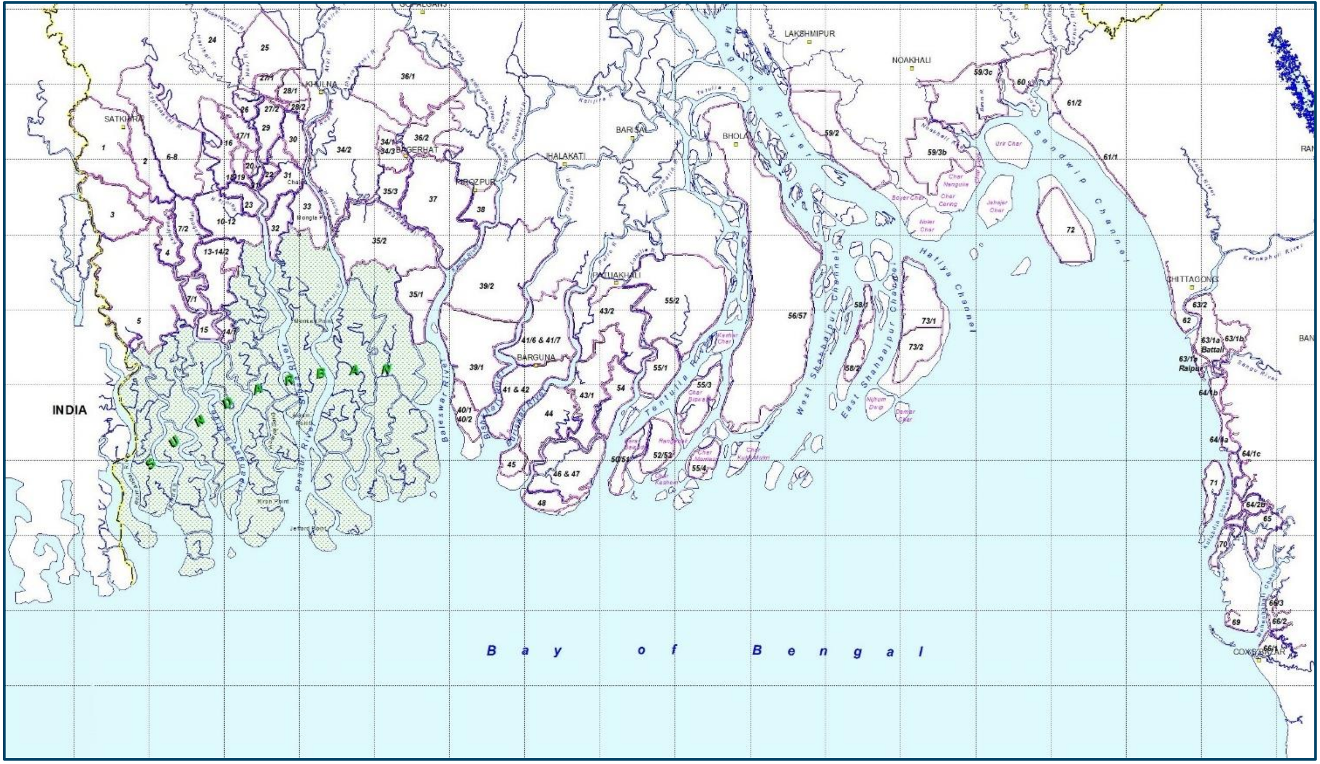
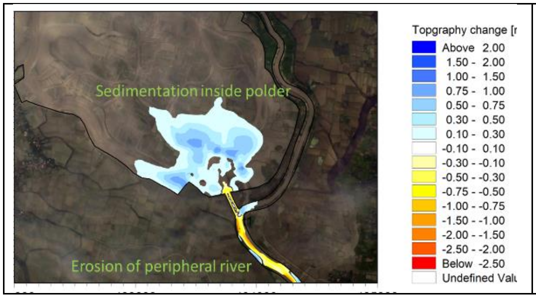
Ministry of Water Resources

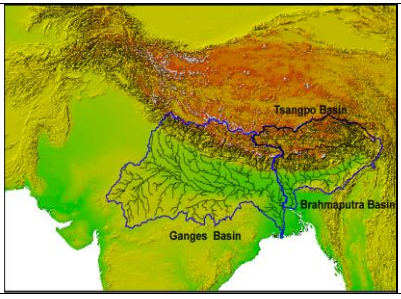
Bangladesh Water Development Board

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-10

May 2021

DHI

Deltares
Enabling Delta Life

IWM
Water Environment & Climate

Columbia University

The expert in **WATER ENVIRONMENTS**

Ministry of Water Resources

Bangladesh Water Development Board

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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, Banani, Dhaka 1213, BANGLADESH Phone +880 1307 693299

Memo No: CEIP/LTMRA/0521/111 23 May 2021

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

Attn: Mr. Syed Hasan Imam, Project Director

Dear Mr Imam,

Subject: Submission of Quarterly Progress Report-10

It is our pleasure to submit herewith three copies of the Quarterly Progress Report-10. This is the 10th Quarterly Progress Report describing the progress made between 1st January 2021 to 31 March 2021. We regret that the submission of the report has been delayed due to interruption of travel and our intra-project communications by the COVID-19 crisis.

The amount of progress made during this quarter has been less than optimal and not uniform on all fronts because of unexpected restriction on staff travel because of COVID-19 lockdowns. However, it was possible to re-negotiate and re-schedule the project outputs to arrive at an accommodation that would allow the project period to be extended by 10 months to enable all the expected project outputs to be realised without additional cost.

This report comprises 6 chapters, including the first three chapters that describe progress in development of input datasets for modelling including coastal database, and two chapters describing modelling followed by a brief chapter describing some progress Capacity Building. Several modelling reports submitted in this quarter are listed in Table 1.3 of the report. Further descriptions of this work is considered unnecessary.

We are unable to report progress in the Polder Development Plan, and the Investment Plan because the travel restrictions arising from the COVID-19 crisis made it impossible to deploy the international staff for this purpose and for developing new design parameters.

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Thanking you,

Yours sincerely,

Dr Ranjit Galappatti
Team Leader

Copies: Engineer A K M Waheduddin Chowdhury, Director General, BWDB
Engr. Md. Mizanur Rahman, ADG (Planning), BWDB
Dr Kim Wium Olesen, Project Manager, DHI
Dr Alessio Giardino, Deltares Project Manager
Mr Zahirul Haque Khan, Deputy Team Leader
Mr AKM Bodruddoza, Procurement Specialist
Swarna Kazi, Sr. Disaster Risk Management Specialist, World Bank

Joint Venture of DHI and Deltares in partnership with
IWM, University of Colorado, Boulder and Columbia University

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Enabling Delta Life
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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

IGDCZ- Interactive Geo-Database for Coastal Zone

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 L - Water Level

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 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. The Third Quarterly Progress Report (QPR-3) covers the period 1 April 2019 to 30 June 2019. QPR-4 covered the period from 1 July 2019 to 30 September 2019. QPR-5 covering the period 1 October 2019 to 31 December 2019 was submitted in February 2020.

The advent of the COVID-19 crisis in early 2020 signalled the beginnings of a global pandemic. QPR-6 covered period 1 January to 31 March 2020. The work of the project during the 6th Quarter was not seriously affected because the international experts working in Dhaka were not recalled by their home offices until the 15th of March 2020. The Eighth Quarterly Progress Report (QPR-8) describing the progress made between 1st July 2020 to 30th September 2020 covered the second period where the original work schedule was badly affected by the travel bans imposed by Denmark, The Netherlands and the United States. The 8th and 9th Quarters had to be completed without a single International Consultant being permitted to travel to Bangladesh.

This report (QPR-10) covers the progress of work in the period 1st January 2021 to 31st March 2021. The constraints imposed by the travel bans which prevented the field inputs (in Bangladesh) by International Staff was the subject of several rounds of protracted negotiations between the Consultant and the Client – has made some progress in the face of growing global uncertainty. The preparation of this report has been delayed due to these difficulties.

1.1 The New Work Plan

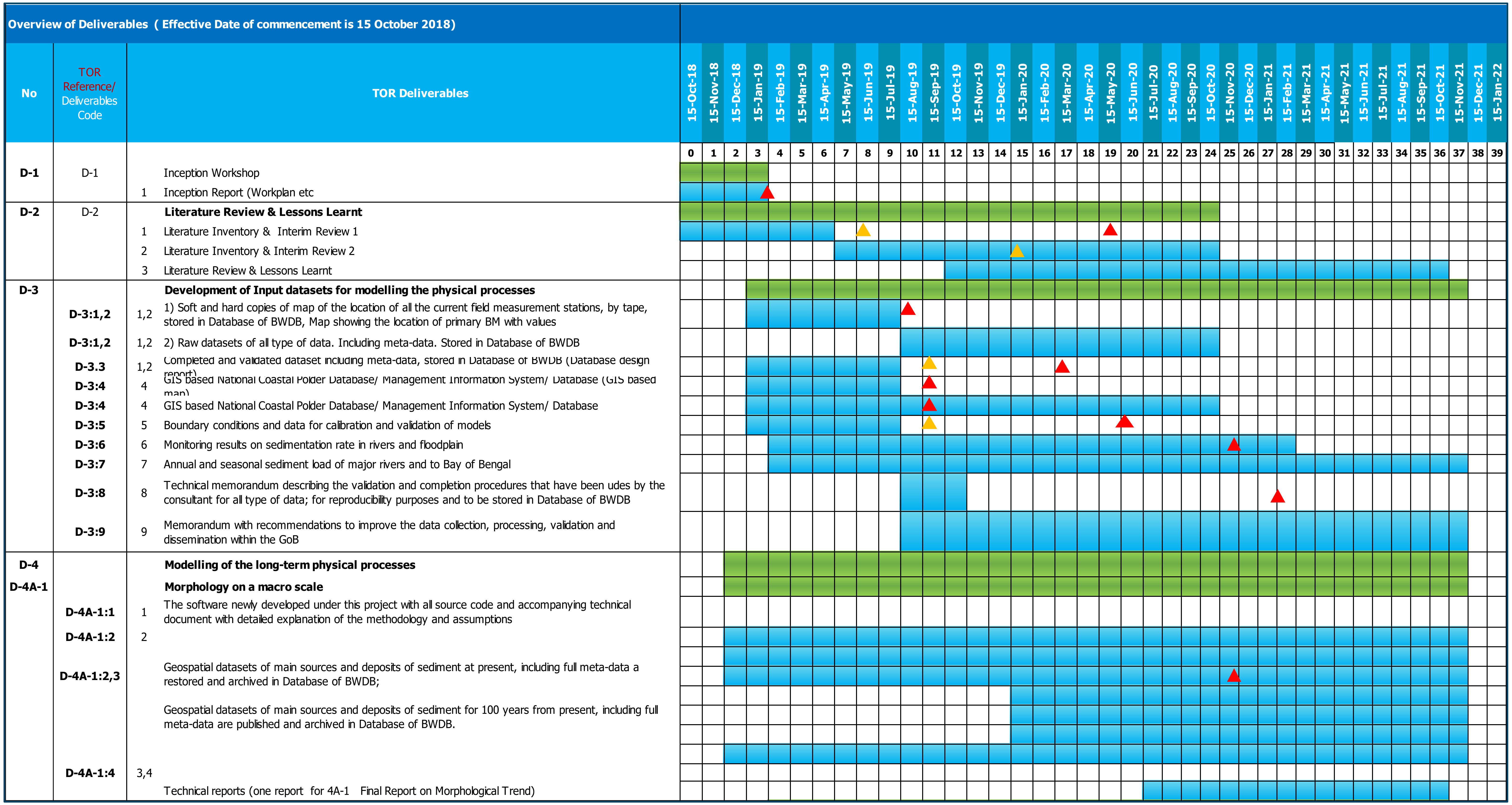
The Inception Report (DHI, 2019) gave a detailed description of the work to be carried out by this project. This programme was disrupted from March 2020 onwards by the advent of the COVID pandemic especially because of the travel restrictions placed on international staff by their respective governments. The work plan and the staff deployment plan has been under continuous negotiation throughout the last three quarters while the international COVID situation continued to evolve. Eventually agreement was reached on a new work schedule with sufficient built in flexibility to cope with future contingencies. This new schedule allowed the project duration to be extended by 10 months and the deliverables and the related man-power inputs to be re-arranged and re-scheduled as necessary.

Table 1.1 shows the new, re-negotiated schedule of activities. The original workplan (not shown here) was published in the Inception Report published in December 2018. This new work plan shows an extension of the project duration until January 2022.

These negotiations proceeded throughout this quarter and have reached a conclusion with the signing of a revised contract on 26 April 2021.

The project duration has now been extended till the end of year 2021. The work programme has been modified to accommodate the travel restrictions imposed by the COVID-19 crisis. This programme involves some staffing and budget changes currently under discussion. Section 1.2 and section 1.3 describe the current adjusted work schedules and the corresponding lists of deliverables.

Table 1. 1: New Activity Schedule Page 1



Overview of Deliverables (Effective Date of commencement is 15 October 2018)

No	TOR Reference/ Deliverables Code		TOR Deliverables
D-1	D-1		Inception Workshop
		1	Inception Report (Workplan etc
D-2	D-2		**Literature Review & Lessons Learnt**
		1	Literature Inventory & Interim Review 1
		2	Literature Inventory & Interim Review 2
		3	Literature Review & Lessons Learnt
D-3			**Development of Input datasets for modelling the physical processes**
	D-3:1,2	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
	D-3:1,2	1,2	2) Raw datasets of all type of data. Including meta-data. Stored in Database of BWDB
	D-3.3	1,2	Completed and validated dataset including meta-data, stored in Database of BWDB (Database design report)
	D-3:4	4	GIS based National Coastal Polder Database/ Management Information System/ Database (GIS based map)
	D-3:4	4	GIS based National Coastal Polder Database/ Management Information System/ Database
	D-3:5	5	Boundary conditions and data for calibration and validation of models
	D-3:6	6	Monitoring results on sedimentation rate in rivers and floodplain
	D-3:7	7	Annual and seasonal sediment load of major rivers and to Bay of Bengal
	D-3:8	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
	D-3:9	9	Memorandum with recommendations to improve the data collection, processing, validation and dissemination within the GoB
D-4			**Modelling of the long-term physical processes**
D-4A-1			**Morphology on a macro scale**
	D-4A-1:1	1	The software newly developed under this project with all source code and accompanying technical document with detailed explanation of the methodology and assumptions
	D-4A-1:2	2	
	D-4A-1:2,3		Geospatial datasets of main sources and deposits of sediment at present, including full meta-data a restored and archived in Database of BWDB;
			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.
	D-4A-1:4	3,4	
			Technical reports (one report for 4A-1 Final Report on Morphological Trend)

Table 1.1 (contd) : New Activity Schedule Page 2

No	TOR Reference/ Deliverables Code		TOR Deliverables	15-Oct-18	15-Nov-18	15-Dec-18	15-Jan-19	15-Feb-19	15-Mar-19	15-Apr-19	15-May-19	15-Jun-19	15-Jul-19	15-Aug-19	15-Sep-19	15-Oct-19	15-Nov-19	15-Dec-19	15-Jan-20	15-Feb-20	15-Mar-20	15-Apr-20	15-May-20	15-Jun-20	15-Jul-20	15-Aug-20	15-Sep-20	15-Oct-20	15-Nov-20	15-Dec-20	15-Jan-21	15-Feb-21	15-Mar-21	15-Apr-21	15-May-21	15-Jun-21	15-Jul-21	15-Aug-21	15-Sep-21	15-Oct-21	15-Nov-21	15-Dec-21	15-Jan-22
				0	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	31	32	33	34	35	36	37	38	39
D-4A-2			**Morphology on a meso scale**					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			
	D-4A-2:1	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					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▲	🟦	▲▲▲	🟦	🟦	🟦	🟦	🟦	🟦	🟦					
	D-4A-2:2,3	3	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; 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																	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
	D-4A-2:4	4	Technical report (one report for 4A-2 - FINAL REPORT ON ESTUARINE MORPHOLOGY)																						🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
D-4A-2			**Bank Erosion on Meso scale**					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩					
	D-4A-2:1,2	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					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▲▲▲	🟦														
	D-4A-2:3	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																				🟦	🟦	🟦	🟦	🟦	🟦	▲	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					
	D-4A-2:4	**4**	Technical report (one report for 4A-1 and 4A-2)																				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					
			Other special purpose models																																								
D-4D-3								🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩					
	D-4D-3:1,2,3,4	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.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦						
			Define extreme water levels in the polder of coastal zone at 25, 50 and 100 years from now, due to cyclonic storm surges					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					

Table 1. 1 (contd) : New Activity Schedule Page 3

No	TOR Reference/ Deliverables Code		TOR Deliverables	15-Oct-18	15-Nov-18	15-Dec-18	15-Jan-19	15-Feb-19	15-Mar-19	15-Apr-19	15-May-19	15-Jun-19	15-Jul-19	15-Aug-19	15-Sep-19	15-Oct-19	15-Nov-19	15-Dec-19	15-Jan-20	15-Feb-20	15-Mar-20	15-Apr-20	15-May-20	15-Jun-20	15-Jul-20	15-Aug-20	15-Sep-20	15-Oct-20	15-Nov-20	15-Dec-20	15-Jan-21	15-Feb-21	15-Mar-21	15-Apr-21	15-May-21	15-Jun-21	15-Jul-21	15-Aug-21	15-Sep-21	15-Oct-21	15-Nov-21	15-Dec-21	15-Jan-22
				0	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	31	32	33	34	35	36	37	38	39
D-4A-3											🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩				
	D-4A-3:1,2,3	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.																																								
D-4B			**Subsidence**																																								
			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.					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩					
	D-4B:1,2,3	1,2,3	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.																			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					
																										🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					
D-4C			**Meteorology**					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			
	D-4C:1,2	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.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
D-4D			**Climate Change Effects**					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
			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.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
	D-4D:1,2,3	1,2,3	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.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
	D-4D:4,5	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.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
	D-4D:6	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.																									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		

Table 1. 1 (contd) : New Activity Schedule Page 4

No	TOR Reference/ Deliverables Code		TOR Deliverables	15-Oct-18	15-Nov-18	15-Dec-18	15-Jan-19	15-Feb-19	15-Mar-19	15-Apr-19	15-May-19	15-Jun-19	15-Jul-19	15-Aug-19	15-Sep-19	15-Oct-19	15-Nov-19	15-Dec-19	15-Jan-20	15-Feb-20	15-Mar-20	15-Apr-20	15-May-20	15-Jun-20	15-Jul-20	15-Aug-20	15-Sep-20	15-Oct-20	15-Nov-20	15-Dec-20	15-Jan-21	15-Feb-21	15-Mar-21	15-Apr-21	15-May-21	15-Jun-21	15-Jul-21	15-Aug-21	15-Sep-21	15-Oct-21	15-Nov-21	15-Dec-21	15-Jan-22
				0	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	31	32	33	34	35	36	37	38	39
D-5								🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩				
	D-5A:1	1	Technical Report on Long Term Polder Improvement measures and Polder Development Plan																			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦												
	D-5A:1	1																						🟦	🟦▲	🟦	🟦	🟦	🟦	🟦	🟦												
	D-5A:2	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																						🟦	🟦					▲												
	D-5A:3	3	Report for each of the 3-5 polders with a description of ; Present situation, boundary conditions (scenarios), Matching with polder options, Including management plan, Costs and benefits. Draft report focusing on initial 4 Polders to be optimised. Final Report, 17 Polders.											🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
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								🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩												
											🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦												
D-6			**Updating of design paramerters and specificaitons for construction works and management paractices**					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
	D-6.1		Report with updated set of design parameters and specifications for construction/ reconstruction of the polders as well as associated appurtenant structures.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
			Detailed delivery plan to be developed druing the inception phase.					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																					
D-6.2 & D-6.3	D-6.2 & D-6.3							🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩				
			Report on Management plans for the polders including review approaches of polder management and performance monitoirng mechanism					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
			Detailed delivery plan to be developed during the inception phase																																								
D-7			**Investment Plan for Entire CEIP**																									🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			
	D-7:1		An investment plan describing a phaased polder improvement roadmap and required budget																									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
	D-7:2		An investment plan for long term management of the polders, including the expansion of monitoring																									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
	D-7:3		An execution plan including financing and fundraising strategies and plan and technical collaboration plan																									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
D-8			**Action Plan for Capacity Building**				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩				
			On the job technical training in country				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
			Report on: results of the on the job training, list of participants				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
			International Workshop																									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
			Teach the teacher, Teaching at the universities																									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
							🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
D-9.1			**Outreach Program**				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	D-9.1:1	1	Workshops				🟦	🟦	🟦▲	🟦▲	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦▲	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	D-9.1:2	2	Workshop Report (Stakeholder's workshop at Barisal and Khulna & Mid-term workshop at Dhaka)												▲	🟦▲				🟦				▲				🟦			🟦												
D-9.2			**Communication Strategy**					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩									
		1	Storage of all datasets of BWDB and Communication materials																																								
QPR								▲	▲				▲			▲				▲			▲		▲						▲		▲										

▲ Draft submission of report ▲ Revised submission of report

1.2 Revised List of Non-Modelling Milestones and Deliverables)

Table 1.2 a: List of non-modelling milestones and deliverables (Part 1)

Overview of Deliverables		As per Consultant				
No	**ToR Deliverables**	**Program Item**	**Status**	**Deadline as per Signed Contract**	**Date of Submission to PIU**	**Proposed Revised Deadline**
D-1	**Inception**					
	Inception Workshop	Inception Workshop	Accepted	4-Jan-19	9-Jan-19	
	Inception Report (Workplan etc)	Inception Report (Workplan etc)	Accepted	4-Jan-19	30-Jan-19	
D-2	**Detailed Literature Review and its Summary and Lessons Learnt**					
	Literature Inventory & Interim Review 1	Literature Inventory & Interim Review 1	Submitted	4-Feb-19	24-Jun-19	January 2021
	Literature Inventory & Interim Review 2	Literature Inventory & Interim Review 2	Submitted	4-Oct-20	15-Jan-20	March 2021
	Literature Review & Lessons Learnt	Literature Review & Lessons Learnt	Pending	4-Oct-20		Oct-21
D-3	**Development of Input Datasets for Modelling the physical processes**					
	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	Data Report, Inventory & Quality Checks (Includes field Data collection and monitoring programmes)	Submitted	4-Jul-19	29-Sep-19	
	Raw datasets of all type of data. Including meta-data. Stored in Database of BWDB					
	Completed and validated dataset including meta-data, stored in Database of BWDB	Database Design Report	Submitted	4-Jul-19	11-Sep-19	
	GIS based National Coastal Polder Database/ Management Information System/ Database	GIS Based Maps	Submitted	4-Jul-19	25-Sep-19	
		GIS Based Database/ MIS system/ Sharepoint	Pending	4-Jul-19		Sep/21
	Boundary conditions and data for calibration and validation of models	Supply of Model Boundary Data	Submitted	4-Jul-19	25-Sep-19	
	Monitoring results on sedimentation rate in rivers and floodplain	Monitoring Results on Sedimentation rate in rivers	submitted	4-Jul-19	12-Dec-20	Nov-20
	Annual and seasonal sediment load of major rivers and to Bay of Bengal	Annual & Seasonal Sediment load of Major rivers & to Bay of Bengal	Pending	4-Aug-19		Nov-21
	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	submitted	4-Aug-19	16-Feb-21	Dec-20
	Memorandum with recommendations to improve the data collection, processing, validation and dissemination within the GoB	Technical Report on improving Data collection	Pending	4-Aug-19		Nov-21
D-5A	**Finalization of approach for reconstruction of the Polder at different coastal zones including their phasing and construction program**					
	Technical Report on Long Term Polder Improvement measures and Polder Development Plan	Draft	Submitted	4-Apr-21	6-Aug-19	Sep-21
		Final	Pending			Oct-2021
	Design of polder improvement measures of 17 polders under CEIP-I with consideration of existing improvements with a description of ; opportunities for livelihood, spatial planning, water management and operation, subsidence, raising of low lying area and future climate change scenarios.	Draft	Submitted	4-Apr-21	17-Jan-21	February2021
		Final	Pending			Oct-21
	Report for each of the 3-5 polders with a description of; · Present situation · Boundary conditions (scenarios) · Establish design, including management plan · Costs and benefits · Matching with polder options	Draft	Pending	4-Jul-20		Oct-21
		Final	Pending			Oct-21
D-5B	**Coherence and Overall picture of Delta**					
	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 Overall Delta	Pending	4-Apr-21		Jul-21
		~~Environmental Assessment of Proposed Interventions~~	Pending			
D-6.1	**Updating of design parameters and specifications for construction works**					
	Report with updated set of design parameters and specifications for construction/ reconstruction of the polders as well as associated appurtenant structures	Updated Design Parameters & Specifications	Pending	4-Apr-21		Dec-21
	Detailed delivery plan to be developed during the inception phase for D-6.1	Detailed Delivery Plan	Submitted	4-Feb-19	11-Apr-20	
D-6.2	**Review of approaches for management of polders with emphasis on active pa**					
	Report on Management plans for the polders	Polder Management Plan	Pending	4-Apr-21		Nov-21
	Detailed delivery plan to be developed during the inception phase for D-6.2	Detailed Delivery Plan	Submitted	4-Feb-19	11-Apr-20	
D-6.3	**Setting up a performance monitoring Mechanism**					
	Report on participatory monitoring mechanism with goals and targets	Performance Monitoring Mechanisms	Pending	4-Apr-21		Nov-21
	Detailed delivery plan to be developed during the inception phase for D-6.3	Detailed Delivery Plan	Submitted	4-Feb-19	11-Apr-20	

Table 1.2 b: List of non-modelling milestones and deliverables (Part 2)

No	ToR Deliverables	Program Item	Status	Deadline as per Signed Contract	Date of Submission to PIU	Proposed Revised Deadline
D-7	**Investment plan for the Entire CEIP**					
	An investment plan describing a phaased polder improvement roadmap and required budget	An investment plan describing a phaased polder improvement roadmap and required budget	Pending	4-Apr-21		Nov-21
	An investment plan for long term management of the polders, including the expansion of monitoring	An investment plan for long term management of the polders, including the expansion of monitoring	Pending	4-Apr-21		Nov-21
	An execution plan including financing and fundraising strategies and plan and technical collaboration plan	An execution plan including financing and fundraising strategies and plan and technical collaboration plan	Pending	4-Apr-21		Nov-21
D-8	**Action Plan for Capacity Building**					
	On the job technical training in country	In-country on-the- job Training	Submitted	Continuous		december 2021
	Report on: results of the on the job training, list of participants	Training Report with list of trainees	Pending	Bi Annually		december 2021
	International Workshop	International Workshop	Pending	4-Jul-20		december 2021
	Teach the teacher, Teaching at the universities	Curriculum Development	Pending	4-Apr-21		december 2021
D-9.1	**Outreach Program**					
	Workshops	Workshop 1 - Barishal	Accepted		30-Mar-19	
	Workshops	Workshop 2 - Khulna	Accepted		27-Apr-19	
	Workshops	Workshop 3 - Mid Term Progress Workshop	Accepted		6-Feb-20	
	Workshops	Workshop 4	Pending			
	Workshops	Workshop 5	Pending			
	Workshops	Workshop 6	Pending			
	Workshops	Workshop 7	Pending			
	Workshop Report	Workshop 1 Report - Barishal	Submitted		20-Feb-20	
	Workshop Report	Workshop 2 Report - Khulna	Submitted		20-Feb-20	
	Workshop Report	Workshop 3 Report - Mid Term Progress Workshop	Pending			
	Workshop Report	Workshop 4 Report	Pending			
	Workshop Report	Workshop 5 Report	Pending			
	Workshop Report	Workshop 6 Report	Pending			
	Workshop Report	Workshop 7 Report	Pending			
D-9.2	**Communication Strategy**					
	Storage of all datasets BWDB	Storage of all datasets BWDB	Pending	4-Apr-21		December 2021
	Communication materials such as brochures, animations etc.	Communication materials such as brochures, animations etc.	Pending	4-Oct-20		December 2021
Q	**QPR**					
	QPR-1	QPR-1	Submitted		30-Jan-21	
	QPR-2	QPR-2	Submitted		7-Apr-21	
	QPR-3	QPR-3	Submitted		20-Aug-19	
	QPR-4	QPR-4	Submitted		7-Nov-19	
	QPR-5	QPR-5	Submitted		2-Mar-20	
	QPR-6	QPR-6	Submitted		10-Jun-21	
	QPR-7	QPR-7	Submitted		6-Sep-21	
	QPR-8	QPR-8	Submitted		20-Jan-21	
	QPR-9	QPR-9	Submitted		21-Mar-21	
	QPR-10	QPR-10				
	QPR-11	QPR-11				
	QPR-12	QPR-12				
	QPR-13	QPR-13				

1.3 Revised List of Modelling Milestones and Deliverables

Table 1.3 a: List of Modelling Deliverables & Milestones (Part 1)

DELIVERABLES RELATED TO MODELLING ACTIVITIES							
TOR Reference	**TOR Deliverables**	**Scale**	**Model**	**Status**	**Delivery Dates as per signed Contract**	**Delivery Dates (by Consultant)**	**Proposed Revised Deadline**
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			Pending	4-Apr-21	At the end of each model	
D-4A-1: 2, 3	Geospatial datasets of main sources and deposits of sediment at present, including full meta-data a restored and archived in Database of BWDB 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.	**Macro**	GBM Basin Model	submitted	D-4A-1: 2 (Jan 20) D-4A-1: 3 (Oct 20)	Mar-20	Nov-21
		Macro	Macro scale River Model	submitted		Mar-20	
		Macro	Macro scale River Model	submitted		Mar-20	
		Macro	GBM Basin Model Applications	Pending		7th Quarter	
		Macro	Macro scale River Model Applications	Pending		7th Quarter	
		Macro	Macro scale River Model Applications	Pending		7th Quarter	
		Macro	Sediment Budget Analyses	Pending		Apr-20	
D-4A-1:-4	Technical report (one report for 4A-1 & 4A-2)			Pending	Draft (Jul 20) Final (Jan 21)	Oct-20	Oct-21
Long Term Morphology Modelling							
D-4A-2: 1	Report on upgrade and update of present meso scale model including detailed explanation of the methodology and assumptions.	**Meso**	Pussur Sibsa	submitted	4-Oct-19	Mar-20	Aug-21
		Meso	Baleswar-Bishkhali Model	submitted		Mar-20	
		Meso	Lower Meghna	submitted		Mar-20	
		Meso	Sangu	submitted		Mar-20	
D-4A-2: 2, 3	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. 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	Pending	D-4A-2: 2 (Apr 20) D-4A-2: 3 (Jul 20)	7th Quarter	Oct-21
		Meso	Baleswar-Bishkhali Model	Pending		7th Quarter	Oct-21
		Meso	Lower Meghna	Pending		7th Quarter	Oct-21
		Meso	Sangu	Pending		7th Quarter	Oct-21
D-4A-2: 4	Technical report (one report for 4A-1 & 4A-2)			Pending	Draft (Jul 20) Final (Oct 20)	Nov-20	Oct-21
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	submitted	4-Oct-19	Apr-20	Interim Reports: October 2020 Final Report May 2021
		Meso	Sibsa	submitted		Apr-20	
		Meso	Baleswar	Pending		Apr-20	
		Meso	Bishkali	submitted		Apr-20	
		Meso	Lower Meghna	Pending		Apr-20	
		Meso	Sangu	Pending		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	Pending	D-4A-2: 2 (Apr 20) D-4A-2: 3 (Jul 20)	Dec-20	Aug-21
		Meso	Sibsa	Pending		Dec-20	
		Meso	Baleswar	Pending		Dec-20	
		Meso	Bishkali	Pending		Dec-20	
		Meso	Lower Meghna	Pending		Dec-20	
		Meso	Sangu	Pending		Dec-20	
		Meso	Pussur-Sibsa fine sediment model- ext	submitted		Jan-20	
D-4A-2: 4	Technical report (one report for 4A-1 and 4A-2)	**Meso**	**FINAL REPORT ON BANK**	Pending	Draft (Jul 20) Final (Oct 20)	Jan-21	Aug-21
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.	**Micro**	Pilot TRM Model for Polders 24 etc	Pending	4-Oct-20	Mar-20	Sep-21
		Micro	5 or more polder models	Pending		20-Sep	Sep-21

Table 1.3 b: List of Modelling Milestones and Deliverables (Part 2)

TOR Reference	TOR Deliverables	Scale	Model	Status	Delivery Dates as per signed Contract	Delivery Dates (by Consultant)	Proposed Revised Deadline
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.		Field Campaigns (several)	Pending	D-4B: 1, 2 (Oct 20) D-4B: 3 (Report: Draft - July 20, Final - Oct 20)	Dec-20	Sep-21
			Subsidence Geospatial Datasets	submitted		Oct-20	
				Pending		Oct-20	
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	Pending	D-4C: 1 (Apr 20) D-4C: 2 (Jul 20)		Oct-21
CLIMATE CHANGE EFFECTS							
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	Pending		Oct-20	Nov-21
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	Pending		Oct-20	Nov-21
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.			Pending		Nov-20	Nov-21
Other special purpose models							
D-4D: 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.	**Bay of Bengal**	Storm Surge Model	Pending		Dec-19	Aug-21
		Bay of Bengal	Storm Surge Model	Pending		Dec-20	Aug-21
		Bay of Bengal	Wave Propagation Model	Pending		Dec-20	
		Bay of Bengal	Salinity Model	Pending		2020 end	

1.4 List of Deliverables Submitted

Table 1.4 a: Total List of Deliverables including revised report submitted to PD

SL No.	Name of the Report	Date of Submission (m/d/y)	Reference as per Tracker	Program Item/Description as per Tracker	Reports under component
1	Final Inception Report	1/30/2019	D-1: 2	Inception Report (Workplan etc)	Component-1
2	QPR-2	04/07/2019	Q 2	QPR-2	QPR
3	1st interim Literature Review Report	6/24/2019	D-2: 1	Literature Inventory & Interim Review 1	Component-2
4	Report on Selection of Polders for Conceptual Design as Pilot Program	8/6/2019	D-5A:1	Polder Development Plan	Component-5
5	QPR-3	08/06/2019	Q 3	QPR-3	QPR
6	Database Design Report (1st submission)	9/11/2019	D-3: 3	Database Design Report	Component-3
7	Report on Regional Stakeholder's Consultation Workshop, Barisal (Both English and Bengali versions),	9/24/2019	D-9.1: 2	Workshop 1 Report - Barishal	Component-9
8	Report on Regional Stakeholder's Consultation Workshop, Khulna (Both English and Bengali versions),	9/24/2019	D-9.1: 2	Workshop 2 Report - Khulna	Component-9
9	Supply of GIS Based Maps	9/25/2019	D-3: 4	GIS Based Maps	Component-3
10	Supply of Boundary Data for Models at Various Scales	9/25/2019	D-3: 5	Supply of Model Boundary Data	Component-3
11	Data Reports, Inventory, Quality Checks	9/29/2019	D-3: 1, 2	Data Report, Inventory & Quality Checks (Includes field Data collection and monitoring programmes)	Component-3
12	QPR-4	11/7/2019	Q 4	QPR-4	QPR
13	Interim Literature Review Report 2	1/15/2020	D-2: 2	Literature Inventory & Interim Review 2	Component-2
14	QPR-5	3/2/2020	Q 5	QPR-5	QPR

SL No.	Name of the Report	Date of Submission (m/d/y)	Reference as per Tracker	Program Item/Description as per Tracker	Reports under component
15	Database Design Report (Revised)	5/21/2020	D-3: 3	Database Design Report	Component-3
16	Revised Interim Literature Review Report 1	5/31/2020	D-2: 1	Literature Inventory & Interim Review 1	Component-2
17	Mid-term Progress Workshop Report	6/8/2020	D-9.1: 2	Workshop 3 Report - Mid Term Progress Workshop	Component-9
18	QPR-6	6/10/2020	Q 6	QPR-6	QPR
19	Boundary conditions and data for calibration and validation of models (Revised Submission)	6/11/2020	D-3: 5	Supply of Model Boundary Data	Component-3
20	GBM Basin Model and Macro Scale river and coastal model -current scenario (1st submission)	8/12/2020; 8/16/2020;	D-4A-1: 2, 3	Model Set up Calibration & Validation	Component-4
21	Meso-scale Interim Report: Effect of human interventions on tidal and sediment dynamics in the Pussur-Sibsa basin (1st submission)	Sep 2020	D-4A-2: 3	Pussur Sibsa Fine Sediment Model	Component-4
22	QPR-7	9/6/2020	Q 7	QPR-7	QPR
23	MIKE 21C Bishkhali Meso-scale Bank Erosion Morphological Modelling Study: Model Development Report	10/08/2020	D-4A-2: 1, 2	Bishkhali: Model Set up Calibration & Validation	Component-4
24	Interim Subsidence Report	10/30/2020	D-4B: 1, 2,3	Report	Component-4
25	MIKE 21C Pussur meso-scale bank erosion morphological modelling study: Model development report	10/30/2020	D-4A-2: 1, 2	Pussur: Model Set up Calibration & Validation	Component-4
26	MIKE 21C Sibsa meso-scale bank erosion morphological modelling study: Model development report	10/30/2020	D-4A-2: 1, 2	Sibsa: Model Set up Calibration & Validation	Component-4
27	GBM Basin Model and Macro Scale river and	11/19/2020	D-4A-1: 2, 3	Model Set up Calibration & Validation	Component-4

SL No.	Name of the Report	Date of Submission (m/d/y)	Reference as per Tracker	Program Item/Description as per Tracker	Reports under component
	coastal model -current scenario (Revised)				
28	Lower Meghna-Tetulia river system morphological modelling study-Current situation	12/02/2020	D-4A-2: 1	Lower Meghna: Model Set up Calibration & Validation	Component-4
29	Meso-scale Interim Report: Effect of human interventions on tidal and sediment dynamics in the Pussur-Sibsa basin (revised)	12/04/2020	D-4A-2: 3	Pussur Sibsa Fine Sediment Model	Component-4
30	Monitoring Results on Sedimentation rate in Rivers and Floodplain	12/12/2020	D-3:6	Monitoring Results on Sedimentation rate in rivers	Component-3
31	Baleswar-Bishkhali morphological modelling study-Current situation-Interim Report	01/06/2021	D-4A-2: 1	Baleswar-Bishkhali: Model Set up Calibration & Validation	Component-4
32	Pussur-Sibsa morphological modelling study-Current situation - Interim Report	01/06/2021	D-4A-2: 1	Pussur Sibsa: Model Set up Calibration & Validation	Component-4
33	Sangu River morphological modelling study- Interim Report	01/06/2021	D-4A-2: 1	Sangu: Model Set up Calibration & Validation	Component-4
34	Review/Improvements on-going work (CEIP-I)	01/17/2021	D-5A:2	Improvement to 17 Polders	Component-5
35	QPR-8	01/20/2021	Q 8	QPR-8	QPR
36	Data Validation and Compilation Report	02/16/2021	D-3:8	Technical Report of Data Analysis and validation	Component-3
37	QPR-9	03/21/2021	Q 9	QPR-9	QPR

2 DATA ACQUISITION

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 in the 10th Quarter (ending March 2021)

In this quarter from January 2021 to March 2021, field survey for the 5 selected polders it has been completed for modelling TRM, cyclone storm surge/ flood hazard and finally conceptual polder design.

In addition, routine discharge and sediment measurements at Bahadurabad of Brahmaputra river and at Hardinge Bridge of Ganges river are also being continued for the better understanding of the sediment rating curve. As the discharge observations at Bahadurabad and Harding Bridge could not be achieved according to the planned schedule during March 2020 to September 2020 due to the lockdown of COVID-19 and also due to breakdown of two number ADCP, it is planned to continue the measurements over those two locations up to September 2021 during the extended period of the project. In this period, measurements will be done with a more frequency to achieve the target number of measurements which would also helpful for more understanding in the sediment rating curve analysis.

The survey methodology for the 5 polders survey employed by IWM survey teams is described in the Seventh Quarterly Report and the methodology for the others survey is described in details in the Second Quarterly Progress Report.

In this quarter from January 2021 to March 2021, the progress of discharge and sediment monitoring has been shown in Table 2.2 to Table 2.3.

Survey methodology/progress for the 5 polders:

The survey was started in Feb-2020. However, due to the lockdown under COVID-19, the field work was suspended in 20/03/2020 which has been restarted again in June-2020.

The main feature of the 5 polders survey included cross-section of surrounding embankment and internal drainage canals, detail structure inventory, cross-section of the surrounding rivers/canals, and land level survey. Out of these, the cross sections survey of the surrounding embankment, internal drainage canal and structure inventory have been already completed. The land level survey has been started from November 2020 and completed during this present quarter in February 10, 2021. The progress of the survey for 5 polders has been shown in Table 2.1.

Establishment of Bench Marks:

1. Bench Mark Fly:

The survey work for the all polders has been conducted with reference to available existing Survey of Bangladesh (SOB) bench mark (BM) situated around the polders area. TBMs have been kept by engraving on the permanent structures like regulator and sluices during the survey. Closing error will be checked to maintain the survey accuracy.

Table 2. 1: List of reference Bench Mark

1	BM-1039	The pillar is situated on the Upazilla Research center compound, PS: Dumuria, Dist: Khulna.	2.135	748347	2524502	Polder 29
2	BM-148	The pillar situated on the N/E corner of pond behind the house of Mr. Rumi commisioner east side of Patharghata Hospital road, Vill: Patharghata Hospital road, UP: Patharghata, Dist: Barguna.	2.137	806423	2439568	In Polder 40/1
3	BM-4103	Situated in the Turabgonj High School Compound, PS: Kamalnagar, Dist: Laxmipur	4.314	280961	2524625	In Polder 59/2
4	GPS-214	Situated in the Motirhat High School compound, PS: Komolnagar, Dist: Laxmipur	3.624	272674	2524873	
5	GPS-274	The pillar is situated at west side of Sandwip Para cyclone shelter and east bank of pond, Vill: Sandwip Para, UP: Bashkhali	3.599	383788	2446678	In Polder 64/1A and Polder 64/1B
6	BM-5117	SOB BM pillar no-5117 situated in SE corner of 73no Sora Primary School. Vill: Sora, Up: Gabura, PS: Shyamnagar, Dist: Satkhira	2.044	732187	2459629	In Polder 15

2. Embankment cross section:

Cross sections of the existing embankment are taken at 500meter intervals. Apart from the Polder 15, a total of 296Km embankment cross section survey has been carried out for the other 5 polders. The embankment cross sections of Polder 15 were conducted during 2016 under CEIP-I. However, some part of the embankment in Polder 15 has been damaged significantly due to the recent cyclone Amphan during May 20, 2020. This changed part of the embankment has been revisited through conducting 44 nos cross sections to cover he damaged part of the embankment. All cross sections are taken with perpendicular to the alignment of the embankment and has been extended at least 15 m beyond the toe in the country side (C/S) and 50 meter in the river side (R/S). At locations of breaches, damages, cross-sections have been taken at the closer intervals to represent the correct configuration of the cross-section. Cross section has been carried out by using optical level and handheld GPS.


Figure: Embankment Cross section Survey

3. Drainage Channel Survey:

The cross section of the Khal has been carried out at an interval of 500 meter or closer where ever necessary, to represent the correct configuration of the khal. A total of 326 Km drainage channel cross section survey are carried out in the five polders excluding Polder 15. The cross-section survey has been conducted during March 2017 at Polder 15 can be utilized here in this study. Cross section has been extended at 15 m beyond the bankline and spot level to be taken maximum 5 m apart or less as necessary to represent the correct configuration of the cross section. Cross sections of the drainage channel have been conducted by using optical level and hand GPS. The tentative locations of the cross section are made by delineating the alignment of the existing drainage channel.

4. Structure Inventory:
The structural dimensions/level, information like operational practice, physical condition of structure, launching apron and drainage channels condition has been recorded during the survey A log-sheet was prepared and followed in the field for recording the necessary information regarding the structure.

Figure. Sluce-10 of P-64/1A


Figure: Asanghar Sluice of P-29

5. Cross section of the surrounding river:

A total of 340 cross-sections of the peripheral river of all 6 polders have been conducted. River section survey was carried out at 500m-1000m interval considering the existence of the drainage regulator and also along the river bend. The cross sections extended up to high bank or up to embankment. The survey has been done by using DGPS & Echo sounder for the channel part while the shallower part and the dry land have been surveyed by using Optical Level.

Figure: Bathymetry Survey at the surrounding river of Polder 29.

6. Topographic Survey:

Spot levels together x, y co-ordinate have been carried out around 50mx50m interval by using optical level and GPS or total station for the drainage model. Spot level are undertaken in the open area mainly and some representative spot levels are also recorded inside the homestead. Initially, it was planned to conduct topography survey along the limited area (30% of the available open area). However, a total of 450 Km^2 has been carried out covering the whole area of 5 polders excluding the polder-15 for interest of this research project. Land level survey conducted during 2017 at Polder-15 under the detail design of CEIP-1 will be utilized for this study. Level data has been processed in Arc View GIS software to produce spot level with reference to MSL vertical datum. The spot levels have been taken along with physical features ID like khals, road, embankment, paddy land etc.

Table 2. 2: Progress/future plan of survey for 5 polders

Sl No	Polder	Item of work	Quantity	Progress up to Dec-2020	Progress in between Jan-Mar-2021	Cumulative Progress	Remarks
1	(P-40/1) Patharghata, Barguna	Embankment (Km)	22	22	0	22	
		structure (Nos.)	27	27	0	27	
		Drainage Canal (Km)	27	27	0	27	
		Perepheral River Section (nos.	43	43	0	43	
		Land Level (Km^2)	20	20	0	20	
2	(P-29) Dumuria/Batiaghata, Khulna	Embankment (Km)	49	49	0	49	
		structure (Nos.)	41	41	0	41	
		Drainage Canal (Km)	121	121	0	121	
		Perepheral River Section (nos.	120	120	0	120	
		Land Level (Km^2)	79	79	0	79	
3	(P-59/2) Char Alexander/Kamalnagar, Noakhali	Embankment (Km)	88	88	0	88	Land level surveyhas been completed in February 2021
		structure (Nos.)	8	8	0	8	
		Drainage Canal (Km)	73	73	0	73	
		Perepheral River Section (nos.	61	61	0	61	
		Land Level (Km^2)	209	0	209	209	
4	(P-64/1A) Bashkhali, Chittagong	Embankment (Km)	54	54	0	54	
		structure (Nos.)	5	5	0	5	
		Drainage Canal (Km)	42	42	0	42	
		Perepheral River Section (nos.	56	56	0	56	
		Land Level (Km^2)	52	52	0	52	
5	(P-64/1B) Bashkhali, Chittagong	Embankment (Km)	83	83	0	83	Land level survey has been completed in January 2021
		structure (Nos.)	50	50	0	50	
		Drainage Canal (Km)	63	63	0	63	
		Perepheral River Section (nos.	24	24	24	48	
		Land Level (Km^2)	90	50	40	90	
6	(P-15) Syamnagar, Satkhira	Embankment (Km)	27	27	0	27	Survey has been conducted during 2017 in connection with CEIP-1 for detail design. For this study revisit has been done through conducting 44 nos. embankment and 49 nos. perepheral river cross section. In addition, some structure inventory has been revisited.
		structure (Nos.)	7	7	0	7	
		Drainage Canal (Km)	20	20	0	20	
		Perepheral River Section (nos.	36	36	0	36	
		Land Level (Km^2)	31	31	0	31	
	Total	Embankment (Km)	323	323	0	323	
		structure (Nos.)	138	138	0	138	
		Drainage Canal (Km)	346	346	0	346	
		Perepheral River Section (nos.	340	340	24	364	
		Land Level (Km^2)	481	232	249	481	

Table 2. 3: Progress of the discharge observation

SL no.	Location/ River Name	Target (Number)		Progress upto Dec-2020	Progress in between Jan - Mar 2021	Cumulative progress upto Mar-2021	Remarks
		TOR	Modified				
A	3 main rivers						
1	Bahadurabad, Brahmaputra	18	48	30	4	34	Data collection will be done up to September 2021 as a part of the extended study.
2	Hardinge Bridge, Ganges	18	48	30	4	34	
3	Bhairab Bazar, Upper Meghna	18	48	26	0	26	
Total of A		54	144	86	8	94	
B	Lower Meghna						
4	Chandpur, Lower Meghna	3	5	5	0	5	2 spring+ 1 neap during monsoon and 2 nos. 1 Spring +1 Neap for dry season
C	5 nos. Tidal rivers surrounding the Polders.						
5	U/S of Mongla port, Pusur	44	8	8	0	8	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	8	0	8	
7	Charduani, Baleswar		8	8	0	8	
8	Bhandaria, Baleswar		8	8	0	8	
9	Polder-17/2, Gangril		8	8	0	8	
Total of C		44	40	40	0	40	
D	Additional 3 tidal River						
10	Dasmina, Tetulia	0	2	4	0	4	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	2	0	2	2 nos. measurement during June-Oct-19, 1 Spring+ 1 Neap
Total of D		0	7	9	0	9	

Table 2. 4: Progress of suspended sediment sampling for total concentration

SL no.	Location/ River Name	Discharge observation		Suspended Sediment Sampling for Total concentration			
		As per TOR	Modified	As per TOR	Progress upto Dec-2020	Progress from Jan-Mar 2021	Cumulative Progress upto Mar 2021
A	3 main rivers						
1	Bahadurabad, Brahmaputra	18	48	1056	2227	180	2407
2	Hardinge Bridge, Ganges	18	48				
3	Bhairab Bazar, Upper Meghna	18	48				
B	Lower Meghna						
4	Chandpur, Lower Meghna	3	5	234	149	0	149
C	5 nos. Tidal rivers surrounding the Polders.						
5	U/S of Mongla port, Pusur	44	40	3432	2736	0	2736
6	Nalian, Shibsha						
7	Charduani, Baleswar						
8	Bhandaria, Baleswar						
9	Polder-17/2, Gangril						
D	Additional 3 tidal River (as per modified plan)						
10	Dasmina, Tetulia	0	2	0	633	0	633
11	Kakchira, Bishkhali	0	3				
12	Taliar dwip,Shangu	0	2				

2.2.3 GPS and RSET-MH Field and Lab Work

Participants:
International
IK-9 Michael S. Steckler, LDEO, Columbia University (steckler@ldeo.columbia.edu)
INK-25 Carol A. Wilson, Louisiana State University (carolw@lsu.edu)
Bar Oryan, Columbia University
National
NNK-12 Abdus Salam Sikder, IWM
Sharmin (Pinky) Akter, Dhaka University
Masud Rana, Dhaka University

RSET Lab work and data processing

In order to measure sedimentation, subsidence, and elevation changes, continuous GPS and Rod Surface Elevation Tables with Marker Horizons (SET-MH) are co-located at multiple sites in SW Bangladesh (**Figure 2.1**). These include Sonatola (SNT1, SNT2), Jorshing (JRSN) and Baintola

(BNTL), Patuakhali (PUST), Khepupara (KHEP), Hiron Point (HRNP), Polder 32 (PD32), and Khulna University (KHL2). RSET-MH locations and dates of their installations are given in **Table 2.4**.

Between January and March, Dhaka University students Sharmin Akter and Masud Rana continued the processing of SET-MH measurements from the last field campaign that took place in December 2020. During this processing, Akter, Rana, and INK-25 Wilson participated in monthly zoom meetings to discuss the data management, calculations of elevation change and sediment vertical accretion, graphing of the data, and interpretations of preliminary findings. Although measurements were taken at all 22 RSET locations, we focused on the results from PD32 and the adjacent Sundarbans, since this has the longest timeline of data. Our findings in the Sundarbans are summarized in **Figure 2. 2**. There appears to be a continued cm-scale elevation gain on yearly basis (x = 1.3-2.1 cm yr^{-1}), a distinct seasonal signal (greater in monsoon; less elevation gain or even loss after dry season), and elevation gain is a direct result of exceptionally large measured vertical accretion (2-3 cm yr^{-1}). These results corroborate those reported by Bomer et al. (2020b), who reported that the platform experiences greater inundation depths & hydroperiod during the monsoon than dry season, sedimentation rates are well-correlated with hydroperiod, and that shallow subsidence (0.8-1.5 cm) is documented during the dry season when the shallow groundwater table lowers (**Figure 2.2**). It is important to note that the Sundarbans appear to be tracking Effective Sea Level Rise (ESLR), as documented by Pethick and Orford (2013), and that the sustainability of the mangrove platform is reliant on adequate sediment input to balance ESLR in this mineralogenic tidal deltaplain (organic content <10%; Bomer et al., 2020a, b). Within Polder 32 (results shown in **Figure 3**), Rana and Akter documented that there is also a distinct seasonal signal, including elevation loss/compaction during dry season. We interpret that drastic changes in elevation follow plowing and/or farming practices. Much larger elevation gain and vertical accretion (x = 2.8 cm yr^{-1}) was measured at peripheral sites (may be some edge effects), and interior sites show modest elevation gain and vertical accretion in comparison, though we caveat this longitudinal dataset is shorter (**Figure 2.3**). There appear to be very complex seasonal shallow subsidence signals that include both soil swell and consolidation, and these results vary spatially (peripheral vs interior) and temporally. Quality control checks and interpretations are ongoing.

Results for the other SET-MH locations are ongoing, but more longitudinal data are needed to make accurate estimates of elevation change, sediment vertical accretion, and shallow subsidence at these sites (**Figure 2.4** shows example data from SNT1 and JRSN). There were plans for another field campaign to take place in early April 2021, however COVID surges at that time prevented travel to the SW region. Field campaigns will resume once travel restrictions are lifted, and it is safe for personnel to travel again.

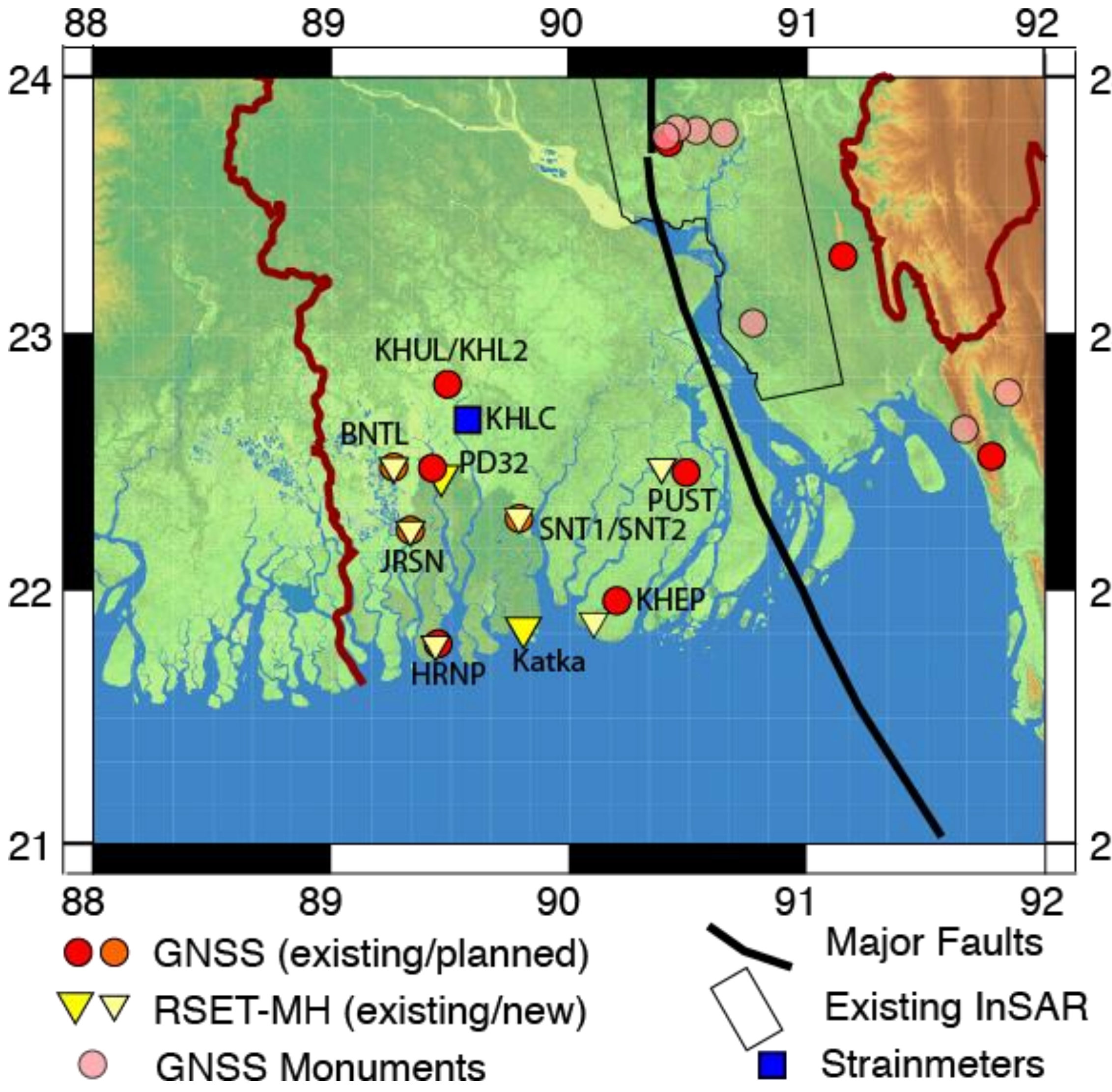


Figure 2. 1: Map of GPS and SET-MH sites installed, measured, and/or serviced.

Table 2. 5: Updated table of all rod SET-MH locations and date installed

RSET #	RSET LOCATION	BWDB Install site	Latitude °N	Longitude °E	Date Installed	Number of 4' rods installed	Notes
RSET-1	Sorbothkhali/P32	P32	22.45943	89.46863	10/26/2013	10	Sundarbans streambank
RSET-2	Sorbothkhali/P32	P32	22.45788	89.46806	10/27/2013	13	Sundarbans interior
RSET-3	Shrinagar/P32	P32	22.51961	89.49201	10/29/2013	8	Inside polder
RSET-4	Shrinagar/P32	P32	22.52029	89.49152	10/30/2013	8	Inside polder
RSET-5	Sorbothkhali/P32	P32	22.44785	89.50017	3/13/2015	10	Sundarbans interior
RSET-6	Sorbothkhali/P32	P32	22.4599	89.4764	3/14/2015	7	Sundarbans streambank
RSET-7	Shrinagar/P32	P32	22.51907	89.49034	10/5/2017	12	Inside polder
RSET-8	Shrinagar/P32	P32	22.51997	89.49043	10/9/2017	9	Inside polder
RSET-9	Katka	Katka	21.86285	89.77966	7/4/2018	9	Sundarbans streambank
RSET-10	Katka	Katka	21.863	89.77913	7/5/2018	13	Sundarbans interior
4A	Sarankhola/SNT1	Site 4	22.255623	89.805673	7/19/2019	20	Inside polder
4C	Sarankhola/SNT1	Site 4	22.24861	89.800921	7/20/2019	16	Outside polder
RSET-11	Hiron Point	Site 3	21.81892	89.45645	7/22/2019	20	Sundarbans interior
RSET-12	Hiron Point	Site 3	21.818385	89.456976	7/22/2019	19	Sundarbans streambank
RSET-13	Koyra/JRSN	Site 2	22.25625	89.33666	7/24/2019	19	Outside polder
RSET-14	Koyra/JRSN	Site 2	22.24704	89.343645	7/24/2019	20	Inside polder
RSET-15	Baintola/BNTL	Site 1	22.4978	89.23315	7/25/2019	19	Inside polder
RSET-16	Baintola/BNTL	Site 1	22.49867	89.25239	7/25/2019	16	Outside polder
RSET-17	Kuakata/KHEP	Site 6	21.85821	90.13929	7/30/2019	16	Outside polder
RSET-18	Kuakata/KHEP	Site 6	21.85627	90.13556	7/31/2019	14	Inside polder
RSET-19	Patuakhali/PUST	Site 5	22.42123	90.45152	8/2/2019	20	Outside polder
RSET-20	Patuakhali/PUST	Site 5	22.42041	90.44698	8/2/2019	18	Inside polder

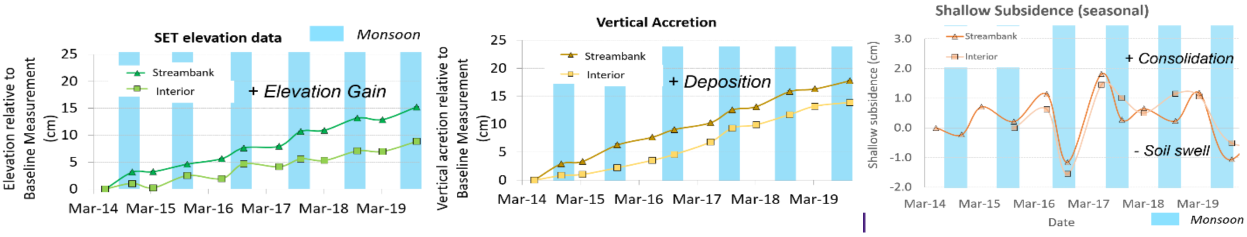


Figure 2. 2: SET-MH results for P32 Sundarbans sites (RSETs 1 & 2, 5 & 6).

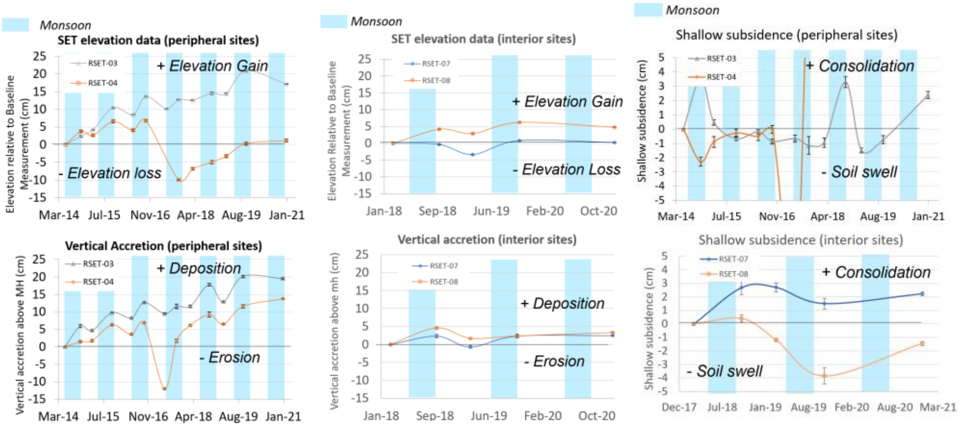


Figure 2. 3: SET-MH results for P32 sites (RSETs 3 & 4 [peripheral], 7 & 8 [interior]).

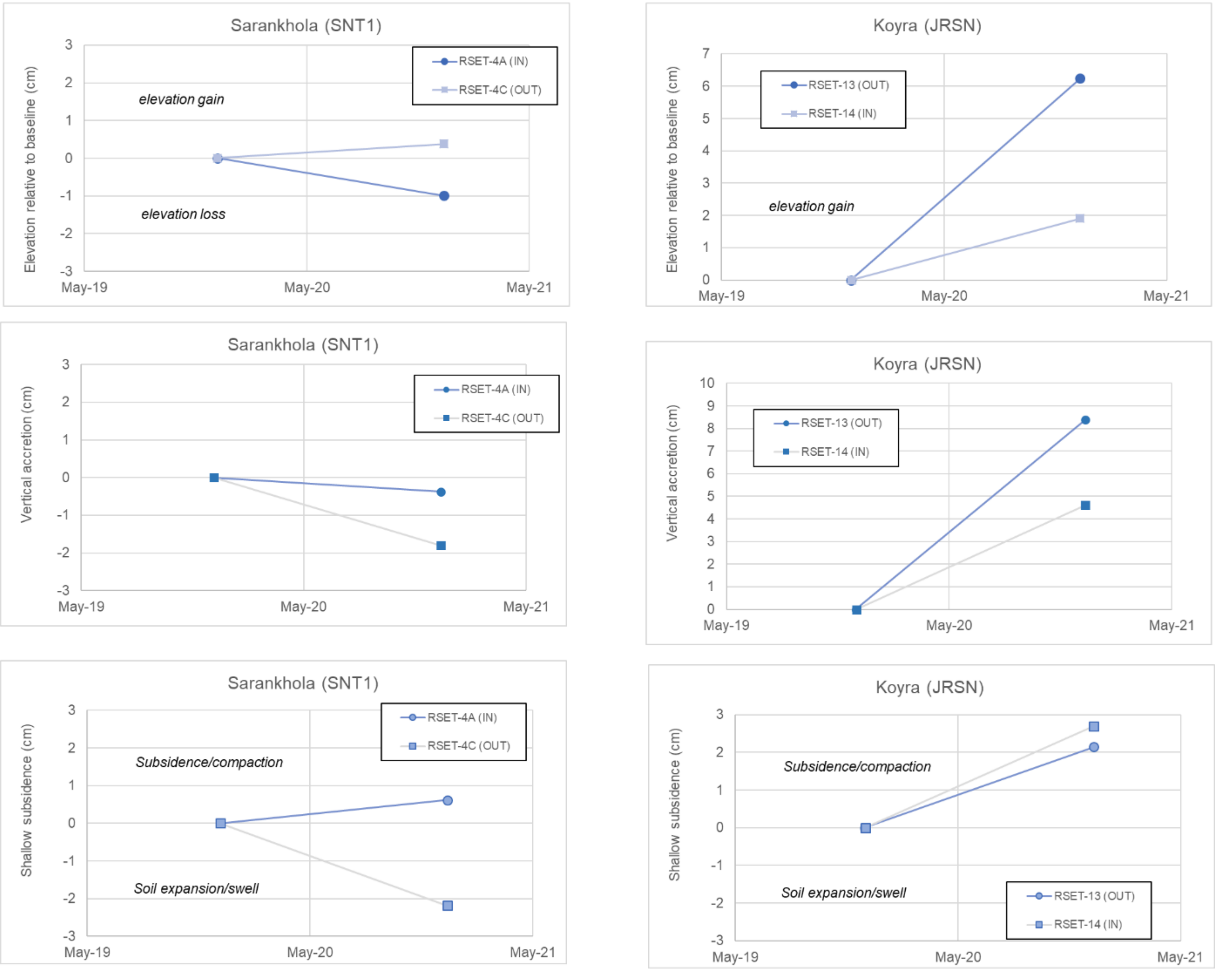


Figure 2. 4: Very preliminary SET-MH results for Sarankhola (SNT1) and Koyra (JRSN). More data from field campaigns and subsequent measurements are needed before accurate rates and interpretations can be made.

GPS Lab work and data processing

Data from the continuous GPS network in SW Bangladesh continues to be downloaded daily. Processing of the data is updated periodically, refining the positions and velocities recorded. GPS enables observations using fixed antennas over years to estimate rates of tectonic deformation of the crust as well as its subsidence or uplift on the order of ±1 mm/y or better. Generally, it takes >2.5 years to determine reliable horizontal rates and >4.5 years for vertical rates (Blewitt and Lavallée, 2002). **Figure 1** shows the latest results. The font size used for the subsidence rates is proportional to the square root of the length of the times series used for determining the rates to reflect the reliability of the rate estimates. The rates for the newest sites, established in 2019 are still too short to be reliable. The larger symbols correspond to sites that have recorded data, sometimes intermittently, for 5-17 years. In the coastal belt, GNSS subsidence rates near the sandy Brahmaputra (Lower Meghna) river mouth are 3-4 mm/y, similar to the Holocene rates determined by Grall et al. (2018) and lower than the river gauge sites (Becker et al., 2020). Farther west, we generally determined higher rates (5-7 mm/y for longer term stations) that exceed the Holocene average rates by several millimeters per year. We associate these higher rates with muddier settings farther from the river mouth that may partially reflect additional near-surface consolidation and organic matter oxidation.

Synthesis of subsidence measurements

We have begun to synthesis the still ongoing data sets implications for estimates of subsidence. We have combined data from RSET-MH, continuous GPS, campaign GPS, tube wells, tide gauges, historic sites and vertical optical fiber strain meters. This collection of subsidence measurements using different methodologies exhibit variations that show systematic patterns both spatially and with depth. The combination of multiple methods of estimating subsidence and compaction in the GBD leads to a pattern of subsidence that varies with timescale, spatial location and depth range of observation (**Figure 2.5**). Holocene averaged subsidence rates (Grall et al., 2018) increase from the Hinge Zone of the early Cretaceous passive margin seaward. These rates, which average over 10,000 year period, increase from the Hinge Zone of the early Cretaceous passive margin seaward. These rates increase from near zero at the Hinge Zone to 4.5 mm/y near the coast. There rates, at our longest timescales, are lower than other measurements. We attribute this to excluding the higher rate at which fresh young sediments undergo their initial compaction and organic matter degradation. The rates for multi-century historic sites and Holocene sites are similar, so we conclude this occurs at the century time scale and the longer time scales reflect compaction and isostasy from a more stable sediment porosity profile.

River gauges (Becker et al., 2020) and the continuous GPS systems yield rates that are a few millimeters a year higher (3-7 mm/y; **Figure 2.6**). These systems are rooted in the ground or on buildings and therefore do not measure very near surface compaction. However, ongoing compaction of their underlying sediments contributes to greater current rates of subsidence than the long-term sites. The campaign GPS measurements made at Survey of Bangladesh monuments record both the shallow and deep subsidence and yield rates as great as 11-15 mm/y.

Systems that measure compaction all the way to the surface record, such as RSET-MH (**Fig. 2.2, 2.3**) and optical fiber strain meters, yield high rates of 9-10 mm/y (**Figure 2.5**). Combining the different results, we begin to discern the subsidence variations with depth. These results indicate that there must be considerable subsidence arising from near surface processes related to compaction, sediment consolidation and organic matter degradation. The upper few meters of sediments tend to be finer grained. These sediments are reworked by shifting channels so that the preserved sediments are generally coarse. However, these loose ephemeral sediments may contribute to high compaction rates in the near surface that could reach 5 mm/y or more (**Figure 2.6**). The depth distribution of the overall compaction contribution is uncertain. The KHLC compaction meter suggests it is mainly in the Holocene in the sediment above the incised Brahmaputra Valley. However, the RSET-MH suggests that it may be even shallower. This significant shallow contribution needs further effort to better quantify the rates.

The deep compaction below the Holocene appears to be limited (**Figure 2.6**). The bulk of the subsidence from compaction is coming from the Holocene. An important consideration is the incision of the delta during the last glacial maximum. Lowstand deltas are found offshore near the shelf edge. Within the Brahmaputra, a large valley 60-90 m deep was incised into the older sediments. Sediments do not significantly decompact with unloading. Further compaction only occurs when the valleys are filled and the overburden pressure exceeds the level previously reached. Thus, during the Holocene compaction primarily occurred in the Holocene sediments and not in the earlier strata. At depths greater than 3-5 km, the sediments in the GBD are highly over pressured (Zahid and Uddin, 2005), which also means that dewatering and compaction of these sediments are very limited (e.g., Gordon and Flemings, 1998).

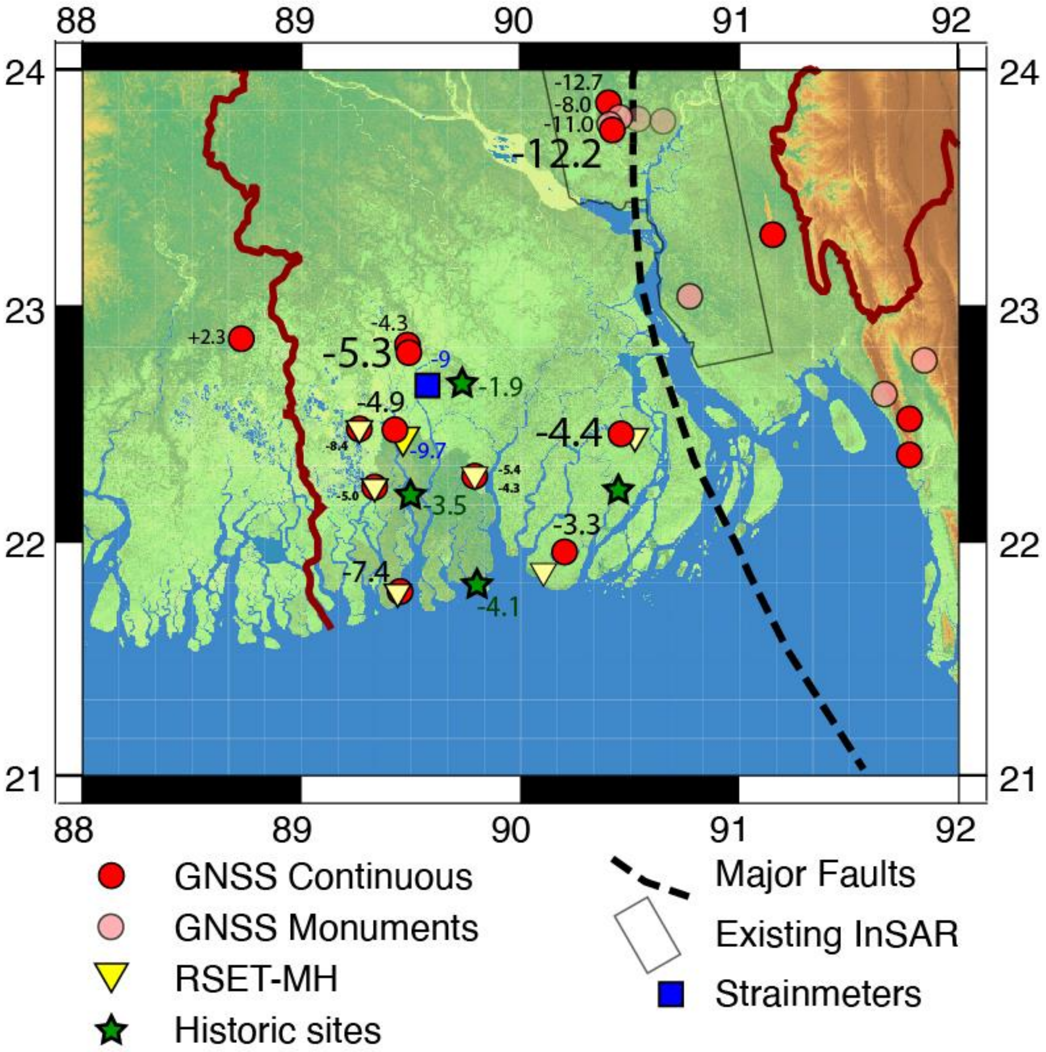


Figure 2. 5: Subsidence rates in the lower Ganges-Brahmaputra Delta west of the deformation front. Except for historic sites, the text size is proportional to the square root of the length of the time series to represent the reliability of the values. High rates around Dhaka reflect subsidence from ground water withdrawal. Historic sites yield values similar to Holocene average rates (Grall et al., 2018). GPS rates are similar to slightly higher, especially farther west. The vertical borehole strain meter (DeWolf et al., submitted) and published RSET-MH value (Bomer et al., 2019) record compaction up to the surface and yield significantly higher rates.

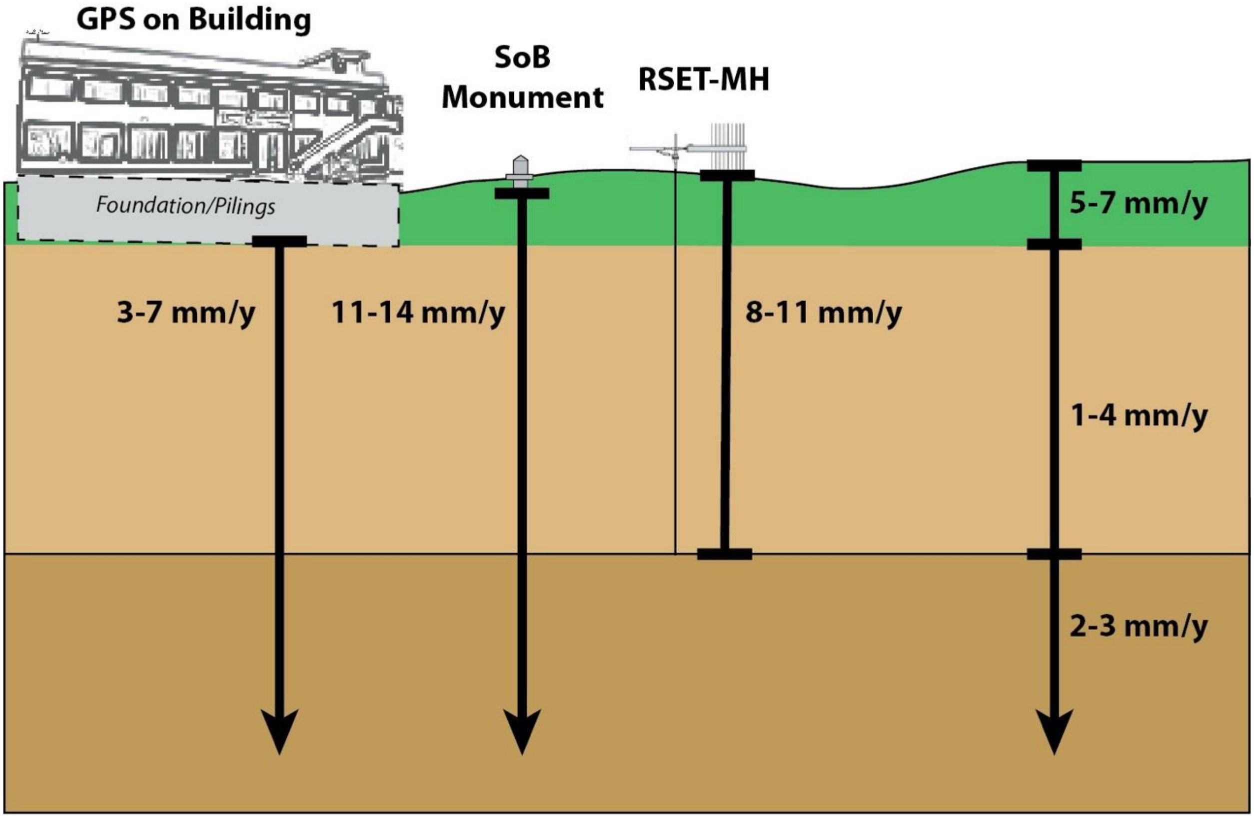


Figure 2. 6: Subsidence measurements from different methods with their relative depth ranges and a possible synthesis of their contribution to subsidence at right.

Implications of subsidence measurements

Given the diversity of subsidence rates, which rates are significant for people living on delta? Reinforced concrete buildings, such as the ones that host the GNSS systems, are subsiding at 3-7 mm/y. Design for reconstructing the embankments must take rates of sea level rise and ground subsidence into account. Are the embankments constructed of compacted sand and concrete pilings settling at a rate similar to the GNSS? In contrast, in regions of active sedimentation, we find significantly higher rates of subsidence. Is this high rate of the shallowest subsidence due to very near surface consolidation only present where there is active sedimentation? If sedimentation stops, how long will higher subsidence continue? From the historic sites, we only know it is shorter than 300-600 years. At Polder 32, Auerbach et al. (2015) found that there was a loss of 1.0-1.5 m of elevation relative to the Sundarbans over 50 years since the embankment was built. Using their values of 11 mm/y of sediment accretion in the Sundarbans and an extra 20 cm of land loss from root extraction, it suggests 4-15 mm/y of subsidence in the interior of the polder since the embankment cut it off from natural sedimentation. Thus, the natural subsidence processes can continue for decades. This means that for restoring polder elevation through nature-based solutions, such as Tidal River Management (Shampa, 2012; Islam et al., 2021), the sediment volumes required need to include the higher subsidence and compaction rates.

The subsidence rates in the GBD vary spatially, with time and with depth. When planning adaptations to rising sea level in the GBD, the physical environment and nature of any construction must be taken into account. The subsidence rate that must be taken into account can differ, even locally, for nature-based solutions and hard constructed solutions. Further work is still required to better understand the variability of subsidence rates and its relationship to the underlying geology and the physical processes that contribute to subsidence.

These results culminated in two presentations for the European Geosciences Union on April 28, 2021, which was attended by IK-9 Steckler, INK-25 Wilson, and DU students Sharmin Akter and Masud Rana:

Wilson, C., Bomer, E.J., Akter, S. Rana, M., Steckler, M., and Oryan, B., 2021. Impacts of poldering: elevation change, sediment dynamics, and subsidence in the natural and human-altered Ganges Brahmaputra tidal deltaplain. European Geosciences Union Annual Meeting, 26-30 April. Oral presentation.

Steckler, M., Oryan, B., Jaman, M.H., Mondal, D., Grall, C., Wilson, C., Akhter, H., DeWolf, S., and Goodbred, S., 2021. Recent measurements of subsidence in the Ganges Brahmaputra delta, Bangladesh. European Geosciences Union Annual Meeting, 26-30 April. Oral presentation.

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Auerbach, L., Goodbred, S., Mondal, D., Wilson, C., Ahmed, K.R., Roy, K., Steckler, M., Gilligan, J., Ackerly, B. (2015). In the Balance: Natural v. Embanked Landscapes in the Ganges-Brahmaputra Tidal Delta Plain, Nature Climate Change. 5, 153-157, doi: 10.1038/nclimate2472.

Becker, M., F. Papa, M. Karpytchev, C. Delebecque, Y. Krien, J.U. Khan, V. Ballu, F. Durand, G. Le Cozannet, A.K.M.S. Islam, S. Calmant, C.K. Shum (2020) Water level changes, subsidence, and sea level rise in the Ganges–Brahmaputra–Meghna delta, Proceedings of the National Academy of Sciences, 117 (4) 1867-1876; doi:10.1073/pnas.1912921117.

Blewitt, G. and D. Lavallée (2002) Effect of annual signals on geodetic velocity. Journal of Geophysical Research, 107, 2145-2156, doi: 10.1029/2001JB000570.

Bomer, E.J., Wilson, C.A., Quirk, T. (2020a). Process Controls of the Live Root Zone and Carbon Sequestration Capacity of the Sundarbans Mangrove Forest, Bangladesh. *Sci* 2(35), DOI:10.3390/sci2020035.

Bomer, E.J., Wilson, C.A., Hale, R.P., Hossain, A.N.M., and Rahman, F.M.A. (2020b). Surface elevation and sedimentation dynamics in the Ganges-Brahmaputra tidal delta plain, Bangladesh: implications for the sustainability of natural and human-impacted coastal systems. *Catena*.187:104312.

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Grall, C., M.S. Steckler, J.L. Pickering, S. Goodbred, R. Sincavage, C. Paola, S.H Akhter, V. Spiess (2018) A base-level stratigraphic approach to determining Holocene subsidence of the Ganges–Meghna–Brahmaputra Delta plain. Earth and Planetary Science Letters, Earth and Planetary Science Letters 499, 23–36, 10.1016/j.epsl.2018.07.008.

Islam, Md.F., H. Middelkoop, P.P. Schot, S.C. Dekker, J. Griffioen (2021). Spatial and seasonal variability of sediment accumulation potential through controlled flooding of the beels located in the polders of the Ganges-Brahmaputra-Meghna delta of Southwest Bangladesh. Hydrological Processes. 35, 14119, doi.org/10.1002/hyp.14119.

Pethick, J. and Orford, J.D., 2013. Rapid rise in effective sea-level in southwest Bangladesh: Its causes and contemporary rates. *Global Planetary Change* 111: 237–245. DOI: https://doi.org/10.1016/j. gloplacha.2013.09.019

Shampa, M.I.M.P. (2012). Tidal river management (TRM) for selected coastal area of Bangladesh to mitigate drainage congestion. International Journal of Scientific and Technology Research,

1:1–6. Zahid and Uddin, 2005)

3 DEVELOPMNT OF INTERACTIVE GEODATABASE OF COASTAL ZONE

3.1 Introduction

This section presents the progress of tasks and activities for developing an Interactive Geodatabase for Coastal Zone (IGDCZ) during the 10th quarter (January 2021 to March 2021) of the project.

According to the Terms and Reference (ToR) of the project in Component-3 the objectives are:

- To collect all input datasets, undertake Quality Assurance/Quality Checking (QA/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 achieve the above objectives, a web GIS based Interactive Geodatabase for Coastal Zone (IGDCZ) has been developing under this project. IWM team have been conducting several tasks and activities during this quarter. The summary of work progress of each tasks are presented in Table 3.1.

Table 3. 1: Summary of work progress

Sl No	Task & Activities	Progress (%) Up to 9th Quarter	Progress (%) 10th Quarter	Overall Progress (%)
1	Inception Phase			
1.1	Review Existing Systems	100	-	100
1.2	Consultation with Project Team	continue		continue
1.3	Consultation with Project Client	continue		continue
1.4	Requirement Analysis	100	-	100
1.5	Data Requirements and Data sources	100	-	100
1.6	Conceptual System Architecture	100	-	100
1.7	Inception Report	100	-	100
2	Data Collection and Processing			
2.1	Coastal Bank Erosion (Satellite Image)	100	-	100
2.2	Land use Classification (Satellite Image)	85	0	85
2.3	Other Data Collection (shapefile & tabular)	90	-	90
2.4	Other Data Processing (shapefile & tabular)	85	5	90
3	GIS Mapping			

Sl No	Task & Activities	Progress (%) Up to 9th Quarter	Progress (%) 10th Quarter	Overall Progress (%)
3.1	Polder Maps for Data Collection	85	0	85
4	Database Design & Development			
4.1	Database Design Development	100	-	100
4.2	Database Design Report	100	-	100
4.3	Database Implement	90	0	90
5	Web GIS Application Development			
5.1	IGDCZ Prototype Development	100	-	100
5.2	Full Version Development	90	3	93
5.3	GIS Core Modules	90	3	93
5.4	Dashboard Development	80	10	90
5.5	Metadata Preparation	40	5	45
5.6	Metadata Interface Development	40	20	60
5.7	User Administrative Module	70	20	90
5.8	Document Archiving	100	-	100
5.9	Tutorial (help tutorial)	100	-	100
5.10	Testing & Debugging	85	5	90
5.11	Data Validation and Check	90	2	92
5.12	Software & Hardware Procurement	-	-	-
5.13	Installation of SW and HW at BDWB Data Centre	-	-	-
5.14	Migration of Database and Application to BWDB Servers	-	-	-
5.15	Fully operational commissioning	-	-	-
5.16	Preparation of User Instruction Manual	-	-	-
6	Reports			
6.1	Database Implementation Report	submitted		
6.2	Validation and Compilation Report (1st version)	submitted		
7	Training & Technology Transfer	-	-	-
8	Feedback and update (ongoing)		12 comments were addressed	

3.2 Report Preparation

- **Database Implementation Report**

A report on “ICT Implementation Plan” regarding implementation of the IGDCZ has been prepared and submitted to World Bank Mission and the client in February 2021. The contents of this report are User requirements and data needs, development platform and Infrastructure, Database development and validation, software testing, operational acceptance plan, implementation plan and finally conclusion and recommendations.

- **Database Validation and Compilation Report**

The first version of Database Validation and Compilation report has been prepared and submitted to the World Bank in February 2021. This report illustrates the methods and technique by which the collected data have been checked, validated and compiled them into the database. The validation process has been applied to each and every feature and data (more than 24 layers and tables) which are stored in the IGDCZ database. This process is ongoing, whenever a new data will come that would be verified and validated and registered into the database.

3.3 Meeting and Presentation

There were two online presentation and meetings held with WB Mission and the client regarding the implementation of IGDCZ at BWDB headquarter. To deploy the IGDCZ in BWDB, the estimation of hardware (Server and peripherals) and storage requirement was done scientifically considering probable maximum number of concurrent users.

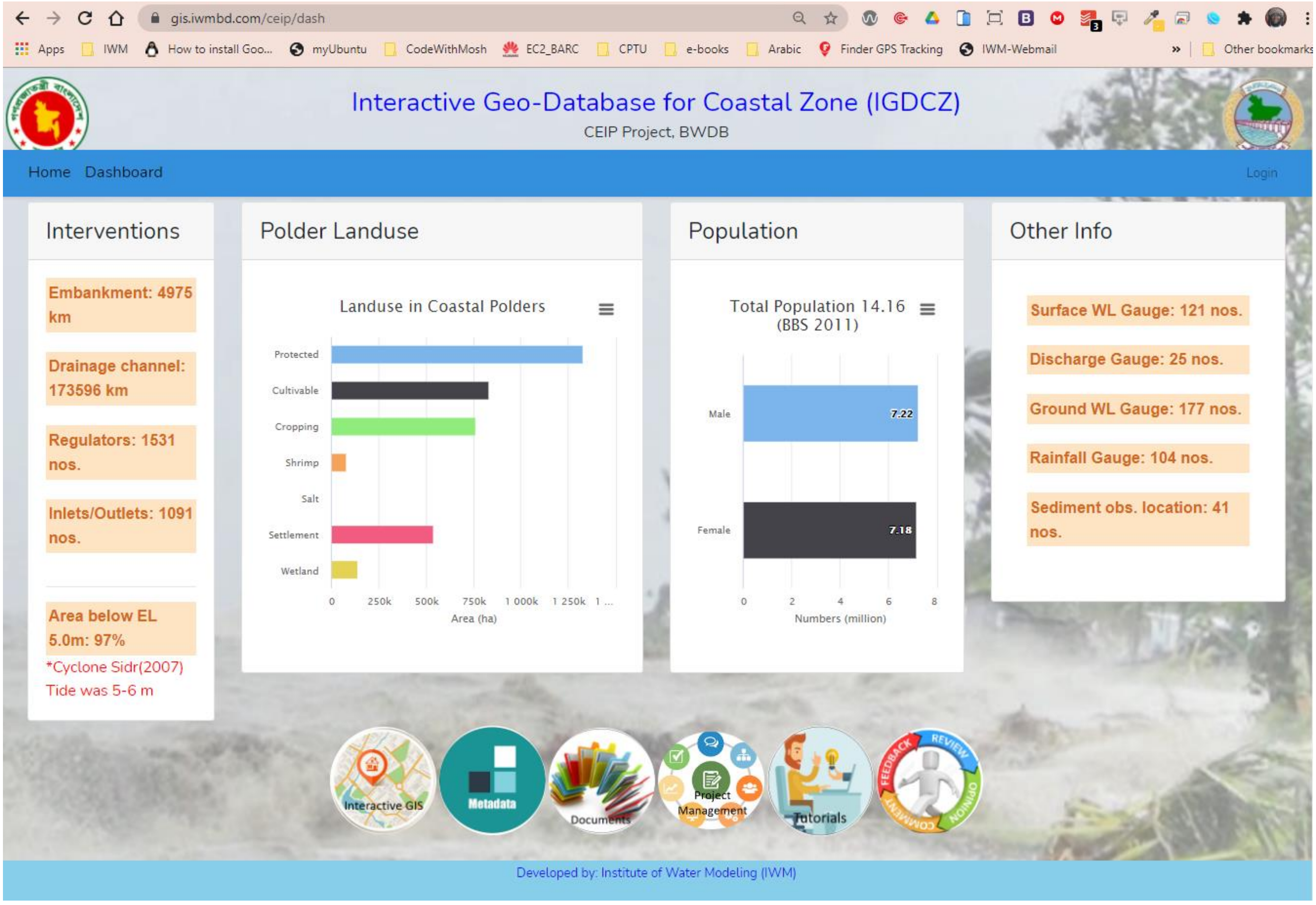
In another meeting held at CEIP project office which mainly discussed the budgets for software hardware procurement.

Required platform, software and capacities were assessed. Detail specifications and costs of the required hardware and software are prepared and submitted to the client and the World Bank for allocating the funds.

3.4 Web Application Development

- **Dashboard Development**

Dashboard has been improved a lot, it consists of interfaces of the summary information of polder database and the gateway to access different modules of the application. It has been made more user friendly. A snapshot of the Dashboard is presented below.



Interactive Geo-Database for Coastal Zone (IGDCZ)
CEIP Project, BWDB

Interventions

Embankment: 4975 km

Drainage channel: 173596 km

Regulators: 1531 nos.

Inlets/Outlets: 1091 nos.

Area below EL 5.0m: 97%

*Cyclone Sidr(2007) Tide was 5-6 m

Polder Landuse

Population

Other Info

Surface WL Gauge: 121 nos.

Discharge Gauge: 25 nos.

Ground WL Gauge: 177 nos.

Rainfall Gauge: 104 nos.

Sediment obs. location: 41 nos.

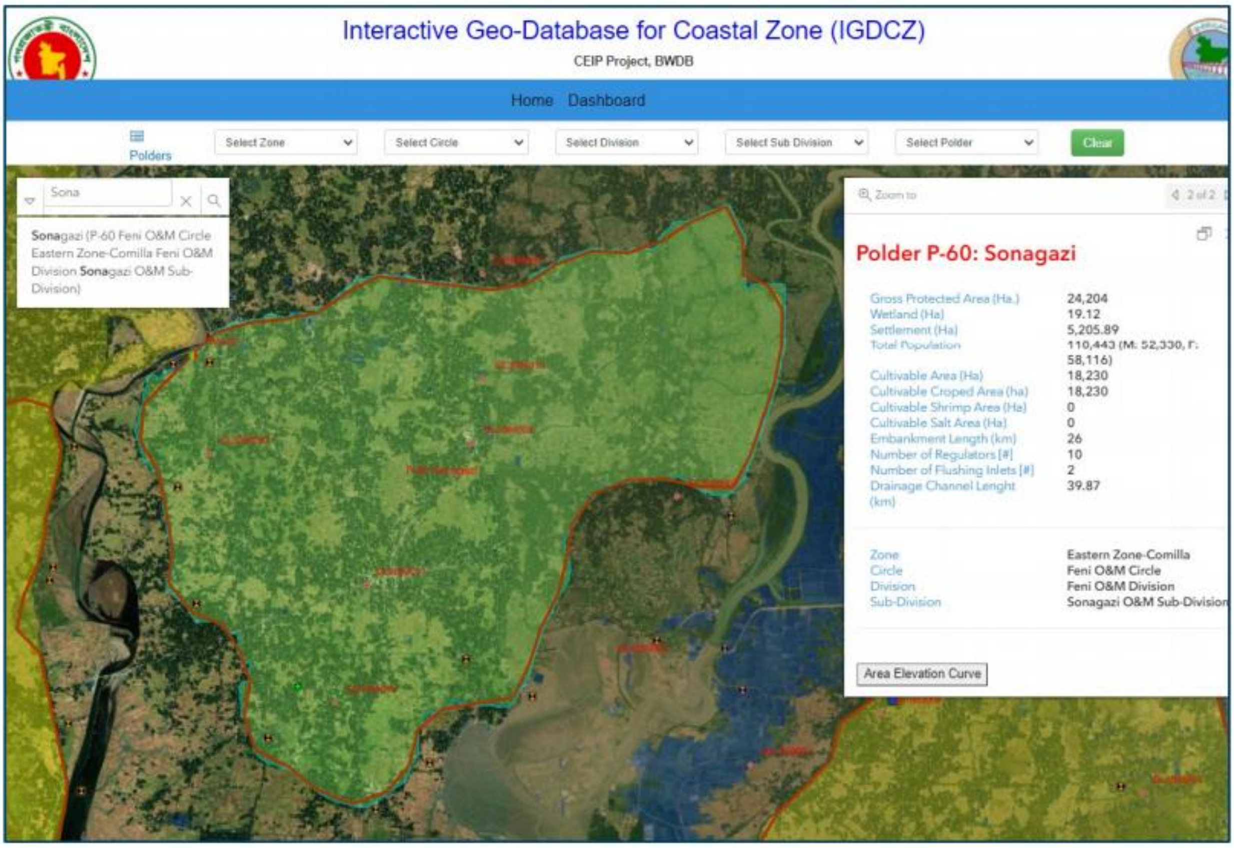
Developed by: Institute of Water Modeling (IWM)

Figure 3. 1: Dashboard of IGDCZ

- **Polder Data Modification**

  A web Interface of Polder Data modification tool has been developed with the core GIS module. User can search a particular polder by selecting a Zone, Circle, Division and Sub-division from Zone, Circle, Division and Sub-division list. Subsequently polder data can be modified on the selected polder attribute table in the database (Figure 3. **2**).

  Also, data polder information can be edited and updated through interactive interfaces. Data entry validation has been applied (**Figure 3. 3**).



Interactive Geo-Database for Coastal Zone (IGDCZ)

CEIP Project, BWDB

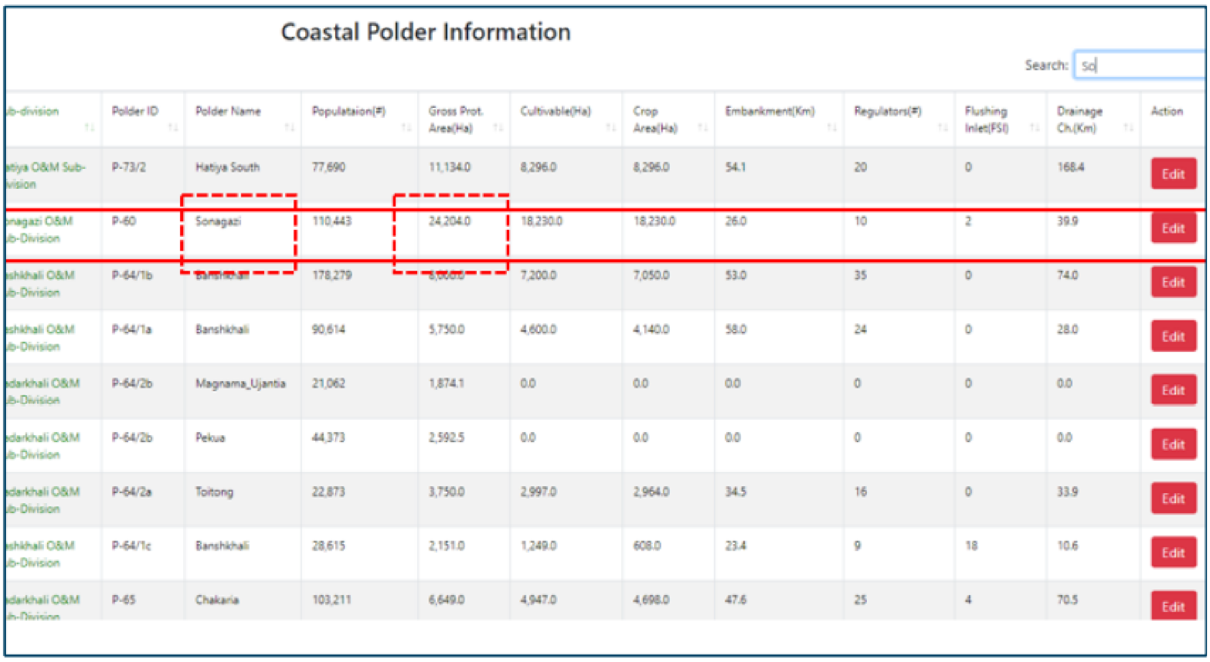
Sonagazi (P-60 Feni O&M Circle Eastern Zone-Comilla Feni O&M Division Sonagazi O&M Sub-Division)

Polder P-60: Sonagazi

Gross Protected Area (Ha.)	24,204
Wetland (Ha)	19.12
Settlement (Ha)	5,205.89
Total Population	110,443 (M: 52,330, F: 58,116)
Cultivable Area (Ha)	18,230
Cultivable Croped Area (ha)	18,230
Cultivable Shrimp Area (Ha)	0
Cultivable Salt Area (Ha)	0
Embankment Length (km)	26
Number of Regulators [#]	10
Number of Flushing Inlets [#]	2
Drainage Channel Lenght (km)	39.87

Zone	Eastern Zone-Comilla
Circle	Feni O&M Circle
Division	Feni O&M Division
Sub-Division	Sonagazi O&M Sub-Division

Figure 3. 2: Interface of Polder Searching and Information



Coastal Polder Information

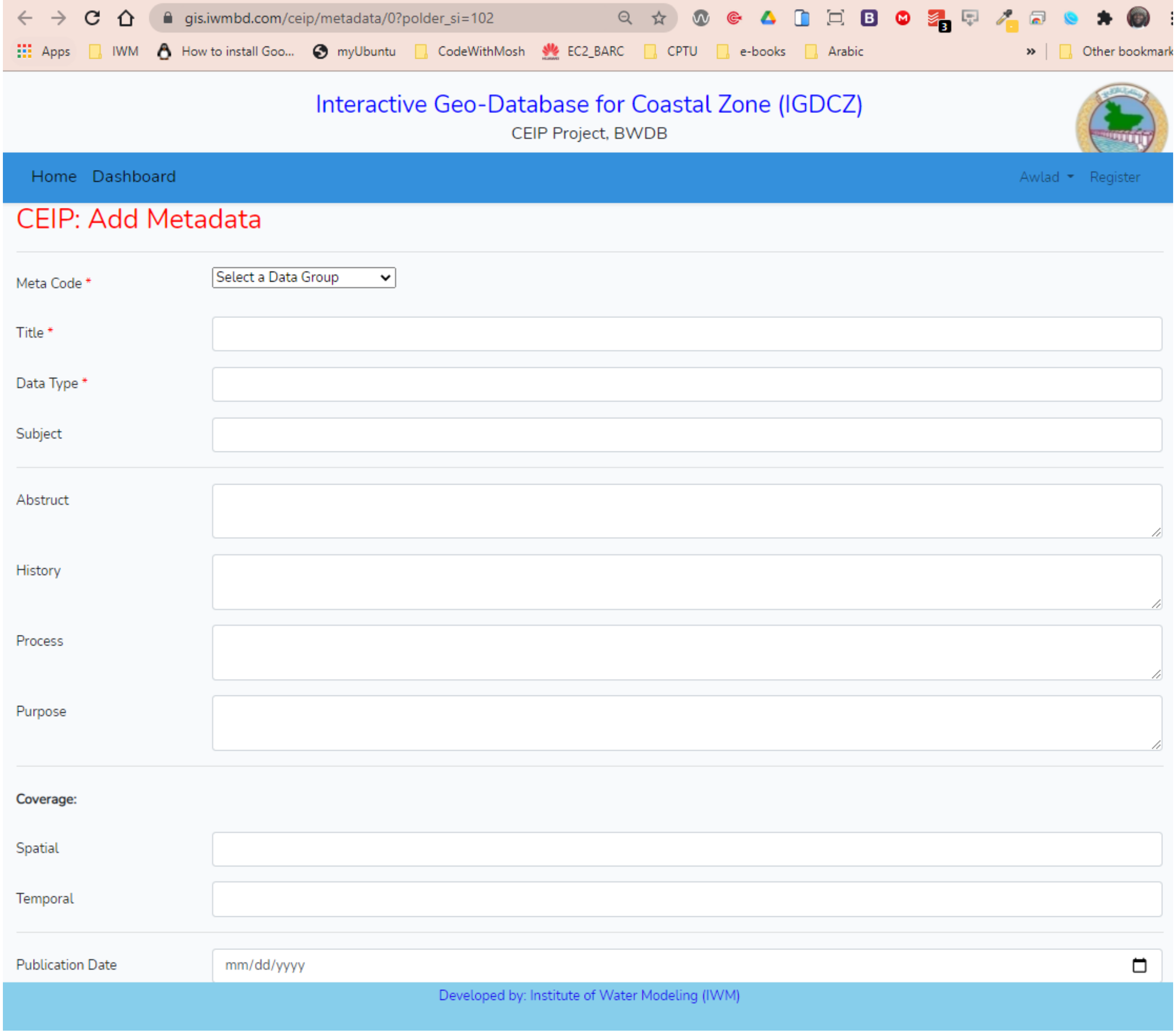
Search: So

b-division	Polder ID	Polder Name	Populataion(#)	Gross Prot. Area(Ha)	Cultivable(Ha)	Crop Area(Ha)	Embankment(Km)	Regulators(#)	Flushing Inlet(FSI)	Drainage Ch.(Km)	Action
atiya O&M Sub-vision	P-73/2	Hatiya South	77,690	11,134.0	8,296.0	8,296.0	54.1	20	0	168.4	Edit
nagazi O&M b-Division	P-60	Sonagazi	110,443	24,204.0	18,230.0	18,230.0	26.0	10	2	39.9	Edit
shkhali O&M b-Division	P-64/1b	Banshkhali	178,279	[illegible]	7,200.0	7,050.0	53.0	35	0	74.0	Edit
shkhali O&M b-Division	P-64/1a	Banshkhali	90,614	5,750.0	4,600.0	4,140.0	58.0	24	0	28.0	Edit
darkhali O&M b-Division	P-64/2b	Magnama_Ujantia	21,062	1,874.1	0.0	0.0	0.0	0	0	0.0	Edit
darkhali O&M b-Division	P-64/2b	Pekua	44,373	2,592.5	0.0	0.0	0.0	0	0	0.0	Edit
darkhali O&M b-Division	P-64/2a	Toitong	22,873	3,750.0	2,997.0	2,964.0	34.5	16	0	33.9	Edit
shkhali O&M b-Division	P-64/1c	Banshkhali	28,615	2,151.0	1,249.0	608.0	23.4	9	18	10.6	Edit
darkhali O&M b-Division	P-65	Chakaria	103,211	6,649.0	4,947.0	4,698.0	47.6	25	4	70.5	Edit

Figure 3. 3: Polder Interface with update option

- **Metadata module**

Metadata module has been started. The data entry form of Metadata is presented below (**Figure 3. 1**).



Interactive Geo-Database for Coastal Zone (IGDCZ)
CEIP Project, BWDB

CEIP: Add Metadata

Meta Code *	Select a Data Group
Title *	
Data Type *	
Subject	
Abstruct	
History	
Process	
Purpose	
Coverage:	
Spatial	
Temporal	
Publication Date	mm/dd/yyyy

Developed by: Institute of Water Modeling (IWM)

Figure 3. 4: Interface of Metadata updating

3.4.1 User Feedback

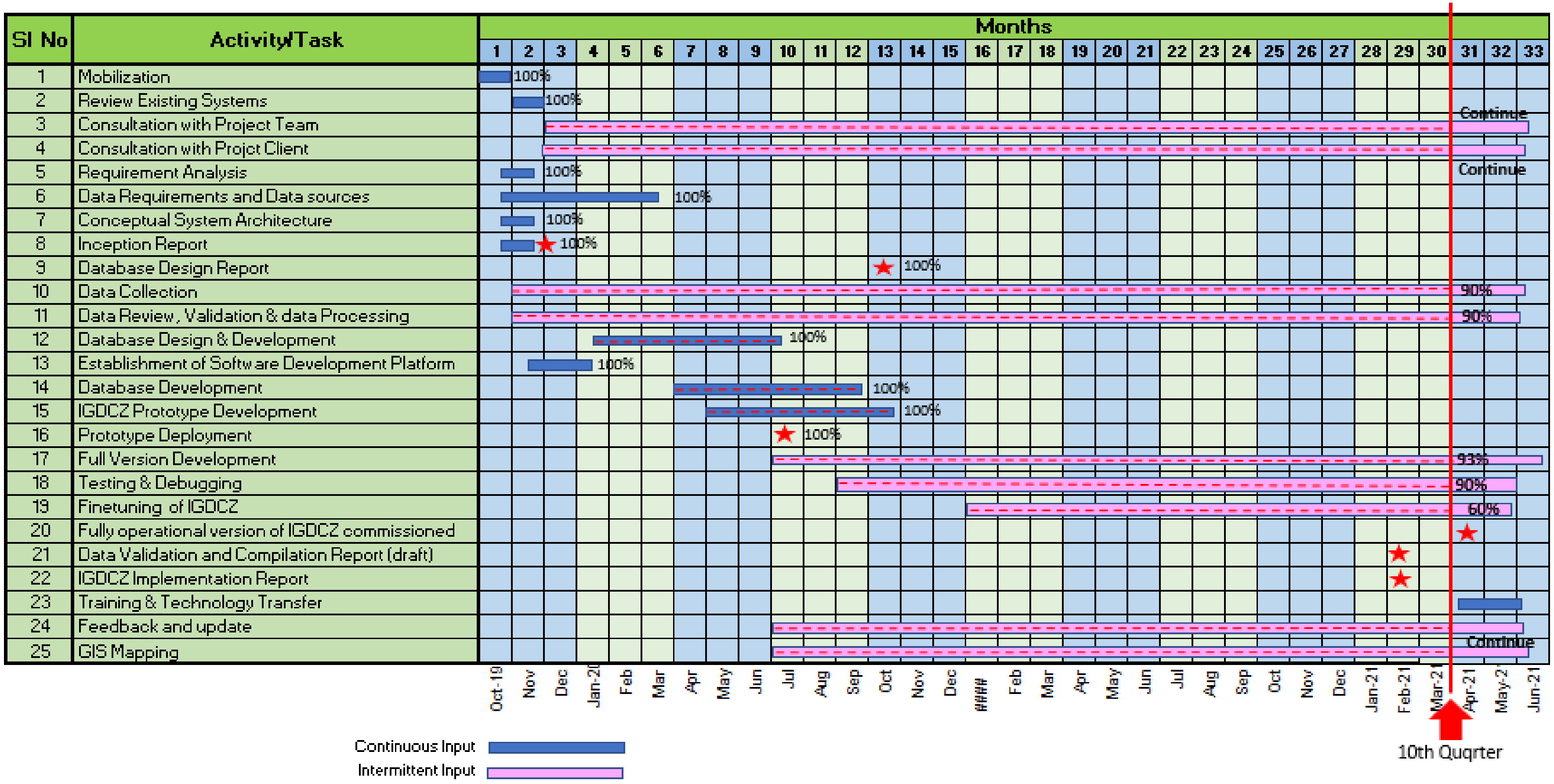
The web GIS based IGDCZ still under developing stage and hosted in development server at IWM. A significant progress has been made during the reported quarter by IWM team, concurrently, online feedback and suggestions received from the potential users of BWDB, World Bank and other stakeholders. Accordingly, the received feedback and suggestions were reviewed and required modifications were made in the application. During the last quarter a number of feedbacks was received and addressed accordingly.

3.5 Workplan

The development work has been conducted according a prepared workplan. Following

Work Plan (Figure 3.5) shows the workplan with current status of different tasks and activities.

Workplan of IGDCZ Development



Sl No	Activity/Task	Months
1	Mobilization	100%
2	Review Existing Systems	100%
3	Consultation with Project Team	Continue
4	Consultation with Projct Client	
5	Requirement Analysis	100% Continue
6	Data Requirements and Data sources	100%
7	Conceptual System Architecture	100%
8	Inception Report	100%
9	Database Design Report	100%
10	Data Collection	90%
11	Data Review, Validation & data Processing	90%
12	Database Design & Development	100%
13	Establishment of Software Development Platform	100%
14	Database Development	100%
15	IGDCZ Prototype Development	100%
16	Prototype Deployment	100%
17	Full Version Development	93%
18	Testing & Debugging	90%
19	Finetuning of IGDCZ	60%
20	Fully operational version of IGDCZ commissioned	
21	Data Validation and Compilation Report (draft)	
22	IGDCZ Implementation Report	
23	Training & Technology Transfer	
24	Feedback and update	
25	GIS Mapping	Continue

Figure 3. 5: Workplan

3.6 Plan for the Next Quarter

Table 3. 2: Plan for the Next Quarter

Sl No	Task & Activities	Progress (%) Upto 10th Quarter	Plan Progress (%) for Next Quarter	Overall Progress (%)
1	**Inception Phase**			
1.1	Review Existing Systems	100	-	100
1.2	Consultation with Project Team	continue		continue
1.3	Consultation with Project Client	continue		continue
1.4	Requirement Analysis	100	-	100
1.5	Data Requirements and Data sources	100	-	100
1.6	Conceptual System Architecture	100	-	100
1.7	Inception Report	100	-	100
2	**Data Collection and Processing**			
2.1	Coastal Bank Erosion (Satellite Image)	100	-	100
2.2	Land use Classification (Satellite Image)	85	15	100
2.3	Data Collection (shapefile & tabular)	90	5	95
2.4	Data Processing (shapefile & tabular)	90	5	95
3	**GIS Mapping**			
3.1	Polder Mappings & Processing	85	5	90
4	**Database Design & Development**			
4.1	Database Design Development	100	-	100
4.2	Database Design Report	100	-	100
4.3	Database Implement	90	5	95
5	**Web GIS Application Development**			
5.1	IGDCZ Prototype Development	100	-	100
5.2	Full Version Development	93	5	98
5.3	GIS Core Module	93	5	98
5.4	Dashboard Development	90	5	95

Sl No	Task & Activities	Progress (%) Upto 10th Quarter	Plan Progress (%) for Next Quarter	Overall Progress (%)
5.5	Metadata Preparation	45	20	65
5.6	Metadata Interface Development	60	20	60
5.7	User Administrative Module	90	5	95
5.8	Document Archiving	100	-	100
5.9	Tutorial (help tutorial)	100	-	100
5.10	Testing & Debugging	90	5	95
5.11	Data Validation and Check	92	5	97
5.12	Software & Hardware Procurement	-	-	-
5.13	Installation of SW and HW at BDWB Data Canter	-	-	-
5.14	Migration of Database and Application to BWDB Servers	-	-	-
5.15	Fully operational commissioning	-	-	-
5.16	Preparation of User Instruction Manual	-	20	20
6	**Reports**			
6.1	Database Implementation Report	Submitted		
6.2	Validation and Compilation Report (1st version)	Submitted		
7	**Training & Technology Transfer**	-		
8	**Feedback and update (ongoing)**	12 comments were addressed		

4 POLDER WATER MODELLING

4.1 Introduction

ToR stipulates to refine (Component-5) concept of polder design and management to see in which of the remaining polders in the CEIP-1 project these concepts could be applied. The scopes of works are to establish design for 3 polders as pilot program considering climate change, subsidence, possible land heights, land use, economic activities, required infrastructure for water management, and drinking water facilities for long-term stability. Make a cost estimate for the redesign of the polders and assess the benefits and beneficiaries in the new situations. It is also important to make reports for each 3-5 polders with a description of; present situations, boundary conditions (scenarios), matching with polder options, established design including management plan, cost and benefits. In accordance with the ToR a technical report needs to be prepared on long term polder improvement measures and polder development Plan.

In view of the above, eleven numbers of representative polders of the different regions of coastal area including polders under CEIP-1 and BlueGold Program were shortlisted to select 5 polders finally (**Figure 4.1**). The selection criteria for shortlisting are representative for a cluster of polders/specific costal region, degree of vulnerability against storm surge, river bank erosion, drainage congestion, subsidence, salinity intrusion, water management, opinion of local BWDB officials and economic activities.

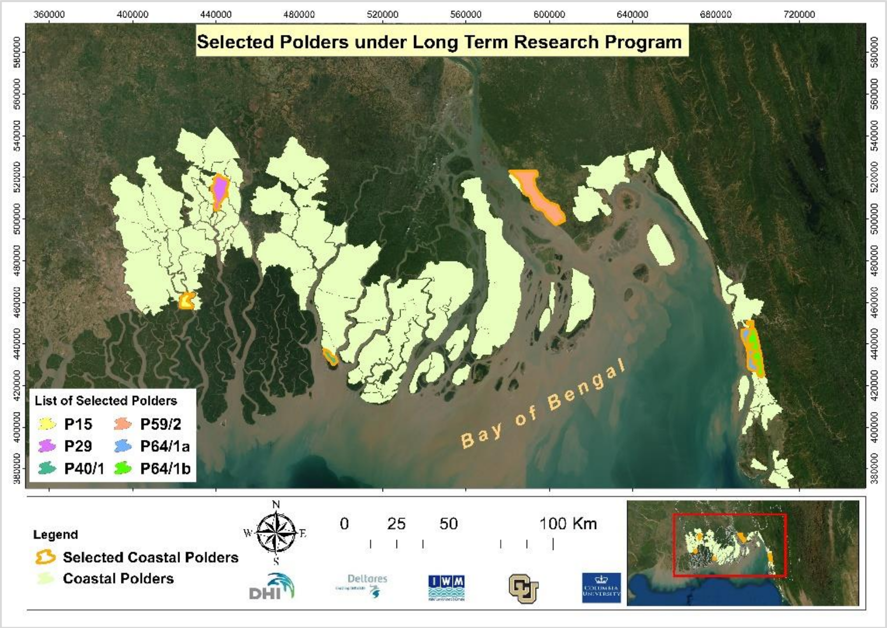


Figure 4. 1: Selected polder under Long-Term Research Program and Monitoring

4.2 Data Collection

Two types of data collection has been carried out in the Long Term Research and Monitoring Program. Hydrological data has been carried out as a secondary data and detailed polder information has been carried out as a primary data

4.2.1 Primary Data Collection

One dedicated survey campaign has been carried out to collect the field data for the selected polders. Modelling team prepared the data requirement as per mathematical model development for the polder system. The following data collection has been carried out from the field as a primary data.

- Polder Embankment Alignment
- Polder Embankment cross sections @ 500m interval or less interval
- Drainage channels/khals alignment
- Drainage channels/khals cross section @ 400m interval or less interval
- Detailed information of the water control structures (drainage regulators and flushing regulators information) i) Types of regulators, ii) Geometric position of the regulators (lat and long), iii) No. of vents, iv) Vent size (width x height), v) Invert level, vi) Deck level and soffit level, vii) Country side and river side loose apron length, viii) Existing condition of regulators, ix) Upstream and downstream photos of all regulators
- Water level at polder side and country side
- Topographic land level of all polders
- Peripheral river cross sections of all polders
- As an example, a detailed survey work has been of the Polder 40/1 has been presented in the **Figure 4.2** and data collection information has given below.

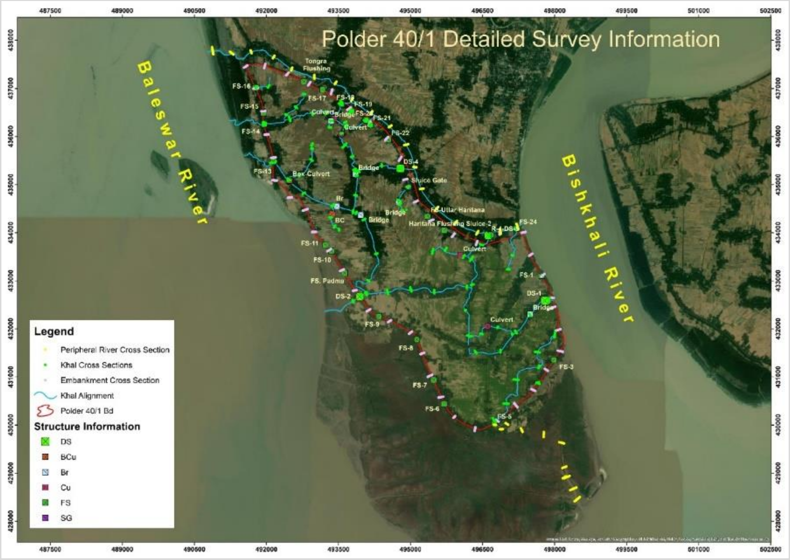


Figure 4. 2: Map showing the surveyed information of Polder 40/1

The present status of the data collection is presented in the following **Table**.

Table 4. 1: Status of the Data Collection of the selected polders

Sl No.	Polder No	Location	Target					Progress of the Field Survey					Remarks
			Embt (Km)	Structure Inventory (nos.)	Drainage Channels (Km)	Perepheral River section (Nos.)	Topo Survey (Km^2)	Embt (Km)	Structure Inventory (nos.)	Drainage Channels (Km)	Perepheral River section (Nos.)	Topo Survey (Km^2)	
1	40/1	Patharghata, Barguna	23	27	27	43	20	Complete	Complete	Complete	Complete	Complete	scattered very fine resolution
2	29	(Dumuria, Botiaghata), Khulna	49	41	121	120	79.3						
3	59/2	(Char Alexander, Kamalnagar), Noakhali	88.5	8	73	61	209						
4	64/1A	Bashkhali, Chittagong	53.7	5	41.6	56	65						
5	64/1B	Bashkhali, Chittagong	83	50	63	24	76.3						
6	15	Shymnagar, Satkhira	27	7	20	36						carried out in 2015	Topo data collected during 2015 by IWM will be utilized for drainage model

4.2.2 Secondary Data Collection

Hydrological Data

Hydrological data like rainfall and evaporation both are collected from the secondary sources. Theisen polygon method was applied to identified the influenced rainfall station for the selected polders (Polder 15, Polder 29, Polder 40/1, Polder 59/2 and Polder 64/1a & Polder 64/1b). IWM developed three calibrated and validated regional models (i South-West Regional Model, ii) South-East Regional Model and iii) Eastern Hilly Regional Model) simulated results also used as a secondary data source

4.3 Data Analysis and Development of Climate Change Scenarios

To understand the total physical processes of a polder, the following considerations needs to carry on i) Hydrological Analysis ii) Development of Rainfall generated Runoff and iii) Inclusion of rainfall generated runoff into the Polder Hydrodynamic Model where all drainage channels, drainage regulators, internal physical process and peripheral condition will be included. However, planning and designing of a polder, incorporation of future changes like hydrological and hydraulic changes should be considered for a selected design flood events to run the polder system in all worst scenarios.

4.3.1 Hydrological Analysis

Polder 15, Polder 29, Polder 40/1, Polder 59/2 and Polder 64/1a & Polder 64/1b, these six polders have been selected under the Long Term Research and Monitoring Project. Bangladesh Meteorological Department (BMD) and Bangladesh Water Development Board (BWDB), both institutes are measuring rainfall stations in district wise/Upazila wise covering the whole Bangladesh. **Figure 4.3** presents the available rainfall stations in the coastal area of Bangladesh.

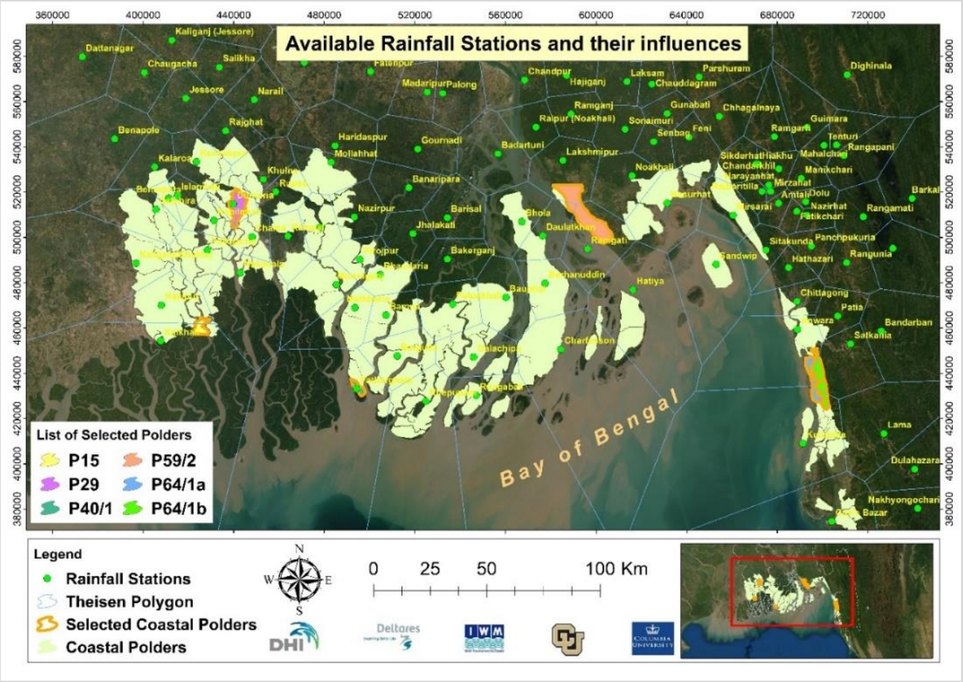


Figure 4. 3: Available rainfall stations and their influences on the coastal polders

The influence on each rainfall station on the coastal polders has been calculated by the Theisen Polygon Technique. The contribution of each rainfall station on the selected polders has been presented in following **Table 4.2**.

Table 4. 2: Influence of each rainfall station on the selected coastal polders

Polder SL	Polder ID	Rainfall Stations	Influenced Area(Sq. km)	Total Area (Sq. km)	% of Influenced Rainfall station	Total
1	Polder 15	**Kaikhali**	21.51	31.14	69%	100%
		Nakipur	9.63		31%	
2	Polder 29	**Dumuria**	76.12	79.76	95%	100%
		Chalna	1.75		2%	
		Kapilmuni	1.88		2%	
3	Polder 40/1	**Patharghata**	20.03	20.03	100%	100%
4	Polder 59/2	**Ramgati**	135.12	204.74	66%	100%
		Lakshmipur	69.62		34%	
5	Polder 64/1a	**Anwara**	23.63	52.24	45%	100%
		Satkania	7.85		15%	
		Kutubdia	20.76		40%	
6	Polder 64/1b	Anwara	16.33	88.83	18%	100%
		Satkania	50.65		57%	
		Kutubdia	21.85		25%	

Considering the influence of the rainfall station into the polder, Kaikhali, Dumuria, Patharghata, Ramgati, Anwara and Satkania rainfall station has been selected for the Polder 15, Polder 29, Polder 40/1, Polder 59/2, Polder 64/1a and Polder 64/1b respectively. To understand the hydrological analysis, Polder 40/1 has been presented below.

4.3.1a Hydrological Analysis of Polder 40/1

It is already discussed in the previous section that Patharghata rainfall station influencing the study area mostly. Different rainfall event has been analyzed from the daily rainfall data to determine consecutive rainfall effects in the study area that already discussed in the previous section. From this analysis, yearly maximum rainfall data for 35 years (1985-2020) has been calculated for determining 1-day, 2-day, 3-day, 4-day, and 5-day cumulative rainfall events.

Three Statistical distribution methods have been considered for determining the rainfall for different return period. Gumbel (Gum), Log Pearson Type III (LP3) and Long Normal Distribution (LN2) statistical distribution methods have been tested to fit the raw rainfall data. Methods of Moment (MOM) has been used as an estimation method and Monte Carlo method has been used for uncertainty calculations. Goodness of fit has been tested with Chi-Square method. Six different return periods (1 in 2.33, 1 in 10, 1 in 20, 1 in 25, 1 in 50 and 1 in 100 year) have been considered to estimate the design rainfall. Among them, 1 in 25-year rainfall is considered as design rainfall for designing any structure according to BWDB design manual. However, in this study, 1 in 50 will be considered for planning and designing the polder water management system as huge investment has been considered for developing the future polder. **Table 4.3** presents the design rainfall for different return periods.

Table 4. 3: Design rainfall of Patharghata for different return periods for different rainfall events

Item	Hydrological Events	1day rainfall (mm)			3-days cumulative rainfall (mm)			5-days cumulative rainfall (mm)		
	Return Period [years]/Methods	LP3	LN2	GUM	LP3	LN2	GUM	LP3	LN2	GUM
Estimated Design Rainfall of Patharghata Rainfall Station for different return periods	2.33	192	184	184	312	306	305	391	384	381
	10	272	282	270	444	450	440	549	558	540
	20	298	324	307	495	511	499	607	631	608
	25	306	337	318	510	530	517	625	654	630
	50	***328***	***379***	***354***	***555***	***590***	***574***	***676***	***725***	***697***
	100	347	421	390	597	648	631	724	795	763
Goodness-of-fit statistics	CHISQ	1.72	3.28	**0.94**	**2.89**	4.44	4.44	**2.89**	**2.89**	6.78

Goodness-of-fit has been tested with the Chi-Squares method. It has been observed that the Gumbel (GUM) statistical distribution method provides the lower Chi-Square value during calculation of 1-day design rainfall compared to Log Normal (LN2) and Log Pearson Type 3 (LP3) statistical distribution methods. It means Gumbel distribution method fitted well with the yearly maximum rainfall for the daily rainfall event. However, when we consider 3-days cumulative rainfall, Log Pearson Type 3 (LP3) method gives the lower Chi-Square values compared to the rest of the two other methods. Different scenario has been observed during calculation of design rainfall for 5-days cumulative rainfall. It has been observed that both Log Normal and Log Pearson Type 3 provides the same value of Chi-Square but Log Normal provides higher design rainfall compared to Log Pearson Type 3 method. It is already determined that the polder water management system will be designed for 5-days cumulative rainfall event and 1 in 50-year return periods rainfall. As there is lots of investment and safety involved, Log Normal statistical distribution will be taken for ensuring the safety of the polder under the extreme flood event condition. Considering this, the water management system of the Polder 40/1 will be designed for 725mm design rainfall which is the nearest of the 5-days cumulative rainfall of the year 2011.

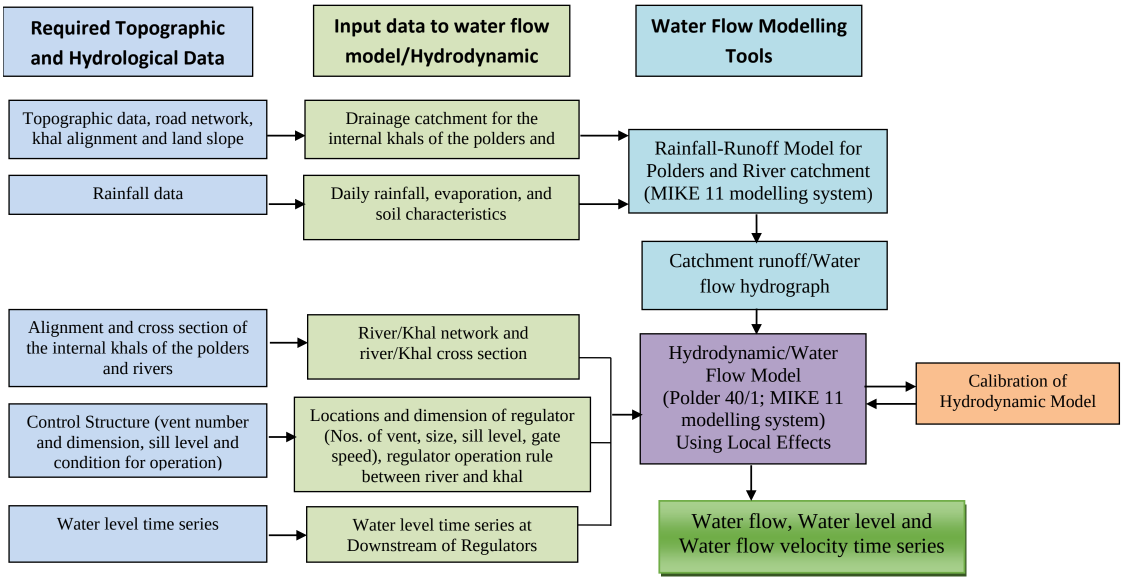
4.3.2 Determination of Climate Change Scenarios

Future changes on the upstream flow conditions and downstream water level conditions will be generated from the Global Hydrological and hydraulic models. At the same time, projections on rainfall and temperature also required to develop the climate changes projections. The changes in the rainfall and temperature will produce the future runoff amount into polder system which will be drain out through the regulators. The changes in the upstream flow boundaries and downstream water level boundaries will be added into the hydrodynamic model to develop the future conditions during planning and designing of a polder.

4.4 Development of Mathematical Model

Two types of mathematical models have been developed in Long Term Research and Monitoring Project for planning and designing of the polder water management system. The models are: i) Polder Hydrological Model and ii) Polder Hydrodynamic Model. The developed Hydrological Model (Rainfall Runoff model) is one kind of lumped and conceptual model which presents the rainfall contribution as a surface runoff into khal system for each catchment. Hydrodynamic Model (Water-Flow Model) which is the illustration of water-flow into the internal Khal/canal systems with the proper operation of control structures (regulators). These two models ensure the planning and design of water availability and water flow direction into the polder system properly. A typical mathematical modelling input parametrs and outcomes are presented in the foloowing flow chart for better underestanding the modelling activities at a glance.

Flow Chart on Drainage Modelling

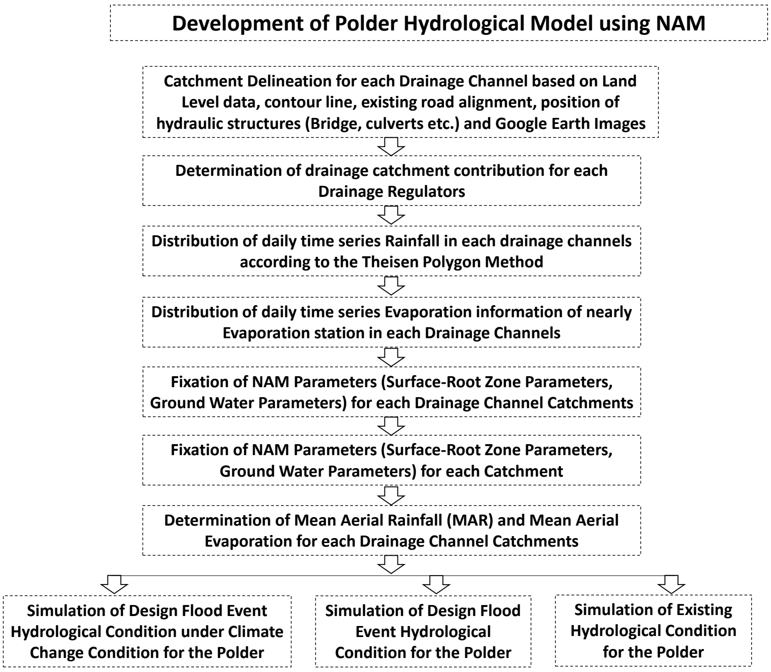


Detailed description, methodology of each modeeling system has beeb described below.

4.4.1 Development of Rainfall Runoff Model

Rainfall-Runoff model for the selected polders has been developed to estimate the rainfall generated runoff. As the study area is influenced by the astronomical tide, therefore, discharge of this rainfall generated runoff mainly depends on the tidal phase conditions (flood tide and ebb tide). If the extreme rainfall happens during flood tide condition, there is the highest possibility to create water logging problem during that period. The stagnant water will be drain-out during the ebb tide condition. Hence, the hydrological condition of the internal khal systems have been considered to connect the rainfall generated runoff with the astronomical tide conditions.

The model takes into consideration the basin characteristics including specific yield, initial soil moisture contents and initial ground water level and irrigation/abstraction from the surface or ground water sources. The catchments delineation of all selected polders is important to distribute the contribution of runoff into the internal drainage khals/channels as a lateral flow. The overall hydrological model development concept is illustrated in the following flow chart.



Polder 40/1 has been selected for showing the detailed model concepts and methodology.

4.4.1a Simulation of Rainfall Runoff Model

Polder 40/1 has been selected for developing the development of hydrological model concept. The existing hydrological condition has been simulated for the year 2019 and design flood event has been simulated for the year 2011 which has been estimated from the hydrological analysis.

4.4.1b Input Parameters

Delineated catchment information of each khal, contribution of rainfall and evaporation in each khal, soil characteristics, overland flow, interflow and ground water flow routing has been included into the rainfall runoff model to generate the rainfall generated runoff for each khal system.

4.4.1c Estimation Runoff at Existing Condition

Catchment of each regulator has been distributed according to the contribution from the remote locations of each tertiary, secondary and primary khal. The contribution of each similar size regulator may be different based on the tidal characteristics of the peripheral river system, human interventions into the drainage channels/khals, existence of culverts, bridges, and conditions of the regulators. However, in the hydrological model of each polder system has been simulated as an ideal consideration using the MIKE 11 NAM which is lumped and conceptual model. Only rainfall generated runoff has been calculated for each catchment by using the soil characteristics, meteorological information. One typical plot of catchment runoff of the Polder 40/1 generated from the rainfall for the Padma sluice (DS-2) has been presented in the Figure 4. **4.**

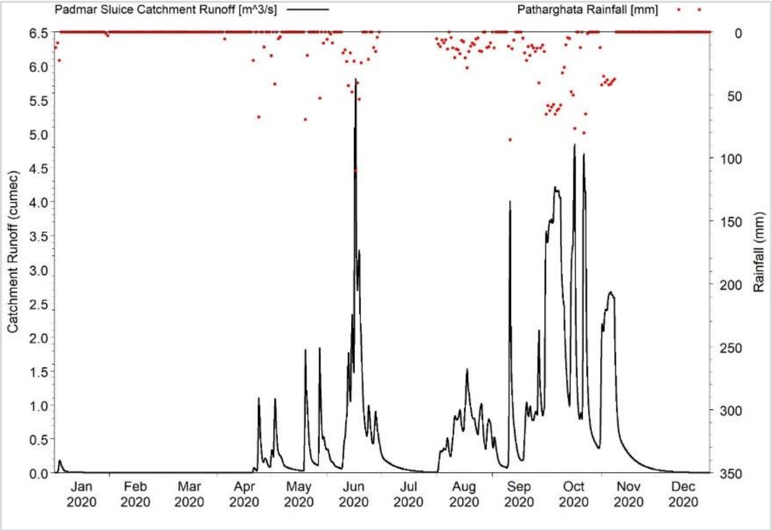
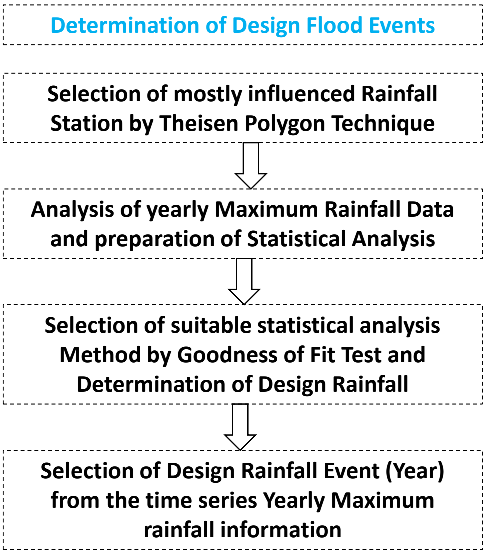


Figure 4. 4: Rainfall generated runoff for the Padmar sluice (DS-2)

Similarly, rainfall generated runoff has been generated for all khal catchments and this generated runoff is linked with the Polder 40/1 Water-Flow model (Hydrodynamic Model) channel network as a lateral flow. The generated runoff is used in the hydrodynamic channel network as linearly routing method considering the catchment area and the length of the khals/channels.

4.4.1d Estimation of Design Flood Runoff

Year 2011 has been selected as design flood event by statistical analysis. The analysis has been discuss in the previous “Data Analysis” chapter.



Later the rainfall data for the year 2011 has been converted into 2019 to compare the rainfall generated design runoff with the existing rainfall generated runoff. **Figure 4.5** presents the comparison of these two runoffs.

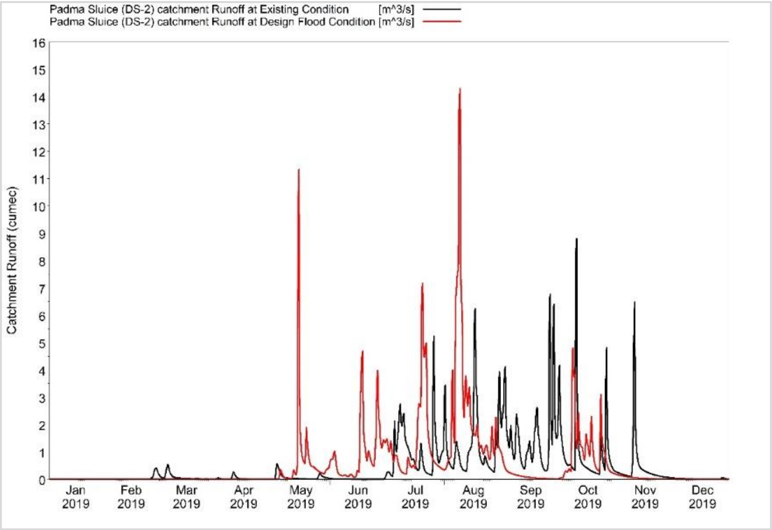


Figure 4. 5: Rainfall generated runoff at existing and design flood event condition

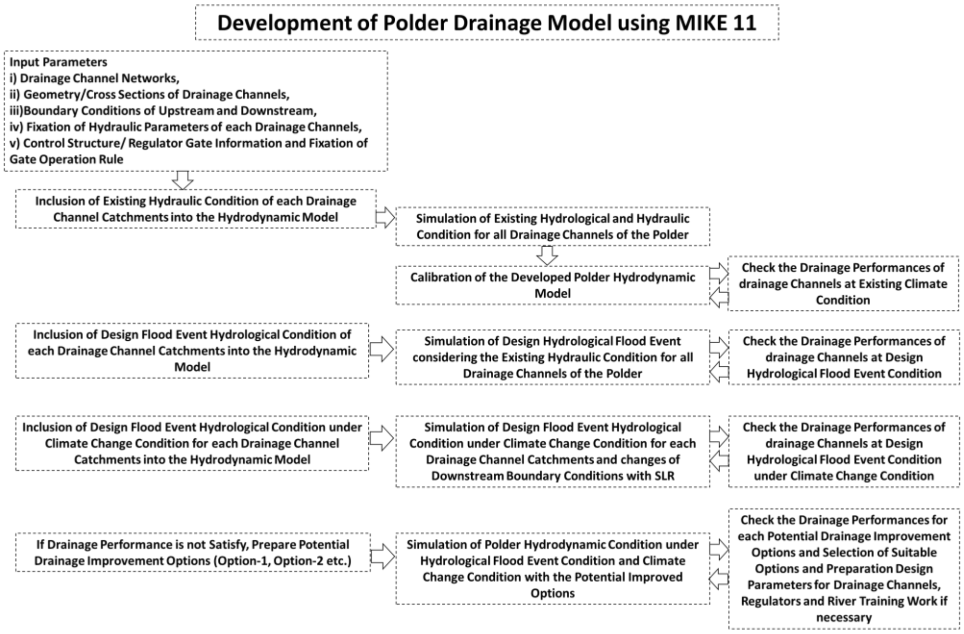
Figure 4.5 indicates that the maximum runoff generated at the existing condition in the month of late September and early of October 2019. However, during design flood period, the maximum runoff occurred at the end of July that has to be drain out through the regulators of the polder.

4.4.1e Estimation of Design Flood Runoff under Climate Change Condition

Changes in the rainfall temperature will be added with the existing meteorological data to develop the climate change scenario. This time series projected rainfall data and evaporation data projected by the temperature will be add with the design flood event hydrological model to develop the hydrological mode under climate change condition.

4.4.2 Development of Polder Water-Flow (Hydrodynamic) Model

The polder drainage model is developed by incorporating newly surveyed cross-section data of the internal drainage channels and existing water control structures within the polder area including detailed catchments distribution for the internal drainage channels and peripheral river systems for developing the polder drainage model. The polder drainage networks are connected to the peripheral rivers through drainage khals and water control structures. The structures have been included in the model providing the input data on their dimensions/size, number of vents and invert levels together with their operating rules of gates.The operation rules is defined in such a way that if outside water level is higher than that of polder water level in the drainage khals/channel, the gates of the structure is closed automatically and vice versa. Within the polder the runoff generated from the catchment is routed into the respective drainage khals in proportion to their respective drainage areas which eventually drained towards the peripheral khals through the structures. The overall polder hydrodynamic model/polder drainage model has been developed based on the following flow chart.



Polder 40/1 has been selected for showing the detailed mathematic modelling development concepts and methodology.

4.4.2a Development of Polder Drainage Model

Internal drainage channels, cross sections of these drainage channels/khals, hydrodynamic of parameters of these drainage channels, upstream and downstream boundary conditions of these drainage channels are the key components of a polder hydrodynamic model. Inclusion of water control structures to drain out the rainfall generated runoff by the water level head differences are represents the polder drainage model. Figure 4.6 presents the total components of a polder drainage model of Polder 40/1.

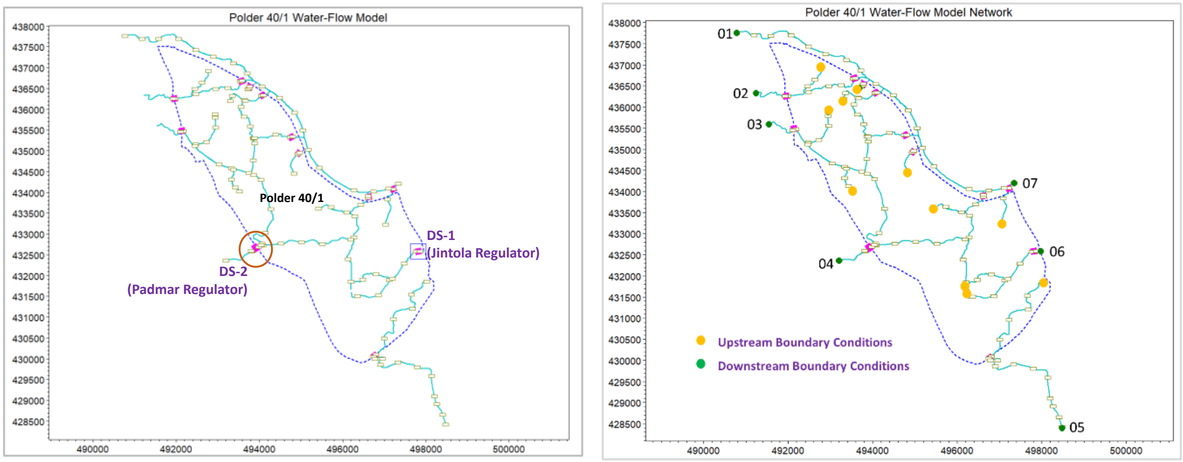


Figure 4. 6: Typical polder drainage model compoents of the Polder 40/1

Downstream boundary conditions have been generated from the calibrated South-West Regional Model (SWRM) for the polder 40/1. Similarly, if we developed the dedicated polder drainage model for the Polder 15 and Polder 29, downstream boundary conditions will be generated from the calibrated SWRM simulation results. Another option, both of these polder will be included into the SWRM model network. Polder 15 and Polder 29 will be included into the calibrated South-West Regional Model (SERM) and Polder 59/2 will be included into the South-East Regional Model or will be developed a dedicated polder drainage model. If dedicated model will develop, boundary conditions will be generated from the SERM Model. As the Polder 64/1a and Polder 64/1b contains only Sangu River, one dedicated model will be developed integrating these two polder system. Calibration of the Polder Water-Flow Model.

Calibration of the polder drainage model completely depends on polder water management system. Local factors are dominating the polder water management system and these local parameters are added into the mode to calibrate the developed polder Water-Flow Model. Local factors are regulator gate operation and management, artificial cross dam into the khal system, water withdrawal from the khals for irrigation and domestic purposes, spatial variation of monsoon rainfall etc. These local parameters are added into the mode to calibrate the developed polder Water-Flow Model of the Polder 40/1.

4.4.3 Calibration of the Polder Water-Flow Model

The hydrodynamic model (water-flow model) has been simulated for three ways based on the field conditions. The simulation options are-

i. Drainage regulator (DS-02), gate operation functions as drainage purpose with observed rainfall information
ii. Drainage regulator (DS-2) gate operation functions as real time gate operation with observed rainfall information
iii. Drainage regulator (DS-2) gate operation function as real time gate operation with modified rainfall information

4.4.3a Drainage regulator (DS-02), gate operation functions as drainage purpose with observed rainfall information

Figure 4. **7** gives the clear idea if we control the regulator Padma Regulator (DS-02) as only drainage regulator, the local parameters and hydraulic parameters are not included properly

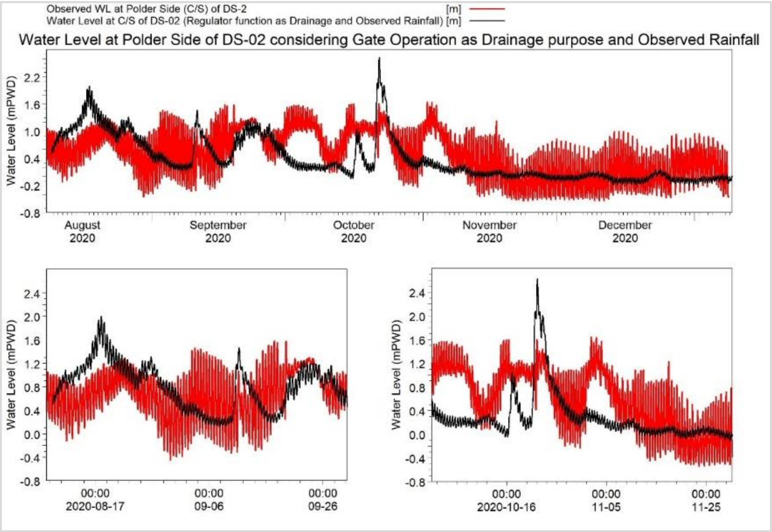


Figure 4. 7: **Water level comparison at upstream of DS-02 regulator when River Side Gate perform as a drainage regulator**

4.4.3b Drainage regulator (DS-2) gate operation functions as real time gate operation with observed rainfall information

Figure 4. **8** presents that if we use the real time gate operation rule, the simulated model provides the similar trend of water level fluctuation inside the polder. It indicates other parameters need to be corrected.

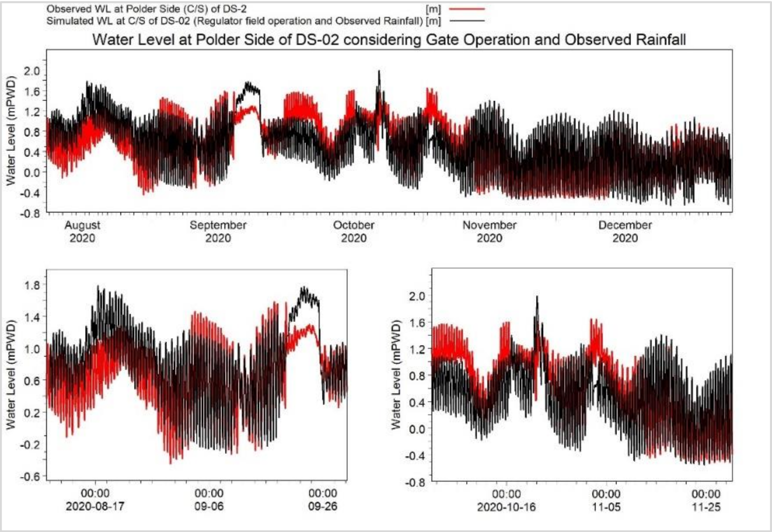


Figure 4. 8: **Water level comparison at upstream of DS-02 regulator when real time gate operation rule applied in the River Side Gate**

4.4.3c Drainage regulator (DS-2) gate operation function as real time gate operation with modified rainfall information

Figure 4. **9** presents the almost similar trend of water level fluctuation inside the polder. In this case real time gate operation rule has been applied and local rainfall has been added into the hydrological mode to get the exact amount of runoff from the catchment.

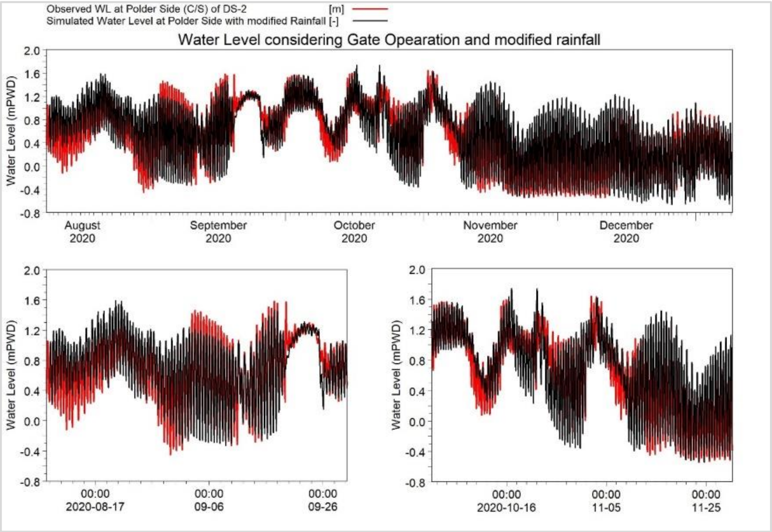


Figure 4. 9: Water level comparison at upstream of DS-02 regulator when real time gate operation rule applied in the River Side Gate with modified rainfall

4.5 Planning and Design of Future Polders

The existing drainage regulators and internal drainage channels and peripheral river morphological conditions are used for preparing the inundation depth for 3-day maximum water level considering the 5-days cumulative rainfall has been used for assessing the existing inundation into the Polder. 1 in 50 year design hydrological flood event also be considered to generate the inundation depth for the polder at design flood event condition. In future, change in precipitation trend, variation in upstream flow from the upstream channels and sea level rise will affect the drainage performance of the coastal area as well as the selected polders. Therefore, climate change scenarios will be applied into the existing condition and design flood event condition of the selected polders to observe the performance of the drainage system in times of climate change and to assess the needs of improvement. Potential drainage improvement options will be developed and simulations of drainage model will be prepared based on consultation with local people and field investigation and modelling results. The overall planning and design of improved polder water management system has been described step by step. Polder 40/1 has been chosen for illustrating the development of inundation depth duration map for the selected polders.

4.5.1 Preparation of Inundation Depth Map

4.5.1a Inundation at Existing Condition

Inundation depth duration map at existing/present condition is prepared for simulated 3-days consecutive water level and 5-days cumulative rainfall event. Year 2019 is selected for presenting the existing condition of the Polder 40/1. Flood inundation depth maps for 3 day duration showing the area of different classes of land (F0, F1, and F2& F3) is prepared applying GIS tool. Figure 4.10 presents the existing inundation condition of the Polder 40/1.

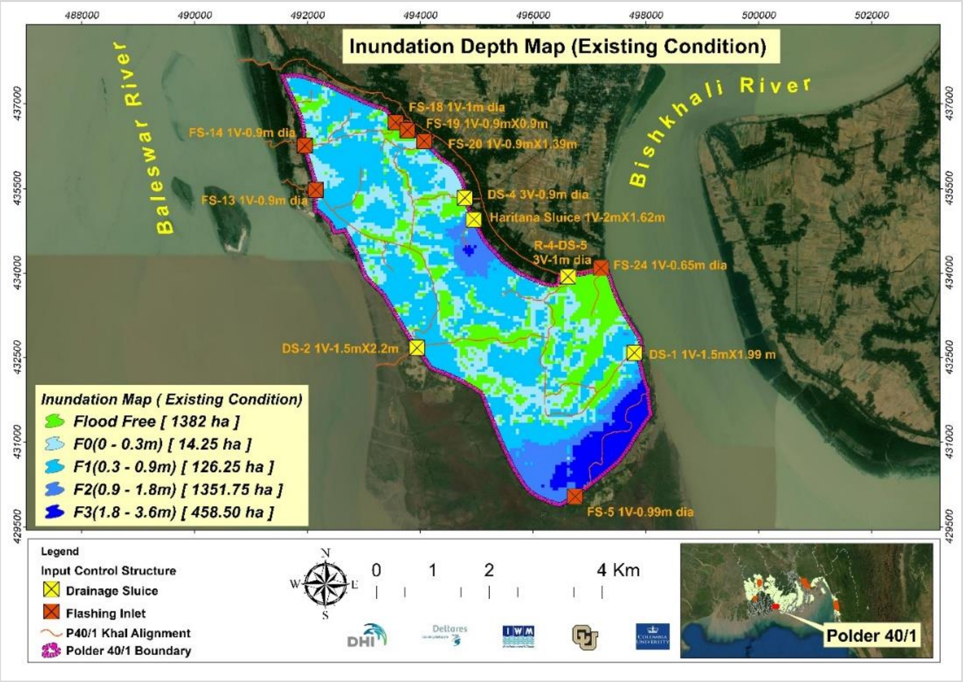


Figure 4. 10: Inundation depth map of the Polder 40/1 for existing hydrological flood condition

Table 4.4 presents different land class of the Polder 40/1 at existing condition where 43.77% lands are flood free (FF+F0 land) and 56.23% lands are under deep water (water depth greater than 30cm). The most inundation areas are showing the most southern part of the Polder.

Table 4. 4: Existing inundation condition of the Polder 40/1

Inundation during 3-days consecutive Water Level at Existing Condition		
Type	Area(ha)	Percentage (%)
FF (<0)	382.00	19.44%
F0(0.0-0.30m)	478.00	24.33%
F1(0.3-0.90m)	806.50	41.04%
F2(0.90-1.80m)	166.25	8.46%
F3(1.80-3.60m)	132.25	6.73%
Total Area	1965.00	100.00%

4.5.1b Inundation during Design Flood Event Condition

Inundation map also prepared for the design flood event condition. The design hydrological flood event has been calculated from the historical rainfall information of Patharghata. Year 2011 has been selected as the hydrological flood event (1 in 50 year return period) by the statistical analysis. **Figure 4.11** presents the inundation situation during hydrological flood event condition inside the Polder 40/1.

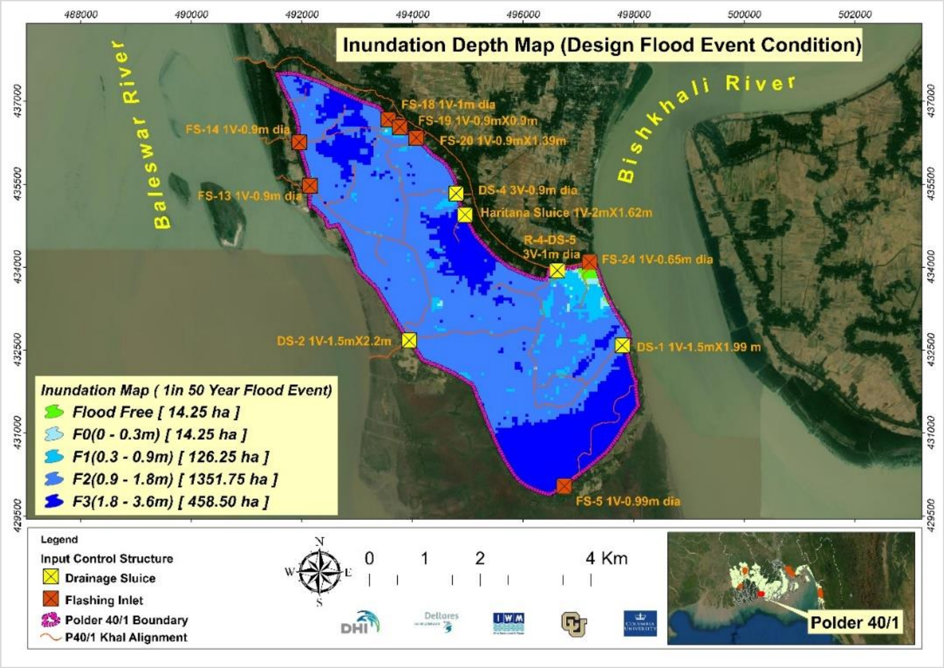


Figure 4. 11: Inundation depth map of the Polder 40/1 for 1 in 50 year design hydrological flood event

From the **Table 4.5**, it is observed that, only 1.45% lands are showing flood free (FF+F0), up to 30cm of water depth. About 6.42% lands are showing under water up to 90cm depth of water. The rest of the area, about 92.12% lands are under deep water (water depth greater than 90cm)

Table 4. 5: Inundation condition of the Polder 40/1 during 1 in 50 year flood event condition

Inundation during 3-days consecutive Water Level at Design Flood Event Condition		
Type	Area(ha)	Percentage (%)
FF (<0)	14.25	0.73%
F0(0.0-0.30m)	14.25	0.73%
F1(0.3-0.90m)	126.25	6.42%
F2(0.90-1.80m)	1351.75	68.79%
F3(1.80-3.60m)	458.50	23.33%
Total Area	1965.00	100.00%

It can be summarized that the polder is most vulnerable to water logging problem and if the design flood events happened again, the existing polder system becomes inactive. Therefore, potential improvement in the polder water management system is required to overcome the design flood event condition. However, potential improvement option should be considered under climate change condition for facing new challenges in future and make the polder robust in all worst scenarios.

5 STORM SURGE MODELLING

5.1 Background

Bangladesh coastal zone is heavily vulnerable to cyclonic storm surges. About 24 numbers of tropical cyclones hit the Bangladesh coast since 1960 to 2020. Among them, nineteen (19) cyclones are classified as severe cyclone, four are classified as cyclone and one is classified as super cyclones. However, it impacts most in the south-West Coast and South-Central Coast of Bangladesh.

List of severe cyclonic storm surge that were developed in IWM

SL No.	Cyclone	Zone	Cyclone Types	SL No.	Cyclone	Zone	Cyclone Types
1	November,1986	South-West	SCS	11	October, 1966	South-East	SCS
2	November,1988	South-West	SCS	12	April,1991	South-East	SCS
3	May, 2009(AILA)	South-West	SCS	13	May,1997	South-East	SCS
4	May, 1961	South Central	SCS	14	September,1997	South-East	SCS
5	May,1965	South Central	SCS	15	May,1998	South-East	SCS
6	November,1970	South Central	SCSH	16	December,1965	East and Hill	SCS
7	November,1974	South Central	SCS	17	November,1983	East and Hill	SCS
8	November,2007(SIDR)	South Central	SCSH	18	May,1985	East and Hill	SCS
9	October, 1960	South-East	SCS	19	November,1995	East and Hill	SCS
10	May, 1963	South-East	SCS				

Note: i) CS: Cyclonic Storm; ii) SCS: Severe Cyclonic Storm and iii) SCSH: Severe Cyclonic Storm with a core of Hurricane winds

In order to access the storm surge vulnerability and for prediction of future scenario storm surge model is developed under this project under “Component 4D: The effect of climate change on Water level, Salinity and Strom Surges”.

5.2 Development of Storm Surge Model

The newly developed calibrated and validated Bay of Bengal Model (developed by MIKE 21FM system) has been applied in this study for developing the storm surge modelling as model domain including the bathymetry of the sea, estuary and the river system. The storm surge model is the combination of Cyclone and Hydrodynamic models. In an addition, cyclonic wind and pressure fields are added into the Bay of Bengal tide model to generate the surge for the specific cyclones. Wind friction factor is acted as the calibration parameter.

In order to incorporate the polder system crest level of the existing embankment has been added in the Model domain as the Dike system. Similar methodology has been applied in this study that has been developed during CEIP-1. The model domain for the storm surge model is shown in Figure 5.1.

5.2.1 Grid and Bathymetry

Mesh System has been selected based on the alignment of the bank lines to define the channel properly. Both triangular and quadrangular elements have been generated with different mesh resolution to ensure a correct geometry of the channels and estuary.

A highest-level accuracy has been used to define the river system because a suitable mesh is essential for obtaining reliable model results. The mesh file is an ASCII file (.mesh extension) that includes information of the geographical position and water depth at each node point in the mesh. The file also includes information about the node connectivity of the triangular and quadrangular elements.

During the mesh development, most of the river systems have been developed by quadrangular elements. Only confluences of different river systems and sharp bends have been defined by triangular elements. The purpose of this is to reduce the number elements and thereby simulation run time.

In order to update the bathymetry, Cross section data surveyed under this project of the Pussur, Shibsha, Baleswar, the Lower Meghna and Sangu River have been used and the rest of the major coastal Rivers like Bishkhali, Buriswar, Tentulia Channels is updated using surveyed data of very recent times under different other projects.

Polder and Sea island land level has been added in the mesh system for distributing the effects of normal tide and cyclonic water level properly. Most of the polders land level has been collected from Survey of Bangladesh (SOB) and few of the polders land level have been garneted from IWM surveyed data.

Figure 5.1 presents the mesh and bathymetry for the whole Bay of Bengal and coastal area of Bangladesh.

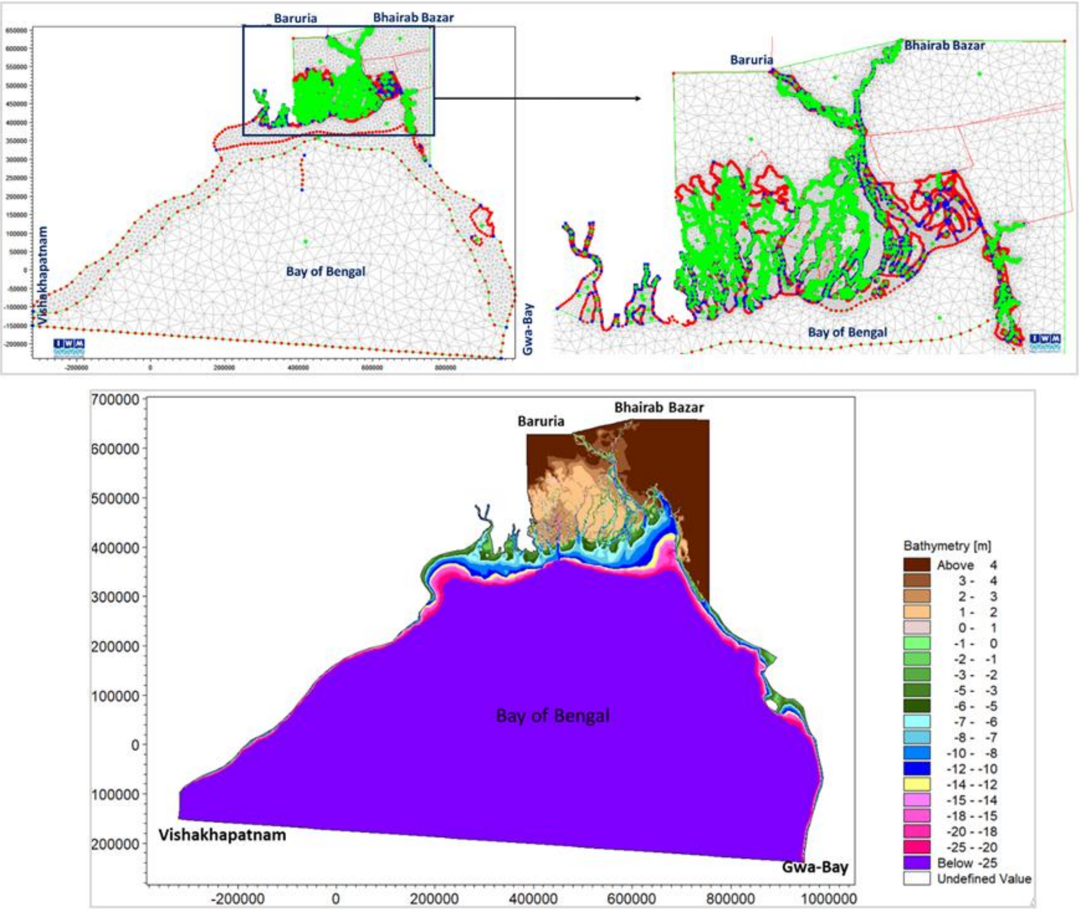


Figure 5. 1: Computational mesh and interpolated bathymetry for Storm Surge Model

5.2.2 Boundary Condition

There are twenty-seven open boundaries are identified in the updated Bay of Bengal hydrodynamic model. Among them, twenty-six open boundaries are located at the upstream where two upstream open boundaries are located at two major river systems and another open boundary is located at the downstream. One upstream boundary is situated in the north of the Upper Meghna River at Bhairab bazar and another is in the Padma River at Baruria. The downstream boundary is in the southern of the Bay of Bengal at 16^{o} latitude connecting Vishakhapatnam to Gwa Bay. The maximum depth along the southern open boundary of the model area is more than 2,000 m.

The upstream boundary at Baruria is showing non-tidal characteristics where rating discharge has been used as upstream boundary condition in the Padma River. However, daily water level fluctuation (tidal effects) has been observed at Bhairab Bazar in the Upper Meghna River. Time series tidal discharge has been used at Bhairab Bazar which is generated from the available North-Central Region Model (NCRM)**.** Figure 5.2 shows the discharge time series in Baruria and Bhairab Bazar.

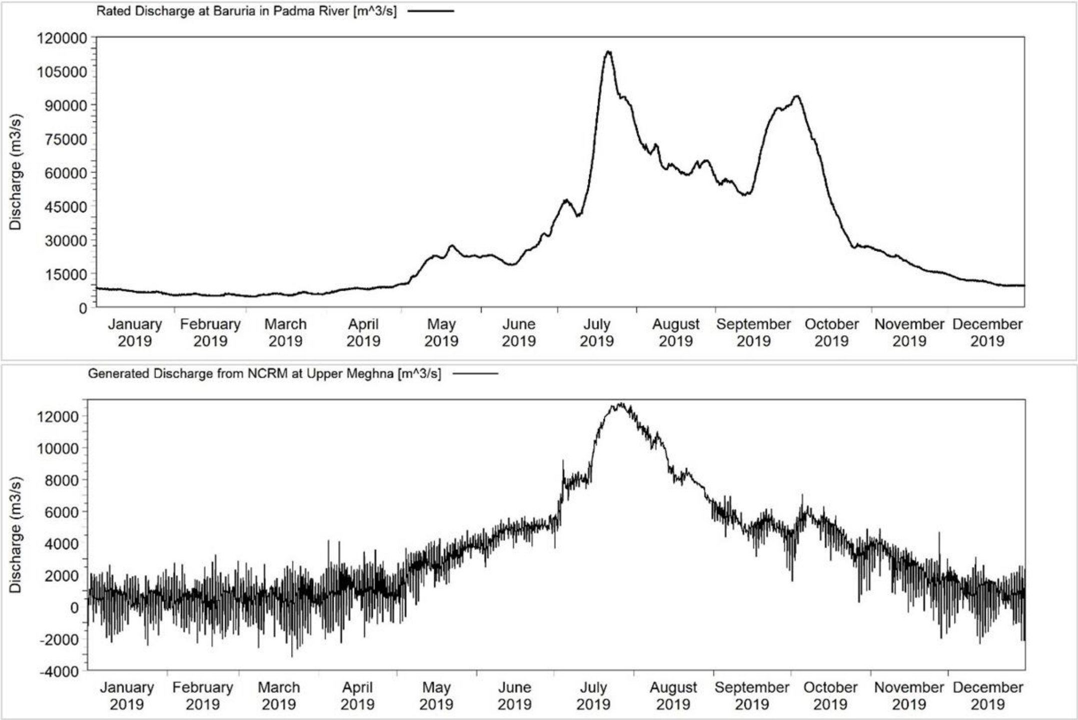


Figure 5. 2: Time Series Discharge Data in Baruria (Upper) and Bhairab Bazar (Lower)

The rest of 24 number boundaries have been generated from the calibrated and validated regional models (South-West and Eastern Hilly Regional Model). Both regional models are available in IWM. One typical plot at the upstream boundary location 15 in the Bay of Bengal Model setup has been presented in the following Figure 5.3.

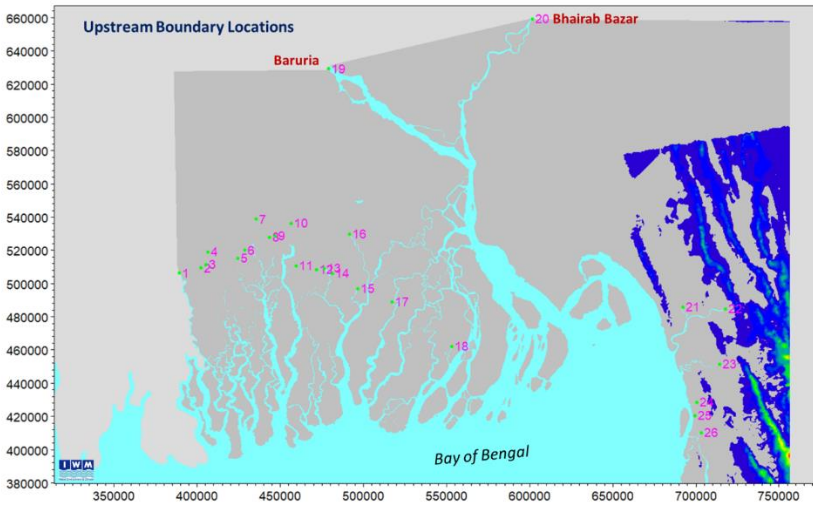


Figure 5. 3: Upstream open boundaries in the Bay of Bengal Model

The downstream boundary has been generated as line series water level from the Global Tide Model.

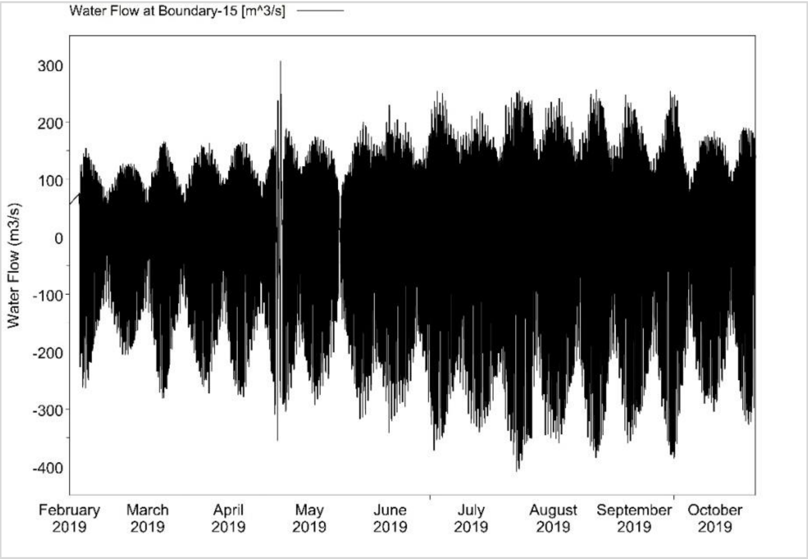


Figure 5. 4: Water flow at the boundary location 15 in the Bay of Bengal Model

5.2.3 Cyclone Data

Bangladesh Metrological Department observed the wind data at different locations in Bangladesh including the coastal area. In the CEIP-1, nine (09) stations were selected for verifying the measured wind speed & direction with the cyclonic model (Holland-Single Vortex) generated wind speed and wind direction. In this study, similar cyclone model and similar wind field and pressure field has been applied during developing the 19 severe cyclonic storm surge model. The wind speed and wind direction will be calibrated if storm surge model develops for the recent cyclones like Cyclone Mahasen, Cyclone Komen, Cyclone Roanu and Cyclone Mora etc.

5.2.4 Bed Resistance

To calibrate the model, it is necessary to adjust the bed resistance. In this study a map with different bed resistance has been used. The relation between Manning number (M) and bed roughness length, Ks can be estimated using the following formula:

$$M = \frac{25.4}{Ks^{1/6}}$$

The Manning number (M) is the reciprocal value of Manning's n. Initially a Manning map was prepared based on the local water depth, however, further corrections have been made during the calibration process of the model. The initial Manning number distribution is presented in Table **5. 1**.

Table 5. 1: Manning number distribution

Areas with depths	Manning number ($m^{1/3}/s$)
Below -20 m	32
-20 to -15 m	60
-15 to -10 m	65
-10 to -5 m	90
Above -5 m	100
Mangrove Forrest	15
Settlement & Rice field	25

Based on the water depth, constant in time and variation in domain Manning's number (M) has been used.

5.2.5 Eddy Viscosity

Constant horizontal eddy viscosity has been used in the upgraded and updated Bay of Bengal Hydrodynamic model. Smagorinsky formulation has been used and constant 0.28 Smagorinsky coefficient, CS has been considered in this model. However, the Smagorinsky coefficient, CS, varies in the interval of 0.25 to 1.0.

5.2.6 Wind Forcing

The drag coefficient can either be a constant value or depend on the wind speed. The empirical formulae proposed by Wu (1980, 1994) is used for the parameterization of the drag coefficient. During calculation of wind friction, the following wind seed and wind friction relation has been used

$$C_d = C_a \ \ when \ \ W_{10} < W_a$$
$$C_d = C_a + \frac{C_b - C_a}{W_b - W_a} * (W_{10} - W_{a)} \ \ when \ W_a \le W_{10} \le W_b$$
$$C_d = C_b \ \ when \ W_{10} > W_b$$

Where Ca, Cb, Wa and Wb are empirical factors and W_{10} is the wind speed 10 m above the sea surface. The default values for the empirical factors are Ca = 1.255·10-3, Cb = 2.425·10-3, Wa = 7 m/s and Wb = 25 m/s. The value gives generally good results for open sea applications. Field measurements of the drag coefficient collected over lakes indicate that the drag coefficient is larger than open ocean data. Considering this issue, wind friction has been used as linear varying with wind speed.

Linear relation with wind speed and wind friction

SL	Wind Speed (m/s)	Wind Friction
1	0	0.0016
2	24	0.0026

5.2.7 Model Calibration & Validation

The Storm Surge model is calibrated with observed Water level, Discharge and Surge level for cyclonic event. The calibration for water level and discharge is done for 15th Feb 2019 to 13th Oct 2019 and for storm surge level for 22th May 2009 to 27th May 2009. Validation of Water Level and Discharge is done with 2015 observed data.

5.2.7a Calibration of Water Level

Water level measurements have been carried out at Seven (07) locations under the Long-Term Research and Monitoring project. The observed locations are presented in the **Figure 5.5** and locations are i) Khaikhali in the transboundary Ichamoti River, ii) Nalian in the Shibsha River, iii) Joymoni in the Pussur River, iv) Char Doani in the Baleswar River, v) Taltoli in the Bishkhali River, vi) Dhulasar in the downstream of Rabnabad Channel, vii) Dasmina in the Tentulia River.

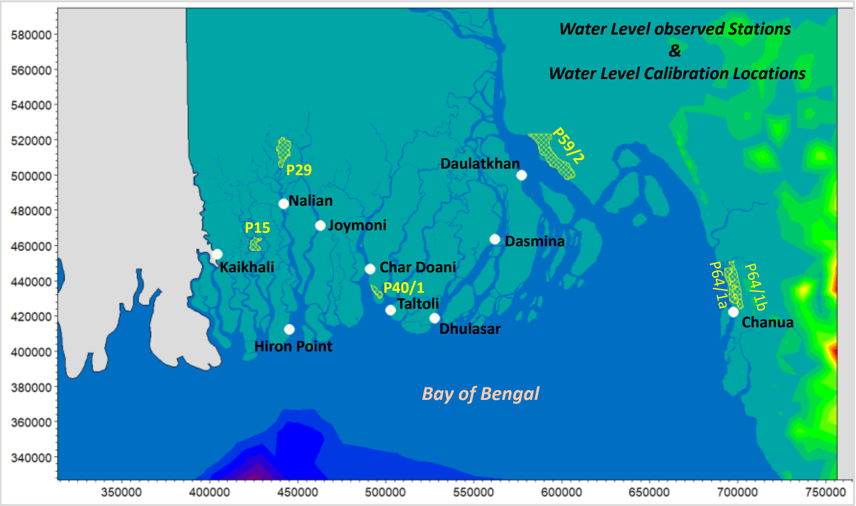


Figure 5. 5: Water level observation and calibration locations

Calibration of water level at Hiron point is shown in Figure 5.6.

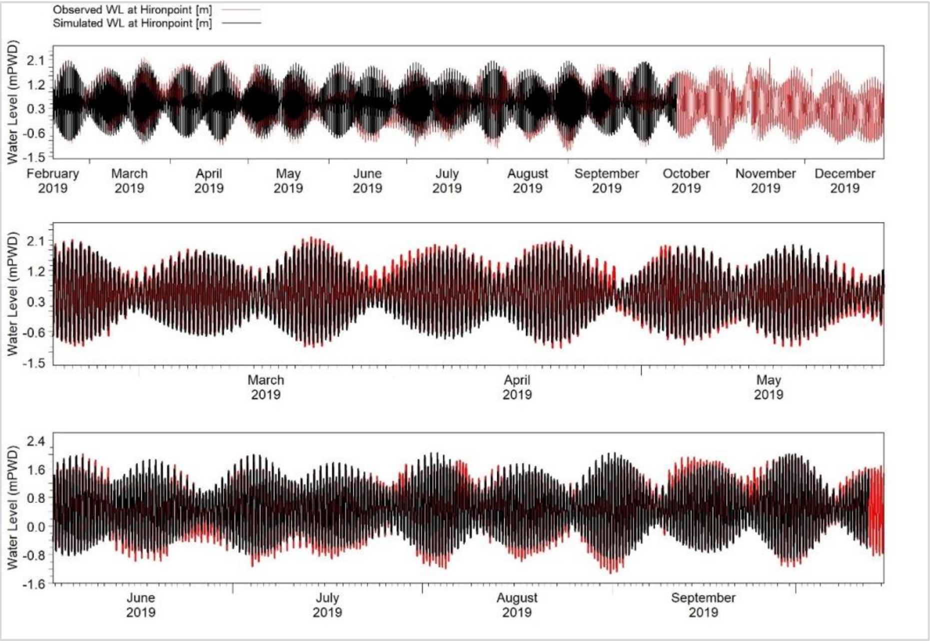


Figure 5. 6: Calibration of Water Level at Hiron Point

5.2.7b Calibration for Discharge

Similarly, the developed upgraded and updated Bay of Bengal Model has been verified at different locations with the observed discharge data. The following **Figure 5.7** presents the discharge calibration plot at Katalia Bazar in the Gangrail River, Nalian in the Shibsha River, Mongla in the Pussur River, Char Doani left bank of Baleswar River, Char Doani right bank of Baleswar River, Nazirpur (Dasmina) in the Tentulia River, Harina Ghat in the Lower Meghna River, at Tailardwip in the Sangu River which are covering the dry season and monsoon along with spring tide and neap tide conditions.

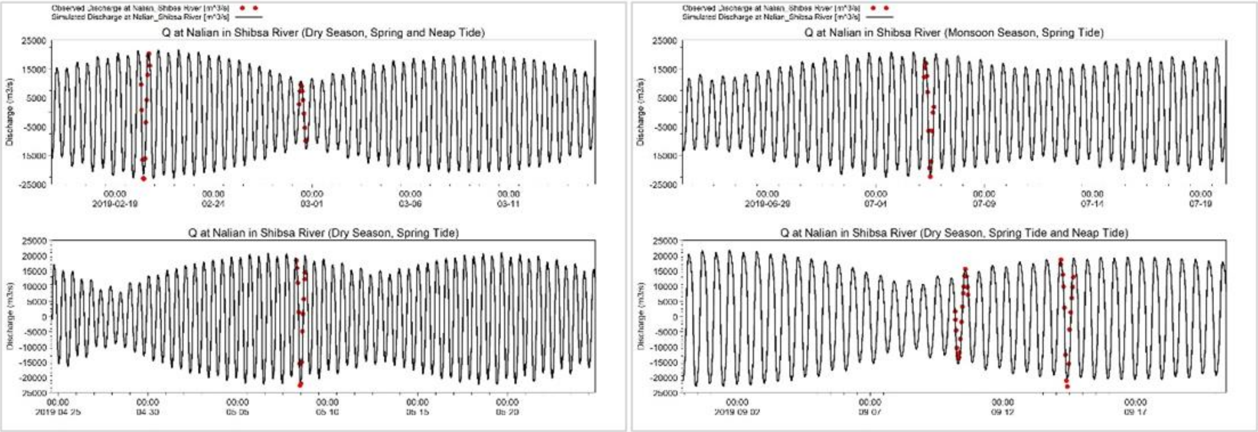


Figure 5. 7: Discharge Calibration at Nalian in Sibsa River

5.2.7c Calibration for Surge Level

In Bangladesh, Survey of Bangladesh (SOB) is maintaining an automated tide gauge at Hiron Point (21.783333 deg lat and 89.466667 deg lon) in the Sundarbans. The cyclonic Storm surge model has been calibrated at Hiron Point with the observed water level. The following **Figure 5.8** presents the comparison of the simulated surge level during cyclone AILA (2009) and observed water level at Hiron Point.

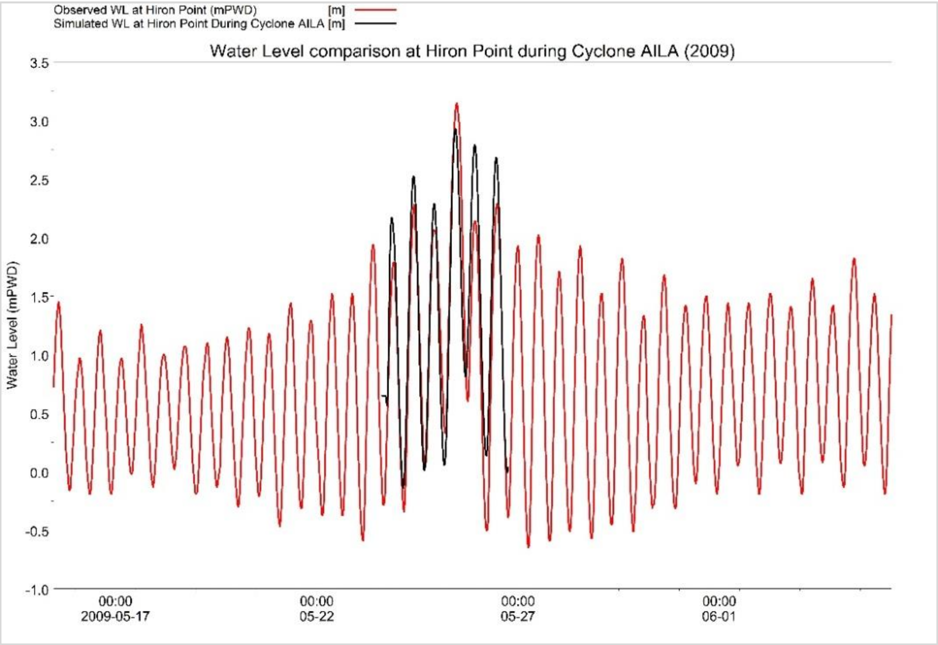


Figure 5. 8: Water level comparison at Hiron Point during the cyclone AILA (2009)

5.2.7d Validation of Water Level

Water level has been collected at seventeen (17) locations during the CEIP-1 only covering the selected 17 no. polders in 2015. Water level comparison has been carried out in the Shibsa River, Baleswar River, downstream of the Bishkhali-Buriswar River and the Payra River. The Comparison of water level at Banishanta in Sibsa River shown in Figure 5.9.

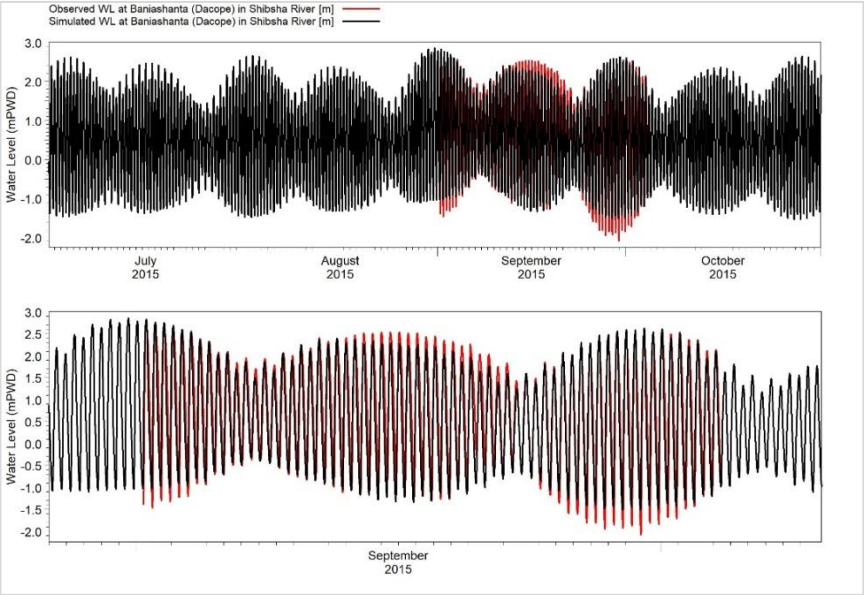


Figure 5. 9: Water Level comparison at Banishanta in Sibsa River

5.2.7e Validation of Discharge

Discharge measurement were carried out about fourteen (14) no. locations during CEIP-1 covering only the monsoon period including spring tide and neap tide. The model has not been validated all measurement location. However, it shows well agreement (Figure 5.10) with the observed discharges at the validated locations.

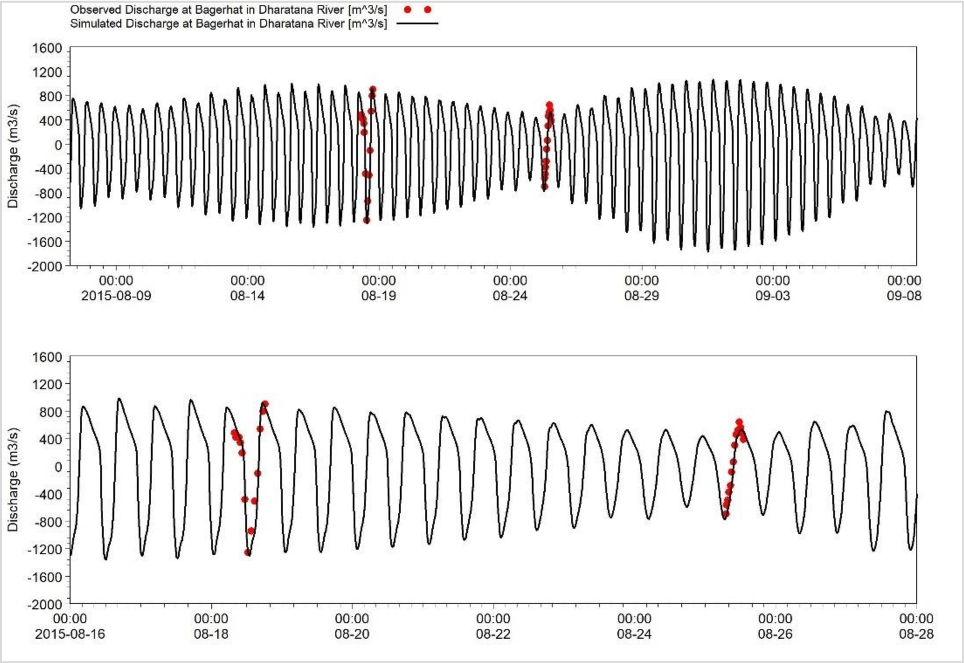


Figure 5. 10: Discharge comparison at Bagerhat in Dharatna River

6 CAPACITY BUILDING

6.1 Training Course on Polder Water Management Modelling and Database

A training programme on “Polder Water Management Modelling” was conducted intermittently (five days) by the Joint Venture of DHI and Deltares in partnership with IWM under “Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone” Consultancy Service of Coastal Embankment Improvement Project, Phase-1 (CEIP-1). The programme was planned for the BWDB engineers which commenced from 15 February and closed on 22 February, 2021 at the office of the Consultant: Flat#3/B, House#4, Road#23/A, Banani, Dhaka-1213. Dr. Md Mizanur Rahman, Addl. Director General (Planning), BWDB virtually inaugurated the programme on 15 February 2021. Mr. Zahir-ul Haque Khan, Deputy Team Leader, Dhaka conducted evaluation of the training course. On 22 February 2021, the training was closed by Mr. Md. Syed Hasan Imam, Project Director, CEIP-1, BWDB and Mr. Abu Saleh Khan distributed the training certificate to participants. The whole training program was coordinated by Mr. Zahir-ul Haque Khan, Deputy Team Leader of the Project and the following IWM professionals provided the training.

IWM:

- Saiful Islam
- Raqubul Hasib

Presently the local people of the coastal polders of Bangladesh are trying to use the system for their own interests by providing cross dams across the khals and keeping the water for their agricultural and domestics uses. It is a common scenario in most of the coastal polders. At the same time people are using their agricultural land for the shrimp firming and use the regulators for flushing the saline water into the polder system. Therefore, day by day the inside and outside of the polders systems are becoming worst due to lack of knowledge on the water management system. People have no idea that the coastal polders are a completely integrated system where agriculture is directly connected with nature (rain) and availability of water in the khals; flow in the khals are directly involve with the condition of the khals and operation of regulators; operation of the regulators relate to the conditions of the gates and the conditions of the peripheral river system. It proves that polder management system is not an individual system and these systems needs the nature-based solutions with some engineering visionary plans immediately.

There are some critical water management related problems in the polders like construction of cross dams in the khals, construction of Union or Upazila connecting roads in the flowing channels by disconnecting the channels and Operation & Maintenance of Regulators

In the polder systems of the coastal region of Bangladesh, there is a need for objective and practical knowledge about the behaviour of the water system, understand the impacts and action perspectives of water management options and share this information among stakeholders. Present communication between stakeholders is often scarce, and information on (practical) water management issues is either not readily available or easily shared. With many different stakeholders in one polder, sharing information is a first step towards solving conflicts, planning for Operation & Maintenance (O&M) and anticipating on events such as floods, waterlogging and droughts.

To overcome such kind of problems detail field investigations and survey (for collecting social, economic, and engineering data) are required. To understand the physical and practical knowledge, detailed mathematical modelling tools are required which will present the existing polder system and also a system with engineering interventions for future. Simultaneously, different kinds of model like social and behavior model, economic growth calculation model are required to be considered to select the best suited engineering options.

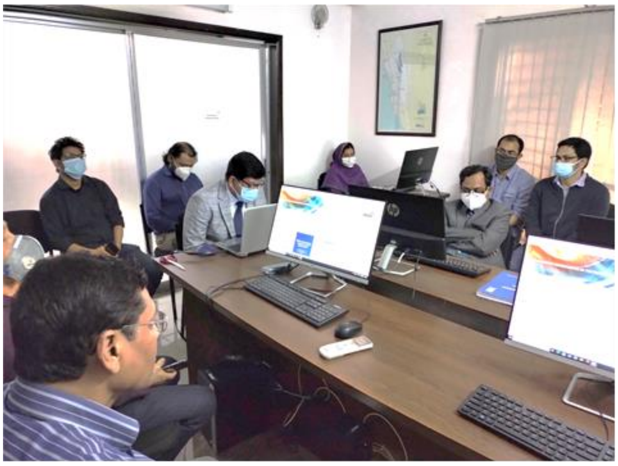
Detailed data collection with mathematical model are being developed for the selected polders under the **Long-Term Monitoring, Research & Analysis of Bangladesh Coastal Zone** project to understand the existing polder system along with future interventions considering climate change scenarios.

Learning: Preparation of Inundation depth maps, assessment of effectiveness of water management system of a polder at present and future, preparation of best suited water management plan.

The following participants were participated from BWDB for the above-mentioned Training Program:

Sl. No.	**Name**	**Designation**	**Contact No.** **Mobile & Email**
1.	Dr. Md. Sarfaraz Banda	Superintending Engineer (CC), Surface Water Hydrology Circle, BWDB, Dhaka	sarfarazbanda48@gmail.com Mobile No- 01724-708905
2.	Dr. Md. Khairul Islam	Superintending Engineer (CC), CSO to DG BWDB, Dhaka	kl96wre@gmail.com Mobile No- 01719-859366
3.	Jakaria Pervez	Executive Engineer, Office of the Chief Monitoring, BWDB, Dhaka	jakariapervez@gmail.com Mobile No- 01712-660025
4.	Mohammad Samiul Hoque	Executive Engineer, PMU, CEIP-1, BWDB, Dhaka	samiul1979@gmail.com Mobile No- 01726-233262
5.	Dr. Muhammad Masood	Superintending Engineer, Design Circle-9, BWDB, Dhaka	masood35bd@yahoo.com Mobile No-01911-576729
6.	Mst. Tasmem Jahan	Executive Engineer, Design Circle-5, BWDB, Dhaka	msttasmemjahan@gmail.com Mobile No-01718-097911
7.	Ms. Poly Das	Executive Engineer, Design Circle-7, BWDB, Dhaka	enggpoly@yahoo.com Mobile No-01670-681427
8.	Ms. Sirazhum Monera Asha	Assistant Engineer, Central GIS Directorate, BWDB, Dhaka.	aasha074@gmail.com Mobile No-01783-921572

Photograph 1: Distribution of Certificate by Mr. Abu Saleh Khan, ED, IWM



Photograph 2: Speech by Mr. Md. Syed Hasan Imam, Project Director, CEIP-1, BWDB

The participants from BWDB realized that this kind of training was very useful to them and needs to be conducted more frequently. However, in the upcoming quarters training on Interactive Geo-Database for Coastal Zone Operations (IGDCZ) and on Salinity will be provided.

Training on Interactive Geo-Database for Coastal Zone (IGDCZ) Operations has been planned to be arranged for 3 days in accordance with the terms of reference (ToR). The training program will be provided for 6 participants which will commence from 24 May 2021 to 30 May 2021 at the Banani Project office (Flat #3B, House #4, Road #23/A, Banani, Dhaka 1213). The program will provide hands on training on the applications of Interactive Geo-Database for Coastal zone (IGDCZ) and its development. The schedule of the training is provided in the following table.

Regarding the training on 24-30 May 2021, Project Director issued and office order (memo No: CEIP/568 dated 20 May 2021) where the name of the 11 participants from BWDB has been mentioned. Office Order of the Project Director is provided in Annex-1.

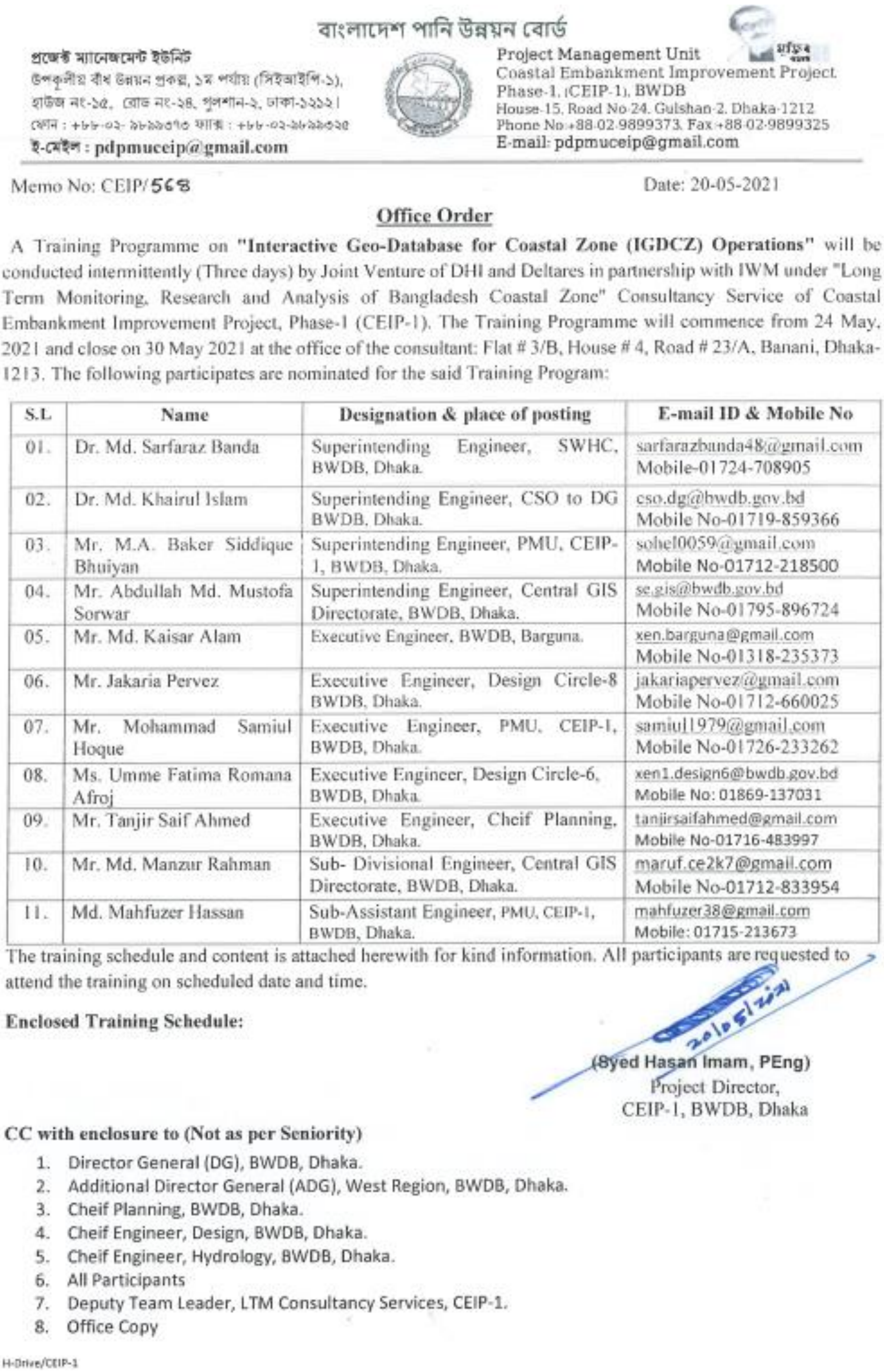
Training Schedule for IGDCZ operations, Long Term Monitoring Project, CEIP, BWDB

Training Venue: Project Office, Flat #3/B, House #4, Road #23/A, Banani, Dhaka 1213

Day	**Time**	**Module**	**Topics**	**Key person/ Trainer**	**Remarks**
Day 1 24/05/2021	10.00 - 10.30 am	Inauguration	Welcome address. Overview of the project	Project Director Md. Zahirul Haque Khan, DED(Opn), IWM	
	10.30 - 11.00 am	Refreshment			
	11.00 – 12.30 pm	Introduction to IGDCZ	- Overall - Database - Platform - Application	Dr. Mollah Md Awlad Hossain, Director, ICT, IWM Md. Humayun Kabir, Sr. GIS & Database Specialist, IWM Mohammad Kamruzzman, GIS Specialist, IWM	Presentation
	12.30 – 1.00 pm	Lunch & Closing			
Day 2 25/05/2021	10.00 – 11.00 am	Web GIS Based IGDCZ Application	IGDCZ Interface IGDCZ Database IGDCZ Operations	Md. Humayun Kabir, Sr. GIS & Database Specialist, IWM Mohammad Kamruzzman, GIS Specialist, IWM	Online Demonstration
	11.00 – 11.30 am	Refreshment			
	11.30 – 12.30 pm	Continuation	IGDCZ Metadata	Md. Humayun Kabir, Sr. GIS & Database Specialist, IWM Mohammad Kamruzzman, GIS Specialist, IWM	Online Demonstration
	13.00 – 14.00 pm	Lunch & Close			
Day 3 30/05/2021	10.00 – 11.00 am	User operations of IGDCZ	Exercise of Data View, Edit, Update by the users and feedbacks	Md. Humayun Kabir, Sr. GIS & Database Specialist, IWM Mohammad Kamruzzman, GIS Specialist, IWM	Practical Exercise
	11.00 – 11.30 am	Refreshment			
	11.00 – 12.30 pm	Continuation	Operations by the users and feedbacks	Md. Humayun Kabir, Sr. GIS & Database Specialist, IWM Mohammad Kamruzzman, GIS Specialist, IWM	Practical Exercise
	12.30 – 01.00 pm	Comments by one trainee Certificate distribution Concluding Remarks		One from the Trainees Project Director	
	1.00 – 1.30 pm	Lunch & Close of Programme			

ANNEX-1

Office Order from Project Director, CEIP-1, BWDB, Dhaka



বাংলাদেশ পানি উন্নয়ন বোর্ড

প্রজেক্ট ম্যানেজমেন্ট ইউনিট
উপকূলীয় বাঁধ উন্নয়ন প্রকল্প, ১ম পর্যায় (সিইআইপি-১),
হাউজ নং-১৫, রোড নং-২৪, গুলশান-২, ঢাকা-১২১২।
ফোন : +৮৮-০২- ৯৮৯৯৩৭৩ ফ্যাক্স : +৮৮-০২-৯৮৯৯৩২৫
ই-মেইল : pdpmuceip@gmail.com

Project Management Unit
Coastal Embankment Improvement Project
Phase-1, (CEIP-1), BWDB
House-15, Road No-24, Gulshan-2, Dhaka-1212
Phone No:+88-02-9899373, Fax:+88-02-9899325
E-mail: pdpmuceip@gmail.com

Memo No: CEIP/৫৬৪

Date: 20-05-2021

Office Order

A Training Programme on **"Interactive Geo-Database for Coastal Zone (IGDCZ) Operations"** will be conducted intermittently (Three days) by Joint Venture of DHI and Deltares in partnership with IWM under "Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone" Consultancy Service of Coastal Embankment Improvement Project, Phase-1 (CEIP-1). The Training Programme will commence from 24 May, 2021 and close on 30 May 2021 at the office of the consultant: Flat # 3/B, House # 4, Road # 23/A, Banani, Dhaka-1213. The following participates are nominated for the said Training Program:

S.L	Name	Designation & place of posting	E-mail ID & Mobile No
01.	Dr. Md. Sarfaraz Banda	Superintending Engineer, SWHC, BWDB, Dhaka.	sarfarazbanda48@gmail.com Mobile-01724-708905
02.	Dr. Md. Khairul Islam	Superintending Engineer, CSO to DG BWDB, Dhaka.	cso.dg@bwdb.gov.bd Mobile No-01719-859366
03.	Mr. M.A. Baker Siddique Bhuiyan	Superintending Engineer, PMU, CEIP-1, BWDB, Dhaka.	sohel0059@gmail.com Mobile No-01712-218500
04.	Mr. Abdullah Md. Mustofa Sorwar	Superintending Engineer, Central GIS Directorate, BWDB, Dhaka.	se.gis@bwdb.gov.bd Mobile No-01795-896724
05.	Mr. Md. Kaisar Alam	Executive Engineer, BWDB, Barguna.	xen.barguna@gmail.com Mobile No-01318-235373
06.	Mr. Jakaria Pervez	Executive Engineer, Design Circle-8 BWDB, Dhaka.	jakariapervez@gmail.com Mobile No-01712-660025
07.	Mr. Mohammad Samiul Hoque	Executive Engineer, PMU, CEIP-1, BWDB, Dhaka.	samiul1979@gmail.com Mobile No-01726-233262
08.	Ms. Umme Fatima Romana Afroj	Executive Engineer, Design Circle-6, BWDB, Dhaka.	xen1.design6@bwdb.gov.bd Mobile No: 01869-137031
09.	Mr. Tanjir Saif Ahmed	Executive Engineer, Cheif Planning, BWDB, Dhaka.	tanjirsaifahmed@gmail.com Mobile No-01716-483997
10.	Mr. Md. Manzur Rahman	Sub- Divisional Engineer, Central GIS Directorate, BWDB, Dhaka.	maruf.ce2k7@gmail.com Mobile No-01712-833954
11.	Md. Mahfuzer Hassan	Sub-Assistant Engineer, PMU, CEIP-1, BWDB, Dhaka.	mahfuzer38@gmail.com Mobile: 01715-213673

The training schedule and content is attached herewith for kind information. All participants are requested to attend the training on scheduled date and time.

Enclosed Training Schedule:

20/05/2021

(Syed Hasan Imam, PEng)
Project Director,
CEIP-1, BWDB, Dhaka

CC with enclosure to (Not as per Seniority)

1. Director General (DG), BWDB, Dhaka.
2. Additional Director General (ADG), West Region, BWDB, Dhaka.
3. Cheif Planning, BWDB, Dhaka.
4. Cheif Engineer, Design, BWDB, Dhaka.
5. Cheif Engineer, Hydrology, BWDB, Dhaka.
6. All Participants
7. Deputy Team Leader, LTM Consultancy Services, CEIP-1.
8. Office Copy

H-Drive/CEIP-1