleswar Model has been calibrated and validated for both 2011 and 2015, keeping in mind that the bathymetry is from 2011. The model bathymetry will be further updated with the 2019 survey data. The Calibration locations are shown in Figure 4.20.

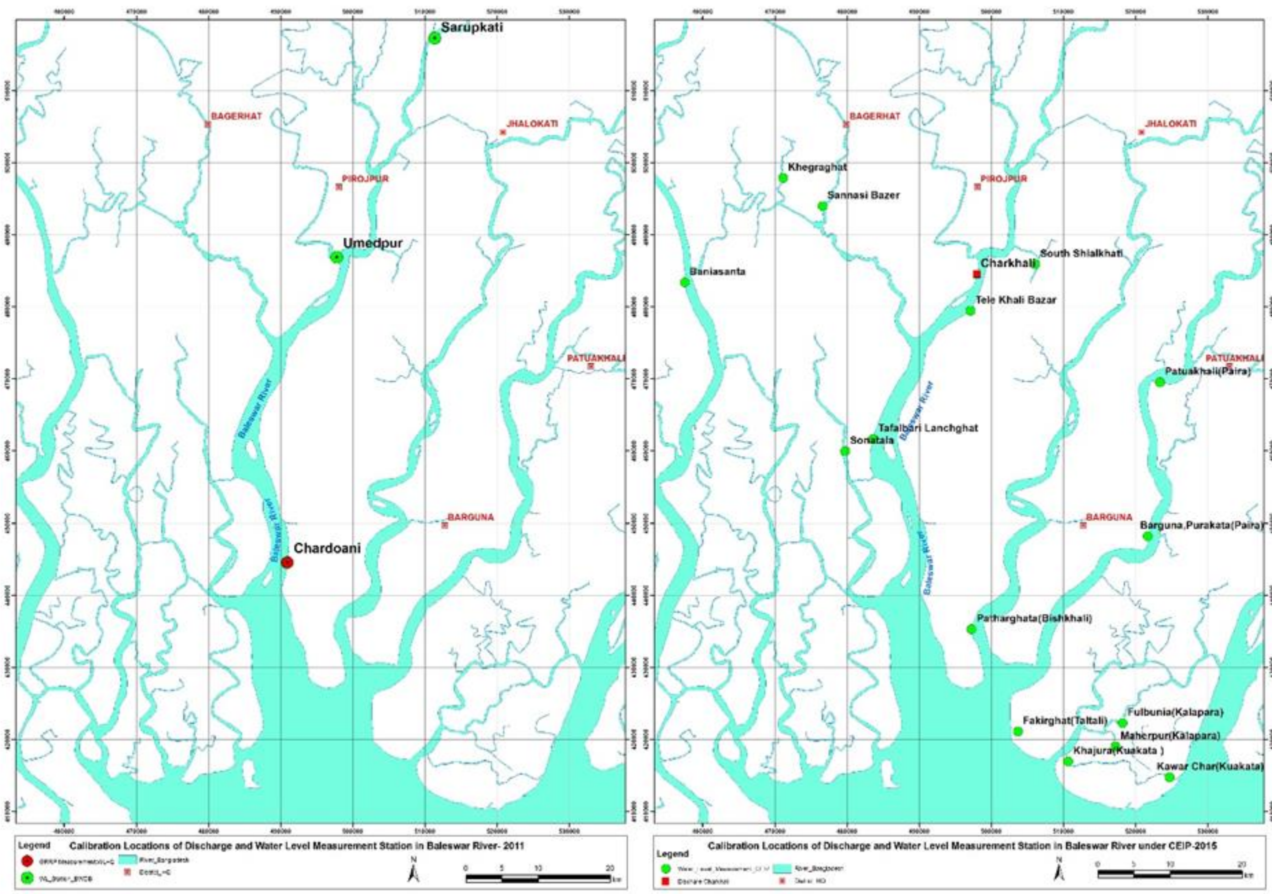
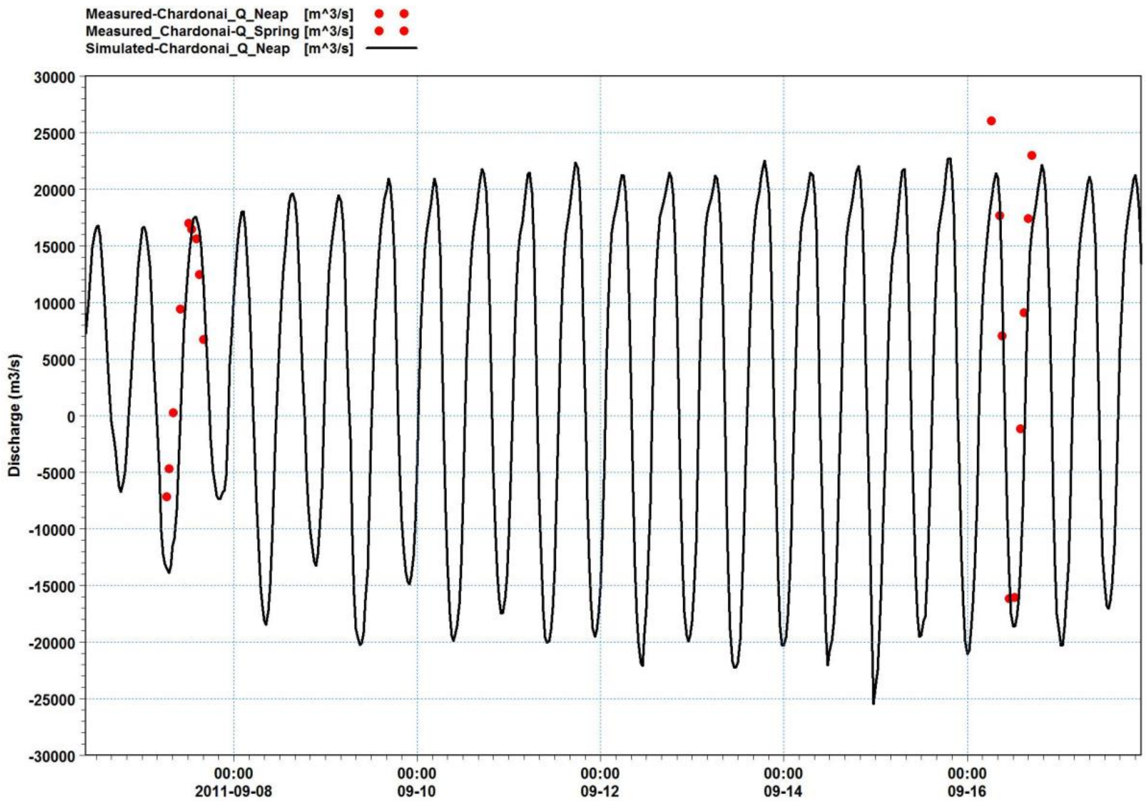


Figure 4-20: Discharge and Water Level Calibration Locations in Baleswar-Bishkhali river systems

The hydrodynamic model was duly calibrated for the year 2011 and 2015. The calibration plot for the year 2011 has been shown in Figure 4.21.



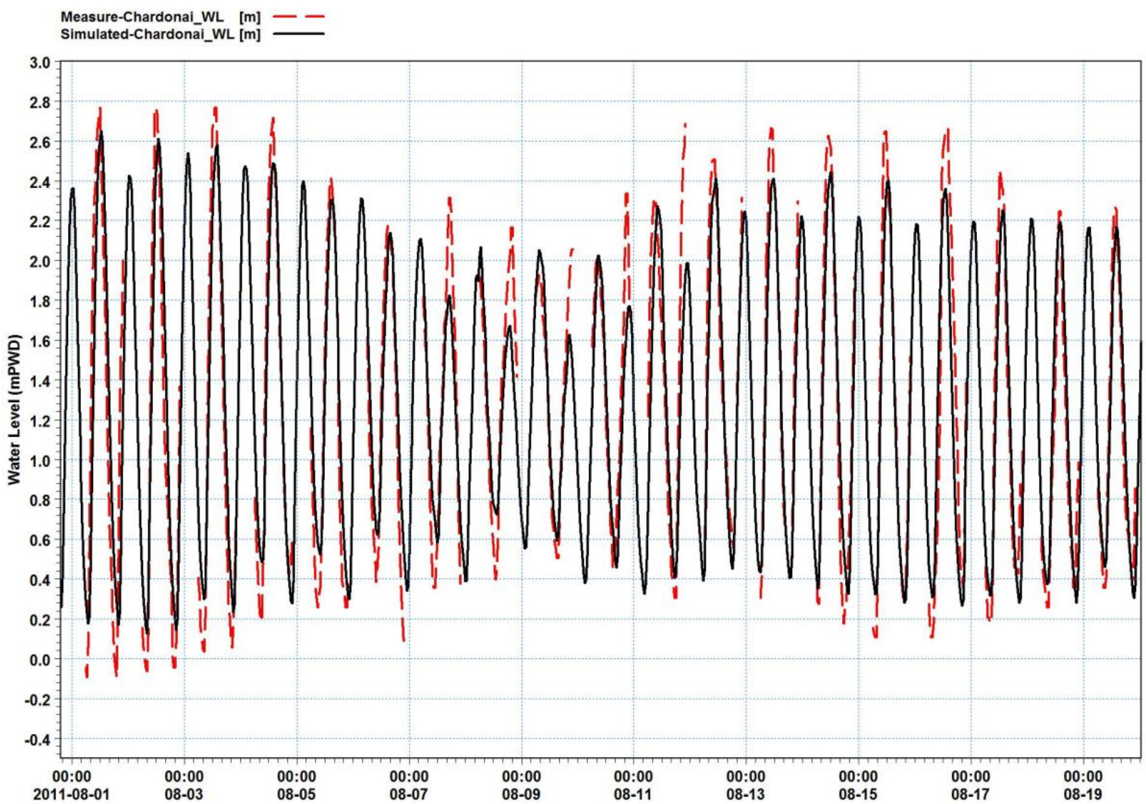


Figure 4-21: Discharge (top) and Water Level (bottom) Calibration at Chardoani for 2011

4.5.2 Pussur-Sibsa River system for bank erosion model study

The hydrodynamic model of Pussur-Sibsa river system were calibrated with field data during 2011 for both dry and monsoon season. The location of the field data is shown in Figure 4.14. Figure 4.22 shows the discharge comparison at Mongla Port in Pussur river during monsoon. The discharge calibration at Akram Point in Sibsa river during dry season is illustrated in Figure 4.23. The hydrodynamic model is well calibrated for both river system.

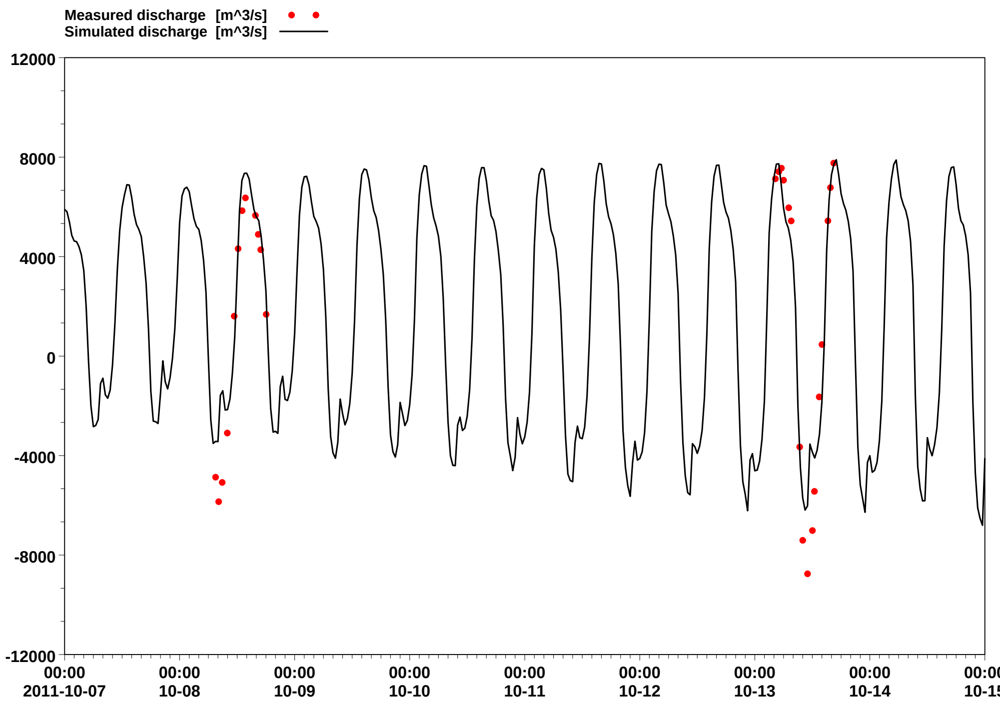


Figure 4-22: Discharge calibration at Mongla Port during monsoon

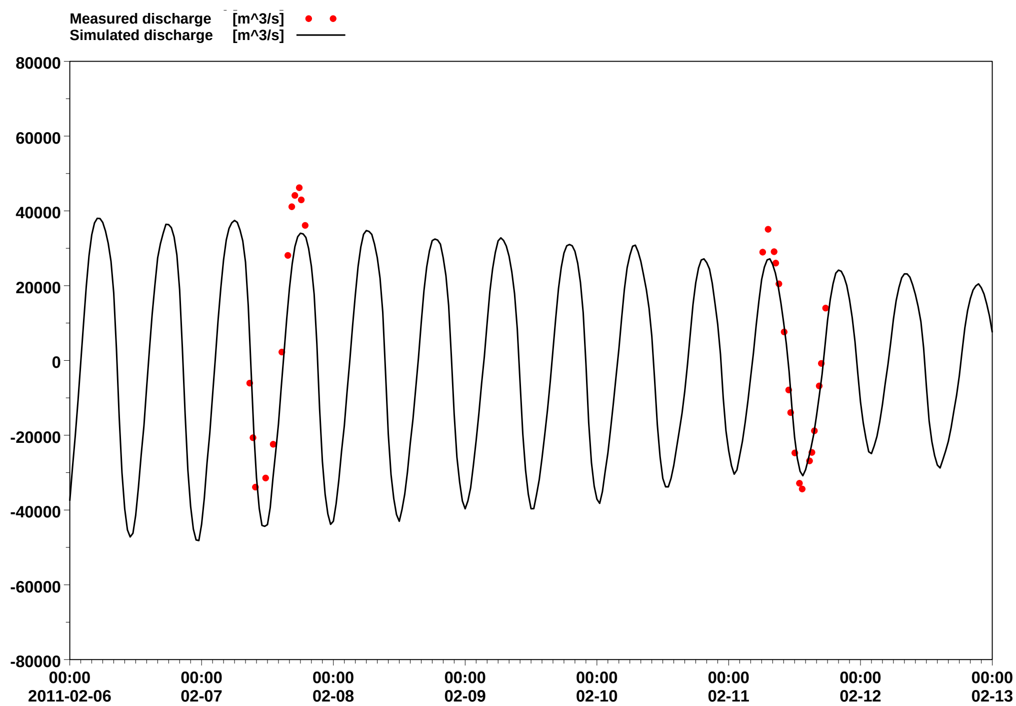


Figure 4-23: Discharge calibration at Akram point in Sibsa river during the dry season

4.6 Morphological Models for TRM (Micro Scale)

Table 4-7: Morphological Modelling on Micro-scale

D-4A-4		**Modelling of the long-term physical processes; Morphology on a micro scale**
		Identify a number of polders requiring especially detailed study (beyond the crest levels and standard drainage designs practiced in the most recent CEIP-1) to investigate operational and management alternatives for sustainably overcoming waterlogging and drainage congestion
		2) A report that describes the pros and cons of the different methodologies to prevent water-logging within the polder and sedimentation of tidal river system including polder subsidence. The report will include meta-data on the models used and measurements, recommendations for polder design including drainage and long term management plan, and recommendations for pilot area/polder to implement the ideas, such as but not limited to location, methods and measurements
		Recommend plans to manage sediment at the downstream stretch of the tidal river and in the polder

4.6.1 Pilot Tidal River Management (TRM) model for Polder 24

The TRM basin in Polder 24 (East Beel Khuksia) was brought into operation on 30th November 2006. Ahead of the opening of the TRM basin about 0.8 x 10^6 m^3 was dredged from the peripheral Hari River along a reach of approximately 8 km to amplify the tide. Before the opening of the TRM basin the tidal volume of the Hari River was about 0.9 x 10^6 m^3 but increased to 1.95 x 10^6 m^3 after two months of operation and 5.3 x 10^6 m^3 after 5.5 months. The major part of the tidal volume increase is caused by flushing of the peripheral rivers that at Rania was deepened by more than 2 meters. A minor part of the tidal volume increase is related to seasonal variations of the tide, which typical has the largest range in the months of March and April.

The significant impact of the TRM basin on the tidal volume and its ability to flush the peripheral rivers and prevent drainage congestion during a relatively fast makes it interesting to investigate using a numerical model. Furthermore, the numerical model has the advantage that different kind of management measures can be investigated and compared in order to develop optimal solutions.

The significant changes of the system before and after the introduction of the TRM basin makes it a challenge to construct the Pilot TRM model for Polder 24. The data basis and quality are of crucial importance for being able to construct the Pilot TRM model, since the applied data sets needs to refer to the same hydraulic conditions and provide enough information. Quite a lot of the efforts at this stage have therefore focused on establishing data, data review, understanding of the TRM history and establishing the data basis needed for a proper model construction.

For the baseline model construction, it is important to have a system considered to be in quasi-steady equilibrium, i.e. where the impact of dynamic flushing (erosion) of the peripheral rivers has stopped and thereby will not be affecting the hydrodynamics. Data for such conditions are partly available for the period August 2011 and April 2012 several years after the opening of the TRM basin and the flushing of the peripheral rivers.

As data basis for the Pilot TRM model construction, the following data has been established so far:

- DTM model 50 m grid covering all polders
- Topographic surveys of the TRM basin (2007, 2011 and 2013)
- Cross sections covering the peripheral rivers and part of the downstream river network connecting to the sea
- Water level observations from six gauging stations upstream, downstream and inside the TRM basin covering the period August 2011 to April 2012
- Discharge measurements at the downstream station Ranai during one tidal cycle in 9th September 2011 and 14th September 2011
- Bed sediment characteristics (presently from Badhra further downstream than Ranai)
- Suspended sediment samples at Ranai and at Beel Khuksa (inside the TRM basin) during different tide conditions in September 2011 and April 2012

To provide boundary conditions or support the creation hereof a MIKE 11 model covering a larger extent of the peripheral river network and the TRM basin has been established. The model has been cropped out of the Southwest regional model. It has been tested that the cropped MIKE 11 model behaves consistently with the Southwest regional model. Further improvement of the local MIKE 11 model is ongoing trying to include a more detailed description of the TRM basin and the Bhabodah regulator further upstream.

An initial MIKE 21 model bathymetry has been established, see Figure 4.24. Further work needs to be done on improving the model bathymetry in order to make it suitable for the hydrodynamic modelling. The bathymetry basis for the peripheral Teka-Hari river is given from measured cross sections, which is not he optimal scatter information for the 2D model interpolation of the bathymetry.

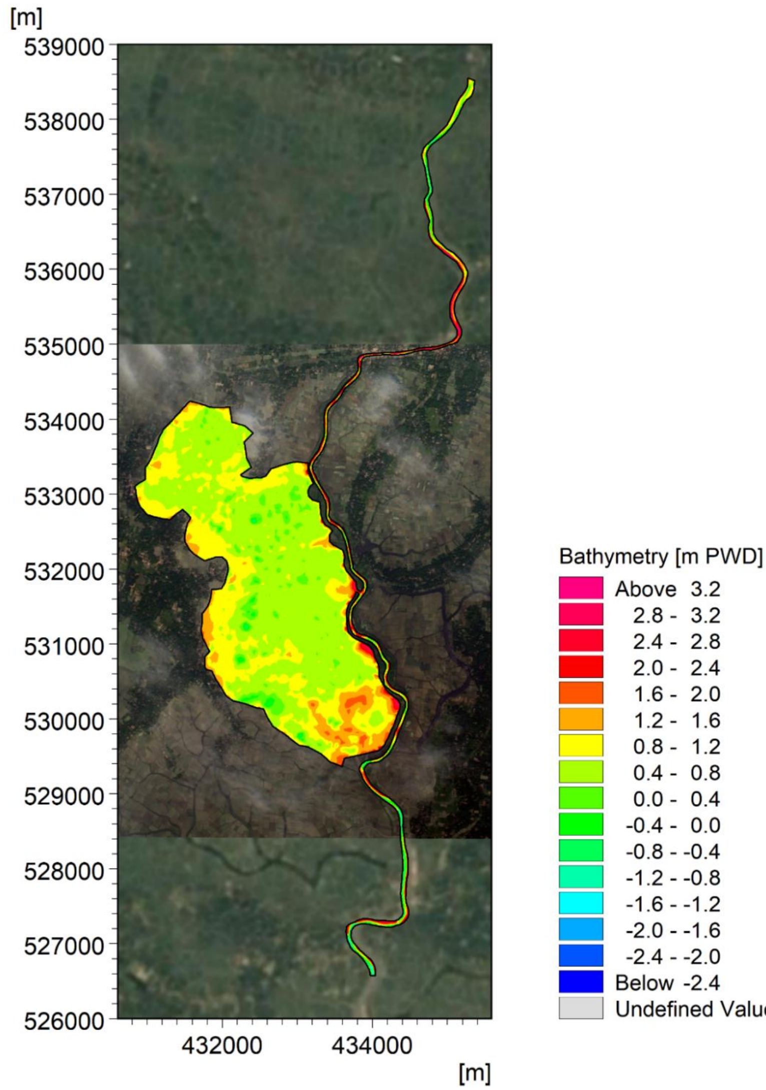


Figure 4-24: Initial model mesh and bathymetry

The build-in standard interpolation technique is not always able to resolve the thalweg properly and may generate artificial bars that creates a none-physical flow resistance and in some cases even block for the tidal flow. A technique to improve the bathymetry basis has been developed taking advantage of the MIKE 21 C curvilinear grid generator tool, which has an option that allows interpolation aligned with the streamwise direction of a curvilinear grid. This technique makes it possible to create additional cross sections and ensure a proper bathymetry interpolation. A comparison of the two methods are illustrated in Figure 4.25 and Figure 4.26. It is clearly seen that the streamwise interpolation or the creation of additional cross section data is required to get a proper channel bathymetry. The technique has so far only been applied for the most upstream part and using measured cross sections from 2015. The technique needs to be applied for the entire reach of the Teka-Hari river in order to develop a suitable bathymetry for the TRM model. Also, the channels routing the tidal flow inside the TRM needs to be resolved to ensure that the model can transport and carry the suspended sediment being brought into the TRM further inside. The present bathymetry does not include the opening/routing channels.

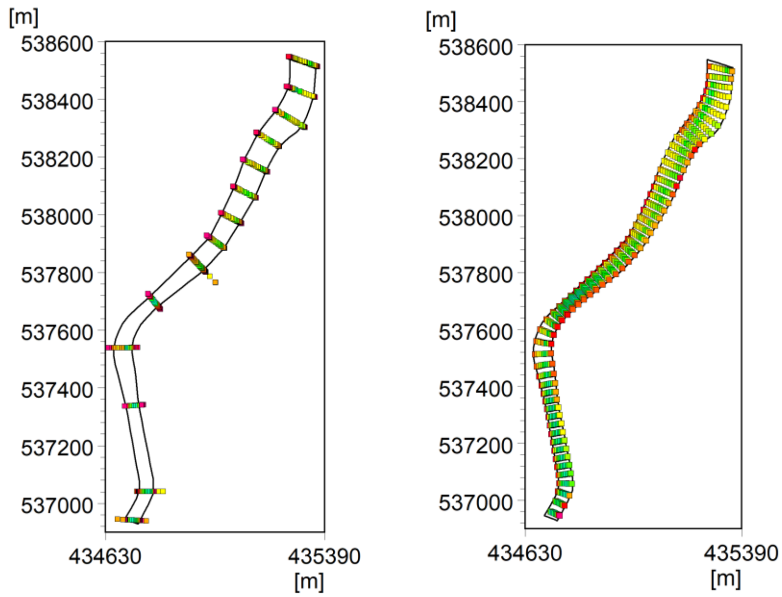


Figure 4-25: Left: The original 14 measured cross sections. Right: Cross section information obtained using streamwise interpolation resulting in a total of 59 cross sections

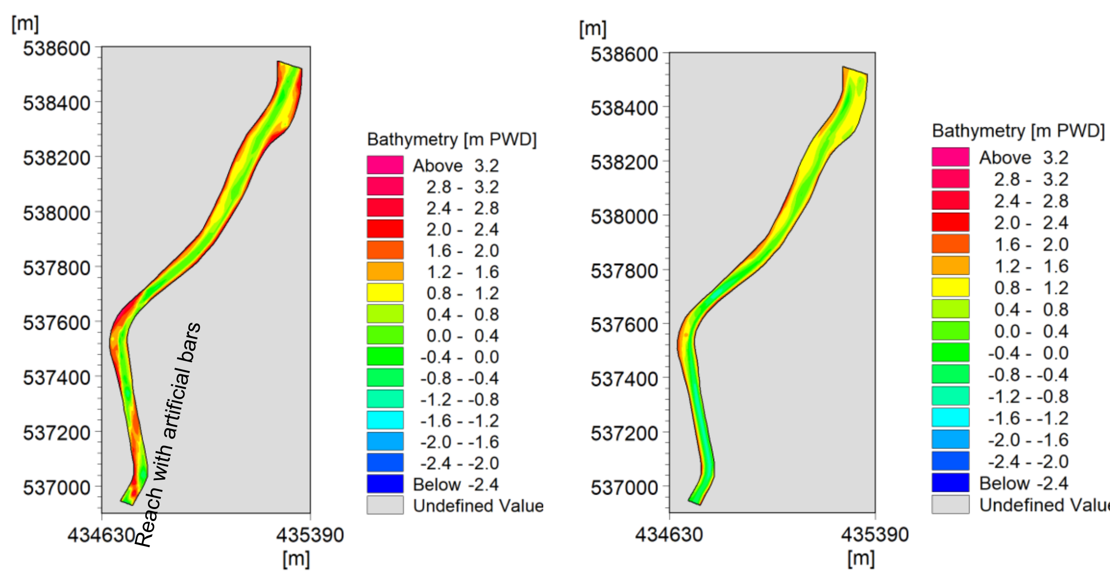


Figure 4-26: Left: Interpolated bathymetry based on the 14 measured cross sections. Right: Interpolated bathymetry based on the 59 created cross sections

The work in the coming months will focus on improving the TRM model bathymetry followed by calibration of the hydrodynamic model.

Tidal River Management has been implemented in some of the polders (polder 6-8 and Polder 24) in south western region. After detailed studying reports on tidal river management (TRM) Polder 24 has been identified as a good case for a pilot model. IWM collected a lot of data at Polder 24 before and after the implementation of the TRM. The available data including:

- River cross-sections, several datasets were collected
- Floodplain elevations, including levees (very important for the hydraulics)
- Discharges and water levels (tidal cycle)
- Sediment particle size distribution data
- Sediment concentrations during the tidal cycle

4.7 Cyclones: Improved Surge and Wave Modelling

The previous work on Storm Surge and Wave Modelling to provide parameters for the CEIP-1 designs, will be updated by providing more detailed bathymetry of the model domain which is being extended to cover the entire coastal zone and to include more advanced methods for selecting the design cyclonic storm events.

4.7.1 Improved Bathymetry

Collection of bathymetry data:
Depth and cross section data have been collected for generation of the model bathymetry that will be applied for the surge and wave modelling of the present conditions. Data applied for previously developed model bathymetries (e.g. as part of previous CEIP project), additional data collected up till the start of the present project and depth data from surveys conducted as part of the present project have been collected. This data set forms the basis for the improved model bathymetry.

Development of model bathymetry and calculation mesh
The model calculation mesh that determines the spatial resolution of the model bathymetry and model results has been updated on the basis of previously developed model bathymetries. The resolution in the narrow rivers has been carefully selected to secure appropriate propagation of tide and surge in the river system. After interpolation of the depth data to the calculation mesh the first version of the model bathymetry has been completed.

Model calibration
The calibration of the two models for surge and wave modelling has started. The process of getting an overview of all available historical data that is available for the model calibration has started. The data covers historical water levels, currents, discharges and waves that has been collected over recent years incl. data from surveys conducted as part of present study. On the basis of the available data, periods with simultaneous data sets will be selected for the model calibration.

Methodology for the modelling
The methodology for the modelling of cyclones, tide and waves, which is not trivial for the complex Bay of Bengal and Bangladesh river system has been discussed in the team (IWM, Deltares, DHI). Different methodologies can be used, and details of the selected method is still being considered. However, Deltares has an ongoing R&D project related to cyclone track modelling from which the present project most likely will benefit by transfer of key results related to cyclone track data. Transfer of preliminary data for initial testing of the selected methodology has been agreed.

4.7.2 Expected progress in the Fifth Quarter2

The work described in the tasks above will continue.

The developed first version of the model bathymetry will be used in the model calibration. As part of the calibration the bathymetry will be adjusted/improved/corrected at several locations and rivers until the calibration shows satisfactory results. Due to the complexity of the model domain (river system) the calibration is a significant task.

When the calibration is satisfactory an interim report will be prepared that documents the model setup and calibration of the surge and wave models.

Model simulations describing the tidal propagation in the river system under present and future conditions (incl. climatological predictions for sea level rise) will be initiated.

Preliminary cyclone track data received from Deltares will be tested using the established models and on the basis of results and experience using these data the methodology for the tide, cyclone and wave modelling will be developed. It is expected that additional cyclone data sets will be defined and transferred from the mentioned Deltares R&D project for use in the modelling.

[2] Fifth Quarter of the Project: October, November and December 2019

5 POLDER RECONSTRUCTION PROGRAMME

5.1 Background

Devising a polder reconstruction programme must be based on agreement on a set of clearly enunciated objectives. There is much literature available as project reports on solving problems associated with the Coastal Embankment System over the past 60 years. These reports cover areas of water resources and flood protection, drainage, operation and maintenance of systems, environment, agriculture, fisheries, socio-economics etc. In more recent times questions of sustainability have begun to play a larger role in design and planning of new systems.

The Coastal Embankment Improvement Programme was initiated in August 2010 as a phased programme of improving the Coastal Embankment System, which had already been in existence for 50 years, to improve its resilience to Climate Change after attention was focussed by two major cyclones, Sidr and Aila, in 2007 and 2009, which caused damage in excess of USD 2 Billion. At that time there were 139 polders protecting the livelihoods of 28 million people occupying 1.2 million hectares of land which was once subject to tidal inundation. While it was necessary to protect the embankment system from storm surges originating in the Bay of Bengal which was now recognised as subject to sea level rise driven by climate change and the lands subject to subsidence, It was clear that the polders would need to be classified in terms of their vulnerability so that a phases improvement programme could be devised to take up the gradual strengthening of the embankment system to resist the impact of climate change

17 polders were selected for CEIP-I as the first stage of this project. The selection was done on the basis of a multi-criteria analysis of all 139 polders. The selection criteria were based on the actual physical attributes of the polder and hydraulic structures and the vulnerability assessment of the respective BWDB Engineers responsible for and possessing intimate knowledge of each polder. The selection of groups of polders for intervention was also influenced by the need to keep the selected polders in groups within close proximity for convenience of access and for determining the design parameters and model boundary conditions.

It is necessary to revisit the original multicriteria analysis and make revisions based on our current understanding of phenomena, which have evolved based on new knowledge of matters such as land subsidence, climate change and changes in the catchments in the upper delta. The original selection was based on the data available in the year 2011. The second group of 10 polders selected (but not finalised) for CEIP-2 was also selected in 2012 based mainly on the same dataset.

There probably has been a tendency to concentrate more on technical solutions and engineering and give less considerations to the operational and management aspects that are also essential to ensure longer term sustainability. There have, in recent times, been efforts to give emphasis to the views of stakeholders – in particular, polder communities – who are direct beneficiaries of the systems under consideration.

In order to broaden the view of the project teams studying the coastal embankment system with a view to creating more sustainable systems, the project has conducted several Stakeholder Consultation Workshops (please see Chapter 9 of this report) to give additional guidance to the teams planning and designing the polder reconstruction programme.

It is now possible to take full advantage of the Polder Database being set up and populated under this project (see Chapter 3) and use it as the principal tool for analysing the properties of the polders into categories suitable for deciding on a strategy for polder reconstruction. The new database would need to be expanded to include much more information in demographic, administrative, socio-economic, environmental and other characteristics in order to make it suitable as a tool for devising a reconstruction strategy.

5.2 Selection of 3-5 Polders for Pilot Study

The Terms of Reference demands that three to five “representative polders” were selected to conduct conceptual designs on a pilot basis to also introduce innovative design approaches where appropriate. These pilot polders were to provide additional guidance towards introducing innovative designs to broaden the choices available to the designers. 5 polders were selected after detailed examination of their physical and geographical characteristics after detailed field inspections. The final choice was ratified by the committee convened by the Project Director.

The details of the selection process are given in the Polder Selection Report (2019). These polders are now under detailed study prior to design. Table 5.1 summarises the salient features of the selected polders.

Table 5-1: Five Polders Selected for Pilot Design Study

Polder Name	District	Coastal region	Key Characteristics
Polder 15 (CEIP-1)	Satkhira	South-West Coastal region	➢ Very little Freshwater flow from upstream River (Ganges) ➢ Influenced by strong tidal action, salinity problem is acute. ➢ Peripheral river Sedimentation is a major Problem; which creates drainage problem. People inside coastal polder ➢ Experiencing prolonged water logging. ➢ River bank erosion problem
Polder 29 Blue Gold programme	Khulna		
Polder 40/1	Barguna	South-Central Coastal region	➢ Polder Embankment is facing river Erosion problem. ➢ Vulnerable to cyclonic storm surges.
Polder 59/2	Noakhali	South-East Coastal region	➢ Morphologically active land accretion is dominant than erosion. ➢ Severe river erosion due to, thalweg migration. ➢ Vulnerable to cyclonic storm surge. ➢ Some area subjected to prolonged water logging due to encroachment and land reclamation by closing of Tidal creeks.

Polder Name	District	Coastal region	Key Characteristics
Polders 64/1a & 64/1b	Chittagong	Eastern Hilly region	➢ Vulnerable to storm surge. ➢ Prone to flash flood due to steep gradient of river and intense rainfall. ➢ Water logging ➢ Erosion around Sangu River

The five polders selected above have properties that are representative of the polder system and the full range of interventions necessary to provide solutions to identified problems, taking into account of their physical characteristics and their location within the coastal zone. It is thought that a thoughtful approach to the design of these 5 polders will enable the development of approaches that will be useful in for responding to the diverse problems to be overcome within the polder system.

The expanded multi-criteria analysis applied to the polder database, will help us to select a strategy for the staged re-construction of several groups of polders.

5.3 A Strategic Approach towards devising a Polder Reconstruction Programme

5.3.1 A Road Map towards a Viable Reconstruction Plan

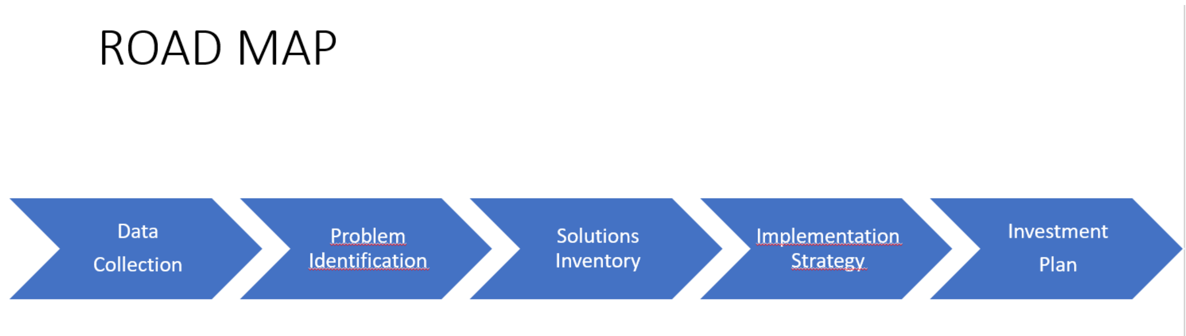


Figure 5-1: Basic steps in the CEIP road map

The Road Map identifies a Plan to approach the problem of setting up an Investment Plan for the entire polder system (139 polders including the 17 polders already taken up) following the basic steps as indicated in Figure 5-1. The five polders selected above have properties that are representative of the polder system in Bangladesh and will be used to illustrate the full range of interventions available for polder rehabilitation on account of their physical characteristics and their location within the coastal zone. It is thought that a thoughtful approach to the design of these 5 polders will enable the development of approaches that will be useful for guiding the re-designing of the large number of polders in the future. The Main steps are described briefly below:

a. Data Collection: The data gathering should include data required for the different analysis required for the road map. In principle all data to be gathered is listed in the "MCA Polder selection" – file (but might not be limited to the items in this list). Field visits to a number of polders is essential in order to further elaborate the data to be gathered.

Table 5-2: Indicators for Polder Data Description

Sl No	unique identifier
Polder description	
Polder No	Official number (name?) of the polder
Type of Dyke	coastal, internal, fluvial
Location of the Polder (Upazila)	Administrative upazila
District (Zila)	Administrative zila
Gross Area of the Polder (HA)	Surface of the polder (gross)
Embankment Length (Km)	Length of embankment. Should be specified to type of dike
Land use	State land use in different categories and surfaces and value, including urban and rural areas (urban, agricultural, industry)?
Population	per polder
Accessebility	Ease of transport (road, rail, ship), density of road and rail network?
Production value	Assess economic importance of polder in terms of value added, contribution to GDP
Problem identification	
Breach of Embankment (Km)	This is part of the problem identification. "Breach" should be further specified
Erosion (Km)	The nature and extend of erosion should be specified
Requirement of BPW (Km)	What is this?
Location in the Risk Zone	This should specify IWRM/ICZM zone, catchment, other? Tidal surge, salinity, flooding, river erosion and cyclones, Make use of the "hot spot" terminology?
Drainage Congestion (Ha)	This is part of problem identification, drainage problems. How should this be described? Also related to waterlogging in low lying areas in a polder (could be linked to solution increase land level)
Salinisation	Is salinisation currently a problem, could it in the future, does it have an impact on (agricultural) production, water supply? Linked to the possibility in provision in fresh water
Subsidence	What is the subsidence rate of the polder, important for dimensioning of solutions
Sedimentation	Is there sedimentation, does it affect the polder, opportunity to expand polder, opportunity to use sediment for land reclamation, increase of polder level?
Climate change	Are there specific effects of climate change (SLR, increased river discharge, droughts) that could impact the FSR in the polder?
Flood probability	Current protection level from floods of the polder
Flood risk	Annual expected damages from floods, cyclones? People affected? Value at risk? Is important for the prioritisation of interventions and setting of standards
Cyclone probability/risk	Susceptibility to cyclones and effects/risks

Water quality	General water quality from pollution
Security	Are there security related risks in the polder
Environment	Would there be potential environmental concern in extension or intensification from polder operation or polder expansion or construction activities?
Socio-economic situation	Is there significant difference in socio-economic status between polder, do we need to account for distributional effects (1 Tk. is worth more for a poor person than a rich person)
FSR/lively hoods	Would (or have) potential problem a significant larger impact on FSR/livelihoods than in other polders (also linked to distributional effects)
Opportunities	
Innovations	Could innovative approaches be tested or implemented in construction/problem solving
Polder management	Can benefits be obtained through combining polder together (or risks reduced by splitting up)
Raising of polder level	Could polder be subject to increased land level through sedimentation measures?
Land reclamation	Would land reclamation (or intensification) be possible
Urban development potential	Would there be a potential for urban developments or real estate development
Co-financing	Could measures be included that could improve opportunities for combined financing of measures ("leveraging" or revenue generation for government budget)
Implementation	
Opinion of Stakeholder	Which stakeholders? Should the stakeholders not do the actual scoring?
Rehabilitation Cost (Crore BDT)	This is cost of rehabilitation (LCC; both investments and O&M costs), but to which standards, solving which problems? Based on general assumptions for interventions and unit costs? Which interventions do we include in the plan? Should we limit ourselves to BWDB mandate? Include other interventions? Are other interventions prerequisites for success? Is budget availability a constraint?
Economic feasibility	The proposed interventions should meet certain economic criteria and benefits in present value should be larger than LCC.
Climate change component	Which component of the investment are CC related?
Compliance to BDP goals	1. Ensure safety against water and climate change related disasters 2. Ensure water security and efficiency of water usages 3. Ensure integrated river systems and estuaries management 4. Conserve and preserve wetlands and ecosystems 5. Develop effective institutions and equitable governance for intra and trans-boundary water resources management 6. Achieve functional and optimal use of land and water
Compliance to SDGs	All 17 or take selection? SDG1 No poverty SDG2 Zero hunger SDG8 Decent work and economic growth SDG9 Industry, innovation and infrastructure SDG10 Reduced inequality SDG11 Sustainable cities and communities SDG13 Climate action SDG14 Life below water SDG15 Life on land
Resource efficiency	Do the measures increase resource efficiency, e.g. land and water, labour, etc?
Flexible	Are interventions flexible, i.e. leave opportunity for future interventions
Robust	Are interventions robust, i.e. interventions provide protection/increased opportunity under future increased challenges
NBS vs Grey infra	Promote the use of NBS, including room for the river approach? (in accordance with BDP)

Transfer of problems	Avoid that interventions in one place lead to bigger problems elsewhere
Resilience	Look at reduction of impact as well as faster recuperation time
O&M	Are adequate provisions for maintainability in place?
Special Criterion	
Remarks	Narrative description of the polder stating overall assessment?

b. Problem Identification: Identification of issues affecting optimal polder management including agricultural production (like drainage, salinisation, etc), liveability (housing problems related to health issues like high groundwater table, water logging, etc). Also the different modelling exercises should deliver essential information on problems and identification of solutions for the identified problems. The identified problems will be specified as much as possible in economic terms like flood damage to assets (infrastructure) and loss of production (agriculture, industry, services, etc).

c. Solutions Inventory: An inventory has to be made of successful measures that contribute to an optimisation in polder management. Measures should be described in terms of physical implementation, effectiveness to identified problem and costs. After the inventory of measures a Cost Effectiveness Analysis (CEA) of the measures can be made, which will serve to identify the most efficient measure for the different identified problems. The description of the measures should also include financing and institutional arrangements for operation and management.

d. Implementation Strategy: In order to develop economically feasible investment strategies potential investment strategies for the different problems that are identified in the polder need to be subject of a Cost Effectiveness Analysis (CEA). This CEA should guide the selection of the most cost-effective investment strategies for the problems that are identified for the different polders. In this report a Multi Criteria Analysis (MCA) is use to quantify the problems identified in the polder in such a manner that a prioritisation based on the MCA is possible. In this analysis the general properties of the polders, the identified problems and the potential investment measures are combined in order to draft economically feasible investment strategies.

e. Investment Plan: In order to transform the investment strategies into an investment plan, not only the costs of the investments but also the financing of the proposed strategies must be considered. In this financing plan the potential contributions from different financing sources will be identified. For the investment strategies it will be investigated how the different financing sources could contribute to the financing of the investment strategy. For these consultations will be done with the different national and international financing agencies. It would be a bonus when financing institutions would indeed commit themselves to certain parts of the investment strategies for the different polders

<u>Some activities to be undertaken in the next Quarter:</u>

As specified in the Terms of Reference, 5 representative polders were selected to carry out pilot conceptual designs based on the great deal of knowledge we have gathered in the last 5 decades but tempered by the new knowledge we have acquired in more recent times; particularly our improved ability to predict of the trajectory of the long term evolution of the Delta. The long-term sustainability of the polder system would now play a more important part in the planning and design of re-construction measures as recognized in the Bangladesh Delta Plan. However well we designed the earlier stages of CEIP, there would be improvements that can be made because of better understanding of natural processes and climate change. The formulation of the reconstruction plan would benefit from the additional experience gained in designing the 5 pilot polders.

Reviewing of reports, data, maps of related projects such as CEP, CDSP, CEIP-I, Blue Gold and others. Through such review their problems and the approach to their solutions will be understood, any gaps will be found, lessons learnt will be gathered. The review will also help to create better estimates of costs.

Detailed consultations with experienced professionals such as past and present project directors, consultants, engineers, polder managers and others will held accumulate knowledge and understanding. This will also help in identifying gaps, any new scope and approach to problem solving.

Discussion meeting with O&M Engineers at BWDB: Field engineers have experiences on polders where they have been working or worked. Their experiences understood, captured over the time will be gathered in improvement endeavor.

Paying field visits: Field visits will be paid to a range of well managed and poorly managed (and or poorly designed) polders. Having facilitated group discussion at field-level will add to the understanding of the challenges that are faced by the different stakeholders in the use and management of the polders. While having field visits as mentioned above, facilitated group discussions will be arranged and thus information will be collected through these in developing the requirements for improvements for the polders. The importance that the stakeholders give to their respective problems will also serve to establish the importance that the different aspects will receive in the MCA, and thus to the importance these receive in the polder rehabilitation strategy and investment plan.

A time-table:

As explained the process of investment planning will include a Multi Criteria Analysis (MCA) and technical and economic feasibility studies in order to establish intervention priorities for the different polders. There will be interaction with stakeholders to assess not only the problems that the different polders are facing, but also to assess the relative priority that stakeholders assign to the different identified issues. The judgement of the different stakeholders will be used to determine the importance of the different aspects that will be used in the MCA to establish the intervention priority between the polders. The final MCA and other analyses (e.g. the Environmental Impact Assessment) combined with field knowledge will be used to devise the eventual implementation plan. The Draft Plan thus formulated would have to be ratified by a Workshop to be held in end-2020/early 2021.

6 INVESTMENT PLAN FOR ENTIRE CEIP

The preparatory work on the Investment Plan is described in Chapter 5. The plan will be described in more detail in QPR-7

7 DESIGN PARAMETERS, CONSTRUCTION MANAGEMENT & MONITORING

No Activity this quarter

8 CAPACITY BUILDING

The national consultants engaged in the project were able to interact closely with visiting experts and jointly carry out the tasks necessary to analyse data and develop and set up numerical models. The national consultants have received on the job training while working intensively with several visiting experts. The subjects covered during this Quarter are:

Code	Name	Designation	Activity
IK-1	Dr. Ranjit Galappatti	Team Leader	General
IK-9	Dr. Michael Steckler	Subsidence Expert/Geo-Morphologist	Subsidence surveys
IK-5	Dr. Bo Brahtz Christensen	Coastal and Estuarine Morphologist	Micro-scale morphology
INK-10	Mr. Henrik Rene Jensen	Storm Surge and Wave Specialist	Storm Surge Modelling
INK-15	Dr. Kim Wium Olesen	River Morphologist	Micro scale Morpholohy, General
INK-11	Dr. Alessio Giardino	Climate Change Risk and Adaptation	Climate changes, cyclone simulations
INK-12	Mr. Mark de Bel	Economist	Investment plan
INK-14	Dr. Christopher Small	Remote Sensing Expert	Gis Subsidence
INK-25	Dr. Carol Wilson	SET Compaction Meters and Polder/TRM I	Flood plain sedimentaton, compaction

The modelling work continues uninterrupted, with regular consultation over skype and emails, after the visiting experts return to their home offices, the modelling work. The following experts who did not visit the project office during this quarter, were nevertheless able to interact effectively to perform their training function.

IK-6	Dr. Søren Tjerry	Tidal River and Sediment Management Specialist
IK-2	Prof. Zheng Wang	River and Estuarine Morphologist
IK-3	Prof. Dano Roelvink	River , Coastal & Estuarine Morphological Modeler
IK-7	Dr. Irina Overeem	Macro Scale Delta Morphologist
INK-33	Dr Jordan Adams	Post Doctoral Fellow

IWM has vast experience in water management modelling of coastal polder processes and cyclonic storm surge modelling. A program for on job training of BWDB engineers on polder water management, storm surge and salinity modelling will be developed in the next quarter. This training is planned to commence from November 2019.

8.1 Training Courses and Study Tours

Three Fellowships were awarded to middle level Engineers at BWDB to undertake post-graduate studies leading to a Masters' Degree each, at I.H.E. in Delft, the Netherlands. The course has already commenced.

Some study tours are also being arranged for senior staff of the BWDB and the MoWR to visit, the Netherlands, Denmark and the US.

9 TRANSPARENCY AND ACCOUNTABILITY

9.1 Stakeholder Workshops

The Inception Workshop which was held 9 January has already been reviewed and acted upon by the entire water resources community in Bangladesh. The Final Inception Report, containing responses to several rounds of comments was finally published on 20 February 2019 and accepted by the Client.

There were two Stakeholder Consultation Workshops; first to be held in Barisal on 30 March 2019, and the second to be held in Khulna. The second Workshop was eventually held on 27 April 2019. The Workshops were held under the patronage of the State Minister of Water Resource, the Secretary of the Ministry and other senior officials. There was a wide cross-section of participants from a range of stakeholder organisations with lively discussions and exchanges of views. Almost the entire proceedings, which were conducted in Bangla has been documented.

The detailed proceedings of these workshops we published in Bangla and in Enlgish in the month of September 2019,

Figure 9-1: Photos from the Barishal Workshop

Figure 9-2: Photos from the Khulna Workshop

9.2 Other Communication Activities

No public events were held for disseminating the work of the project. Several consultative meetings were held with other projects active in this field, such as

Blue Gold Project

Delta Plan 2020

CEIP Project (several phases)

10 CONCLUSION

This report describes the extent of work done in the Fourth Quarter of this project from 1 July to 30 September 2019.

Only the outline of the work is described in this report because of the fact that the technical/scientific results of the work are being published in a separate series of technical reports.

Some difficulties have been experienced by the fact that the contract budget does not cover some expenditure that are unavoidable. Among these are the payment of the domestic air travel costs for project staff and the payment of customs duties and taxes that arise when goods and equipment are imported to be handed over to the BWDB after they are deployed for field work. It will be necessary to apply to the Project Director to obtain additional budget to cover these costs.