Climate Change, Sea level Rise & It's Impact on Water Management for the Coastal Communities of Bangladesh

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Institute of Water Modelling

BANGLADESH

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- Challenges of Water Resources Management for Coastal Area
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  - ✓ *Storm Surge Inundation*

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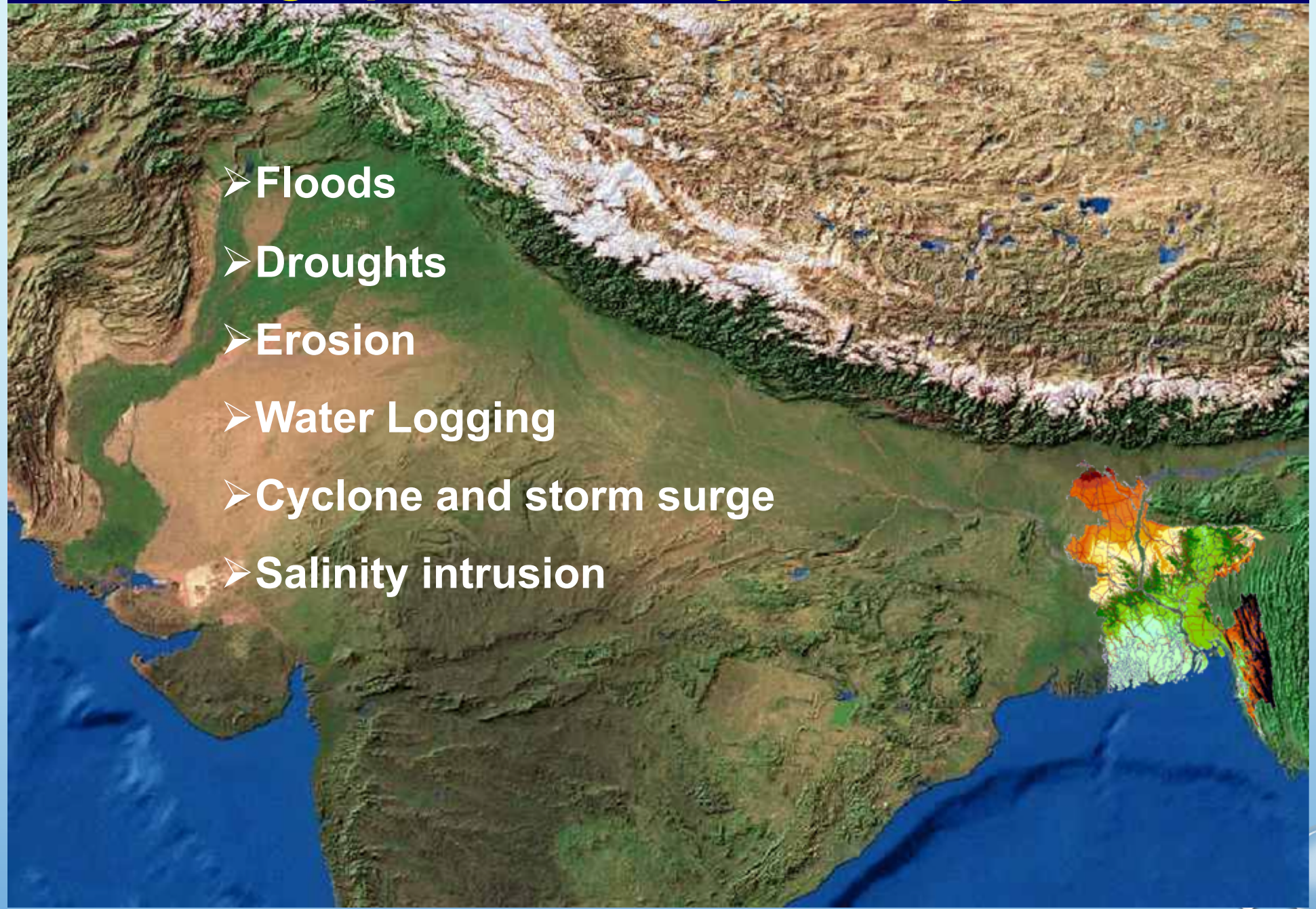
Geographical Setting of Bangladesh



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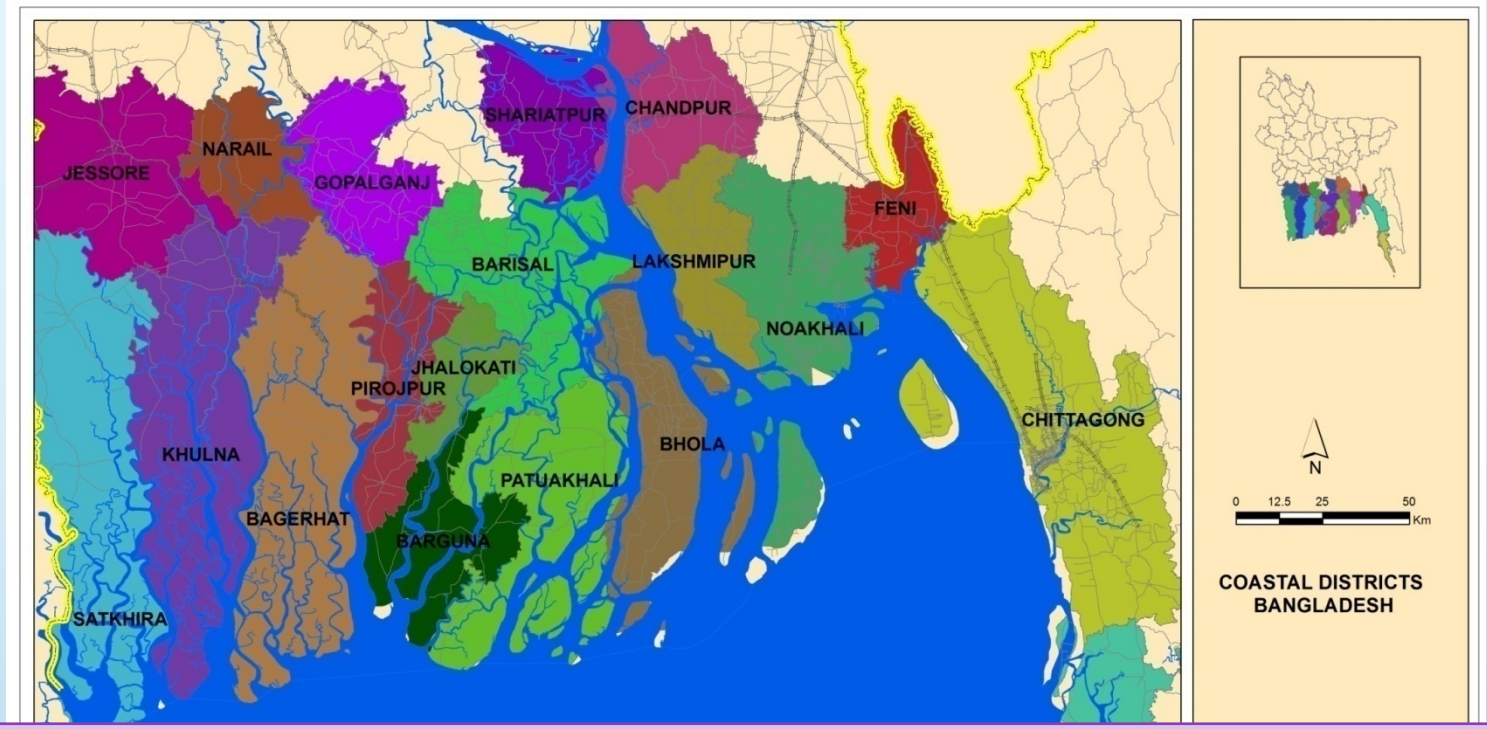
Coastal Area of Bangladesh



Total Districts = 19 (out of 64)

Area = 47,150 km2 (32% of the country, 2011 census)

Population = 3,85,17,968 (25.72% of the country) Density of Population = 817 per km2

Total coastal polders = 139

Length of embankment = 5107 km

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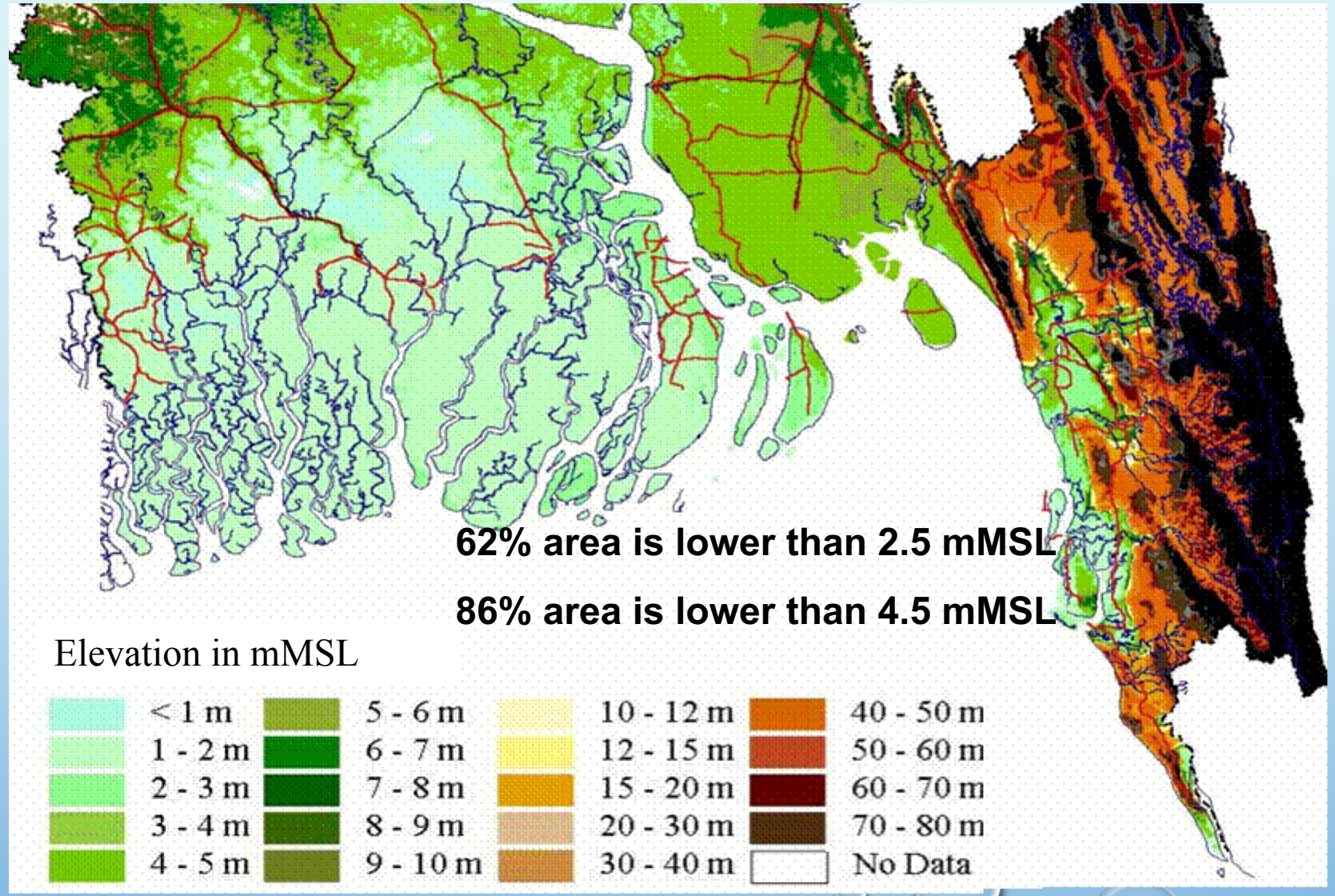
Land Elevation of Coastal Area



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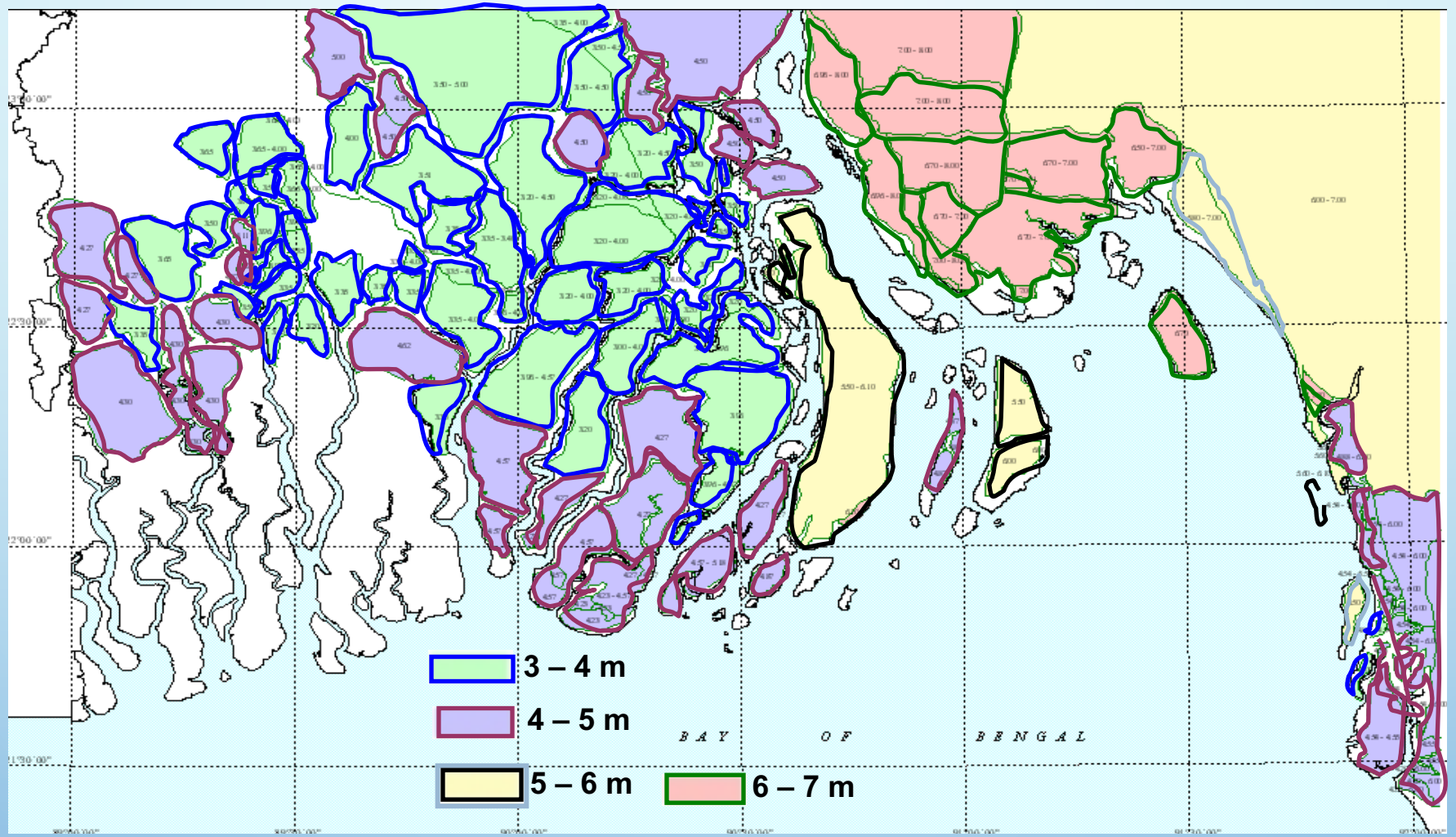
Coastal Polders

Largest Infrastructure in the Coastal Area of Bangladesh



Polders are designed considering tide, monsoon water level and some freeboard

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Challenges of Water Resources Management for Coastal Area

- ❑ Cyclone and Storm Surge
- ❑ River and Coastal Erosion
- ❑ Water logging in Coastal Polders
- ❑ Salinity Intrusion
- ❑ Scarcity of Water in Dry season
- ❑ Climate change and Sea Level Rise
- ❑ Land use change
- ❑ Sedimentation and navigability problems in river and ports

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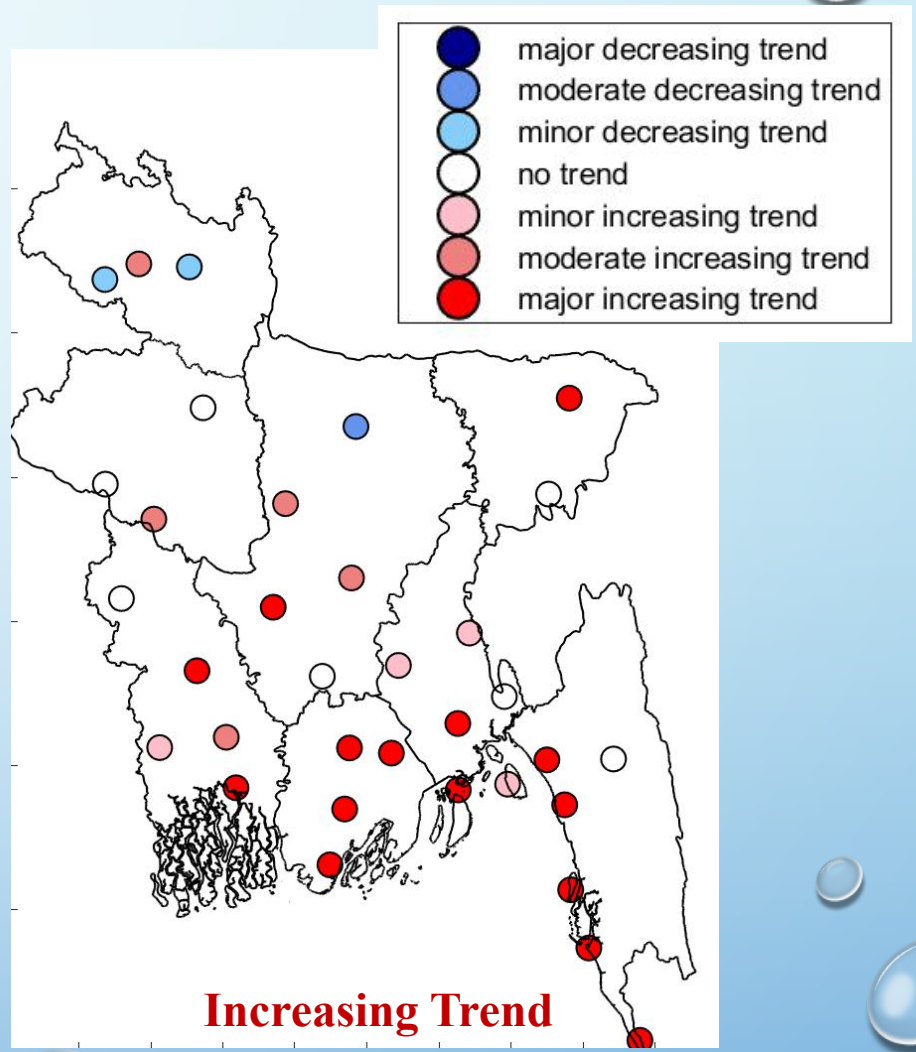
Climate Change in Bangladesh (Past Trends)

Drought

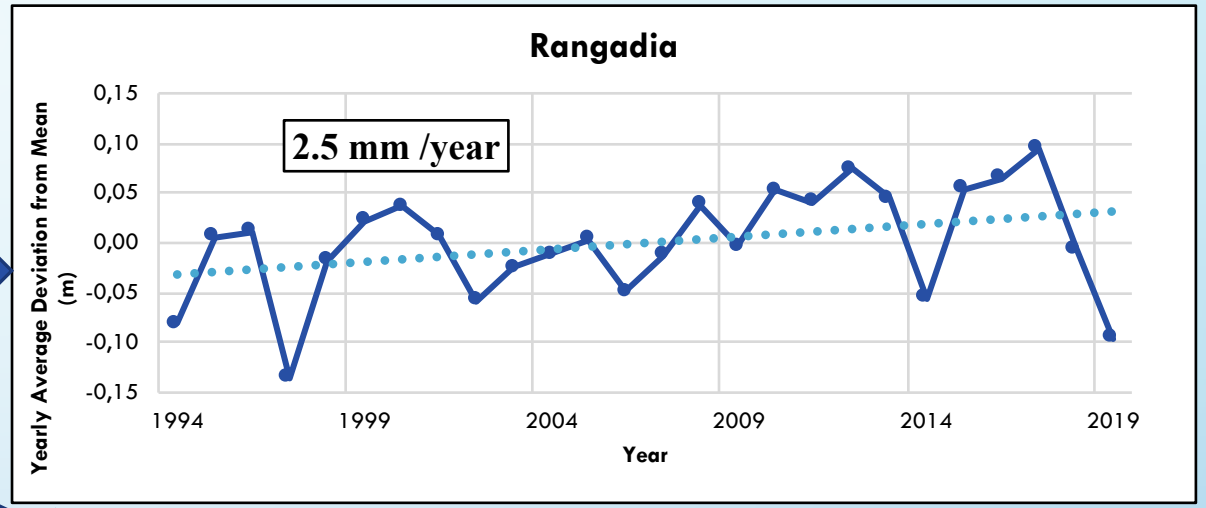
Climate change threatens lives and futures of over 19 million children

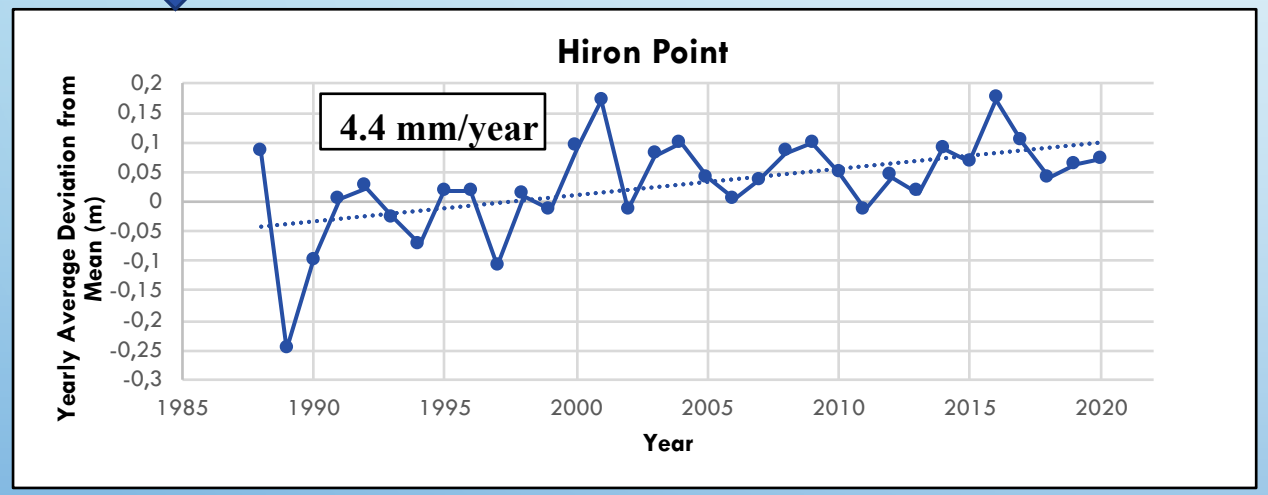
Annual Mean Temperature

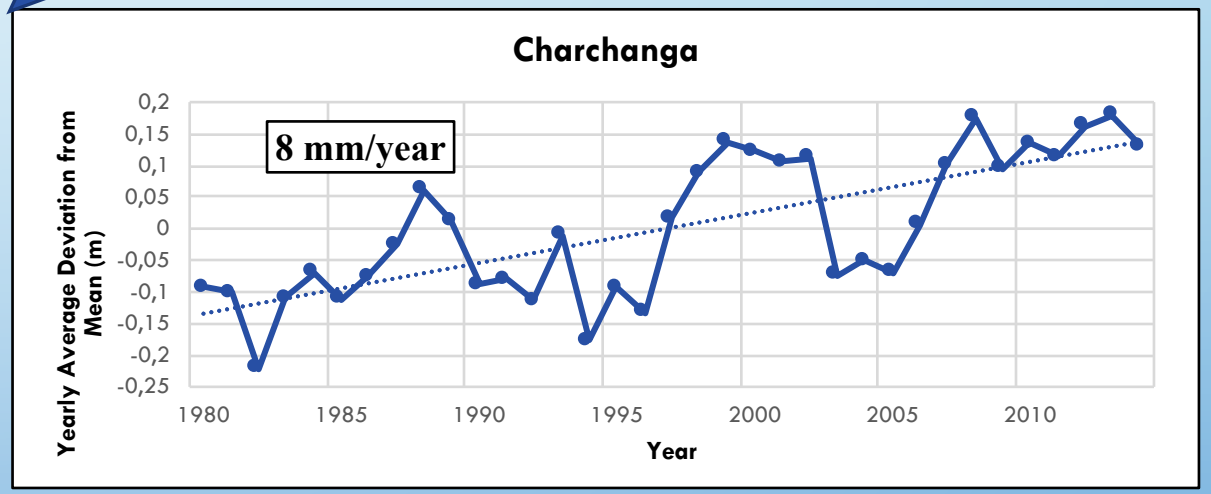


Ref: DHI, Deltares, IWM, Columbia University, University of Colorado, 2021, Climate Change Scenarios, LTRM

Sea Level Rise in Bay of Bengal (Past Trends)



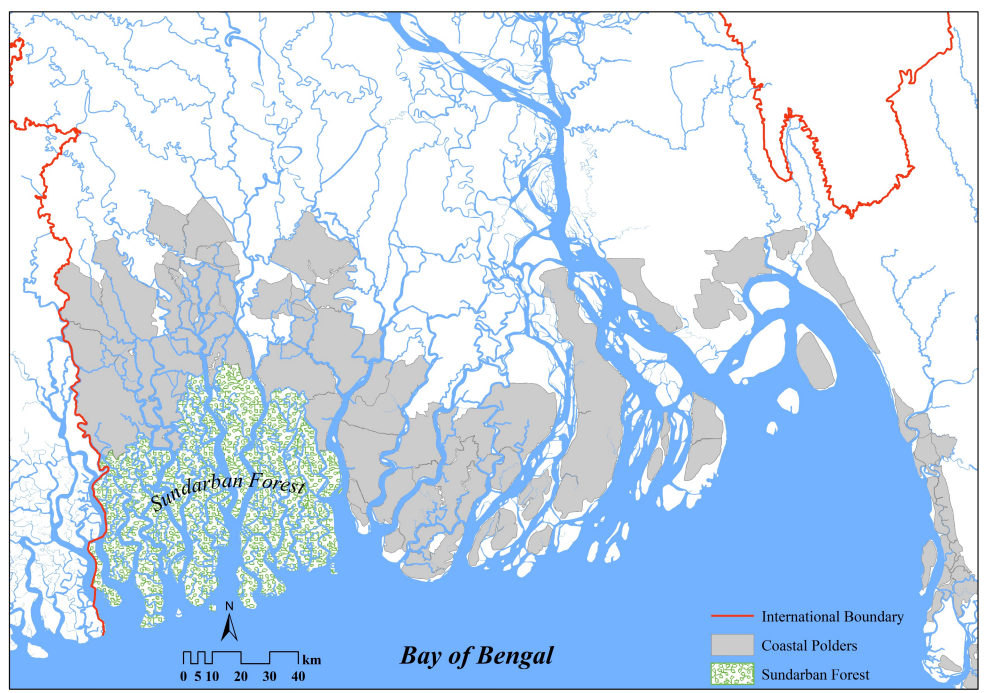




Ref: IWM, 2023, Final Report, Understanding the Sea Level Rise Dynamics of Bangladesh along the Coast

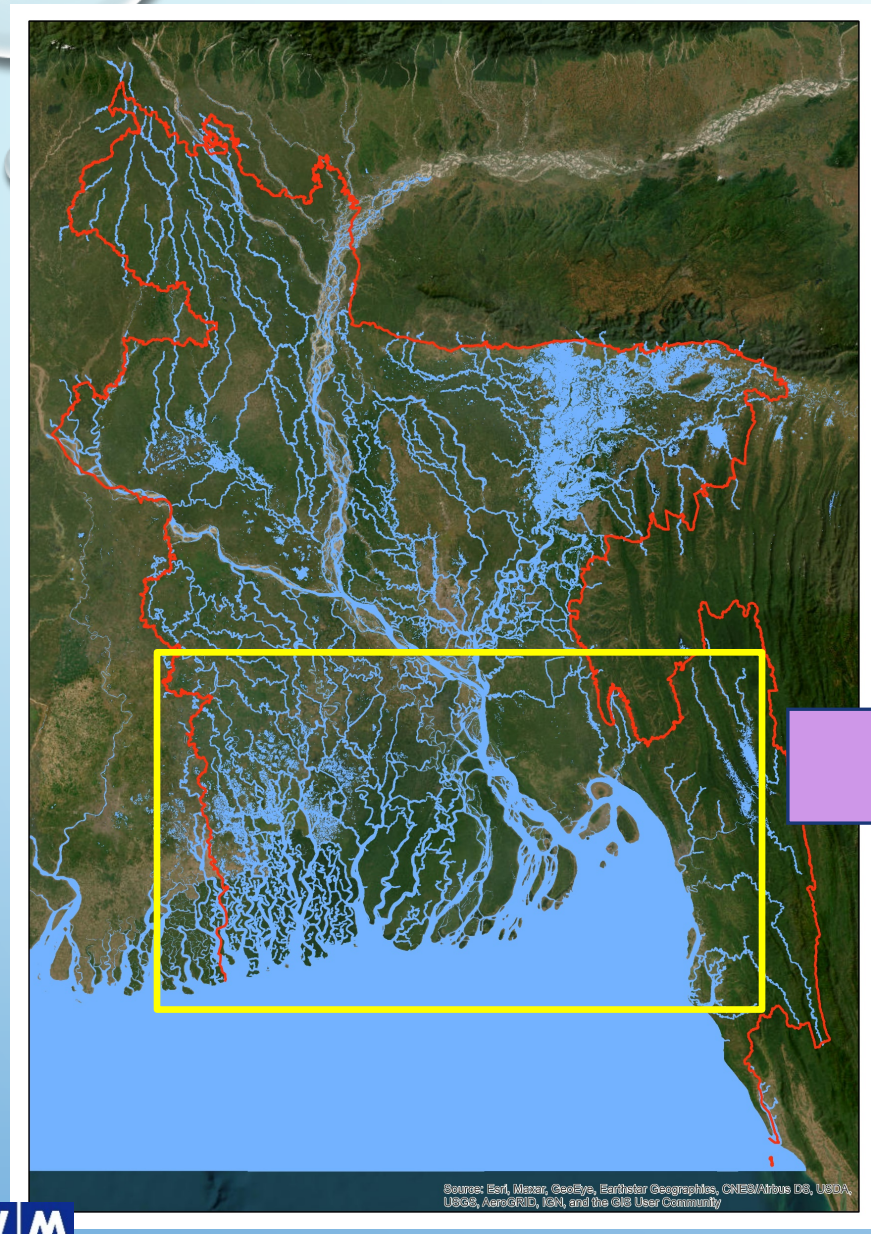
Water Logging in Coastal Polders

- Coastal embankment/polders were constructed in 1960's and 70's keeping minimum setback distance between river and embankment
- The actual floodplain was disconnected from the river due to construction of polders
- Upstream flow reduced significantly in dry season due to construction of dam's and barrage in the upstream in 1970's
- Eventually, river became silted up gradually
- Polder drainage system is mainly gravity drainage system
- Due to high elevation in peripheral rivers, water logging started in different polders from 1980's

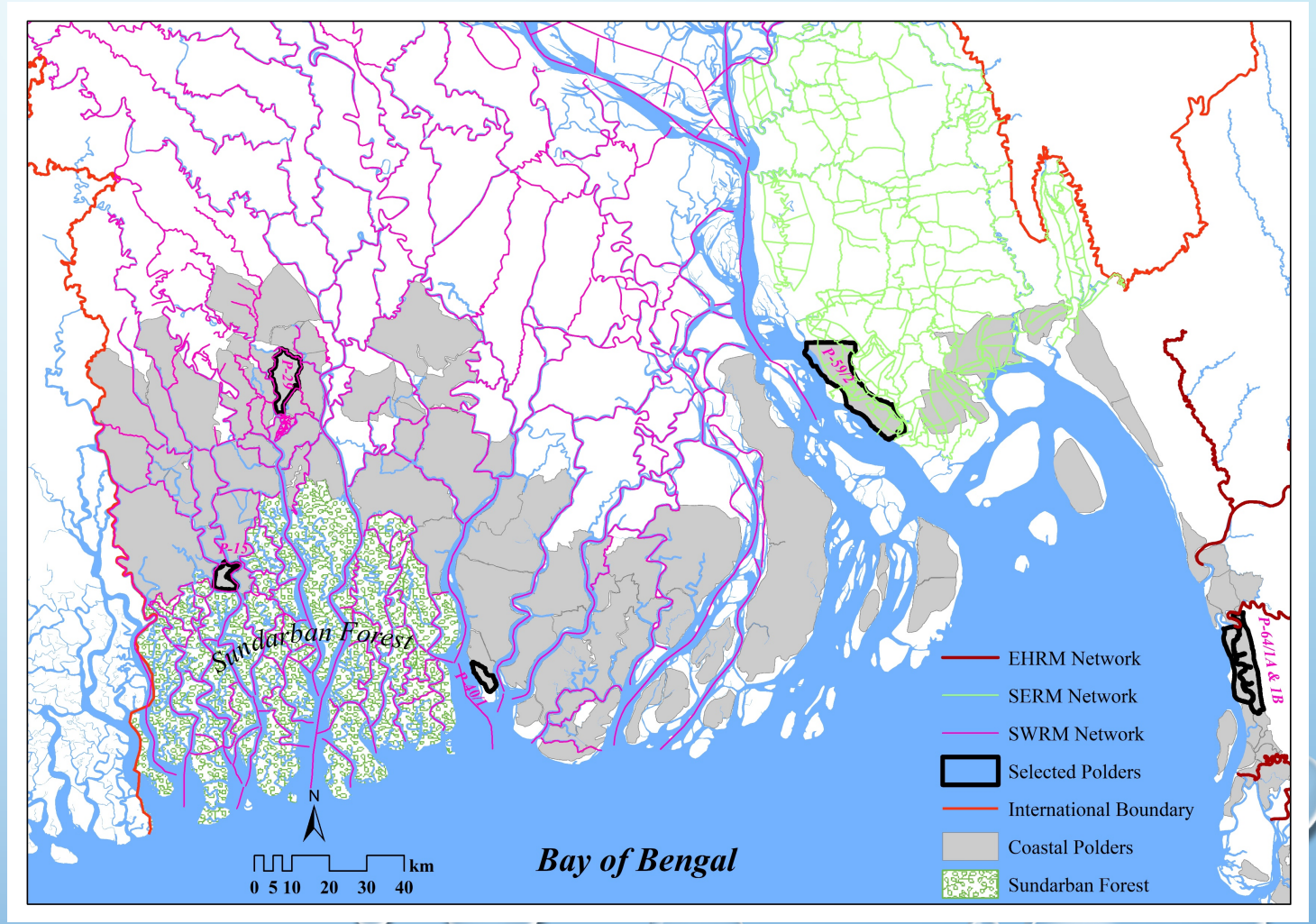


Primary School, September 2016

Water Logging in Times of Climate Change and Sea Level Change



Study Area for Polder Drainage Modelling and River Network of Regional Model



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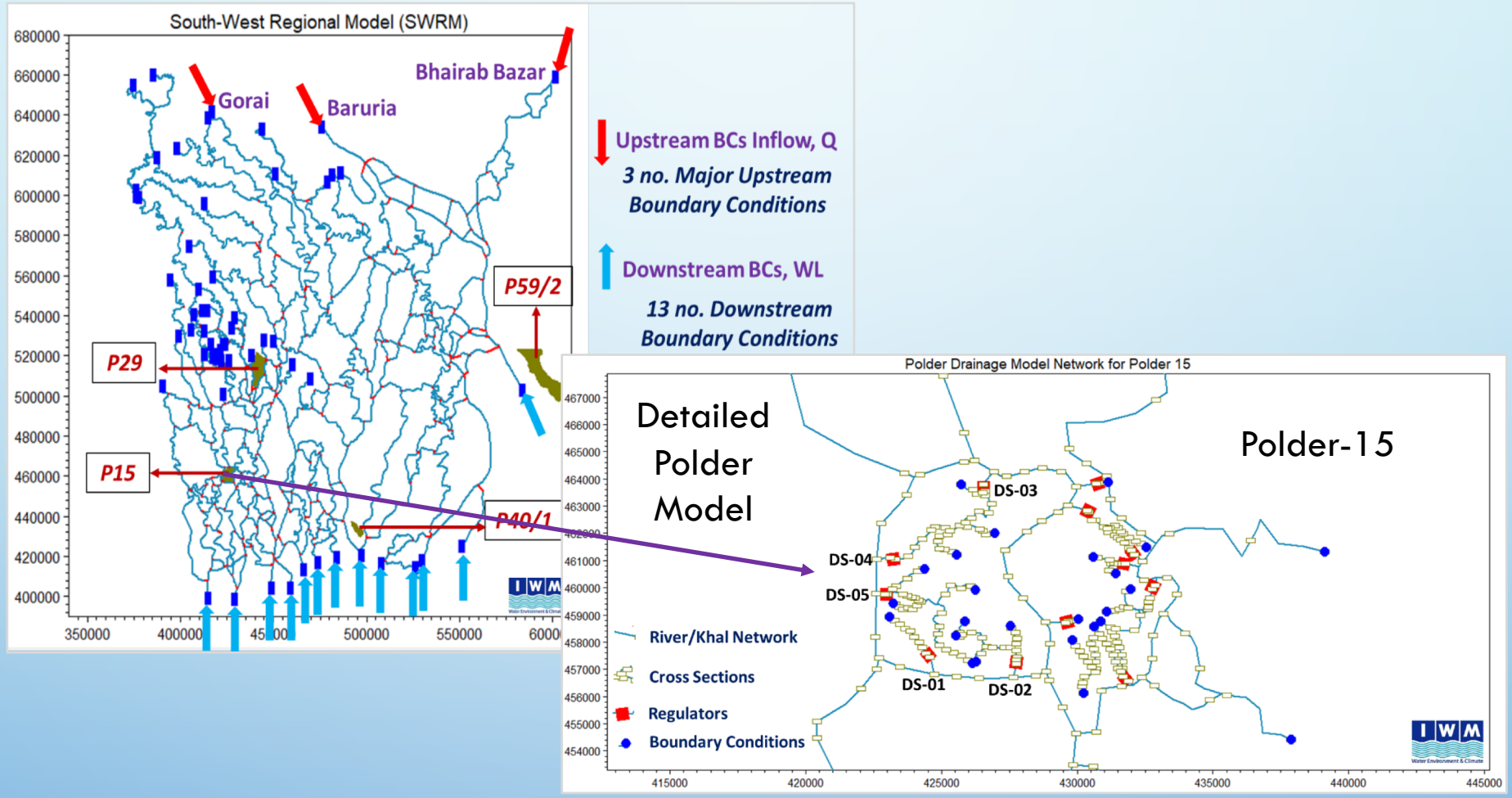
Detailed Polder Models

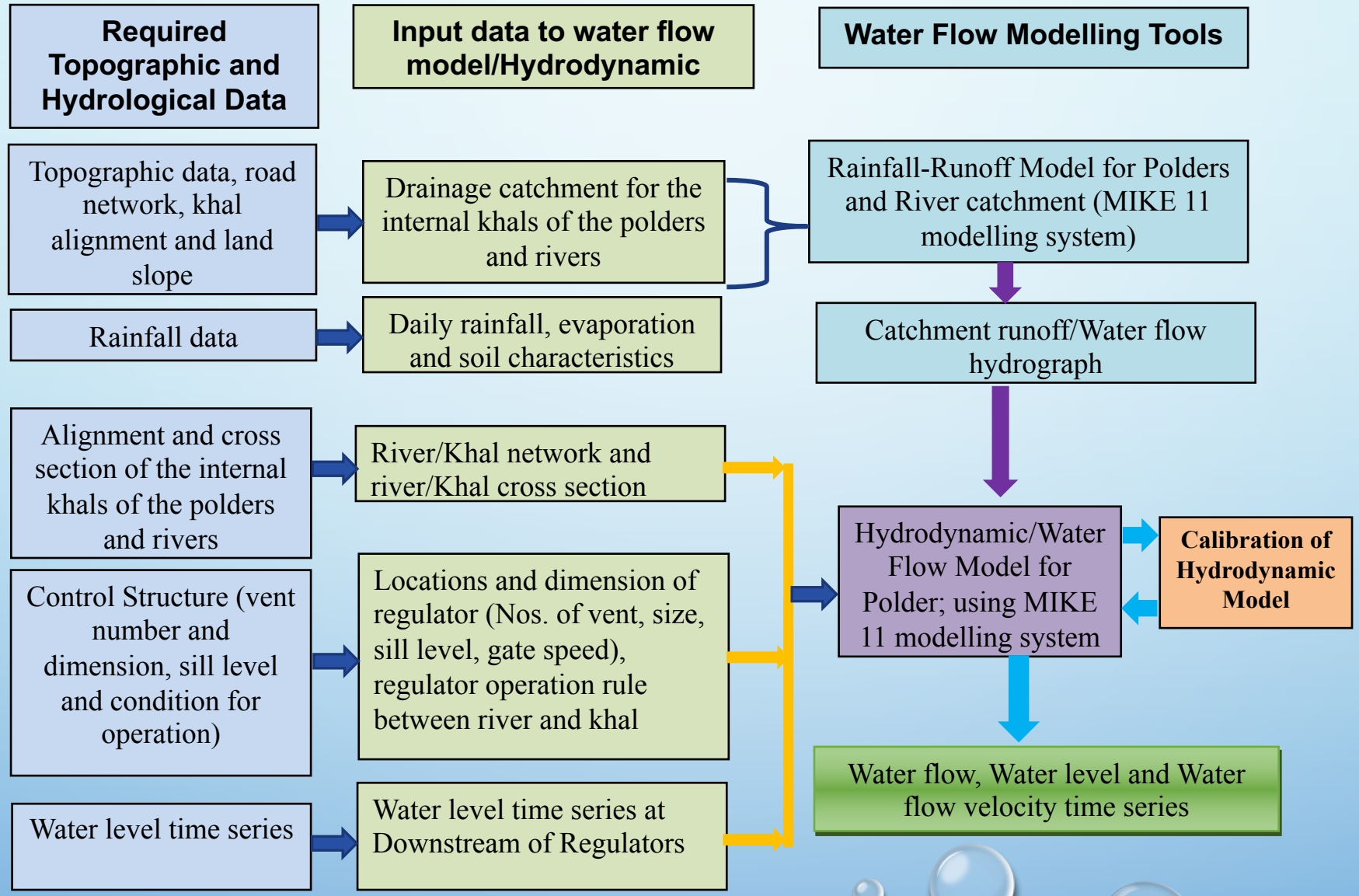
(Water Logging in Coastal Polders)

South-West Regional Model (SWRM)

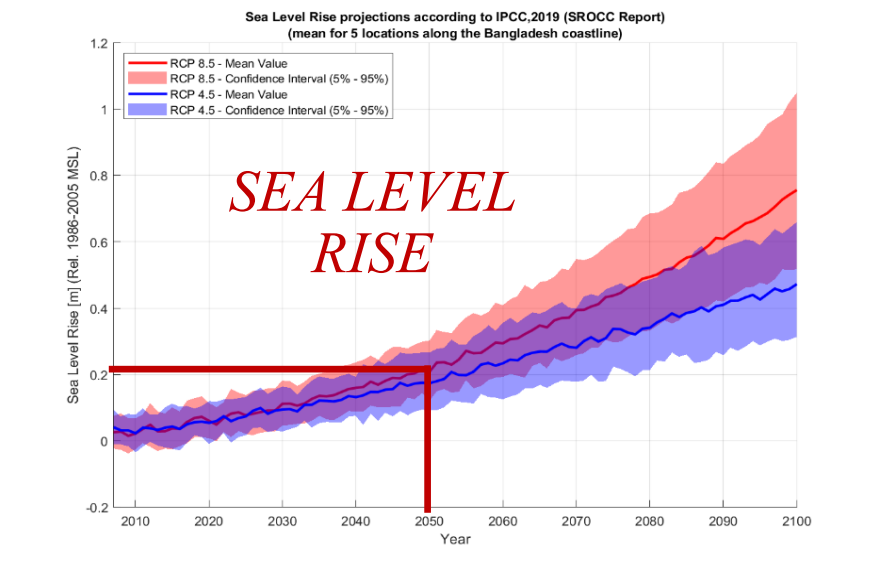


Development of Polder Models

(Water Logging in Coastal Polders)



Climate Change Scenarios

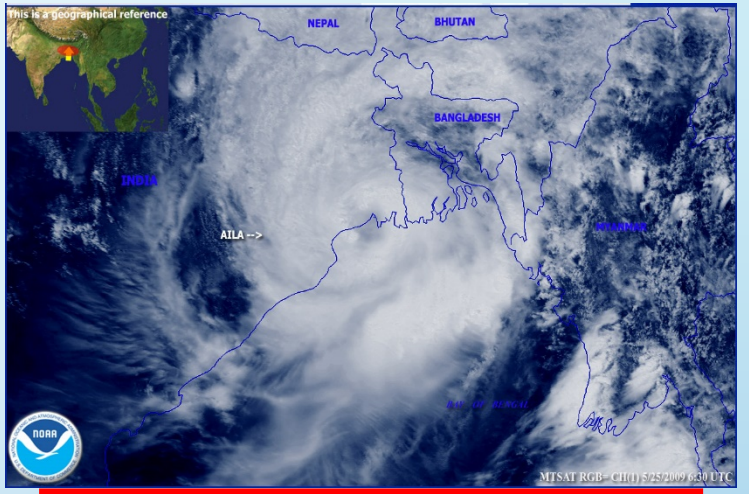


Scenarios	Absolute Mean SLR (meter) value for BD coast (95% upper boundary)
RCP4.5 (year-2050)	0.158
RCP8.5 (Year-2050)	0.199
RCP4.5 (year-2100)	0.551
RCP8.5 (Year-2100)	0.919

PRECIPITATION

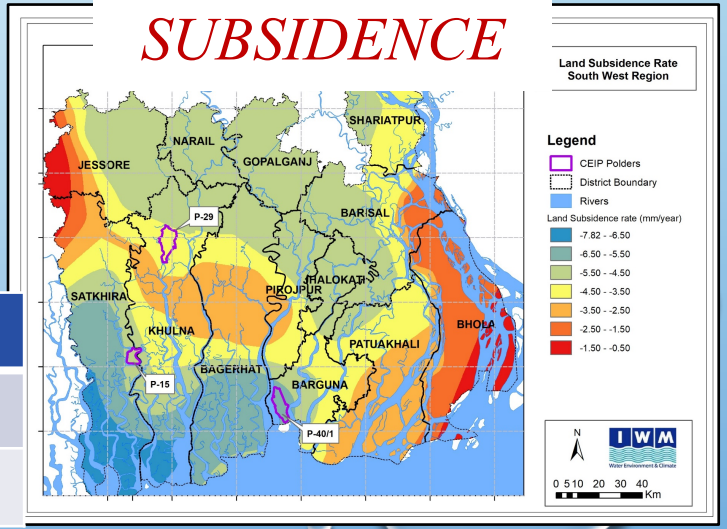
Month	2050	2100
	High Scenario	
Jan	38.2	-3.8
Feb	83.7	42.5
Mar	47.4	18.9
Apr	15.8	42.4
May	23.1	46.1
Jun	15.1	27.8
Jul	11.5	29.1
Aug	5.9	28.6
Sep	15.7	27.2
Oct	22.5	22.3
Nov	30.5	45.3
Dec	35.5	53.3

CYCLONIC WIND SPEED



Increased 8% for 2050

SUBSIDENCE



Subsidence Rate (mm/year)				
P-15	P-29	P-40/1	P-59/2	P-64/1A&1B
5	4	6	4.7	2

Ref: DHI, Deltares, IWM, Columbia University, University of Colorado, 2021, Climate Change Scenarios, LTRM

Ref: DHI, Deltares, IWM, Columbia University, University of Colorado, 2022, Final Subsidence Report, LTRM

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Simulation of Polder Inundation Using the Model

(Water Logging in Coastal Polders)

Polder-40/1

Inundation in 2019

Inundation in 2050

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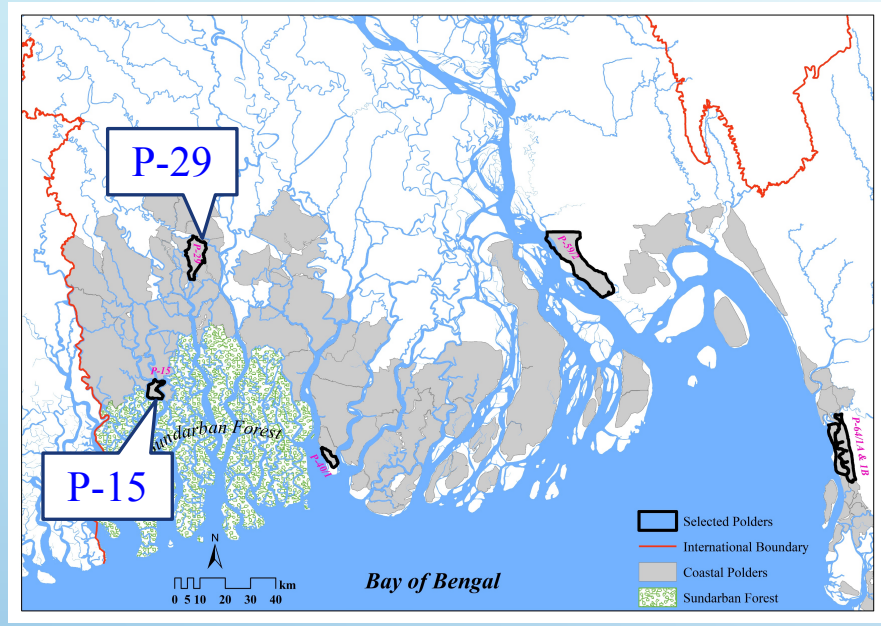
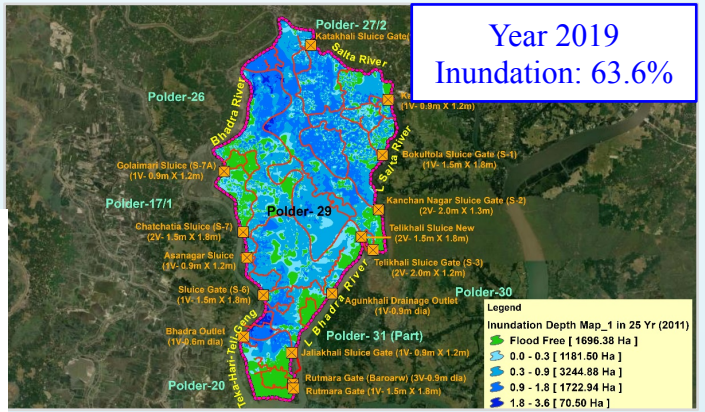
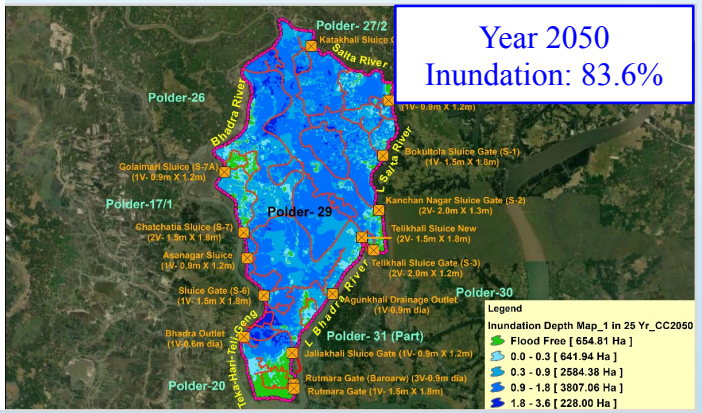
Inundation in Coastal Polders due to Climate Change and Sea Level Rise

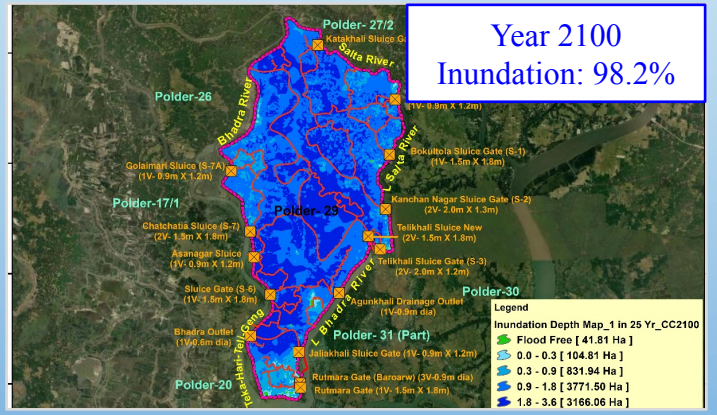
(Water Logging in Coastal Polders)



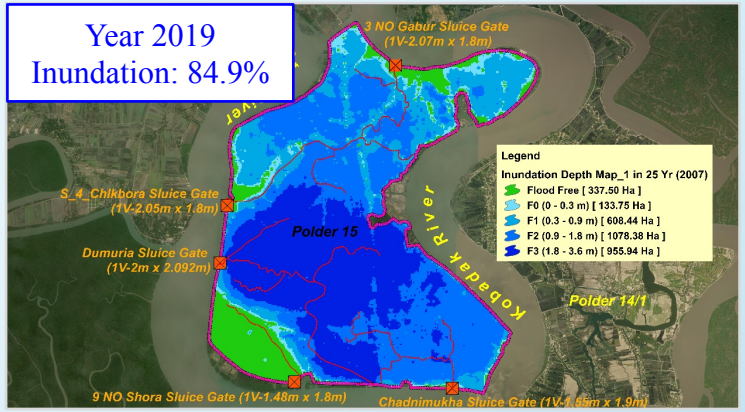
Polder-29

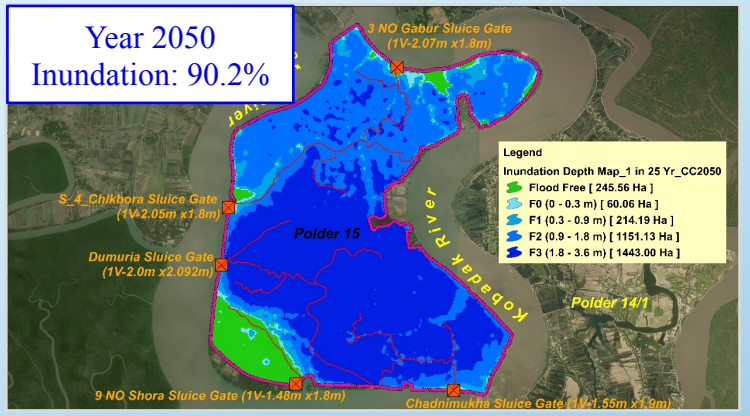


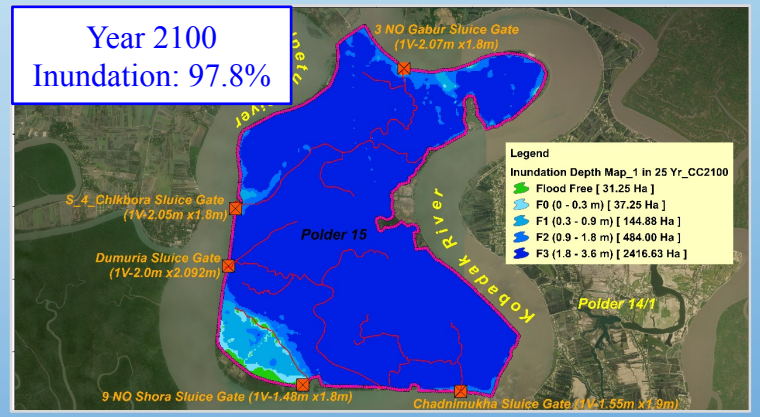




Polder-15







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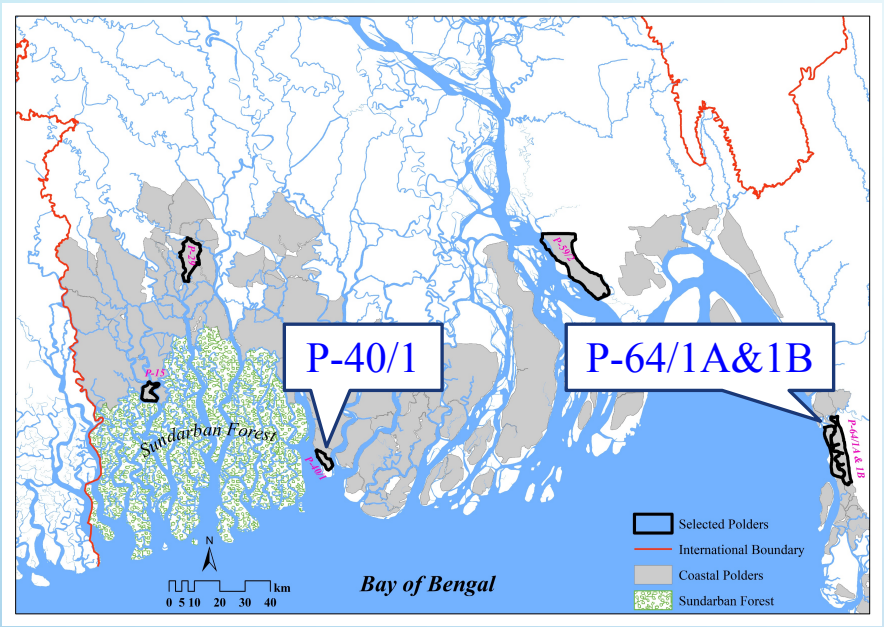
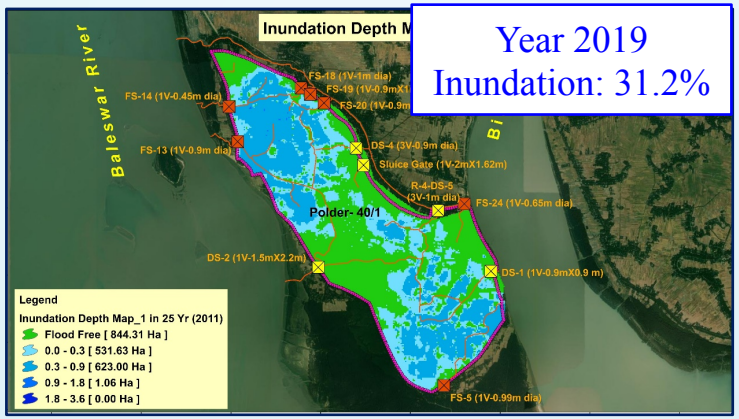
Inundation in Coastal Polders due to Climate Change and Sea Level Rise

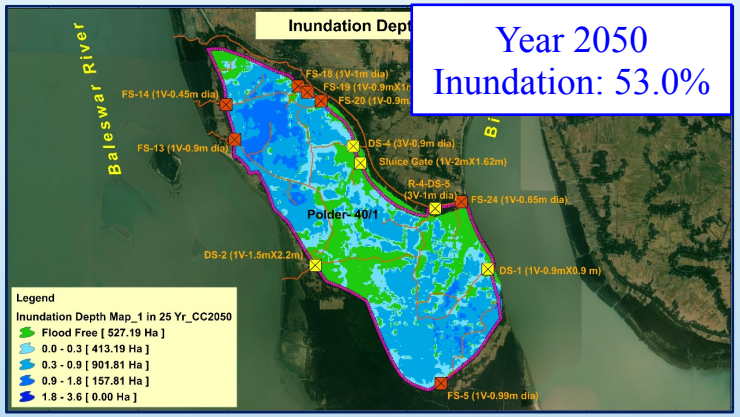
(Water Logging in Coastal Polders)



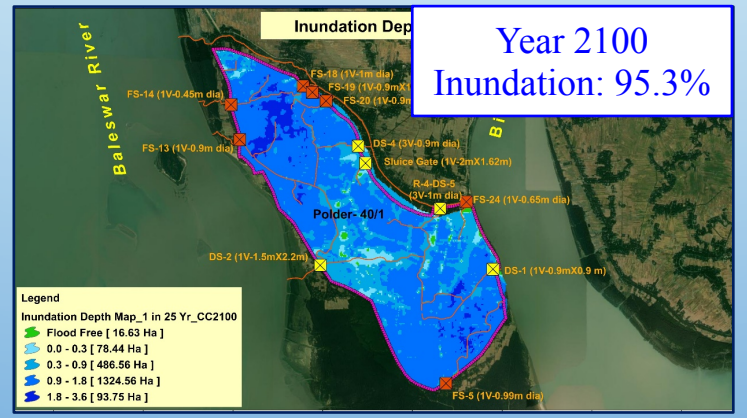
Polder-40/1



Year 2019
Inundation: 31.2%



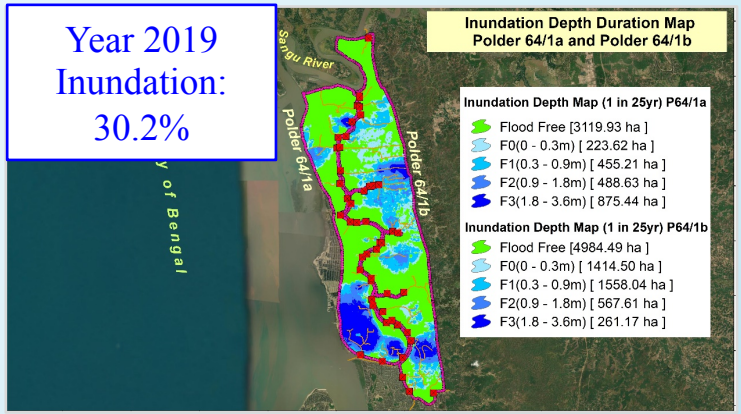
Year 2050
Inundation: 53.0%



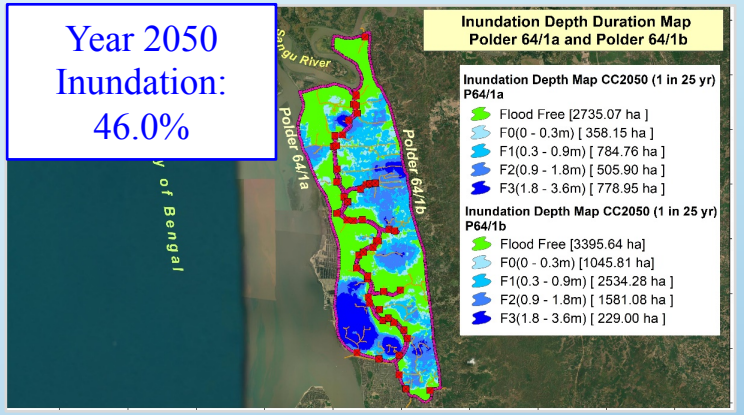
Year 2100
Inundation: 95.3%

Polder-64/1A&1B

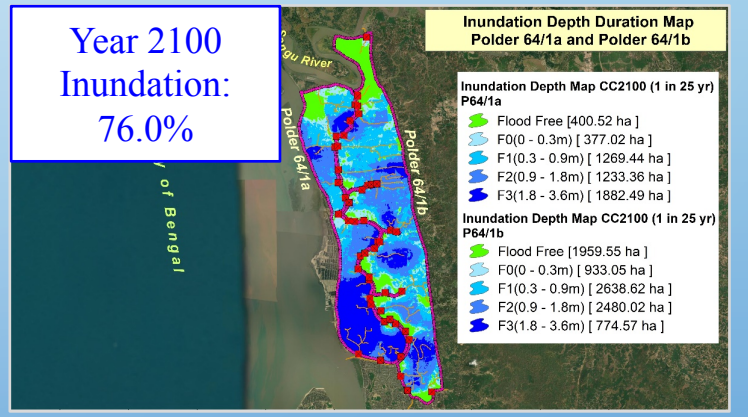
Year 2019
Inundation:
30.2%



Year 2050
Inundation:
46.0%



Year 2100
Inundation:
76.0%



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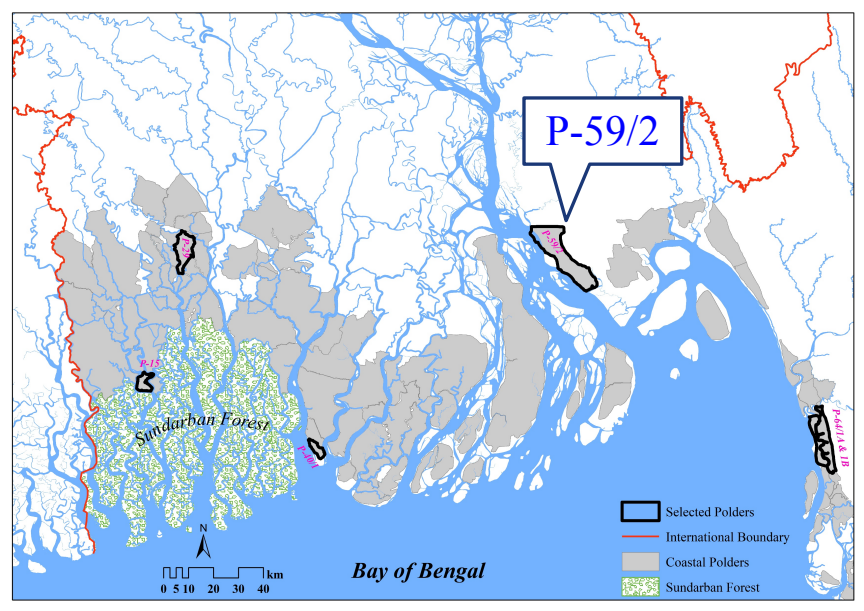
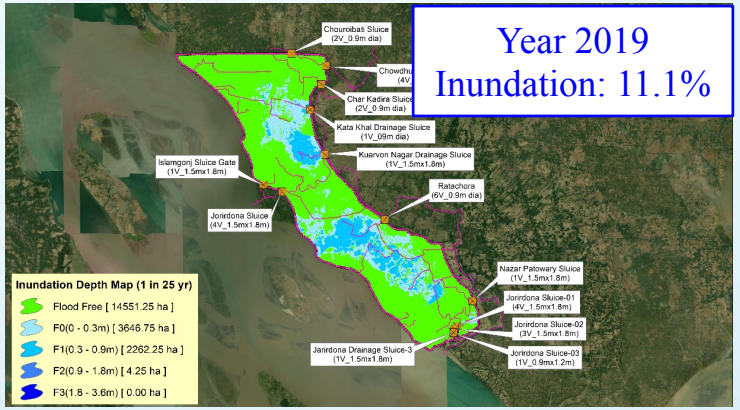
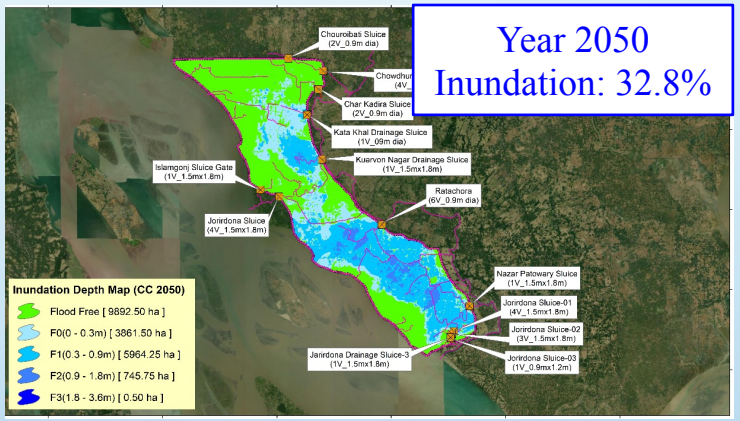
Inundation in Coastal Polders due to Climate Change and Sea Level Rise

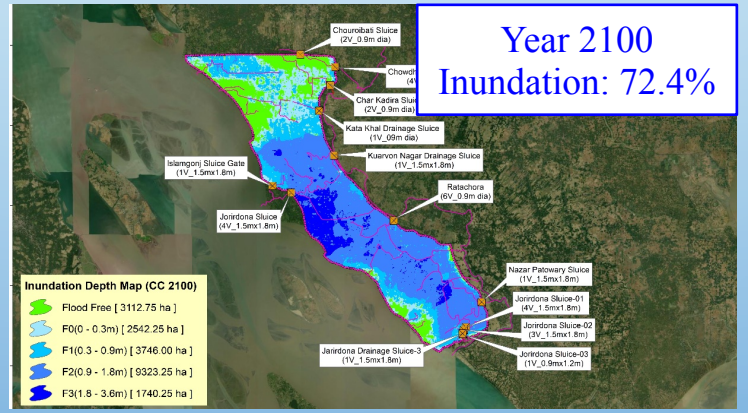
(Water Logging in Coastal Polders)



Polder-59/2







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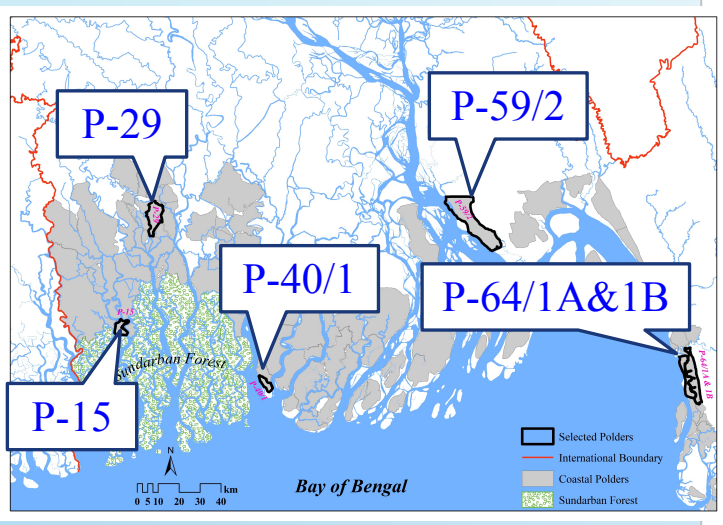
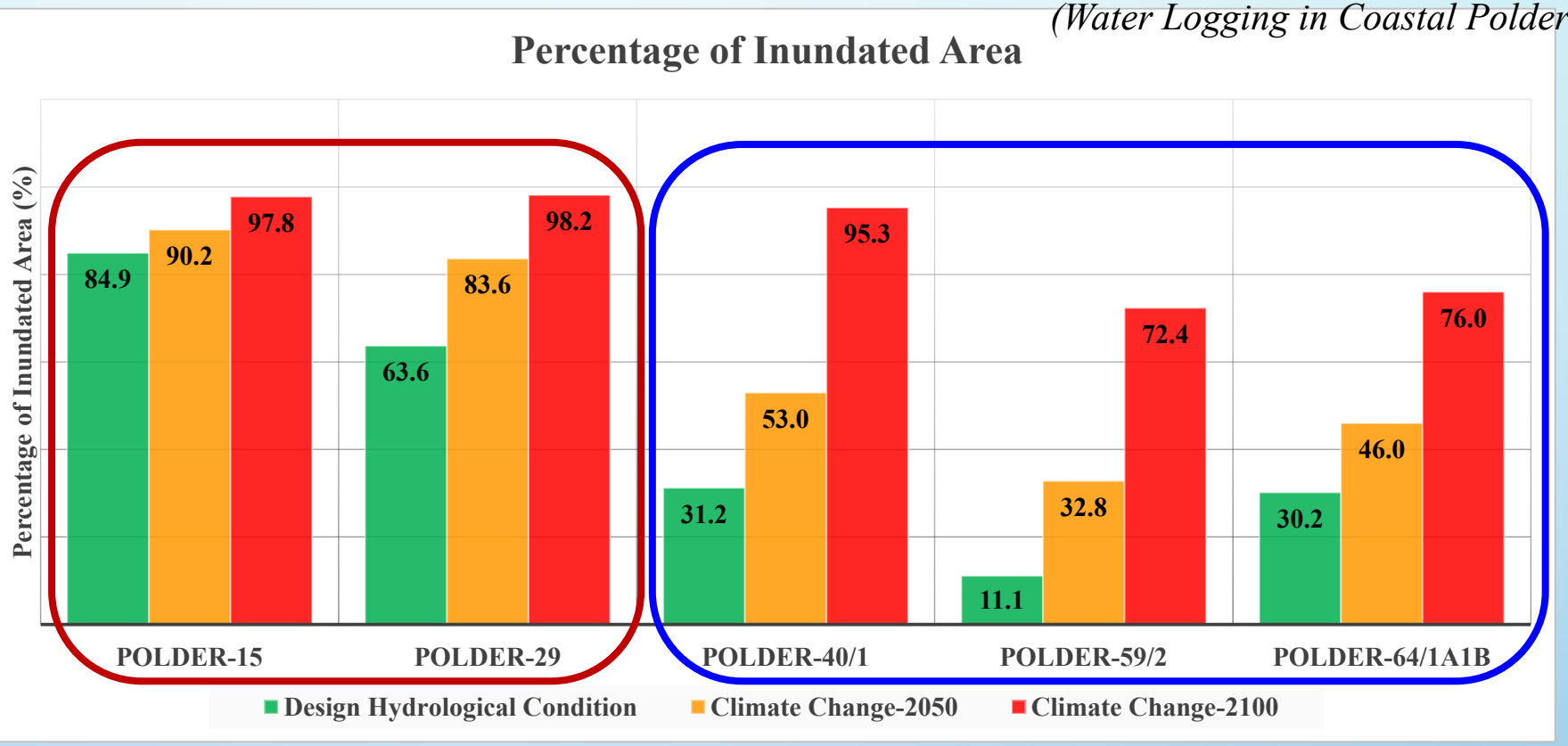
Inundation in Coastal Polders due to Climate Change and Sea Level Rise

(Water Logging in Coastal Polders)





- Drainage problem in Polder-15 & 29 is still very severe and Almost all of its area will be inundated in 2100. Inundation will be ranges from 83.6% to 90.2% in 2050 and 97.8% to 98.2% in 2100
- Drainage problem in Polder-40/1, 59/2 & 64/1A&1B is not so severe at present. However, drainage condition will be severely impacted due to climate change and sea level rise. Inundation will be ranges from 32.8% to 53.0% in 2050 and 72.4% to 95.3% in 2100

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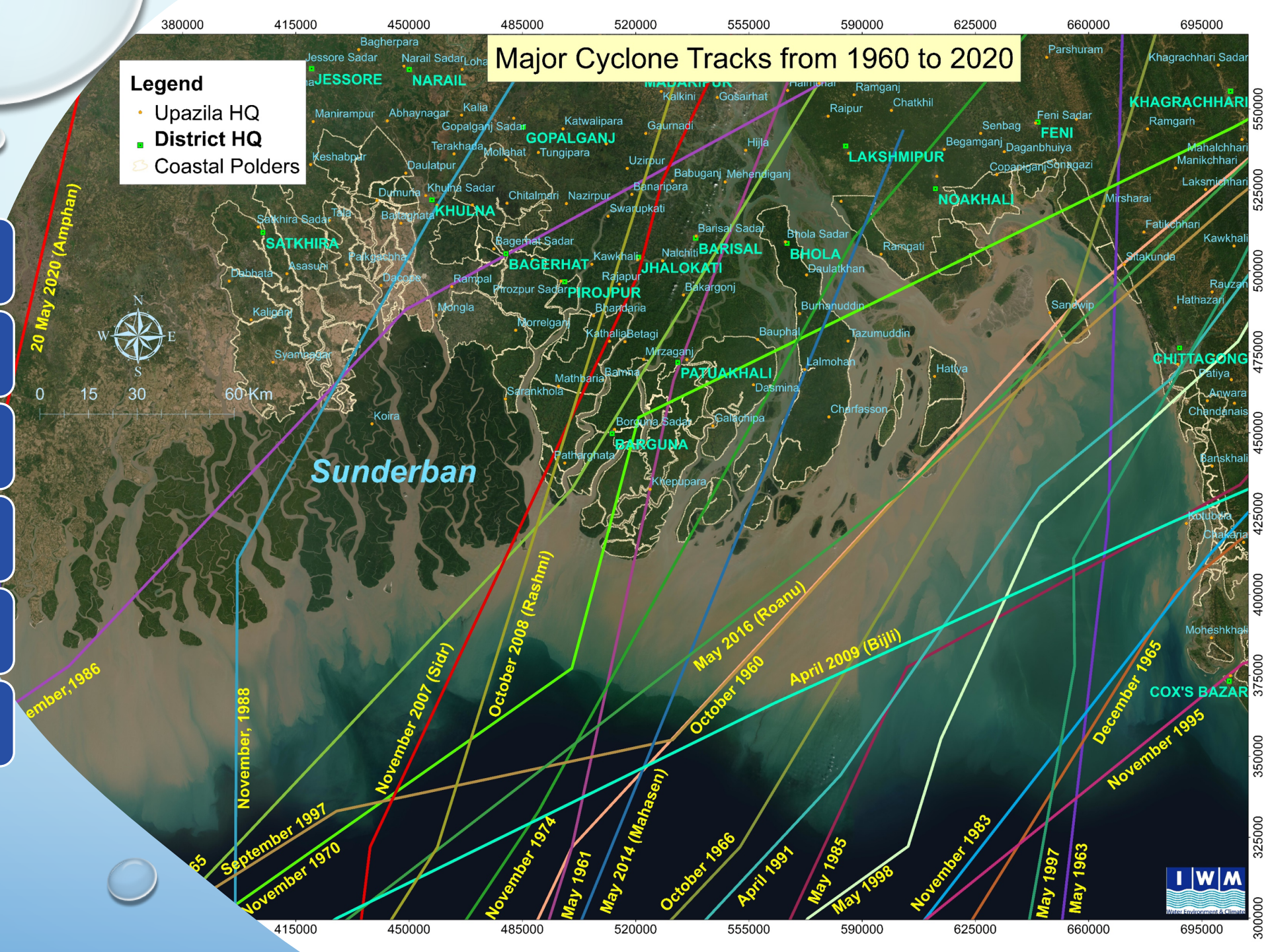
Cyclone & Storm Surge

- Whole coast is vulnerable to cyclonic storm surge
- About 47 Severe Cyclone hit the coast in last century (1900-2022)
- Cyclone 1970: deaths: 300,000; damage: $86.4 million
- Cyclone 1991: deaths: 138,000; damage: $1.7 billion
- Cyclone Sidr, 2007: deaths: 3406; damage: $2.31 billion
- Cyclone Aila, 2009: deaths: 190; damage: $1 billion



Storm Surge Inundation due to Climate Change and Sea Level Rise

(Cyclone & Storm Surge)

MATHEMATICAL MODEL SETUP

Storm Surge Model

Hydrodynamic Input data

- Sea bed Topography/River bed Topography/ Land level
- Bed friction/resistance
- Hourly water level/flow at boundaries

STORM SURGE MODEL

HYDRODYNAMIC MODEL + **CYCLONE MODEL**

Cyclone Model Input data

- Cyclone track, forward speed and direction
- Maximum wind speed
- Radius of maximum wind
- Central & neutral pressure

DEFINING BOUNDARY CONDITION

SIMULATION

CALIBRATION & VALIDATION

SIMULATION OF SCENARIOS

RESULT ANALYSIS

Outputs → **STORM SURGE LEVEL/HEIGHT**

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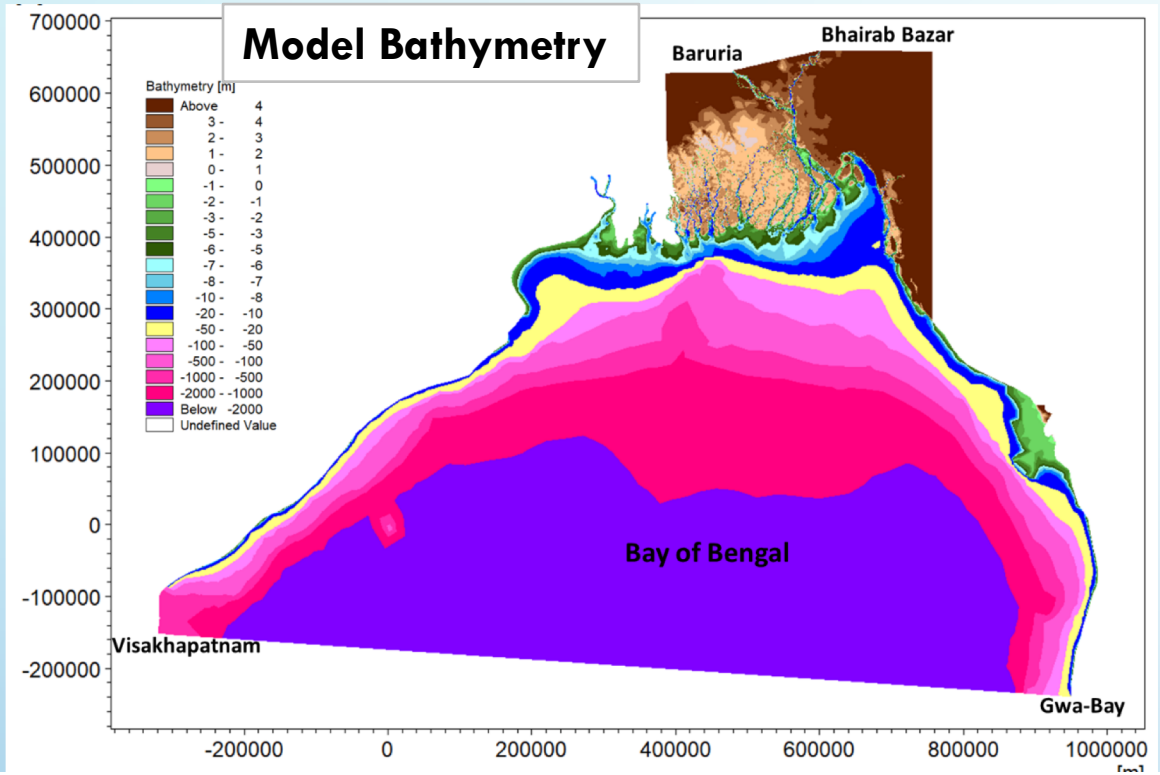
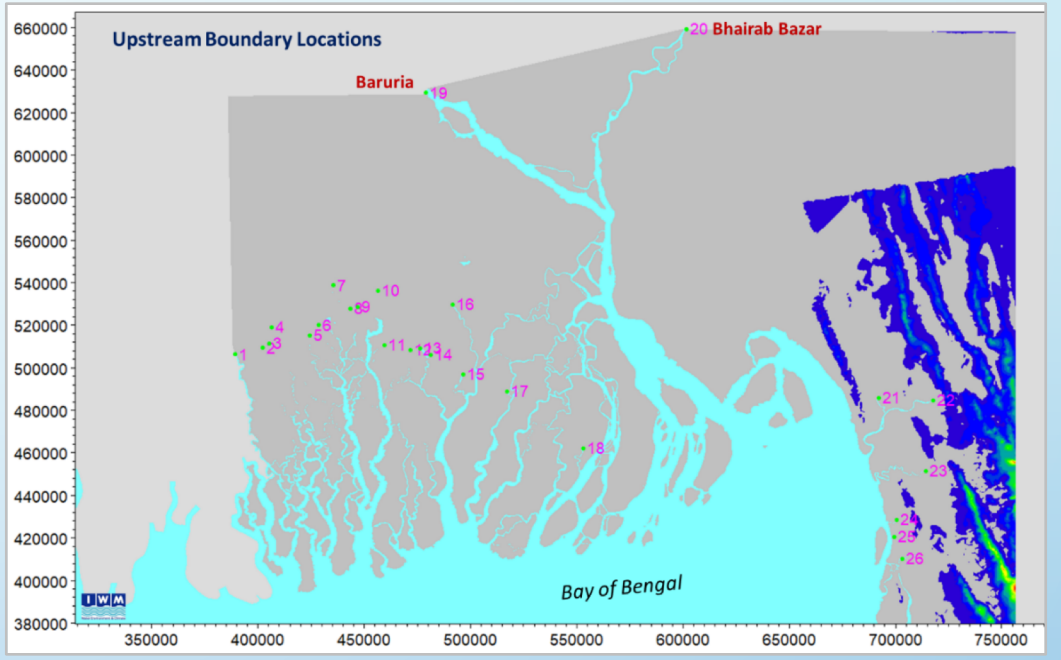
Storm Surge Model

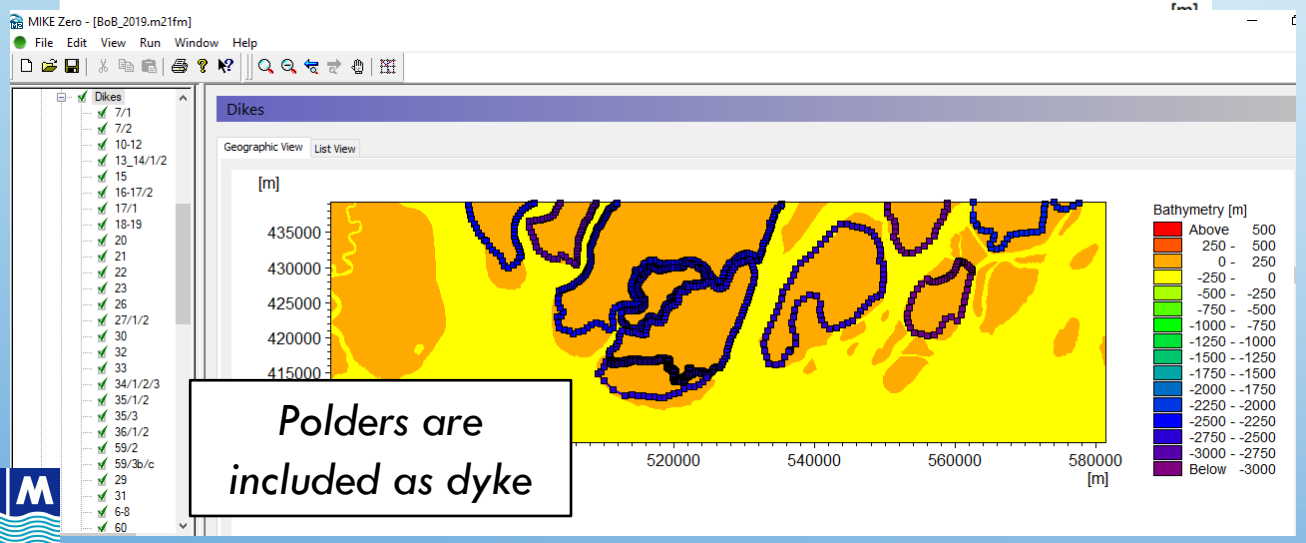
(Cyclone & Storm Surge)

Model Bathymetry



Boundary Locations





Polders are included as dyke

- 26 nos. Upstream boundary
- 1 nos. Downstream boundary

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Development of Storm Surge Models

Storm Surge Model = Hydrodynamic Model + Cyclone Model *(Cyclone & Storm Surge)*

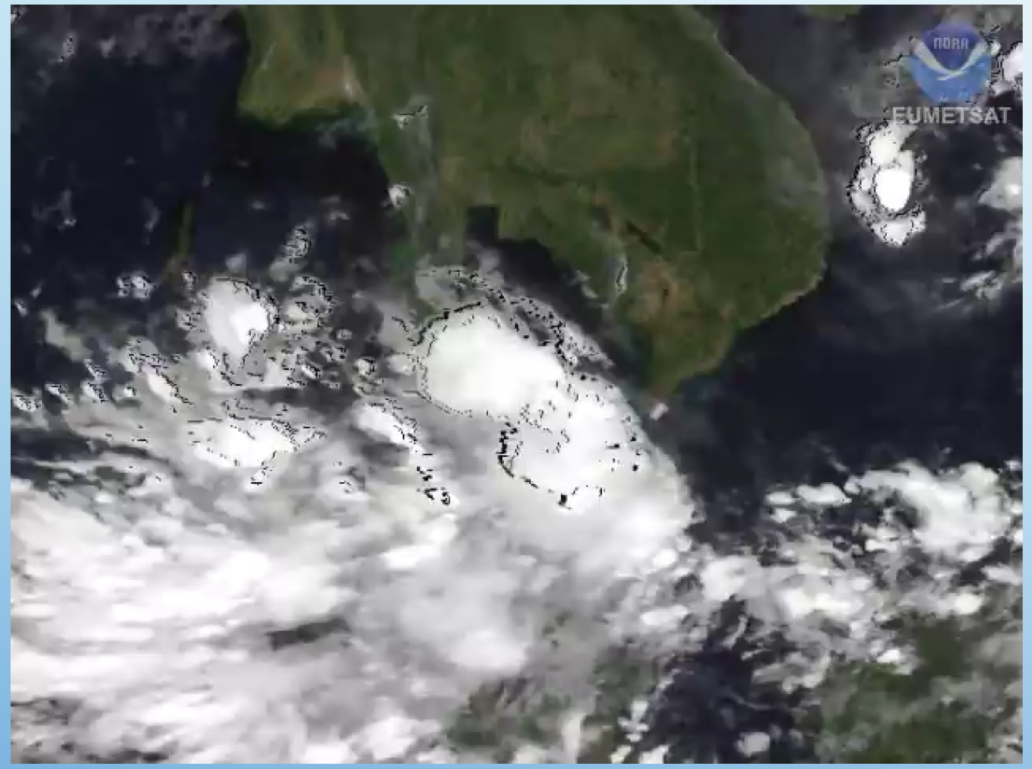
Cyclone Model

- Cyclone track, forward speed and direction
- Maximum wind speed
- Radius of maximum wind
- Central & neutral pressure

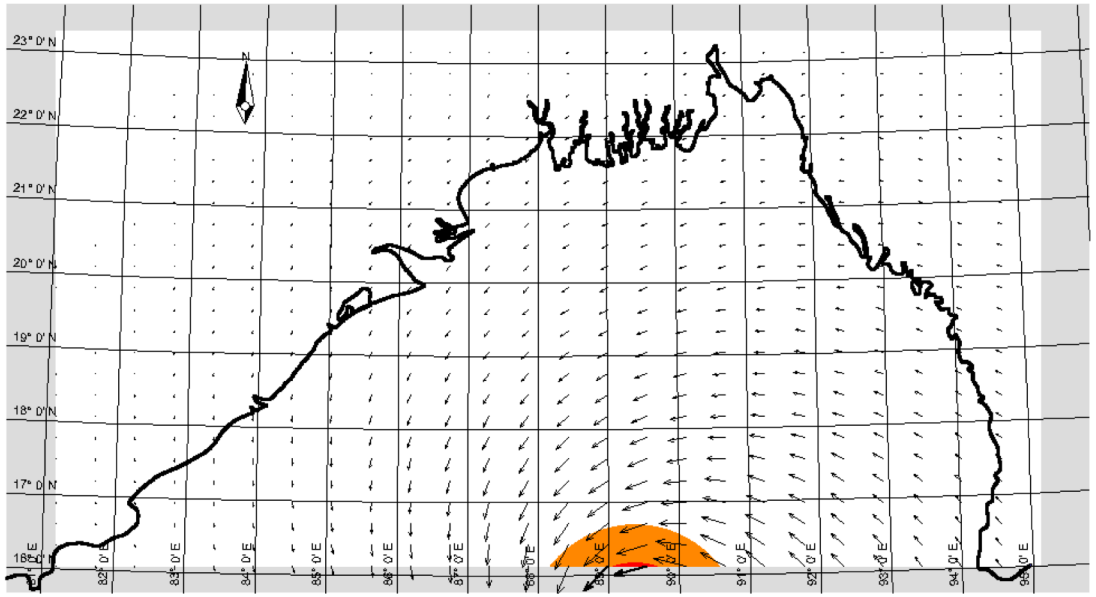
Holland Single Vortex Theory

$$B = 2\frac{\rho_c - 900}{160} \quad for\ 1.0 < B < 2.5$$

Observed Track (Sidr, 2007)



Model Simulated Track (Sidr, 2007)



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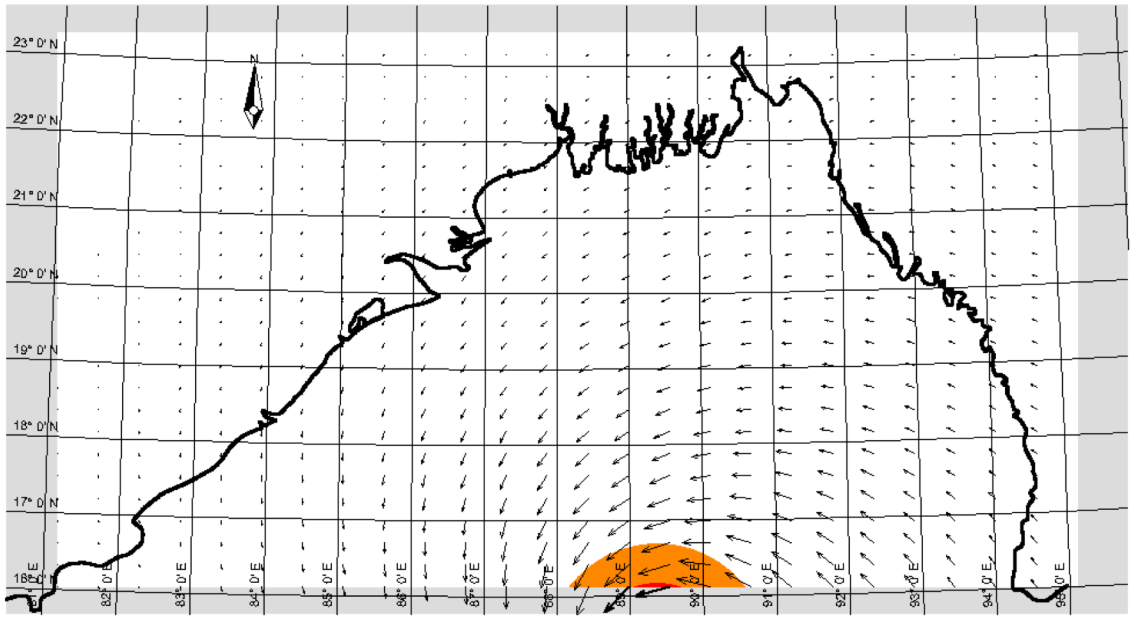
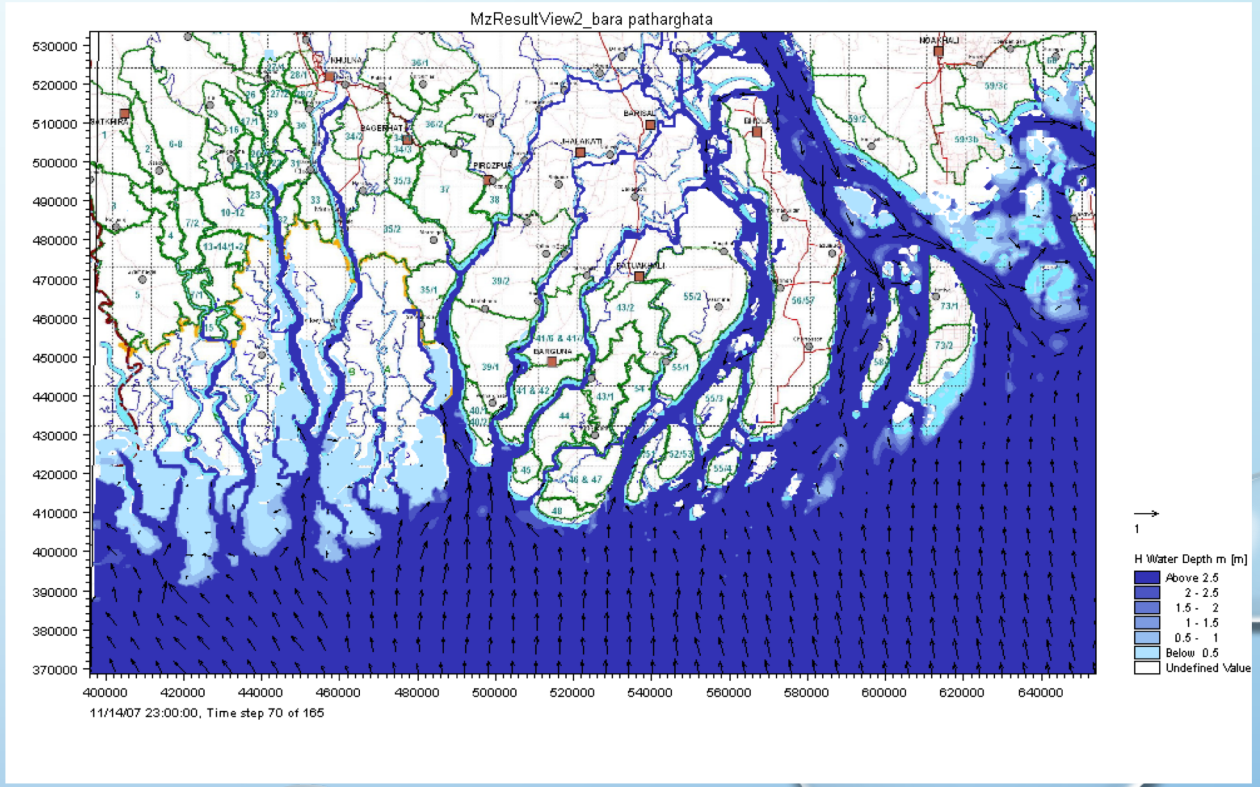
Storm Surge Level in the Coast of Bangladesh

(Cyclone & Storm Surge)

Cyclone Track (Sidr, 2007)



Inundation during SIDR, 2007



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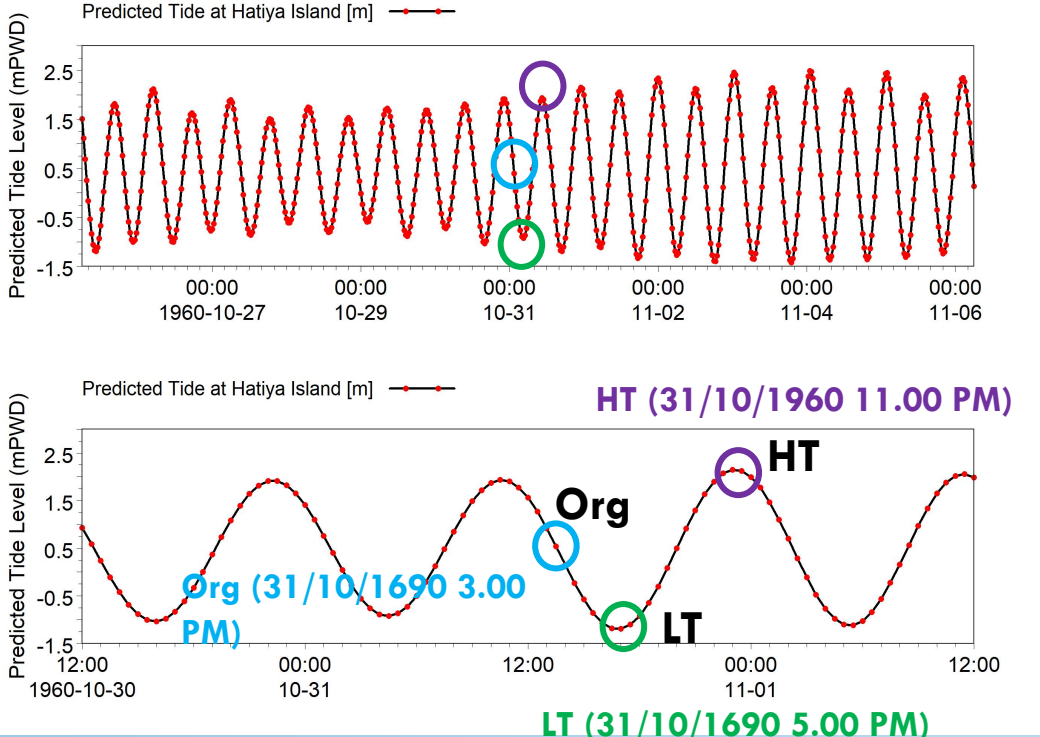
Simulation of Severe Cyclones during 1960-2020

(Cyclone & Storm Surge)

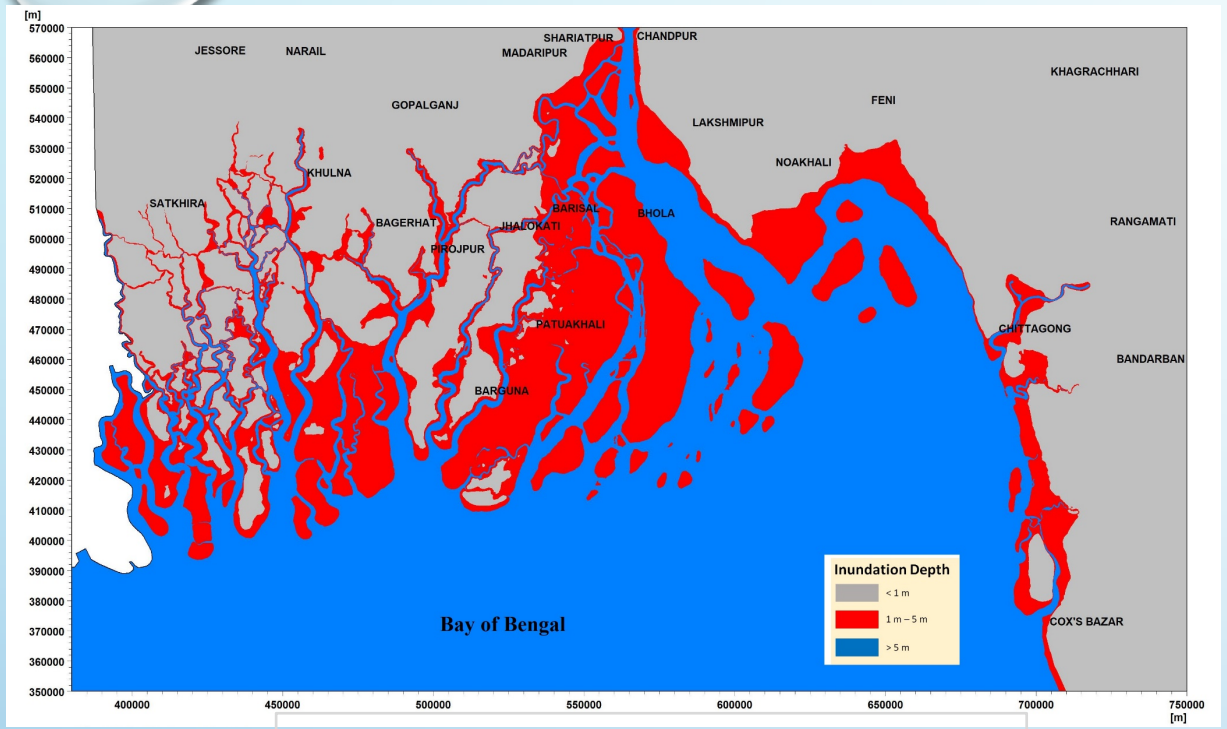


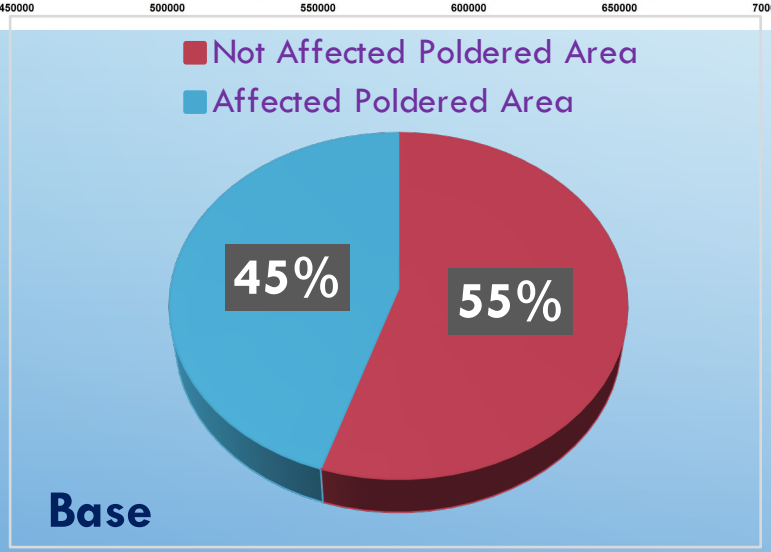
- All 19 sever cyclones have been simulated at original tidal phase
- If a cyclone made landfall on the transition between high and low tide, then both low and high tidal conditions are considered for simulation
- If any cyclone made landfall exactly on high or low tidal condition, then opposite tidal condition has been simulated for that event
- Total 54 cyclonic events have been simulated including original, high and low tidal condition
- Again, these 54 cyclonic events have been simulated for climate change condition

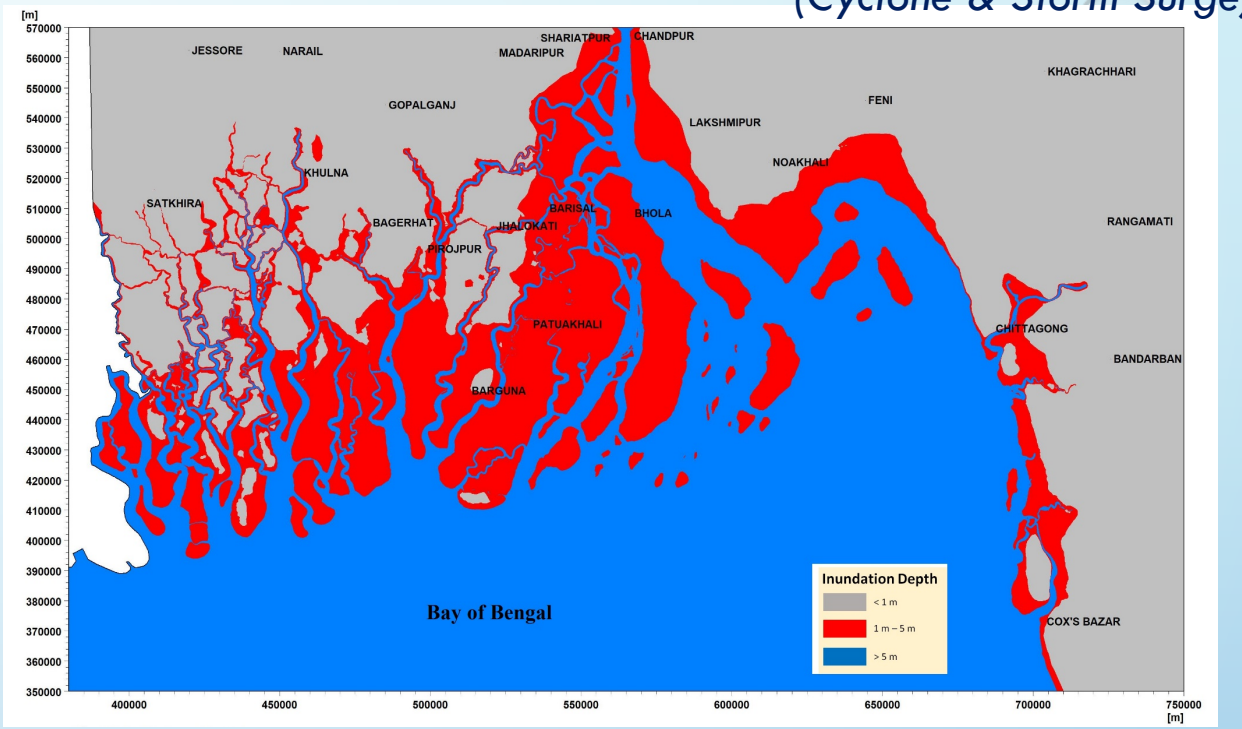
IWM Water Environment & Climate

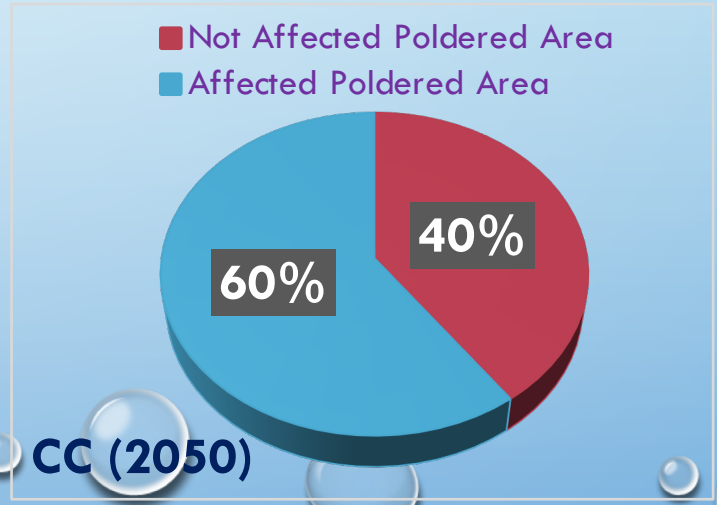
Inundation due to Cyclonic Storm Surge

(Cyclone & Storm Surge)





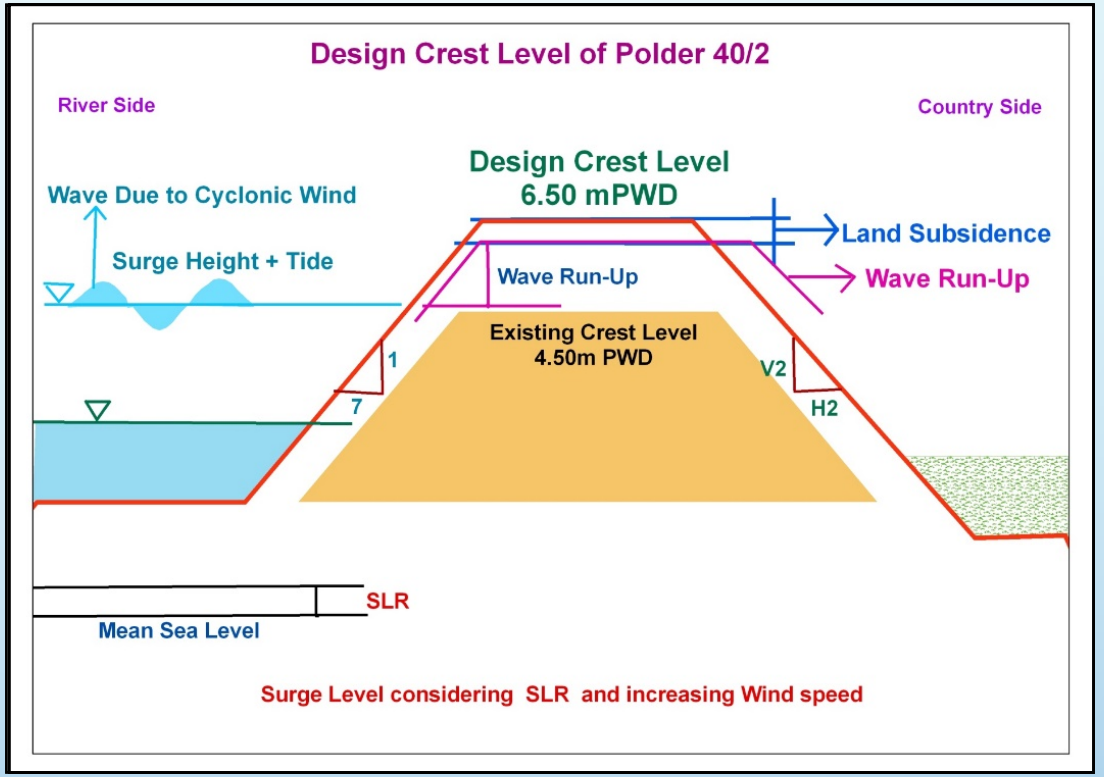




Adaptation Against Climate Change & Sea Level Rise

Design of Climate resilient coastal Polder

- Total 139 coastal polders in Bangladesh
- Of them **17** and **20** polders designed considering cyclonic storm surge in climate change condition under **CEIP 1** & **CEIP 2** project respectively
- BWDB is constructing some of them (**17 polders** of **CEIP1)**



Design Considerations

i. **Cyclonic storm surge level in climate change condition**

ii. **Cyclonic wave height in climate change condition (Sea level rise, wind speed increase)**

iii. **Allowance for land subsidence;**

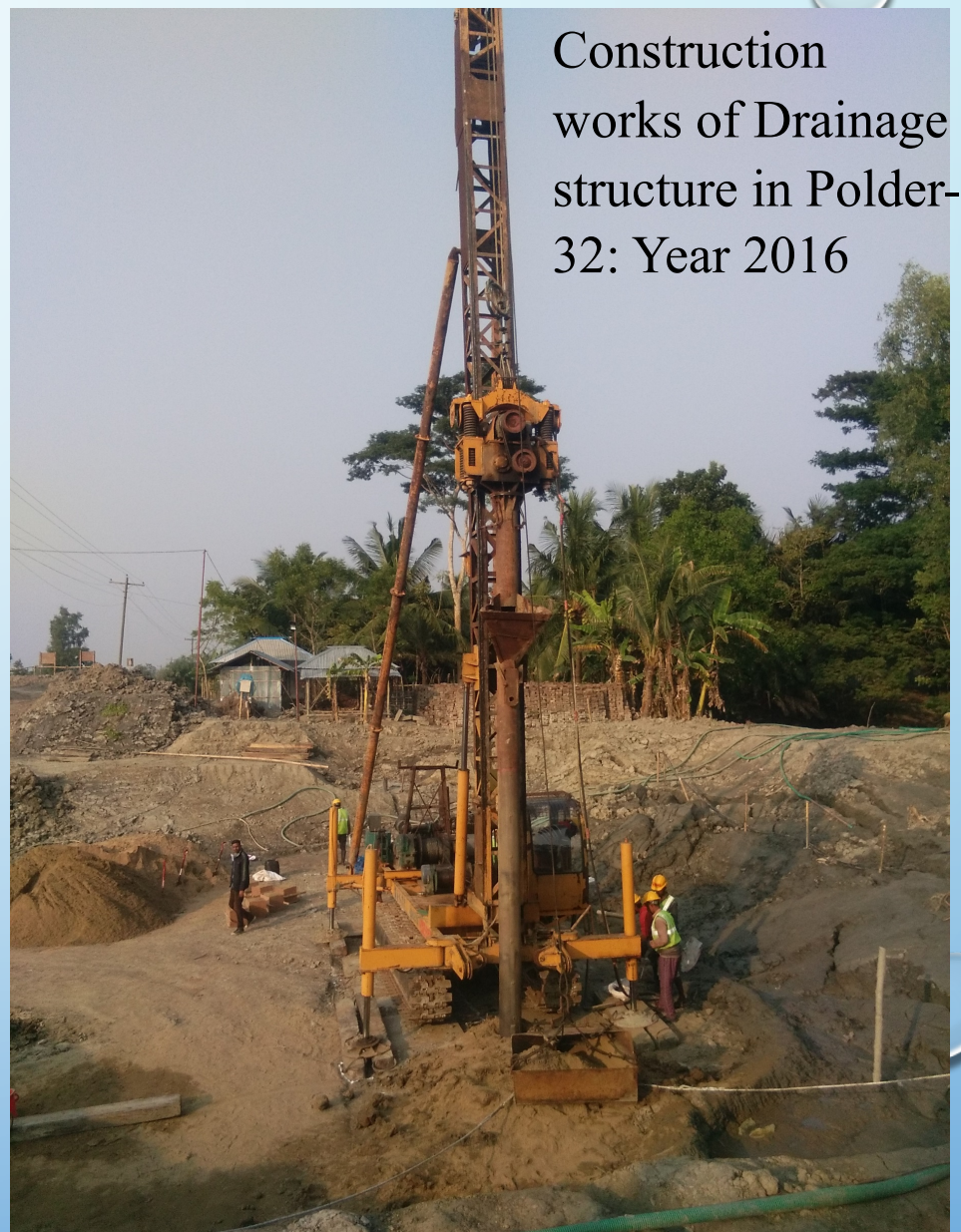
Construction of Climate Resilient Embankment in CEIP Project

Completed embankment of
Polder-33: Year 2021

Construction of embankment of
Polder-33: Year 2016

Construction of Climate Resilient Drainage Structure in CEIP Project

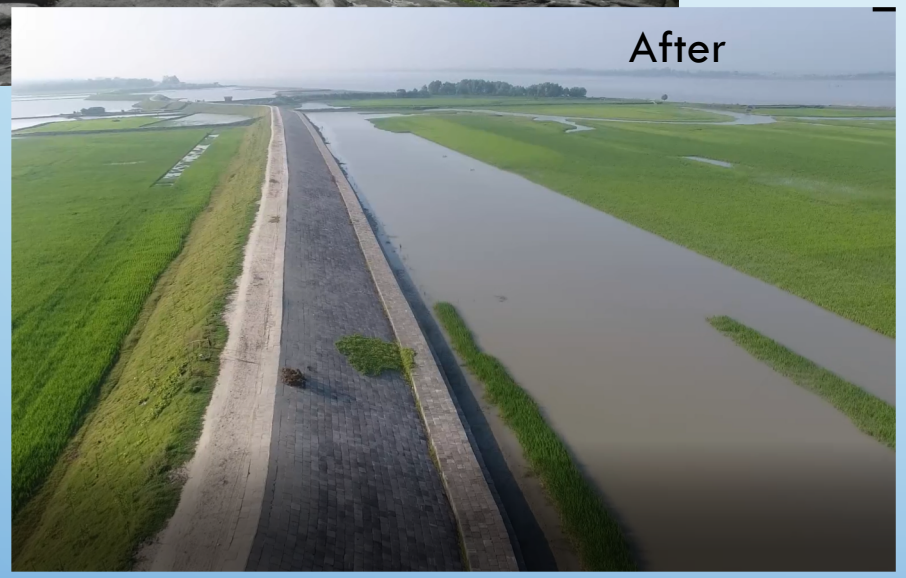
Completed Drainage Structure in Polder-32: Year 2019



Construction works of Drainage structure in Polder-32: Year 2016

Climate Resilient Polder Construction in Bangladesh

Polder-32



Polder-35/1


Thank You For
Your Attention