Government of the People's Republic of Bangladesh
Bangladesh Water Development Board (BWDB)

Coastal Embankment Improvement Project

Consultancy Services for Feasibility Studies and Preparation of Detailed Design for the Following Phase of the Coastal Embankment Improvement Project (CEIP)

Polder Screening Report

June 2022

Royal HaskoningDHV Enhancing Society Together | IL | nhc northwest hydraulic consultants | SMC | CEGIS | DDC Development Design Consultants Limited | KMC Ltd Working for safe living

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Abbreviations, acronyms and units

ACL	Authorized Crest Level
ADCP	Acoustic Doppler Current Profiler
AHP	Analytical Hierarchy Process
ARIPA	Acquisition and Requisition of Immovable Property Act
ARIPO	Acquisition and Requisition of Immovable Property Ordinance
AsDB	Asian Development Bank
BADC	Bangladesh Agriculture Development Corporation
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BoB	Bay of Bengal
BoB SAL	Bay of Bengal Salinity
BoQ	Bill of Quantities
BRRI	Bangladesh Rice Research Institute
BTM	Bangladesh Transverse Mercator
BWDB	Bangladesh Water Development Board
BM	Bench Mark
BoBM	Bay of Bengal Model
CBA	Cost-Benefit Analysis
CC	Climate Change
CCL	Cash Compensation Under Law
CDPo	Coastal Development Policy
CDMP	Comprehensive Disaster Management Program
CDS	Coastal Development Strategy
CDSP	Char Development and Settlement Project
CEGIS	Center for Environmental and Geographic Information Services
CEIP	Coastal Embankment Improvement Program / Project
CEIP-1	Coastal Embankment Improvement Program / Project – Phase 1
CEIP-2	Coastal Embankment Improvement Program / Project – Phase 2
CEP	Coastal Embankment Project
CERP	Coastal Embankment Rehabilitation Project
CES	Coastal Embankment System
CPP- I	Cyclone Protection Project - I
CPP- II	Cyclone Protection Project - II
CZ	Coastal Zone
CZE	Coastal Zone Embankment

CZPo	Coastal Zone Policy
CZWMP	Coastal Zone Water Management Program
CSPS	Cyclone Shelter Preparatory Study
DAE	Department of Agriculture *Extension*
DCF	Discounted Cash Flow
D&CSC	Design & Construction Supervision Consultants
DDC	Development Design Consultants
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute Denmark
DISREP	Distribution Sector Recovery Program
DGPS	Differential Global Positioning System
DLR	Director Land Records
DoE	Department of Environment
DoF	Department of Fisheries
DPM	Design Planning and Management
DPP	Development Project Proforma/Proposal
DSM	Digital Surface Model
DTM	Digital Terrain Model
EA	Environmental Assessment
EAD	Estimated Annual Damage
EAP	Environmental Action Plan
ECA	Environmental Conservation Act
ECR	Environmental Conservation Rules
ECRRP	Emergency Cyclone Recovery and Restoration Project
ED	Executive Director
EDP	Estuary Development Program
EEWS	Early Erosion Warning System
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EMA	External Monitoring Agency
EMP	Environmental Management Plan
EMF	Environmental Management Framework
EPG	Embankment Protection Group
EPs	Entitled Persons
ES	Embankment Settlers
ESS2	Environmental and Social Standard 2
ESCP	Environmental & Social Commitment Plan
ESF	Environmental and Social Framework
ESS	Environmental Social Standards
FAO	Food and Agricultural Organization
FAP-7	Flood Action Plan-7

FCD	Flood Control & Drainage
FCDI	Flood Control Drainage and Irrigation
FGD	Focus Group Discussion
FFG	Foreshore Forestry Group
FM	Flood Management
FO	Field Office
FREMIP	Flood and Riverbank Erosion Risk Management Investment Program
FWOP	Future-Without-Project
FWIP	Future-With-Project
GBV	Gender Bases Violence
GCC	General Conditions of Contract
GCPs	Ground control points
GDP	Gross Domestic Product
GeoDASH	Geospatial Data Sharing Portfolio
GIS	Geographic Information Systems
GOB	Government of Bangladesh
GO	Government Organization
GPP	Guidelines for People's Participation
GPS	Global Positioning System
GRM	Grievance Redress Mechanism
GRRP	Gorai River Restoration Project
IA	Implementing Agency
IBRD	International Bank for Reconstruction & Development
ICB	International Competitive Bidding
ICZM	Integrated Coastal Zone Management
ICZMP	Integrated Coastal Zone Management Plan
ICZMP	Integrated Coastal Zone Management Program
IDA	International Development Agency
IESCs	Important Environmental and Social Components
IPC & WMPs	Infection Prevention Control and Waste Management Plans
IRR	Internal Rate of Return
INROS	Inros Lackner
IoL	Inventory of losses
IPCC	Intergovernmental Panel on Climate Change
IPSWAM	Integrated Planning For Sustainable Water Management
ITC	Information and Communication Technologies
IUCN	International Union for Conservation of Nature
IWM	Institute of Water Modelling
IEE	Initial Environmental Examination
KJDRP	Khulna Jessore Drainage Rehabilitation Project
KII	Key Informant Interview

KMC	Knowledge Management Consultants
LAPs	Land Acquisition Plans
LGED	Local Government Engineering Department
LGI	Local Government Institution
LMP	Labour Management Procedure
LRP	Land Reclamation Project
MCA	Multi-Criteria Analysis
M&E	Monitoring and Evaluation
MES	Meghna Estuary Studies
MIS	Management information systems
MoEF	Ministry of Environment and Forest
MoFDF	Ministry of Food and Disaster Management
MOWR	Ministry of Water Resources
MoL	Ministry of Land
MSL	Mean Sea Level
NBS	Nature-Based Solutions
NCB	National Competitive Bidding
NEP	National Environmental Policy
NEMAP	National Environment Management Action Plan
NGO	Non Government Organization
NHC	Northwest Hydraulics Consultants
NWMP	National Water Management Plan
OCC	One-stop Crisis Cell
O&M	Operation and Maintenance
OP	Operation Policies
PSC	Project Steering Committee (PSC)
RAP	Resettlement Action Plan
REA	Rapid Environmental Assessment
RMS	Root Mean square
RPF	Resettlement Policy Framework
RTK	Real Time Kinematic
PAP	Project Affected People
PAVC	Property Assessment and Valuation Committee
PBM	Permanent Bench Marks
PD	Project Director
PDC	Polder Development Committee
PIU	Project Implementation Unit
PMU	Project Management unit
POM	Project Operations Manual
PPCR	Pilot Programme for Climate Resilience

PPR	Project Progress Report
PMIS	Polder Management Information System
PVS	Property Valuation Survey
PWD	Public Works Department
PRA	Participatory Rapid Assessment
JV	Joint Venture RHDHV-NHC-INROS
RAP	Resettlement Action Plan
RRA	Rapid Rural Appraisal
RCC	Reinforced Cement Concrete
RHDHV	Royal HaskoningDHV
RoR	Record of Rights
SA	Social Assessment
SCM	Stakeholders Consultation Meeting
SEP	Stakeholder Engagement Plan
SIA	Social Impact Assessment
SLR	Sea Level Rise
SMRPFW	Social Management and Resettlement Policy Framework
SPARSO	Space Research & Remote Sensing Organization
SPMC	Strategic Planning and Management Consultants
SRP	System Rehabilitation Project
SRDI	Soil Resource Development Institute
SSHSMP	Site-Specific Health and Safety Management Plan
SWMC	Surface Water Modelling Centre
SWZ	South Western Zone
SZ	Southern Zone
SOB	Survey of Bangladesh
SWRM	South West Region Model
SEA	Strategic Environmental Assessment
SEAA	Sexual Exploitation and Assault
SMRPF	Social Management & Resettlement Policy Framework
SWRSAL	South West Region Salinity
TRM	Tidal River Management
TBM	Temporary Bench Mark
ToR	Terms of Reference
WARPO	Water Resources Planning Organization
WB	World Bank
WMA	Water Management Association
WMIP	Water Management Improvement Project
WRS	Water Retention Structures
WSIP	Water Sector Improvement Project
WUA	Water Users Association

MWh	Megawatt hour
m	Metre
cm	Centimetre
ha	Hectare
l	Litre
mm	Millimetre
m^3/s	Cubic metres per second
m^3	Cubic metres
km	Kilometre
km^2	Square kilometres
Mt	Mega ton (10^9 kilogram)

1. Introduction

1.1 General

This report constitutes the contractual deliverable "Polder Screening Report" as per Consultancy Contract and indicated in the Terms of Reference (ToR) as "Preliminary List of screening of 23 Polders". The draft Polder Screening Report was submitted on 27th December 2021 and comments received on 19th May 2022 have been included as per Appendix 5.

In the Inception Report, the Consultant has already partially elaborated on the approach and process of pre-selection of 23 polders out of the 125 remaining polders and has set the groundwork for this Polder Screening Report as far as was possible with the data available and time span of only one month. In this Report, the Consultant has taken forward and refined the aforementioned approach, updated the assessment with more secondary data, conducted more consultations with the Main Stakeholders and developed a Multi Criteria Analysis (MCA) which has been filled in for all 125 polders with the available secondary data.

1.2 Background of the Project

Known as one of the largest, youngest, and most active deltas in the world, the Coastal Zone of Bangladesh spans more than 580 km along the Bay of Bengal and covers an area of 32% of the country (47,201 km^2)[1]. The delta consists mainly of the confluence of the Ganges, Brahmaputra and Meghna (GBM). Together they form the largest delta in Asia, which delivers an enormous volume of sediment to the Bay of Bengal[2].

The GBM delta, with its abundance of natural resources defines Bangladesh, both when it comes to its physical and cultural characteristics as well as the livelihoods of its people. The delta is characterized by its flatness. Sixty-two percent of the coastal land has an elevation less than 3 m above sea level. Raising this level up to 5 m increases this percentage to eighty-three percent[3]. The strength of the tides in conjunction with the lack of elevation of the delta causes the tides to have an influence a long way upstream in the southern estuaries.

Roughly 46 million Bangladeshi (29% of the total population[4]), call the Bangladesh's Coastal Zone their home. The region is predominantly used for agriculture and more than 30% of the countries cultivatable land can be found in the coastal area [5]. Other economic activities that can typically be found in the region include shrimp and fish farming, forestry, tourism, salt production, ship-breaking and ports. There are ample growth opportunities to be found in the coastal region. However, these all come with risks as the coastal zone is well-known for its vulnerability to coastal hazards[6].

Bangladesh's coastal communities are endangered by the constant threat of cyclones, which can cause inundation of the coastal land from high storm surges. To add to this, slow-moving

[1] Ministry of Water Resources, 2003. Delineation of the Coastal Zone, Program Development Office for Integrated Coastal Zone Management Plan (PDO-ICZMP), WP005. The administrative delineation of the Coastal Zone comprises 19 Districts, 147 upazilas and the exclusive economic zone
[2] Kuehl, S.A., Hariu, T.M. and Moore, W.S., 1989. Shelf sedimentation off the Ganges Brahmaputra River System: evidence for sediment bypassing to the Bengal Fan. Geology. 17, 1132-1135
[3] Bangladesh Water Development Board. Coastal Embankment Improvement Project, Draft Final Report, Sept 2012
[4] Ahmad, H., 2019. Bangladesh Coastal Zone Management Status and Future Trends, Journal of Coastal Zone Management
[5] Ministry of Agriculture Bangladesh (2010). SRMAF Project, Soil Resource Development Institute
[6] Tessler et al. 2015. Profiling risk and sustainability in coastal deltas of the world

chronic stressors such as erosion, saline intrusion and waterlogging occur frequently and to a large extent in the coastal zone. These stressors can result in loss of land, failure of infrastructure, challenges to operate the drainage systems in the polders and overall reduced agricultural productivity.

Due to the constant coastal threats formed by the cyclonic events, chronic stressors and the zone being influenced by the river system's fluctuations, Bangladesh is considered one of the most disaster-prone and climate vulnerable countries in the world.

In order to reduce risk, save lives, reduce economic losses and protect the hard-earned development gains, the Bangladeshi Government has been making considerable attempts over the past decades. The development of Polders has played a key role in these attempts. To protect the people and agricultural land from tidal inundation and saline water intrusion, as well as recover a large extent of land for permanent agriculture, the Government has been constructing polders since the early 1960's.

A polder can be defined as a "low-lying tract of land, enclosed by embankments known as dykes that form an independent hydrological entity which has no physical connection with the outside water other than through manually operated devices (i.e. water control structures)". Polders protect the coastal zone in several ways. First of all, they prevent saline water to enter the agricultural fields, which improves agricultural productivity and thereby providing food security for the zone's inhabitants. Second, they protect against frequent tidal flooding, which prevents damage to both people and crops, resulting in the stimulation of economic development of the local communities.

Drainage and flushing sluices control the water inside the embanked polder. Along the coastal zone, an area of 1.2 million ha is covered by a total of 139 polders. These combined, cover roughly 25% of the coastal zone and contain a total embankment length of about 5,665 km. In addition to this, a total of 1,697 regulators, 1,202 flushing inlets and a length of about 5,707 km of drainage channels are in place to control the water. The current embankment crest levels can typically provide protection to a storm surge level that would occur typically once every 5 to 10 years only (2% wave overtopping level)[7].

The Bangladesh's Government progress to reduce the vulnerabilities of the coastal zone communities, included the construction of 139 polders, and has been outstanding during the last 60 years. However nowadays, the effectiveness of the polders has been compromised by either direct or indirect causes. Direct causes are amongst others, severe cyclones, shifting coastal and riverbank lines and indirect causes are siltation and waterlogging.

The prevailing vulnerability of the coastal zone to direct and indirect coastal threats, highlights the urgency to rehabilitate the damaged infrastructure as well as improve their resistance to climate change threats. Even though polder rehabilitation projects from severe cyclones have been introduced recently, such as Emergency Cyclone Recovery and Restoration Project[8] (ECRRP), the need to action is vital.

When the polder concept was introduced, polders have been designed to protect only against tidal flooding. Recently, and by taking projections of climate change into consideration, the

[7] Design Manual Procedures for Designs of Polders in Tidal Areas in Bangladesh, Md. Abdul Quassem, P.F. Raijmakers, J. Burger, Delta Development Project Bangladesh Water Development Board, 1983

[8] Emergency Cyclone Recovery and Restoration Project, World Bank, 2018

polder design has been upgraded by including additional protection measures against storm surges and cyclone flooding. The upgraded design was introduced and is currently being implemented under the first phase of the Coastal Embankment Improvement Program (CEIP-1) implemented by the Bangladesh Water Development Board and funded by the World Bank.

In 2013, the first phase of the Coastal Embankment Improvement Project (CEIP-1) was initiated whereby 17 priority polders have been selected for feasibility and implementation of rehabilitation and improvements. The polders were clustered in six Districts: Khulna, Bagerhat, Pirojpur, Barguna, Patuakhali and Satkhira mainly in the Southwest region. The commonalities between the selected polders lay on their underlying threats by storm surges, drainage congestion, sedimentation and erosion. Currently only 10 polders of Package-1, being polders 32, 35/1, 33, 35/3, and Package-2, being polders 39/2C, 40/2, 41/1, 43/2C, 47/2 and 48, are being implemented under CEIP-1 and the 7 remaining polders of the envisaged Package-3, being Polders 14/1, 15, 16, 17/1, 17/2, 23 and 34/3, are planned to be implemented in the next phase of CEIP.

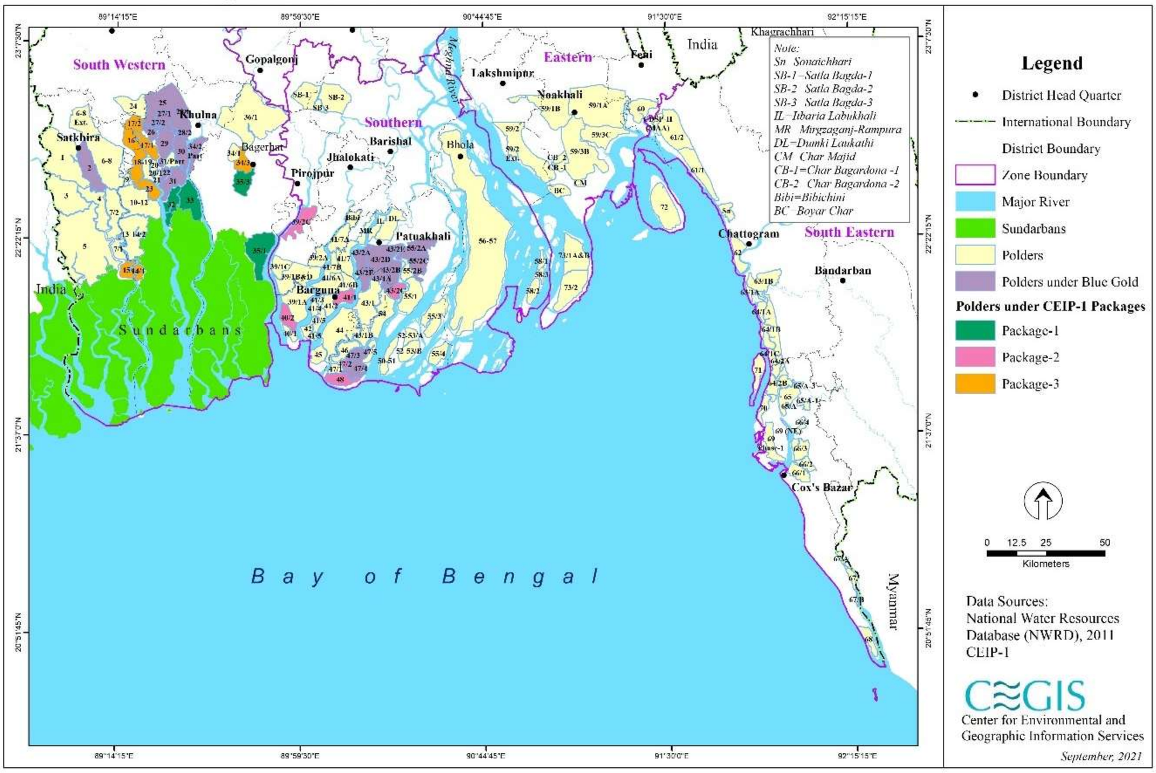

Figure 1-1: CEIP-1 Polders and other polders

Within the scope of the preparations for the next phase of CEIP, an assessment will be made of the remaining 125 polders and select a next batch of 13 polders. The selection of the polders will be done in stages and the approach and methodology is delineated in the following Chapter. This Chapter focuses on the first step of the pre-selection of the 23 polders out of the 125 remaining polders.

1.3 Methodology

A polder Screening Framework for the 125 polders in the coastal zone is carried out via means of the flow chart presented in Figure 1-2. The Screening Framework begins with gaining a profound understanding of the complex coastal dynamics, the prevailing hazards, the socio-economic developments and environmental challenges. This overall assessment, in combination with the lessons learned from past and ongoing relevant projects, allows the Consultant to define the principles which will guide the polder screening process. Thereafter, the guiding principles are translated into solid criteria which are used for the Multi Criteria Analysis (MCA). The MCA is developed and filled in for all 125 polders, which allows to gain good understanding of the condition and needs of all polders and at the same time, be able to compare and prioritize on balanced grounds. The MCA, now developed for the current preparations of the next phase of CEIP-2, incorporates updates from the MCA developed in 2012 within the preparation Feasibility Studies[9] for CEIP and includes several new additions based on the Consultant's technical and physical knowledge as well as lessons learned from CEIP-1 and other relevant projects/ programmes.

At the same time, a number of polders are currently under other ongoing programs, either Government of Bangladesh (GoB) or International Development Agency (IDA) funded[10]. A so-called Development Project Proposal (DPP) has been approved for some of them, and for others the DPP approval procedures are underway. These polders have been included in the polder screening in terms of data collection and consultations but have not been taken into account in the pre-selection for the next phase of CEIP and thus not taken into account in the MCA assessment; the latter has been confirmed by Officials from the BWDB.

1.4 Contents of the Polder Screening Report

This Polder Screening Report is the second Contractual deliverable in connection to the Consultancy Services for Feasibility Studies and Detailed Design for next Phase under CEIP. This introduction chapter provides the setting for the report. The remaining chapters and appendices are:

- Chapter 1: Data collection;
- Chapter 2: Coastal zone analysis and guiding principles;
- Chapter 3: Pre-selection of 23 polders;
- Appendices 1 to and including Appendix 5 are supporting the above chapters providing detailed explanations and overview.

[9] Feasibility Studies CEIP, 2013, Bangladesh Water Development Board, DevCon and Partners
[10] The information was obtained through consultations with Officials from the Bangladesh Water Development Board and verification with CEIP-1 PMU

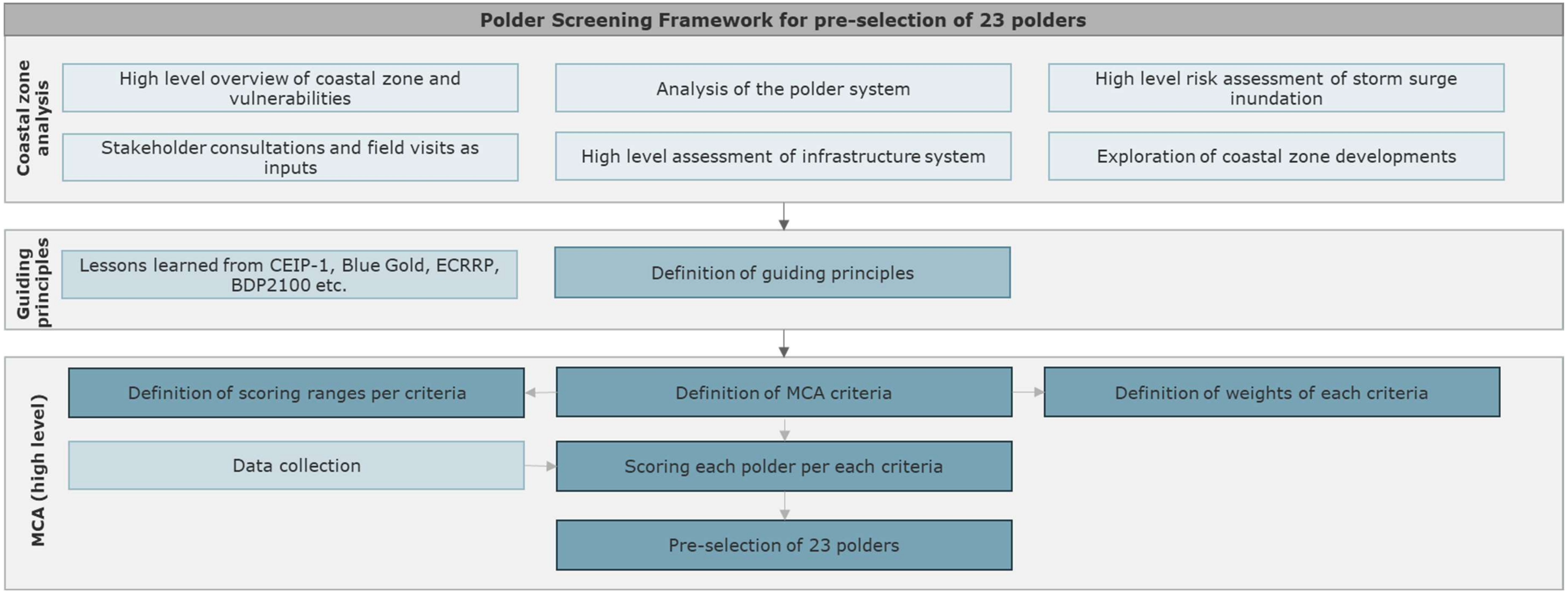

Figure 1-2: Polder pre-screening framework

1.5 Data collection

1.5.1 Introduction

Data collection is a crucial aspect for this report, as the assessments are carried out based on available secondary data as well as on the results of the initial high-level assessments. The Consultant collected secondary data from various sources which are thoroughly explained in the following sections. Amongst others, of high importance and relevance are the data collected from the Bangladesh Water Development Board (BWDB), CEIP-1 as well as from the Long-Term Monitoring, Research and Analysis (LTM) Reports and Database. In addition, consultations with stakeholders of the polders at field level and officials at different levels of the BWDB and public representatives have taken place, which provided very significant insights to the Consultant.

The data collection process will remain on-going throughout the study and more detailed data (primary and secondary) will be collected for the feasibility studies. As part of the feasibility studies, engineering surveys as well as social surveys will be carried out. In addition, field offices of the BWDB have been visited and polder wise information will be collected.

1.5.2 Information from relevant projects

The Consultant has collected data and information in relation to relevant projects such as the Coastal Embankment Improvement Project Phase-1 (CEIP-1), the Blue Gold Programme, Emergency Cyclone Recovery and Restoration Project (ECCRP), Bangladesh Delta Plan 2100 (BDP2100)[11] and other documents; for an overview, reference is made to the Inception Report prepared under the current studies. Review of this data has made it possible to derive lessons learned which are already incorporated in the study. At the same time data and information in relation to the polders, design procedures and other relevant aspects have been derived. In addition, the Consultant has reviewed an analysed the World Bank Technical Assistances: 1) Coastal Resilience: Developing New and Innovative Approaches in India and Bangladesh along the Bay of Bengal, Component 1: Improving empirical evidence and analytical support to future investments; 2) Developing Concept Design Solutions for Coastal Erosion In Bangladesh, and 3) Analytical Study on the Role of a Probabilistic Approach in Polder and Embankment Design in Bangladesh. It is worth mentioning that the Long-Term Monitoring (LTM), Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics), provides valuable information, data and insights for the next phase of CEIP.

More specifically, an overview of the information collected from CEIP-1 and LTM is presented below.

Coastal Embankment Improvement Project Phase-1 (CEIP-1)

Lessons learned from CEIP-1 as well as CEIP-1 assessment results and data, have been taken into consideration for this report. Some examples of the most relevant CEIP-1 information for this assessment are presented as follows:

- Storm surge and wave modelling results – boundary conditions;
- Design criteria;
- Embankment, slope protection, bank protection and sluice detailed designs;

[11] The Bangladesh Delta Plan (BDP) 2100, Government of Bangladesh, 2018

- Typical construction materials used as well as respective quantities and volumes depending on various boundary conditions;
- Unit rates for construction materials and components (escalated to 2021), and
- MCA 2012 polder wise data (used to a limited extent since Consultant has been trying to update as much information as possible).

Long Term Monitoring Research and Analysis Study and Database

The LTM Reports provides invaluable insights for system understanding, modelling and boundary conditions. Some examples of LTM reports relevant for this deliverable are:

- Morphology Report;
- Climate Change Report;
- Subsidence Report, and
- Data Report.

In addition, the "Interactive Geo-Database for Coastal Zone (IGDCZ)" developed as part of the LTM Study [12], provided important information for the assessment of the current condition of the polders and consecutively determine the needs and requirements. Table 1-1 illustrates the data that was possible for the Consultant to retrieve.

Table 1-1: Data available (and not available) in LTM database

Sl.	Category	Data name	Available LTM data base
1	Admin Boundary	District Boundary	Yes
2	Admin Boundary	Division Boundary	No
3	Admin Boundary	Union Boundary	Yes
4	Admin Boundary	Upazila Boundary	Yes
5	BWDB Boundary	BWDB Circle	Yes
6	BWDB Boundary	BWDB Division	Yes
7	BWDB Boundary	BWDB Zone	Yes
8	BWDB Boundary	CEIP Project Boundary	Yes
9	Environmental	Biodiversity	No
10	Environmental	Environmentally Critical Area (ECA)	No
11	Environmental	Aquatic, Fisheries	No
12	General	Population in Polders	No
13	Hydro-Meteorological	Cyclone Track	No
14	Hydro-Meteorological	Discharge (Timeseries)	No
15	Hydro-Meteorological	Discharge Stations	Yes
16	Hydro-Meteorological	Ground Water Levels (Timeseries)	No
17	Hydro-Meteorological	Ground Water Stations	Yes
18	Hydro-Meteorological	Rainfall (Timeseries)	No
19	Hydro-Meteorological	Rainfall Stations	Yes
20	Hydro-Meteorological	Sediment Observations	Yes
21	Hydro-Meteorological	Surface Water Level Stations	Yes
22	Hydro-Meteorological	Surface Water levels (Timeseries)	No

[12] https://gis.iwmbd.com/ceip

Sl.	Category	Data name	Available LTM data base
23	Impact/Model Results	Flooding and Inundations	No
24	Impact/Model Results	Subsidence	No
25	Hydro-Meteorological	Salinity	No
26	Infrastructure	Roads	No
27	Infrastructure	Bridge and Culverts	No
28	Interventions	Embankment	Yes
29	Interventions	Embankment (elevations)	Yes
30	Interventions	Embankment Cross Sections (lines)	Yes
31	Interventions	Embankment Cross Sections (points)	No
32	Interventions	Hydraulic Structures	Yes
33	Interventions	Irrigation (Khals)	No
34	Infrastructure	Navigation Routes (BIWTA Routes)	Yes
35	Interventions	Protective Works	No
36	Interventions	River Cross Sections along polders(lines)	Yes
37	Interventions	River Cross Sections along polders (points)	No
38	Interventions	River Cross Sections in downstream river sections used for modeling purposes (points)	No
39	Land Use	Settlements	Yes
40	Land Use	Agricultural Land Use	No
41	Land Use	General Land Use	No
42	Morphological	Coastal and River Bathymetry	No
43	Morphological	Erosion Accretion 1989 1995	Yes
44	Morphological	Erosion Accretion 1995 2000	Yes
45	Morphological	Erosion Accretion 2000 2005	Yes
46	Morphological	Erosion Accretion 2005 2010	Yes
47	Morphological	Erosion Accretion 2010 2015	Yes
48	Morphological	Erosion Accretion 2015 2020	Yes
49	Natural	Bay of Bengal Bathymetry (points)	Yes
50	Natural	Bay of Bengal Bottom Contours	Yes
51	Natural	Bay of Bengal Bottom Surface	No
52	Natural	Forest	Yes
53	Natural	Polder Contours	No
54	Natural	Polder DEM	No
55	Natural	River Centerlines	Yes
56	Natural	Rivers (polygon)	No
57	Natural	Soil Lithology (borehole locations)	Yes
58	Natural	Soil	Yes
59	Natural	Borehole Lithology	No
60	Natural	Wetlands	Yes
61	Physiography	Physiographic Features (AEZ Map)	No
62	SE_Demographics	Population	No
63	SE_Demographics	Employment	No
64	SE_Demographics	Health	No

Sl.	Category	Data name	Available LTM data base
65	SE_Demographics	Livelihood	No
66	SE_Demographics	Income	No

1.5.3 Consultations

Key stakeholder consultations are performed, aiming to gain valuable insights as well as to gather knowledge and information in relation to the polders.

BWDB

Throughout preparation of the Polder Screening Report and Prioritisation Report, a list of officials from BWDB were contacted for polder data collection which provided very significant insights to the Consultant (see Table 1-2). The information collected is mostly in relation to:

- General information on polders;
- Vulnerabilities of polders;
- Condition of polder infrastructure and structures;
- Collection of polder index maps.

Table 1-2: List of Field officials of Bangladesh Water Development Board (BWDB) who were contacted for collection of coastal Polders data/information

Sl. No.	Name and Designation	Authority
1	Fazlur Rashid	Director General, BWDB.
2	AKM Tahmidul Islam	Additional Chief Engineer, BWDB, Khulna.
3	Md. Enayet Ullah	Additional Chief Engineer, Design, BWDB, Dhaka.
4	Swarna Kazi	Task Team Leader, World Bank.
5	Syed Hasan Imam	Project Director, CEIP-I, BWDB, Dhaka.
6	Md. Abu Baker Siddiqe Bhuiyan	Superintending Engineer, CEIP-I, BWDB, Dhaka.
7	Md. Samiul Hoque	Executive Engineer, PMU, CEIP-I, BWDB, Dhaka.
8	Md. Towshikur Rahman	DRM Consultant, WB
9	Shahriar Sarkor	Sub-Divisional Engineer, PMU, CEIP-I, BWDB, Dhaka.
10	Md. Nurul Islam Sarkar	Additional Chief Engineer, BWDB, Barisal.
11	Jakaria Pervez	Executive Engineer, Design Circle-8, BWDB, Dhaka.
12	Md. Aminul Islam	Superintending Engineer, Design Circle-2, BWDB, Dhaka.
13	Dr. Shamal Chandra Das	Superintending Engineer, Planning-1, BWDB, Dhaka.
14	Md. Saif Uddin	Superintending Engineer, Design Circle-8, BWDB, Dhaka.
15	Md. Mozammel Hussain	Senior Design Engineer, DDC Ltd. Dhaka.
16	Sarder Sirazul Hoque	Procurement Specialist, SPMC Ltd.Dhaka.
17	KM Humayun Kabir	Water Resource Specialist, SPMC, Dhaka.Ltd.
18	Md. Rokon Ud-Doula	Additional Secretary (Dev.), MOWR
19	Akhil Kumar Biswas, Chief Engineer	South-Eastern Zone, BWDB, Chattagram
20	Md. Rafiq Ullah, Chief Engineer	South Western Zone, BWDB Khulna
21	Md. Nurul Islam Sarker, Additional Chief Engineer	Southern Zone, BWDB, Barisal
22	A K M Tahmidul Islam, Chief Engineer	South-Western Zone, BWDB, Khulna.
23	Md. Abul Hossain, Super Intending Engineer	Khulna O & M Circle, BWDB, Khulna

Sl. No.	Name and Designation	Authority
24	Mozibur Rahman, Super Intending Engineer	Patuakhali Water Development Circle, BWDB, Patuakhali
25	Md. Ashraful Alam, Executive Engineer	Khulna O & M Division-1, BWDB, Khulna.
26	Md. Abul Khayer, Executive Engineer	Satkhira O & M Division-1, BWDB, Satkhira.
27	Md. Rashidur Rahman, Executive Engineer	Satkhira O & M Division-2, BWDB, Satkhira.
28	Bishajit Baydda, Executive Engineer	Bagerhat O & M Division, BWDB, Bagerhat.
29	Md. Halim Salehe, Executive Engineer	Patuakhali O & M Division, BWDB, Patuakhali.
30	Md. Kaisar Alam, Executive Engineer	Barguna O & M Diveision, BWDB, Barguna.
31	Hasan Mahamud, Executive Engineer	Bhola O & M Division-2, BWDB Charfashon, Bhola
32	Md. Nasir Uddin, Executive Engineer	Noakhali O & M Division, BWDB, Noakhali
33	Md. Faruk Ahmed, Executive Engineer	Laxmipur O & M Division, BWDB, Laxmipur.
34	Nahid-Uz- Zaman, Executive Engineer	Chittagong O & M Division-2, BWDB, Chittagong
35	Prabir Kumar Goahswami, Executive Engineer	Cox's-Bazar O & M Division, BWDB, Cox's Bazer.
36	M.M. Md. Mehidi Hasan, Executive Engineer	Perojpur O & M Division, BWDB, Perojpur.
37	Md. Ariful Islam, Executive Engineer	Patuakhali O & M Division, BWDB, Patuakhali.
38	Md. Arif Hossain, Executive Engineer	Patuakhali WD Division, Kalapara, Satkhira.
39	Md. Miraz Gazi, Sub-Divisional Engineer	Patuakhali O & M Sub-Division, BWDB, Patuakhali.
40	Md. Shaha Alam Bali, Sub-Divisional Engineer	Motbaria O & M Sub-Division, BWDB, Motbaria, Pirojpur.
41	Shawkot Iqbal Maharaj, Sub-Divisional Engineer	Patuakhali, WD Division, BWDB, Kalapara, Patuakhali
42	Rahidul Hassan Khan, Sub-Divisional Engineer	Satkhira O & M Division-2, BWDB, Satkhira
43	Sayed Tariqur Rahman, Sub-Assistant Engineer	Patuakhali WD Division, BWDB Kalapara, Patuakhali
44	Rabbi Hasan, Sub-Assistant Engineer	Satkhira O & M Division-2, BWDB, Satkhira

Meetings with Honourable State Minister and Honourable Permanent Secretary

On 3rd October 2021 (see Figure 1-3*Figure 1-3:*) and on 7th November 2021 meetings were held with the Honourable State Minister and the Honourable Permanent Secretary respectively, where the following phase of CEIP has been presented. The objectives of the next phase of CEIP have been elaborated as well as the methodology. Special focus was given to the polder screening and prioritization. The views and insights of the Honourable Key Stakeholders have been taken into consideration for the selection procedure.

Figure 1-3: Meetings with the Honourable State Minister

Other Consultations

Consultations with public representatives have taken place, for collection of data in relation to the polders (see Table 1-3).

Table 1-3: List of Public Representative contacted for collection of coastal Polders information

Sl. No.	Name and designation	Office address
1.	Md. Fazlu Gazi, Chairman	Mohipur Union Parishad, Patuakhali (Polder No.:- 47/1)
2.	Md. Rakibul Hasan Sabuj, Member	Mohipur Union Parishad, Patuakhali (Polder No.:- 47/1)
3.	Ataur Rahman, Chairman	Padmapukur Union Parishad, Satkhira (Polder No.:-7/1)
4.	Alim Molla, Chairman	Baradal Union Parishad, Satkhira (Polder No.:-7/2)
5.	Abu hena Shakil, Chairman	Shriola Union Parished, Satkhira (Polder No.:-4)

Consultations with experts from the ongoing CEIP-1 Project have also taken place, both in Dhaka and in the field. More specifically, consultations with the Design Engineer and the Procurement Specialist have facilitated the understanding of the rationale behind selection of certain interventions per location and the selection of design criteria. In addition, the Procurement Specialist provided a good insight on unit rates and other components, which lead to a realistic development of costs for the next phase of CEIP. In terms of implementation, consultations were held with the Deputy Team Leader and the Construction Resident Engineer.

In addition, the Consultant maintained communications with the Project Director and Team Leader of the Blue Gold Project[13], giving specific focus to the lessons learned, bottlenecks and success stories of the project. This Dutch funded Blue Gold Project, which is building on the results and lessons learned from previous programs and on-going projects in Bangladesh, notably the Southwest Area Project, Coastal Embankment Improvement Project and the Bangladesh and Dutch experiences and expertise in participatory water management in polders. The Consultant has also liaised with the Dutch Embassy in Dhaka who is funding the Blue Gold Project.

Consultations were also held with key staff of the Asian Development Bank and Dutch funded Southwest Area Integrated Water Resources Planning and Management Project[14] which is helping Bangladesh to improve the management of water resources in the southwest of the country. The project supports flood control, drainage and irrigation system upgrades to address current water use problems that are hampering agriculture and fisheries.

Last but not least, the Consultant had consultations and meetings with the Senior Modellers, Coastal Zone Management Specialist and Economist of the LTM team on using data collected under LTM, sharing the various intervention modelling results and flood damage curves.

1.5.4 Other data sources

Several other data sources have been used such as:

- Bangladesh Bureau of Statistics (BBS) – for information in relation to population, housing, agriculture, aquaculture, and;
- Bangladesh Water Development Design Standards and Approaches.

[13] http://www.bluegoldbd.org/
[14] https://www.adb.org/projects/34418-023/main

2. Coastal zone analysis and guiding principles

As said, the Screening Framework begins with gaining a profound understanding of the complex coastal dynamics, the prevailing hazards, the socio-economic developments and environmental challenges. This overall assessment, in combination with the lessons learned from past and ongoing relevant projects, allows the Consultant to define the principles which will guide and conduct the polder screening process.

2.1 Coastal zone analysis

Gaining a good understanding of the coastal zone dynamics (physical, social, environmental and economic), constitutes the first crucial step. Screening of the polders cannot take place before a good comprehension is established.

2.1.1 High level overview of coastal zone and vulnerabilities

The coastal zone of Bangladesh can be divided into four zones[15] (see Figure 2-1). Each of these zones has different physical characteristics related to tidal amplitude, sediments, morphological dynamics and vegetation. A brief presentation of the analysis results is presented below, and each of the components are more thoroughly elaborated in Appendix 1.

Ganges Tidal Plains West (GTPW): This region contains the renowned and UNESCO world heritage accredited Sundarbans mangrove forest, covering the first 60 to 80 km inland from the coastline. An effective, nature-based, coastal protection is provided by the Mangrove belts which provides the Northern regions with protection from the surges and waves caused by cyclonic activity. Still, cyclones will have an impact. Upstream of the Sundarbans, up to 125 km from the coast an area with complex river networks exists. The area has long drainage routes with a shallow gradient and is characterized as a moribund delta formation. Very little fresh water flows from into this region from its parent river the Ganges. Tides play a major role in this region, penetrating the entire area, introducing both salt water and fine sediments to the system and causing tidal fluctuations. Compared to other places such as Khulna, where the tidal variation is about 1.5 meters, the tidal variation in the GTPW is very high, reaching around 3 meters. In this are cyclones can generate extreme water levels and wind speeds. Furthermore, cyclic erosion as well as sedimentation occur along the tidal rivers. The open coast however, is mostly eroding. Waves are mostly wind driven and the interior part of the coastal zone is faced by monsoon flood levels. Both man-made and natural large-scale and long-term changes in the bifurcation of water and sediment over the rivers in the delta have affected the fresh water and sediment input to the coast. The Tidal River Management (TRM) of beels (large depressions filled with static water) is seen as vital to solve the serious problem of restricted drainage, which causes waterlogging and affects agricultural production. TRM has already been implemented into several beels.

Ganges Tidal Plain East (GTPE): This area is intersected by a large number of rivers which are fed from the Lower Meghna River as well as the Padma River via the Arial Khan river. The GTPE contains no substantial forest area, with only a very limited number of mangrove forest pockets located along the coastline. With its flat topography, the area rises barely a meter above sea level in most places. Along the coast the tidal range is about 3.5 m but further inland this

[15] Hugh Brammer (2014). Bangladesh's dynamic coastal regions and sea-level rise

dampens down. From the coastline inland, the polders extend about 60 km. The challenges the sea facing polders meet are mostly related to the eroding of embankments by coastal erosion and lateral migration of the rivers. The tidal effects form another challenge for this area, although river floods do not form a major problem for the region. A third major vulnerability of the area is formed by the cyclonic storm surges and related damages to infrastructure, agriculture and aquaculture.

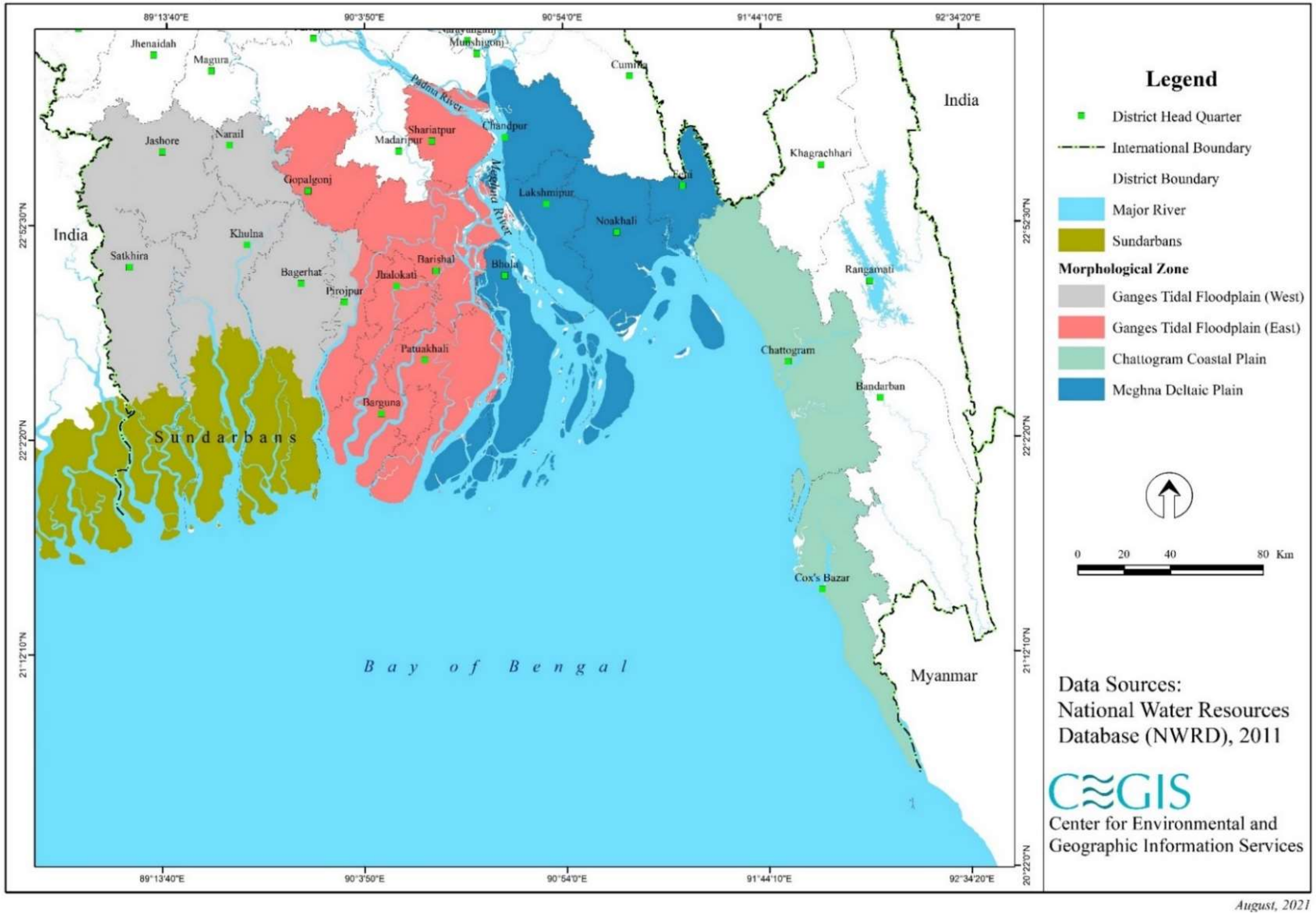

Figure 2-1: Coastal zone of Bangladesh

Meghna Deltaic Plain (MDP): the MDP includes several large islands such as Bhola, Hatia and Sandwip as well as mainland areas on the left bank of the Meghna river. The area is morphologically very active, with an excess in land accretion compared to land erosion. Due to the outflow of the GBM system into the Bay of Bengal this region is a highly dynamic and flat estuarine coastal system. The GBM system transports large quantities of sediment that are continuously transported towards the shallow coastal areas. A high tidal range defines this region, reaching about 6 meters near Sandwip Island. Both erosion and accretion play a role in this region. An example of this is the Meghna Plain, which is outbuilding as new land is being formed at a faster rate compared to the erosion of the older land in this area. Another example is the planform of the region, which is rapidly changing, by up to 100 m or more per year in some areas. As with the other areas, the high-water levels related to cyclones affect the land. In the MDP, the newly accreted low-lying areas are very vulnerable to these high water level rises. Still, due to the urgent need for land, people will settle on these relatively new deposits. Furthermore, river floods can be severe in parts of the Meghna estuary, most notable near the Districts of Chandpur, Lakshmipur, Noakhali and Feni.

Chittagong Coastal Plain (CCP): This area is the only region defined by elevation, with steep hills towards the east. The area is directly exposed to the Bay of Bengal and includes the world's longest natural sea beach (from Cox's Bazar to Teknaf), which forms a popular tourist destination in the country. The CCP is formed by a relatively narrow, stable flat coastal area, which features a very steep topographical gradient towards the border with Myanmar in the east. Along the coastline the tidal range varies, from 6 meters in the North, all the way down to 3 meters near the most southern point at Teknaf. The coastal strip is not protected from the elements and directly exposed to the wind and storm surges caused by cyclones. Flash floods from the hills form a unique challenge in this region that is not observed in the other three areas. Due to the steep gradient, in combination with the natural tendency to generate rainfall of the hill, the hills at the CCP can cause significant rainfall, which the rivers cannot convey safely. The areas beaches define the coastline. Parts of the beach suffer from coastal erosion, in particular the section along Marine Drive, South of Cox's Bazar. Sedimentation distribution along the coast is mostly directed northward by the wave generated northward alongshore current. Natural variations in the wave forcing have created variations in the sedimentation supply, deposition and erosion along the coastline over time and location.

2.1.2 Polder system

Nowadays, 139 polders lay across 25% of the coastal zone and cover an area of 1.2 million ha. The size of the polders varies with an average polder size in the order of 9,000 ha.

Each polder is defined by surrounding coastal embankments and drainage structures. The total embankment length in the coastal zone of Bangladesh is in the order of 6,000 km[16]. Most of the embankments are constructed from earth and turfing is provided to maintain their integrity, while some other embankments in vulnerable locations to waves, have a layer of slope protection from concrete CC-blocks. The elevation of these embankments varies, but is typically 2 m to 4 m above

[16] Dasgupta, S. et al. (2011) 'Climate proofing infrastructure in Bangladesh: The incremental cost of limiting future flood damage', Journal of Environment and Development, 20(2), pp. 167–190. doi: 10.1177/1070496511408401.

ground level, providing protection for an average 10-year return period storm surge/cyclonic event (not including climate change).

The polders contain an internal drainage network. The components of the drainage network are small channels (khals), and drainage and flushing sluices and outlets. The function of the two latter is to regulate the water levels and drain excess water outside from the polder. The small channels are connected to the regulators and the regulators, located along the embankment, are connected to the peripheral rivers outside from the polder. The 139 polders contain approximately 8,000 km of canals, more than 1,300 drainage structures and more than 1,700 regulators.

The use of the drainage sluices/ regulators has changed over time. In the beginning, the purpose of drainage sluices was to drain excess water from the polder area, and flushing sluices permitted water from peripheral rivers to enter the rivers. In more recent years, and under the influence of agricultural production, an attempt has been made to collect fresh water into the polder during the monsoon period for later use. That meant that drainage sluices started being used for flushing purposes as well. Following those practises, CEIP-1 both drainage and flushing sluices are constructed as two-way regulators.

When the polder concept was introduced, Polders have been designed to protect only against tidal flooding. Recently, and by taking projections of climate change into consideration, the Polder design has been upgraded by including additional protection measures against storm surges and cyclone flooding. The upgraded design was introduced and is currently being implemented under the Coastal Embankment Improvement Program (CEIP-1).

The existing 139 polders can be seen in Figure 2-2, Figure 2-3, Figure 2-4 and Figure 2-5.

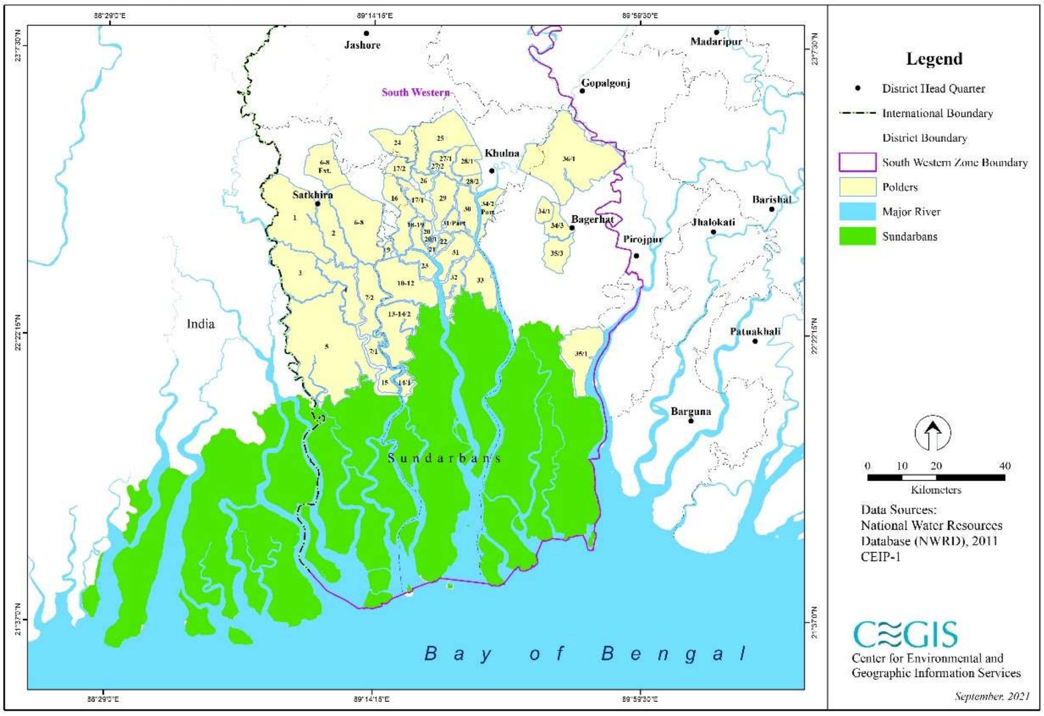

Figure 2-2: Polders South Western Zone

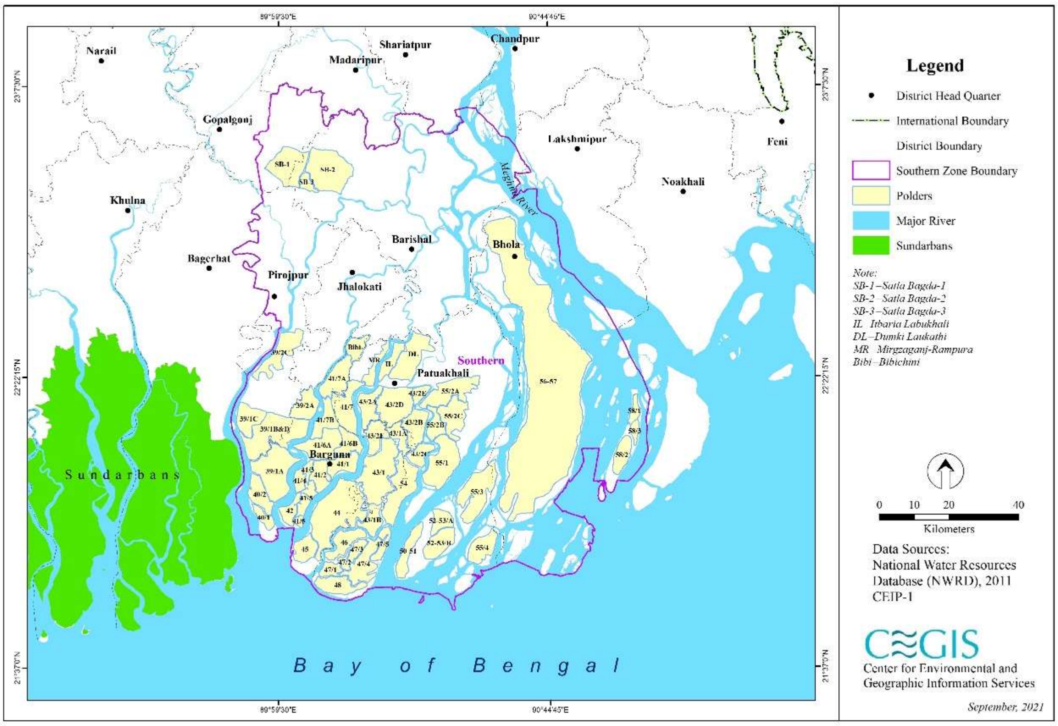

Figure 2-3: Polders Southern Zone

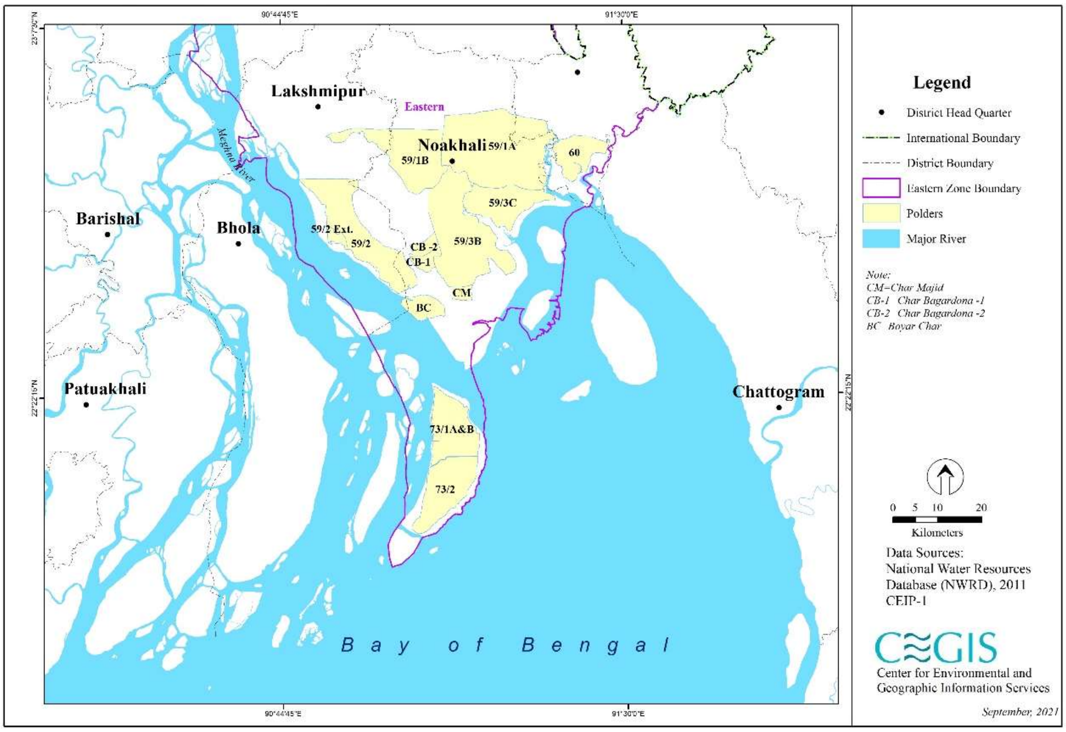

Figure 2-4: Polders Eastern Zone

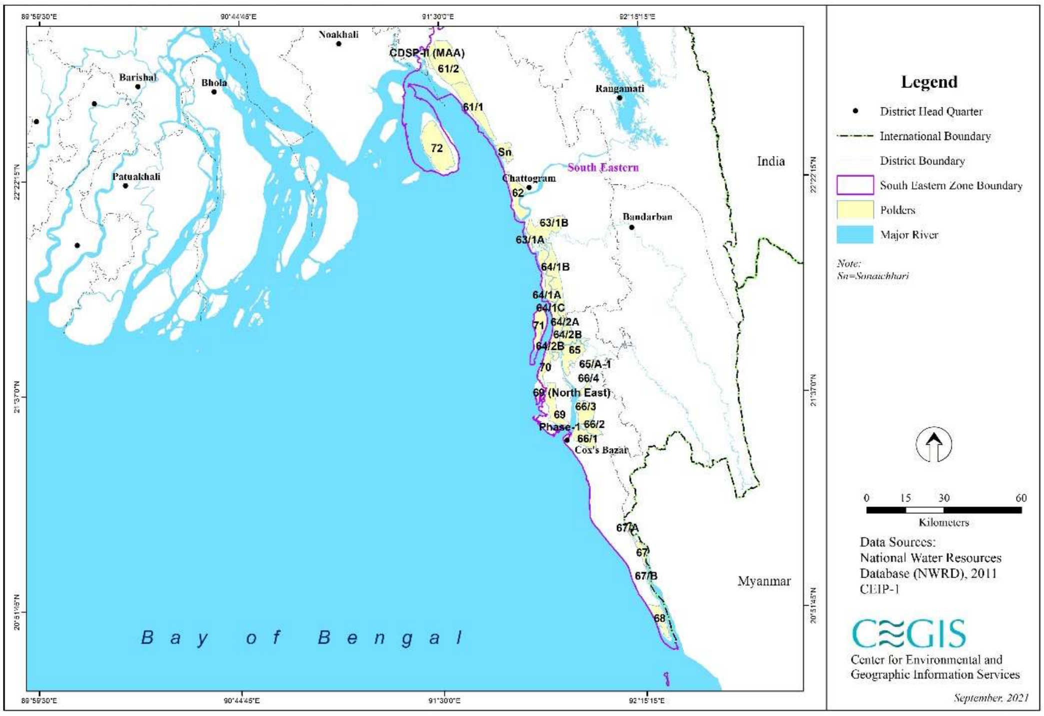

Figure 2-5: Polders South Eastern Zone

The delineation of the coastal zone in interior[17] and exposed has led to the following (see Figure 2-6) classification amongst the polders.

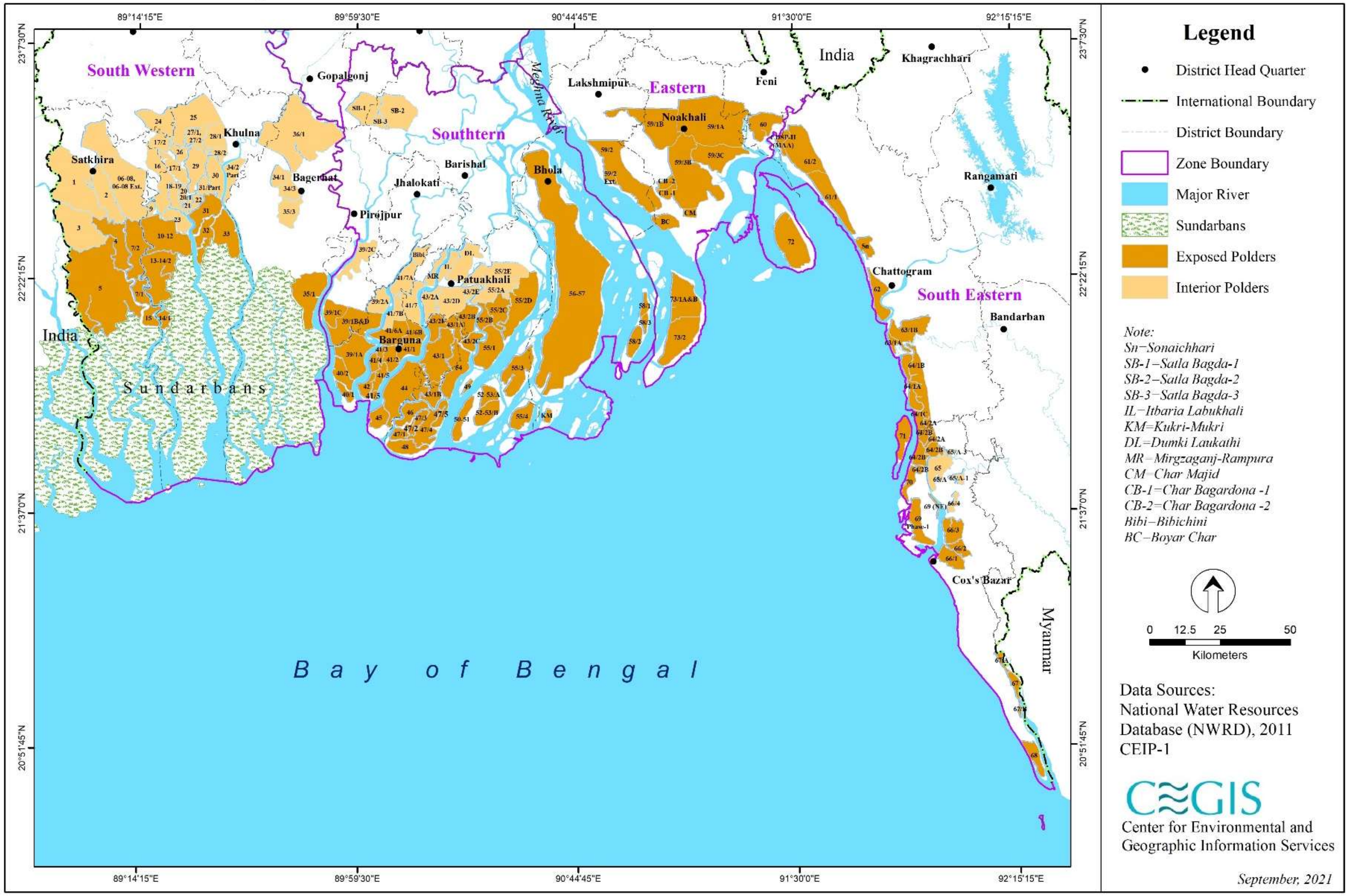

Figure 2-6: Exposure map of Coastal Upazilas of Bangladesh

[17] http://warpo.portal.gov.bd/sites/default/files/files/warpo.portal.gov.bd/page/aa04373f_0ca3_49a5_b77e_5108186638dc/wp005.PDF

2.1.3 High level risk assessment of storm surge inundation

The disaster risk quantifies the chance of adverse effects in the future and consists of three factors, namely, the *Hazard* of the event itself, the *Exposure* to it and the *Vulnerability* of the coastal area.

In this case, the inventory of elements in an area in which hazards events may occur is defined as the *Exposure.* Furthermore, the propensity of exposed elements such as human beings, their livelihoods and assets to suffer adverse effects when impacted by hazard events[18,19], or the degree of incapability of the coastal system to cope with the effects of climate change, extremes and sea level rise[20]. is defined as the *Vulnerability.* Finally, the probability of harmful effects or expected losses as a result of an interaction between a natural or human-induced hazard and vulnerable conditions[13] is defined as *Risk.*

By combining the Exposure and Vulnerability with the potential for harm, loss or damage during an event at a specific location, a risk assessment can be made.

In this case, tropical cyclones form the most prominent hazard in the coastal region, posing risk to people, livelihoods and infrastructure due to excessive water levels and wind speeds. The related risks are mostly defined by the physical vulnerability and related to the probabilistic nature of the cyclones (cyclone track and return period). By combining the exposure with socio economic vulnerability, it is possible to determine the area specific impact of cyclonic storm surge inundation levels.

Along those lines, a risk assessment of storm surge inundation of the coastal polders, paves the road towards obtaining an overview of associated impacts of such extreme events, which when combined with the probability of occurrence, result to bringing risk hotspots to the surface, which could subsequently be prioritized. Within the current preparations of the next phase of CEIP, a GIS-based high-level risk assessment has been developed. This tool will evolve and needs to be updated further in the study because some of the currently used data does not provide the required accuracy, such as digital elevation model, inundation model, level of detail and date of data. In addition, for the sake of the purpose and the timeframe within which this risk assessment was required to be built, few assumptions have been made in relation to aspects such as existing level of protection and types of housing.

A brief description of the assessment of exposure and physical and socio-economic vulnerability, as used in this tool is also presented in Appendix 1 (A1.8).

The high-level risk assessment is used to perform a vulnerability assessment and thereafter transforming those damages into risk. By definition, risk considers the consequences and weighs in the aspect of the probability of occurrence of a hazardous events such as storm surge inundation. Large events that normally cause substantial damage may not contribute a great deal to the average annual costs due to their low probability. Increasing return periods also means an increase in the damage costs, however also a lower probability of occurring, yielding the relation seen in

[18] UNDRO, 1980: Natural Disasters and Vulnerability Analysis. Report of Experts Group Meeting of 9-12 July 1979, UNDRO, Geneva, Switzerland
[19] Cardona, O.D., 1986: Estudios de vulnerabilidad y evaluación del riesgo sísmico: Pla nificación física y urbana en áreas propensas. Boletín Técnico de la Asociación Colombiana de Ingeniería Sísmica, 33(2), 32-65
[20] Intergovernmental Panel on Climate Change (IPCC). 2001b. Climate change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the IPCC. Cambridge, UK: Cambridge University Press

this figure between the flood risk and the return period[21]. Through estimation of Expected Annual Damage (EAD), the mean loss (the "expected value") that occurs in any given year is signified, which represents a long-term average. Based on the Estimated Annual Damage (EAD), risk maps for the baseline and climate change scenario have been generated as shown in Figure 2-7 and Figure 2-8.

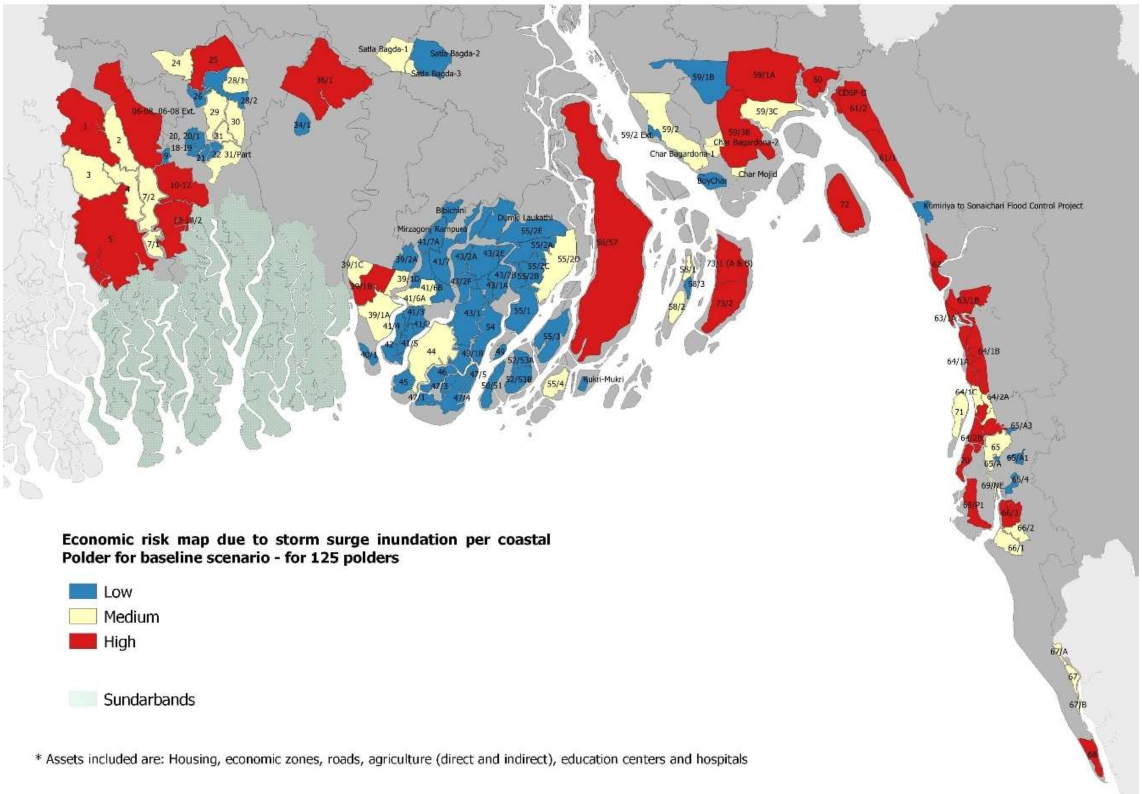

Figure 2-7: Risk map due to storm surge inundation in baseline scenario

[21] Anders Skovgård Olsen et al. (2014) Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments

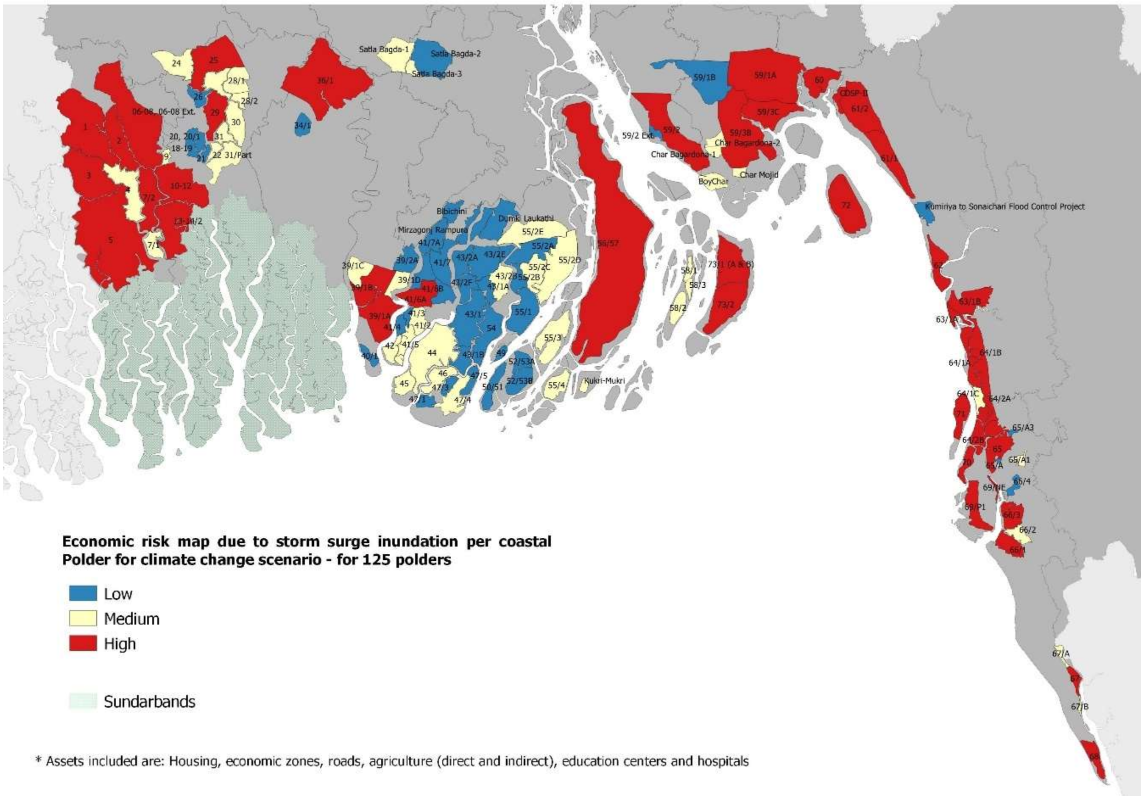

Figure 2-8: Risk map due to storm surge inundation polder in climate change scenario

2.1.4 Field visits as inputs

Field visits have been performed to a significant number of polders among the ones pointed out during the stakeholder consultations. The purpose of the field visits was to perform a quick-visual inspection of the condition of the water infrastructure. The most vulnerable/ damaged spots have been visited and pictures have been taken which are presented in Appendix 2.

2.1.5 Exploration of coastal zone developments

2.1.5.1 Bangladesh Delta Plan 2100 (BDP2100)

The investment plan presented in the Bangladesh Delta Plan (BDP2100) consists of a total of some 80 projects: 65 are physical projects, and 15 are institutional and knowledge development projects. These 80 projects were then grouped into the seven 'hotspots' defined in the Delta Plan, among which the Coastal Zone and the River and Estuarine Hotspots are the most relevant to CEIP.

Some interventions within the investment plan simply build and expand on what is already being done (Cluster 0+ projects). Others require a change from the current approach (Cluster 1 projects). At the extreme, some may require changing the behaviour of the water system (Cluster 2 projects).

Coastal zone hotspot:

The 23 projects included in the BDP2100 related to the coastal area are predominantly focused on the theme of 'preventing too much water' and include flood protection infrastructure, land reclamation projects, and development of chars and polders.

The knowledge-oriented projects include the development of GIS and remote sensing technologies for Integrated Coastal Zone land use planning; preparatory studies of ways to reclaim land beyond the coast; a study on the morphological dynamics of the Meghna Estuary; a study on integrated management of drainage congestion for the Greater Noakhali (southeast region); studies aiming to develop a suitable institutional arrangement for proper management of polders, and environmental and social impacts of TRM; Rationalization of Polders in vulnerable areas; studies of the possibilities for multipurpose sea-dykes and barriers; and development of a Climate Smart Integrated Coastal Resource Database.

Twelve projects relatively simply build and expand on what is already being done, are slated for immediate commencement. Two of the Coastal Zone projects require a change from the current approach to project development, meaning that they involve a step change in approach. The first of these is the Urir Char- Noakhali cross dam project. This is programmed to start in 2022, after finalising necessary documentation and obtaining approvals of the Competent Authorities. The second project which is relevant for CEIP involves land reclamation by constructing a cross dam between Hatiya and Nijhum Dwip.

Two investment plans are put on the spotlight which are highly relevant for the next phase of CEIP and being:

- Rationalization of Polders in Baleshwar – Tentulia Basin (CZ1.44), and
- Rationalization of Polders in Gorai-Passur Basin (CZ1.40).

These investment plans are aiming to reduce the loss of assets, crops and livestock; reduce vulnerability loss; reduce salt water intrusion; increase agricultural production; improve drainage congestion situation; improve institutional setting.

Rivers and Estuaries hotspot:

The Rivers and Estuaries Investment Plan includes seven projects focused on improving management of rivers. Two are knowledge projects, and five are infrastructure development projects.

The most significant of these is the Integrated Jamuna- Padma Rivers Stabilization and Land Reclamation Project. The aim of the project is to stabilize the banks of the Jamuna-Padma to control river-bank erosion, increase land reclamation, reduce flood risk by construction of embankments, restore navigation and maintain safe navigation channels, increase land-based productivity through intensified agriculture, and designate environmental protection zones along the river.

The other three infrastructure projects aim to ensure that there is enough water when and where it is needed, whether for navigation, irrigation, or municipal supply. The Sustainable Restoration of Connectivity of Major Navigation Routes will use dredging and other techniques to restore and maintain navigability of 24 river routes by dredging; open up around 2,500 km of waterways for smooth and year-round plying of waterways; increase the water flow of the respective rivers.

Based on, amongst others, the Bangladesh Coastal Policy of 2005 and more recently the said BDP2100, potential and ongoing developments are shown in Figure 2-9.

2.1.5.2 Coastal zone Policy

The Coastal Zone Policy[22] (CZPo) and the Coastal Development Strategy[23] consider that out of the 19 Districts belonging in the coastal zone, a total of 48 Upazilas/thanas are considered as 'exposed' directly to vulnerabilities from natural disasters. The exclusive economic zone (EEZ) is regarded as the seaward coastal zone. The Government has made the coastal zone policy statements in relation to development objectives. These policies provide general guidance so that the coastal people can pursue their livelihoods under secured conditions in a sustainable manner without impairing the integrity of the natural environment. It is mentioned that Cox's Bazar, Nijhum Dwip, St. Martin Island and Kuakata sea beaches and Sundarbans will be further developed to attract tourists and those areas and islands will be developed as "Special Zone for Tourism".

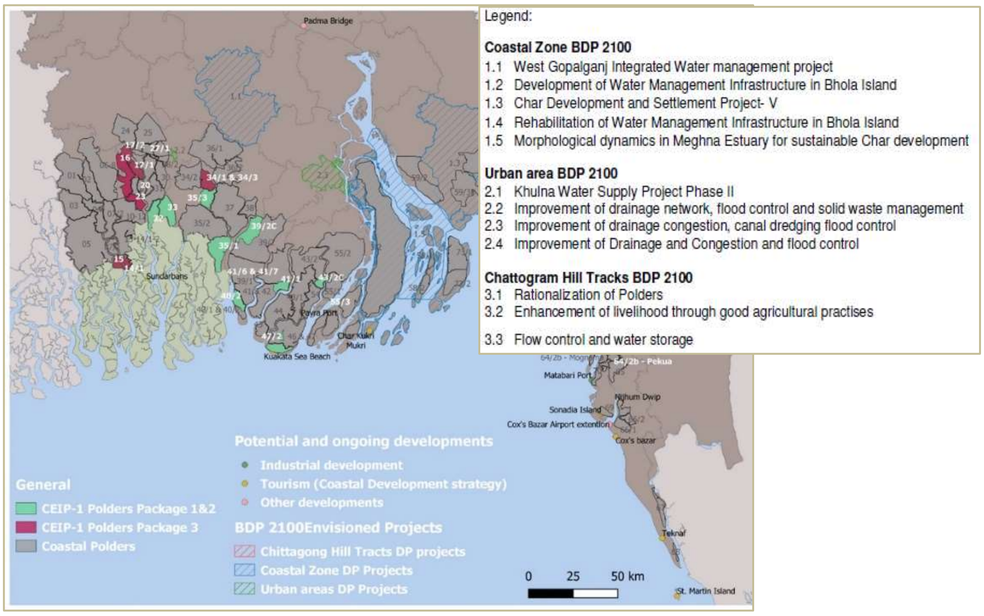

Figure 2-9: Potential developments in coastal zone of Bangladesh

CEIP-1, ECRRP and Blue Gold

Several polders have been recently rehabilitated under ECCRP and under CEIP-1. In addition, the Blue Gold Programme Program[24] has rehabilitated several polders and has improved the drainage

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[22] Coastal Zone Policy, Ministry of Water Resources, Government of the People's Republic of Bangladesh, 2005.
[23] Coastal Development Strategy, http://old.warpo.gov.bd/strategy/coastalDevPolicy.pdf, 2006.
[24] http://www.bluegoldbd.org/

practises and infrastructure next to enhancing internal polder water management. In general, a number of these polders are considered to be in a good condition since those projects have only been recently completed. However, there are many polders which have deteriorated and severely damaged due to impacts from recent cyclonic events and monsoon discharges. In addition, ECRRP performed rehabilitation works as a response to the damages caused by cyclones, amongst others Sidr and Aila, and did not consider aspects such as heightening embankments to consider climate change not enhancing the capacity of drainage structures. It is noted that CEIP-1 is developing polders where all polder components such as embankment, sluices, protective works and channels are all updated to standards and as such, forming an integrated safe and sustainable polder whereas ECRRP and Blue Gold Programmes have not been doing so. The development of polders for the next phase of CEIP will follow the same approach as currently is applied for CEIP-1.

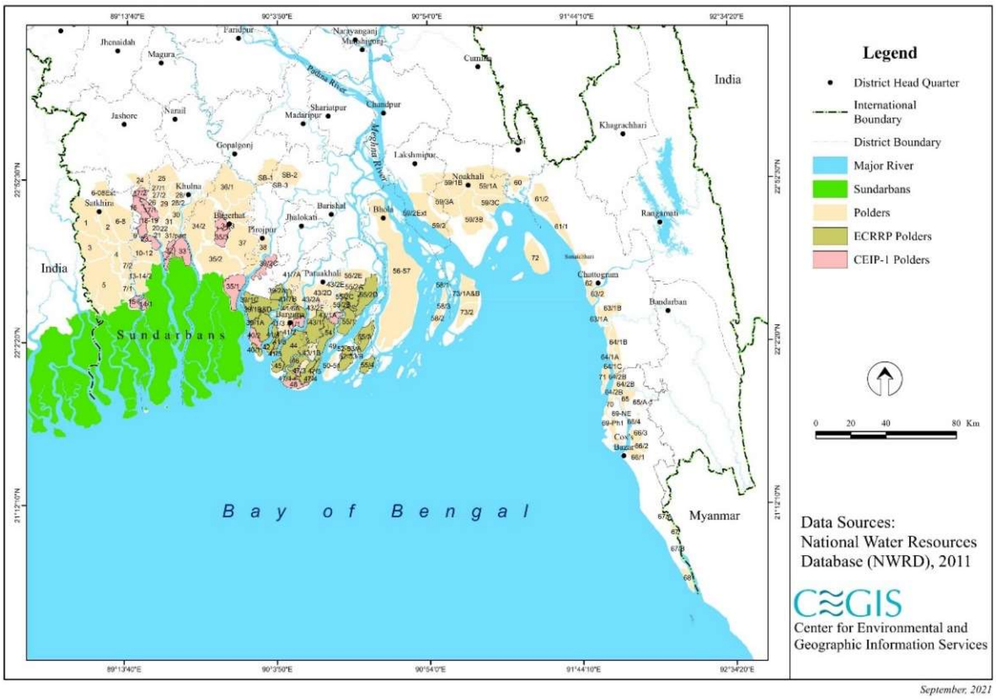

Figure 2-10: CEIP-1 and ECRRP polders

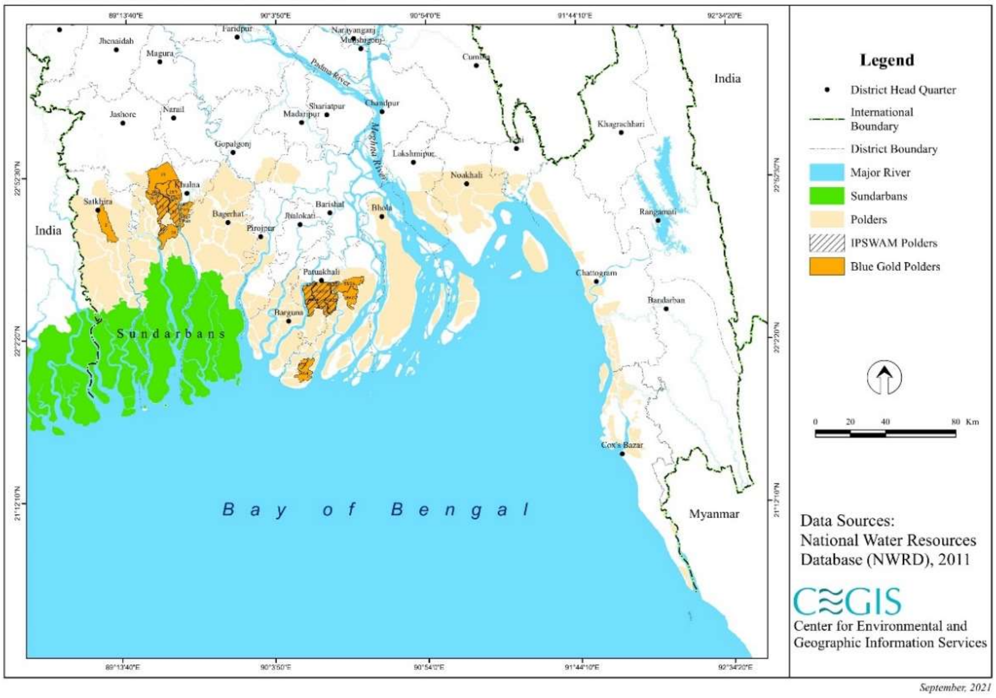

Figure 2-11: IPSWAM and Blue Gold Programme rehabilitated polders

Payra Port development

The main objective of the Payra Port development is to develop the region by adding much needed port capacity in Bangladesh. One of the current drivers of the port development are the powerplants located 20 km inshore (30 million tons of coal are expected). Even though the Master Plan has not yet been finalized, an alternative location of the port would be in the confluence of Galachipa River and Rabnabad Channel. Sedimentation volumes are expected to be very large based on previous studies conducted and that would require continuous dredging of the access channel.

With port developments on the way, in combination with raising and strengthening the embankment, the next phase of CEIP may consider widening the embankments to accommodate the future traffic load. Within the development scenarios, the export/import potential will increase the investment in the existing shrimp/fishing inside and outside the embankments which might complicate the planned width and alignment of the embankments, and this these considerations should be well addressed in the planning.

Mongla Port and Rampal Power Station

Mongla Port the second largest seaport, 48 km south of Khulna town and is situated on the confluence of the rivers Pasur and Mongla at mouza Selabunia of Rampal Upazila of Bagerhat District. The port often remains closed because of insufficient depth required for the ocean-going ships. Currently studies are ongoing to improve the access channels from sea to Mongla Port. It is noted that nearby Mongla Port, the Rampal Power Station is being constructed which is a 1,320 MW coal-fired power station.

2.1.6 Assessment of infrastructure conditions

The infrastructure systems in Bangladesh's coastal zone play various roles, both from a perspective of the livelihoods of the coastal communities as well as for the Bangladesh economy as a whole. They provide protection from flooding (polder embankment systems), transportation of people, goods and materials (roads, waterways and ports) and for economic activities such as agriculture/aquaculture in the polders (water management). In this assessment the water management infrastructure will be the focus.

Two main water infrastructure elements play a role in the polders, namely the coastal embankments, forming the protective boundary of the polder, as well as the internal drainage system. Within the coastal region, more than 5,000 km of embankments protect an area that measures about 25% of the total coastal area (1.2 million ha). These consist of an earthen embankment covered with grass. The embankments typically vary from 2 meter up to 4 meter above ground level and often feature a road surface on top for ease of transportation. In certain locations, to protect from cyclone waves, slope protection is applied. In addition to the slope protection, bank protection is put in place below the waterline where the erosion needs to be prevented in order to ensure the stability of the embankment. As rock is a rare commodity in Bangladesh, slope and bank protection are typically constructed out of concrete blocks, so called CC-blocks.

Small canals, named Khals run through the polders and form a gravity-based drainage network which is used to manage water levels and drain off excess rainwater. Khals generally are a few meters wide and relatively shallow. To regulate the water level, control structures (regulators) are placed in these canals. These simple structures have a relatively small size and can be used to regulate the canal levels and flow. Drainage structures however, are located inside of the embankment surrounding the polder and are much larger. These connect the internal drainage system to the outside river system and can be used to either drain off water from inside of the polder, or to let water in during high water to flush the canals. In total, it is estimated that the 139 coastal polders feature about 8,000 km of drainage canals, more than 2,000 drainage structures and more than 1,000 regulators [25].

As the proper functioning of this infrastructure is of vital importance to the coastal communities, both from a hazard, as well as livelihood perspective, assessment of the current condition was required. This has been done via stakeholder consultations and field visits.

2.1.7 Observations

Identification of vulnerable areas

As a result of the high-level overview of the coastal zone and its vulnerabilities, and in combination with the findings of the BDP2100 (the Districts that face serious natural hazard risks have been assessed), the following could be concluded, in terms of District-wise presence of natural hazards (see Table 2-1). The ranking is based on a simple methodology whereby Districts facing the most number of hazard risks are ranked as most hazard-prone[26]. More specifically, Districts that face 4

[25] These numbers are estimated based on the CEIP-1 documentation for 17 polders and scaled to the entire polder system.
[26] BDP2100, 2018, GED, Government of Bangladesh

or more types of hazards are rated as the most hazard-prone Districts and are given a rating of 1. Districts that face 3 types of hazards are rated as next most hazard-prone and given a rating of 2. Some Districts that face 2 types of hazards but where the intensity and potential economic damage is large are also rated as 2. The methodology does not seek precision but is intended as indicative to enable an assessment of the relationship with welfare indicators, especially poverty and income.

Table 2-1: District level natural hazard ranking (source: BDP2100)

District	Hazard ranking	Sea Level Rise[1]	Flood	Cyclone[2]	Salinity	Drought	River erosion[3]	Water logging[4]
Bagerhat	1	x	x	x	x			x
Barguna	1	x	x	x	x		x	
Barisal	2		x	x			x	
Bhola	1	x	x	x	x		x	
Chandpur	1		x				x	
Chittagong	1	x	x	x				
Cox's Bazar	1	x	x	x	x			
Feni	1	x		x	x		x	
Jessore	2				x	x		x
Jhalokati	2		x		x			
Khulna	1		x	x	x			x
Lakshmipur	1	x	x	x	x		x	x
Noakhali	1	x		x	x		x	x
Patuakhali	1	x	x	x	x		x	
Pirojpur	1		x	x	x		x	
Satkhira	1	x	x		x	x		x
Shariatpur	2		x				x	

Impact from climate change increase of storm surge: Calculated by differences in modelled storm surges between baseline and climate change scenario based on CEIP-1 modelling results. It appears that the coastal polders located in the East Ganges Plain are impacted mostly from enhanced storm surge from climate change.

Vulnerability to past cyclones: West and East Ganges plain have been most severely impacted from the three last cyclones (Sidr, Aila and Amphan). Particularly cyclone Sidr affected severely Bagerhat, Barguna, Patuakhali Districts. Cylone Aila had strong impacts in Satkhira, Khulna and Patuakhali Districts. And last but not least, cyclone Amphan's effects were maximized in Satkhira, Khulna, Barguna and Patuakhali Districts. In addition, Khulna and Satkhira presented the largest damages in embankments and infrastructure during Amphan.

Erosion: An understanding of the dynamics of the morphology in the coastal zone, in combination with visualization of the erosion map from the Aqua Monitor tool (Deltares[27]) and from discussions with the Long-Term Monitoring Study Consultant, the rivers located in the West and East Ganges Plain suffer from significant erosion. Rivers such as Pussur, Biskhali and Baleshwar experience high erosion rates. In addition, CEIP-1 polders which are located along the Baleshwar river have revealed fluctuating erosion rates which peak when current velocities are maximized. In addition, the sediment–water dynamics within the Meghna Estuary are very complex due to its irregular shape, wide seasonal variations, and the role of the tide.

Waterlogging: Recent remote sensing images show that water logging is occurring mainly in southwestern region (Bagerhat, Khulna and Satkhira) of the coastal zone.

[27] https://www.deltares.nl/en/software/aqua-monitor/

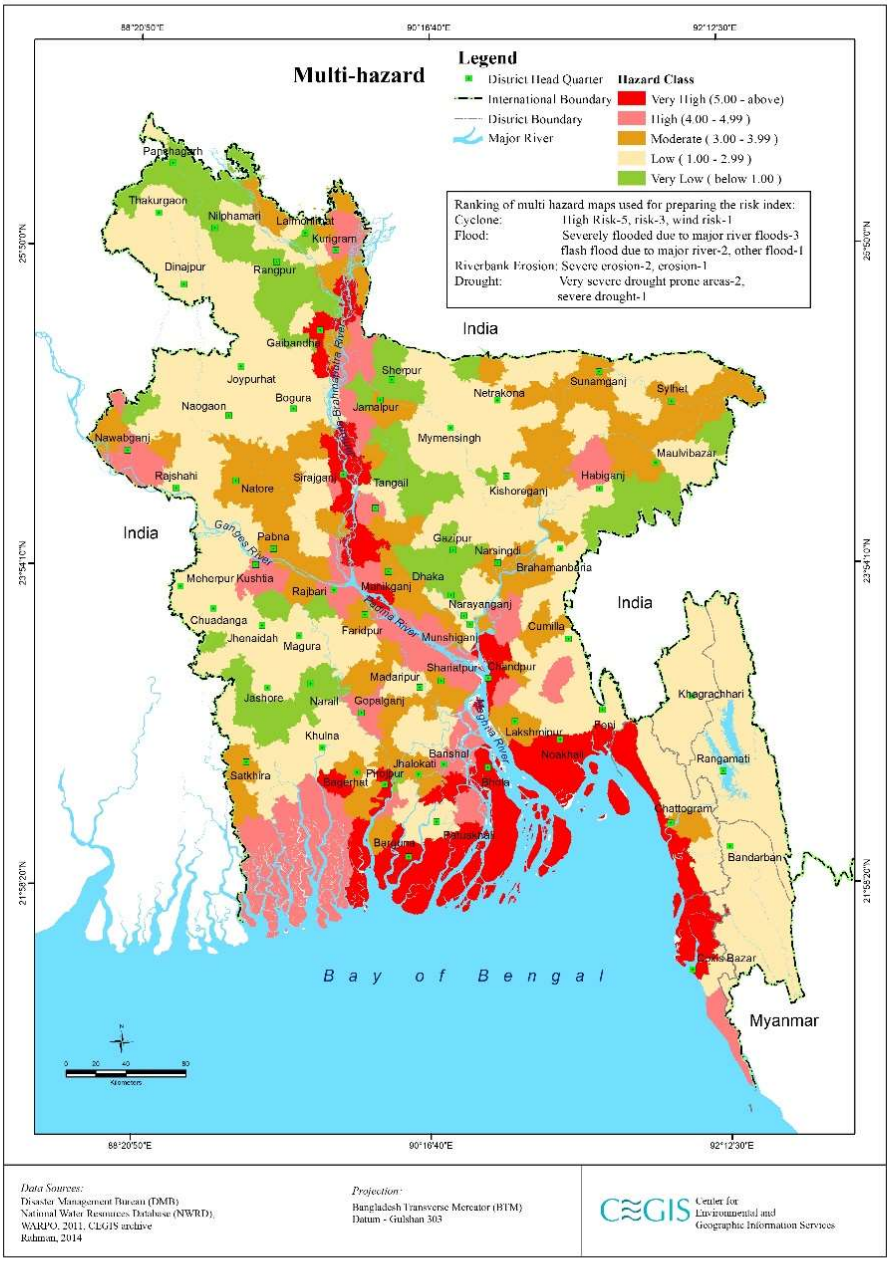

Figure 2-12: Hazard map Bangladesh[28]

[28] Rahman, 2014, May 15

High level risk assessment: Polders in the West and East Ganges Plain are under risk of storm surge, due to combination of low land elevation, frequent occurrence of cyclonic events and large population and economic activities.

Stakeholder consultations: During key-stakeholder consultations (BWDB), the importance to rehabilitate polders which have been impacted by Amphan was indicated since these polders are currently in a bad condition and are located in the south-western part of the coastal zone. In addition, some other polders have been highlighted as top priority, in relation to the condition of the infrastructure, as well as since they are part of wider development plans.

Field visits and condition of embankments: The field visits performed in the polders which have been identified as very vulnerable, throughout the high-level analysis and during the stakeholder consultations, verified their bad condition.

Development plans: The development plans in the coastal zone have put in the spotlight the polders in Baleswar – Tentulia Basin as well as Gorai-Passur Basin which, as indicated in the BDP2100, there are plans to rationalize those polders.

In addition, potential development of Payra port leads to focus on polders that are located along the future access channel. In addition, several polders that have been rehabilitated under ECRRP (completed in 2018) and are already in bad condition indicates the urgency for rehabilitation due to two the following main reasons:

- Since water related infrastructure is newly constructed, eventual damages indicate significant exposure to hazards;
- Those polders may be less capital extensive since large extent has already been rehabilitated, and
- Acting soon is important since the condition of the infrastructure adjacent to the damaged parts could deteriorate soon, due to absence of a polder system behaviour.

The same refers to the Blue Gold Programme polders but to a lesser extent, since Blue Gold Programme is mostly water management oriented. However, this component is also significant for the next phase of CEIP.

Pre-screening results: The pre-screening polder framework has brought into the surface the vulnerability of the East and West Ganges Plain and specifically the Baleshwar – Tentulia Basin as well as Gorai-Passur Basin.

The Consultant understands that the entire coastal zone is exposed to a wide range of threats and is highly vulnerable but after all, the prioritization will only define which polders will be improved sooner and which polders will be dealt with later. In that respect, and in terms of efficiency in planning and construction works, polder clustering will be an important parameter, as has been also proved through the CEIP-1 implementation. Since the primary focus is on areas which have been impacted by the most recent cyclones (thus the West and East Ganges Plain), The Consultant recommends to cluster the selected polders in packages which are located in those two wider areas. Consequently, polders located in the Meghna Estuary Plain and the Chittagong Plain will not be taken forward in the selection procedure.

2.2 Guiding principles

Definition of the guiding principles of this project is crucial for setting up an MCA which takes into account all the aspects which are relevant and important for successful project execution. In other words, the guiding principles outline the rationale of the MCA and the content of the scoring criteria. Definition of the guiding principles will be extracted from important lessons learned from past/ ongoing projects, visions of plans and policies, personal judgement of the Consultant and last but not least, the views of the BWDB and other key stakeholders.

Both feasibility study and implementation phase of CEIP-1 are widely relevant to this present study, and its lessons learned will assist in shaping the guiding principles for CEIP-2. Important aspects are amongst others, feasibility, technical design, numerical modelling, environmental and social assessment, land acquisition, resettlement, bidding and construction. The lessons learned for each of those aspects have been elaborated in detail in the Inception Report.

The Blue Gold Programme is also very relevant for the next phase of CEIP, as it focuses on establishing and empowering rural community co-operatives to sustainably manage their sea defence, drainage and irrigation infrastructure in order to achieve, amongst others, an increased sustainability of the development of the polders and effective use of water resources. Internal water management is applicable for CEIP-2, since it goes hand in hand with the rehabilitation and construction of new regulators. The lessons learned from Blue Gold Programme are used as guiding principles for the development of the next phase of CEIP.

The BDP2100 paints the horizon and defines the wider direction of CEIP. The BDP2100 has thus been very closely looked at in order to derive socio-economic development scenarios, projections and visions.

Lessons learned from other projects and reported in the Inception Report as well as the wide experience of the Consultant in the coastal zone of Bangladesh and stakeholders’ views have contributed in the delineation of the guiding principles as presented below.

Land acquisition

The significance and relevance of land acquisition to the project is two-fold.

Firstly, resettlement of people during construction and land acquisition is affecting the people of the coastal community, both positively and negatively by, amongst others:

- Straining on the social fabric with addition of employment business opportunities in providing goods and services to the project and to the labour force;
- Leaving their place would potentially make them socially and culturally dislocated and yearning for opportunities to be resettled in their original cluster community;
- Disruption of settlements and agricultural activity by the land taken temporarily to service the contractors’ activities and additional land that is acquired permanently for embankment retirement and re-sectioning, and;
- Necessary eviction of embankment settlers, at least for the period when the embankment is being re-sectioned.

Secondly, land acquisition is a critical factor for the progress of the works. To obtain physical possession of the site first affected landowners need to be compensated. Within CEIP-1, the approval of payment of compensation to the affected landowners has taken a very long time, resulting in delays of the works in the field.

Erosion and land acquisition

If a polder is located along a dynamic river and erosion rate is high, then there is the risk that when time for implementation comes, significant changes have appeared in this stretch and thus land acquisition may be required for the retirement of the embankment. Therefore, when a high erosion rate is present the requirement for land acquisition will be larger, accounting for a larger set back distance. During CEIP-1, in several locations, the original alignment through the existing embankment had to be changed and it was decided to construct a retired embankment. Subsequently a revised LAP had to be prepared which is an extremely lengthy process. It took a long time to obtain the physical possession of lands for continuation of the ongoing works.

Construction logistics

The availability and accessibility of construction materials is highly important for the timely progress and quality of the construction works. Polders located in remote areas are more likely to present difficulties in accessing construction materials. In CEIP-1, the construction/re-sectioning of the embankments had to be carried out by the contractor collecting earth by their own initiatives. Since there were no free borrow pit areas adjacent to the alignment, the contractor had to make the earth available with the help of local people. Sometimes they had to deal with people who took money without fulfilling their commitment.

In terms of construction logistics, clustering of polders which are located in the same wider area is very significant for the effective execution of works. In that way, both supervision staff and equipment can operate within a wider area, avoiding traveling long distances. In addition, the connection among those polders, as well as the connection of each polder to urban areas is very significant.

Plans and policies such as the BDP2100

Key stakeholder views, policies and strategies play a crucial role when prioritizing the polders. For example, the BDP2100 is a strategic plan with a long-term horizon of 100 years as well as a short-track implementation programme to solve urgent problems which contributes to the overall development of Bangladesh. Thus, consideration should be given to the various investment plans and development scenarios.

Risk appreciation

A risk assessment leads to a good understanding of the resilience of the coastal communities and assets to coastal threats and other hazards.

Risk is defined as the product of the hazard, the exposure and vulnerability:

- *Hazard* is inherently connected to the coastal zone. The most prominent one in Bangladesh coastal zone is cyclone activity, but riverbank and coastal erosion, salinity intrusion and land subsidence are also important hazards in this area. Trends such as sea level rise, but also the possible change in cyclone activity may exacerbate these impacts. These hazardous events are not deterministic events such as the tide but are probable events in the future and can vary in terms of intensity, landfall location. Therefore, these types of events are generally expressed in terms of probabilities;

- *Exposure* refers to the entire inventory of elements in the coastal zone that can be impacted by coastal hazards. This includes the population and their homes and belongings, public infrastructure such as roads, drinking water, sanitation, drainage and flood protection infrastructure, healthcare and school facilities, but also environmental assets such as mangrove systems and sediment buffers in the coastal zone. This inventory is not static, but dynamic in time due to changes due to physical processes, population growth, migration to cities, changes in economic activities (e.g. change from agriculture to aquaculture);
- *Vulnerability* is the degree in which exposed elements such as human beings, their livelihoods, and man-made and natural assets suffer adverse effects when impacted by hazards. Hazards can cause casualties, direct damage to assets and disruption of services in the coastal zone. High vulnerability is generally the outcome of skewed development processes, such as those associated with environmental management which leaves room for improvement, demographic changes, rapid urbanization in hazardous areas, governance, and the scarcity of livelihood options for the poor.

It is noted that '*vulnerability*' depends on both the hazard and the exposure. Hence, vulnerability and risk are often used interchangeably. There is, however, an important difference in that vulnerability expresses to what extent an exposed element is affected by a specific hazard situation whereas risk weighs in the aspect of the probabilities of all hazardous events.

The appreciation of the risk that threatens the community and assets in each polder is very important, due to the following reasons.

First of all, generally speaking hazardous events are probabilistic in nature. Coincidentally, cyclones are a great example of this behaviour. This can simply be exemplified as follows. Often and at various locations the coast is struck by small tropical storms, resulting in a low and only temporal effect on the region. However, every once in a while, a more severe tropical storm will form, resulting in significant and long-lasting impact. To put it in terms of money, the larger occurrences may not affect the annual cost much, as they occur relatively infrequent. The increasing return period relates to an increase in damage costs, but also a lower probability. The resulting relation is seen in this figure between the flood risk and the return period[16]. By estimating the EAD, the "*expected value*" or mean loss that is encountered in an average year is quantified. This represents a long-term average.

Second, by better understanding the effects of the hazard, exposure and vulnerability it becomes possible to more effectively select the most suitable interventions. These interventions can be used to reduce the vulnerability, exposure or the hazard itself, or a combination of the three.

As an example, it is possible to lower the probability of coastal floods by building embankments. Another example is the application of drainage structures, which reduce the community's vulnerability by reducing salinity intrusion and avoiding water logging. Both options reduce the risk by making use of an intervention, but in a very different way.

Climate change

Climate change is culpable for rising temperatures, changing precipitation patterns, and intensifying extreme events, such as storms and droughts. Nowadays, flood protection interventions cannot be designed without considering climate change and specifically sea level rise, leading to increase of surge level. It is expected that existing embankments may be subject to more frequent overtopping in 50 years' time

As indicated in the BDP2100, accelerated sea level rise is expected to be 1 meter or more by the year 2100. This is likely to cause significant changes in river salinity in the southwest coastal zone of Bangladesh during the dry season (October to May) by 2050. Inundation of between 17-21% of total area of the coastal zone is expected. In addition, future storm surge heights will double due to higher wind speeds. All current polders will be flooded with prolonged water logging, damages to infrastructure, agriculture and aquaculture. Last but not least, storm surge height is expected to increase with sea level rise and will affect at least 50% of coastal zone and increased salinity and destruction of polder embankments.

The current height of the embankments is not in line with the height attainable by storm surges, further increased by climate change. However, not every area of the coastal zone interacts the same with sea level rise. The Sundarbans in the west effectively trap sediment and can keep up with sea level rise better than the Ganges Tidal Plain West, which is not protected by mangroves. The Meghna Estuary delivers a lot of sediment to the coast, which makes this part of the coastline less vulnerable to sea level rise. Because of low rates of sea-level rise or even the record of sea-level fall, lower vulnerability has been indicated in the eastern part of the Bangladesh coast. Vertical upward movement of land in this zone is causing a fall in sea level.

Participatory water management

Participatory water management, is very important not only for the proper operation of the drainage structures but also for effective O&M of embankments and said drainage structures. One of the key elements in the approach of the Blue Gold Programme is working with / enhancing the Water Management Groups (WMG) and and Water Management Associations (WMA) within a polder. Below are presented some of the key lessons learned in relation to participatory water management from the Blue Gold Programme:

- Water Management Groups and Associations flourish when working closely with local government institutions and line agencies. This partnership must be extended to the whole country;
- New legislation establishes local and regional water resource committees. Such bodies must enhance the synergy between national, regional and local interest;
- Water Management Groups and Associations develop small-scale infrastructure but also are stakeholders in main infrastructure. The planning of small and large-scale infrastructure must be optimized to complement each other;
- Participatory water management (combining infrastructure, stakeholder partnerships and agricultural commercialization) should be part and parcel of future water sector investments, and

- O&M Agreement required setting down respective roles and responsibilities of BWDB and WMA.

Soil quality

The environmental quality in terms of water and soil quality are important concerns for the coastal area since people's life and livelihood are directly linked to both. For example, the quality of the soil is directly linked to the agriculture yield. The coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country where 53% of the coastal areas is affected by salinity. The agricultural land use in these areas is very poor compared to the country's average cropping intensity.

The salinity of the soil is mainly caused by tidal floods during the wet season (June-October), direct inundation by saline or brackish water and upward or lateral movement of saline ground water during dry season (November-May). Moreover, the increasing degree of salinity of some areas and expansion of salt affected area as a cause of further intrusion of saline water, normal crop production becomes more restricted. Thus, it has become increasingly important to explore the possibilities of increasing the potential of these (saline) lands for increased production of crops. Other than the pH and nutrient contents are also important for plant growth. Higher pH cause deficiency in nutrients as well. On the other hand, the water quality is also important for both drinking purpose and livelihood especially for fish and agricultural production. The saline river water may cause an increase in salinity of both the ground and surface water and make it unsuitable for irrigation.

Room for innovations and nature-based solutions

CEIP-1 has already proven to be a success story, even with its implementation still ongoing. Within CEIP-1, mostly traditional coastal protection works are being used consisting of 'hard' structures which reduce or stop natural dynamics and, in this way, may also reduce or stop the erosion processes as well. In many cases, such hard structures are the only viable option, however, they can also have negative side effects to the natural system, like for example downdrift erosion. Although in CEIP-1 as well as in other coastal protection projects in Bangladesh, new technologies have been introduced from time to time (which have proven highly beneficial and cost effective), the basic design and monitoring approaches applied can still be seen as traditional when compared to global practices.

An important prerequisite for embankment works is the required safety level which determines the embankment height. A zonally varying safety level (defined by the land-use, inhabitation and other factors) may potentially result in cost reduction and consequently more flexible and sustainable solutions. Within the context of planning of coastal interventions to fight climate change in Bangladesh, a policy should be developed which, among other things, describes how to protect the Coastal Zone against storm surges and associated erosion and flooding. Following the latter, new design guidelines for design of coastal protection works should follow a more adaptive approach which takes functional requirements, land use zoning and safety levels into account. The Netherlands can be taken as an example where this adaptive approach is applied.

Several of those interventions, following a more adaptive approach, fit under the umbrella of the 'Building with Nature' concept. Through this innovative concept, natural strengths and dynamics are identified and incorporated into the coastal protection works to combat erosion and/or flooding risks rather than enforcing designs controlling nature and at the same time developing additional functions promoting socio-economic development, such as ecological, recreation and some examples that have been successfully implemented around the world are: Dike realignments to create sufficient "Room for the River" and reduce flooding sand nourishments are examples of innovative designs to fight erosion and create suitable habitat conditions for restoration of wetlands and coral reefs..

Preliminary assessment of potential benefits for scoring and selection

In this phase a preliminary estimation of potential benefits of protective interventions has been undertaken for 125 polders. Due to data constraints (especially regarding recent data on aquaculture and agriculture production, yields per polder and hydro modelling risk results) and the large number of polders it was not [possible and feasible to develop detailed absolute costs (capex, opex) and benefits estimations. In this phase indicative estimations have been developed regarding potential benefits for 125 polders based upon available data regarding:

- Demographic situation at the polders: population, people affected by floods and serious fatalities or injuries possibly prevented by flood reduction interventions;
- Economy: size of the economic zones, agricultural land and aquaculture potentially affected by flooding. Polders with larger areas for these economic functions obtain a larger score;
- Prevention of asset damage: annual expected damage (AED) of housing, buildings and infrastructure possibly to be reduced by protective interventions. Direct benefits in terms of asset damage reduction were tentatively estimated based upon flood maps. For this some typical flood events (return periods T10, T25, T50, T100) were assumed and translated into an AED reduction.

Each type of the potential (absolute) benefits of protective interventions has been translated into a score (0 for lowest expected benefits- 5 for highest expected benefits) and combined into an overall score based upon weighting and scoring system in the Multi Criteria Analysis (MCA). This overall score signals the potential for effectiveness of flood protective interventions for the relevant polder based upon the potential for absolute benefits.

3. Pre-selection of 23 polders

3.1 Multi Criteria Analysis

The evaluation of the most urgent investment locations, in other words, the selection of the polders, is performed using a Multi-Criteria Analysis (MCA). The MCA is a decision-making tool that provides a systematic approach for supporting complex decisions according to pre-determined criteria and objectives. It compares different options by assessing a set of defined criteria and results in an informative selection of the polders which will present the highest performance and impact.

For the current preparations of the next phase of CEIP, the MCA is used during two stages having different levels of detail as follows:

- MCA (high-level) to select 23 polders out of 125 pre-screened polders (presented in this Polder Screening Rerport), and;
- Detailed MCA to select 13 polders out of the 23 prioritized polders (presented in the Prioritization Report.

Using as a basis the guiding principles as defined in Chapter 2, five cluster categories have been defined which represent the themes of the guiding principles:

1. Social and institutional;
2. Technical;
3. Constructability;
4. Environmental, and
5. Economic.

Each of these cluster categories comprises from a list of criteria. Each criteria has been selected so to reflect the guiding principles. The cluster categories and respective criteria are presented in the sections, along with a description of what they are representing, the method and source, the criteria for scoring and the applied scoring categories for the MCA. The gathered information is based on secondary data of other (recent) studies, stakeholders' consultations and assessment of the data.

3.2 Social and institutional criteria

3.2.1 People affected

Flood can cause damage to property, businesses, and infrastructure, and dramatically affect people's lives and livelihoods. When an area gets flooded, the water destroys homes, crops, and social networks. Tropical cyclones generate excessive water levels and wind speeds, leading to extreme tangible risk on people.

A risk assessment due storm surge inundation is executed to quantify the social risk to flooding (Annex A1.8). The preliminary flood risk assessment (PFRA) considers storm surge return period of 10, 25, 50 and 100 years defined within CEIP-1[29].

The social risk to flooding is calculated for:

- Population affected: the population who live within the flood extent, and;
- Population at severe risk: the population at risk of loss of life.

The population affected and the population at severe risk have been calculated based on the inundated percentage area in the polder. For each return period mentioned above, the estimated number of people affected is estimated using a simplified approach: if 20% of the polder is inundated, then 20% of the population will be affected, assuming a uniform distribution of the population in the polder. This simplified approach has been taken due to limitations of the vertical accuracy of the MERIT DEM. Additional information on the latter is presented in Annex A1.8. The same approach is used for the calculation of the population at severe risk. The loss of life rate is calculated from the inundation depth using the formula of Boyd et al. (2005), which describes the relation between mortality and depth of water[30].

It is known that cyclone shelters are contributing significantly in reduction of life losses. In the 23 polders, nearly 800 cyclone shelters are present with capacity of more than 500 people (on an average) though the government and partner organizations are constructing new shelters with improved facilities[31]. The main problems with the cyclone shelters in Bangladesh are the capacity and basic facilities such as toilet, drinking water, sanitary facilities etc.) and regular maintenance of the shelters. Moreover, the location of a shelter plays a crucial roles in potential use of it. In many cases the shelters are too far from the settlement cluster which discourage people to use which in other way increase their cyclone risk. Many of them are in dilapidated condition and lack of provision for the special needs of women and people with disabilities, as well as lack shelter space for livestock. On the other hand, lack of proper transport facilities influence people's vulnerability to cyclone disasters. Most of the roads near coastal areas are built from earth. Prior to cyclone, heavy rainfall and wind damages most of the transport routes. Since cyclone shelters are mostly scattered, therefore people are reluctant to relocate to far away areas as they do not want to leave their livelihoods. Women and girls are also often concerned with protection and privacy issues in cyclone shelters[32]. Due to lack of data on specific location of the shelters, this parameter has not been included in the assessment.

The annual average population affected and population at severe risk have been calculated. Through estimation of the annual expected population affected (or population at severe risk), the mean number of people (the "expected number") that are affected in any given year is signified, which represents a long-term average.

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[29] CEIP-1 (2018). IWM: Technical Report on Storm Surge, Wave, Hydrodynamic Modelling and Design Parameters on Drainage System and Embankment Crest Level, Package III

[30] Boyd E (2005) Toward an empirical measure of disaster vulnerability: storm surges, New Orleans, and Hurricane Betsy. Poster presented at the 4th UCLA conference on public health and disasters, Los Angeles, 1–4 May 2005

[31] Food Security Cluster

[32] https://reliefweb.int/sites/reliefweb.int/files/resources/180409%20Start%20Fund%20Tropical%20Storm-Cyclone%20Disaster%20Summary%20Sheet.pdf

The social risk to storm surge flooding is scored based on both the population affected and the population at severe risk per hectare. Both criteria are individually scored and averaged for the total score.

The population at risk (affected/at severe risk) is scored based on the following criteria:

Score	*Criteria*
1	Population affected / ha < 0.5 Population at severe risk / ha < 0.02
2	0.5 < population affected / ha < 1 0.02 < population at severe risk / ha < 0.04
3	1 < population affected / ha < 1.5 0.04 < population at severe risk / ha < 0.06
4	1.5 < population affected / ha < 2 0.04 < population at severe risk / ha < 0.06
5	Population affected / ha > 2 Population at severe risk / ha > 0.08

3.2.2 Community vulnerability

Cyclone-induced flooding leads to fatalities and damage to housing and critical infrastructure. The rehabilitation often needs a considerable amount of time causing widespread disruption to the livelihoods of the inhabitants. The recent three cyclones, Sidr in 2007, Aila in 2009 and Amphan in 2020, have impacted the coastal zone to a different extent and magnitude. Sidr is considered a category 5 cyclone equivalent on the Saffir–Simpson scale, accordingly Aila is scored as a category 1 cyclone and Amphan as a category 4 cyclone. With Amphan and Aila the disaster risk reduction and emergency response efforts to take precautions in anticipation of the cyclone resulted in a limited loss of lives and livelihoods as compared to Sidr.

The vulnerability of the community is addressed using report findings, stakeholder consultations and site visits. The Khulna and Barisal Division have been most impacted by Sidr, Aila and Amphan. Cyclone Sidr affected severely Bagerhat, Barguna and Patuakhali DDistricts[33]. Cyclone Aila had strong impacts in Satkhira, Khulna and Patuakhali Districts. Cyclone Amphan's effects were strongest in Satkhira, Khulna, Barguna and Patuakhali Districts[34] (see Figure 3-1, Figure 3-2 and Figure 3-3).

The regional impacts of these cyclones are categorized based on the recorded number of fatalities, the population affected, and destroyed houses. The people affected are defined as those members of a population:

- whose physical security, basic rights, dignity, living conditions or livelihoods are threatened or have been disrupted, and

[33] GoB (2008). Cyclone Sidr in Bangladesh- Damage, Loss and Needs Assessment for Disaster Recovery and Reconstruction. Dhaka, Bangladesh. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/F2FDFF067EF49C8DC12574DC00455142-Full_Report.pdf

[34] CARE Needs Assessment Working Group (2020). Cyclone Amphan, Join Needs Assessment (JNA). Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/cyclone_amphan_joint_needs_assessment_final_draft_31052020.pdf

- whose current level of access to basic services, goods and social protection is inadequate to re-establish normal living conditions with their accustomed means in a timely manner without additional assistance[35].

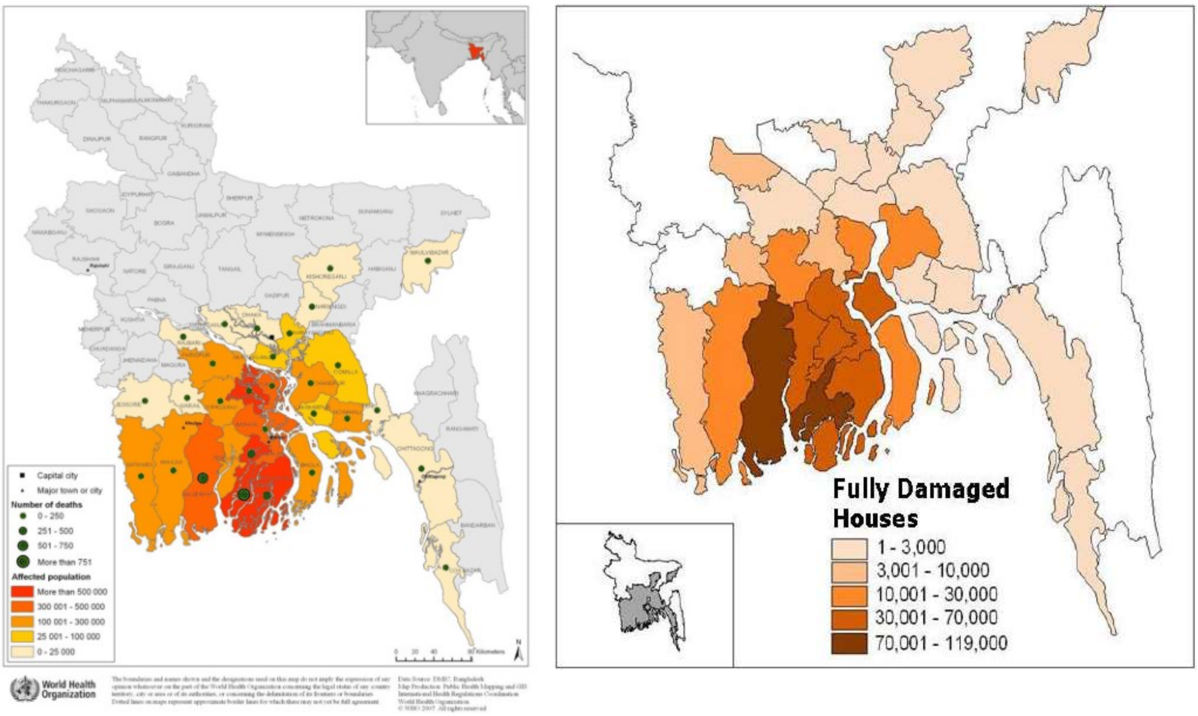


Figure 3-1: Number of fatalities and affected population (left) and number of fully damaged houses (right) by District from cyclone Sidr[3]

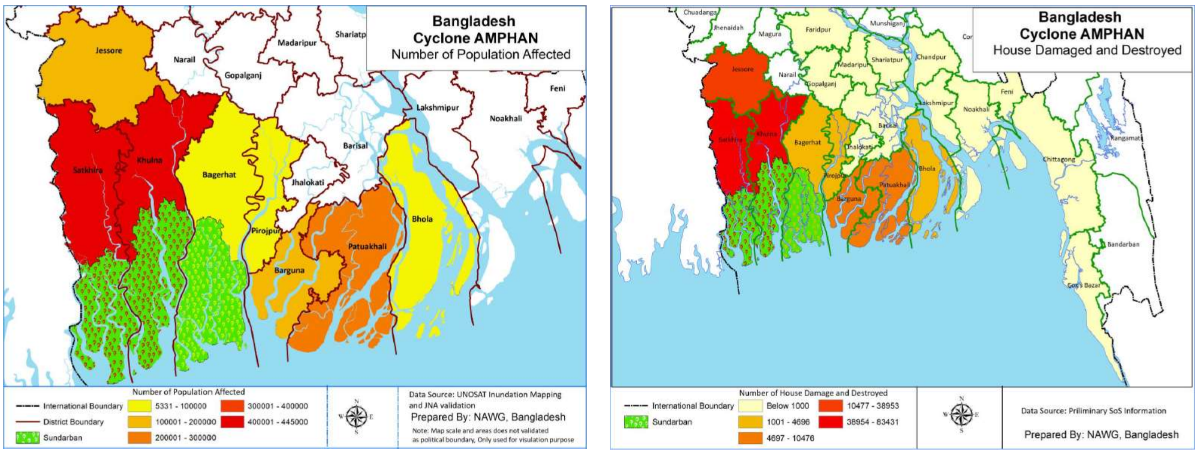


Figure 3-2: Affected population (left) and the houses damaged and destroyed (right)

[35] Humanitarian population figures. Inter-Agency Standing Committee, Information Management Working Group; April 2016. Available at: https://www.jips.org/jips-publication/humanitarianpopulation-figures-iasc-information-managementwg-2016/

by District from cyclone Amphan

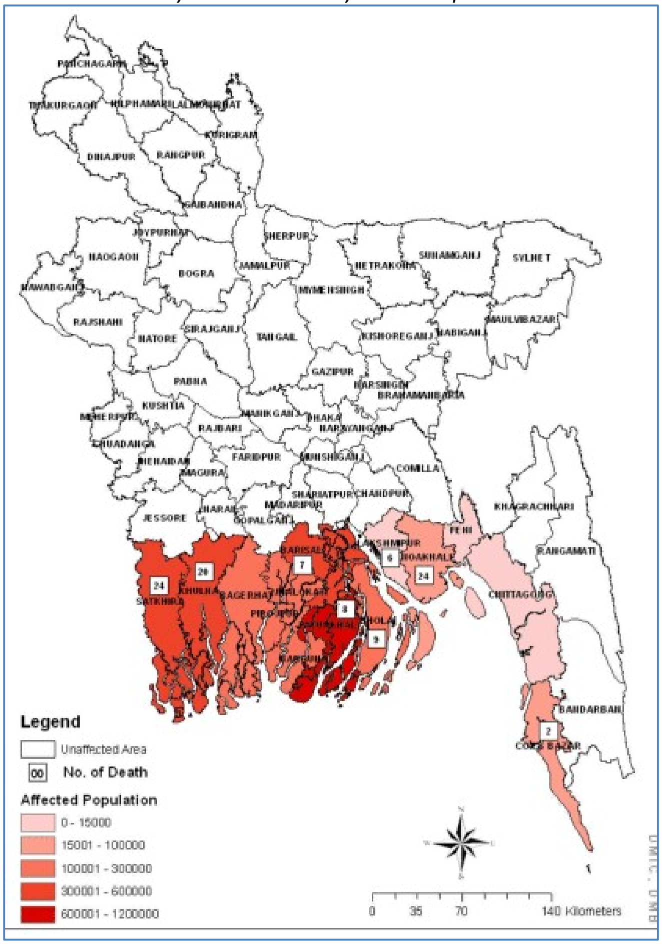


Figure 3-3: Population affected and number of deaths by District from cyclone Aila

As it can be seen from Figure 3-1, Figure 3-2 and Figure 3-3, the cyclones affected different Districts in the coastal region. Based on the available data, the vulnerability of the polders was individually scored based on the impacts from Sidr, Aila and Amphan.

For the MCA the highest score is taken if either of the following criteria is met:

Score	*Criteria (per District)*
1	Population affected < 100,000 Destroyed houses < 10,000 Fatalities < 20
3	100,000 < Population affected < 300,000 10,000 < Destroyed houses < 30,000 20 < Fatalities < 100
5	Population affected > 300,000 Destroyed houses > 30,000

	Fatalities > 100

3.2.3 Land acquisition and displacement

Land acquisition and displacement of people is a difficult and lengthy procedure which impacts the coastal community. To obtain physical possession of the site, the affected landowners need to be compensated. In addition, the continuance of the construction is dependent on the land acquisition as it can cause major delays. If the polder is located along a dynamic river with high erosion rates, the risk arises that implementation of the work consists of significant changes and thus land acquisition may be required for the retirement of the embankment. The locations where no land acquisition is possible due to the land use, the need arises to maintain the position of the embankment and bank protection work is considered.

The potential land acquisition of the polders is quantified through the total land acquired in the CEIP-1 packages and the observed bank erosion. Ratios of land acquisition are calculated for internal polders (river facing) with Package-1 and for exposed (sea-facing) polders with Package-2. These fractions are used to calculate the land acquisition area with the total embankment length of the polders. The land acquisition is enlarged when the polder is subject to strong erosion and the requirement for land needs to account for a larger set back distance. The calculation method is elaborated in more detail in Appendix A3.1.

Land acquisition is considered a negative impact for the polder selection, giving a higher score to polders with low land acquisition.

For the MCA the land acquisition is scored into based on the following criteria:

Score	*Criteria*
1	Land acquisition > 40 ha
2	30 ha < land acquisition < 40 ha
3	20 ha < land acquisition < 30 ha
4	10 ha < land acquisition < 20 ha
5	Land acquisition < 10 ha

3.2.4 Community water management

The community Water Management Organizations (WMO) are responsible for the operation and maintenance of the drainage structures but also for effective O&M of embankments and said drainage structures. The participation and status of the WMO is important to maintain the local water management and increase the sustainability of the efforts undertaken by the construction works.

Information about the community water management is gathered from relevant project reports and field visits. During the Inception Phase, the status of the WMOs of polders in the Satkhira and Khulna District have been identified. Relevant projects to the development and strengthening of the capacity of the WMO are the Blue Gold Programme and the Integrated Planning for Sustainable Water Management (IPSWAM) Programme.

The status of the WMO is categorized into non-active, semi-active or active. The WMO is considered non-active when there is no WMO present or the WMO are comprised by limited people participating in decision making or there are institutional conflicts within the organization. The WMO are categorized as semi-active when there are few participating people, and there is no institutional conflict. The polders from relevant projects are considered active as the WMO are under development. Active WMO consists out of many participating people and encounter no institutional conflict. The active participation in decision making can be defined as attending the Executive Committee Meetings in key planning and decision-making process.

Active WMOs are considered a positive impact for the polder selection and therefore are assigned a higher score.

The status of the WMOs is scored based on the following criteria:

Score	*Criteria*
1	Non-active WMOs comprised by limited people participating actively, encountering institutional conflicts
3	Semi-active WMOs
5	Active WMOs comprised by many participating people actively and no institutional conflicts

3.2.5 Stakeholder policies and strategies

Key stakeholder views, policies and strategies play a crucial role when prioritizing the polders. For example, the BDP2100 is a strategic plan with a long-term horizon of 100 years as well as a short-track implementation program to solve urgent problems that contribute to the overall development of Bangladesh. Thus, consideration should be given to the various investment plans and development scenarios.

Stakeholder consultation was a crucial input to establish the stakeholder policies and strategies. The consultations with Honorable State Minister and Honorable Senior Secretary of MWR brought valuable information of the high-priority polders in connection to potential development in the coastal zone and the conditions of the polder water infrastructure.

Polders with low priority are identified from other ongoing programmes, either GoB or IDA funded. As said, the Development Project Proposal (DPP) has been approved for some of them, and for others the DPP approval procedures are underway. These polders are already under development and not relevant for the prioritization. Figure 3-4 shows the polders with ongoing work under relevant rehabilitation and improvement projects.

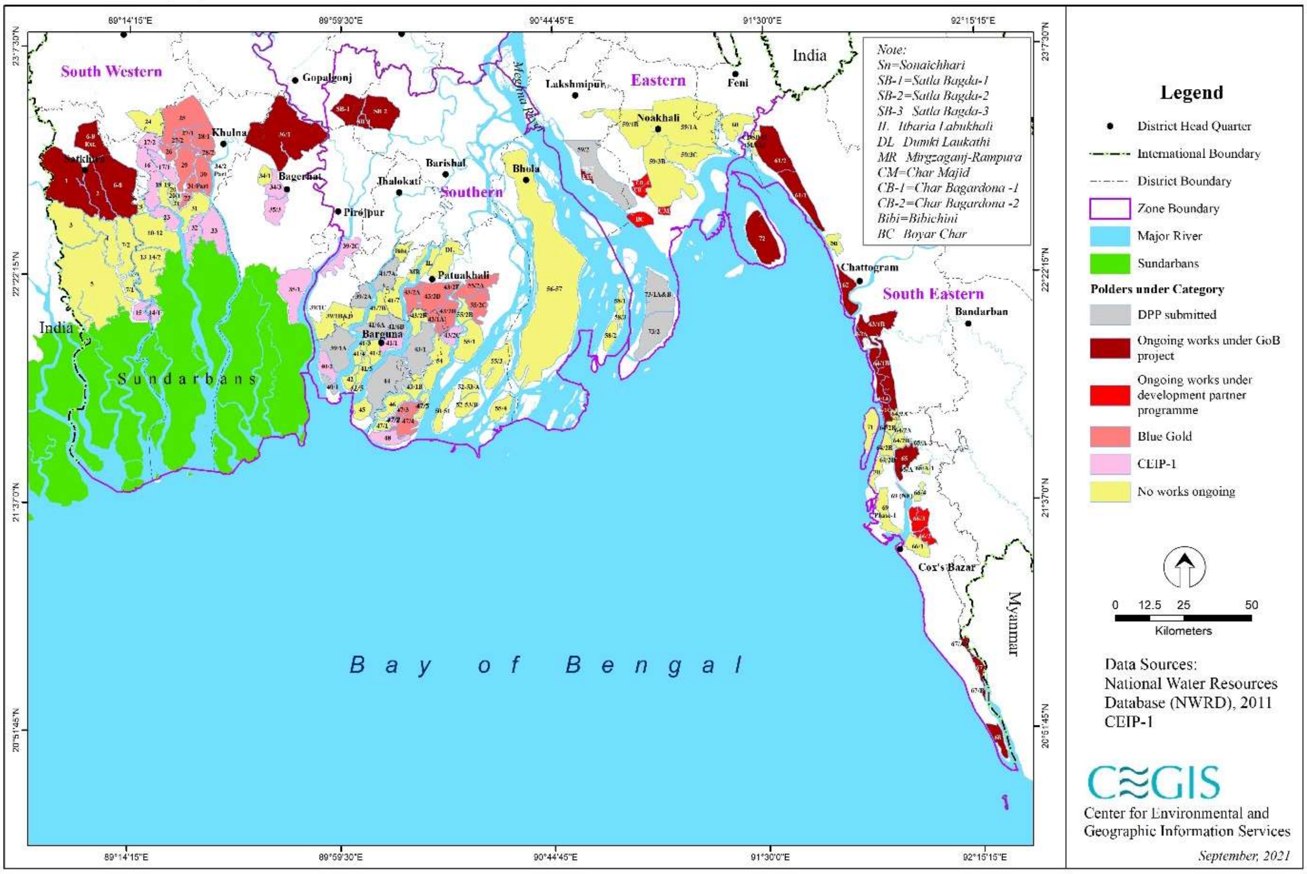


Figure 3-4: The polders with ongoing work from relevant rehabilitation and improvement projects

Based on the stakeholder consultation and other relevant ongoing projects, the stakeholder policies and strategies is scored in two categories, based on the following criteria;

Score	*Criteria*
1	Wider polder area and/or polder itself is not included in development plans/policies nor the polder is considered crucial to rehabilitate based on stakeholder consultations and ongoing rehabilitation and improvement projects.
5	Wider polder area and/or polder itself is included in development plans/policies and the polder is considered crucial to rehabilitate based on stakeholder consultations

3.3 Technical Criteria

3.3.1 Condition of embankments

The embankments protect the polder and its inhabitants from tidal surges, inflow of saline water and seasonal flooding form the rivers. In the polders poor maintenance of the embankments can cause breaches in the embankments during cyclones. Closure work may be required to enhance the state of the polders.

The condition of the embankments is quantified by the length of embankments that are breached and in bad condition with the consideration of the construction year. The length of breached/bad embankments is retrieved from field visits and CEIP-1 data. In addition, the construction year of the embankments is considered as polders constructed in the 1960s are general in worse condition as compared to the polders constructed in the 1980's and later.

The bad condition of the embankments is considered a high priority for polder selection. The condition of the embankments is scored for both the construction year and the embankment breached/in bad condition. For the MCA the highest score is taken.

The criteria is scored into the following categories:

Score	*Criteria*
1	Embankment breached/in bad condition < 1 km Construction year < 1970
2	1 km < Embankment breached/in bad condition < 2 km 1970 < construction year < 1980
3	2 km < Embankment breached/in bad condition < 4 km 1980 < construction year < 1990
4	4 km < Embankment breached/in bad condition < 6 km 1990 < construction year < 1995
5	Embankment breached/in bad condition > 6 km Construction year < 1995

3.3.2 Erosion of banks

The morphology of the coastal zone is highly dynamic. Rivers such as Pussur, Biskhali and Baleswar experience high erosion rates with peak discharges. The morphologic conditions are complex due to the irregular shape of the Meghna estuary together with seasonal variations and the role of the tide. The riverbanks and embankments are at risk of erosion from both waves and river flows.

To quantify bank erosion the erosion rate and the length of banks experiencing erosion are considered. Historical shoreline dynamics are available from in the Aqua Monitor and from the LTM project. The Aqua Monitor provides changes in land and water occurrence between 1985 and 2016 analyzed with satellite imagery from multiple Landsat missions[36]. The LTM project provides historical banklines mapped every 5 years to estimate the erosion rates. Both datasets are used to quantify the bank erosion, where the LTM project data is used to quantify the erosion rate in time and the Aqua Monitor to quantify the total erosion length. The erosion and accretion for polder 41/5 and polder 42 from both the Aqua Monitor and the LTM project is seen in Figure 3-5.

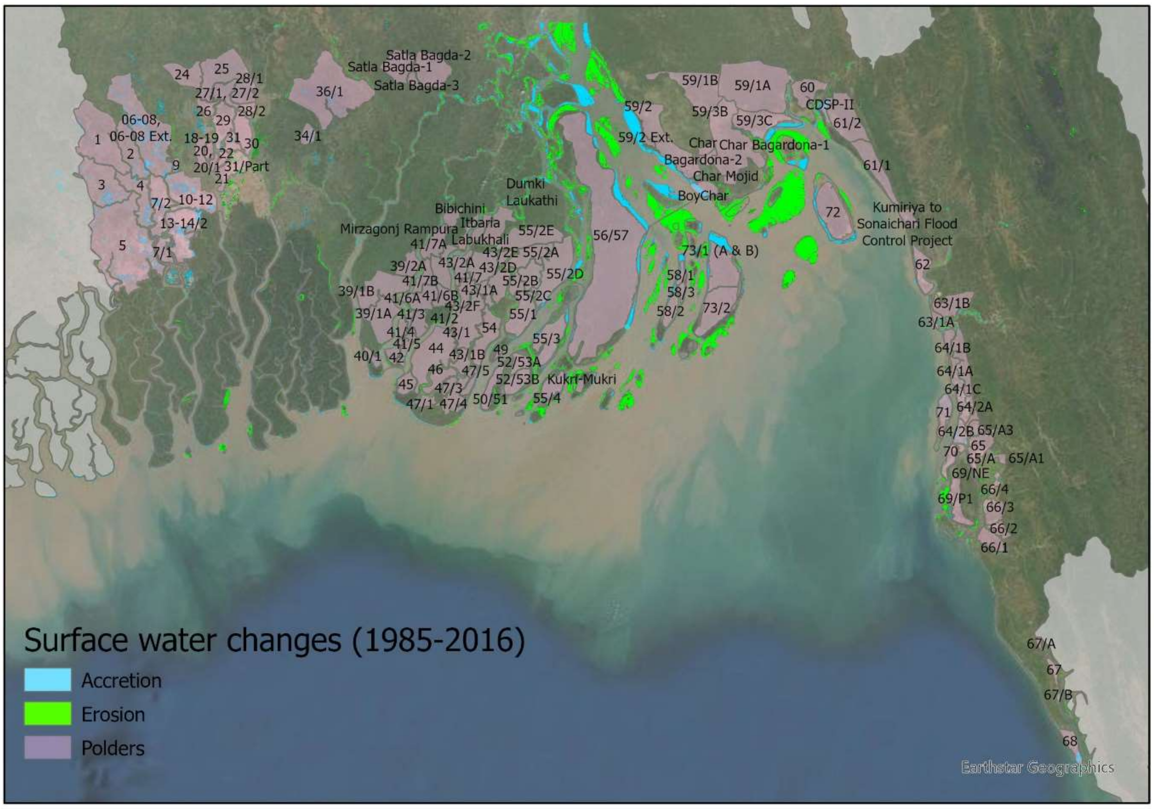


Figure 3-5: Surface water changes between 1985 and 2016 for the polders
Source: Aqua Monitor[36]

[36] Donchyts, G., Baart, F., Winsemius, H. *et al.* Earth's surface water change over the past 30 years. *Nature Clim Change* 6, 810–813 (2016). https://doi.org/10.1038/nclimate3111

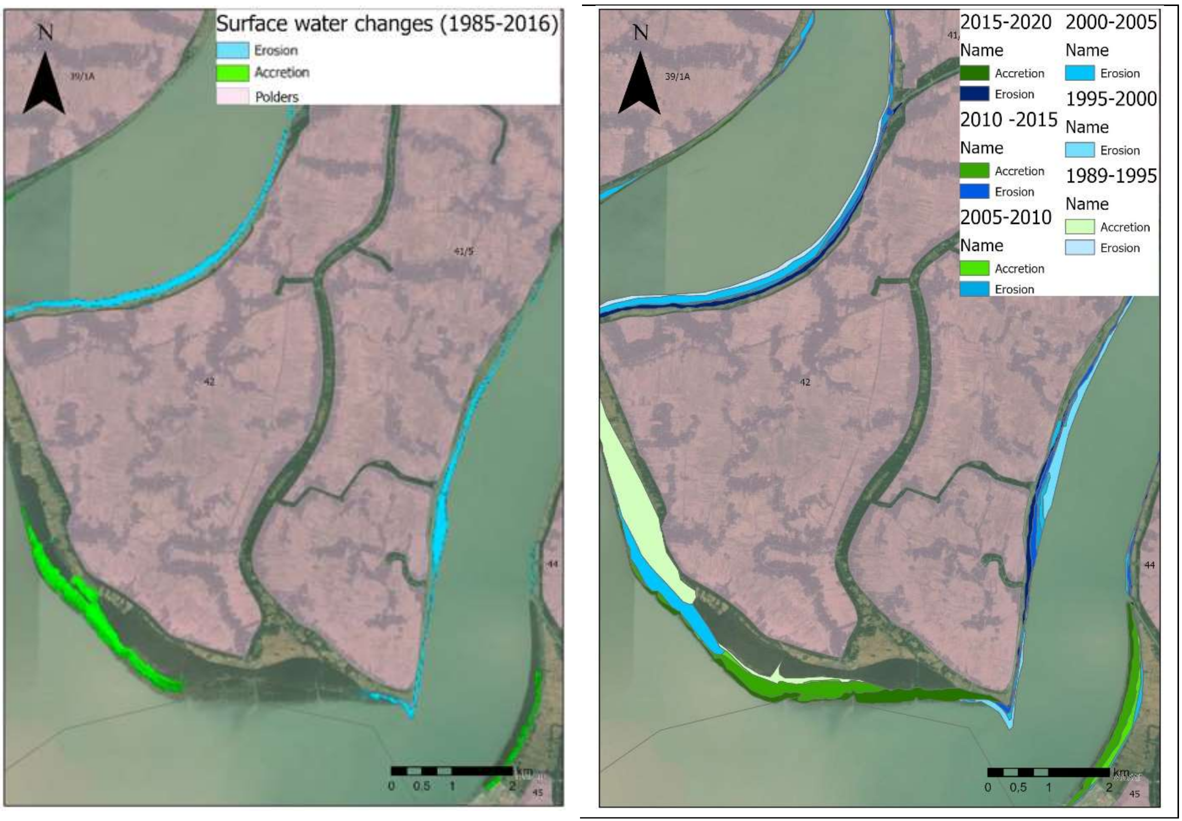


Figure 3-6: Erosion and accretion for polder 41/5 and polder 42 from the Aqua Monitor (left) and the LTM project (right)

As different historical trends in the erosion rates can be observed over the last 30 years, the bank erosion is qualitatively scored into low to high-dynamic polders when erosion was observed.

The erosion rate and bank erosion lengths were visually inspected by observing the data and scored into the based on the following criteria:

Score	*Criteria*
1	No dynamic: • No observed erosion
2	Very low dynamic: • Erosion < 5 m/year Length of bank erosion < 1 km
3	Low dynamic: • Erosion < 5 m/year • Length of bank erosion < 5 km
4	Mid dynamic: • 5 m / year < erosion < 10 m / year • 5 km < Length of bank erosion < 10 km

Score	*Criteria*
5	High dynamic: • 10 m / year < erosion < 15 m / year • 10 km < Length of bank erosion < 15 km

3.3.3 Drainage congestion

Major water management issues arise in the polders because of seasonal drainage congestion. Poor maintenance and inadequate internal water management of the polders have contributed to internal drainage congestion and heavy external siltation. As a result, the soil fertility and agriculture production decline because of water logging and soil salinity increase.

The condition and performance of the drainage and flushing infrastructure is essential to maintain a good level of drainage. Information about the total number of drainage and flushing sluices and drainage channels is retrieved from field visits and an overview of the existing drainage and flushing sluices is retrieved from the "Interactive Geo-Database for Coastal Zone (IGDCZ)" developed within the Long-Term Monitoring, Research and Analysis Study[37].

The potential drainage infrastructure in bad condition is determined with ratios from the executed work for the different packages of the CEIP-1 polders. The ratio of implemented work is used to calculate the number of sluices up for repair or re-construction and the drainage channels for re-excavation. Information about the drainage congested area is taken from the CEIP-1 MCA.

With this information, the drainage congestion in the polder is quantified based on the following aspects:

- The number of drainage and flushing sluices in bad condition;
- Condition of the drainage channels, and;
- The drainage congested area.

The mean of the three aspects is used to calculate the final drainage congestion score. The number of bad drainage and flushing sluices, the condition of the drainage channels and the drainage congested area are individually scored based on the following criteria:

Score	*Criteria*
1	Bad drainage and flushing sluices < 5 Drainage congested area < 100 ha Drainage channels to be re-excavated < 20 km
2	5 < Bad drainage and flushing sluices < 10 100 ha < drainage congested area < 500 20 km < Drainage channels to be re-excavated < 40 km
3	10 < Bad drainage and flushing sluices < 15 500 ha < drainage congested area < 1000 40 km < Drainage channels to be re-excavated < 60 km

[37] https://gis.iwmbd.com/ceip

Score	*Criteria*
4	15 < Bad drainage and flushing sluices < 20 1000 ha < drainage congested area < 2000 60 km < Drainage channels to be re-excavated < 80 km
5	Bad drainage and flushing sluices > 20 Drainage congested area > 2000 ha Drainage channels to be re-excavated > 80 km

3.3.4 Design under climate change

Climate change is culpable for rising temperatures, changing precipitation patterns, and intensifying extreme events, such as storms and droughts. Nowadays, flood protection needs to be designed with consideration of climate change and specifically the expected sea level rise including the increase of storm surge level. The design height of the embankment needs to account for future storm increased by climate change. It is expected that existing embankments may be subject to more frequent overtopping in 25 years' time.

The effect of climate change to the polders is quantified with the increase in storm surge level. Future storm surge water levels are simulated with a combination of cyclone and hydrodynamic models in CEIP-1[38]. For simulating the storm surge and associated flooding, the Bay of Bengal model based on Mike 21FM hydrodynamic modelling system has been adopted with meteorological forcing (wind and pressure field) due to cyclone. Storm surge and monsoon water levels are available in point locations (Figure 3-7) and matched to the polders.

[38] CEIP-1 (2018). IWM: Technical Report on Storm Surge, Wave, Hydrodynamic Modelling and Design Parameters on Drainage System and Embankment Crest Level, Package III

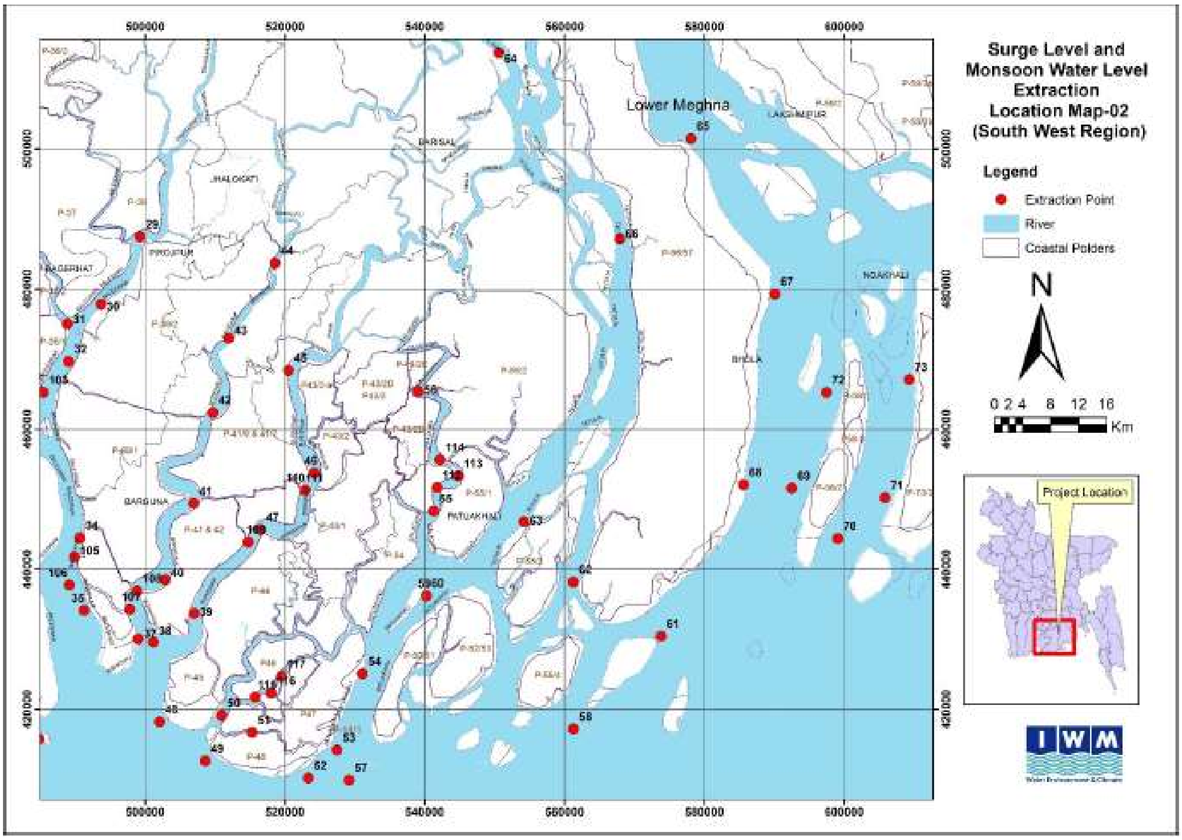


Figure 3-7: Locations of storm surge and monsoon water level extraction points. Source: CEIP-1[38]

The water level difference for the future 25-year return period is compared with the baseline scenario and used to score the effect of climate change based on the following criteria:

Score	*Criteria*
1	Storm surge increase > 0.01 m
2	0.01 m < storm surge increase < 0.5 m
3	0.5 m < storm surge increase < 1.0 m
4	1.0 m < storm surge increase < 2.0 m
5	Storm surge increase > 2.0 m

3.4 Constructability Criteria

3.4.1 Logistics and time travel

The presence and the condition of infrastructure in and to the polders is important during construction. As construction material is transported from urban areas and harbors, the accessibility and travel distance to these locations is significant to avoid long travel time to the construction sites.

The accessibility of the polders in terms of travel time is considered with the Accessibility to Cities Dataset from the Malaria Atlas Project[39]. This dataset consists of the accessibility to high-density urban centers as measured by travel time. The travel time is based on two leading roads datasets, Google Roads Database and Open Street Map data, and therefore comprises also the roads in low-resource settings. Long travel time is considered a negative impact for the constructability, making polders with short travel times more favorable in the polder selection.

The maximum travel time in the polder is taken to score the travel time based on the following criteria:

Score	*Criteria*
1	Travel time > 120 minutes
2	90 minutes < travel time < 120 minutes
3	60 minutes < travel time < 90 minutes
4	30 minutes < travel time < 60 minutes
5	Travel time < 30 minutes

3.4.2 Availability of construction materials

The availability and accessibility of construction materials influences the progress and quality of the construction works. Polders located in areas with limited availability of earth for the embankments are more likely to present difficulties in accessing construction materials, as it has to be retrieved from remote areas. In CEIP-1 earth for the construction / re-sectioning of the embankments had to be retrieved with local initiatives of the contractor as sufficient materials were not available.

From experience in CEIP-1, it appears that the polders with widespread agriculture construction material is abundant, whereas earth in the more rural polders is often an issue. To estimate the availability of construction materials, the ratio of the agricultural land over the settlement areas is calculated. The total agricultural area and settlement area is taken from the land use map from the National Water Resources Database (NWRD) 2011 and divided by the total polder area.

The ratio agricultural / settlement area is scored based on the following criteria:

Score	*Criteria*
1	Ratio agriculture/settlement area < 1
2	1 < Ratio agriculture/settlement area < 2
3	2 < Ratio agriculture/settlement area < 3
4	3 < Ratio agriculture/settlement area < 4
5	Ratio agriculture/settlement area > 4

[39] D.J. Weiss, A. Nelson, H.S. Gibson, W. Temperley, S. Peedell, A. Lieber, M. Hancher, E. Poyart, S. Belchior, N. Fullman, B. Mappin, U. Dalrymple, J. Rozier, T.C.D. Lucas, R.E. Howes, L.S. Tusting, S.Y. Kang, E. Cameron, D. Bisanzio, K.E. Battle, S. Bhatt, and P.W. Gething. A global map of travel time to cities to assess inequalities in accessibility in 2015. (2018). Nature. doi:10.1038/nature25181

3.4.3 Polder clustering into packages

In terms of construction logistics, clustering of polders which are in the same wider results in effective execution of the works. In that way, both supervision staff and equipment can operate within a wider area, avoiding long travel distances between the polders.

The Inception Report includes Fan analysis of the dynamics of the coastal zone of Bangladesh based on a high-level risk assessment to identify vulnerable areas. From this assessment, high priority development zones were identified via desk studies and consultations based on the information available to the Consultant. To estimate the possibility of polder clustering into packages, the travel distance of the polders is estimated from this preliminary list of 23 polders.

The minimum distance between the centroids of the polder with any of the potentially selected polders is calculated through a GIS analysis.

The distance between the polders is scored into the following categories:

Score	*Criteria*
1	Polder located >300 km from majority of potentially selected polders
2	Polder located > 200 km and <300 km from majority of potentially selected polders
3	Polder located > 100 km and <200 km from majority of potentially selected polders
4	Polder located >50 km and <100 km from majority of potentially selected polders
5	Polder located <50 km from majority of potentially selected polders

3.5 Environmental Criteria

3.5.1 Ecologically sensitive areas

Preservation of Ecologically Sensitive Areas (ESA) is important for the environmental conditions in a polder. The functioning of the polder can greatly impact the ESAs, as on the other side the ESAs can be impacted from construction works.

The effect of ESAs is quantified by the total area present in the polder. The location of the ESAs is available from the Department of Forestry (DoF).

The ECAs of the polder is scored based on the total area in the polder based on the following criteria:

Score	*Criteria*
1	No ESA area
2	0 ha < ESA area < 400 ha
3	200 ha < ESA area < 400 ha
4	400 ha < ESA area < 600 ha
5	High ESA area > 600 ha

3.5.2 Aquatic fauna

The presence of good conditions for aquatic fauna are important for the aquaculture sector. Shrimp culture was traditionally limited to the area between the levees and the river channels. However, the practices have grown in spatial coverage inside the polder systems over the last three decades because of foreign demand. Nowadays, aquaculture plays a vital role in the nation's food security and generates significant employment and foreign exchange earnings. The presence of cultivable land for aquaculture is used to quantify the effect of aquatic fauna in the polder selection. The fresh and brackish water aquaculture is taken from the land use map from the National Water Resources Database (NWRD) 2011.

Rehabilitation works in the polder contributes to more favorable conditions for the growth of aquatic species, therefore high presence aquaculture is considered favorable for polder selection as more land can be optimally utilized.

The aquaculture area is scored based on the following criteria:

Score	*Criteria*
1	Cultivable land for aquaculture < 1,000 ha
2	1000 ha < cultivable land for aquaculture < 2,000 ha
3	2000 ha < cultivable land for aquaculture < 4.000 ha
4	40000 ha < cultivable land for aquaculture < 6.000 ha
5	Cultivable land for aquaculture > 6,000 ha

3.5.3 Soil quality

Crop production in the polder is influenced by the soil quality. Salinity intrusion is the dominant factor behind low crop productivity, decreasing crop yields. Changes in salinity intrusion threaten the agricultural production and aquatic ecosystems. Coastal farmers have adopted saline-tolerant rice varieties, thereby increasing their rice production. Salinity levels up to five parts per thousand (ppt) starts affecting agricultural yields[40]. For aquaculture the optimum surface water is less than four ppt for the giant freshwater prawn and ten to twenty ppt for the black tiger shrimp[41].

To assess the soil quality, both the agricultural land and saline area (land with salinity levels higher than 5 ppt) of the polders are considered. A special field survey was carried out in the south-western part of the coastal arable land excluding the Sundarbans by soil survey teams of SRDI[42]

[40] Salehin, M. et al. (2018) 'Mechanisms and Drivers of Soil Salinity in Coastal Bangladesh', in Nicholls, R. J. et al. (eds) Ecosystem Services for Well-Being in Deltas: Integrated Assessment for Policy Analysis. Cham: Springer International Publishing, pp. 333–347. doi: 10.1007/978-3-319-71093-8_18.

[41] Dasgupta, S. et al. (2015) 'River Salinity and Climate Change: Evidence from Coastal Bangladesh', in World Scientific Reference on Asia and the World Economy. WORLD SCIENTIFIC, pp. 205–242. doi: 10.1142/9789814578622_0031.

[42] Soil Resource Development Institute (2010). Saline Soils in Bangladesh. SRMAF Project. Ministry of Agriculture

in May 2009. The report gives the cultivated and saline area of the coastal area per Upazila. This data is transformed to the saline area per polder.

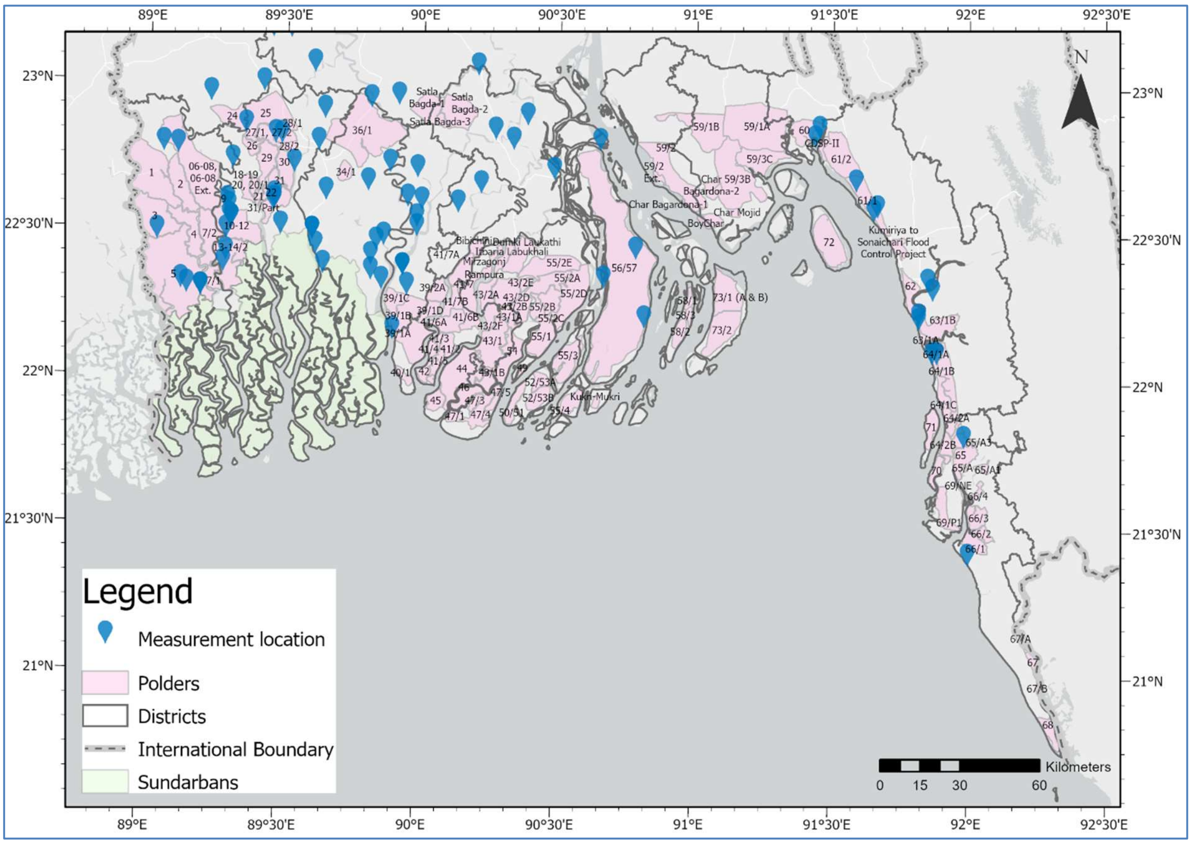


Figure 3-8: Soil and water quality SRDI measurement locations in respect to the 125 polders[42]

To quantify the soil quality, both the cultivable land and the area subject to salinity intrusion is used. The mean of the score of cultivable area and salinity is taken to calculate the soil quality score.

The cultivable land and salinity are scored based on the following criteria:

Score for MCA	*Criteria*
1	Cultivable land > 15,000 ha Saline area < 2,000 ha
2	12,000 ha < cultivable land < 15,000 ha 2,000 ha < Saline area < 4,000 ha
3	8,000 ha < cultivable land < 12,000 ha 4,000 ha < Saline area < 6,000 ha
4	4,000 ha < cultivable land < 8,000 ha

	6,000 ha < Saline area < 8,000 ha
5	cultivable land < 4,000 ha
	Saline area > 8,000 ha

3.5.4 Water quality

The access to clean water is critical for people's life and productive uses as agriculture to realize livelihood. The quality of the water is determined by the presence of different kind of salts. With poor water quality, various soil and water problems may arise.

One of the major parameters to determine the water quality of the coastal area is the total salt concentration measured by the electrical conductivity (ECe). As saline salt contains a high EC, this parameter can be used to assess the water quality. The EC is taken from the field survey data from SRDI[42]. Crops are sensible to salinity starting from 2 dS/m as stated by the Bookers Tropical Soil Manual[43]. From 4 dS/m the salinity restricts the yields of many crops.

As per this manual, the EC is scored based on the following criteria:

Score	*Criteria*
1	Good quality: ECe <2 dS/m
3	Marginal quality: 2.0 dS/m < ECe < 4.0 dS/m
5	Poor quality: ECe >4.0 dS/m

3.5.5 Opportunities for Nature-Based Solutions

To combat erosion in Bangladesh's dynamic coastal zone, large-scale bank and slope protection works have been carried out. Such traditional 'hard' embankment protection reduces or stop the natural dynamics. New design guidelines, Nature-Based Solution (NBS), for coastal protection follow a more adaptive approach, where the natural strengths are identified and incorporated into the coastal protection work to combat erosion and/or flooding risk.

NBS in the coastal zone include mangrove forest conservation and restoration to protect the embankments. In addition, mangrove forests are key to the health of nature and contribute to livelihood benefits for the local community. Another NBS is using the natural channel evolution to combat bank erosion in rivers, or by redirecting river flows to keep waterways open. Often hybrid solutions consisting of a combination of 'hard' structures such as protection works and 'soft' measures such vegetation restoration are recognized as a feasible option. A hybrid solution can be less intrusive to the natural processes as they consist of dynamic solution that are more adaptable with rising sea levels. It is important that these NBS solutions developed elsewhere, are properly implemented in Bangladesh, taking both the physical and cultural setting into account[44].

For the purpose of this assessment, two categories of NBS solutions are looked at: natural channel evolution for erosion prevention and potential for development of mangrove habitats. Limitation

[43] London, J. R. (1984). Booker tropical soil manual. New york, Booker Agriculture Intrnational Limited.
[44] World Bank, Bangladesh, Coastal Resilience and Delta Plan, Knowledge Exchange to the Netherlands, September 27, 2019 to October 6, 2019, Findings Report no. 1 – October 2019.

to consideration of these two potentials is due to data inadequacy, however Consultant will further explore during feasibility.

Using the natural morpho-dynamic channel evolution to combat erosion was investigated for Polder 35/1 in the Technical Assistance (TA) report[45] for developing concept design solutions for erosion in Bangladesh. The natural dynamics in the Baleshwar River at Polder 35/1 seem to indicate the formation of a new channel along the char. Further development of this new channel may reduce the erosion when it takes over the tidal conveyance of the current channel. The idea of the intervention is to accelerate the current morpho-dynamic evolution by dredging a channel to reduce the erosion pressure as this channel takes most of the hydrodynamic conveyance. Optionally combined with sediment disposal (nourishment) at the erosion hotspot, see Figure 3-9 for the layout of the intervention.

To assess the possibility of using the natural channel evolution to reduce erosion certain requirements were established to identify the polders feasible for this NBS. The first requirement is the existence of erosion hotspots. The second is the need of a wide channel where multiple ebb dominated channels can develop. The erosion locations are identified with the Aqua Monitor and the channel morphology with satellite imagery at rivers where chars form and sand bars are dynamic. These locations are predominantly in the in the Meghna Deltaic Plane.

[45]World Bank Technical Assistance (2020). Developing concept design solutions for coastal erosion in Bangladesh, Phase 3 Report.

Figure 3-9: Layout of intervention in Polder 35/1:
dredging of channel and deposition at the erosion hotspot[45]

The opportunity for mangrove forest conservation and restoration is identified with the work of van Berchum et al. (2020)[46] using observed mangrove areas from the Global Mangrove Watch[47] and tidal range information. The areas located between MSL and MHW are considered suitable ground elevations for mangrove growth (see Figure 3-10). Polders with potential mangrove habitat located outside the embankments are considered an opportunity for mangrove restoration sites.

[46] Van Berchum, E.C. et al. (2020) Enhancing Coastal Resilience in Bangladesh. Report.

[47] Bunting P., Rosenqvist A., Lucas R., Rebelo L-M., Hilarides L., Thomas N., Hardy A., Itoh T., Shimada M. and Finlayson C.M. (2018). The Global Mangrove Watch – a New 2010 Global Baseline of Mangrove Extent. Remote Sensing 10(10): 1669. doi: 10.3390/rs1010669.

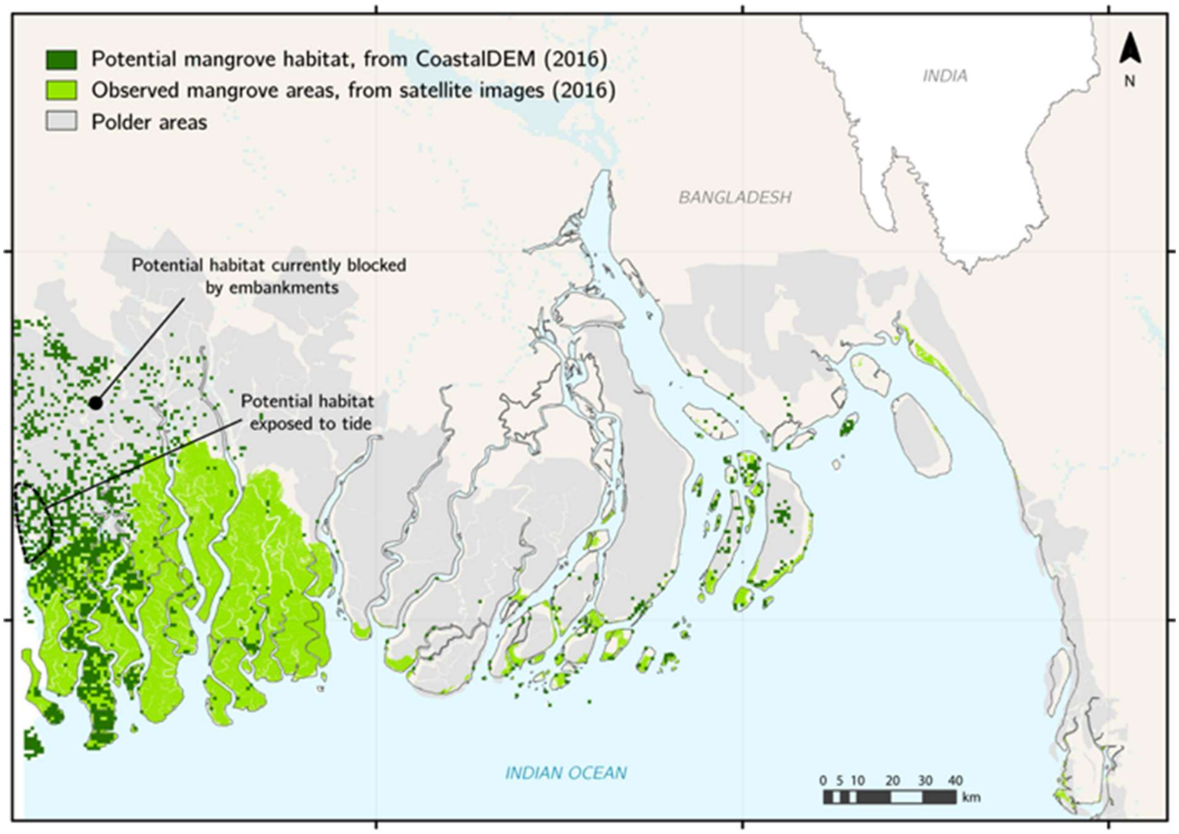


Figure 3-10: Potential mangrove habitat in Bangladesh in 2016.
Source: van Berchum et al.[46]

Potential locations for natural channel evolution or mangrove habitat conservation and restoration are used to determine the opportunity for NBS. The potential for mangrove conservation and restoration and natural channel evolution are individually scored. For the MCA the highest score is taken.

The NBS is scored based on the following criteria:

Score	*Criteria*
1	• No existing mangrove • No potential location for natural channel evolution
2	• Low potential for mangrove habitat areas: scattered existing mangrove • No potential location for natural channel evolution
3	• Medium potential for mangrove habitat areas: mangrove is existing, but no potential mangrove habitat. • No Potential location for natural channel evolution

4	• High potential for mangrove habitat areas: mangrove is existing and potential mangrove habitat is identified. • Potential location for natural channel evolution

3.6 Economic Criteria

3.6.1 Rehabilitation cost

Rehabilitation cost estimates of the interventions of the polders are roughly estimated based on the condition of the existing structures, the expected required crest of the embankments, the need for bank protection works and the required land acquisition and resettlement. The volumes and quantities for the construction work are estimated for:

- the construction/re-sectioning of embankments;
- construction/repairment of drainage sluices and flushing inlets;
- excavation/re-excavation of drainage channels;
- river bank protections, and;
- slope protections.

The condition of the existing structures is retrieved from field visits conducted during the current studies and the data from the LTM project. The volumes and quantities for the construction/re-sectioning of embankments and the river bank and embankment slope protection are derived from the ratio of implemented work from the design of CEIP-1 polders. The needed bank protection works is increased when the polder is subject to strong erosion or when land acquisition is not possible and therefore the only option is to combat erosion with bank protection works.

The total rehabilitation costs consist out of costs estimates for construction work, expected land acquisition and resettlement, mobilization, contingencies and cost for project management, detailed designs, supervision services and other services required for project implementation. The unit rates are based on current market prices based on Bangladesh Schedules of Rates and the unit rates in the current Contractor's Packages 1 and 2. The calculation method is elaborated in more detail in Appendix A3.2.

In the prioritization of the polders, low rehabilitation costs are favorable to select an optimal investment option inside the budget. The rehabilitation costs are divided by the total embankment length to overcome the prioritization of the larger polders.

The costs are scored based on the following criteria:

Score	*Criteria*
1	Rehabilitation costs / km > 20 Crore BDT
2	15 Crore BDT < rehabilitation costs / km< 20 Crore BDT
3	10 Crore BDT < rehabilitation costs / km < 15 Crore BDT
4	7.5 Crore BDT < rehabilitation costs / km < 10 Crore BDT

5	Rehabilitation costs / km < 7.5 Crore BDT

3.6.2 Comparative benefits

A high total economic risk (USD/polder) and a low rehabilitation cost results in a very profitable option. On the other hand, a medium total economic risk and a high rehabilitation cost results in a less profitable option.

For derivation of potential benefits from improvement of the polders, data was gathered on several relevant components. In Table 3-1 the data is grouped into three classes of potential benefits:

- **Demography**: population, population affected and population at severe risk as defined in section 3.2.1;
- **Economy**: the size of agricultural land, aquaculture and economic zones in the polders;
- **Asset damage**: potential asset damage in the do-nothing scenario with climate change (IPCC 2014 AR5, RCP 8.5). The potential asset damage per polder includes damage on dwellings, other buildings, roads and railways and is estimated using a high-level flood risk assessment tool and global flood depth-damage functions from Huizinga et al. (2017)[48] (see Annex A1.8). The Expected Annual Damage (EAD) is calculated as the annual average of T10, T25, T50 and T100 events. This annual average expresses the cost that would occur in any given year if monetary damages from storm surge inundation probabilities and magnitudes were spread out equally over time.

Table 3-1: Potential benefit data used for the indicative assessment of protective measures

Potential benefit	**Data**	**Sources**
Demography	Population (2020)	Population and Housing Census, 2011 projected into 2021
	Population affected (future)	Calculated based on inundation of the polders under the assumption that if 30% of the polder inundates then 30% of the population will be affected
	Population at severe risk (future)	Based on formula of Boyd et al., (2005) relationship between mortality and depth of water[49]
Economy	Agriculture area (ha)	Based on Landsat 2020
	Aquaculture area (ha)	Based on Landsat 2020
	Economic zones (ha)	Based on World Bank interactive poverty maps[50]

[48] Huizinga, J., De Moel, H. and Szewczyk, W., Global flood depth-damage functions: Methodology and the database with guidelines, EUR 28552 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-67781-6, doi:10.2760/16510, JRC105688.
[49] Boyd E (2005) Toward an empirical measure of disaster vulnerability: storm surges, New Orleans, and Hurricane Betsy. Poster presented at the 4th UCLA conference on public health and disasters, Los Angeles, 1–4 May 2005
[50] https://www.worldbank.org/en/data/interactive/2016/11/10/bangladesh-poverty-maps

Potential benefit	Data	Sources
		reference to percentage of population being involved in industries, assumptions have been made to convert to industrial area per polder
Asset damage (including households, roads, railway, hospitals and schools)	Expected annual damage (considering T=10, 25, 50, 100) Asset damage T100 Asset damage T50 Asset damage T25 Asset damage T10	High-level flood risk assessment tool (Annex A1.8)

Based on the data, an internal weighting and scoring system is developed to define the potential benefit. The internal weights have been deduced from shares of benefit items in total benefits in the cost-benefit study CEIP-1[51]. In that study the benefits from asset protection (housing, roads) are about 70%, agricultural benefits about 15%, other economic sectors 15% and fisheries 1% of the total benefits. As aquaculture has become more important over time since 2012, the weight is increased to 5%.

Overall, it is seen in other flood management studies and cost-benefit studies that direct benefits from asset protection are dominant. As most of the studies do not quantify and monetize impacts related to population (fatalities and injuries) and social aspects (health, impacts on communities and religious events, etc.) this aspect is corrected with an assumed 15% weight for this type of social-demographic benefits.

The scoring interval and given weights are given in Table 3-2.

Table 3-2: Scoring interval and weights for the MCA

Data category of potential benefits	Data	Scoring interval	Weight
Demography – people at risk (Weight 15%)	Population (2020) Population affected (future) Population at severe risk (future)	1-5	5% 5% 5%
Economy (Weight 30%)	Agriculture (land in ha) Aquaculture (area in ha) Economic zones (ha)	1-5	15% 5% 10%
Asset damage (Weight 55%)	Expected Annual Damage (EAD) of Asset damage T100, Asset damage T50 Asset damage T25, Asset damage T10	1-5	55%

For each polder the following equation will be applied to come to the comparative benefit estimate:

[51] CEIP-1 (2012) Final Report, volume VI: Economic and Financial Analysis)

$$\sum_{Benefit\ category=}^{6}\left(\textbf{Weight}\ (\text{benefit category}) * \frac{\boldsymbol{Value}\ (benefit\ category)}{\boldsymbol{Max\ Value}\ (benefit\ category)} * 5\right)$$

High comparative benefits are a positive impact for the polder selection and therefore are assigned the higher score. The scoring range is based upon the ratio of the data relevant for the polder as compared to the maximum value of the data found for one of the polders. This implies that the polders close to maximum values obtain a score of 5 and polders with the minimum value obtain a score of 1 regarding the relevant data source used (for example the amount of agricultural land in ha at risk).

It should be noted that only absolute potential impacts have been taken into account. This implies that large polders in terms of population, assets and or the economy will score higher compared to small polders, although some smaller polders might be more productive in terms of production per acre land or density of population and assets. In this respect this benefit scoring only refers to **potential absolute effectiveness** (benefits) and not to relevancy (the technical needs for protection or maintenance) or efficiency (the costs of potential protective interventions per acre or polder) related criteria. These relevancy and efficiency related criteria are being assessed in the previously described sections of the MCA.

One could also regard the benefits per ha of land as input to an efficiency criterion next to the absolute potential benefits (effectiveness) per polder. This would imply to protect more dense and productive polders over for example larger polders in terms of population and assets. (In the priority report Consultants will also look into this efficiency related criterion. However, in welfare economic terms it is the absolute to be prevented damage which matters (in terms of asset damage, economic damage and affected population). These absolute welfare gains will be included in the feasibility phase for the selected polders.

In conclusion a number of polders turn out to have the largest expected benefits of potential protective measures (due to the size of affected population, economic sectors and potential assets (buildings, roads etc.) at risk. These polders are 56/57, 5, 59/1A, 59/3B, 36-1, 73-2, 72 etc.

All in all there seems to be quite a high correlation of the population with the other benefit factors (economy and assets), which is quite plausible as people follow work opportunities and vice versa and assets follow people.

3.7 Weighting

Very often qualitative data cannot be expressed in the form of absolute values. For this reason, many decision-making methods aim to determine the relative importance of each parameter involved in the problem[52].

52 Triantaphyllou, E., & Mann, S. H. (1995). Using the analytic hierarchy process for decision making in engineering applications: some challenges. International journal of industrial engineering: applications and practice, 2(1), 35-44.

In the pairwise comparison method, also known as the Analytical Hierarchy Process (AHP)[53], a decision-maker must indicate for each pair of criteria at a time which criterion is the most important one. Subsequently one must indicate in qualitative terms to what extent a criterion is more important than another. The pairwise comparison method converts these comparisons of all pairs of criterions to quantitative weights for all criteria.

For the purpose of this study, a simplified AHP approach is used, where the following options are available for a comparison between two criteria: less important, equally important, more important. In other words, the extent of importance has been removed for simplicity reasons and for different audiences to participate in the weighting formulation, such as governmental agencies, engineers, climate change specialists, people living in the polders etc.

The first stage of the pair-wise comparison estimates the relative importance of five criteria clusters (social and institutional, technical, constructability, environmental and economic) through a pair-wise comparison made between them and provides their respective weights Ws, Wt and Wc, We and Wec.

In the second stage, pair-wise comparison is made individually between the identified criteria 'i' for each cluster criteria Wis (i = 1 to 5), social Wit (i = 6 to 9) and Wic (i = 10 to 13), Wie (i = 14 to 17), Wiec (i = 18 to 20) and the weights of them in their cluster category are found.

The comparative importance has been obtained through personal interviews with stakeholders, normalized weights and the average of normalized weights. The normalized values are obtained by dividing by its corresponding column sum. The set-up of the spreadsheets which are provided to key-stakeholders, enabling them to provide their views of comparative importance is presented in Figure 3-11 and Figure 3-12.

In the third stage, the weights for each dimension to estimate each criterion weights is found by multiplying the Wis, Wit, Wic, Wie and Wiec with their respective Ws, Wt and Wc, We and Wec.

i.e.
Wi = Ws * Wis (i = 1 to 5)
Wi = Wt * Wit (i = 6 to 9)
Wi = Wc * Wic (i = 10 to 13)
Wi = We * Wie (i = 14 to 17)
Wi = Wec * Wiec (i = 18 to 20)

53 Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International journal of services sciences, 1(1), 83-98.

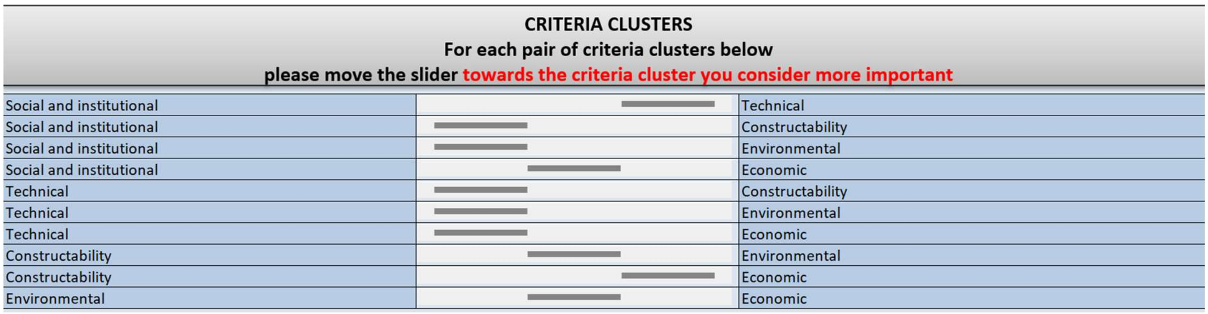


Figure 3-11: Comparison of criteria clusters (example answer from Stakeholder)

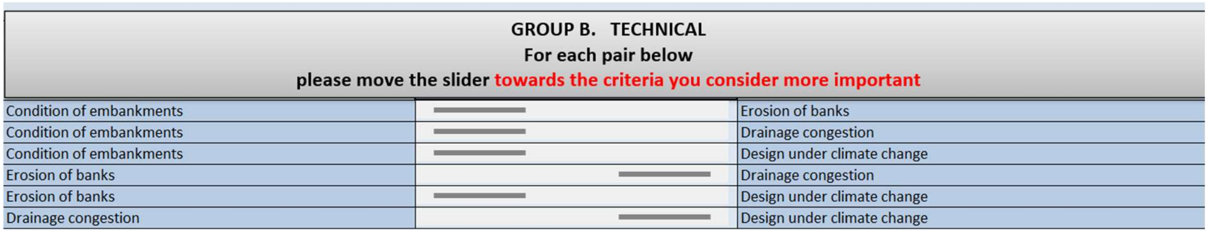


Figure 3-12: Comparison of technical criteria (example from answer of stakeholder)

From consultation with stakeholders, the average weight is calculated to be used in the MCA. Table 3-3 gives an overview of the weights per criteria.

Table 3-3: Weight of the criteria for the MCA retrieved from consultations with stakeholders

	Criteria	**Weight**
Social and institutional	People affected	**4.68%**
	Community vulnerability to recent cyclonic events	**5.51%**
	Land acquisition and displacement	**3.59%**
	Community water management	**4.29%**
	Stakeholder policies and strategies	**11.29%**
Technical	Condition of embankments	**5.19%**
	Erosion of banks	**5.06%**
	Drainage congestion	**5.06%**
	Design under climate change	**5.06%**
Construc-tability	Logistics and time travel	**4.87%**
	Polder clustering into packages	**4.87%**
	Availability of construction materials	**4.10%**
Environmental	Ecologically sensitive areas	**4.21%**
	Soil quality	**2.21%**
	Aquatic fauna	**4.21%**
	Water quality	**2.87%**

	Criteria	Weight
	Opportunities for NBS	**4.21%**
Econo mic	Rehabilitation cost	**9.77%**
	Comparative benefits	**8.77%**

3.8 Selection of 23 polders

As mentioned in the ToR, it is required to update the CEIP for the remaining 122 (now 125 polders as after consultations with field officials some new polders came up) polders and select a next batch of polders for implementing measures in the future. As explained in the previous sections, further enhance the quality and success of CEIP, Consultant has incorporated results of ongoing activities, such as lessons learned when implementing the current work packages under CEIP-1, the Blue Gold Programme and the LTM Studies under CEIP-1.

Some of the practical experiences, such as the difficulties to mobilize implementation capacity, land acquisition and resettlement procedures, distances between work sites within one construction contract and to produce protection material have been considered via means of weighting criteria. Also planning studies like BDP2100 have been considered. Use has been made of data and information available within the BWDB and no additional surveys were required as per ToR. Nevertheless, the Consultant has been conducting some preliminary field surveys and consultations.

Amongst others, the above aspects have been used and applied in the MCA for the pre-selection of a potential set of 23 polders for next phase of CEIP. Based on the approach described in the previous sections and more specifically the weighting criteria adopted, a batch of 23 polders has been selected and presented in Table 3-4.

The results from the high-level application of the MCA are presented in Appendix 4. In addition, Consultant has prepared a spreadsheet which contains the detailed calculations (link: https://we.tl/t-pjoabog979).

Table 3-4: Batch of 23 polders to be considered for the next phase of CEIP

Sl. No.	Polder	Name of Thana	District
1	4	Assasuni	Satkhira
2	5	Kaliganj, Shyamnagar	Satkhira
3	7/1	Assasuni, Shyamnagar	Satkhira
4	7/2	Assasuni	Satkhira
5	10-12	Koyra, Paikgacha	Khulna
6	13-14/2	Koyra	Khulna
7	28/1	Dumuria	Khulna
8	28/2	Batiaghata	Khulna
9	29	Batiaghata, Dumuria	Khulna
10	31	Dacope	Khulna
11	31 part	Batiaghata	Khulna

Sl. No.	Polder	Name of Thana	District
12	39/1B	Motbaria	Pirojpur
13	39/1C	Motbaria	Pirojpur
14	41/5	Barguna Sadar	Barguna
15	41/7	Mirjaganj	Patuakhali
16	43/2A	Patuakhali	Patuakhali
17	43/2E	Patuakhali	Patuakhali
18	45	Taitoli	Barguna
19	47/1	Kalapara	Patuakhali
20	50-51	Rangabali	Patuakhali
21	54	Kalapara, Galachipa, Amtoli	Patuakhali, Barguna
22	55/2E	Patuakhali, Dashmina, Bouphol	Patuakhali
23	55/2D	Dashmina	Patuakhali

Figure 3-13: Location of the pre-selected 23 polders

Appendices

Appendix 1 Analysis of coastal zone

A1.1 Socio-economic conditions

Demographics and poverty

The coastal zone has 19 Districts with 153 Upazilas in which 41 million currently make their livelihoods. The coastal zone accounts for 32% of the land area and 25.7% of the population of Bangladesh[54]. The average density in the coastal zone is some 1000 persons per square kilometer[55]. The population density generally increases away from the coast: the interior coast (1180 / sq km2) has roughly a 50% higher population density than the exposed coast (770 / sq. km2). Despite this difference, the population is quite evenly spread throughout the coastal zone. About 70% of the Upazilas in the coastal zone have a population density between 500 and 1500 per sq. km2. There are 10 Upazilas with a high population density (> 10,000 / sq.km2 or more). West of the Meghna estuary, these are Jessore, Khulna, Khalispur, Sonadanga and Palong which are all located at the interior coast. East of the Meghna estuary, however, the Chittagong District has 5 Upazilas with a high population density (Chittagong port, Doble mooring, Pahartali, Panchlaish and Chandgaon) located in the exterior coast.

The various areas in Bangladesh show significant spatial differences in the pace as well as quality of development, having regional differences in livelihood opportunities and living standards. The income disparity between urban and rural areas is still prevalent with headcount poverty levels of 35.2% in rural and 21.3% in urban areas in 2010. The coastal belt of Bangladesh is considered as being among the poorest regions of the country (in 15 out of the 19 coastal Districts) with a below national average GDP per capita, with Chattogram and Khulna being the two relatively advanced coastal Districts of Bangladesh[56]. In relation to gender equality and occupation opportunities, Bangladesh as a whole, ranks 116 out of 137 countries in the Gender Inequality Index (GII), which reflects the huge differences in the daily lives of men and women in the country, particularly in rural areas[57]. On the other hand, woman labour force participation is slightly increasing in the coastal zone.

Economic activities

Physiographic influences play a large role in the socioeconomic conditions of Bangladesh's Coastal Region.

The Central area in the figure for instance, consists mainly of Char lands and is thus not easily accessible from the rest of the country by road or train. The main sources of income for the people from this region are fishing, agriculture and overseas work in Middle Eastern countries as laborers. As said before, accessibility plays a large role in the central area, with some areas hardly being accessible. In addition to this, there is hardly any barrier to natural disasters in place, which puts the local people in a very vulnerable position.

[54] BBS (Bangladesh Bureau of Statistics). 2011. Bangladesh Population and Housing Census. Accessed February 2014. http://www.bbs.gov.bd/PageReportLists.aspx?PARENTKEY=41.
[55] Based on WB data set
[56] Dr Muhammad Abdul Mazid (2020), Containing intra-regional imbalance in coastal Districts, Article in The Financial Express
[57] UN Women, Bangladesh Centre for Advanced Studies (BCAS), (2014). Baseline Study on the Socio-Economic Conditions of Women in Three Eco-Zones of Bangladesh. Available online at: http://www.uncclearn.org/sites/default/files/inventory/unwoman30112015.pdf

In contrast, the western region for instance, thrives mainly on tourism, shrimp farming, fishing and agriculture. Industrial zones can be found in the Districts surrounding Jessore and Khulna. These zones ensure the participation of significant numbers of people in tertiary and secondary activity. Transportation and accessibility is much less of an issue in the western region, due to the availability of an excellent road and rail network connecting the Chittagong Metropolitan area (CMP), Chittagong Port and Cox's Bazar with the rest of the country. Furthermore, the region attracts people from other parts of the country by offering jobs in industries such as shipbreaking, which, in addition also has a large secondary and tertiary economy[58].

The majority of coastal population are highly dependent on agriculture as a source of income and for food security. This is especially true for the polder areas which are dominant in the Ganges Tidal floodplain West and East and the Meghna estuary. Due to the construction of the embankments in the 1960s-1980s, the scale of the agricultural production in Bangladesh has seen an increase of up to 200 to 300 percent in certain areas. In 2013, 1.2 million hectares of land were being utilized for agricultural purposes within the embankment system, which represents almost 15% of Bangladesh's total arable land.

Fisheries are increasingly important activities in the coastal zone. Marine captured fish was around 650,000 ton (2018)[59] of which Hilsa shad (Tenualosa ilisha) is the dominant species. This generates income and employment for 2.5 million people. Aquaculture has grown rapidly in the past decades in the past decades in the polders of the coastal zone around Cox's Bazar-Chittagong in the southeast and in particular near Jessore and Khulna in the southwest. This activity is predominantly carried out in ponds in the coastal zone. Both brackish water shrimp (bagda) and freshwater shrimp (galda) are produced in small-sized farms which use more than 200 000 ha. Bangladesh has now a 2% contribution to the global shrimp market[60].

Other important activities in the coastal zone are industrial/commercial areas, salt production, ship-breaking and recycling, and tourism[61]. The three main city centers Barisal, Chittagong and Khulna are hubs for commercial and industrial activities. Salt production has a long tradition in Bangladesh and is concentrated in the southeast near Chittagong and Cox's Bazar. This activity is economically important for about 1 to 1.5 million people in the coastal zone. The ship-breaking and recycling industry is another important economic activity mainly concentrated in Chittagong. This activity converts end-of-life ships into steel and other recyclable parts. It provides direct employment to about 30,000 people but also indirect jobs are created. Tourism is at its infancy in Bangladesh but growing. Cox's Bazar is a well-developed tourism destination with natural and cultural attractions. The Sundarbans, Kuakata Beach and St Martin's Island also attract local but also foreign visitors.

The 153 administrative regions (coastal Upazila), even though the coastal Upazilas hold the same coastal character with predominant dependency on agricultural activities and ancillary reliance on industries and other services, the extent of their development varies significantly along the coast (Figure_Apx 1, Figure_Apx 2 and Figure_Apx 3). With Upazilas having more

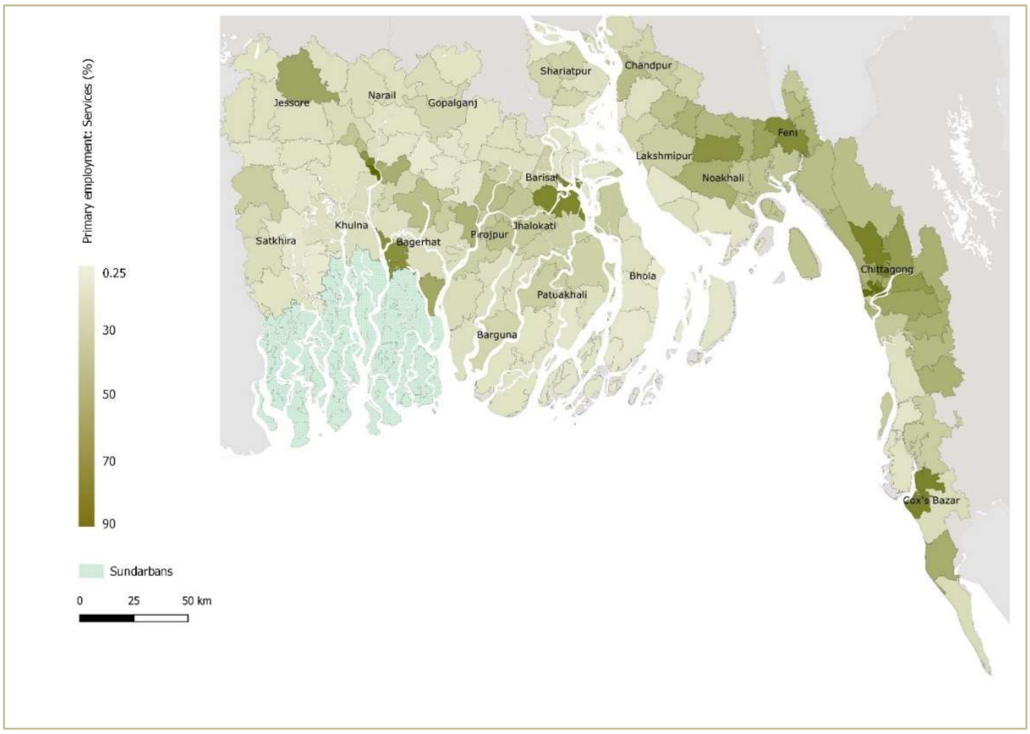
[58] Rabby, Y. W., Hossain, M. B., & Hasan, M. U. (2019). Social vulnerability in the coastal region of Bangladesh: An investigation of social vulnerability index and scalar change effects. International Journal of Disaster Risk Reduction, 41, 101329. https://doi.org/10.1016/j.ijdrr.2019.101329
[59] Department of Fisheries. 2005. Fishery statistical yearbook of Bangladesh 2003–2004. Dhaka, Fisheries. Resources Survey System, Department of Fisheries.
[60] See: https://tbsnews.net/economy/trade/bangladesh-loses-export-market-whiteleg-shrimp-35693
[61] Bangladesh Delta Plan, 2100. Coastal zone.

resources available and experiencing wider opportunities than others, the poverty level is also expected to differentiate along the coast.

Figure_Apx 1: Primary employment: Agriculture (% of Upazila population)[62]

Figure_Apx 2: Primary employment: Industry (% of Upazila population)[62]

[62] World Bank (2016). Bangladesh Interactive Poverty Maps



Figure_Apx 3: Primary employment: Services (% of Upazila population)[62]

Housing and public services

Residential housing quality shows a strong variation throughout the coastal zone. This ranges from permanent housing to temporary or shanty types of housing. Housing has been classified into four categories based on quality[63]: Pucca (permanent quality), semi-Pucca, Kutcha, and Shanty. These classifications depend the on roof and wall materials used in construction. Typically, the urbanized centers show a better housing quality compared to the more rural areas. In the coastal zone, houses of better quality, with roofs and walls made of brick/cement have shown an increase the last years, while roofs made of stray/bamboo have decreased significantly.

Furthermore, due to weak infrastructure, communication systems, and natural hazards such as arsenic and salinity, a huge portion of the population lacks access to safe drinking water, sanitation, and public health facilities. The development of communication and infrastructure for supporting public utility services may be facilitated by improving the coastal polders. Sanitation and drinking water are two essential public services for coastal communities. The coverage of sanitation was about 55% - 58%[64] in 2012 and does not differ very much between urbanized and rural areas in Bangladesh. The access to clean drinking water is much higher (85%) and predominantly achieved by piped water and tube wells, with the latter being the less sanitary. The number of households utilizing piped water has increased in the coastal zone, yet the main source of water remains to be tube wells[65]. Arsenic is a major thread of water supply

[63] Household Income and Expenditure Survey (2005)
[64] Joint Monitoring Program (JMP) 2012 Report, see also BDP 2100
[65] BDP 2100

in both rural and urban areas and this issue is particularly relevant for the divisions Khulna and Chittagong in the coastal zone.

Education and healthcare access and quality also provide insight into the state of the living conditions in the coastal zone. At this moment, the school life expectancy from primary to tertiary education in Bangladesh is 12 years[66]. The current literacy rate in Bangladesh is above 71% (2015)[67]. A literacy survey from 2008[68] shows that the rural literacy rate was found to be 12% lower than that of urban areas, whereas differences across the country and also between men and women were small. The access of necessary healthcare remains challenging for the people living in the coastal areas, particularly the marginalized and disabled[69]. These areas suffer from a lack of appropriate health facilities and skilled healthcare providers.

Land use

Bangladesh's coastline area includes a variety of land uses, including agriculture/fallow lands (63 percent), towns (19 percent), aquatic bodies/rivers, and forest (Figure_Apx 4). Mangroves and other woods cover the majority of the Ganges Tidal West Plain and Chittagong Coastal Plain zones. The Sundarbans, the world's biggest mangrove forest, is in the southern section of the Ganges Tidal West Plain zone, and it is extremely significant for biodiversity and ecosystem services both locally and globally. Char lands, rivers, and agriculture/fallow lands cover the centre zones Ganges Tidal East Plain and Meghna Deltaic Plain.

Agriculture/fallow lands, communities, roads, and river channels are all prominent land uses within the coastal polders. Agriculture/fallow lands and settlements account for 64 percent and 30 percent of the total area of 139 polders, respectively. In this estimate, shrimp farms and salt farms are included in the agriculture/fallow land use pattern. Shrimp farms are primarily found in brackish water locations along the coast, while salt farms are primarily found in the Chittagong Coastal Plain zone.

One of the most visible forces of change in the southwest coastal area has been the conversion of agricultural and mangrove forest to brackish water aquaculture[70]. Shrimp culture was traditionally limited to the area between the levees and the river channels. However, because of foreign demand, such practices have grown in spatial coverage inside polder systems over the last three decades (post-1980s).

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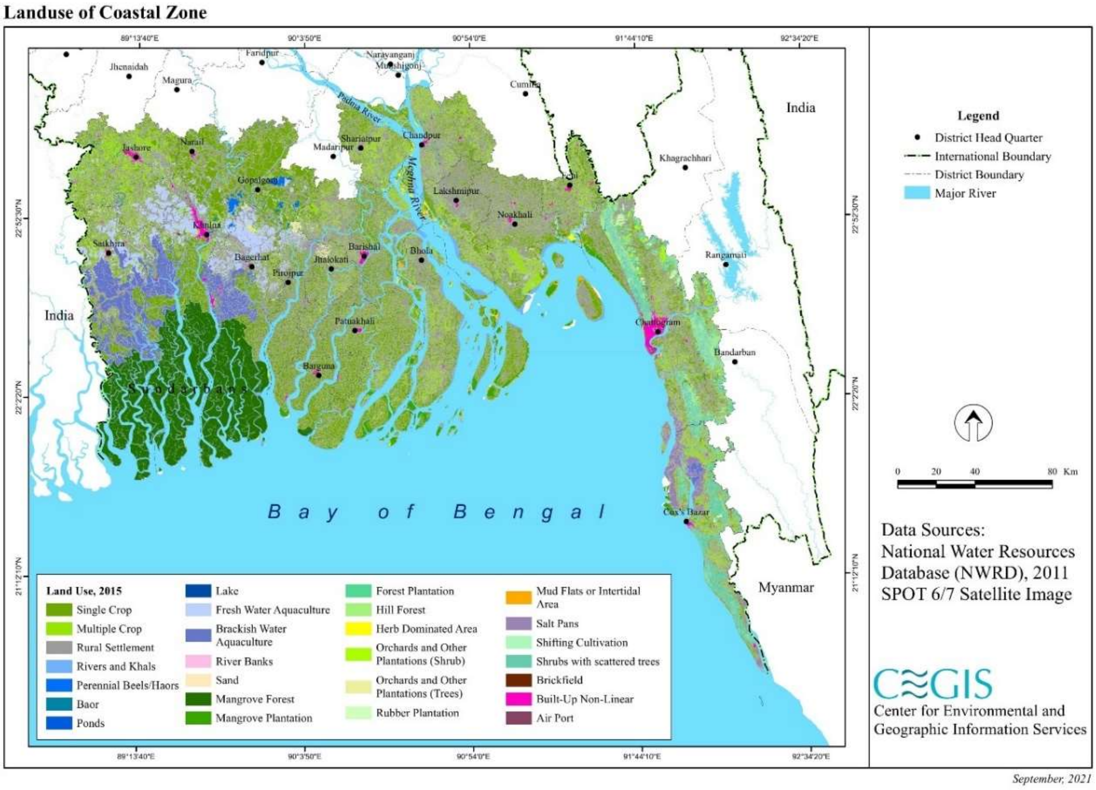
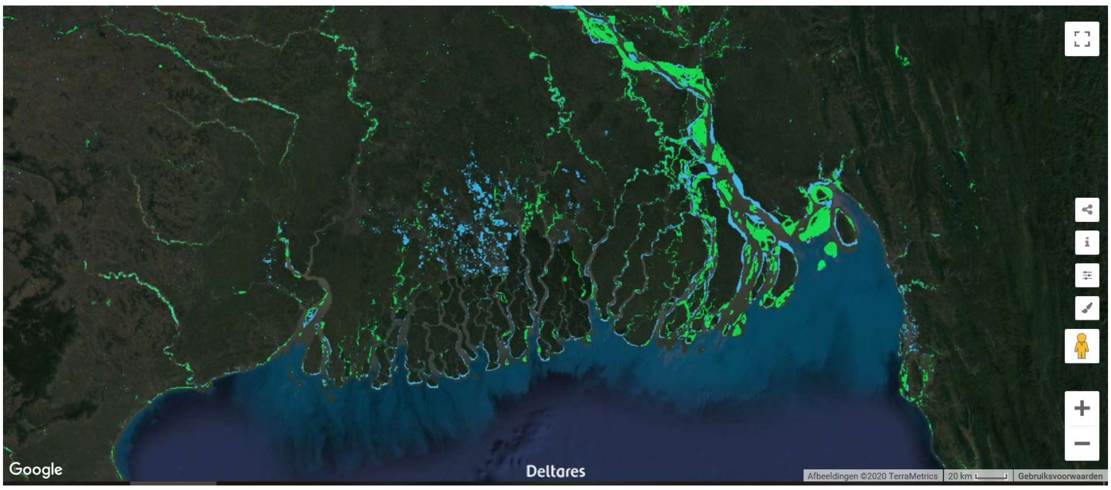
[66] https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html
[67] See: https://en.wikipedia.org/wiki/Education_in_Bangladesh#Literacy_rate
[68] Literacy Assessment Survey 2008, UNESCO, BBS, 2008.
[69] Fauzia Akhter Huda, Hassan Rushekh Mahmood, Aniqa Tasnim Hossain, Jasmin Khan, Omar Faruk, Zahed Shafiqur Razzak, Kazi Tamara Binta Kamal, Shams El Arifeen (2020) Health Needs and Health System Response in the Coastal Districts of Bangladesh. International Centre for Diarrhoeal Disease Research, Bangladesh
[70] Datta et al. 2010. Shrimp Culture: Trend, Consequences and Sustainability in the South-western Coastal Region of Bangladesh



Figure_Apx 4: Land use Map of Coastal Area

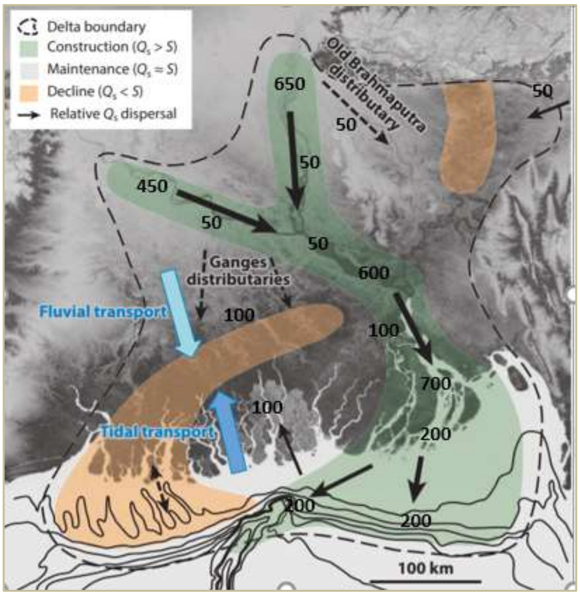
A1.2 Morphological condition

Due to the large population, there is a large pressure on land and newly formed land is quickly inhabited and/or empoldered. However, due to the enormous natural morpho-dynamics in the system (i.e. rivers meander and braid, chars are formed, migrating and disappearing, coastlines are eroding, land is accreting), these inhabited/empoldered areas also suffer from erosion.



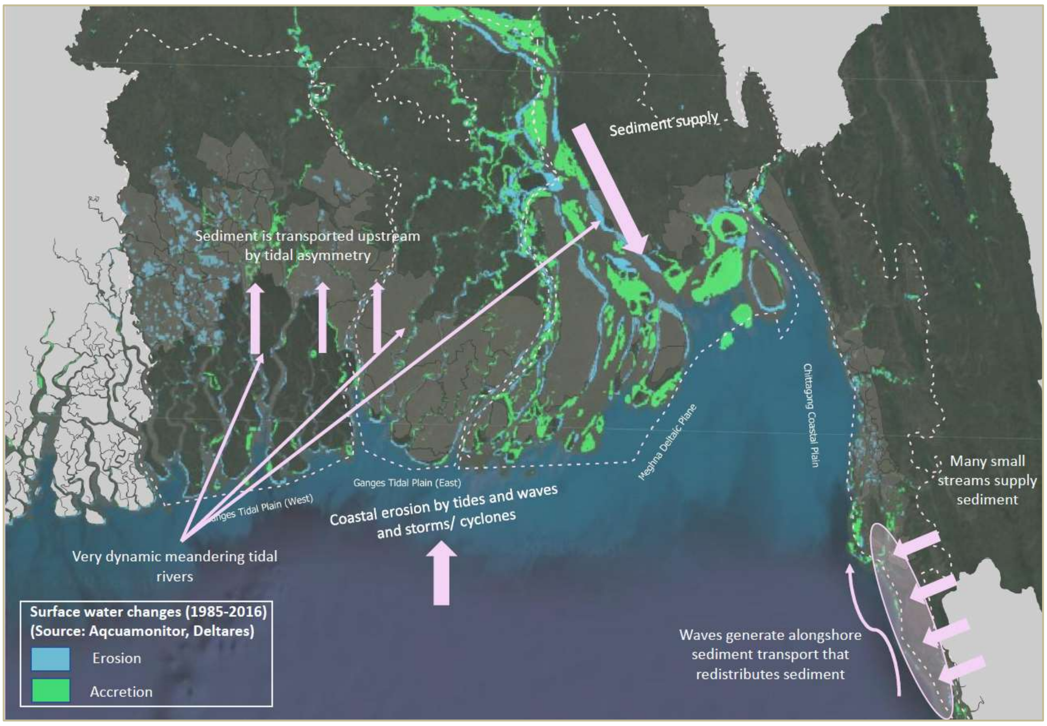
Figure_Apx 5: Erosion and accretion (2000-2017) in Bangladesh from Deltares Aqua Monitor

Figure_Apx 5 shows the erosion (blue) and accretion (green) at the Bangladesh coastline between 2000 and 2017 as taken from the Aquamonitor (http://aqua-monitor.appspot.com/), in which the position of the Satellite Derived Shoreline (SDS) is given with subpixel accuracy (10 – 30 m), using a method that combines multiple satellite images into a single image[71]. Blue areas north of the Sundarbans may be attributed to water logging and/or aquaculture. The Meghna estuary delivers large amounts of sediment that results in accretion. Part of the fine sediment is transported towards the west (see Figure_Apx 6) where it is partly transported landward into the many estuaries of the Sundarbans. Large scale changes and processes that take place over long time scales contribute to changes in hydrodynamics and sediment transport in the coastal system. For example, the construction of dams in upstream rivers, such as the Farakka barrage in the Ganges (upstream of the border with Bangladesh) and man-made shortcuts, but also natural morpho-dynamics affect hydrographs and reduce the amount of water and sediment distribution to the downstream branches. Also, the 1950's Assam earthquake is hypothesized to have delivered large amounts of sediment into the rivers that have been eroded slowly over time, first increasing and later on decreasing the amount of sediment delivered towards the coast. North and east of the Sundarbans, a system of polders exists surrounded by estuaries/rivers and peripheral rivers. Polder construction started in the 1960's and reduced the intertidal area of this coastal system. All these developments affected the hydrodynamics and sediment transport, resulting in up-estuary sediment transport, siltation in the upstream branches and a sediment deficit at the coast. The large-scale sediment transport patterns, in combination with high tidal currents, wave attack, episodic erosion events during cyclones and relative sea level rise, all contribute to large scale erosion and accretion at the Bangladesh coastline at the Sundarbans and east of it.



Figure_Apx 6: Left: Large scale sediment transport pattern (from Wilson and Goodbred, 2016)

[71] Hagenaars, G., de Vries, S., Luijendijk, A. P., de Boer, W. P., & Reniers, A. J. H. M. (2018). On the accuracy of automated shoreline detection derived from satellite imagery: A case study of the sand motor mega-scale nourishment. Coastal Engineering, 133 (June 2017), 113–125. https://doi.org/10.1016/j.coastaleng.2017.12.011



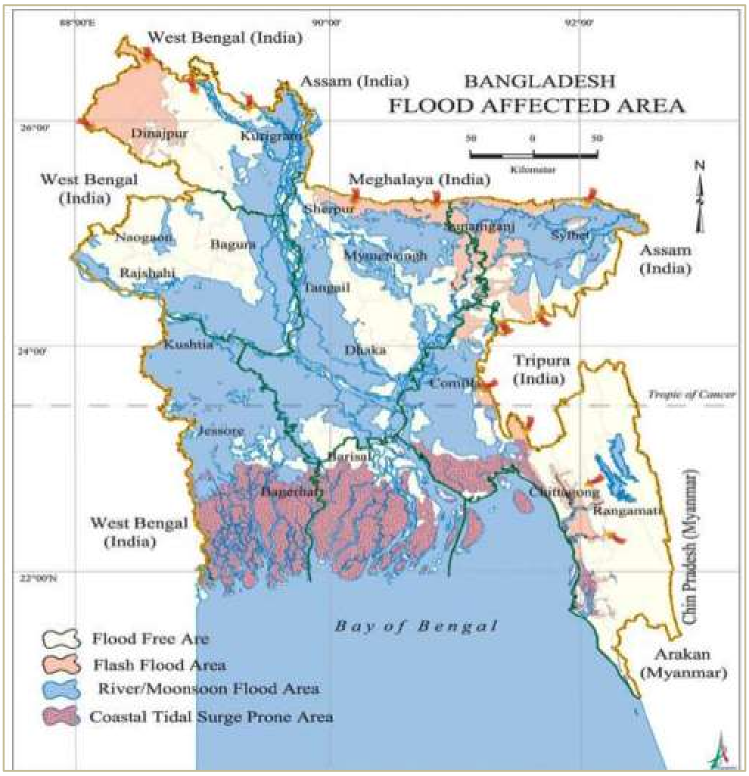
Figure_Apx 7: Coastal and riverine characteristics Bangladesh coastal zones

Large parts of the coast of Bangladesh suffer from erosion as a result of a combination of factors. Natural morpho-dynamics that are very variable, driven by tides, waves, salinity- and sediment-driven density flows, river discharges and variation herein due to monsoon seasons. Cyclones have an indirect impact by influencing the natural morpho-dynamics by episodic erosion and sedimentation events and directly threaten inhabited parts and polders. (Relative) Sea level (RSL) rise affects the system on longer time scales.

Whether coastal or bank erosion is predominantly caused by tides, waves, high river discharge during the summer monsoon, cyclones or sea level rise, is dependent on site-specific conditions. For bank erosion in rivers, tides are more prominent than waves, while cyclonic storm surges may still have a considerable effect. Also, during the summer monsoon, the rivers and estuaries might be flushed by high river discharges causing erosion. The polders just north and east of the Sundarbans suffer mostly of erosion due to a combination of high river discharge during the monsoon period and residual sediment transport as a result of estuarine circulation and tidal asymmetry. At the open coast along the Bay of Bengal, the coast is affected by waves and cyclones. Especially at estuary mouths, the tidal velocities might be substantial, and the erosion might be a combination of tide driven current and wave resuspension. Along the entire Ganges tidal plain, erosion along the coastline of the Bay of Bengal is occurring (Figure_Apx 6 Figure_Apx 7), suggesting a large-scale process is cause. This might be a combination of long-term changes in river flow and sediment supply and division of water and sediment over the various rivers in the delta with both human and natural causes, increased tidal asymmetry due to empoldering and siltation in upstream rivers, and sea level rise. Of course, waves and cyclones cause coastal erosion, but the hydrodynamic energy from waves and cyclone has probably not changed as much as the beforementioned factors.

A1.3 Hydraulic dynamics

The coastal zone of Bangladesh is mostly prone to tidal surge and to a lesser extent affected by riverine/ monsoon flooding (Figure_Apx 69), although the maximum significant wave height in monsoon (July-August) can vary between 0.60 m to 1.60m.



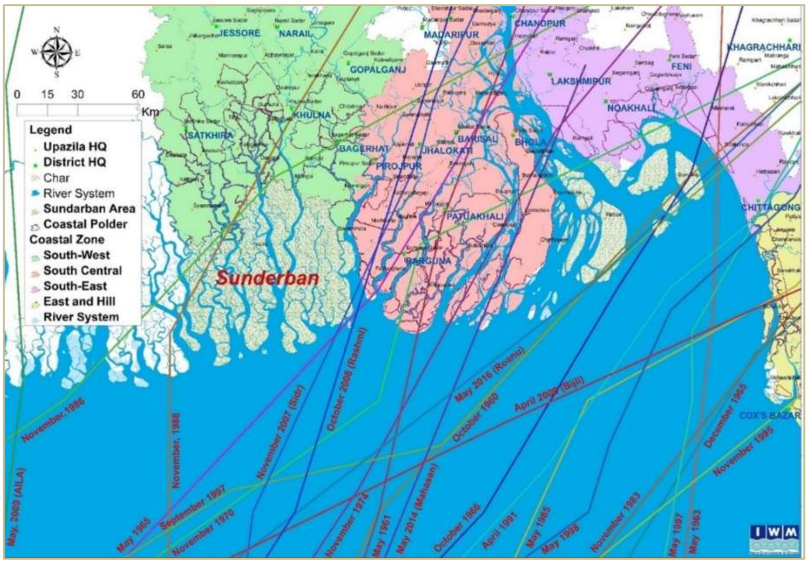
Figure_Apx 8: Flood affected area of Bangladesh
(Source: Banglapedia)

Cyclones and Storm surge

Tropical cyclones is the prime natural disaster faced by Bangladesh almost every year causing huge damage to people's life and property. UNDP (2004)[72] identified Bangladesh as most exposed country to tropical cyclone with and with an average of four cyclone striking every year. About 5% of the global tropical cyclones form over the Bay of Bengal[73]. Cyclones affect the region with strong winds accompanied by powerful storm surges and widespread inundation over a vast area. These cyclones generally occur in early summer (April-May) and late rainy season (October-November) and generally follow a track in northeastern direction. These cyclones are accompanied with strong winds, storm surge waves, and rainfall. Numerous devastating cyclone events have recurred in the past, following different tracks and intensities (Figure_Apx 9). Analysis of historical records shows that the major centers in the coastal zone

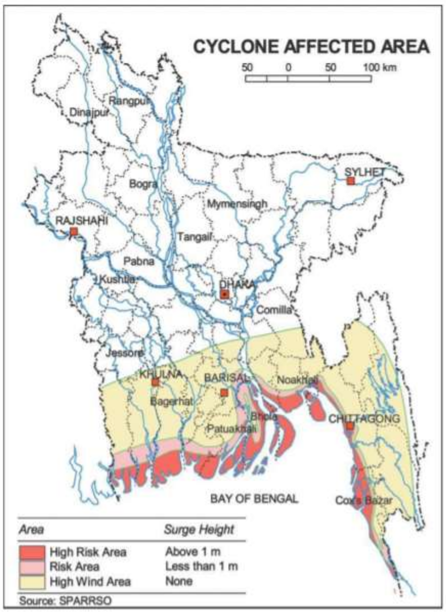
[72] UNDP, 2004. 'A Global Report: Reducing Disaster Risk: A Challenge for Development', United Nations Development Programme, http://ipcc-wg2.gov/njlite_download.php?id=5953, retrieved on 10 May 2014.
[73] Joint WMO-IOC technical Commission for Oceanography (2014). Coastal Inundation Forecasting Demonstration Project

(Khulna, Barisal, Chittagong) have been struck with an comparable number of 40 – 50 cyclones[74].



Figure_Apx 9: Cyclone tracks Bay of Bengal
(source: Institute of Water Modelling)

The coastal zone of Bangladesh is particularly exposed to cyclones, with the southern strip being a high-risk area, transforming to a medium risk area as moving more landwards (Figure_Apx 10).



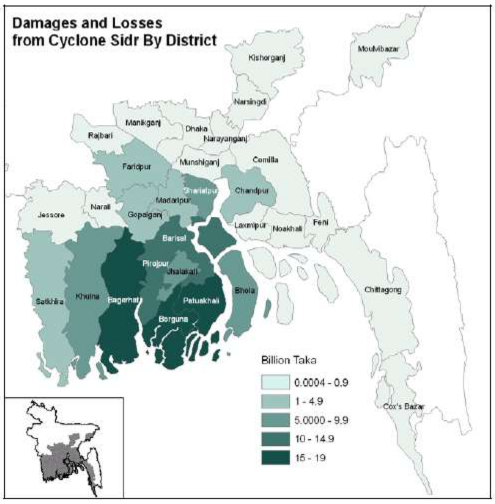
Figure_Apx 10: Cyclone affected areas in Bangladesh[75]

[74] Alam, E., Momtaz, S., Calgaro, E., 2012. A History of Tropical Cyclone Events, their Spatial-temporal Distributions and Effects in Bangladesh, AGU conference, San Francisco.
[75] Bangladesh Disaster Knowledge Network, 2013

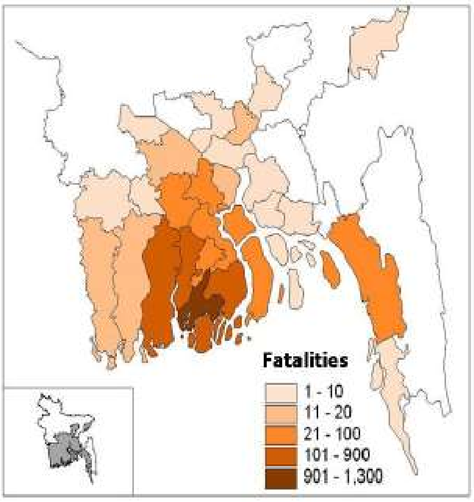
Storm surge generated by the tropical cyclones are subject to being further intensified in Bangladesh, which is attributed to the phenomenon of re-curvature of tropical cyclones in the Bay of Bengal and the shallow continental shelf, especially in the eastern part of Bangladesh. The triangular shape at the head of the Bay of Bengal also attribute to surge amplification. Also, the tidal phase and amplitude are important factors that determine the storm surge levels. Due to these factors, the Meghna Estuarine region is therefore the area where the highest storm surge has been observed. Typical storm surge water levels range from 3 – 5 meters for severe cyclones to more than 10 meters for Cyclone Bhola which was the most devastating in recent history. The storm surge travels far inland along the river branches and thus cause very high water levels around the polders at a far distance from the coast.

Cyclone winds also generate waves which are mainly affecting the exposed locations along the coast. These waves are generated due the strong winds and propagate towards the shoreline. The shallow bathymetry near the coast partly results in breaking of these waves and limits the wave height. The coastal areas that are most exposed to these waves are the polder areas along the coastline west of the Meghna estuary, the polders in the mouth of the Meghna estuary and the Chittagong-Teknaf coastal strip. Typical wave heights nearshore during cyclones in these areas are 2 - 4 meters. At the tidal rivers and the Meghna estuary in the coastal zone, the wind also generates waves but these are often smaller (1 – 2 meters) due to the limited width of the rivers and also the reduced wind speed more inland.

A very devastating event was Cyclone Sidr which hit thirty (30) Southern Districts of Bangladesh on Nov 15, 2007 inflicting colossal damages to infrastructures of Coastal Embankment Polders (CEP) and to the lives and properties of Polder residents. The Districts of Patuakhali, Barguna, Pirojpur and Bagerhat were the worst affected ones. Joint Damage Loss and Need Assessments (JDLNA) were done by Government of Bangladesh (GoB) with the support from the international Communities and the estimated loss was assessed at around US$ 1.7 billion (BDT 136 billion). More than two third of these covered physical damages and the rests were economic losses.

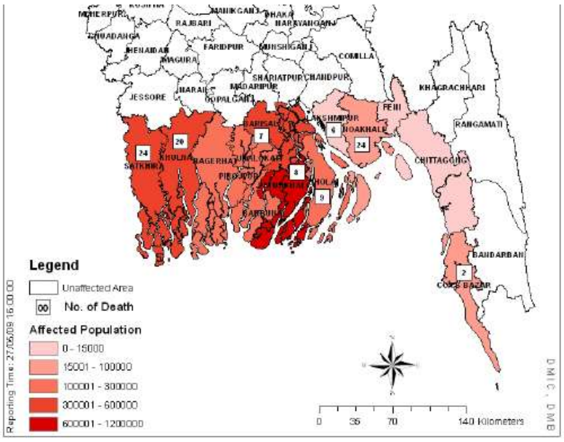


Figure_Apx 11: Most affected Districts in damages and losses by Sidr (2007) Source: Estimates of JDNLA Team



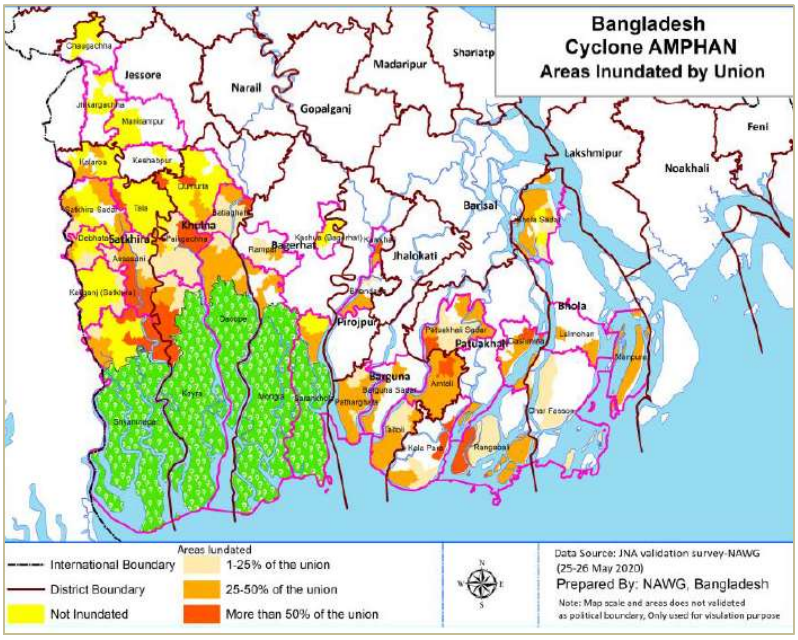
Figure_Apx 12: Number of fatalities per District from Sidr Source: MoFDM, 2008

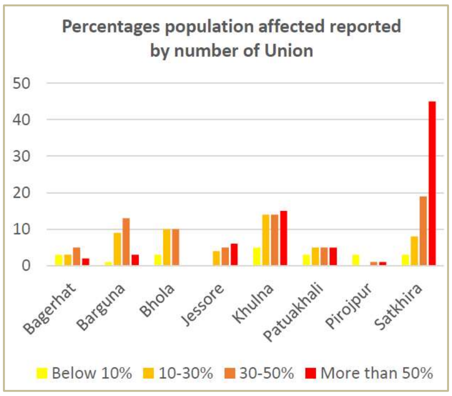
Two years later, in 2009, Severe Cyclonic Storm Aila hit Bangladesh, and affected about 40 million people; washed away several thousand homes, took 190 lives, wounded more than 7103 people, flattened huge standing crops, hampered communications system and destroyed infrastructure, livestock, fisheries, social and economic activities.

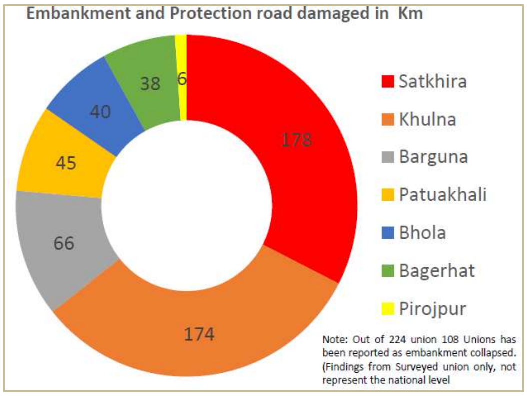


Figure_Apx 13:Most affected Districts in terms of population from cyclone Aila (2009)
Source: ReliefWeb

Cyclone Amphan is the most recent example of a severe cyclone attacking the coastal Districts of Bangladesh under Great Danger Signal #10 on Wednesday evening, the 20th May 2020. While the cyclone made landfall in West-Bengal, India, significant impacts were reported in Bangladesh, among which, collapsed embankments, inundation of several villages, damaged houses due to high winds and generally a large extent of economic damages.







Figure_Apx 14: Impacted population and infrastructure due to Amphan
(Source: Joint Needs Assessment (JNA)

Rivers and flooding

Dynamic river and estuary processes are, of course, mostly to be seen in the Meghna Deltaic Plain (MDP), rather than in the other three areas. The Brahmaputra and Ganges rivers, via the Jamuna and Padma rivers, bring roughly two billion tons of sediment per year into the system, of which some 70% is fine material, very fine sand and silt. In comparison to this, the sediment from the Meghna River's own catchment is negligible (CERP-II, 2000). Most of the sediment is initially carried through the estuary and deposited in the Bay of Bengal. The shifting and sorting of the sediments is done by coastal and marine processes, like tides, waves and surges, as well as by fluvial ones.

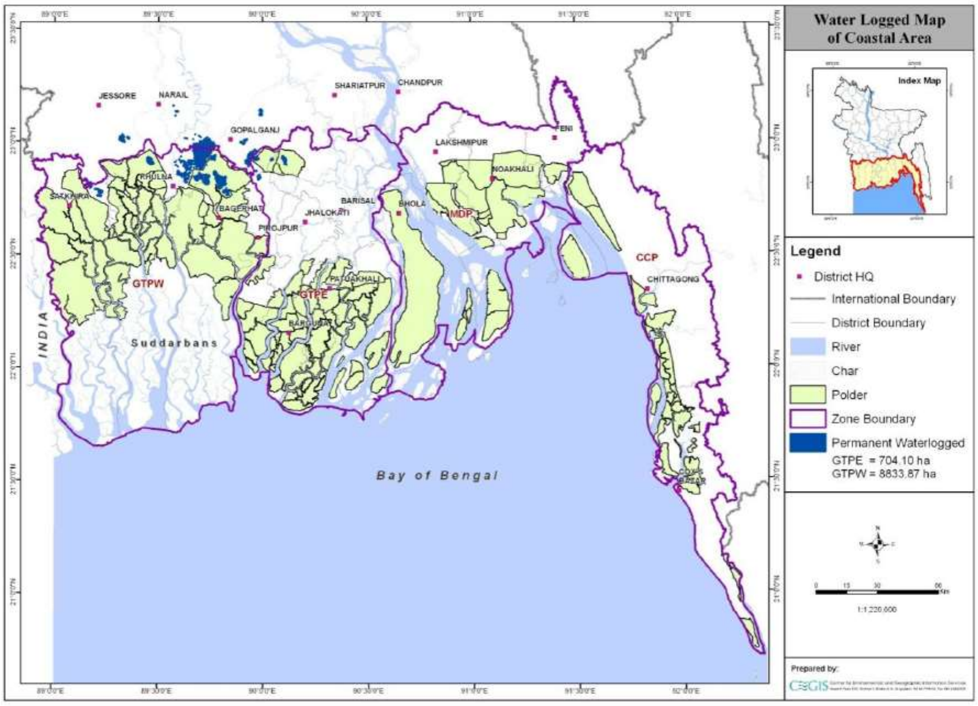
Near the head of the Meghna estuary, around Chandpur and upstream, the dominant processes are fluvial, resulting in braiding and the migration of the thalweg (deepest or main channel). Further downstream, tidal and salinity effects begin to have an influence also, but as far south as Ramgati the migration of the thalweg is the most important process. Dramatic thalweg migration in the much smaller estuary of the Feni River is also eroding a polder embankment. When a thalweg approaches a riverbank it tends to erode the bank mainly below water level, so that an embankment built close to the bank will be undermined or outflanked by removal of soil below the level of its toe.

In the seaward parts of the estuary, tidal processes tend to dominate over fluvial ones. In many parts the tidal flow is bi-directional, but the ebb and flood velocities are unequal (tidal asymmetry, leading to 'tidal pumping' of sediment). In other places, notably north and west of Sandwip Island, ebb and flood currents follow different routes (mutually evasive currents). In both cases, tidal action moves sediment often in an inland direction. Under some circumstances sediment can be trapped.

A1.4 Water-logging and salinity intrusion

Drainage of excess water from the polder systems has become increasingly challenging in the past decades due to changing conditions inside and outside the polders. This is especially true for the southwestern region (Khulna, Satkhira, Jessore Districts) and Noakhali region, resulting to a total 30% of all polders are now experiencing water logging in the coastal area. This water logging is partly a result of siltation in the drainage canals within the polders resulting from soil erosion which blocks the water flow through the drainage network and towards the drainage structures. Another factor inside the polders is land subsidence due to lack of sediment supply in the polders but also the lowering the ground water table.

Changes outside the polders also impede drainage but these have a different origin in the Ganges Tidal Plain West and the Noakhali region. The Ganges Tidal Plain West has seen a reduction of freshwater inflow during the dry season from the Ganges but also a reduction in tidal prism due the construction of the polder system. These interventions have accelerated river siltation in the past decades in this region. This siltation process in the tidal rivers has resulted in steady increase of tidal water levels in this part of the system. Increasing water levels has reduced the time window of low water periods for draining excess water. In the Noakhali region, a major factor has been the construction of several cross-dams for land reclamation purposes. As a result, the pathways for drainage have become much longer worsening the drainage capacity of these areas.



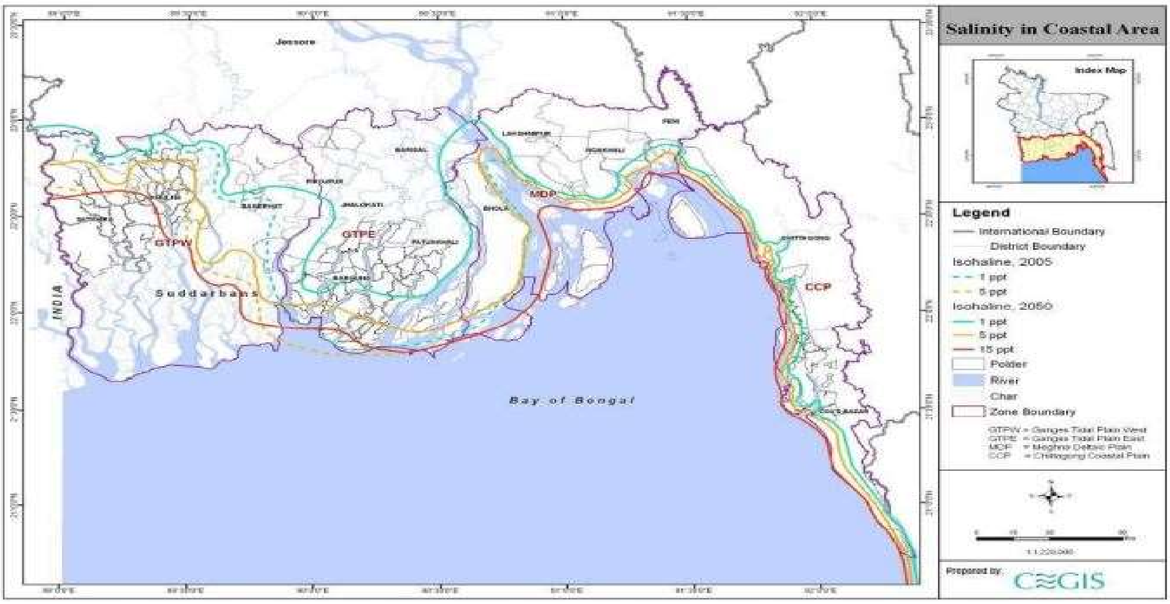
Figure_Apx 15: Water logging affected areas in coastal zone
(Source: CEGIS, 2011)

In general, sedimentation processes can be considered beneficial if they occur along the coastline as they cause accretion of land. However, sedimentation proves very detrimental to the efficient functioning of some parts of the river system, especially in upstream stretches of the tidal rivers which are currently experiencing considerable siltation. Siltation of rivers and drainage channels are culpable for causing water logging; saturation of soil with water. In addition, the subsequent loss of tidal range has made it impossible for some polders to be drained through drainage regulators. Siltation had several effects, such as to the navigation route from Hiron Point originally to the Port of Chalna and later to Mongla Port, which began experiencing navigation depth problems in the 1980's[76].

[76] DHI, 1994

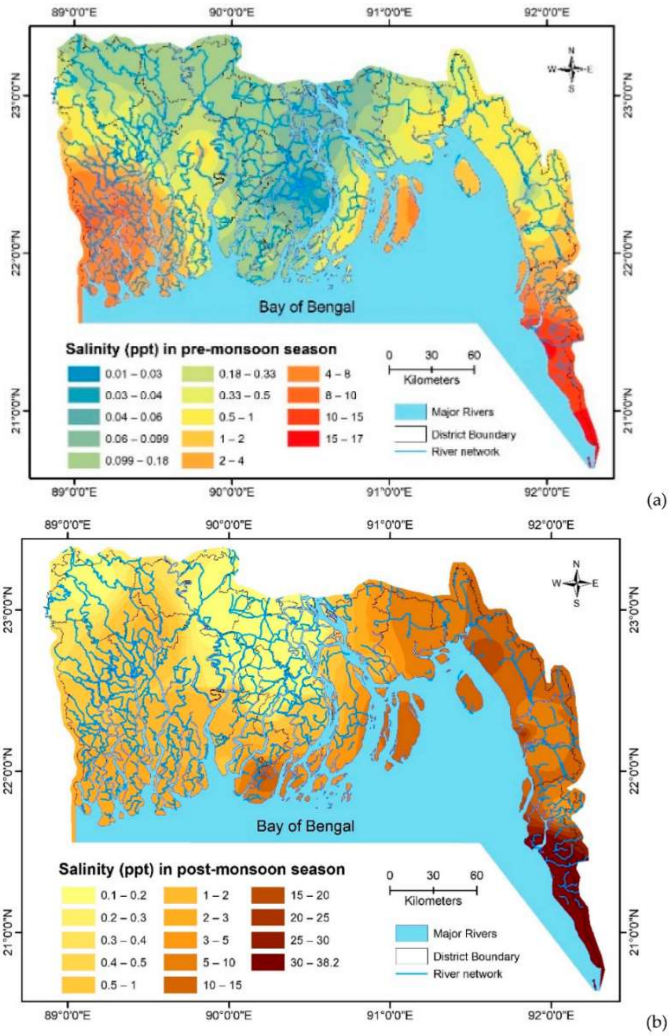
Saline water intrusion is closely linked to sea level rise caused by climate change. Salinity has an impact on the coastal ecology, fisheries, agriculture, and public health depending on temporal and spatial fluctuations. According to IWM and CEGIS (2007), future sea level rise will cause more coastal areas to be afflicted by excessive salinity than current saline affected areas. During monsoon, the 1 ppt salinity line may move upstream by 10 to 20 km, particularly in the central section (through the Baleshwar and Buriswar rivers) due to 27 cm and 62 cm sea level rises, respectively. In the year 2000, SRDI conducted a soil survey in Bangladesh's coastal areas. Over the last three decades, the salinity of 187300 hectares has grown. The majority of the Satkhira soil is influenced by salinity, which ranges from moderate to severe. Salinity problems stemming from seawater intrusion are especially intense during the dry months of March and April, and fields are frequently left uncultivated because agricultural productivity is limited by salts[77].

Maximum salinity levels in the Meghna Estuary's Hatya and Manpura islands might climb to 3-5ppt for a 27 cm (in 2050) and 62 cm (in 2080) sea level rise, respectively (IWM and CEGIS, 2007). The salinity problem in the project area will be alleviated due to an enhanced drainage system or protection from saline water intrusion by embankment and water control structures through CEIP. Saline intrusion in khals, ponds, and other surface water sources will be prevented with the projected implementation work of embankment retirement and replacement, as well as new building of water control structures. Flushing during the wet season will also reduce salinity (IWM and CEGIS, 2007).



Figure_Apx 16: Salinity Condition in Coastal Area (for 2005 and 2050)

[77] Rimi, R. H., Rahman, S. H., Karmakar, S., & Hussain, S. G. (2009). Trend Analysis of Climate Change and Investigation on Its Probable Impacts on Rice Production at Satkhira, Bangladesh. Pakistan Journal of Meteorology, 6(11), 37–50



Figure_Apx 17: Seasonal variation in salinity Condition in Coastal Area

A1.5 Climate change

Based on Becker et al. (2020)[78], an overview of estimated Relative Sea Level Rise (RSLR) for the different coastal regions is reported in Table_Apx 1, and derived based on 101 water level gauges available for the period 1968-2012. The values estimated indicate that RSLR over the analysed 45 years is ≈ 3 mm/year (i.e. therefore larger than global median values reported for the same period ≈ 2mm/year) and with relatively minor differences across the first three regions (i.e. Western Ganges Tidal Plain, Eastern Ganges Tidal Plain, Meghna Deltaic Plain), which are within the uncertainty band. The region with the lowest RSLR is the Chittagong Coastal Plain, however statistical trends are not significant for this region. It should be considered. ASLR rates were also estimated[78] based on satellite altimeter datasets over 1993 to 2012 (Table_Apx 1).

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

Surprisingly, reported estimated values of ASLR are on the same range as reported RSLR. However, the two datasets have been derived based on completely different datasets and periods. Maximum subsidence rates within the region, estimated as local differences between RSLR and ASLR over 1993 to 2012, can be considerable and up to 7 mm/y. No value was reported for Chittagong Coastal Plain area in view of the large differences with the rest of the delta and enhanced tectonic activity in this region[78]. As also discussed[78], local subsidence is expected to largely enhance the effect of ASLR locally.

Table_Apx 1: Relative sea level rise[79]

Region	Relative sea level rise 1968-2012 (mm/y)	Absolute sea level rise 1993-2012 (mm/y)	Expected max subsidence 1993-2012 (mm/y)
Western Ganges Tidal Plain	2.7 ± 1.3 (P≤0.001)	2.1 ± 1.4 (P≤0.1)	2.4
Eastern Ganges Tidal Plain	3.6 ± 1.8 (P≤0.001)	3.2 ± 1.6 (P≤0.001)	7.0
Meghna Deltaic Plain	3.0 ± 2.6 (P≤0.1)	3.4 ± 1.6 (P≤0.001)	5.2
Chittagong Coastal Plain	1.3 ± 1.4	3.4 ± 1.7 (P≤0.001)	-

Conclusions:

- Relative sea level rise across the GBM delta can be locally several time larger than global absolute sea level rise as a result of local subsidence;
- It is expected that the effect of subsidence will have a similar (or locally even larger) effect than absolute sea level rise in the future, at least in the short- and medium-term
- Differences in absolute sea level rise scenarios across the delta are minimal and can be well approximated by one averaged value. However, local differences in relative sea level rise are important and are related to local differences in subsidence levels. In addition, changes in high water, tidal range and mean water levels within (some of) the river channels and resulting from long-term morphological processes can be locally much larger than the rise in global absolute sea level rise;
- Regional absolute sea level rise projections following SROCC data (IPCC, 2019; Oppenheimer et al. 2019), indicate mean sea level rise values by 2100 for Bangladesh equal to 0.473 m (95% = 0.661m) according to RCP4.5 and 0.756 m (95% = 1.049m) according to RCP8.5, and
- Recent studies have described physically plausible mechanisms leading to high-end SLR scenarios as a result of accelerated ice mass-loss from Antarctica and Greenland. These processes could lead to a median value increase in mean sea level up to (or beyond) 2 m by 2100. It is advisable to take these high-end values into account in the longterm planning of the polders across the GBM delta.

[79] estimated based on water level gauges for the period 1968-2012, absolute sea level rise estimated based on satellite altimetry data for the period 1993-2012 and expected max subsidence for the period 1993-2012. The P-values in brackets provide an indication of how statistically significant trends are (adapted from Becker et al., 2020[78])

Cyclone frequency and intensity

Information on TC events derived from the IBTrACS database[80,81] and specifically from the subset by the Joint Typhoon Warning Center (JTWC) were used as a basis to assess possible historical changes in TC frequency and intensity.

Figure_Apx 18 suggests that the number of cyclone events and most extreme cyclone events has been slowly increasing through time during the last 5 decades in the North Indian Ocean. Very remarkable has been the year 2019, which was characterized by 6 TCs, all of them in the "severe" category. This finding is consistent for example with Singh et al. (2000)[82] and Deo et al. (2011)[83] that have shown an intensification of the most extreme TCs. When we focus on the Bay of Bengal only (Figure_Apx 18), one can see that the number of TCs has been decreasing, however the number of most extreme TCs has been increasing through time. The estimated changes have been equal to -0.4% per year and +1.7% respectively for all the TC events and the most extreme ones only. Similar conclusions were reported for example by Webster et al. (2005)[84] and in the BDP2100, indicating that the number of TC is decreasing but the intensity is increasing. Finally, Figure_Apx 18 focuses on the Bangladesh coastal zone only. The figure suggests that, if we focus on the Bangladesh coastal area only, it is difficult to draw firm conclusions on whether the number of events and intensity has decreased/increased over time.

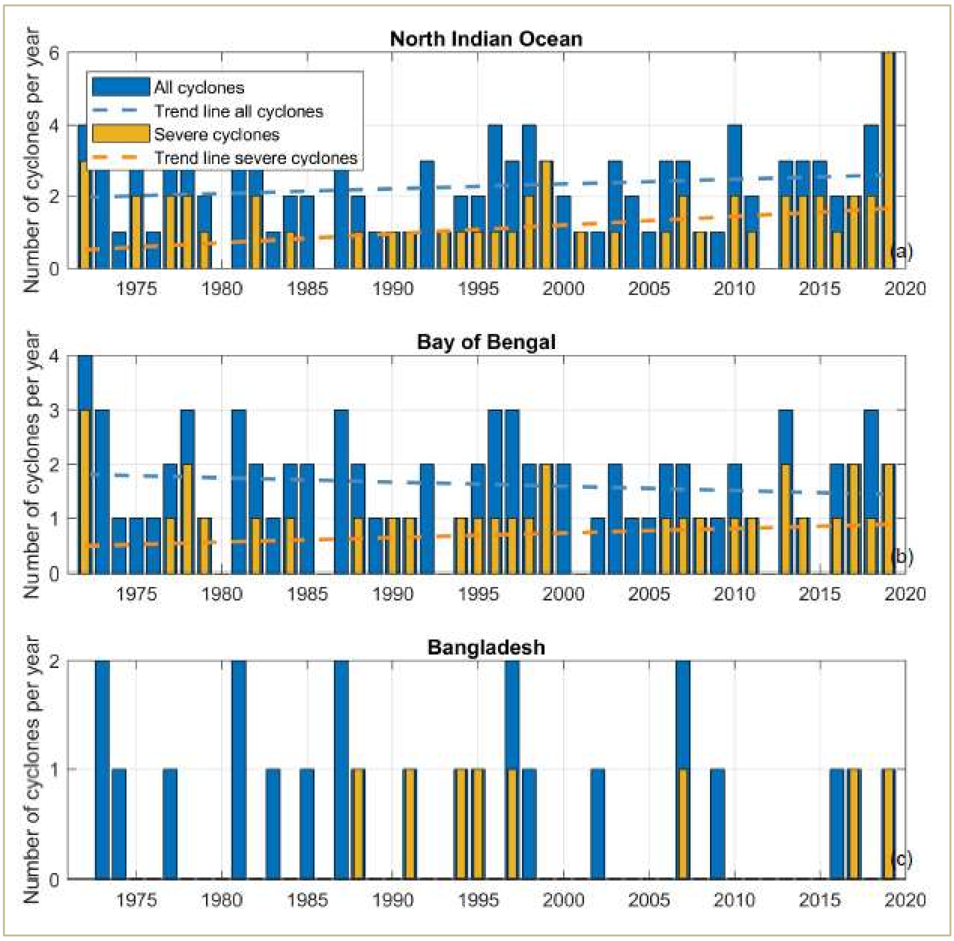
[80] Knapp, K.R., Kruk, M.C., Levinson, D.H., Diamond, H.J., and Neuman, C.J., 2010. The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying Tropical Cyclone Data. American Meteorological Society. https://doi.org/10.1175/2009BAMS2755.1

[81] Knapp, K.R., Diamond, H.J., Kossin, J.P., Kruk, M.C., Schreck, C.J., 2018. International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4. NOAA National Centers for Environmental Information. https://doi.org/10.25921/82ty-9e16.

[82] Singh, O. P., Khan, T.M.A., Rahman, S, 2000. Changes in the frequency of tropical cyclones over the North Indian Ocean. Journal of Meteorology and Atmospheric Physics. 75, 11-20. https://doi.org/10.1007/s007030070011

[83] Deo, A.A., Ganer, D.W., and Nair, G., 2011. Tropical cyclone activity in global warming scenario. Journal of Natural Hazards. 59(2), 771-786. 10.1007/s11069-011-9794-8.

[84] Webster, P.J., Holland, G.J., Curry, J.A., and Chang, H.-R., 2005. Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment. Science, 309, 1844- 1846, 1575.



Figure_Apx 18: Number of cyclones per year since 1972[85]

Conclusions

- Warming of the surface oceans as a result of climate change is likely fuelling more powerful TCs.
- Analysis of historical data from 1972 in the North Indian Ocean and Bay of Bengal indicates that the number of most sever cyclones (cat 4-5) has increased over time. Differently, the total number of cyclones does not show a clear trend over time and may even have decreased in time.
- Future changes in TC frequency and intensity depends on the chosen scenario. The most recent regional projections by Knutson et al.[86] are derived assuming a 2°C global mean surface temperature increase. These projections indicate, for the North Indian Ocean, a median change in frequency for all TC equal to about -5%, with an interquartile range equal to -15% / +6%, and with a 5th/95th percentiles equal to about -35% / +30%. When looking at the very intense TC only (cat 4-5), the prediction suggests a mean

[85] as retrieved from the JTWC database for: (a) the North Indian Ocean, (b) the Bay of Bengal and (c) the Bangladesh coastal zone. Plots are made for all cyclones (in blue) and only the severe cyclones (maximum wind speed larger than 40 m/s) (in orange). Linear trend lines have been added to show estimated changes in cyclone frequency over the time period.
[86] Knutson, T., Camargo, S.J., Chan, J.C.L., Emanuel, K., Ho, C.-H., Kossin, J., Mohapatra, M., Satoh, M., Sugi, M., Walsh, K., and Wu, L., 2020. Tropical cyclones and climate change assessment. Part II: Projected Response to Anthropogenic Warming, Vol. 101, Issue 3, https://doi.org/10.1175/BAMS-D-18-0194.1

increase in frequency of about +5% with an interquartile range equal to -15% / +40% and a 10th/90th percentile equal to -70% / +80%.

- Following Knutson et al. [86], changes in TC intensity suggest an overall increase of about +4%, with an interquartile range equal to +2% / +6%, and a 10th/90th percentile equal to -1% and +8%.
- Changes in TC induced precipitation suggest a median increase equal to about +18%, with an interquartile range equal to +14% / +19%, and a 10th/90th percentile equal to +12% and +20%[86].
- TCs induced precipitations are projected to increase due to enhanced atmospheric moisture associated with anthropogenic global warming.
- According to global CMIP5 climate models[86] a mean 2°C surface temperature increase will be reached around mid-century, under RCP 8.5 scenario. It is likely that these temperature increase will be largely exceeded by the end of the century. However, the uncertainties are currently too large to provide reliable projections for more extreme scenarios, which could be valid for larger temperature increases.
- The impact of individual TCs will be largely amplified by rising sea levels.

A1.6 Climate and quality environment

Climate

Bangladesh's climate is dominated by subtropical monsoons, which are marked by large seasonal changes in rainfall, relatively mild temperatures, and high humidity. The entire country of Bangladesh is classified into seven climate zones, with three climatic zones in the coastal areas: (A) South-eastern zone, (F) South-western zone, and (G) South Central zone. Pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and winter are the four major seasons in a year (December-February).

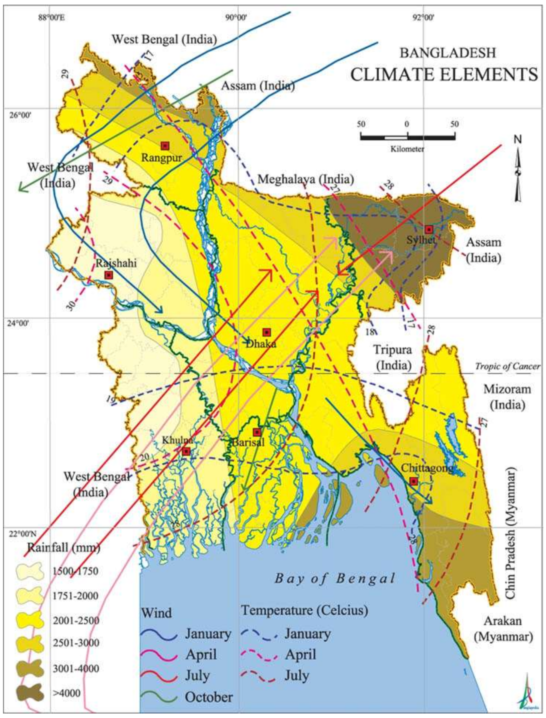
Maximum and minimum temperatures in Bangladesh's coastal zone range from 30°C to 36°C and 11°C to 23°C, respectively[87]. April and May have higher temperatures, whereas January is the coldest month of the year.

Annual rainfall in Bangladesh's coastal region ranges from little over 1,700 mm in the west to more than 3,200 mm in Cox's Bazar in the east. From Feni to Cox's Bazar, the east coast receives the most rainfall. Aside from the southwest air mass's connection instability, the sea breeze adds to the orographic lifting induced by the Chittagong and Chittagong Hill Districts' north-south oriented hills. Most of the rain falls in the foothills.

Humidity levels in the coastal zone are lowest in January and April, and highest in June and October. Only in the months of December and January does evaporation exceed rainfall. Evaporation outweighs rainfall in all other months. The highest excess occurs from May to October, with the lowest excess occurring from February to April and November.

The wind blows primarily from two directions in the coastal zone: NE and SE. During the winter, the NE winds dominate, while the SE winds dominate during the summer. The greatest average wind speed is 80 km/ hr.

[87] WARPO, 2006.State of the Coast 2006, Integrated Coastal Zone Management Program, Bangladesh



Figure_Apx 19: Climate Scenario of Bangladesh

Air quality

In Bangladesh's coastal region, air pollution is not a major perturbation. Road and river transportation, as well as businesses (such as cement mills, petroleum refineries, and power plants), account for most emissions. Air quality (mostly three metrics - SPM, SOx, and NOx) was measured in eight places throughout the coastal area (4 urban and 4 rural). The current air quality indicators are noted to be within standard norms in most regions, except for high SPM in Khulna city, Chittagong, Cox's bazar, and Noakhali town, which is primarily owing to high traffic loads.

Table_Apx 2: Air Quality Parameters

Sample Location	**Type of Location**	**Date**	**Air Quality Parameters**		
			SPM (μg/m^3)	SOx (μg/m^3)	NOx (μg/m^3)
Shibbari moor, Khulna City, Khulna	Urban	01/05/12	410	27	46
In front of upzila Polli Unnyon board office, Thana moor, Sharankhola, Bagerhat	Rural	03/05/12	140	11	20
Bus stand moor, Pirojpur town, Pirojpur	Urban	02/05/12	180	10	18
In front of Upazila office, Mathbaria, Pirojpur	Rural	02/05/12	148	5.2	15
Foy's Lake Moore, Khulshi, Chittagong	Urban	20/05/12	314	5.4	14.2
Chokoria Bus Stand, Cox's Bazar	Rural	23/05/12	290	ND	10.2
Court road, Maijdi, Noakhali	Urban	21/05/12	280	4	12.5
In front of Haji Bari, Laksmi Narayanpur village, Noakhali	Rural	21/05/12	45	ND	ND
ECR standard for Residential and Rural area			200	80	80

Water quality

The principal sources of water pollution in the coastal area are domestic sewerage, industrial effluent, and oil spills from water transports. The water quality of various important rivers and ponds in the coastal region was examined and the results showed that most of the water quality indicators were within acceptable limits. Both river and pond water had salty pH and electrical conductivity (EC) values, indicating that they were both saline. In addition, pond waters had a high coliform content. In addition, the quality of groundwater was assessed by collecting tube-well water samples from eight distinct coastal locations. Most water quality measures are within threshold limits, with a few exceptions (for example, high chloride in Khulna city, high iron content in Noakhali town, and high arsenic concentration in Noakhali area). In general, all tube-wells had increased chloride content, i.e. salinity.

Table_Apx 3: Surface Water Quality Parameters

Sample Location Date	**Date**	**Surface Water Quality Parameters**									
		Temp.(ºC)	**pH**	**EC (µS/cm)**	**DO (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**	**TDS (mg/L)**	**SS (mg/L)**	**Coli colonies(No/100ml**	**N-nitrate(mg/l)**
Baleshore river (up), Chalna Namajpur, Pirojpur	01/05/12	29.2	6.86	0.49	7.8	0.4	25	1463	45	350	2
Baleshore river (down), Mathbaria, Pirojpur	01/05/12	29.1	6.86	1.12	7.2	0.4	20	1163	45	375	2
Gunakhali river nearRaenda bazar, Sharankhola, Bagerhat	02/05/12	31.5	6.86	2.33	7.8	0.4	20	353	60	250	2
Rupsha river ghat Side point, Khulna	03/05/12	29.2	7.71	3.34	7.2	0.8	28	817	70	520	2
Surface water sample of Karnafully river water 15No ghat, Potenga, Chittagong	20/05/12	32	7.84	2.81	7.3	2.4	351	1268	1079	190	1.3
Surface water sample ofMaijdi DC office Dighi, Noakhali	21/05/12	31.6	7.4	2.36	7.9	2.6	8	950	67	1150	0.5
Surface water sample ofHaji Bari Pond, Lakki Narayonpur, Sadar Noakhali	21/05/12	30	7.21	2.72	8.6	8.4	12	1400	234	1420	0.8

Surface water sample of Matamuhuri river Chokoria Cox's Bazar, Cox's Bazar	23/05/12	31	6.94	2.44	8.2	1.1	3	1540	75	210	0.2
Standard for inland surfacewater for fisheries as per ECR'97		NA	6.5 – 8.5	NA	≥5	≤6	NA	NA	NA	NA	NA

Note: ND = Not Detected; NA= Not Available
(Source: Lab test by DoE, Khulna and Chittagong, May 2012)

Table_Apx 4: Ground Water Quality in Different Rivers in Coastal Area

Sample Location	**Date**	**Ground Water Quality Parameters**					
		Temp	**pH**	**Chloride (mg/l)**	**Iron (Fe) (mg/l)**	**SS (mg/l)**	**As (mg/l)**
Tube well water of Danishafa UP office, Mothbaria, Pirojpur	01/05/12	25.4	7.56	355	0.78	5	0
Tube well water of Pirojpur Upazila health complex, Pirojpur town, Pirojpur	02/05/12	25.3	7.25	421	0.8	4	0
Tube well water of Upazila primary school, Sharankhola, Bagerhat	02/05/12	25.2	7.45	532	0.88	4	0
Tube well water of Divisional Commissioner office, Khulna	03/05/12	25.6	7.57	667	0.45	5	0
Deep T/W sample of Akbarsha mosque, Khulshi, Chittagong	20/05/12	28.0	7.2	66	0.14	1	0
Deep T/W sample of Mojaffor Haji Bari, Laksmi Narayanpur, Noakhali Sadar, Noakhali	21/05/12	26.0	8.3	224	0.76	3	0.5
Deep T/W sample of Kiron Hotel, Maijdi Court, Noakhali	21/05/12	28.7	7.7	388	2.86	2	0.6
Deep T/W sample of Mr. Zakir Hossain home, Kakara, Chokoria, Cox,s Bazar	23/05/12	29.0	6.7	182	0.78	3	0.03
Drinking water quality standard as per ECR'97			6.5 – 8.5	150 –600	0.3 – 1.0	10	0.05

(Source: Lab test by DoE, Khulna and Chittagong, May 2012)

A1.7 Environmental

In general

The Ganges Tidal Floodplain West: The Sundarbans mangrove forest (including the part in India) is a globally unique ecosystem due to its size, its variety of mangrove species but the abundance and diversity of fauna. This mangrove forest covers 6,017 km2 in Bangladesh and has 12-13 different mangrove types out of the 35 worldwide. The biotic diversity comprises 400 species of fishes, 53 species of reptiles, over 315 species of birds and 50 species of mammals. Large animals include spotted deer, crocodiles and tigers. Fishes include finfish and shellfish including shrimp and prawn, lobster, crabs, snails, mussels and shells, cuttlefish, squids. Marine mammals like sharks, rays, sea horses, whales, dolphins and also marine reptiles such as turtles and sea snakes live in this region too. The Sundarbans is a RAMSAR site declared under "The Convention on Wetlands". In addition, the Government of Bangladesh has declared three wildlife sanctuaries and three dolphin sanctuaries in the north of the Sundarbans along the Pussur, Shela and Bhola Rivers.

The Meghna Deltaic (Estuary) Plain: The Meghna estuary is an extraordinarily rich ecosystem due to mixing of tidal and river waters, the continuous supply of sediments and nutrients and the remote intertidal areas. The islands in the estuary mouth are a strategic location in the migratory East Asian-Australasian Flyway, in particular waders and other waterbirds during winter. More than a hundred thousand birds visit this area amongst which critically endangered birds like Spoonbill Sandpiper, Nordmann's Greenshank, Asian Dowitcher, Great Knot. These birds feed themselves with benthic organisms, mollusks, crustaceans, and marine worms. The intertidal areas in the estuary are also nursery and feeding ground for many fish species such as Hilsa and Pangas.

The Chittagong Coastal Plain: This region has a large variety of different ecosystems with some small pockets of natural mangrove forests, small estuaries, sand dunes and beaches. One mangrove area of ecological importance is present near Cox's Bazar where it occupies the low-lying saline swamp at the mouth of the Matamuhuri River delta. This area known as Chakoria Sundarban provides a habitat for a variety of marine and terrestrial organisms[88]. Another area of ecological interest is the Teknaf Peninsula with one of the longest sandy beach ecosystems (80 kilometres) in the world. This area has a mixture of mangroves, mudflats, beaches and sand dunes, and lagoons. It provides breeding ground for two globally threatened species of marine turtles and, is located along international bird migration flyways. To protect this rich biodiversity along the coast, the region has three protected areas: Cox's Bazaar - Teknaf Wildlife Sanctuary, Himchhari National Park and Inani National Park.

Soil and agriculture

Several soil types can be found along the coast, ranging in texture from sandy loams to heavy breaking clays. Except for some soils in the Old Ganges and Meghna floodplain basins, most coastal soils are saline and non-calcareous. The majority of coastal zone soils are moderately to severely alkaline.

The coastal region contains approximately 3.6 million acres of Net Cultivated Area (NCA), with an average cropping intensity of 175 %, and is primarily planted with local and hybrid rice crops. The 139 polders occupy a total area of around 1.12 million acres, of which about 64% is suitable for crop production. Rain-fed cropping and irrigated cropping systems are the most common agricultural strategies in the coastal zone.

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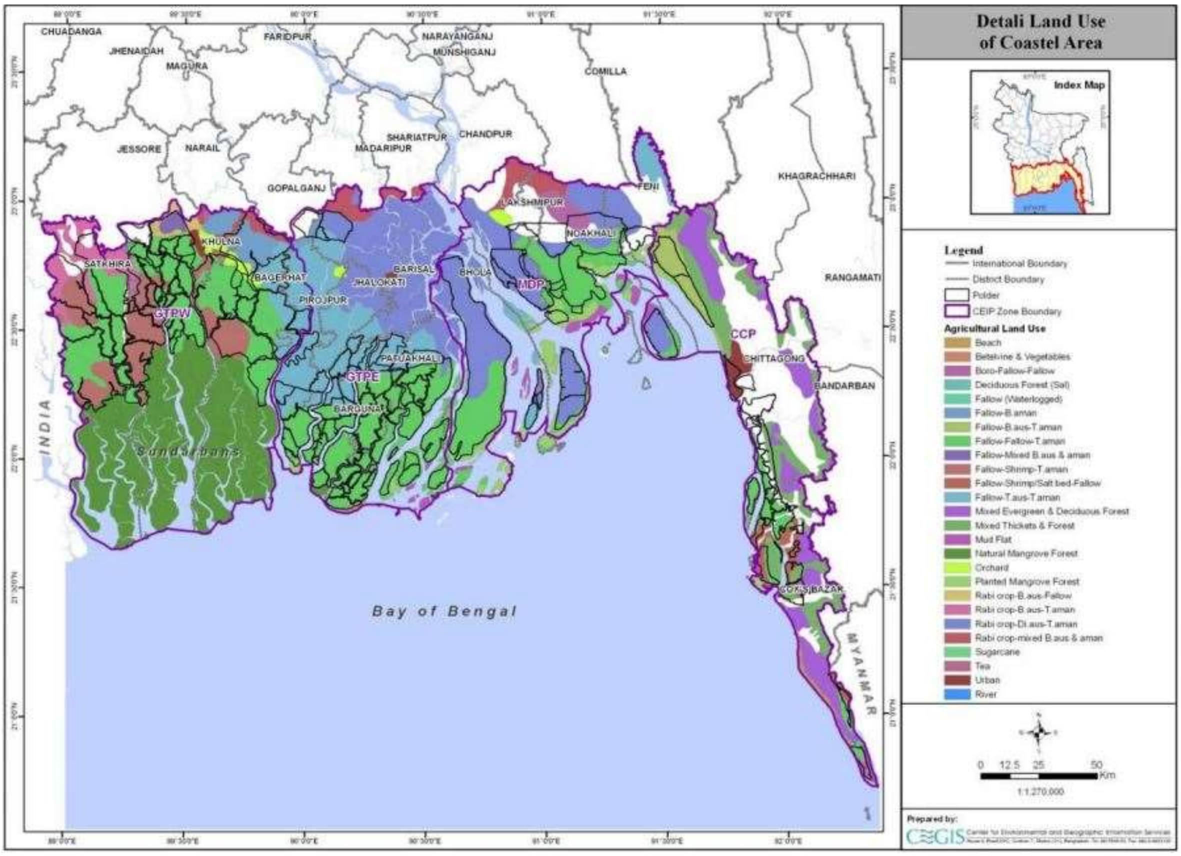
[88] Hossain, M. S., C. Kwei Lin, and M. Z. Hussan. 2001. Goodbye Chakaria Sunderban: The Oldest Mangrove Forest. The Society of Wetland Scientists Bulletin. No. 18 (Sep 2001):19-22.



Figure_Apx 20: Agricultural Land use Map of Coastal Area

The principal cropping sequences in rain-fed highlands include local/HYV broadcast Aus followed by local/HYV transplanted Aman, and local broadcast Aus followed by a wide range of Rabi crops, depending on the residual soil moisture. In regions with sufficient soil features and access to highways and arterial routes, a broad variety of Kharif vegetables are produced in place of Aus. Jute is the dominant cash crop in the area, with broadcast Aus taking its place in the planting pattern. Kharif vegetables can also be cultivated as a substitute for Aus or jute.

Local / HYV broadcast Aus is followed by local / HYV transplanted Aman as the dominant cropping sequence on medium highland, occasionally flooded up to 90 cm. Rabi crops such as wheat, legumes, oilseeds, vegetables, spices, and minor cereals are also grown as a third or second crop after transplanting Aman. To avoid damage from floods, which begins in June and peaks in mid-August, early broadcast Aus or late transplanted Aman is grown on medium lowland. Jute, wheat, and potato are also farmed on this sort of ground.

Agricultural techniques are determined by factors such as soil and land type, irrigation availability, crop product demand, and so on. Rice is the major crop in the current cropping pattern. Rice takes up a significant amount of the total planted area (approximately 75 percent). In both the Kharif and Rabi seasons, the residual space is used for other crops. Wheat, winter vegetables, bean, cowpea, pulses, oilseeds, potato, sweet potato, chile, cowpea, millet, water melon, ground nut, and other Rabi crops are among them.

The following are the major challenges in the 'agriculture' sector that are related to CEIP:

Soil salinity is the region's most significant limiting factor for agricultural techniques, particularly during the dry season. During the dry season, there is a scarcity of good irrigation water, which inhibits the cultivation of boro rice and rabi (winter) crops, as well as aus cultivation during the kharif-1 (March-July) season. Rainfall variability, unknown dates for the commencement and receding of seasonal floods, and the risk of drought limit the production of aus and aman rice. Waterlogging in the polder areas is a constant problem due to poor drainage and improper sluice gate operation.

Fisheries

In the fresh to brackish water environment, the coastal fishery primarily comprises of two types of fisheries: capture and cultural fisheries. Capture fisheries are divided into three types: river and canal fisheries, marine artisanal fisheries, and post larvae (PL) fisheries. Similarly, the habitat type of cultural fishery includes ponds and shrimp ghers.

River/ canals *Ponds/Ditches* *Gher*

Figure_Apx 21: Coastal fish habitats

In the coastal zone, two types of aquaculture are practiced: fish culture (mostly freshwater species) and shrimp culture. Pond fish farming is more common in the polders of the Ganges Tidal Plain West and East, as well as the Meghna Deltaic Plain (MDP). The ponds/ditches are primarily stocked with white fish, while the Ghers are stocked with either monoculture shrimp or shrimp mixed with white fish/prawn.

The overall cultivable land area in the CEIP area is approximately 931,300 ha, with the shrimp farm covering 89,200 ha. The polder areas of Khulna, Bagerhat, Satkhira, and Cox's Bazar Districts are home to the majority of shrimp farms. Bagda (Penaeus monodon, P. indicus), Golda (Macrobrachium rosenbergii), Baila (Glossogobius giuris), Golshatengra (Mystus sp), and other species are part of the Gher cultural fisheries.

Shrimp's importance in the coastal zone has increased dramatically during the previous 30 years. Shrimp farms are important sources of employment and foreign cash in Bangladesh. In 2008-2009, shrimp output in the coastal zone accounted for 99.89 percent of the country's total, according to DoF statistics[89]. It is the country's second-largest foreign exchange earner.

Despite the fact that the coastal area is rich in capture fisheries, particularly brackish water fisheries, culture fisheries such as shrimp culture practices are rapidly expanding in the southwestern and south eastern zones. As a result, mono fish farming will be expanded,

[89] DoF, 2010. Fishery Statistical Year Book of Bangladesh, 2008-2009. Fisheries Resources Survey System, Department of Fisheries (DoF), Dhaka

influencing the growth of certain fish species. Salinity intrusion due to sea level rise, on the other hand, could restrict freshwater fish habitat in the coastal area. As a result, freshwater fisheries productivity may be impeded, as freshwater carp, catfish, perch, and other species are especially susceptible to moderate salinity.

The following are the significant concerns and issues in the coastal fisheries sector:

Changes in river morphology, poor fisheries management, and aquatic biological conditions; Due to siltation and surface water salinity increase, fish habitat and depth are decreasing. Due to excessive shrimp farming practices, floodplain fisheries are being lost. Inadequate migratory paths between rivers and diverse interior water sources obstruct feeding and spawning migration. Due to a lack of communication and infrastructure, the fish marketing system and post-harvest facilities are inadequate.

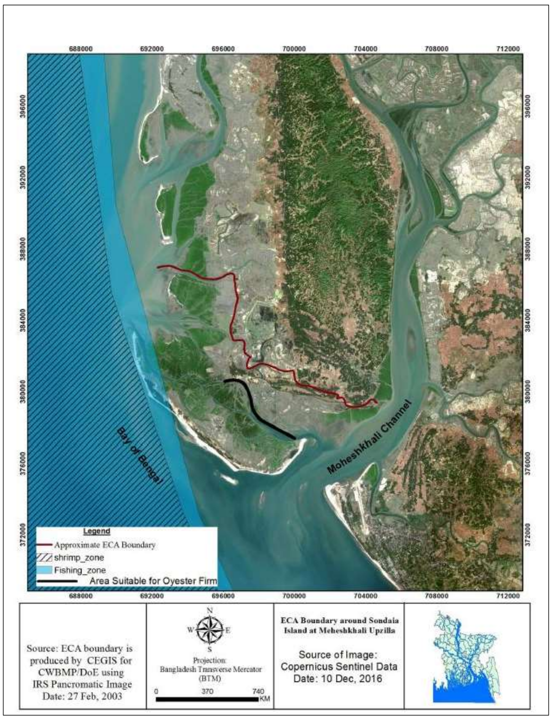
Ecosystems and biodiversity

The Ganges floodplain and major rivers, Coastal marine water, Meghna floodplain, Sundarbans, Chakaria Sundarban, Coastal plains, Offshore islands, and Meghna estuarine floodplain are the ten bio-ecological zones that make up Bangladesh's coastal zone. Due to its ecological and physical conditions, the coastline area is enhanced with a variety of fresh and brackish water environments. Marine, brackish water, freshwater, mangrove, Sundarbans, floodplain, island, peninsula, and terrestrial ecosystems are some of the habitat types found in the region (roadside and homestead). This area also contains a shrimp farming pond (Gher) habitat.

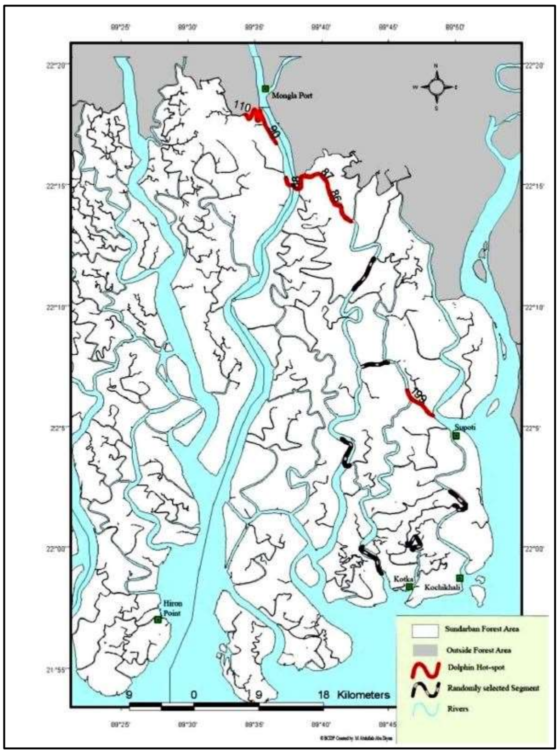
Ecologically Critical Areas (ECAs), Ramsar sites, National Parks, Wildlife Sanctuaries, Eco-parks, Game Reserves, World Heritage Sites, Marine Reserves, and Fish Sanctuaries are some of the ecosystem management approaches used to safeguard sensitive ecosystems in Bangladesh's coastal region.

Some coastal polders are located within these protected regions, primarily within the Sundarbans Reserve Forest's 10 km perimeter, which has been designated as an ECA (in Satkhira, Khulna and Bagerhat District).

The coastal zone has a healthy terrestrial and aquatic environment, which supports a diverse range of flora and wildlife. The native prominent flora includes Hargoza (Acanthus illicifolius), Narikel (Cocos nucifera), Khejur (Phoenix sylvestris), and Bhadi (Lennea coromandelica).



Figure_Apx 22: Ecological Critical Areas in Sonadia Island (Source: CWBMP/UNDP/DoE)



Figure_Apx 23: Dolphin Sanctuary outlined by red lines[90]

[90] SMITH, B. D., DIYAN, M. A. A., MANSUR, R. M., MANSUR, E. F. and AHMED, B. 2010. Identification and channel characteristics of cetacean hotspots in waterways of the eastern Sundarbans mangrove forest, Bangladesh. Oryx 44(2): 241-247.

The prominent local animals in the area where shrimp aquaculture is limited are the jackal (Canis aureus), grey mask shrew (Suncus murinus), and little Indian civet (Viverricula indica). The Saurs crane (Grus antigone), the Black-winged stilt (Himantopus himantopus), the Little grebe (Tachybaptus ruficollis), and the Redwattled lapwing (Vanellus indicus) were previously plentiful in this area, but they are now uncommon. In this location, ring lizards (Varanus salva), banded sea snakes (Hydrophic fasciatus), estuarine sea snakes (Hydrophic obscura), and other reptiles are plentiful, but they are rarely seen in areas where heavy shrimp farming is practiced.

Mangroves

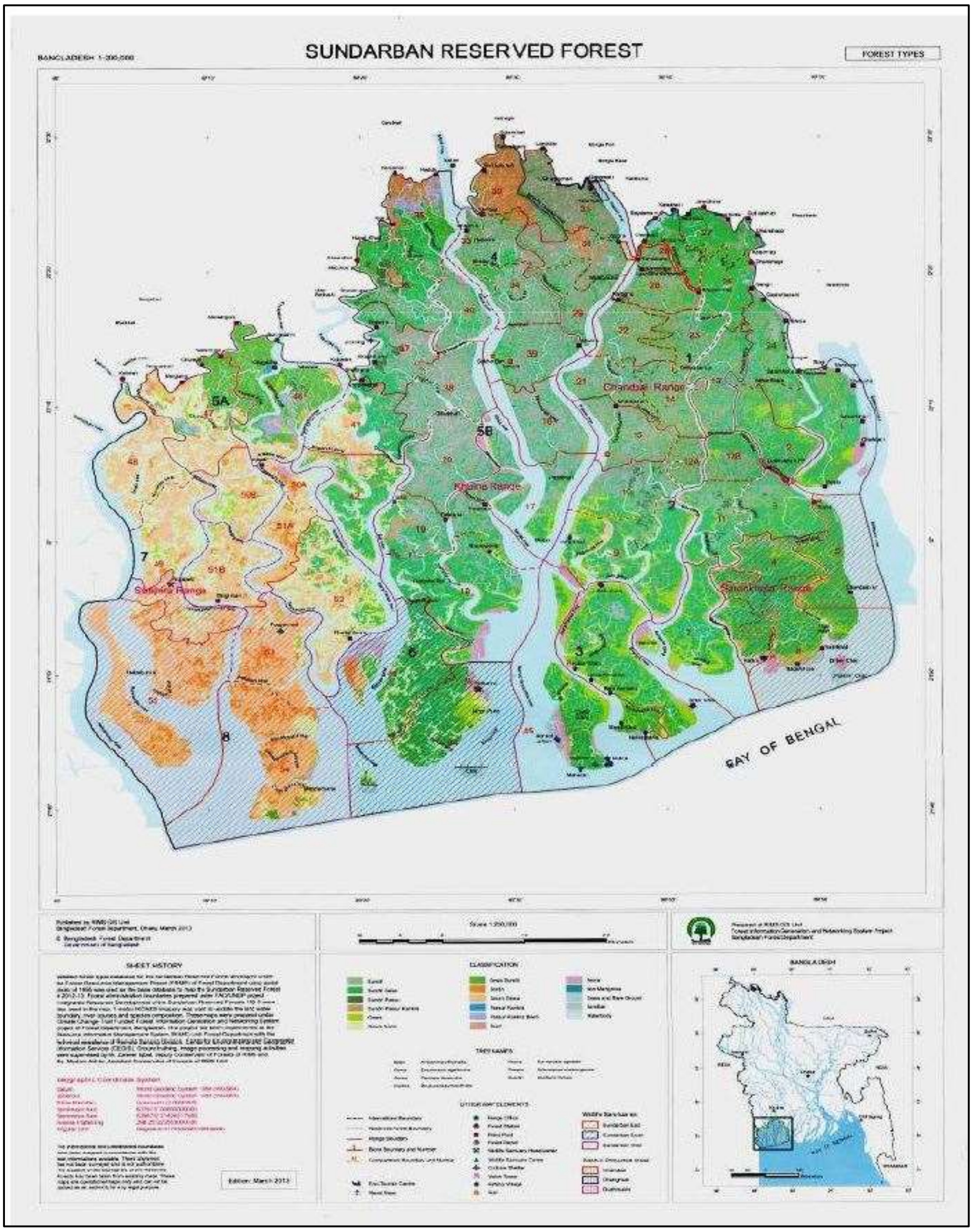
The Sundarban, the world's biggest mangrove forest, is in the southwestern part of the coastal region. Mangrove forests are transitional zones between fresh and salt water, with a diverse range of marine and terrestrial vegetation and fauna. Mangrove forests also provide as a natural barrier against cyclonic storms and tidal surges, as well as stabilizing coasts, enhancing land accretion, and enriching soil near the water. The Sundarbans Reserve Forest covers 601,700 hectares, with 406,900 hectares of forest, 187,400 hectares of water (rivers, rivulets, ponds, and canals), 30,100 hectares of wildlife sanctuaries, and 4200 hectares of sand bars.

The mangrove forest is extremely diverse, supporting 334 plant species, 77 insect species of various orders, 7 crabs, 1 lobster, 23 shrimp/prawns, 400 fish, 8 amphibians, 35 reptiles, 270 birds, and 42 mammal species. In the Sundarbans, there are roughly 13 orchid species and 23 medicinal plant species, respectively.

The Sundari (Heritiera fomes) and Gewa (Heritiera sp.) are the two most important commercially important plant species in the Sundarbans (Excoecariaag allocha). Gewa and Goran (Ceriops roxburghiana) are among the trees that are utilized in newsprint mills for paper manufacturing as well as for fuel. The timber woods Sundari and Keora (Sonneratia apetala) are employed. Golpata is the most major non-wood forest product (Nypa fruiticans). This plant's leaves are commonly utilized for thatching roofs of buildings and boats, as well as fencing the homes of millions of people living along the coast. According to the Forest Department, between 2001-02 and 2009-10, the annual output rate of timber, fuel wood, and thatching materials (Golpata) was roughly 3567 m3, 120 tonnes, and 26653 tonnes, respectively.

Sundarban's forest resources and biodiversity are threatened by natural disasters such as cyclones and storm surges, as well as overexploitation. The hurricane Sidr (in 2007) wreaked havoc on the Sundarban and its surrounding areas, wiping out vast swaths of biodiversity. Sea level rise as a result of climate change is another threat to the Sundarban's biodiversity. Increased salinity is expected to put the Sundari in the mangrove forests in jeopardy. Furthermore, city wastewaters, industrial pollution, oil pollution, and shipbreaking, among other things, are detrimental to coastal and marine biodiversity, particularly in the Chittagong and Khulna regions.

The Sundarbans, South Asia's largest mangrove forest, is near to six Districts and seventeen polders. Bagerhat, Sathkhira, and Khulna are all within the Sundarbans' effect zone (10 km outside the Sundarbans). The quantity and pattern of water flow inside the Sundarbans' canals may be affected indirectly by polder rehabilitation and reconstruction.



Figure_Apx 24: Sundarban Reserve Forest
(Source: CEIP I review report 2019)

A1.8 High level risk assessment

A1.8.1 Storm surge inundation

Physical vulnerabilities delineated by cyclonic induced storm surges spans the entire Bangladesh coastline. The 19 cyclones which made a landfall in Bangladesh between 1960 and 2009, can collectively define the current cyclone related vulnerability in Bangladesh. While historical records of storm surge height are scarce in Bangladesh, the existing literature suggests typical storm surge height during severe cyclones is between 1.5 and 9.0 meters, while storm surge heights in excess of 10 m are less common[91], and are expected to occur approximately every 25 years[92]. When combined with an expected rise in sea level, cyclone-induced storm surges are projected to inundate an additional 15% of the coastal area.

Each cyclonic event generates different storm surge levels along the coast, following diverse amplification or compression patters after intersecting with the low-lying areas and the waterbodies, whose dynamics are determining factors. Hence, for the sake of this assessment, the coastal zone of Bangladesh is divided in zones which present similar characteristics, observing which Upazilas experience similar storm surge levels.

The storm surge levels used within this exercise are the ones defined within CEIP-1[93]. Two scenarios have been assessed: baseline and climate change. The climate change scenario's storm surge levels have been generated under climate change scenario of RCP 8.5 (IPCC, AR5).

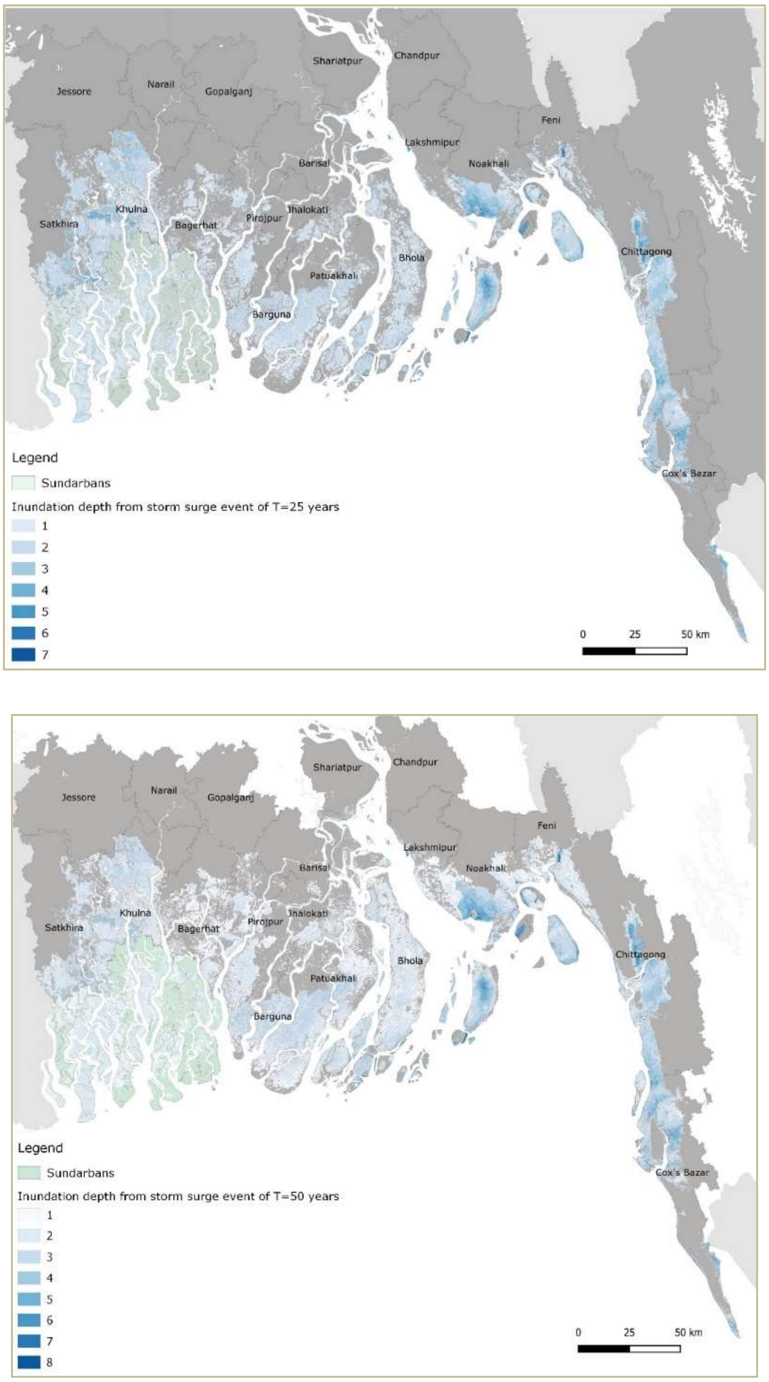
Those figures should be treated with caution considering the exposure underprediction which follows the use of global freely available Digital Elevation Models such as the MERIT DEM, as a proper DEM is not available, the topography is estimated using the MERIT DEM. After removing multiple error components from these existing DEMS, the MERIT DEM reaches approximately 90m horizontal resolution at the equator. The currently existing embankments are not included in the DEM in great detail. However, while using the MERIT DEM to estimate the topography of the polders, elevations of the embankments are only partially captured. It should be noted however that due to the ~ 90m horizontal resolution, the approximation of the embankment heights and/or position cannot be expected to be fully accurate and could result in an underestimation of the actual embankment height, and therefore an overestimation of inundation. For that reason, the model includes an additional calculation to account for this underestimation of embankment height. Some additional limitations of the MERIT DEM are described in a later box "Limitations MERIT DEM".

The predominantly low-lying topography of the coastal zone determines the inundation levels and extents as follows (examples are presented for storm surge of 25 and 50 years return period for the climate change scenario in Figure_Apx 25).

[91] SMRC (SAARC Meteorological Research Centre). 2000. The Vulnerability Assessment of the SAARC Coastal Region due to Sea Level Rise: Bangladesh Case. Dhaka: SAARC Meteorological Research Centre, SMRC Publication

[92] Multi-purpose Cyclone Shelter Project (MCSP). 1993. Summary Report. Dhaka: Bangladesh University of Engineering and Technology and Bangladesh Institute of Development Studies

[93] CEIP-1 (2018). IWM: Technical Report on Storm Surge, Wave, Hydrodynamic Modelling and Design Parameters on Drainage System and Embankment Crest Level, Package III



Figure_Apx 25: Inundation extent and depth for different return periods (indicatively presented 25 and 50 years storm surge return periods)

A1.8.2 Physical and socio-economic vulnerability

With physical vulnerability describing the ability of the built environment to withstand impacts, it is generally represented as the monetary value of physical assets in the hazardous zone[94]. In other words, physical vulnerability can be expressed by the expected damage to physical structures such as buildings, bridges, roads, and public utilities, which is one of the most devastating impacts of cyclonic induced storm surges. By definition, damage expressed the amount of money needed to restore the area back to its original condition before the disaster[95]. In recent years, vulnerability assessments have moved away from being solely focused on physical assets and are increasingly incorporating social vulnerability, defined as the susceptibility of social groups to the impacts of hazards, as well as their ability to adequately recover from them[96].

The specific asset categories considered for this present vulnerability assessment are the following:

- Population and housing units (from Population and Housing Consus , 2011). The projection population and household for 2021 was carried out using following formula:

  $Pp = P_0 (1 + r)^n$

  Pp = Projected population

  P_0 = Population 2011

  r = Annual rate of increase or decrease of population (this data was collected District census book 2011)

  n = Number of years (Here n is 2021 – 2011 = 10 years)
- Classification of housing among (pucca, semi-pucca, kutcha, jhupri) (Population & Housing Census – 2011) – *for definition of main character of each poler (urban, semi-urban and rural) and subsequently apply damage value reduction factors*;
- Roads (Shapefile - LGED, 2018);
- Agriculture areas (Landsat, 2020);
- Economic zones (Word Bank, Bangladesh Interactive Poverty maps https://www.worldbank.org/en/data/interactive/2016/11/10/bangladesh-poverty-maps);
- Education facilities (Shapefile - LGED, 2017);
- Health facilities (Shapefile - LGED, 2018).

Since most of the data (excluding the shapefiles) are provided in an Upazila level, they have been translated in polder figures, multiplying the Upazila figures with the percentage of the Upazila area that falls in a polder. This method also accounted for polders being part of several Upazilas.

Flood damage curves

Determining direct flood damage is commonly done using depth-damage curves[97], which denote the flood damage that would occur during certain storm surge return periods and associated water depths per asset or per land-use class. In essence, combining the extent and depth of

[94] Sierra Woodruff, Todd K. BenDor (2018), in Comprehensive Geographic Information Systems, 2018
[95] Kang, J., Su, M., & Chang, L.. (2005). Loss functions and framework for regional flood damage estimation in residential areas. Journal of Marine Science and Technology, 193–199.
[96] Sierra Woodruff, Todd K. BenDor (2018), in Comprehensive Geographic Information Systems, 2018
[97] European Comission (2017) Global flood depth-damage functions

inundation with asset information such as houses, roads, and other damage classes provides a damage cost estimation. Distinctly, damage curves are assigned to particular asset classes and construction types. For instance, the values and respective damage functions are different for residential buildings and industrial buildings. Likewise, construction type and quality even within the same structure also presents significant variations[98] (see Box below).

Flood damage curves - cost

The global flood depth-damage functions database released by the European Commission[99] are used for the estimation of the damage curves and consequently the maximum damage of specific storm surge events .

Asia-specific depth damage curves have been used with maximum damages for each type of asset in this database refer to 2010 prices and thus are corrected with an inflation rate of 1.89. In addition, the conversion rate from EUR to BDT in 2010 has been considered and thereafter translated into USD considering the conversion rate from BDT to USD in 2020 (see calculations below):

$Maxdamage^{2020} = Maxdamage^{2010} * CPI^{2020}/CPI^{2010}$

- 1 BDT=0.011 EUR (2010)
- Based on source https://www.theglobaleconomy.com/Bangladesh/cpi/ : CPI BGD^{2010}= 100 and CPI BGD^{2020} = 189.9
- 1 BDT=0.01178 USD (2020)

Final Correction Factor applied (inflation and currency)= 2.03

Residential damages considerations

To account for the building variations along the coastal zone, those values are multiplied with a factor, estimated based on the urban, semi-urban or rural character of each Upazila, leading to a case specific appreciation of the price of damages. Maximum damage values presented within the Flood Damage Curves are for buildings made of generally resistant material such as concrete or masonry. Correspondingly, this relates to western countries or urban areas in more rural countries. When a case study is in more rural areas in developing countries (where less resilient building materials are assumed to be used), it may be useful to set the undamageable part to zero, and reduce the maximum damage value[100].

Correction (reduction) factors are introduced to account for the type of materials and construction. Assumed undamageable parts, materials used and value of objects in the houses are expected to vary depending on the urban, semi-urban and rural character of the Upazilas.

The following reduction values have been included in the assessment:

Types of areas	EUR/m2 2010	USD/m2 2020	Reduction factor per type of area	Size of house
Urban	136	263.84	0.8	70 m2
Semi-urban	80	155.2	0.5	40 m2
Rural	33	64	0.2	30 m2

It should be mentioned that the number of houses in each Upazila is considered equally distributed within each Upazila, implying that in the case of 20% of the total Upazila area is inundated, then 20% of the total houses will be impacted.

Damages economic Zones

The economic zones' information has been retrieved from Government of Bangladesh https://www.beza.gov.bd/all-zones/ , for which the Flood Damage Curves values for industrial land use have been used. Since the areas given are very large comparatively to the size of the Upazilas' in which they are contained, the area considered for this assessment has been reduced by 50%, in order to avoid overestimating the damages.

Roads

The road shapefiles retrieved from LGED and have been overlayed with the inundation depth, obtaining as a result the length of the impacted roads. The level of damage has been classified based on the type of road (highway, Zila road, Upazila road, Union road or village road) and the quality of the road (pucca or kutcha). Based on the Road Design Standards (LGED, 2004), the width dimension has been considered 5m for highways, 3.7m for Zila and Upazila roads, and 3m for Union and Village roads.

[98] World Bank (2016). Methods in Flood Hazard and Risk Assessment
[99] European Commission JRC, April 2017 (European damage functions updated in October 2017).
[100] European Commission JRC, April 2017 (European damage functions updated in October 2017).

Agriculture

The agricultural land use per Upazila has been retrieved from the Agriculture Census, 2008. The agricultural losses are calculated based on the values given in the Flood Damage Curves, however, in a country such as Bangladesh, whose economy greatly depends on agriculture, the indirect losses related to value added are significant and constitute approximately 90% of the crop losses.

Asset vulnerability

Overlaying the inundation depth/extent with the foregoing types of assets and combining with the flood damage curves, introduces the area distributed damages.

In relation to each asset type (excluding the shapefiles which are georeferenced), the following assumption has been made: when x% of the polder is flooded then x% of the population, housing and economic zones is flooded.

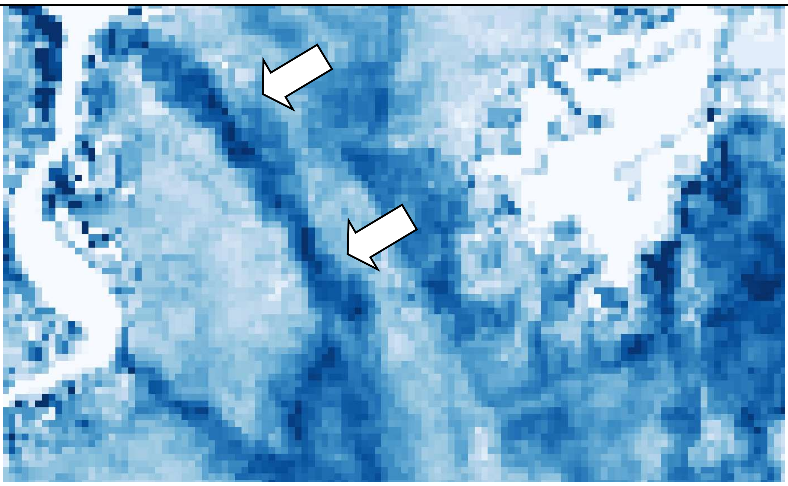
This method is chosen due to the accuracy limitation of freely available DEMs (i.e. MERIT and NASADEM). The accuracy depends greatly on the unique characteristics of the study region. Height overestimation occurs in densely forested areas by all DEMs. However, MERIT is slightly less affected by forested areas, mainly due to the vegetation removal procedure.

From inspection of both MERIT and NASADEM in the polders, it becomes clear that height overestimation is visible at canopy. To remove the effect of vegetation and retrieve a DTM a detailed land use map is needed that follows the contours of the forested areas. As the settlements are concentrated at the forest areas, the settlements are higher compared to the surrounding land and will not flood. The box below gives an example of the height overestimation.

Limitation of MERIT DEM

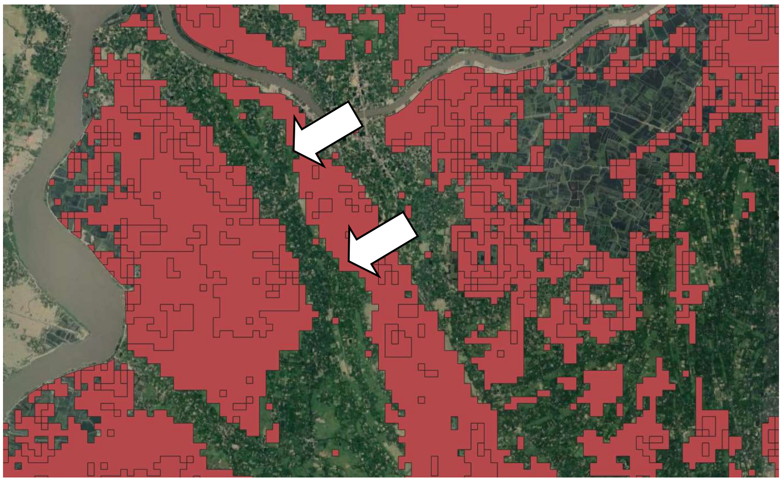
The figures below give an example of the height overestimation, which occurs in every polder.

The satellite image with a high concentration of buildings at densely vegetated area.

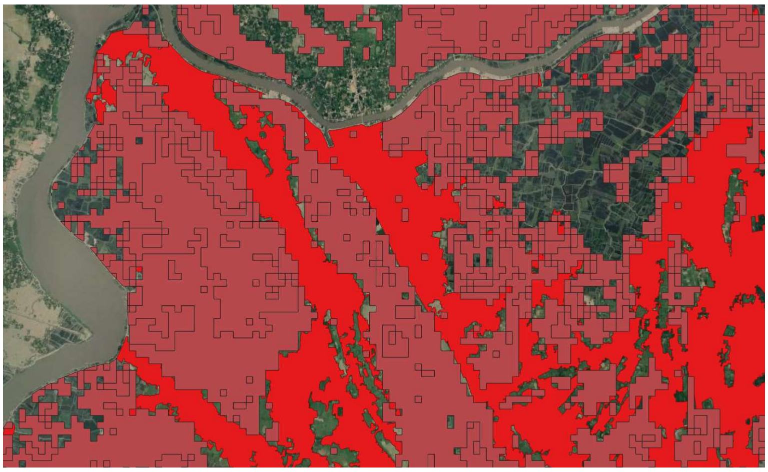


The MERIT DEM gives higher values at the settlement / densely vegetated area compared to the surrounding area.

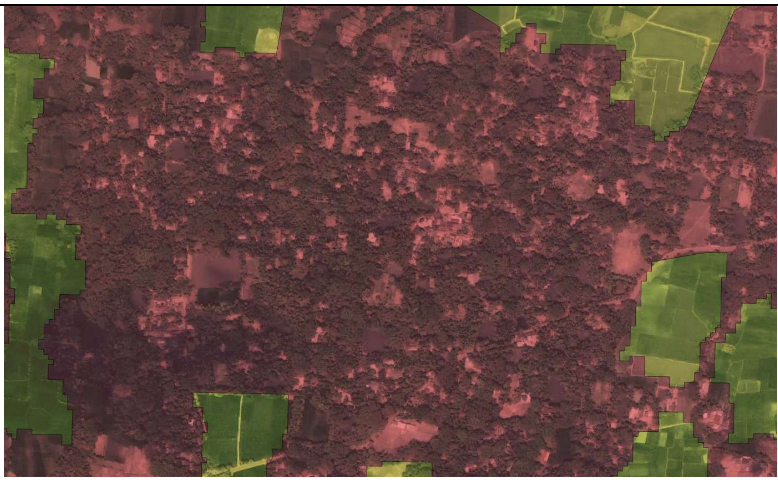
So even when the 100 years storm surge water depth is applied, the settlement areas are not affected:



To prove that, Consultant has used the landsat shapefile with the "Rural settlements" (in red):



It becomes clear that almost all the settlements' polygons are outside the affected area, which is not a realistic scenario. Apart from the above, the "Rural settlement" is, in many cases, an overestimating the populated areas. The example bellow is just one of the many areas checked that have the same problem.



The reddish area is considered as rural settlement, while it mostly contains vegetation and with a low density of houses.

From this overestimation it becomes clear that no use can be made of the rural settlement contours to remove the effect of vegetation in densely populated areas, since it is expected to produce large errors and will not give a right estimation of the terrain height.

As mentioned, since the land elevation is not precise in portraying the protective structures in place (which provides an average protection from a storm surge event of 10 years return period without climate change), in order to avoid overestimating the figures, the damages have been reduced for the case of a 10 year return period storm surge event including climate change.

People affected/ Loss of life estimation

In the last decades there have been developed many empirical models to approach the estimation of the storm surges fatality risks. After examination of the available literature various considerations arise regarding the overall performance of the models:

a. Factors that can reduce greatly the theoretically estimated casualties include mainly the presence of an early warning system, a solid evacuation protocol (tailored for each area) and the presence of storm shelters.
b. Parameters like the age composition of the involved population (higher vulnerability of children and elderly), the distance from the breached areas, the distance from high rise areas, the flow velocity of the waters, the speed of water rise and the structural strength of the buildings have to be taken into consideration for more accurate estimations, and some of them are, in fact, included in a number of models.

Considering that no such info is available, it has been decided to use the model proposed by Boyd et al. (2005), that derived from the post-flood survey data of seven flood events:

$$\mathrm{F(h)} = \frac{0.34}{(1 + \exp(20.37 - 6.18\mathrm{h}))}$$

where F(h) = loss of life rate from inundation depth h.

This function is S-shaped and it has an asymptote for mortality F D = 0.34 for water depth values that are approximately above 4 m. This implies that about two thirds of the population will always survive regardless of the water depth. With respect to this asymptote for mortality the authors state: "*One basic empirical fact of flood events is that there are always survivors.*

Rarely, if ever, has the entire population exposed to the flood perished. Instead, even if the water is extremely deep people tend to find debris, trees, attics, roofs, and other ways to stay alive. Only under the most extreme situations would one expect the fatality rate to reach one." (Boyd et al. 2005).

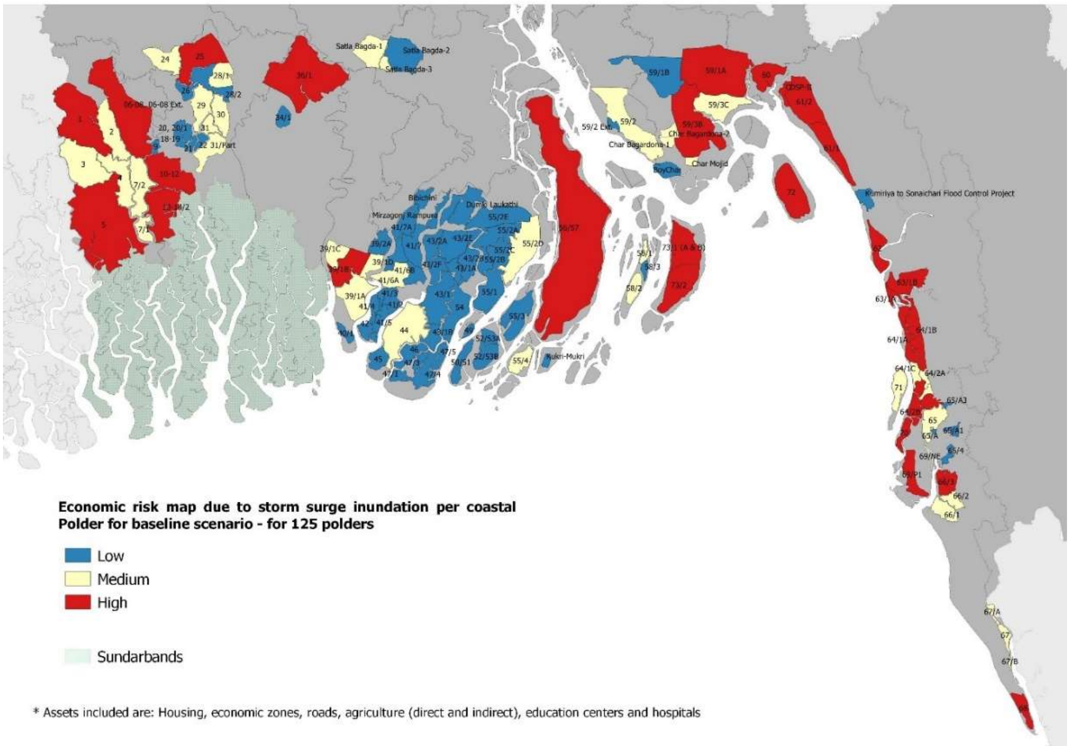
A1.8.3 Risk

Once a hazard and vulnerability assessment has been completed, straightforward steps can lead to the estimation of the storm surge inundation risk. By definition, risk considers the consequences and weighs in the aspect of the probability of occurrence of a hazardous events such as storm surge inundation. The risk is represented as monetary damage for various exceedance probabilities, while it can be presented via means of an exceedance probability curve.

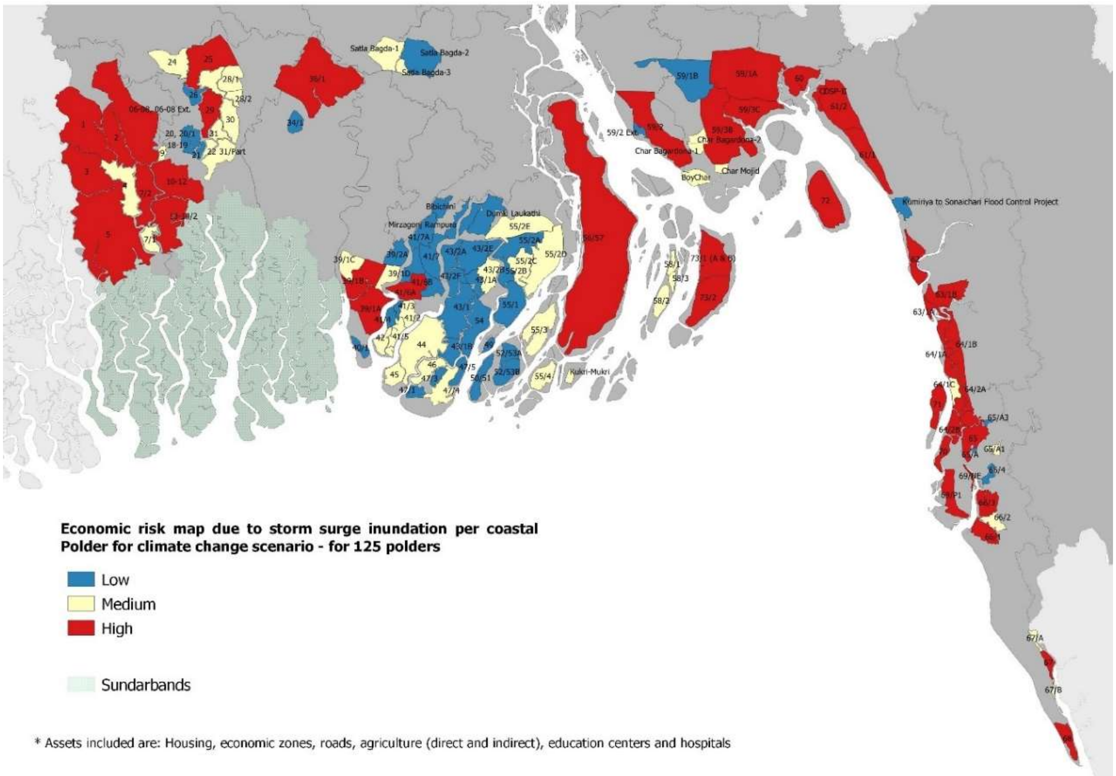
Large events that normally cause substantial damage may not contribute a great deal to the average annual costs due to their low probability. Increasing return periods also means an increase in the damage costs, however also a lower probability of occurring, yielding the relation seen in this figure between the flood risk and the return period[101]. Through estimation of Annual Expected Damage (EAD), the mean loss (the "expected value") that occurs in any given year is signified, which represents a long-term average.

Figure_Apx 26 and Figure_Apx 27 represent the economic risk map in 125 polders for baseline and climate change scenario respectively. Figure_Apx 28 and Figure_Apx 29 represent the social risk map (people affected by storm surge) for baseline and climate change scenario respectively.

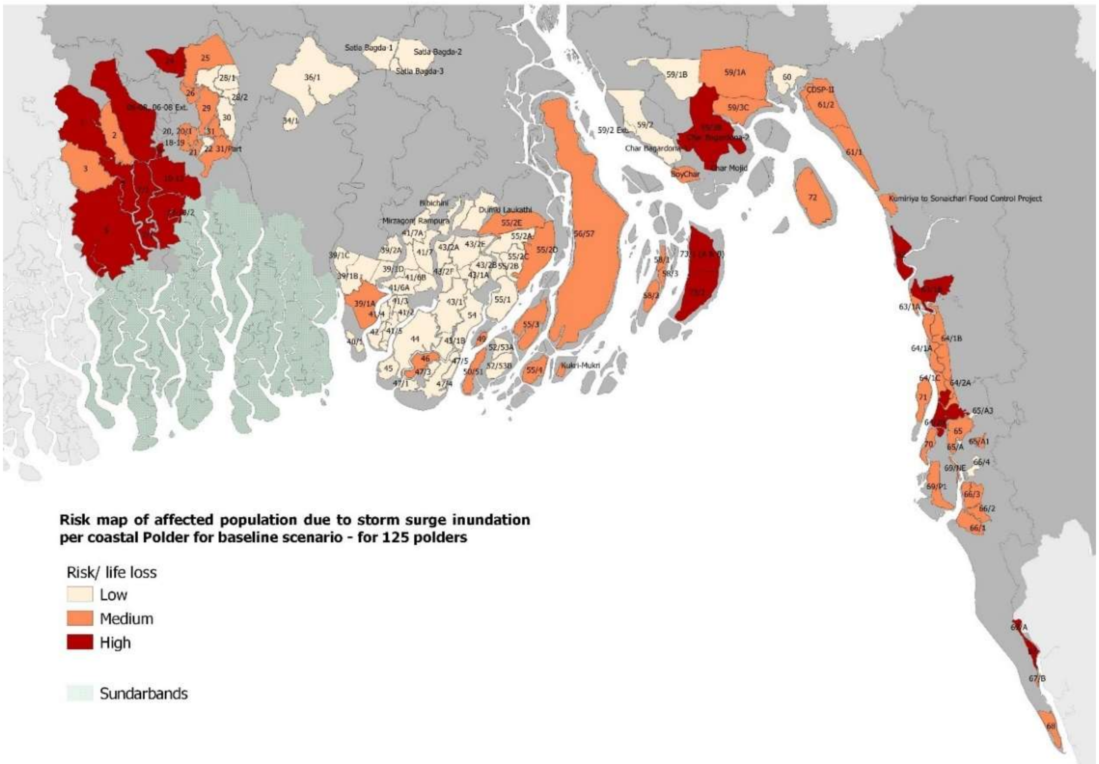
[101] Anders Skovgård Olsen et al. (2014) Comparing Methods of Calculating Expected Annual Damage in Urban Pluvial Flood Risk Assessments



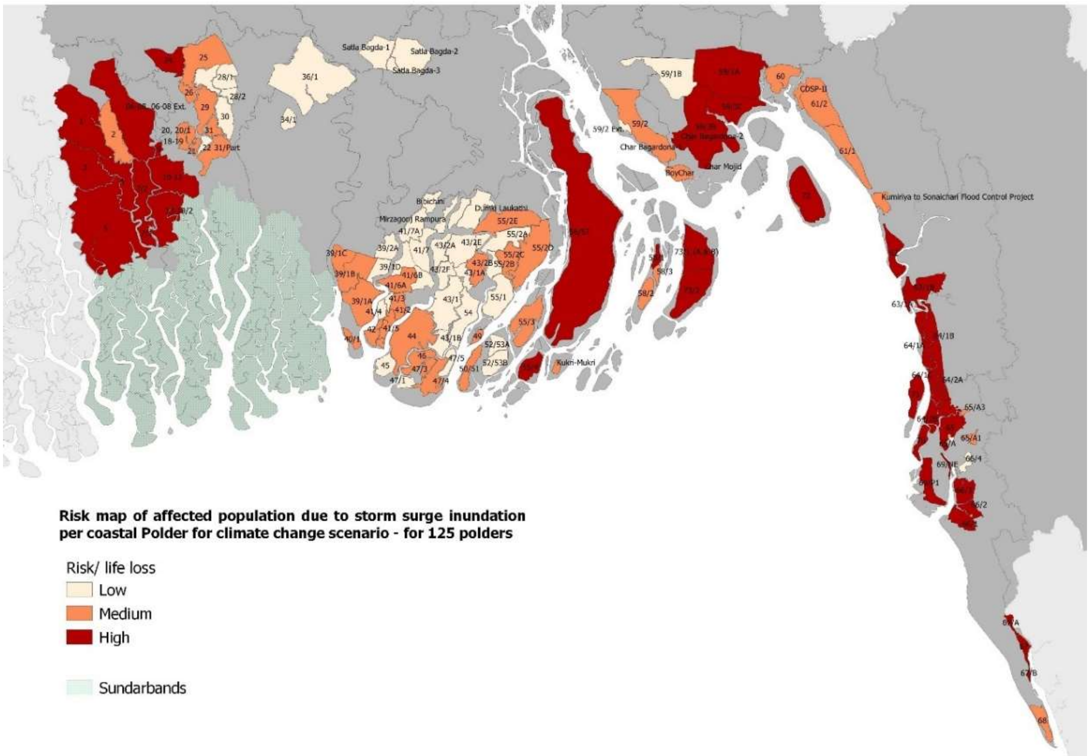
Figure_Apx 26: Economic risk map due to storm surge inundation for baseline scenario



Figure_Apx 27: Economic risk map due to storm surge inundation for climate change scenario



Figure_Apx 28: Risk map of affected population due to storm surge inundation per coastal polder for baseline scenario



Figure_Apx 29: Risk map of affected population due to storm surge inundation per coastal polder for climate change scenario

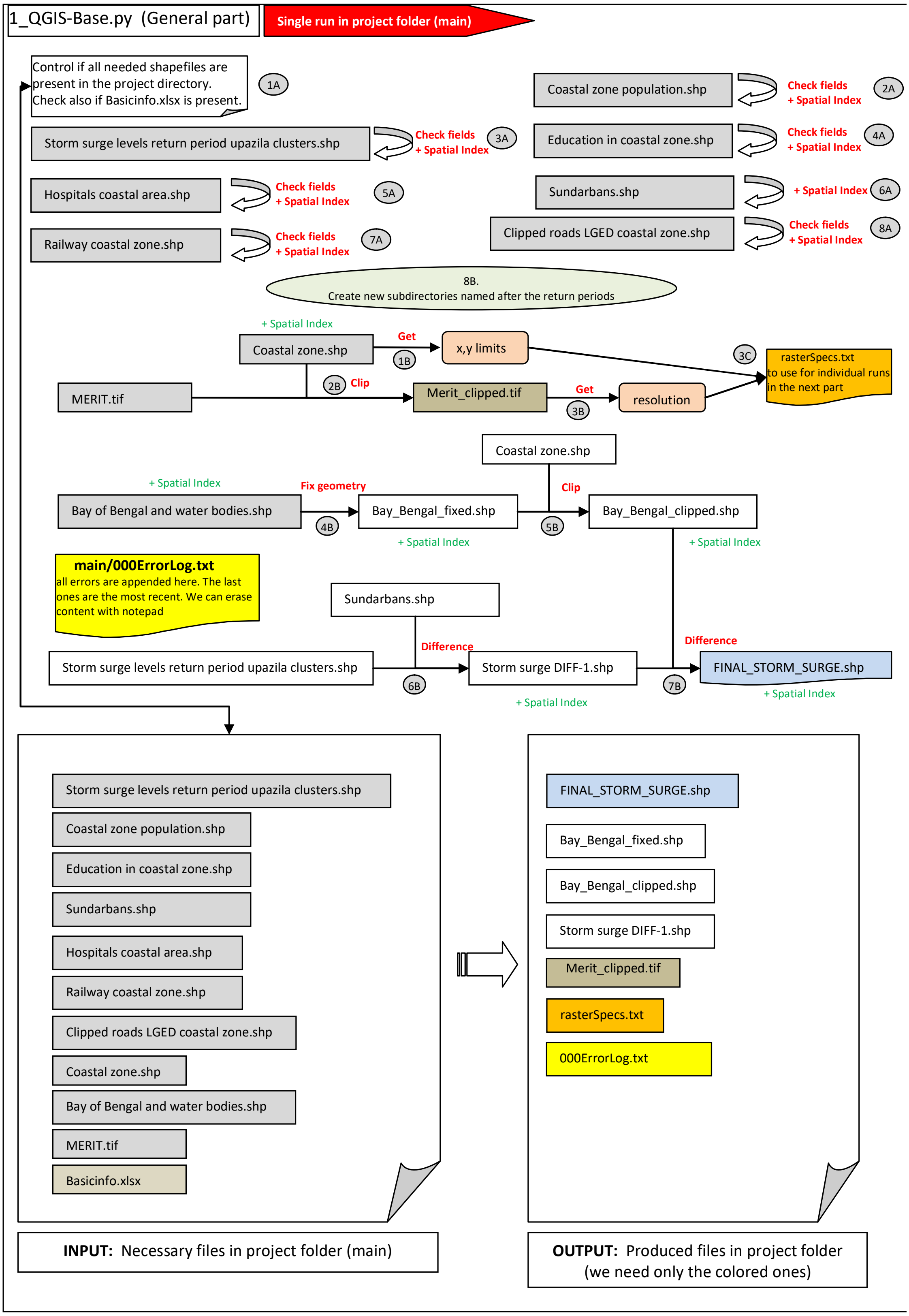
A1.8.4 QGIS/Python Tool

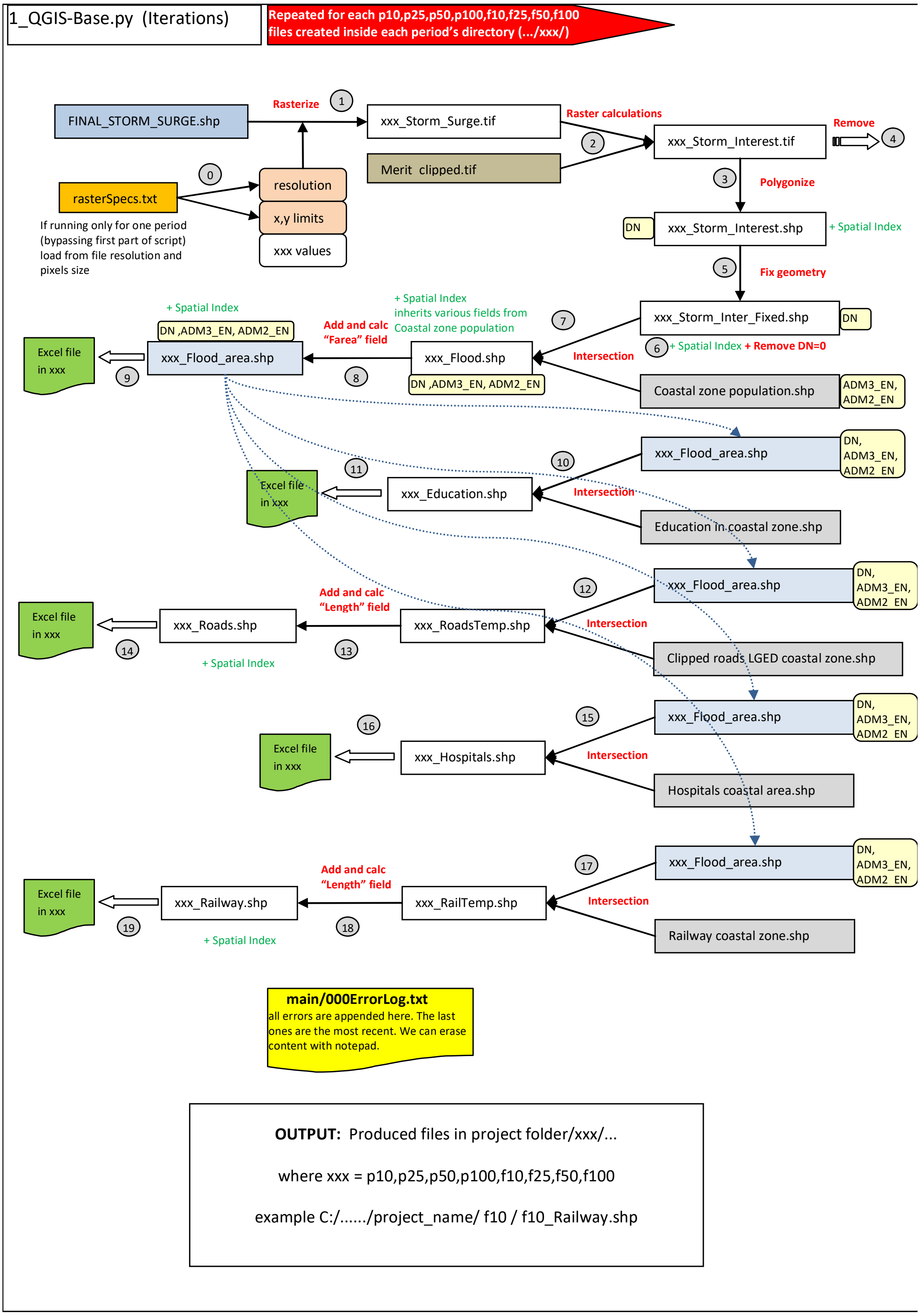
The Preliminary Flood Risk Assessment Tool was developed in Quantum GIS (QGIS) and Python for the data processing. In order to have a better control of the processing procedures, two different Python modules were developed. The first one working inside the QGIS shell as a console script, and the second one as a standalone python script that has as input the output of the first module.

QGIS Python module

It runs inside QGIS after being loaded in the console. It combines the data of the various shapefiles regarding the main categories of the polders' geoinformations (roads, rails, hospitals, polder area, agriculture, etc), the Merit DEM and the shapefile of the storm surge events of 10, 25, 50 and 100 years (spatial extension of the inundation depth both with and without climate change). After a series of computations the module produces for each return period various excel files regarding the inundation depths of each segment (area or length) in each category (for example, Polder X, road length xx meters, inundation depth xx meters, road type xxx, or Polder X, agriculture area xx sqm, inundation depth xx meters).

In the two figures that follow the computational flow charts of the first Python module are supplied.

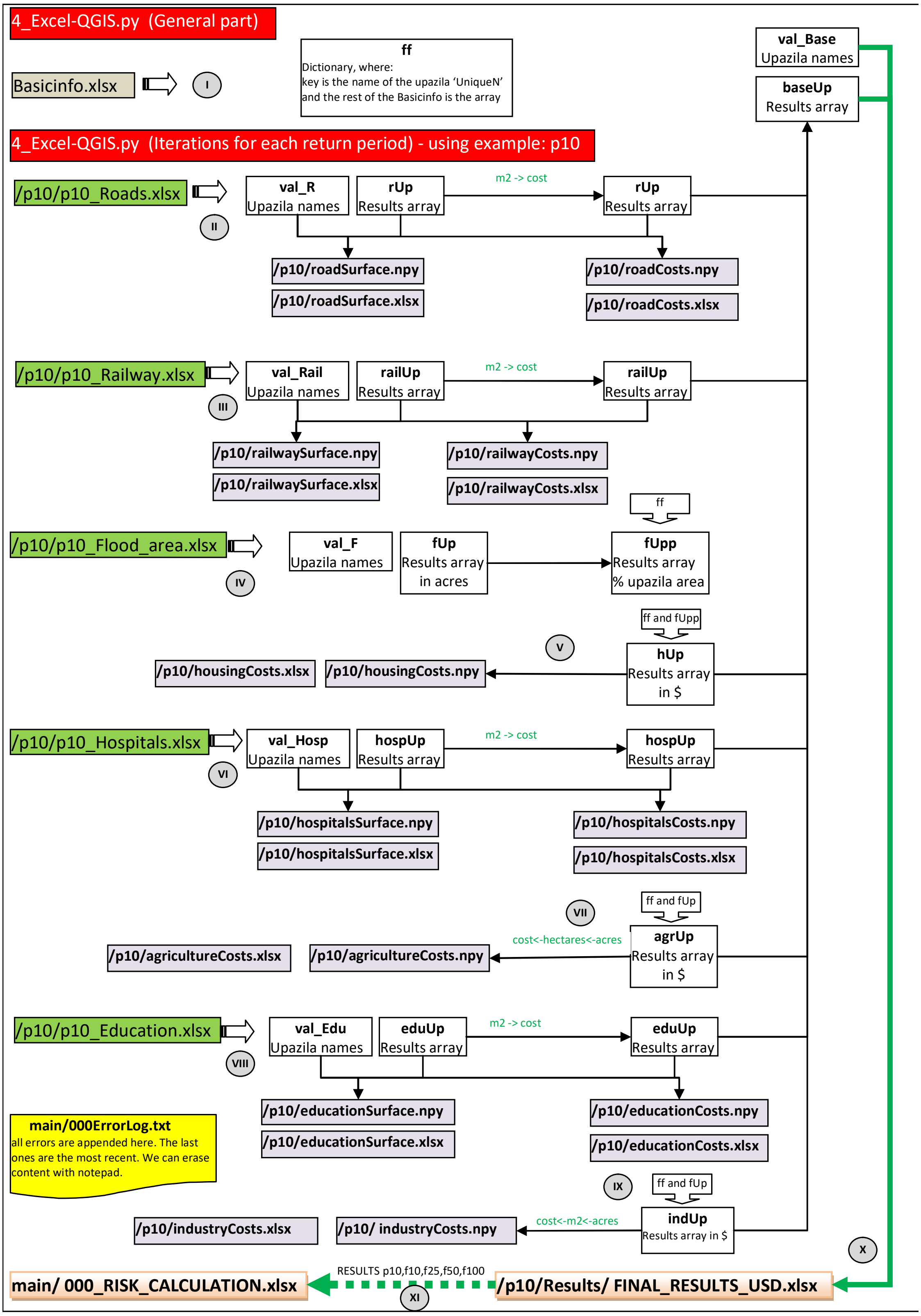

1_QGIS-Base.py (General part)
Single run in project folder (main)
Control if all needed shapefiles are present in the project directory. Check also if Basicinfo.xlsx is present.
1A
Storm surge levels return period upazila clusters.shp
Check fields + Spatial Index
3A
Hospitals coastal area.shp
Check fields + Spatial Index
5A
Railway coastal zone.shp
Check fields + Spatial Index
7A
Coastal zone population.shp
Check fields + Spatial Index
2A
Education in coastal zone.shp
Check fields + Spatial Index
4A
Sundarbans.shp
+ Spatial Index
6A
Clipped roads LGED coastal zone.shp
Check fields + Spatial Index
8A
8B. Create new subdirectories named after the return periods
+ Spatial Index
Coastal zone.shp
Get
1B
x,y limits
3C
rasterSpecs.txt to use for individual runs in the next part
MERIT.tif
2B
Clip
Merit_clipped.tif
Get
3B
resolution
Coastal zone.shp
+ Spatial Index
Fix geometry
Clip
Bay of Bengal and water bodies.shp
4B
Bay_Bengal_fixed.shp
5B
Bay_Bengal_clipped.shp
+ Spatial Index
+ Spatial Index
main/000ErrorLog.txt
all errors are appended here. The last ones are the most recent. We can erase content with notepad
Sundarbans.shp
Difference
Difference
Storm surge levels return period upazila clusters.shp
6B
Storm surge DIFF-1.shp
7B
FINAL_STORM_SURGE.shp
+ Spatial Index
+ Spatial Index
Storm surge levels return period upazila clusters.shp
Coastal zone population.shp
Education in coastal zone.shp
Sundarbans.shp
Hospitals coastal area.shp
Railway coastal zone.shp
Clipped roads LGED coastal zone.shp
Coastal zone.shp
Bay of Bengal and water bodies.shp
MERIT.tif
Basicinfo.xlsx
FINAL_STORM_SURGE.shp
Bay_Bengal_fixed.shp
Bay_Bengal_clipped.shp
Storm surge DIFF-1.shp
Merit_clipped.tif
rasterSpecs.txt
000ErrorLog.txt
INPUT: Necessary files in project folder (main)
OUTPUT: Produced files in project folder (we need only the colored ones)


1_QGIS-Base.py (Iterations)
Repeated for each p10,p25,p50,p100,f10,f25,f50,f100 files created inside each period's directory (.../xxx/)
FINAL_STORM_SURGE.shp
Rasterize
1
xxx_Storm_Surge.tif
Raster calculations
Merit clipped.tif
2
xxx_Storm_Interest.tif
Remove
4
3
Polygonize
rasterSpecs.txt
0
resolution
x,y limits
xxx values
If running only for one period (bypassing first part of script) load from file resolution and pixels size
DN
xxx_Storm_Interest.shp
+ Spatial Index
5
Fix geometry
xxx_Storm_Inter_Fixed.shp
DN
6
+ Spatial Index + Remove DN=0
+ Spatial Index inherits various fields from Coastal zone population
7
Intersection
Coastal zone population.shp
ADM3_EN, ADM2_EN
xxx_Flood.shp
DN ,ADM3_EN, ADM2_EN
Add and calc "Farea" field
8
+ Spatial Index
DN ,ADM3_EN, ADM2_EN
xxx_Flood_area.shp
Excel file in xxx
9
xxx_Flood_area.shp
DN, ADM3_EN, ADM2_EN
10
Intersection
Education in coastal zone.shp
xxx_Education.shp
11
Excel file in xxx
xxx_Flood_area.shp
DN, ADM3_EN, ADM2_EN
12
Intersection
Clipped roads LGED coastal zone.shp
xxx_RoadsTemp.shp
Add and calc "Length" field
13
xxx_Roads.shp
+ Spatial Index
Excel file in xxx
14
xxx_Flood_area.shp
DN, ADM3_EN, ADM2_EN
15
Intersection
Hospitals coastal area.shp
xxx_Hospitals.shp
16
Excel file in xxx
xxx_Flood_area.shp
DN, ADM3_EN, ADM2_EN
17
Intersection
Railway coastal zone.shp
xxx_RailTemp.shp
Add and calc "Length" field
18
xxx_Railway.shp
+ Spatial Index
Excel file in xxx
19
main/000ErrorLog.txt
all errors are appended here. The last ones are the most recent. We can erase content with notepad.
OUTPUT: Produced files in project folder/xxx/...
where xxx = p10,p25,p50,p100,f10,f25,f50,f100
example C:/....../project_name/ f10 / f10_Railway.shp

<u>Standalone Python module:</u>

The second module reads the categories' excel files resulting from the first module and for each return period and category orders the data per polder and clusters them in their designated inundation depth class (the depth classes used are 1, 2, 3, 4, 5 and ≥6 meters). Once the clustering is done the geometry characteristics (area or length) are summed and translated in damage estimation per category, polder and return period, using appropriate conversion factors. Lastly, the module computes the risk assessment for all return periods per polder.

In the figure that follows the computational flow chart of the second Python module is supplied.


4_Excel-QGIS.py (General part)
Basicinfo.xlsx
I
ff
Dictionary, where:
key is the name of the upazila 'UniqueN'
and the rest of the Basicinfo is the array
val_Base
Upazila names
baseUp
Results array
4_Excel-QGIS.py (Iterations for each return period) - using example: p10
/p10/p10_Roads.xlsx
II
val_R
Upazila names
rUp
Results array
m2 -> cost
rUp
Results array
/p10/roadSurface.npy
/p10/roadSurface.xlsx
/p10/roadCosts.npy
/p10/roadCosts.xlsx
/p10/p10_Railway.xlsx
III
val_Rail
Upazila names
railUp
Results array
m2 -> cost
railUp
Results array
/p10/railwaySurface.npy
/p10/railwaySurface.xlsx
/p10/railwayCosts.npy
/p10/railwayCosts.xlsx
ff
/p10/p10_Flood_area.xlsx
IV
val_F
Upazila names
fUp
Results array
in acres
fUpp
Results array
% upazila area
ff and fUpp
V
/p10/housingCosts.xlsx
/p10/housingCosts.npy
hUp
Results array
in $
/p10/p10_Hospitals.xlsx
VI
val_Hosp
Upazila names
hospUp
Results array
m2 -> cost
hospUp
Results array
/p10/hospitalsSurface.npy
/p10/hospitalsSurface.xlsx
/p10/hospitalsCosts.npy
/p10/hospitalsCosts.xlsx
VII
ff and fUp
/p10/agricultureCosts.xlsx
/p10/agricultureCosts.npy
cost<-hectares<-acres
agrUp
Results array
in $
/p10/p10_Education.xlsx
VIII
val_Edu
Upazila names
eduUp
Results array
m2 -> cost
eduUp
Results array
/p10/educationSurface.npy
/p10/educationSurface.xlsx
/p10/educationCosts.npy
/p10/educationCosts.xlsx
main/000ErrorLog.txt
all errors are appended here. The last ones are the most recent. We can erase content with notepad.
IX
ff and fUp
/p10/industryCosts.xlsx
/p10/ industryCosts.npy
cost<-m2<-acres
indUp
Results array in $
X
main/ 000_RISK_CALCULATION.xlsx
RESULTS p10,f10,f25,f50,f100
XI
/p10/Results/ FINAL_RESULTS_USD.xlsx

Appendix 2 Field visit reports

A2.1 Polder 4

The CEP was taken up for construction of embankment and other infrastructure by creating polders for safeguarding the area from salinity & increasing the agricultural lands in 1960. Polder 4 has a 80 km long embankment covering Assasuni Upazila under Satkhira District surrounded by mighty flowing rivers like Kobadak and Kholpetua and other small rivers. Due to the cyclonic surges hit of "Ayla" in 2009, "Foni" & "Bulbul" in 2019 and "Amphan" in 2020, polder 4 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges.

Polder description

As per information from field division, out of 80km of Polder 4, 30 km is situated on the right bank of Kobadak river and others are situated by the side of other rivers. The gross protected area is 10,500 ha of which total cultivable area is 8,400 ha. Crop & shrimps are being cultivated here (crop:3,360 ha & shrimp: 5,040 ha).

Technical

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30m and side slopes were 1:2 in C/S (country side) & 1:3 in R/S (river side). There are many fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankment become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 80 km embankment need complete rehabilitation out of which 6.80 km is most vulnerable and 11.90 km is vulnerable.

Tidal affect

The high tide waves around the turbulent rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 15 km riverbank protective works and 22 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 20. Moreover, 25 numbers box inlet are to be constructed. 54 km drainage channel is required to be re-excavated for smooth navigation.

Afforestation

For environmental safeguarding, a green belt of about 30 ha area is required to be brought under afforestation. For this, around 150,000 seedlings will be planted.

Figure_Apx 30: Polder 4 at Kakrabunia, Assasuni, Satkhira.

Figure_Apx 31: Polder 4 at Hazratkhali, Assasuni, Satkhira.

Figure_Apx 32: Polder 4 at Daksin Puijala, Assasuni,

A2.2 Polder 5

The CEP was taken up for construction of embankment and other infrastructure by creating polders for safeguarding the area from salinity & increasing the agricultural lands in 1960. This polder system was started from Satkhira, the then sub-division of Khulna District and now a District situated in the south-western zone of Bangladesh adjacent to Indian border. This is the largest polder with a 194.35 km long embankment covering Shyamnagar & Kaliganj Upazila and surrounded by mighty flowing rivers like Kalindi, Kholpetua, Kakshiali, Goalghesia, Chuna, Chunkuri, Malancha and many others. Due to the cyclonic surges hit of "Ayla" in 2009, "Foni" & "Bulbul" in 2019 and "Amphan" in 2020, polder 5 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure in order by fighting against river erosion, high tide, flood & drainage congestion and especially the cyclonic surges.

Polder description

As per information from field division, out of 194.35 km of polder 5, 27 km is situated on the right bank of Kholpetua river, 46 km is situated on the left bank of Kalindi river and others are situated by the side of Mothergang, Mirgang, Kakshiali, Golghesia rivers. The gross protected area is 55,061 ha of which total cultivable area is 48,583 ha. Crop & shrimps are being cultivated here (crop:34,008 ha & shrimp: 14,575 ha).

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD & 4.57 mPWD respectively along the river of Kholpetua & Kalindi with crest width of 4.30m and side slopes were 1:2 in C/S & 1:3 in R/S. There are plenty of fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankment become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 194.35 km embankment need complete rehabilitation.

Tidal affect

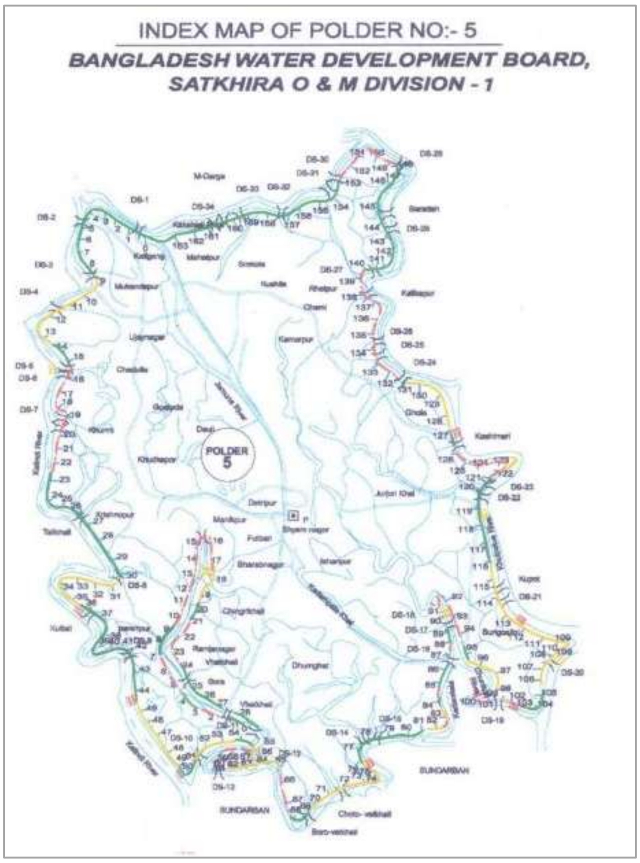
The high tide waves around the turbulent rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 20.083 km riverbank protective works and 23.313 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 43. Moreover, 63 numbers box inlet are to be constructed. 104 km drainage channel and 11 km small river are required to be re-excavated for smooth navigation. In addition to this, 18.8 km river dredging is required.

Afforestation

For environmental safeguarding, a green belt of about 140 ha area is required to be brought under afforestation. For this, around 400,000 seedlings will be planted.



Figure_Apx 33: Index map of Polder 5

Figure_Apx 34: Polder 5 km 89.500 at Chuna, Shyamnagar, Satkhira

Figure_Apx 35: Polder 5 km 110.200 at Dargabati, Shyamnagar, Satkhira

Figure_Apx 36: Polder 5 km 32.500 at Noikati, Shyamnagar, Satkhira

Figure_Apx 37: Polder 5 km 132.500 at Madinar Darga, Kaliganj, Satkhira

Figure_Apx 38: Polder 5 km 123.500 at Biral Laxmi, Shyamnagar, Satkhira

Figure_Apx 39: Polder 5 km 6.100 at Hadda, Kaliganj, Satkhira

A2.3 Polder 7/1

Polder 7/1 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges. 34.21 km embankment need complete rehabilitation out of which 7 km is most vulnerable and 13.50 km is vulnerable. Therefore, the field division is asking 5 km riverbank protective works and 15 km embankment slope protection work for safeguarding the embankment. In addition, The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 7. Moreover, 12 numbers box inlet are to be constructed. 32 km drainage channel is required to be re-excavated for smooth navigation. For environmental safeguarding, a green belt of about 5 ha area is required to be brought under afforestation. For this, around 50,000 seedlings will be planted.

Polder description

As per information from field division, out of 34.21 km of Polder 7/1, 10 km is situated on the right bank of Kobadak river and others are situated by the side of other rivers. The gross protected area is 3,110 ha of which total cultivable area is 2,700 ha. Crop & shrimps with overlapping (Crop & Shrimp are producing in same area) are being cultivated here (crop:1,866 ha & shrimp: 2,500 ha).

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30m and side slopes were 1:2 in C/S & 1:3 in R/S. There are plenty of fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankment become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 34.21 km embankment need complete rehabilitation out of which 7 km is most vulnerable and 13.50 km is vulnerable.

Tidal affect

The high tide waves around the turbulent rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 5 km riverbank protective works and 15 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 7. Moreover, 12 numbers box inlet are to be constructed. 32 km drainage channel is required to be re-excavated for smooth navigation.

Afforestation

For environmental safeguarding, a green belt of about 5 ha area is required to be brought under afforestation. For this, around 50,000 seedlings will be planted.

Figure_Apx 40: Polder 7/1:at Jhapa-1, Assasuni, Satkhira.

Figure_Apx 41: Polder 7/1 at Jhapa-1, Assasuni, Satkhira.

Figure_Apx 42: Polder 7/1 at Jhapa-2, Assasuni, Satkhira.

A2.4 Polder 7/2

Polder 7/2 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges. 59.59 km embankment need complete rehabilitation out of which 15.50 km is most vulnerable and 19.20 km is vulnerable. Therefore, the field division is asking 15 km riverbank protective works and 25 km embankment slope protection work for safeguarding the embankment. In addition, the existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 14. Moreover, 32 numbers box inlet are to be constructed. 62 km drainage channel is required to be re-excavated for smooth navigation. For environmental safeguarding, a green belt of about 55 ha area is required to be brought under afforestation. For this, around 150,000 seedlings will be planted

Polder description

As per information from field division, out of 59.59 km of Polder 7/2, 20 km is situated on the right bank of Kobadak river and others are situated by the side of other rivers. The gross protected area is 10,486 ha of which total cultivable area is 8,390 ha. crop & shrimps with overlapping (Crop & Shrimp are producing in same area) are being cultivated here (crop: 5,870 ha & shrimp: 2,520 ha).

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30m and side slopes were 1:2 in C/S & 1:3 in R/S. There are plenty of fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankments become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 59.59 km embankment need complete rehabilitation out of which 15.50 km is most vulnerable and 19.20 km is vulnerable.

Tidal affect

The high tide waves around the turbulent rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 15 km riverbank protective works and 25 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 14. Moreover, 32 numbers box inlet are to be constructed. 62 km drainage channel is required to be re-excavated for smooth navigation.

Afforestation

For environmental safeguarding, a green belt of about 55 ha area is required to be brought under afforestation. For this, around 150,000 seedlings will be planted.

Figure_Apx 43: Polder 7/2 at Tutikhali-1, Assasuni, Satkhira

Figure_Apx 44: Polder 7/2 at Tutikhali-2, Assasuni, Satkhira

Figure_Apx 45: Polder 7/2 at Tutikhali-3, Assasuni, Satkhira.

Figure_Apx 46: Polder 7/2 at Banyatola, Assasuni, Satkhira.

Figure_Apx 47: Polder 7/2 at Bamondanga, Assasuni, Satkhira.

A2.5 Polder 10-12

The CEP was taken up for construction of embankment and other infrastructure by creating polders for safeguarding the area from salinity & increasing the agricultural lands in 1960. Polder 10-12 has 67 km long embankment covering Koyra and Paikgacha Upazila under Khulna District surrounded by mighty flowing rivers like Shibsha, Kurulia and Koyra. Due to the cyclonic surges hit of "Ayla" in 2009, "Foni" & "Bulbul" in 2019 and "Amphan" in 2020, polder 10-12 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges.

Polder description

As per information from field division, out of 67 km of Polder 10-12, 10 km is situated on the left bank of Shibsha river and others are situated by the side of Kurulia and Koyra rivers. The gross protected area is 16,315 ha of which total cultivable area is 12,715 ha. crop & shrimps are being cultivated here (crop:6,870 ha & shrimp: 5,845 ha).

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30m and side slopes were 1:2 in C/S & 1:3 in R/S. There are many fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankment become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 67 km embankment need complete rehabilitation out of which 15 km is most vulnerable and 28 km is vulnerable.

Tidal affect

The high tide waves around the mighty rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 11 km riverbank protective works and 23 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 15. Moreover, 28 numbers box inlet are to be constructed. 52 km drainage channel is required to be re-excavated for smooth navigation.

Afforestation

For environmental safeguarding, a green belt of about 70 ha area is required to be brought under afforestation. For this, around 260,000 seedlings will be planted.

Figure_Apx 48: Polder 10-12 at Kumkhali, Paikgacha, Khulna

Figure_Apx 49: Polder 10-12 at Near Kumkhali, Paikgacha, Khulna

Figure_Apx 50: Polder 10-12 at Baintala Gate, Paikgacha, Khulna

A2.6 Polder 13-14/2

The CEP was taken up for construction of embankment and other infrastructure by creating polders for safeguarding the area from salinity & increasing the agricultural lands in 1960. Polder 13-14/2 has 91.77 km long embankment covering Koyra Upazila under Khulna District surrounded by mighty flowing rivers like Kobadak, Ungtihara and Koyra. Due to the cyclonic surges hit of "Ayla" in 2009, "Foni" & "Bulbul" in 2019 and "Amphan" in 2020, polder 13-14/2 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges.

Polder description

As per information from field division, out of 91.77 km of Polder 13-14/2, 45 km is situated on the left bank of Kobadak river and others are situated by the side of Koyra and Ungtihara rivers. The gross protected area is 17,854 ha of which total cultivable area is 14,280 ha. crop & shrimps are being cultivated here (crop:12,850 ha & shrimp: 1,430 ha).

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30 m and side slopes were 1:2 in C/S & 1:3 in R/S. There are some fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankment become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 91.77 km embankment need complete rehabilitation out of which 35.70 km is most vulnerable and 30.68 km is vulnerable.

Tidal affect

The high tide waves around the mighty Kobadak river are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field Division is asking 25 km riverbank protective works and 25 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 16. Moreover, 33 numbers box inlet are to be constructed. 74 km drainage channel is required to be re-excavated for smooth navigation. In addition to this, 15 km river dredging is required. Conditions of all the 12 sluices/water control structures is very bad and 4 of them are fully damaged. Some of the collected pictures of damaged embankment, sluice and protective works are given bellow.

Figure_Apx 51: Embankment failure in polder 13-14/2

Afforestation

For environmental safeguarding, a green belt of about 40 ha area is required to be brought under afforestation. For this, around 250,000 seedlings will be planted.

Figure_Apx 52: Polder 13-14/2 at Hogla-1, Koyra, Khulna.

Figure_Apx 53: Polder 13-14/2 at Hogla-2, Koyra, Khulna.

Figure_Apx 54: Polder 13-14/2 at Dashalia, Koyra, Khulna

A2.7 Polder 29

The CEP was taken up for construction of embankment and other infrastructure by creating polders for safeguarding the area from salinity & increasing the agricultural lands in 1960. Polder 29 has 49 km long embankment covering Batiaghata and Dumuria Upazila under Khulna District surrounded by mighty flowing Rivers like Gangrail, Bhadra and Upper Shaltha. Due to the cyclonic surges hit of “Ayla” in 2009, “Foni” & “Bulbul” in 2019 and “Amphan” in 2020, polder 29 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges.

Polder description

As per information from field division, out of 49 km of Polder 29, 10 km is situated on the left bank of Gangrail river and others are situated by the side of Bhadra and Upper Shaltha rivers. The gross protected area is 8218 ha of which total cultivable area is 6,570 ha. Only Crops are produced in all 6,570 leaving no shrimp to cultivate here.

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30 m and side slopes were 1:2 in C/S & 1:3 in R/S. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 49 km embankment need complete rehabilitation out of which 10 km is most vulnerable and 18 km is vulnerable.

Tidal affect

The high tide waves around the mighty rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 9 km riverbank protective works and 13 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 11. There are also 81 numbers of flushing inlets which need rehabilitation. 72 km drainage channel is required to be re-excavated for smooth navigation.

Afforestation

For environmental safeguarding, a green belt of about 70 ha area is required to be brought under afforestation. For this, around 240,000 seedlings will be planted.

Figure_Apx 55: Polder 29 at Chandgar, Dumuria, Khulna

Figure_Apx 56: Polder 29:at Baroaria, Batiaghata, Khulna

A2.8 Polder 31

The CEP was taken up for construction of embankment and other infrastructure by creating polders for safeguarding the area from salinity & increasing the agricultural lands in 1960. Polder 31 has 47 km long embankment covering Dacope Upazila under Khulna District surrounded by mighty flowing rivers like Possure, Shibsha, Dhaki, Bhadra, Jhapjhapia and Chunkuri. Due to the cyclonic surges hit of "Ayla" in 2009, "Foni" & "Bulbul" in 2019 and "Amphan" in 2020, polder 31 has been damaged tremendously. It has now become a challenge for BWDB to maintain its embankment and other infrastructure from river erosion, high tide, flood & drainage congestion and especially the cyclonic surges.

Polder description

As per information from field division, out of 47 km of Polder 31, 12 Km is situated on the right bank of Possure river and others are situated by the side of Shibsha, Dhaki, Bhadra, Jhapjhapia and Chunkuri rivers. The gross protected area is 7,288 ha of which total cultivable area is 6,500 ha. Crop & shrimps with overlapping (crop & shrimp are producing in same area) are being cultivated here (crop:6,072 ha & shrimp: 4,858 ha).

Technical embankment description

During construction phase, the embankment was constructed keeping its reduced level at 4.27 mPWD with crest width of 4.30 m and side slopes were 1:2 in C/S & 1:3 in R/S. There are plenty of fish culture projects owned by local people (locally called "Gher") inside the polder. The Gher owners usually take saline water from the river through pipes installed beneath the embankment by boring without taking sufficient protective measures and thereby the embankment become weak. Due to lack of proper maintenance and prolonged use, the design level in many places has been lost. The situation becomes critical and overtopping of embankment/ breach in the embankment occurs when cyclonic surge like Amphan/Ayla hits the embankment. Besides this, river erosion is also one of the reasons for damage of embankment. Some photographs are pasted below this report. Thus, 47 km embankment need complete rehabilitation out of which 13 km is most vulnerable and 18 km is vulnerable.

Tidal affect

The high tide waves around the mighty rivers are damaging the embankment twice daily by hitting its slopes. River erosion is also damaging the embankment. For protecting the embankment, requisite measures for protecting the slope of embankment and riverbank are required to be taken up. The field division is asking 15 km riverbank protective works and 22 km embankment slope protection work for safeguarding the embankment.

Drainage

The existing drainage regulators are not functioning due prolonged use and required to be rebuilt and the number is 24. Moreover, 24 numbers box inlet are to be constructed. 72 km drainage channel is required to be re-excavated for smooth navigation.

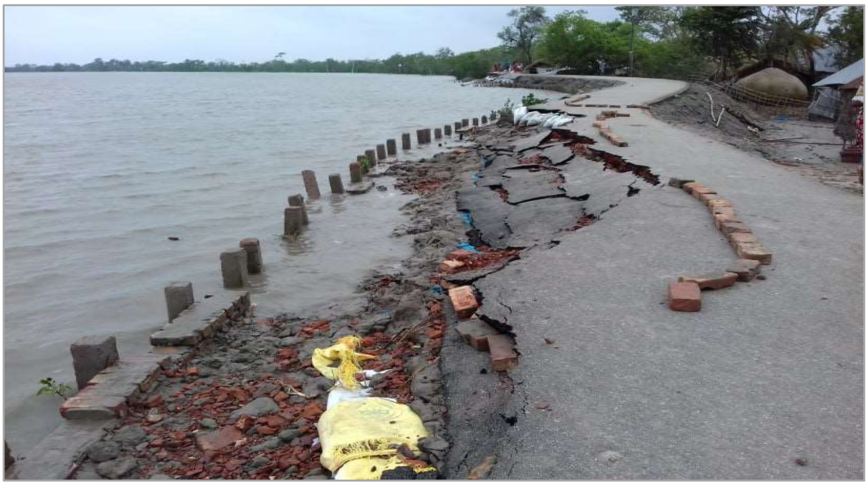
Afforestation

For environmental safeguarding, a green belt of about 60 ha area is required to be brought under afforestation. For this, around 225,000 seedlings will be planted.

Figure_Apx 57: Polder 31 at Jhalbunia, Dacope, Khulna.

Figure_Apx 58: Polder 31:at Kaminibashi, Dacope, Khulna.

Figure_Apx 59: Polder 31 at Khona, Dacope, Khulna



Figure_Apx 60: Polder 31 at Botbunia, Dacope, Khulna

A2.9 Polder 30

Polder description

Polder No- 30 is located at Batiyagata Upazila of Khulna District. Total length of the embankment is about 40 km out of which about 22 km is paved road. The polder is situated in three unions covering a total of 8,048 ha land inside the polder, 27 water management structures (drainage sluice and flashing sluice) and 39 km of drainage canal inside the polder.

In many placed the local people took shelter on the embankment for their residential purposes. A lot of shops are also found on the embankment in particularly settlement areas. Some community properties including mosques, clubs, etc. are also constructed on the embankment. Main occupation of local people are business and fish cultivation.

Water Management Organization (WMO)

WMO is quite active in this polder. Local people are involved in the committee. Conflict among the committee members is not reported during the reconnaissance visit. The water management committee supervises the entry and exit of river water into the polder.

Potential impact on land acquisition and resettlement

Two locations have major impact due to the erosion of river and therefore, need to construct retired embankment. Re-sectioning of the embankment is also required in most areas of the embankment. Approximately 5 ha land will need to be acquired for rehabilitation of the embankment. It is estimated that about 800 residential household, more than 300 commercial enterprises and 6 Community Properties (CPRs) will potentially be affected due to rehabilitation of the polder.

Tidal affect

Aila and Sidr damaged the embankment though the Yeas, Mohasen, Bulbul and Nargis had very little impact on the Polder 30. Still the local people remains scared as the river water could damage the embankment and cause severe impact on their livelihood. Also water can over flow the embankment during the cyclone as the embankment height is very low.

Public opinion

Local people think that in some places embankment situation is very critical. The risk is higher as the Poshur River is very close. Moreover, river erosion can damage the embankment at any time and therefore they will be in trouble to manage the crop production and fish culture. Rehabilitation of the polder is an urgent need of the people.

Photographs below have been taken on 5th august 2021.


Figure_Apx 61: Foron Para, Botiiaghata, Khulna.

Figure_Apx 62: Gopalkhali, Botiaghata, Khulna.

Figure_Apx 63: Kismot Fultola, Botiaghata, Khulna

A2.10 Polder 39

Polder description

Polder No- 31 is located at Dacope Upazila of Khulna District. Total length of embankment is about 47 km out of which 15 km is paved road. The remaining area is very vulnerable to river erosion threat. The polder is situated in two union and one municipality covering total 14,998 ha land inside the polder, 27 water management structures (DS and FS) and 7.5 km of drainage canal. The polder is always under river erosion and tidal surge threat. Main occupation of local people are business and fish cultivation

WMO

There is no WMOs in this polder. But people are interested to be the part of water management by forming WMOs.

Potential impact on land acquisition and resettlements

Five locations along the embankment are very vulnerable and need to be reconstructed. Most of the areas of the embankment are under threat of erosion and for rehabilitation of this polder about 10 hector land will need to be acquired. Around 900 residential households, about 800 commercial enterprises and 9 CPRs (mosque, club, etc.) will be affected due to the project.

Tidal affect

Aila and Sidr created damage to the embankment. In many places the embankment breached. Moreover, the people faced severe loss during the YEAS and Amphan due to damage of the embankment. Water over-topping during large high tide is a common phenomenon since the embankment height is very low. This creates a massive crop loss almost every year.

Public opinion

Local people opined that in some places the embankment condition is very bad and they can be affected by tidal affect at any time. The risk of natural disaster is higher as the Shibsha River is very close. Moreover river erosion will create great loss unless the embankments are strengthened.

Photograph have been taken on 5th August 2021

Figure_Apx 64: Gorkathi, Dacope, Khulna

Figure_Apx 65: Khona, Dacope, Khulna

Figure_Apx 66: Kamini basia, Dacope, Khulna.

Figure_Apx 67: Botbunia Bazar, Dacope, Khulna

Figure_Apx 68: Pankhali, Dacope, Khulna

A2.11 Polder 40/1

Polder description

Polder No- 40/1 is located at Patharghata Upzilla of Barguna District. The polder 40/1 situated in one union covering a total of 3,567 ha land and 22,326 population in 5,535 families inside the polder. The polder contains 12 primary schools, 2 high schools, 1 college, 3 madrashas, 4 community clinics and 3 cyclone shelters. Total length of embankment is about 27 km out of which about 3 km is paved road. Remaining area is mostly exposed to the river and quite vulnerable.

WMO

There is no WMO in polder 40/1. Due to non-existence of WMO people cannot take any decision collectively. People are very much interested to be the part of WMO for agriculture and fishery activities.

Potential impact on land acquisition and resettlement

About 6 km of the area has river erosion threat. 1.5 km of embankment has to be replaced and 4.5 km has to be strengthened. Also protective work for 4.5 km embankment is urgently required. Rehabilitation of the embankment including reconstruction of flushing sluice and drainage sluice will require about 17 ha land acquisition. There are more than 200 shops and more than 400 families have taken shelter on the embankment due to displacement by river erosion and other reasons.

Tidal affect

As it is close to the sea, normal waves hit the embankment. Due to cyclone Yeas and Aila the embankment has suffered a lot of damage. High tide usually affects the polder and local people suffers every year.

Public opinion

The opinion of the people of the area is to build sustainable and high-quality embankment without repairing the dams every year. The BWDB has to work every year to protect the embankment. WMO is required to keep the people in unity and get benefit from the project.

Figure_Apx 69: Polder-40/1, Location- Chorlathimara, Uapzilla: Patharghata , District: Barguna

Figure_Apx 70: Polder-40/1, Location- Haringhata Bazar, Uapzilla: Patharghata , District: Barguna

Figure_Apx 71: Polder-40/1, Location- Padma, Uapzilla: Patharghata , District: Barguna

Figure_Apx 72: Polder-40/1, Location- Ruhita Bazar, Uapzilla: Patharghata , District: Barguna

A2.12 Polder 41/6A

Polder description

Polder No- 41/6A is located at Barguna Sadar Upzilla, Barguna District. Total length of embankment is about 34 km out of which 13 km paved road. Remaining areas are in bad condition and about 3 km area is under river erosion threat. The polder situated in 2 union covering total 5,200 ha land with 26,500 population in 6,500 families inside the polder. Total 25 primary schools, 6 high schools, 1 college and 5 Madrasahas are inside the polder.

WMO

There is no WMO inside the polder. People are interested to be part of the WMO for maximize benefit of the polder.

Potential impact on land acquisition and resettlement

About 3 km of area have river erosion threat. About 2.5 km of retired embankment is to be constructed and 1.5 km to be strengthened to protect from river erosion threat. Also protective work for 2.5 km embankment has to be done. Rehabilitation of the polder including retired embankment, protective work, re-sectioning and construction of flashing sluice & drainage sluice require about 13 ha of land acquisition and displacement of more than 400 shops in various small markets and more than 600 houses from the embankment.

Tidal affect

Due to cyclone Yeas & Aila the embankment got a lot of damage. It gets tidal affect in almost every year and people faces trouble.

Public opinion

People strongly opined to build sustainable and high-quality embankment so that it doesn't need to repair every year. The DWDB have to work every year to maintain the embankment.

Photograph have been taken on 5th august 2021

Figure_Apx 73: Polder-41/6A, Location- Jangalia, Uapzilla: Barguna Sadar , District: Barguna

Figure_Apx 74: Polder-41/6A, Location- Khadempur, Uapzilla: Barguna Sadar , District: Barguna

Figure_Apx 75: Polder-41/6A, Location- Adam Bazar, Uapzilla: Barguna Sadar , Barguna

Figure_Apx 76: Polder-41/6A, Location- Khadempur, Uapzilla: Barguna Sadar , Barguna

A2.13 Polder 47/1

Polder description

Polder No- 47/1 is located at Kalapara Upzilla, Mohipur thana under Patuakhali District. Total length of embankment is about 22 km out of which only 5 km paved road. Remaining area is mostly vulnerable and about 3.5 km embankment has river erosion. The polder situated at three Mouza in one union covering total 2,834 ha or 16 square km with 20,086 population in 6,155 families. The polder contains 13 primary schools, 1 high schools, 1 college, 2 Madrashas, 4 community clinics, 3 cyclone centres, 1 coast guard station and 1 police station inside the polder.

There are 400 vulnerable people (fishermen community) are found on the embankment and no commercial fish culture field (Gher) though there are many ponds near the embankment. The amount of agricultural land is high. Main occupation of the people is fishing in the river and sea.

WMO

There is no WMO in polder 47/1. General people know nothing about it.

Potential impact on land acquisition and resettlement

About 3.5 km retired embankment is required and another 4 km protective work has to be done. All flashing sluice & drainage sluices need to repair. Rehabilitation of the embankment and construction /repairing of the sluices require about 18 ha of land will have to be acquired. About 250 shops and about 800 houses are to be displaced.

Tidal affect

Due to the proximity of the sea and the shallowness of the river, tidal surge hit the embankment. Due to cyclone Yeas & Aila the embankment suffered a lot of damage.

Public opinion

The people strongly opined to build a sustainable and high-quality embankment. They also expressed their views to keep provision of fishermen community beside the embankment since they depend on the fishing in the river and sea. Maintenance of the embankment is very much necessary in every year to protect the people and crops inside the polder.

Figure_Apx 77: Polder-47.1, Location- Komolpur, thana- Mohipur, Upzilla: Kalapara, Dist-Patuakhali

Figure_Apx 78: Polder-47.1, Location- Nazibpur, thana- Mohipur, Upzilla: Kalapara, Dist-Patuakhali

Figure_Apx 79: Polder-47.1, Location- Nizampur, thana- Mohipur, Upzilla: Kalapara, Dist-Patuakhali

Figure_Apx 80: Polder-47.1, Location- Sudhirpur, thana- Mohipur, Upzilla: Kalapara, Dist-Patuakhali

Figure_Apx 81: Polder-47.1, Location- Sudhirpur, thana- Mohipur, Upzilla: Kalapara, Dist-Patuakhali

Figure_Apx 82: Polder-47.1, Location- Puran Mohipur, thana- Mohipur, Upzilla: Kalapara, Dist-Patuakhali

A2.14 Polder 55/1

Polder Description

Polder No. 55/1 is located at Galachipa Upzilla under Patuakhali District. Total length of embankment is about 47 km out of which about 22 km paved. Remaining area is in bad condition and about 12 km is under river erosion threat. The polder situated at four Union and one Municipality covering a total of 5,200 ha land and around 60,000 population in about 15,000 families inside the polder. The embankment has almost disappeared into the river along 5 km of the Lohalia River and 7 km of the Kajaldi River. There is most of the land is agriculture land and few is Fish Gher.

WMO

There is no WMO. The committee was there 15 to 20 years ago when OMIP worked.

Potential impact on land acquisition and resettlement

About 2.5 km retired embankment is required and 10 to 12 km protective work is to be done. All flashing sluice & drainage sluices are to be repaired. About 13 ha of land will have to be acquired to develop the embankment. About 1,000 shops and 800 houses will be displaced from the embankment. Apart from them there are about 1,500 vulnerable people (fishermen community) on the embankment who led their livelihood by fishing from the river/sea.

Tidal affect

The polder 55/1 is exposed to the river and vulnerable to river erosion threat. Due to cyclone Yeas and Aila the embankment has been damaged a lot.

Public opinion

The people living on and inside the polder expressed their views to strengthen the embankment with a sustainable solution so that repairing will not be required every year.


Figure_Apx 83: Polder-55/1, Location- Barnatali, Uapzilla: Galachipa , District: Patuakhali

Figure_Apx 84: Polder-55/1, Location- Bibirhaola, Uapzilla: Galachipa , District: Patuakhali

Figure_Apx 85: Polder-55/1, Location- Dakua, Uapzilla: Galachipa , District: Patuakhali


Figure_Apx 86: Polder-55/1, Location- Panpatti Lunch Ghat, Uapzilla: Galachipa , District: Patuakhali

Figure_Apx 87: Polder-55/1, Location- Panpatti Lunch Ghat, Uapzilla: Galachipa , District: Patuakhali

Figure_Apx 88: Polder-55/1, Location- Ratandi Taltali, Uapzilla: Galachipa , District: Patuakhali

Figure_Apx 89: Polder-55/1, Location- Ratandi Taltali, Uapzilla: Galachipa , District: Patuakhali

A2.15 Polder 59/3B

Consultant visited 2 spots of the polder-59/3B in Noakhali District on 18-08-2021. During their field visits, they have been collected some pictures which are given below;

Figure_Apx 90: Polder 59/3B, Akhter Miar Hat, Union: Mohammadpur, Upazila: Subarnachar, District: Noakhali

The segment of embankment in the first picture is in the home state area and is used as the road. For frequent movement of people and domestic animals, the grass turf has been damaged and has become into this shape. The sluice in the second picture is good and only requires some minor maintenance.

Appendix 3 MCA calculation of criteria

This Appendix describes in detail the calculation method the different criteria for the MCA.

A3.1 Land acquisition

This section describes the method to calculate the land acquisition areas for the high-level MCA. The potential land acquisition of the polders is calculated with the ratios of land acquisition from the executed work in the CEIP-1 polders. Different land acquisition ratios are calculated for internal (river facing) polders of package 1, and exposed (sea-facing) polders of package 2. From CEIP-1 the total length and the total area of land acquisition is known. These values are used to calculate the ratio of km land acquisition over the total embankment length and the land acquisition area over land acquisition length, see Table_Apx 5 for the used values and the calculated ratios. The average fractions are used to calculate the potential land acquisition area with the total embankment length of the polders.

Table_Apx 5: Calculation of land acquisition ratios with values from Package-1 and Package 2 of CEIP-1 polders

Package	Polder	Total embankment length [km]	Land acquisition length [km]	Land acquisition area [ha]	Land acquisition over total embankment length [km/km]	Land acquisition area over land acquisition length [ha/km]
1	32	48.8	29.4	50.6	0.60	1.7
	33	49.5	12.3	14.3	0.25	1.2
	35/1	62.0	19.6	41.5	0.32	2.1
	35/3	40.1	23.8	25.0	0.59	1.1
Average		**50.1**	**21.3**	**32.8**	**0.44**	**1.5**
2	39/2C	59.3	57.8	124.9	0.98	2.2
	40/2	35.6	7.6	11.7	0.21	1.5
	41/1	33.8	2.9	8.3	0.08	2.9
	43/2C	25.7	25.4	23.1	0.99	0.9
	47/2	17.6	5.6	2.6	0.32	0.5
	48	37.9	0.3	1.1	0.01	3.6
Average		**35.0**	**16.6**	**28.6**	**0.43**	**1.9**

In addition, the potential land acquisition is enlarged when the polder is subject to strong erosion and the requirement for land needs to account for a larger set back distance. Based on the bank erosion score different ratios are applied ranging between 0.95 and 1.1 to enlarge the potential land acquisition when the polder is subject to strong erosion and to reduce the potential land acquisition when erosion is not present or in small quantities. An example calculation for both river and sea facing polders is visible in Table_Apx 6.

Table_Apx 6: Calculation of land acquisition areas with difference ratios for sea and river facing polders and erosion scores

Polder	Sea / river facing	Erosion Score MCA	Total embankment length [km]	Land acquisition over total embankment length [km/km]	Land acquisition length [km]	Land acquisition area over land acquisition length [ha/km]	Land acquisition area [ha]	Erosion ratio	Land acquisition area with erosion [ha]
1	River	2	97.0	0.44	42.7	1.5	64.4	0.95	61.2
7/2	River	4	59.6	0.44	26.2	1.5	39.6	1.05	41.6
47/5	Sea	5	33.0	0.43	14.2	1.9	27.2	1.1	30.0

A3.2 Rehabilitation costs

This section describes the method to calculate the rehabilitation costs for the for the high-level MCA. The rehabilitation costs consist out of costs estimates for the construction work, the expected land acquisition and resettlement, the mobilization, the contingencies and the cost for project management, detailed designs, supervision services and other services required for project implementation.

The construction work is roughly estimated based on the condition of the existing structures, the expected required crest of the embankments and the need for bank and slope protection works. Volumes and quantities for the construction work are estimated for:

- the construction / re-sectioning of embankments;
- construction / repairment of drainage sluices and flushing inlets;
- excavation / re-excavation of drainage channels;
- river bank protection, and
- slope protection.

The potential construction work in the polder is calculated with the ratios of implemented work from the design of CEIP-1 polders. The ratios are calculated with the total structures and the executed work in the CEIP-1 polders. The average fractions of the packages are calculated for package 1 and 3, river facing polders, and package 2, sea facing polders. The ratios of implemented works over existing is visible in *Table_Apx 7*.

Table_Apx 7: Ratio of implemented work over existing structures from the design of CEIP-1 polders

Ratio of implemented works over existing structures	Ratio riverine polders (Average package 1 and 3)	Ratio coastal polders (Average package 2)
Construction/ Re-sectioning of Embankment over total length of embankment	1.00	1.00
Excavation/ Re-excavation of Drainage Channel over existing length of drainage channel	1.03	0.89
Construction of Drainage Sluices over total number of existing drainage sluices	0.91	1.08
Repairing of Drainage Sluices over total number of existing drainage sluices	0.06	0.06
Construction of flushing Inlets over total number of existing flushing inlets	0.37	0.74
Repairing of Flushing Inlets over total number of existing flushing inlets	0.10	0.33
Embankment Slope Protection Work over total embankment length	0.06	0.04
Riverbank Protection Work over total embankment length	0.01	0.02
Land acquisition per km over total embankment length	0.44	0.43
Land acquisition area over land acquisition length	1.51	1.92

The costing of the interventions is calculated with unit rates based on current market prices based on Bangladesh Schedules of Rates and the unit rates in the current Contractor's packages in CEIP-1. Costs from CEIP-1 are taken for package 1 (riverine polders) and package 2 (coastal polders) as both contain prices that have are contracted and negotiated. Table_Apx 8 gives the unit rates of the structures calculated from the total per package in the contract and the unit rates of the land acquisition and resettlement based on the executed work.

The unit rates for the structures are escalated to 2021 with an annual inflation rate of 105,7% based on an average annual inflation of consumer prices from 2015-2021 in Bangladesh[102]. The average inflation of Bangladesh is chosen as the price of each construction material is influenced differently by multiple factors, i.e. country of origin, means of transportation. The escalation rate for the land acquisition is taken at 400% to account for a cost increase of land foreseen in

[102] World Bank, https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD Accessed 27 September 2021

the coming years. The resettlement costs are not foreseen to change and therefore not escalated.

Table_Apx 8: Unit rates for structures and land acquisition and resettlement calculated from current CEIP-1 Packages 1 and 2 escalated to 2021.

Interventions	Unit	Package 1 (riverine polders)		Package 2 (coastal polders)	
		2015	2021	2015	2021
Embankment Earth	[BDT /km]	7,084,712.00	9,883,804	8,409,250	11,731,652
Drainage Sluices	[BDT /Nos]	16,734,812.79	23,346,555	30,451,479	42,482,526
Repairing Drainage Sluices	[BDT /Nos]	4,200,865.50	5,860,582	3,039,089	4,239,800
Flushing Inlets	[BDT /Nos]	9,167,034.63	12,788,830	11,442,084	15,962,726
Repairing Flushing Sluices	[BDT /Nos]	2,745,388.73	3,830,062	2,061,891	2,876,521
Excavation Drainage Channels	[BDT /km]	822,200.02	1,147,042	1,037,055	1,446,784
Embankment Slope Protection	[BDT /km]	57,333,551.50	79,985,412	113,884,433	158,878,930
Riverbank Protection	[BDT /km]	172,401,683.07	240,515,707	672,309,349	937,931,440
Land acquisition	[BDT /ha]	11,936,528	47,746,114	29,775,800	119,103,201
Resettlement	[BDT /ha]	2,090,432	2,090,432	5,688,264	5,688,264

Based on the bank erosion score different ratios are applied to enlarge the potential bank protection when the polder is subject to strong erosion and more bank protection is required for protection. The earth for embankment is enlarged when the needed embankment reinforcement height is high. The reinforcement height is calculated based on the average crest level and the design crest levels from the CEIP-1 designs. The ratios used to enlarge the potential bank protection and the embankment earth quantities are given in *Table_Apx 9*.

Table_Apx 9: Ratios to change the quantities of embankment earth and riverbank protection based on the bank erosion and the required embankment reinforcement height

	Range	ratio
Erosion Score	1	1
	1	1
	3	1.1
	4	1.3
	5	1.5
Embankment reinforcement height [m]	0-1	0.98
	1-1.5	1
	1.5-2	1.05
	2-2.5	1.1
	2.5-3	1.15

Appendix 4 MCA polder screening results

	Social and institutional					Technical				Constructability			Environmental					Economic			
	People affected	Community vulnerability	Land acquisition	Community water management	Stakeholder policies	Condition of embankments	Erosion of banks	Drainage Congestion	Design under climate change	Logistics and travel times	Availability of construction materials	Polder clustering into Packages	Ecologically sensitive areas	Aquatic fauna	Soil quality	Water quality	Opportunities for NBS	Rehabilitation Cost	Comparative benefits	**Total score**	**Rank**
	0.05	0.06	0.04	0.04	0.12	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.02	0.03	0.04	0.10	0.09		
Polder No	**Score (1-5)**																				
1	1	5	1	3	1	5	2	4	2	4	2	2	1	5	3	5	1	5	2	2.77	34
2	1	5	2	3	1	5	2	4	2	4	2	3	1	3	2	5	1	4	1	2.67	45
3	1	5	1	3	1	5	3	4	2	3	1	3	1	3	1	5	1	4	1	2.53	62
4	2	5	1	3	5	5	4	4	3	3	1	5	1	1	1	5	1	5	1	3.31	11
5	1	5	1	3	5	4	4	4	2	3	1	5	4	1	4	5	4	5	2	3.48	4
06-08, 06-08 Ext.	1	5	1	3	1	3	3	5	2	4	2	2	1	5	1	5	1	4	2	2.65	48
7/1	2	5	3	3	5	5	5	2	2	5	1	5	1	3	1	5	3	5	1	3.53	2
7/2	1	5	1	3	5	5	5	3	3	4	2	5	1	4	2	5	1	5	1	3.51	3
9	4	5	5	3	1	4	3	1	3	5	1	3	1	1	1	5	1	4	1	2.69	44
10-12	1	3	1	3	5	4	3	3	2	2	2	5	1	5	2	5	4	5	1	3.26	14
13-14/2	1	5	1	3	5	4	5	3	2	4	1	5	5	5	1	5	4	5	1	3.68	1
18-19	1	5	3	3	1	5	2	2	2	4	1	3	1	1	1	5	1	5	1	2.50	71
20, 20/1	1	5	4	3	1	2	2	2	3	5	1	4	1	1	1	5	1	5	1	2.53	63
21	1	5	4	3	1	4	2	1	2	4	1	4	1	1	1	5	1	5	1	2.51	68

22	1	5	4	5	1	4	5	1	2	4	2	5	1	3	1	5	1	5	1	2.95	24
24	1	5	4	3	1	5	2	3	2	4	1	2	1	2	1	5	1	4	1	2.51	70
25	1	5	3	5	1	4	2	4	2	3	1	3	1	1	1	5	1	4	1	2.52	64
26	1	5	4	5	1	5	2	2	3	5	1	4	1	1	1	5	1	5	1	2.77	33
27/1, 27/2	1	5	3	5	1	4	2	2	2	4	1	4	1	3	1	5	1	5	1	2.69	43
28/1	1	5	4	5	5	4	2	2	2	5	2	5	1	5	1	5	1	5	1	3.45	5
28/2	1	5	4	5	5	4	3	2	2	5	2	5	1	2	1	5	1	5	1	3.36	8
29	1	5	2	5	5	4	5	3	3	3	3	5	1	3	2	5	1	4	1	3.44	6
30	1	5	3	5	1	4	4	3	2	5	4	4	1	1	3	5	1	4	1	2.90	25
31	1	5	2	3	5	4	4	3	2	5	4	5	1	2	1	5	1	4	1	3.34	10
31/Part	1	5	3	5	5	4	5	2	2	2	3	5	1	5	1	5	1	4	1	3.40	7
34/1	1	5	5	3	1	5	2	2	2	5	1	2	1	1	1	5	1	4	1	2.47	79
36/1	1	5	1	3	1	4	3	5	2	3	1	2	1	3	2	5	1	4	2	2.53	61
39/1A	1	5	1	3	1	2	5	5	3	4	2	5	1	1	2	3	5	2	1	2.64	52
39/1B	1	5	1	3	5	2	4	3	3	4	3	3	1	1	3	3	5	2	1	2.96	22
39/1C	1	5	3	3	5	3	5	2	3	4	2	3	1	1	2	3	5	5	1	3.27	13
39/1D	1	5	4	3	1	2	3	3	3	4	1	4	1	1	1	3	2	4	1	2.47	78
39/2A	1	5	3	3	1	5	4	4	2	4	2	3	1	5	2	3	1	4	1	2.78	32
40/1	1	5	3	1	1	5	5	2	4	4	2	5	1	1	1	3	4	2	1	2.64	53
41/2	1	5	2	3	1	5	3	4	3	4	2	4	1	1	1	4	1	2	1	2.46	82
41/3	1	5	4	3	1	5	3	2	4	4	2	4	1	5	1	4	1	4	1	2.86	29
41/4	1	5	4	3	1	5	4	3	3	4	2	4	1	1	1	4	1	4	1	2.72	39
41/5	1	5	1	3	5	5	5	3	4	4	3	3	1	1	1	4	5	2	1	3.22	17
41/6A	1	5	3	1	1	2	4	2	4	4	2	5	1	1	2	4	5	4	1	2.72	38
41/6B	1	5	2	3	1	5	4	3	2	4	2	4	1	1	1	4	1	4	1	2.59	58

41/7	1	5	2	3	5	3	5	3	2	4	2	5	1	1	2	4	1	4	1	3.11	20
Mirzagonj Rampura	1	5	2	3	1	5	5	2	2	4	2	5	1	1	1	4	1	5	1	2.74	36
41/7A	1	5	3	3	1	2	3	3	2	4	2	5	1	1	1	4	1	4	1	2.49	73
Bibichini	1	5	4	3	1	5	3	1	2	4	2	4	1	1	1	4	1	5	1	2.64	51
41/7B	1	5	3	3	1	2	5	3	2	4	2	4	1	1	1	4	5	4	1	2.73	37
42	1	5	3	3	1	5	5	3	4	5	3	4	1	1	1	4	5	2	1	2.89	26
43/1	1	5	1	3	1	2	3	4	2	4	3	3	1	1	3	4	1	5	1	2.54	60
43/1A	1	5	4	5	1	3	2	3	2	5	3	3	1	1	1	4	1	4	1	2.62	55
43/1B	1	5	4	3	1	5	2	2	2	5	4	3	1	1	1	4	1	4	1	2.65	46
43/2A	1	5	3	5	5	3	5	3	2	4	2	5	1	1	1	4	1	4	1	3.24	16
43/2B	1	5	3	5	1	2	3	3	3	4	3	4	1	1	1	4	1	5	1	2.72	41
43/2D	1	5	3	5	1	1	2	4	2	4	2	4	1	1	2	4	1	4	1	2.48	75
43/2E	1	5	4	5	5	2	2	3	2	5	2	5	1	1	1	4	1	4	1	3.09	21
43/2F	1	5	3	3	1	1	2	3	2	4	2	4	1	1	1	4	1	4	1	2.34	90
Dumki Laukathi	1	5	2	3	1	5	3	2	2	5	2	3	1	1	2	4	1	5	1	2.60	56
Itbaria Labukhali	1	5	3	3	1	5	5	1	2	4	2	5	1	1	1	4	1	5	1	2.76	35
44	1	5	1	3	1	3	4	4	3	3	4	3	1	1	4	4	3	2	1	2.52	66
45	1	5	3	3	5	5	5	4	4	4	3	5	1	1	1	4	4	2	1	3.36	9
46	1	5	2	3	1	5	3	2	3	5	3	4	1	1	2	4	1	2	1	2.48	76
47/1	1	5	4	1	5	5	5	2	3	5	3	5	1	1	1	4	4	2	1	3.24	15
47/3	1	5	4	5	1	5	3	2	3	5	4	4	1	1	1	4	1	4	1	2.86	30
47/4	1	5	1	5	1	5	3	4	4	4	5	4	1	1	3	4	4	2	1	2.87	28
47/5	1	5	3	3	1	5	5	3	3	5	4	4	1	1	1	4	5	2	1	2.87	27

49	1	5	4	3	1	5	5	2	3	3	3	3	1	1	1	4	2	4	1	2.70	42
50/51	1	5	1	3	5	5	5	2	3	5	5	5	1	1	2	4	5	1	1	3.28	12
52/53A	1	5	4	3	1	2	2	1	3	4	3	3	1	5	1	4	3	2	1	2.44	85
52/53B	1	5	3	3	1	2	2	2	3	5	4	4	1	1	2	4	4	2	1	2.47	80
54	1	5	1	3	5	5	5	2	3	4	3	3	1	1	2	4	5	2	1	3.13	19
55/1	1	5	1	1	1	3	5	4	3	5	2	2	1	1		4	2	2	1	2.32	94
55/2A	1	3	3	5	1	2	2	3	2	5	3	4	1	1	2	4	1	4	1	2.48	77
55/2B	1	3	3	3	1	3	4	2	3	5	2	3	1	1	1	4	1	5	1	2.52	65
55/2C	1	3	2	5	1	2	3	2	3	4	3	3	1	1	2	4	1	5	1	2.51	67
55/2D	1	3	1	3	5	3	5	2	3	4	2	3	1	1	2	3	5	5	1	3.13	18
55/2E	1	3	1	3	5	3	3	4	3	4	2	5	1	1	3	3	1	4	1	2.96	23
55/3	1	1	1	3	1	2	5	3	3	4	4	2	1	1	2	4	4	2	1	2.27	104
55/4	1	1	3	3	1	2	5	2	4	4	5	2	1	1	2	4	4	2	1	2.36	89
Satla Bagda-1	1	1	4	3	1	3	2	2	2	4	5	1	1	1	2	3	1	5	1	2.30	100
Satla Bagda-2	1	1	3	3	1	3	2	2	2	4	2	1	1	1	2	1	1	5	1	2.08	120
Satla Bagda-3	1	1	4	3	1	4	2	2	2	5	3	1	1	1	1	4	1	5	1	2.31	98
56/57	1	1	1	3	1	4	5	5	3	3	2	2	1	1	3	3	3	2	2	2.33	93
58/1	1	3	2	3	1	2	5	2	2	5	2	1	1	1	1	4	3	2	1	2.14	117
58/2	1	3	3	3	1	2	5	2	3	5	3	1	1	1	2	4	4	2	1	2.34	91
58/3	1	3	4	3	1	3	4	1	3	5	2	1	1	1	1	4	4	2	1	2.26	107
59/1A	1	3	2	3	1	5	4	3	3	5	1	1	1	1	3	4	1	2	2	2.30	101
59/1B	1	3	3	3	1	4	2	3	3	5	1	1	1	1	2	4	1	4	1	2.29	103
59/2	1	3	1	3	1	4	5	2	3	4	2	1	1	1	2	4	1	2	1	2.15	116
59/2 Ext.	1	3	4	3	1	4	2	1	3	4	2	1	1	1	1	4	1	2	1	2.03	124
59/3B	3	3	1	3	1	5	2	3	3	4	2	1	1	1	5	4	1	2	2	2.32	95

59/3C	1	1	2	3	1	1	3	2	3	4	3	1	1	1	2	3	1	2	1	1.87	125
60	1	1	3	3	1	5	3	2	3	5	1	1	1	1	1	3	1	2	2	2.06	121
61/1	1	1	3	3	1	4	4	3	3	5	2	1	1	1		3	4	1	2	2.16	115
61/2	1	1	4	3	1	3	2	4	3	4	2	1	1	1	3	3	4	2	3	2.30	99
62	3	1	4	3	1	5	4	2	3	5	3	1	1	1	1	5	3	2	2	2.50	72
63/1A	3	1	1	3	1	5	5	3	3	3	2	1	1	1	1	5	3	2	2	2.32	97
63/1B	2	1	3	3	1	3	4	2	2	4	2	1	1	1	2	5	1	5	2	2.39	87
64/1A	2	1	1	3	1	5	5	3	3	4	2	1	1	1	2	5	1	2	1	2.24	109
64/1B	3	1	2	3	1	3	4	4	3	4	2	1	1	1	2	5	1	4	2	2.40	86
64/1C	3	1	4	3	1	5	2	2	3	5	1	1	1	1	1	4	1	1	1	2.03	123
64/2A	3	1	3	3	1	5	2	2	3	5	2	1	1	1	1	3	1	4	2	2.32	96
64/2B	2	1	1	3	1	5	3	3	3	4	2	1	1	1	1	3	2	2	1	2.09	118
65	2	1	2	3	1	5	4	4	4	4	3	1	1	1	1	3	1	4	1	2.47	81
65/A	1	1	5	3	1	3	2	1	4	5	1	1	1	1	1	3	1	5	1	2.20	111
65/A1	2	1	5	3	1	3	2	1	4	5	3	1	2	1	1	3	1	4	1	2.33	92
65/A3	2	1	5	3	1	4	4	1	4	5	2	1	1	1	1	3	1	4	1	2.38	88
66/1	1	5	4	3	1	5	3	2	4	5	3	1	1	1	1	5	2	1	1	2.44	83
66/2	3	5	4	3	1	5	2	2	4	5	2	1	1	1	1	4	1	4	1	2.62	54
66/3	3	1	2	3	1	5	2	3	4	3	2	1	1	1	1	4	4	4	2	2.44	84
66/4	1	1	3	3	1	2	2	3	4	4	1	1	1	1	1	4	2	4	1	2.09	119
67	4	3	5	3	1	4	2	2	4	5	5	1	1	1	1	4	1	4	1	2.72	40
67/A	5	1	5	3	1	3	2	2	4	4	5	1	1	1	1	4	1	5	2	2.64	49
67/B	5	1	5	3	1	3	3	1	4	5	3	1	1	1	1	4	1	4	2	2.54	59
68	1	5	3	3	1	4	4	3	3	4	1	1	1	1	1	4	1	2	1	2.25	108
69/NE	4	5	5	3	1	3	2	2	4	5	4	1	1	1	1	4	1	4	2	2.79	31

69/P1	2	1	3	3	1	3	4	2	4	1	2	1	1	1	1	4	4	2	3	2.22	110
70	2	3	3	3	1	5	5	2	4	4	1	1	1	1	1	3	3	2	3	2.49	74
71	2	1	2	3	1	5	5	3	3	5	1	1	1	1	1	4	1	2	1	2.19	112
72	2	1	1	3	1	3	5	3	3	5	1	1	1	1	3	4	4	2	2	2.26	105
73/1 (A & B)	2	1	1	3	1	5	5	4	2	4	2	1	1	1	3	4	3	2	2	2.29	102
73/2	1	5	1	3	1	5	4	3	3	5	3	1	1	1	3	4	4	2	2	2.60	57
Boychar	1	5	3	3	1	3	5	1	3	3	2	1	1	1	1	4	1	2	1	2.17	114
CDSP-II	1	3	5	3	1	3	3	1	3	5	5	1	1	2	1	3	4	2	3	2.51	69
Char Bagardona-1	4	3	3	3	1	4	3	1	3	5	2	1	1	1	1	4	1	2	1	2.26	106
Char Bagardona-2	4	5	4	3	1	4	2	2	3	5	2	1	1	1		4	1	5	1	2.64	50
Char Mojid	4	3	5	3	1	1	2	2	3	5	2	1	1	1	1	4	1	2	2	2.18	113
Kumiriya to Sonaichari Flood Control Project	1	5	5	3	1	3	2	1	3	5	1	1	1	1	1	3	2	1	1	2.04	122
Kukri-Mukri	1	5	4	3	1	3	5	1	4	2	5	1	5	1	1	4	4	2	1	2.65	47

Appendix 5 Comments from BWDB as per Memo No. CEIP-1/S23/598 dated 19th May 2022

Comments on Prioritization Report for the Consultancy Services for "Feasibility Studies and Preparation of Detailed Design for the Following Phase of CEIP (CEIP-2)"				
SI. No	**Ref.: Article No/ Page/ Existing text**	**Comments PMU, CEIP-1**	**Consultants reply to comments/changes in Polder Screening Report and MCA**	**Given response reference page/section no**
1	As in PDF 19-05-2022		References made to 15 new polders and 5 CEIP-1 polders have been removed	Page 19
2	As in PDF 19-05-2022		Not applicable	-
3	As in PDF 19-05-2022		Not applicable	-
4	As in PDF 19-05-2022		Not applicable	-
5	As in PDF 19-05-2022		Not applicable	-
6	As in PDF 19-05-2022		Not applicable as it was correctly mentioned in this report	-
7	As in PDF 19-05-2022		Not applicable	-
8	As in PDF 19-05-2022		In general, regarding the comment about changing the number of polders from 125 to 122, no changes were made since after consultations with field officials, some new polders came up resulting to 125 polders	Section 3.8, Page 82
9	As in PDF 19-05-2022		Changed. Score of no erosion is added as 1 and existing scores are ascending from 2-5	Section 3.3.2, Page 64
10	As in PDF 19-05-2022		Description of the scoring table is changed to a low score to high distance between the polders. This scoring is correct in the MCA and does not change the scores.	Section 3.4.3, Page 69
11	As in PDF 19-05-2022		The term salinity is explained and changed to saline area	Section 3.5.3, Page 70
12	As in PDF 19-05-2022		Not corrected as an higher score (poor quality of the Electrical Conductivity >4.0 dS/m) reflects the needs to improve the water quality and are therefore favorable to select in the MCA	Section 3.5.4, Page 72

Comments on Prioritization Report for the Consultancy Services for "Feasibility Studies and Preparation of Detailed Design for the Following Phase of CEIP (CEIP-2)"

SI. No	Ref.: Article No/ Page/ Existing text	Comments PMU, CEIP-1	Consultants reply to comments/changes in Polder Screening Report and MCA	Given response reference page/section no
13	As in PDF 19-05-2022		Description of the scoring table is changed to a low score to high rehabilitation costs. This scoring is correct in the MCA and does not change the scores.	Section 3.6.1, Page 77
14	As in PDF 19-05-2022		Not applicable	-
15	As in PDF 19-05-2022		Not applicable	-
16	As in PDF 19-05-2022		Not applicable	-
17	As in PDF 19-05-2022		Not applicable	-
18	As in PDF 19-05-2022		Not applicable	-
19	As in PDF 19-05-2022		Not applicable	-
20	As in PDF 19-05-2022		Description of the scoring table is changed to a low score to high rehabilitation costs. This scoring is correct in the MCA and does not change the scores.	Section 3.6.1, Page 77
21	As in PDF 19-05-2022		Not applicable	-
22	As in PDF 19-05-2022		Changed as per comment	Section 3.7, Page 79
23	As in PDF 19-05-2022		Changed as per comment	Table 3-3, Page 81
24	As in PDF 19-05-2022		Not applicable	-
25	As in PDF 19-05-2022		Not applicable	-
26	As in PDF 19-05-2022		Not applicable	-
27	As in PDF 19-05-2022		Not applicable	-
28	As in PDF 19-05-2022		Not applicable	-

Comments on Prioritization Report for the Consultancy Services for "Feasibility Studies and Preparation of Detailed Design for the Following Phase of CEIP (CEIP-2)"				
SI. No	**Ref.: Article No/ Page/ Existing text**	**Comments PMU, CEIP-1**	**Consultants reply to comments/changes in Polder Screening Report and MCA**	**Given response reference page/section no**
29	As in PDF 19-05-2022		Not applicable	-
30	As in PDF 19-05-2022		Not applicable	-

Comment by Consultant: Consultant observed few other inconsistencies in the MCA and has finetuned it, which resulted to a slight change of the ranking of the polders with the same data and criteria. The tunings refer to: method of scoring polders for which information is lacking, inclusion of the criteria 'comparative benefits' in the total score as it was inadvertently left out from the overall polder score calculation and update of the ranges of scoring between the 23 polders for the criteria 'people affected' and 'polder clustering into packages.