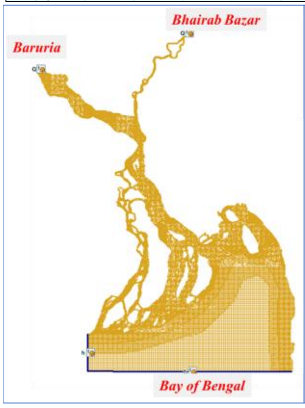
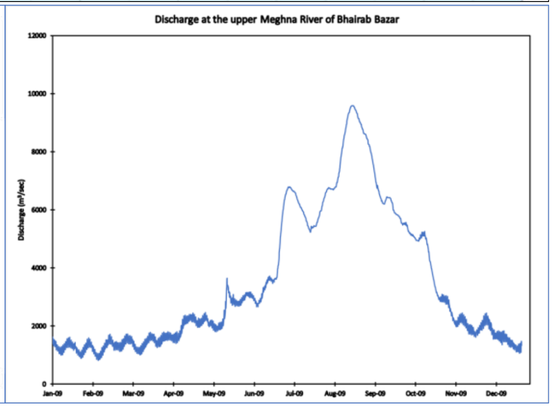
Ministry of Water Resources

Bangladesh Water Development Board

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

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





Boundary conditions and data for calibration and validation of models

Revised Submission March 2021

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1. Background

The main objective of the “long-term monitoring, research and analysis of the Bangladesh coastal zone” project is to create a framework for polder design, based on understanding of the long-term and large-scale dynamics of the delta and sustainable polder concepts. The modelling work within the project is carried out to improve our understanding of the long-term and large-scale dynamics of the Ganges-Brahmaputra-Meghna (GBM) delta. The knowledge on sediment dynamics, distribution, erosion-deposition processes and sediment management at present and in the future under climate change, land use changes and proposed interventions in the upstream reaches of the Ganges-Brahmaputra river systems are essential for the framework of polder design. The cascade of models applied considers three different spatial and temporal scales:

- ✓ Macro-scale: annual sediment balance of the Bengal part of the GBM delta, and long-term morphodynamics.
- ✓ Meso-scale: regional river and estuary dynamics, driven by seasonal fluctuations in forcing conditions.
- ✓ Micro-scale: water-logging and polder management.

This report describes the boundary conditions and data for calibration and validation of meso-scale morphodynamic models which covering the following selected River system (Figure 1):

- Pussur – Sibsa River system (Polder 32 & 33)
- Baleswar – Bishkhali River system (Polder 35/1, 39/1, 39/2, 40/1, 40/2, 41 & 42)
- Lower Meghna- Tetulia River system (Polder 56/57,55/1,55/2, 55/3 & 59/2)
- Sangu River system (Polder 63/1a, 63/1b & 64/1b)

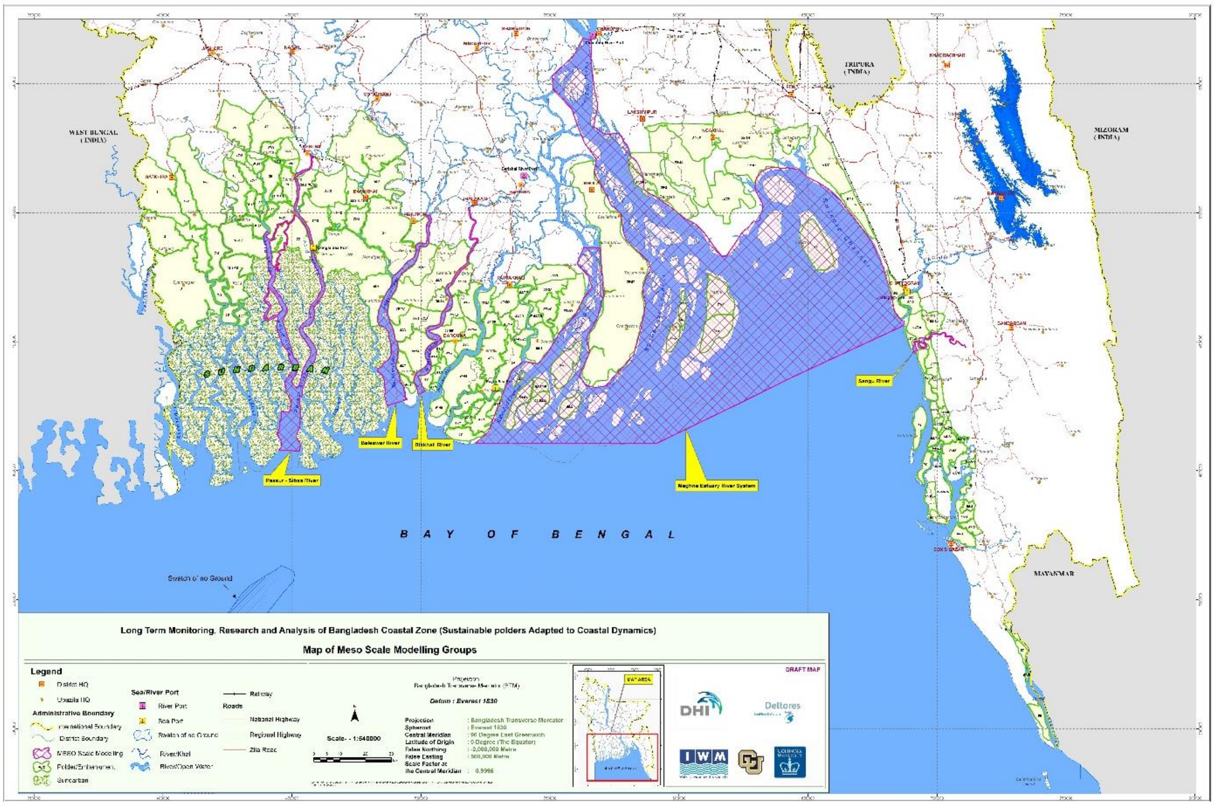

Figure 1 Map of meso-scale modelling groups

The available boundary conditions for the above meso-scale modelling groups are describe in the following section.

2. Boundary Conditions for Meso-Scale Models for Bank Erosion

2.1. Sibsa River

2.1.1 Model development

The two rivers, Pussur and Sibsa, were originally modelled in one single model. However, that idea was abandoned in the present study because we can make simpler models; the interaction between the rivers can be handled via the SWRM.

The river system has some influence from floodplain (e.g. mangrove forest and outside the polder areas), which was identified from the available DEM elevations. The MIKE 11 model (SWRM) also shows significant floodplain along both rivers, which is reflected in the output from the MIKE 11 model.

The most important evidence of floodplain flow can be found in the 2D model behavior, which is very difficult to get correct if the floodplain is not included. In particular the downstream discharge in Sibsa becomes significantly underpredicted in MIKE 21C if we do not include floodplain, and the hydraulics associated with this is not overly complicated: It is about tidal prism, if it is too small, the flows are too small. Morphological models are very sensitive to discharge errors, although models can be calibrated to still yield correct concentrations, but such models do not produce correct sediment fluxes due to incorrect discharges.

Therefore, the floodplain was incorporated with the river in the MIKE 21C modelling system. The available 2011 bathymetry data for the main river channel and floodplain data from IWM DEM (FinMap 1993-94) were interpolated in the curvilinear grid system. Figure 2 shows the computational grid and interpolated bathymetry for Sibsa river.

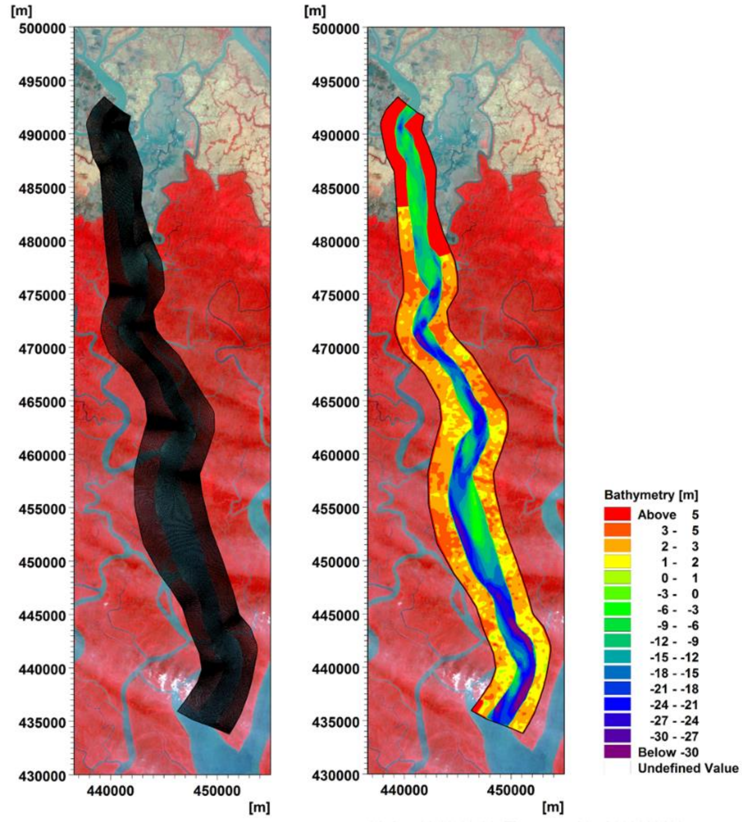

Figure 2 Computational curvilinear grid and interpolated bathymetry for the Sibsa River. This version of the model includes floodplain and has a fine grid in the river channel (1000x30).

2.1.2 Boundary Conditions

Hydrodynamic

The Sibsa River model has upstream discharge and downstream water level boundary conditions. The upstream boundary discharge was collected from the calibrated and validated South West Regional Model (SWRM). The downstream boundary water level was extracted from the combined river system model which has a water level boundary at Hiron Point.

The side channels discharges were added as source points (adding and removing water to reflect the interaction with the side channels) in the models. The side channels are essential to include in the hydrodynamic model, as the flow exchanges with these side channels are not insignificant. Without the side channels, it becomes challenging to get the correct discharges in the Sibsa River models. All the sources were extracted from the South West Regional Model. Figure 3 shows all boundaries and sources locations in the river.

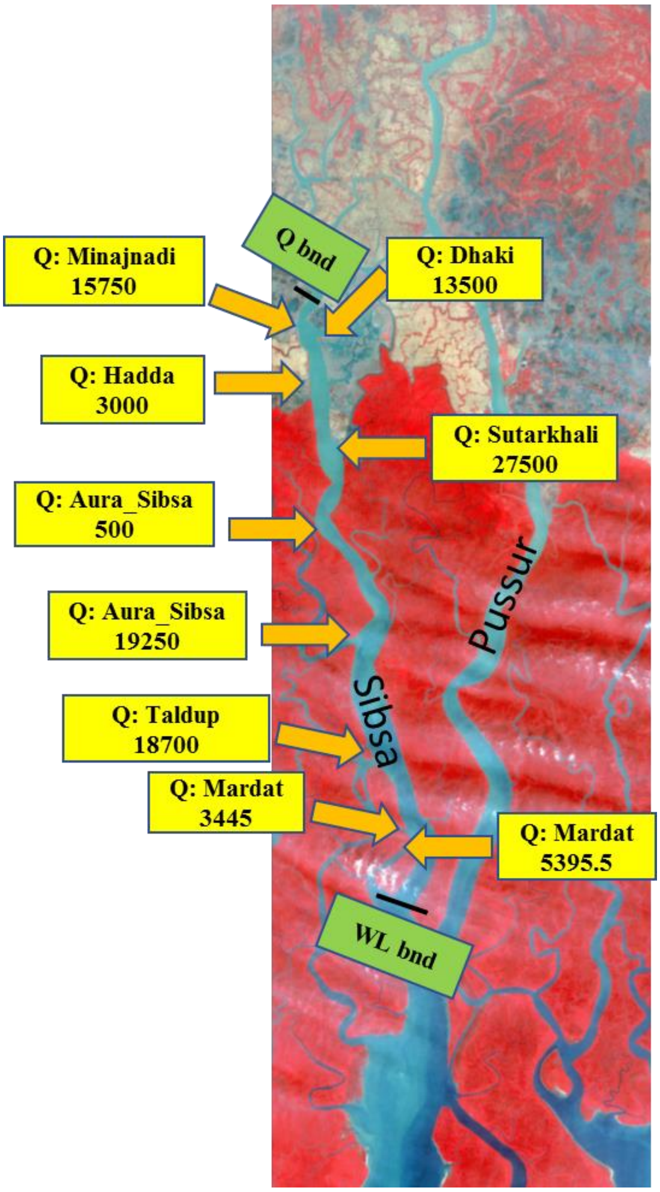

Figure 3 Boundaries and sources location map in the Sibsa River

Sediment Concentration

All boundaries use constant sediment concentrations in the Sibsa Sediment Transport Model:

- Upstream concentration: 200 g/m^3
- Side channels: 200 g/m^3
- Downstream: 200 g/m^3

All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “MIKE 21C Sibsa meso-scale bank erosion morphological modelling study: Model development report”. (Ref-1)

2.1.3 Calibration and Validation

The hydrodynamic model was calibrated with field data during 2011 both dry and monsoon season. The validation was done for 2016. The locations of the field data are shown in Figure 4.

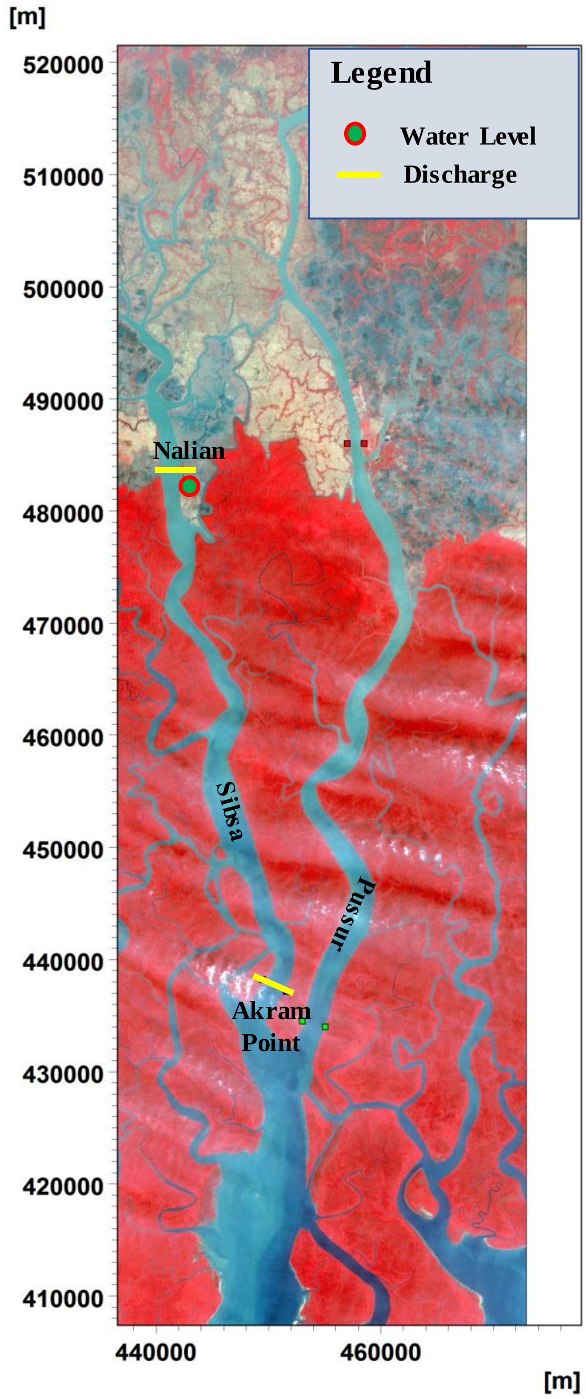

Figure 4 Field data collection map for 2011, 2015, 2016 and 2019 in Sibsa River.

The resistance calibration was partly inherited from the MIKE 11 SWRM.

Mike 21C modelling system uses Manning number M instead of Manning´s n. The Manning number is the reciprocal value of the Manning´s n. The current calibration for Sibsa is done a constant Manning’s M (=50 m1/3/s) for river.

Only for model with floodplain: In the floodplain, we set constant low Manning's M=20 m1/3/s as the roughness is usually high in the floodplain. The floodplain resistance should be high, but the model may still not capture the flow exchange correctly, as the flow exchange in mangroves often goes through smaller khals that are not resolved in the model, and the smaller khals are much more effective than overbank flows. The floodplain resistance in the current formulation will influence the water exchange between the river and the floodplain, such that higher resistance reduces the exchange speed between the river and the floodplain.

In the SWRM, the floodplain resistance in MIKE 11 is the same as in the river channel, which is potentially a better representation if the exhange happens through small khals.

The downstream discharge stations are extremely valuable because they give an overall handle on the tidal prism, while we do not have a downstream water level station in Sibsa.

Figure 5-7 show the discharge calibration at Akram point in Sibsa River during 2011 monsoon and dry season.

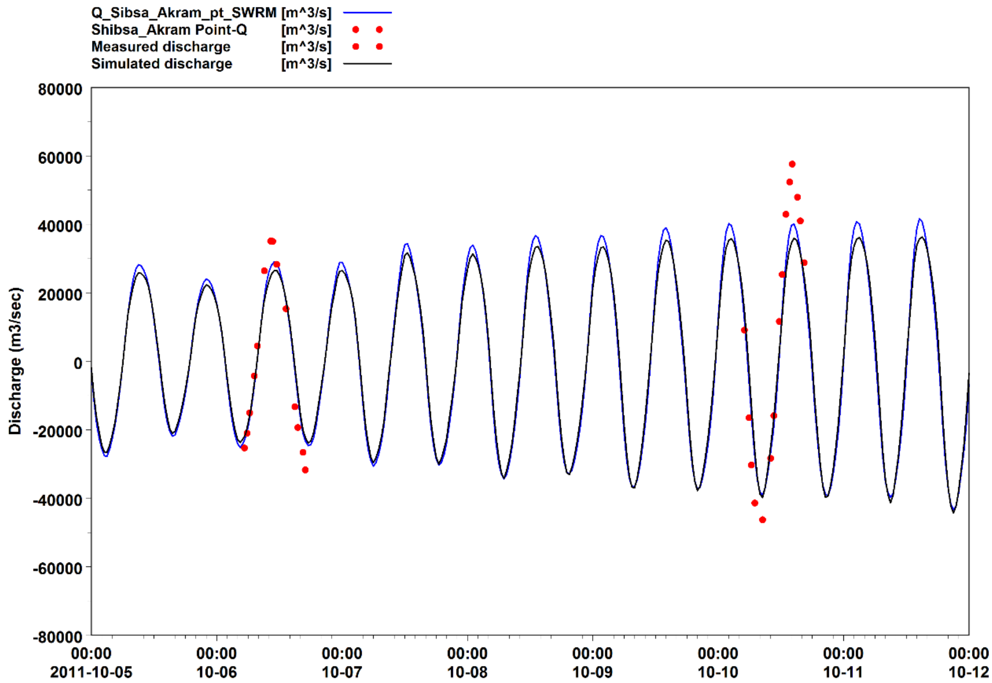

Figure 5 Discharge calibration at Akram Point in Sibsa River during the 2011 monsoon

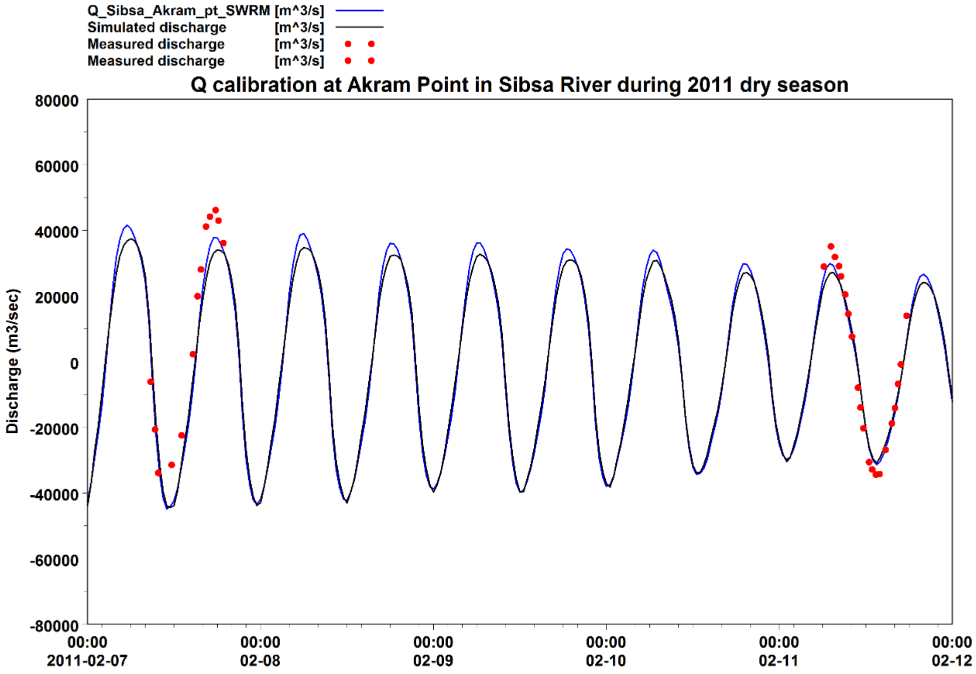

Figure 6 Discharge calibration at Akram Point in Sibsa river during the dry season (February)

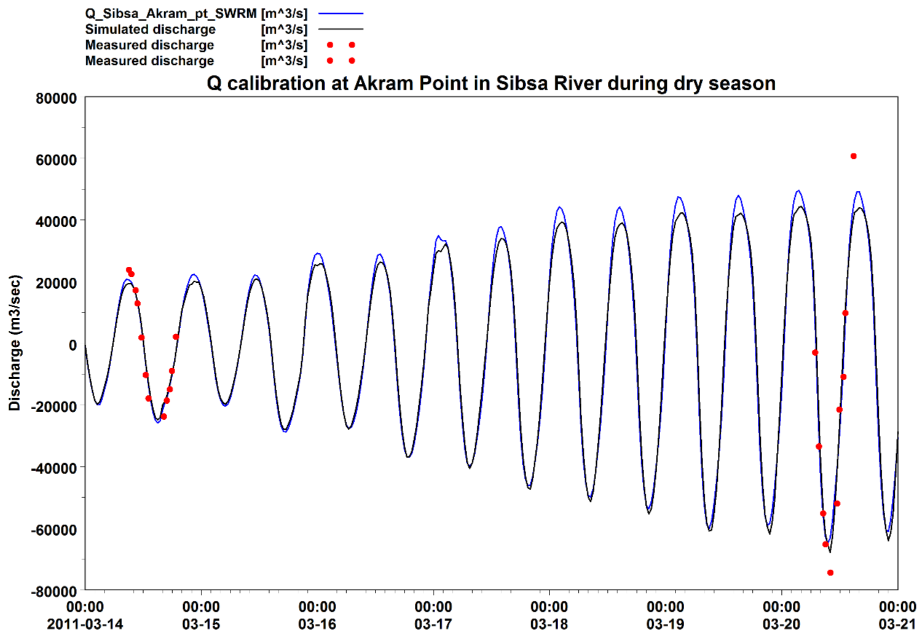

Figure 7 Discharge calibration at Akram Point in Sibsa River during the dry season (March).

Water level observations are available in 2015 at Nalian. These are the only water level observations at this stage, while later revisions of this report will include the 2019 water level observations at Nalian.

Figure 8 compares the observed and simulated water levels at Nalian in October 2015. The simulated water levels agree very well with the observations, which further supports that the real problem with the Sibsa River model is the lack of floodplain flow (downstream of this location).

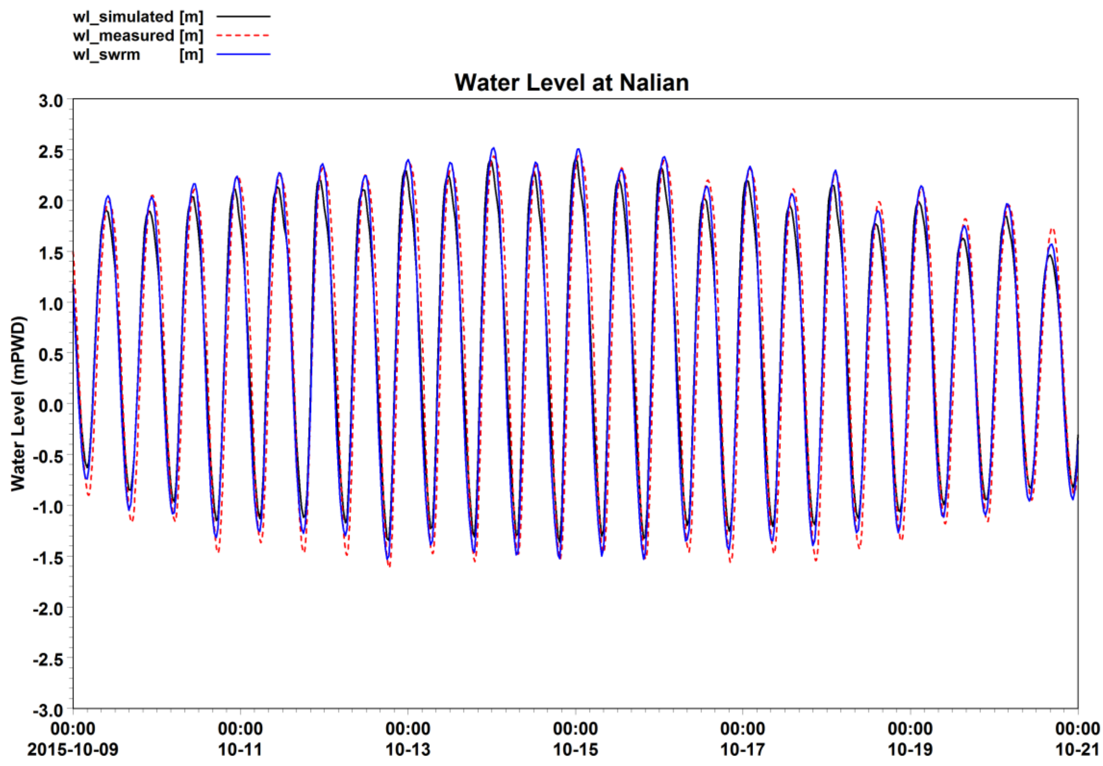

Figure 8 Water level validation at Nalian in Sibsa River during 2015. The results include the Sibsa model and the SWRM, and both validate convincingly against the Nalian water level observations.

The calibrated model is now validated against 2016 data. The hydrodynamic validation was done at Nalian for 2016 which is shown in Figure 9 The agreement is excellent, even though we know that further downstream at Akram Point we underpredict the discharge.

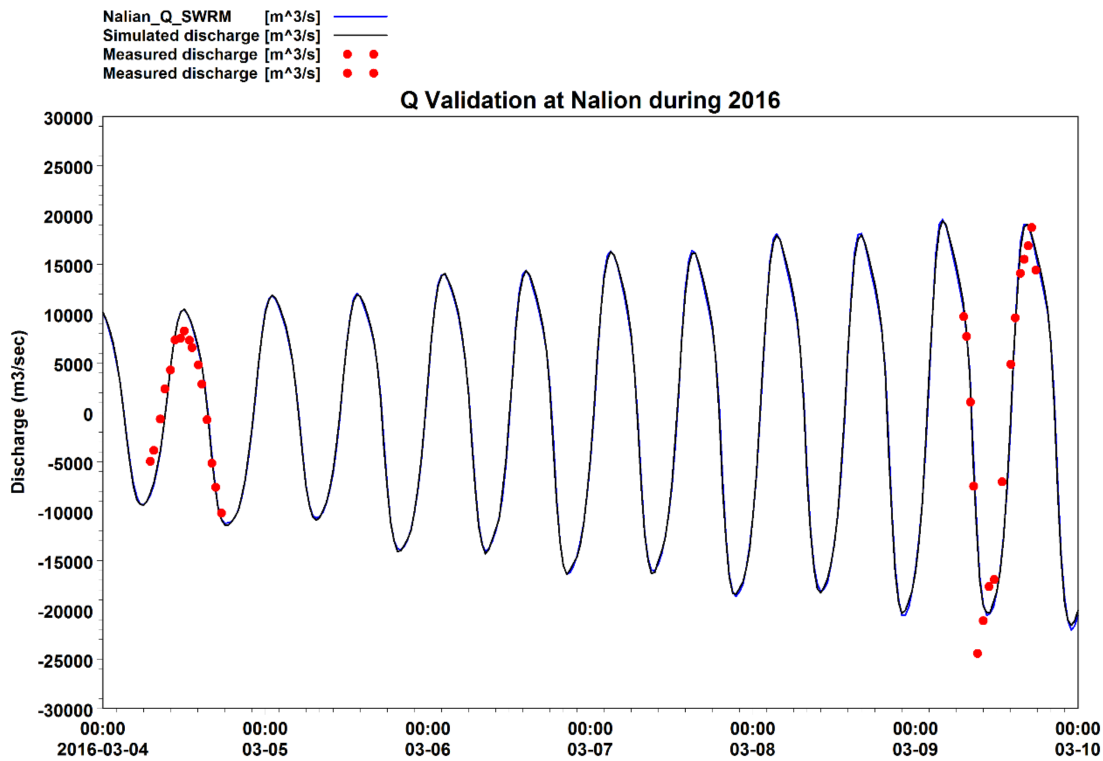

Figure 9 Discharge validation at Nalian in Sibsa River during 2016

2.2 Passur River

2.2.1 Model development

The two rivers, Pussur and Sibsa, were originally modelled in one single model. However, this idea was abandoned in the present project because we can make simpler models. We know that there is inceraction between the two rivers, which is at least reasonably accounted for in the boundary conditions representing the channels connecting the two rivers.

The river system has some influence from floodplain (e.g. mangrove forest and outside the polder areas), which was identified from the available DEM elevations. The MIKE 11 model (SWRM) also shows significant floodplain along both rivers, which is reflected in the output from the MIKE 11 model. The available 2011 bathymetry data for the main river channel and floodplain data from IWM DEM (FinMap 1993-94) were interpolated in the curvilinear grid system. Figure 10 shows the grid and bathymetry for the Pussur river.

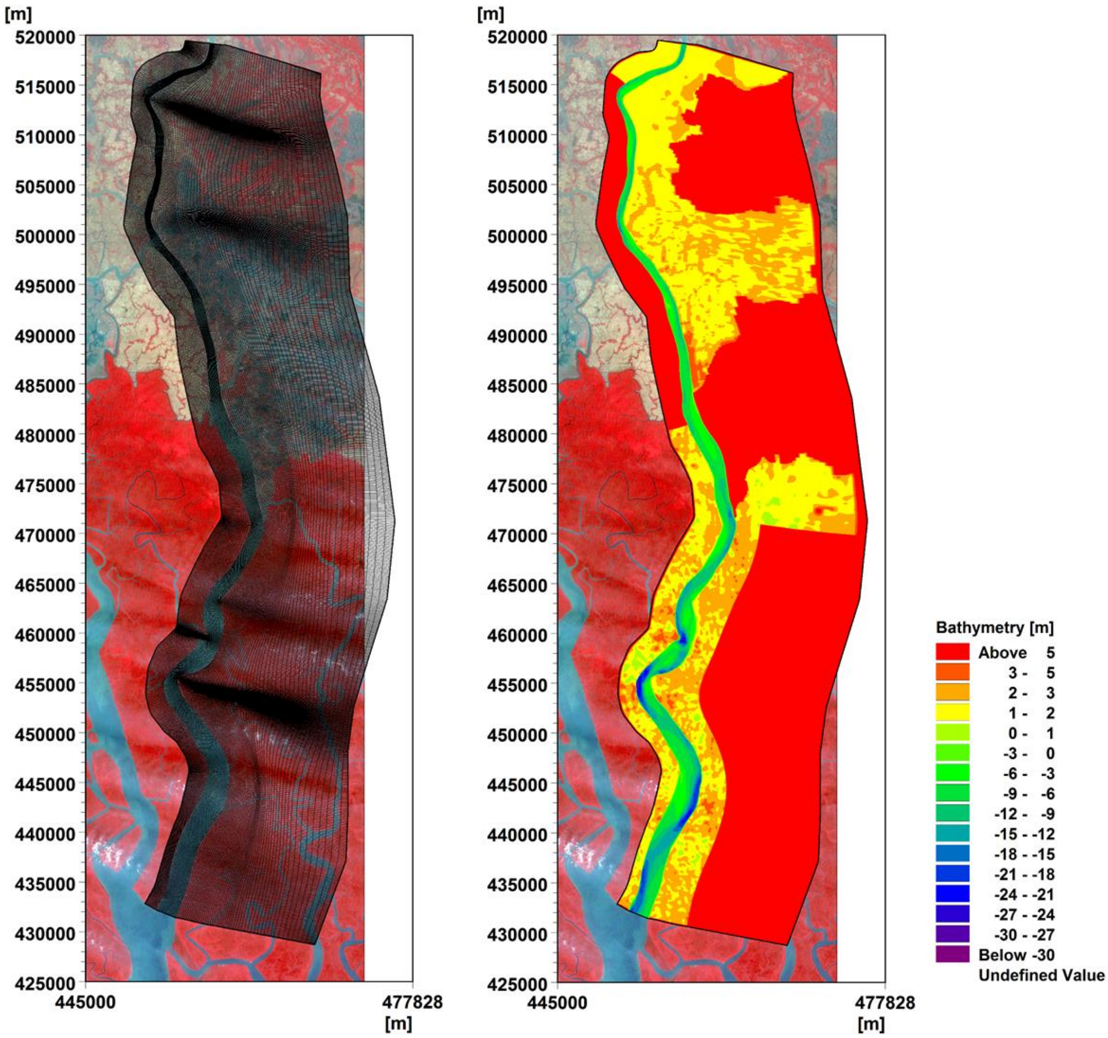

Figure 10 Computational curvilinear grid and interpolated bathymetry for the Pussur River.

The current model for Pussur is a fairly low Manning M upstream and a higher value in the downstream end, in accordance with conditions at the confluence between the two rivers.In the floodplain, we set constant low Manning's M (=10 m1/3/s) as the roughness is usually high in the floodplain. The floodplain resistance should be high, but the model may still not capture the flow exchange correctly, as the flow exchange in mangroves often goes through smaller khals that are not resolved in the model, and the smaller khals are much more effective than overbank flows. The floodplain resistance in the current formulation will influence the water exchange between the river and the floodplain, such that higher resistance reduces the exchange speed between the river and the floodplain.

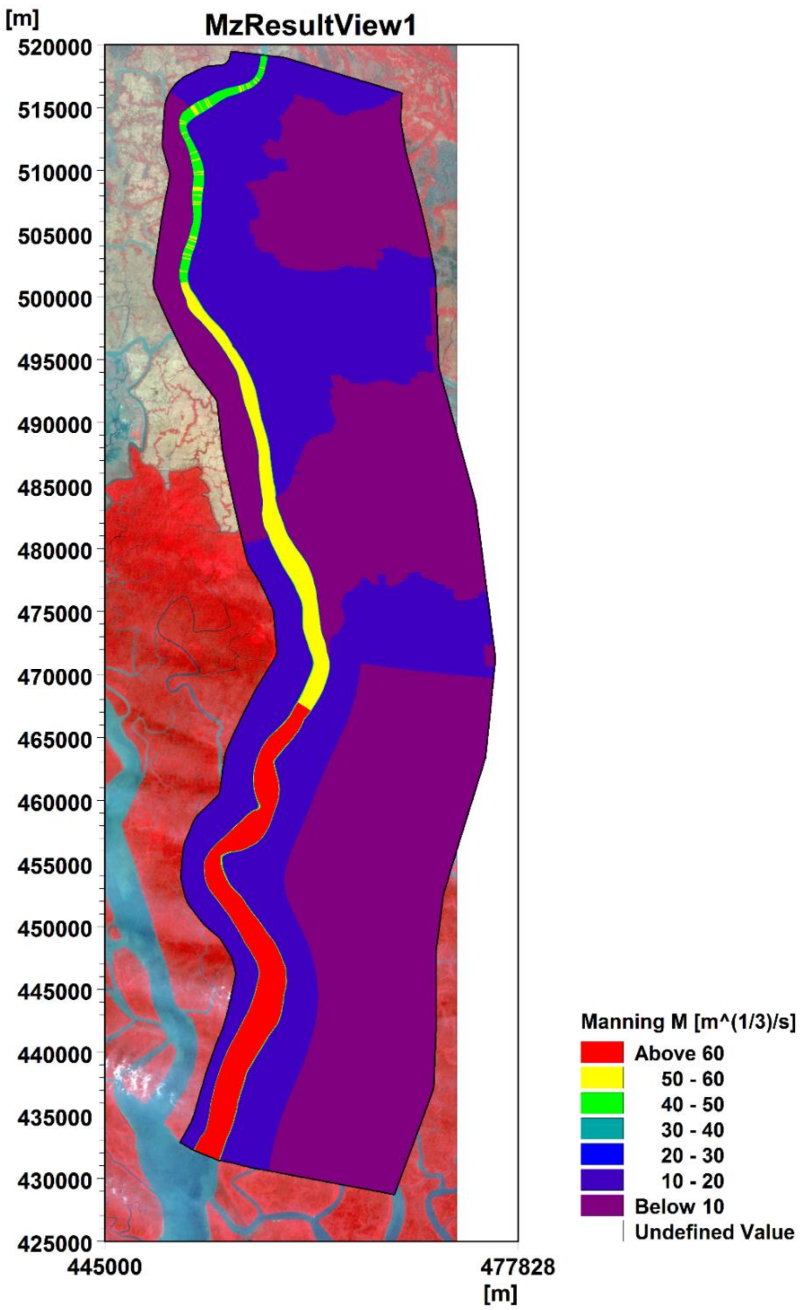

Figure 11 Horizontal distribution of resistance map (Manning's M) for the Pussur River.

2.2.2 Boundary Conditions

Hydrodynamic

Upstream boundaries were collected from calibrated and validated South West Regional Model (SWRM). The downstream boundaries were extracted from the combined river system model which has a water level boundary at Hiron Point.

The side channels discharges were added as source points (adding and removing water to reflect the interaction with the side channels) in the models. The side channels are essential to include in the hydrodynamic model, as the flow exchanges with these side channels are quite significant. All the sources were extracted from the South West Regional Model. Figure 12 shows all boundaries and sources locations in both rivers.

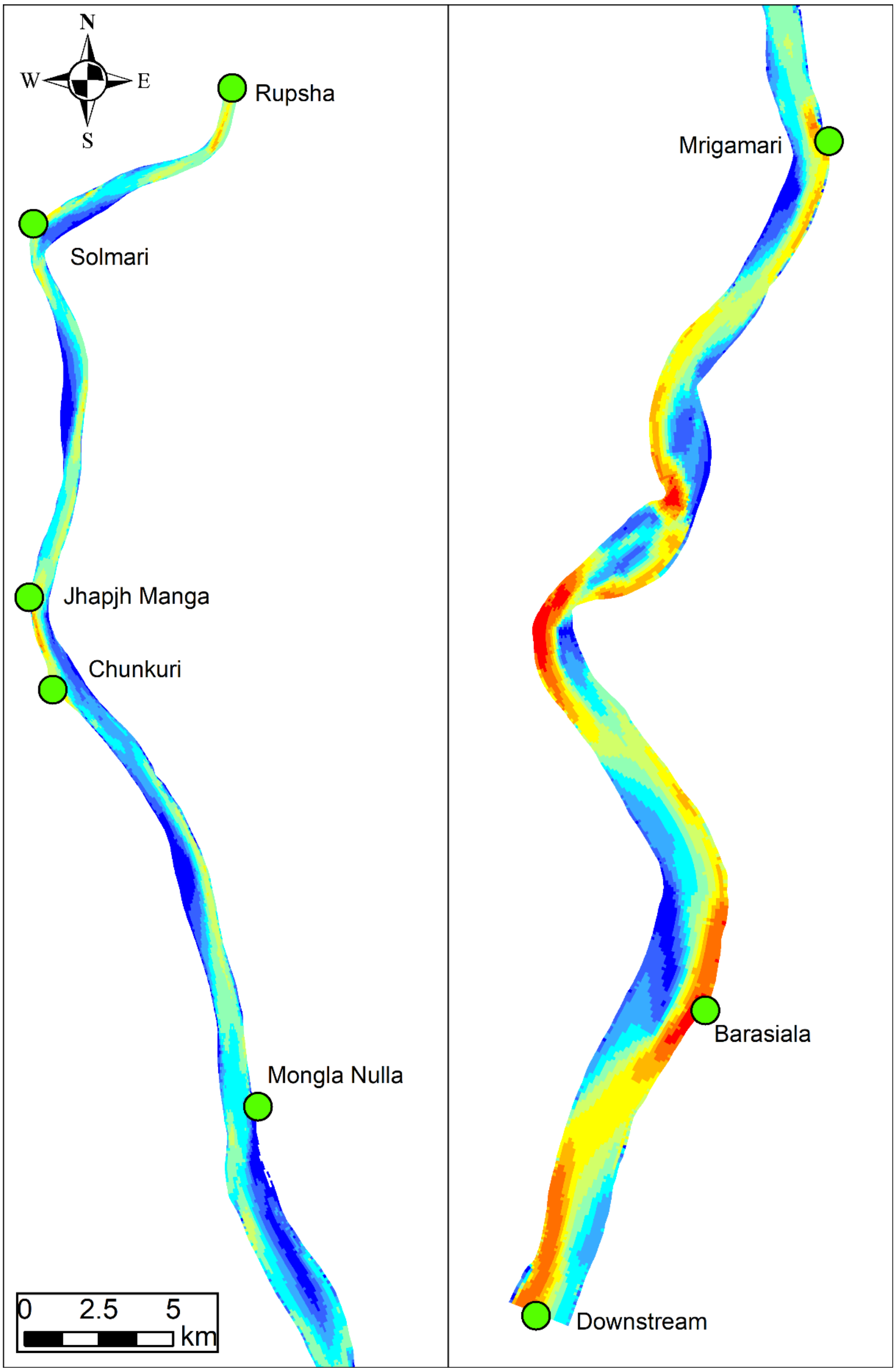

Figure 12 Boundaries and sources location map in the Pussur model; the location "Jhapjh Manga" is called Badurgacha in the SWRM.

Sediment Concentration

At Upstream (Rupsha) we used the observed suspended sediment concentrations to generate a sediment rating curve. We used a simple expression for the Rupsha total concentration:

$C(Q) = C_0 * (Q/Q_0)^2$

Where C_0=1200 g/m^3 and Q_0=800 m^3/s.

The Downstream (Akram Point) sediment concentration boundary condition are:

- Silt 100 g/m^3
- Sand 0 g/m^3

All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “MIKE 21C Pussur meso-scale bank erosion morphological modelling study: Model development report”. (Ref-DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (October 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *MIKE 21C Pussur meso-scale bank erosion morphological modelling study: Model development report*.2)

2.2.3 Calibration and Validation

Hydrometric data include water levels and discharges. Water level data is available for Mongla, while discharge data is available for Rupsha, Mongla and Akram. The stations are shown in Figure 13. The calibration and validation were done for those measured locations.

The water level calibration plots at Mongla Port are shown in Figure 14 and Figure 15 for the monsoon and dry season respectively. The computed water level is underpredicted specially in flood tide, but in the ebb tide, the water levels match quite well.

Figure 16-19 show the discharge calibration and validation at different location during monsoon and dry season. The computed discharge is well calibrated and validated.

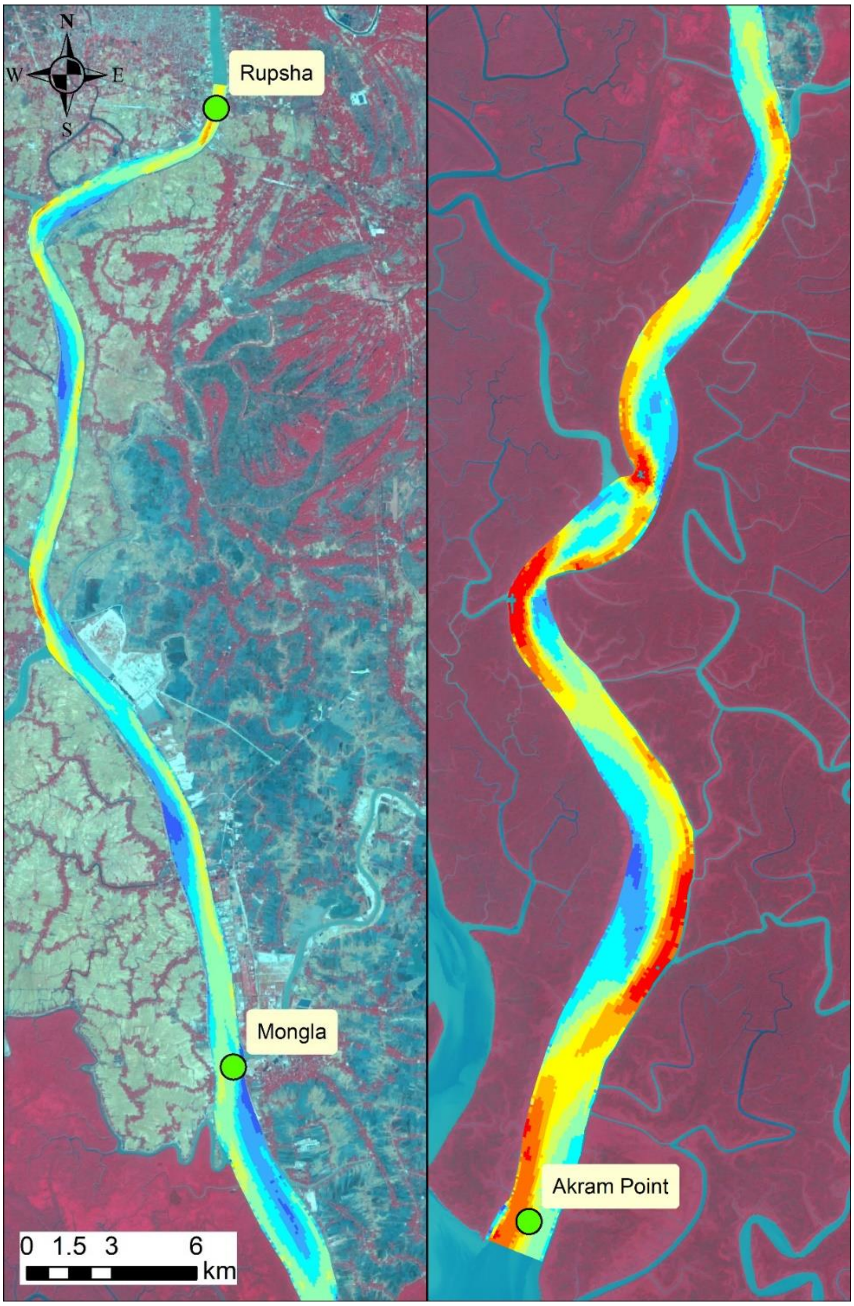

Figure 13 Field hydrometric data collection map for 2011. All three stations have discharge data, while only Mongla has water level data.

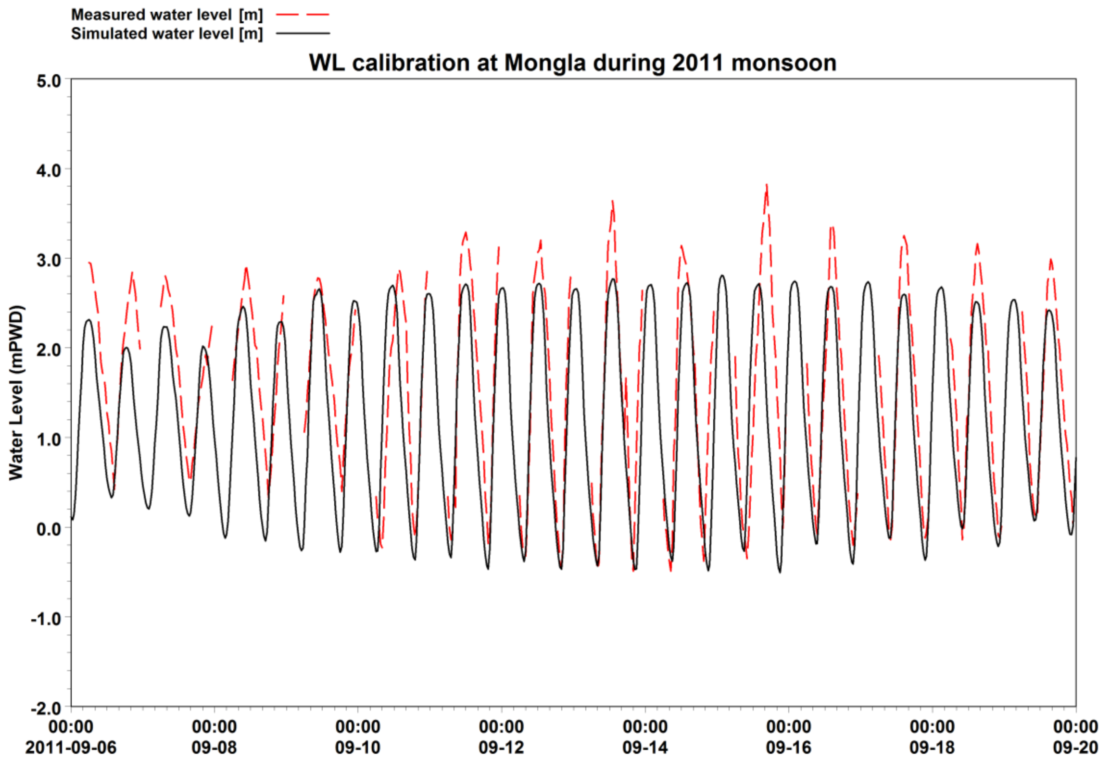

Figure 14 Comparison between observed and computed water level at Mongla port during Monsoon.

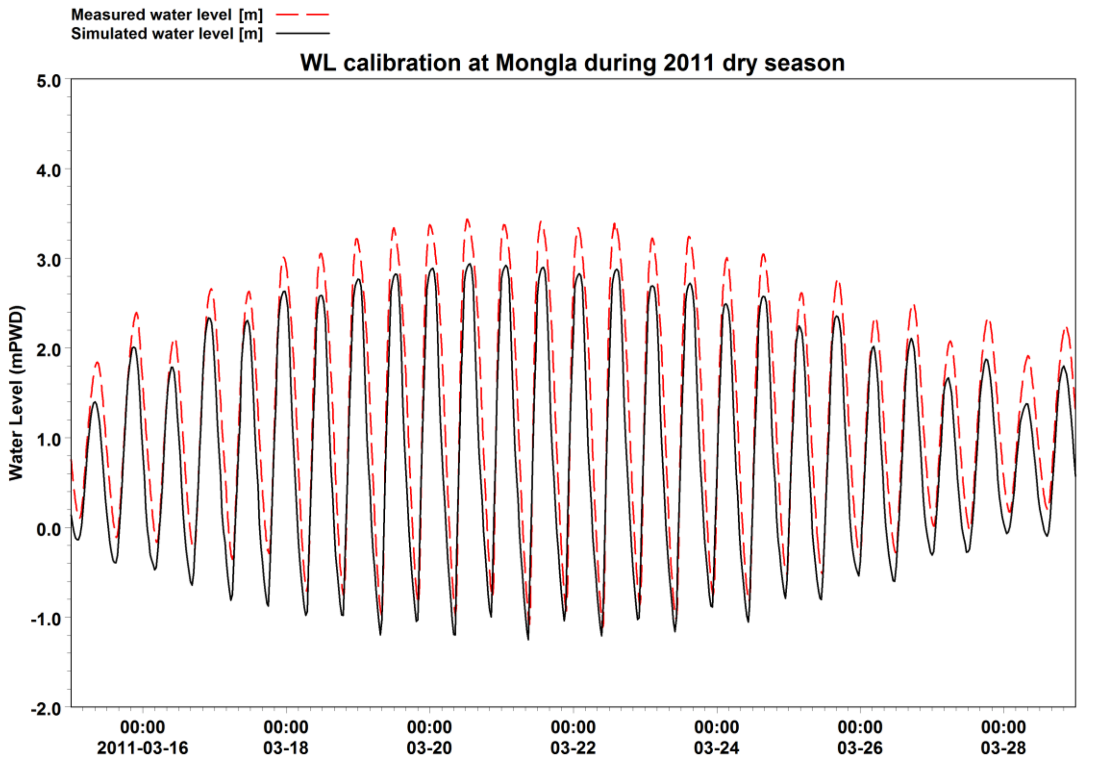

Figure 15 Comparison between observed and computed water levels at Mongla port during the dry season

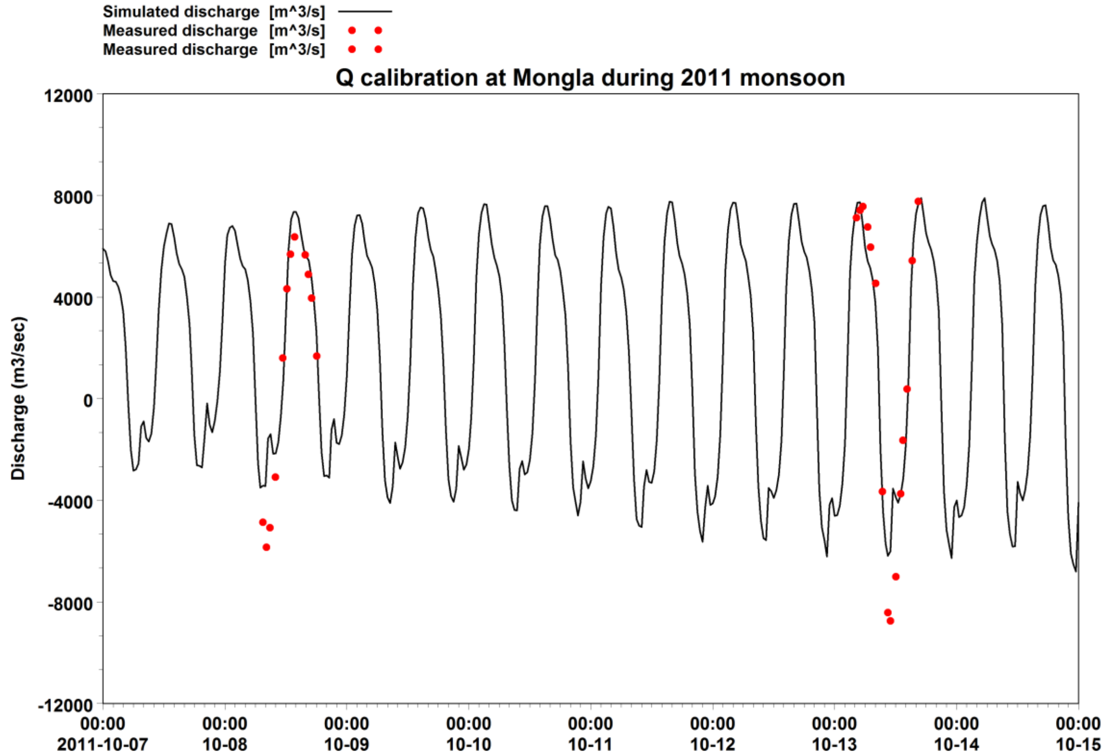

Figure 16 Discharge calibration at Mongla Port during monsoon.

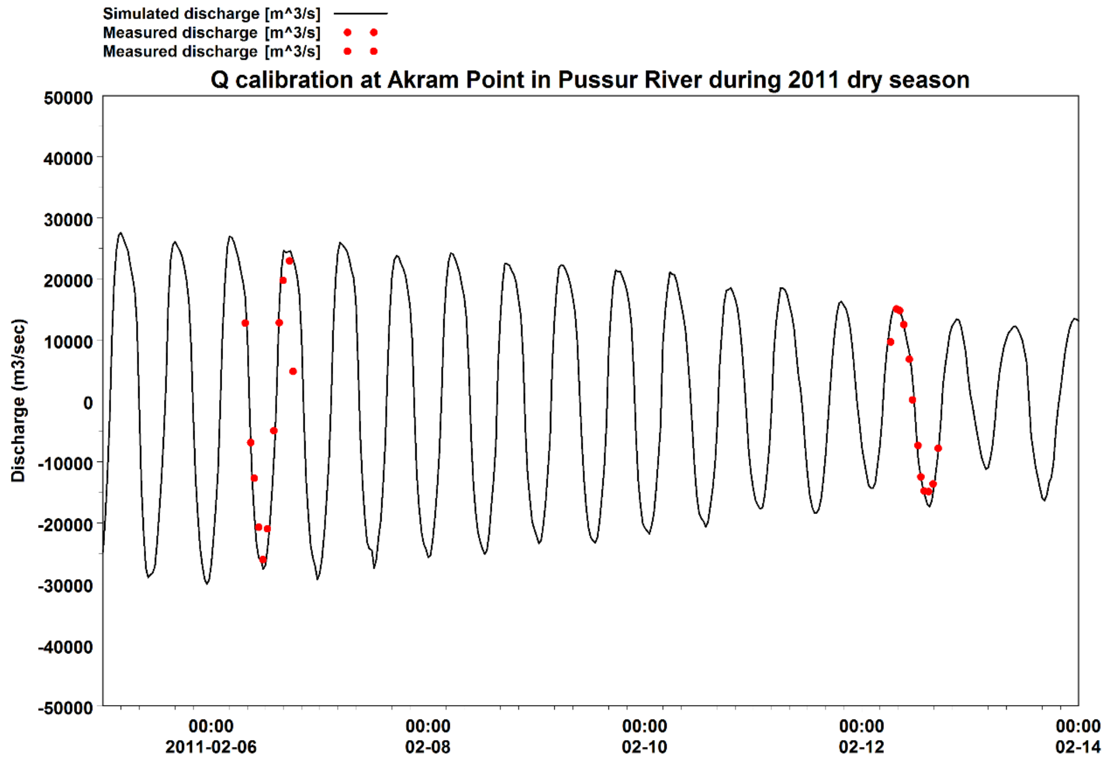

Figure 17 Discharge calibration at Akram point in Pussur river during the dry season (February).

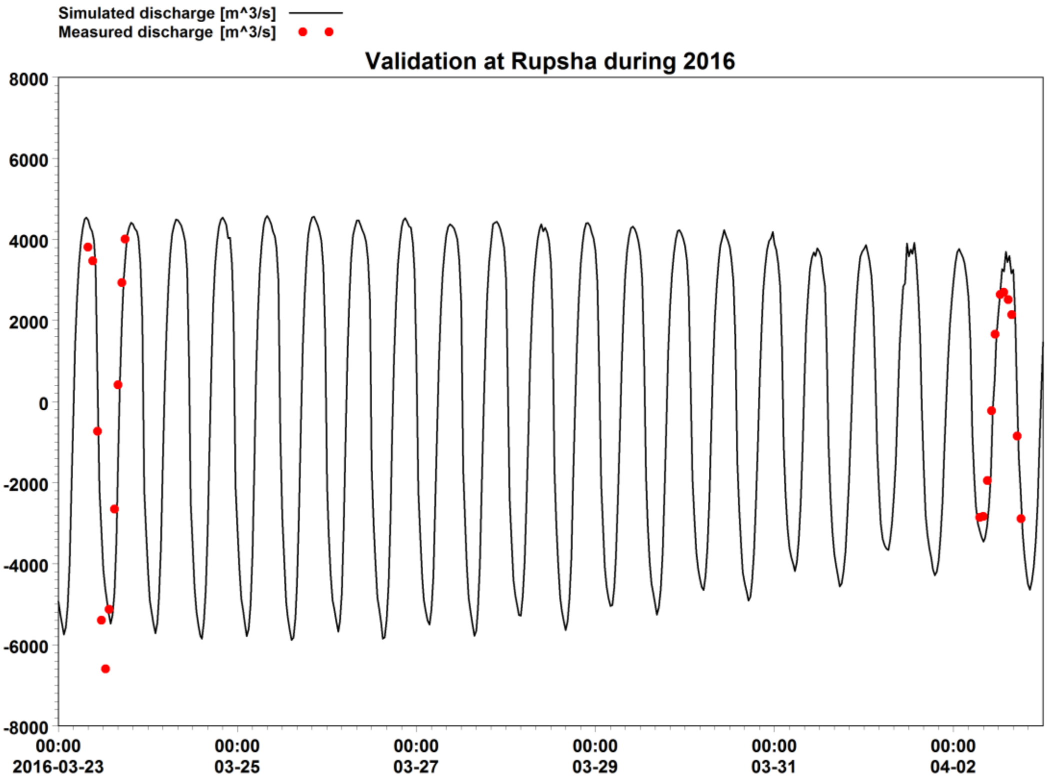

Figure 18 Discharge validation at Rupsha in Pussur river during 2016.

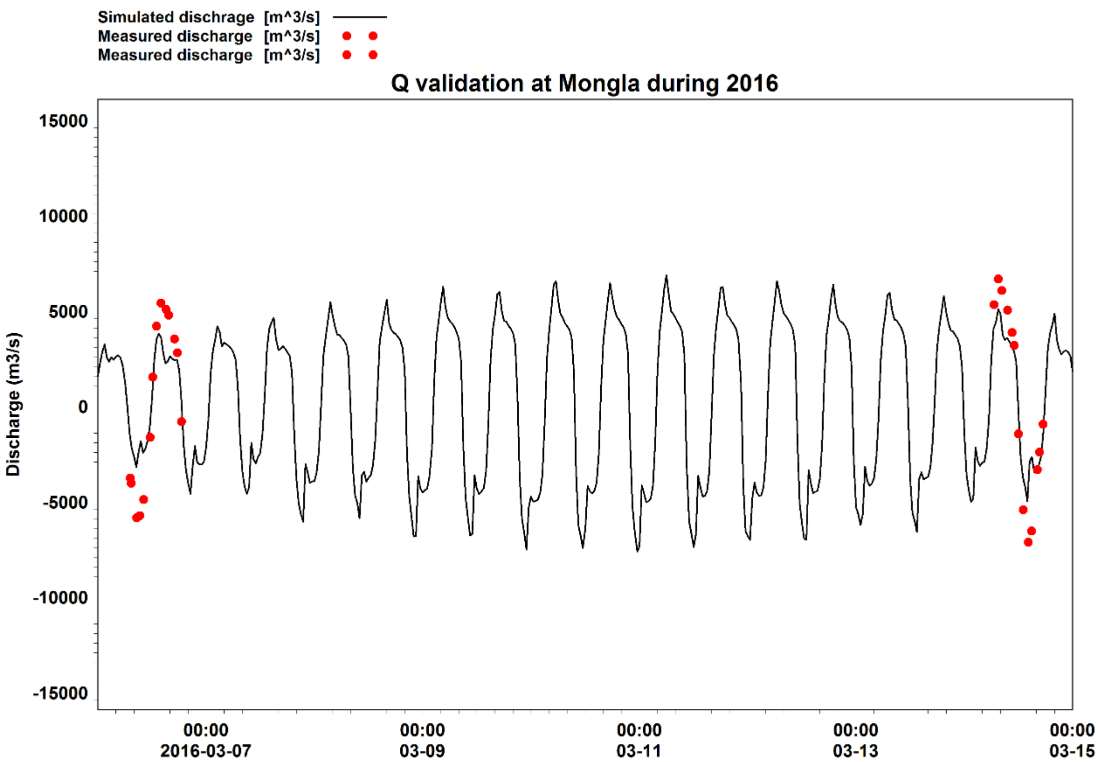

Figure 19 Discharge validation at Mongla in Pussur river during 2016.

2.3 Baleswar River

2.3.1 Model Setup

MIKE 21C model is a curvilinear model, meaning that it requires a curvilinear grid with bathymetry values defined in the cell centres. The grid and bathymetry are defined in two separate dfs2 files, with the grid file containing one more point in each direction because the grid contains vertex coordinates, while the bathymetry contains cell center values. Two separate models were developed:

- 2011: Calibrations before 2019, hindcast 2011-2019
- 2019: Validations for 2019, scenario simulations from 2019, e.g. bank erosion forecast

Although we have a bathymetry for 2015, we did not develop a separate 2015 model. Also, the grid for 2011 was used in e.g. the hindcast simulation 2011-2019, i.e. the 2019 bathymetry exists in a version on the 2011 grid, although the bank lines in 2019 are different. However, the bank line differences are small, and it is much easier to compare model results on the same grid (e.g. we can subtract bed levels directly).

2.3.2 Boundary conditions

Hydrodynamic

The Baleswar River model has one upstream boundary, one downstream boundary and several source points representing side channels. Upstream boundary and sources were collected from the calibrated and validated SWRM for 2011 and 2015. The water level of Haringhata was corelated from Hiron Point used as downstream boundary for the year 2011. Measured Water level data Fakirghat was used and downstream water level boundary for the year 2015. The side channels locations are also shown in Figure 20.

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

Time series boundaries plot at u/s of Baleswar River and Haringhata are presented in Figure 21.

Sediment Concentration

There are three types of boundary conditions in the Baleswar River model:

- Upstream concentration 200 g/m^3
- Bay of Bengal concentration 400 g/m^3
- Side channels concentration 200 g/m^3

The sediment boundary conditions were set to constant in the Baleswar River model because data were not available to allow a more sophisticated approach.

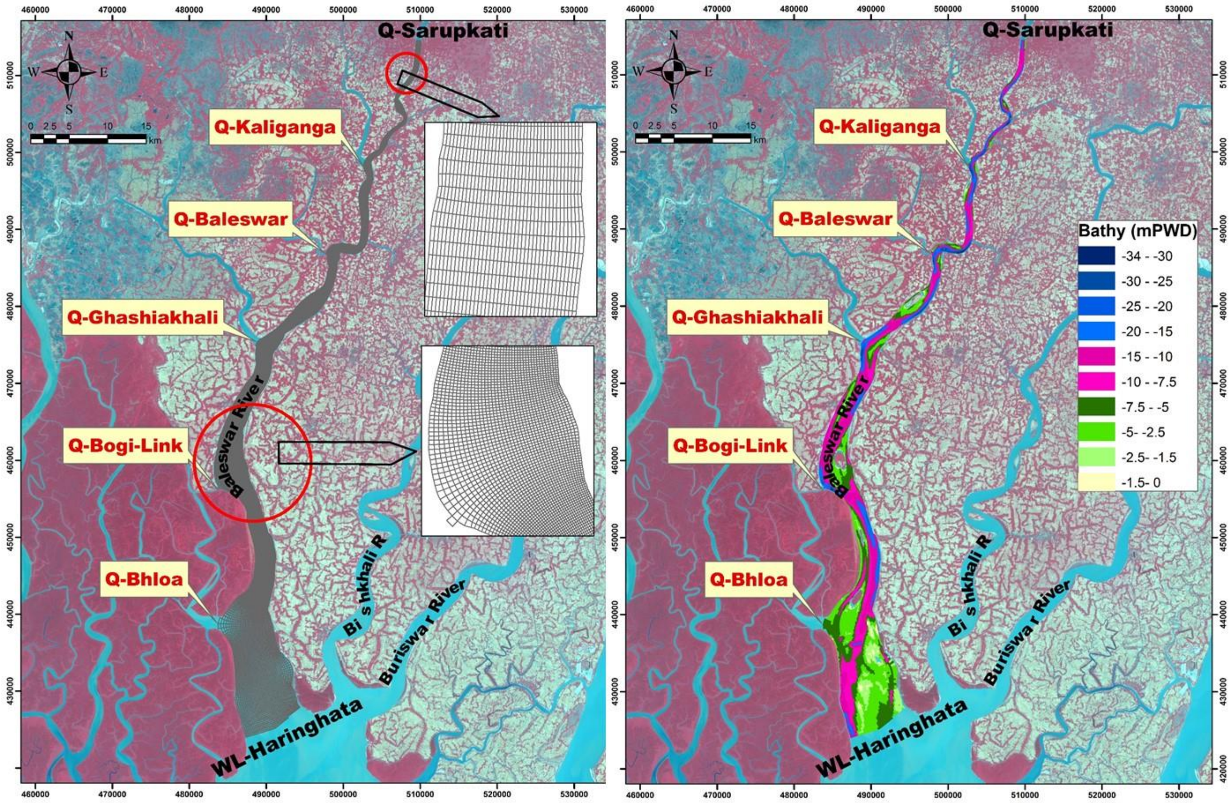

Figure 20 Boundaries location map in the Baleswar river system.

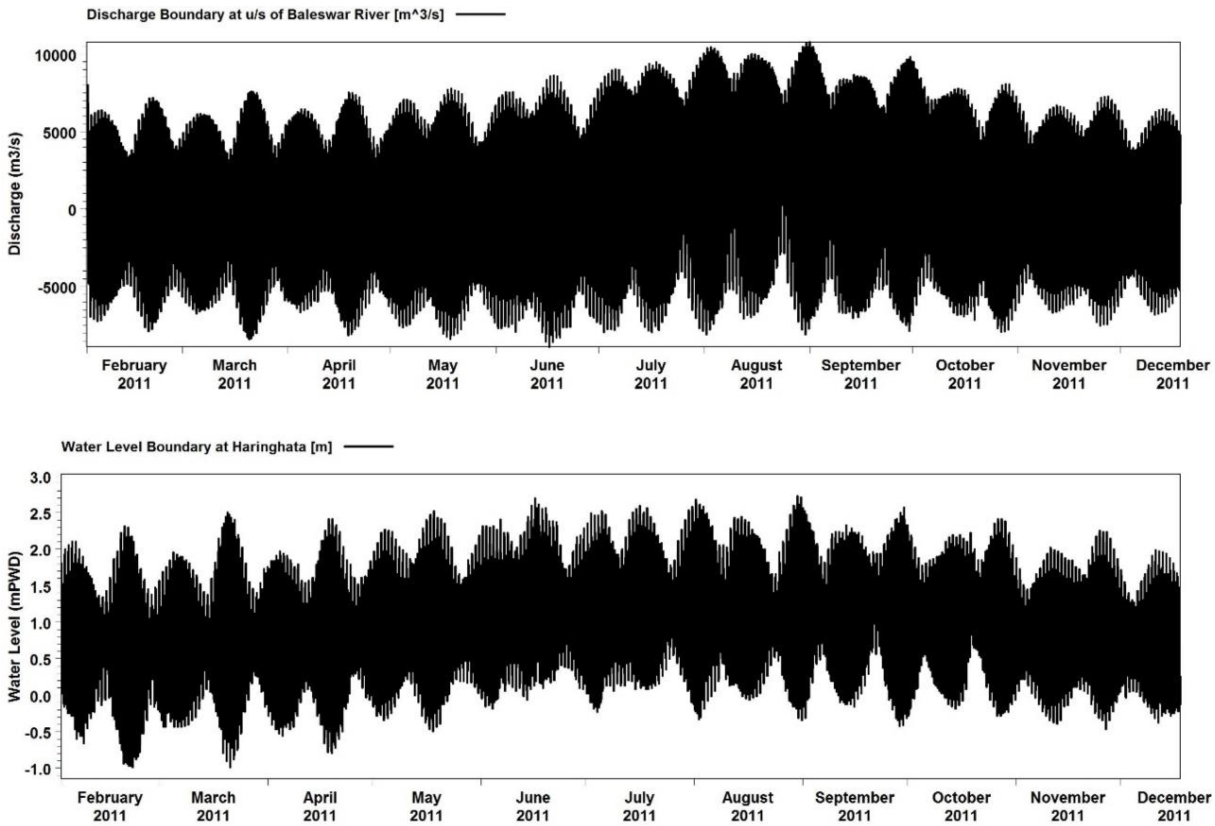

Figure 21 Discharge boundary at u/s of Baleswar River (upper panel) and Water level boundary at Haringhata (bottom panel)

2.3.3 Calibration and Validation

The well calibrated and validated hydrodynamic model is needed to develop a reliable MIKE 21C Bank erosion sediment transport model. We have calibrated and validated for both 2011 and 2015, keeping in mind that the bathymetry is from 2011.

The resistance calibration was partly inherited from the MIKE 11 SWRM. The Manning number varies from 35 m1/3/s upstream to 50 m1/3/s downstream. Those Manning numbers also work in the MIKE 21C model.

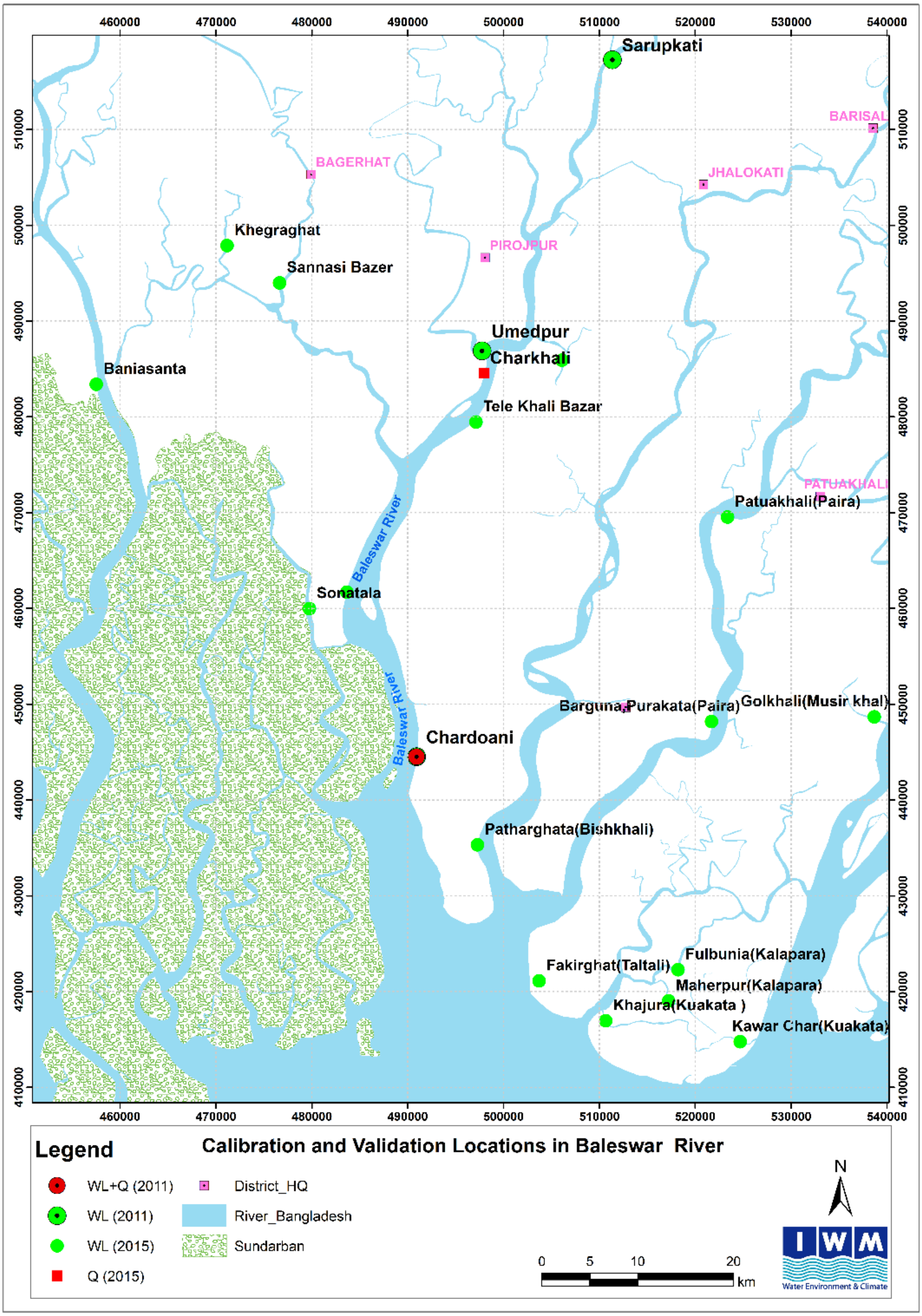

Figure 22 Discharge and water level Calibration (2011) and validation (2015) locations in Baleswar River

The 2011 HD model calibration is presented in below:

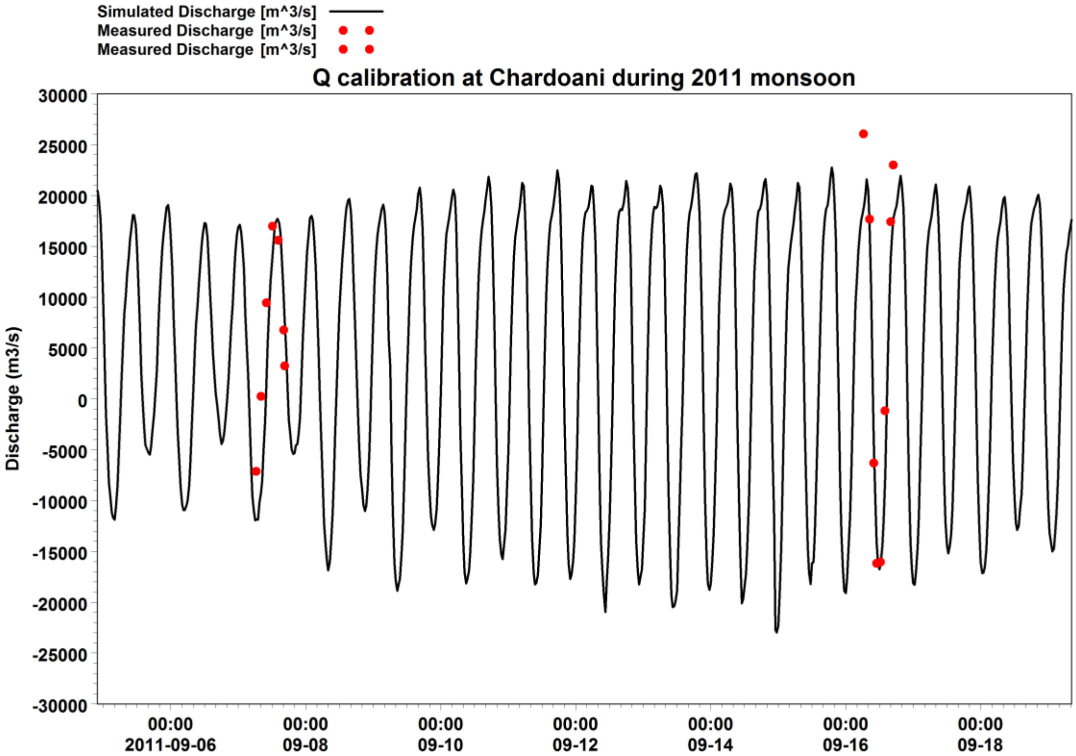

Figure 23 Discharge calibration at Chardoani for 2011

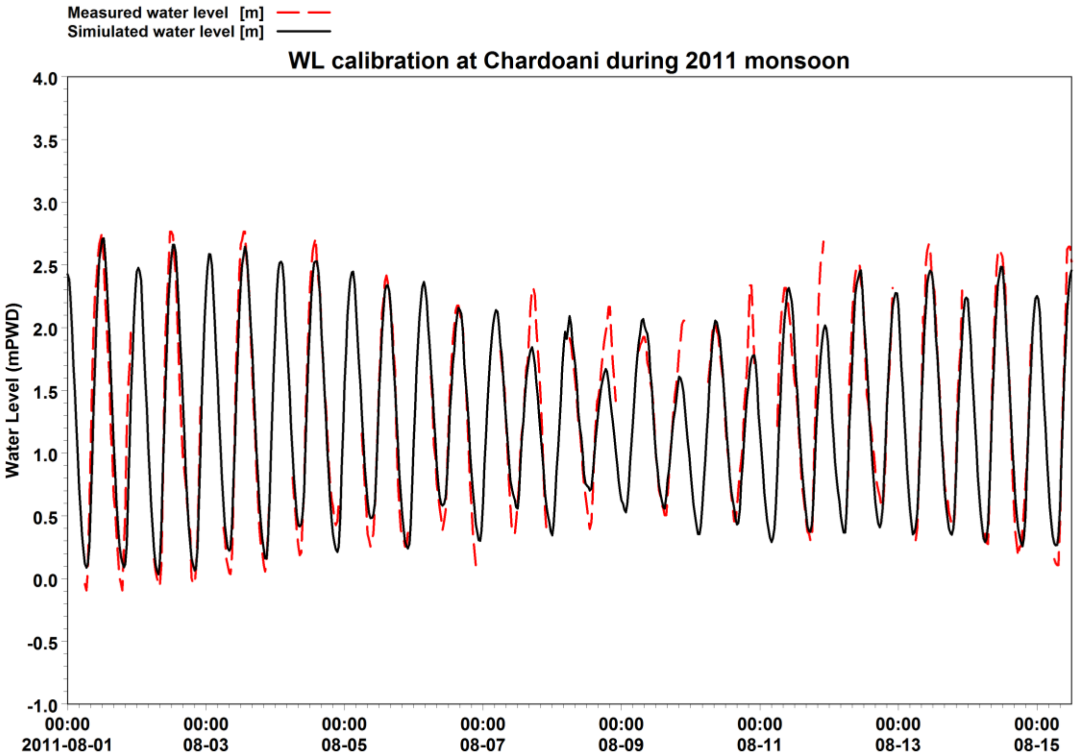

Figure 24 Water Level calibration at Chardoani for 2011

The 2015 HD model validation is presented in below:

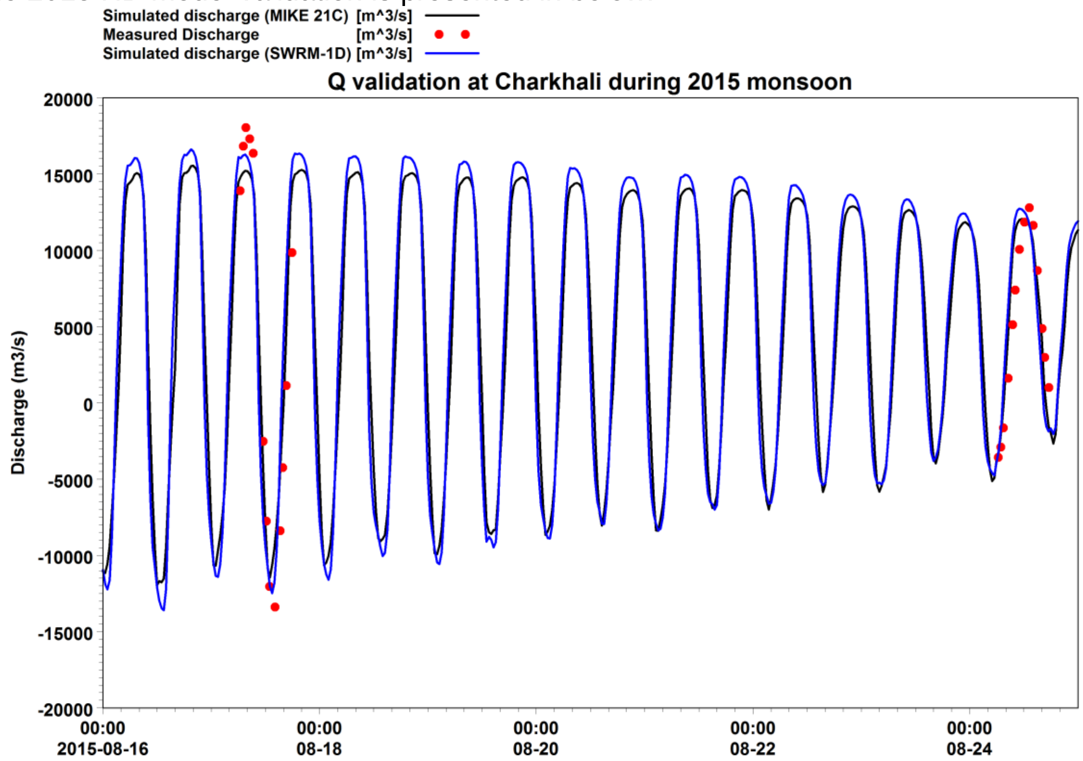

Figure 25 Discharge validation at Charkhali for 2015, also showing the SWRM 2015 results.

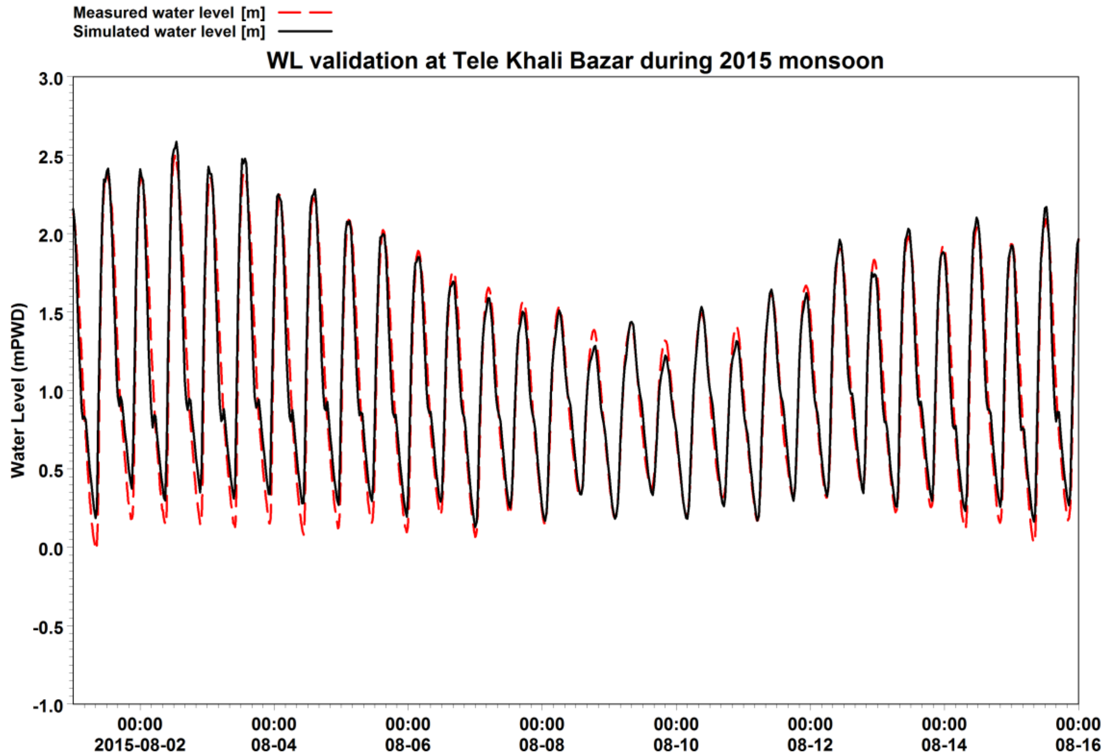

Figure 26 Water level calibration at Tele Khali Bazar for 2015

2.4 Bishkhali River

2.4.1 Model Setup

The preliminary model has been developing using MIKE 21C. For Bishkhali we only have 2019 bathymetry data, and therefore there is only one Bishkhali model (2019).

2.4.2 Boundary Conditions

Hydrodynamic

The Bishkhali River model has one upstream boundary, one downstream boundary. The Bishkhali River only has smaller side channels, which can be ignored in the hydrodynamic model. Hence the model only has an upstream discharge and a downstream water level. The model grid & boundary locations are also shown in Figure 27.

Time series boundaries plot at u/s of Bishkhali and downstream of Patharghata are presented in Figure 28.

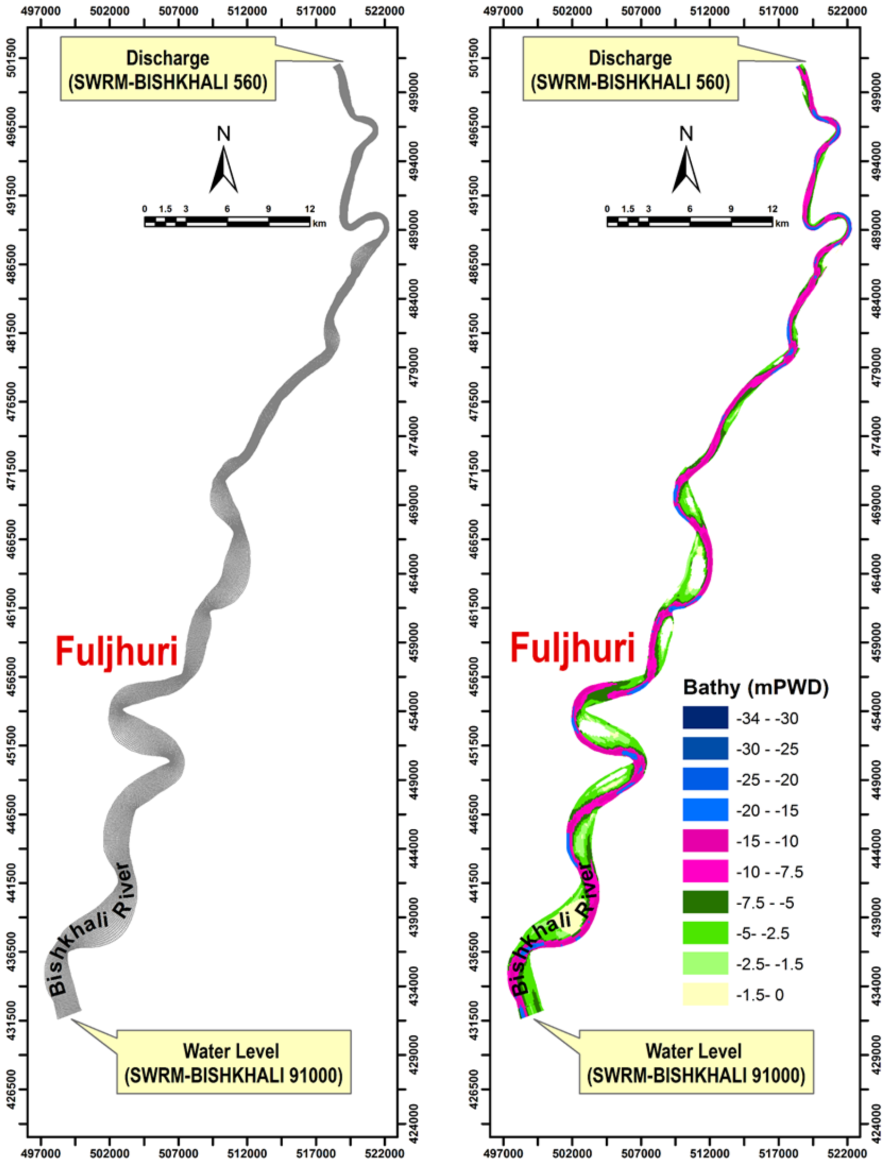

Figure 27 Boundaries location map in the Bishkhali river system

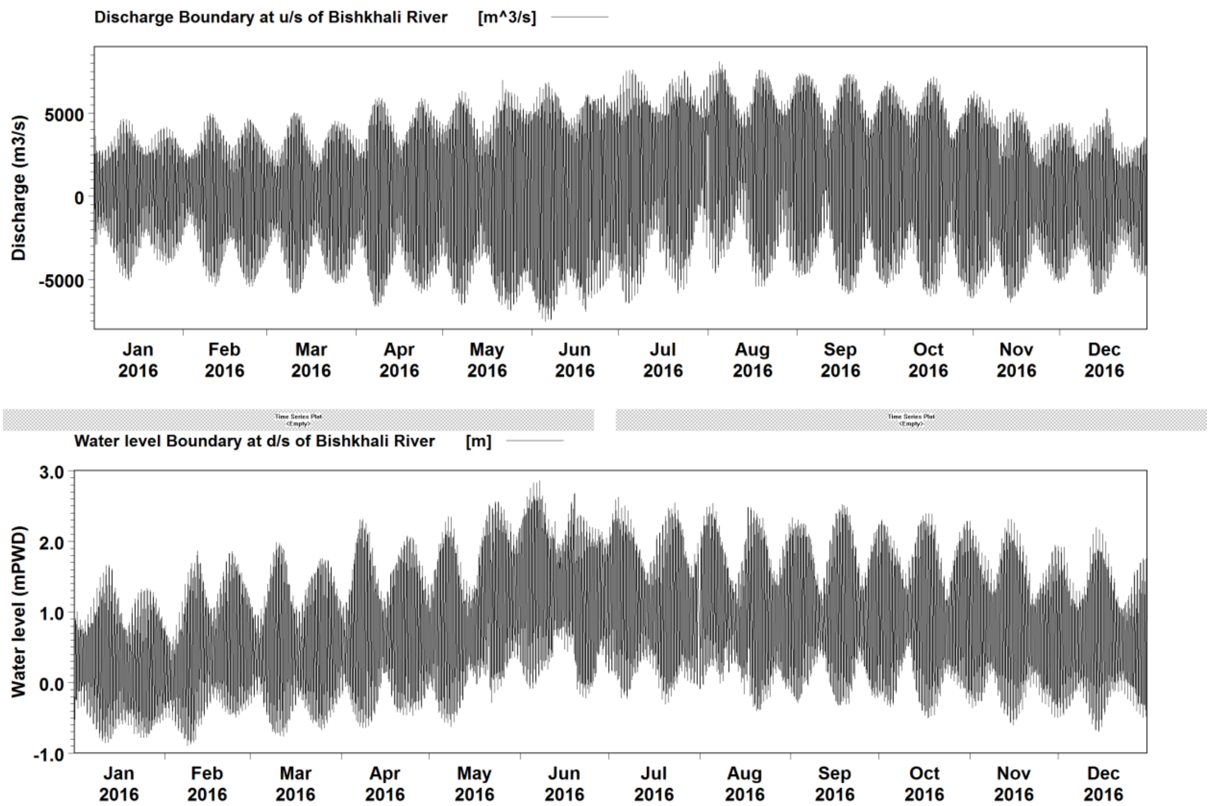

Figure 28 Discharge boundary at u/s of Bishkhali River (upper panel) and Water level boundary at d/s of Patharghata (bottom panel)

Sediment Concentration

There are two types of boundary conditions in the Bishkhali River model:

- Upstream concentration C(Q)
- Bay of Bengal concentration (constant)

The upstream total sediment concentration was calculated from the simple rating curve: $C(Q) = C_0 * (Q/Q_0)^2$

With C_0=800 g/m^3 and Q_0=10,000 m^3/s. We assumed 80% clay in the total concentration, and 80% silt in the 20% non-clay portion, i.e. 80% clay, 16% silt and 4% sand in the total concentration. The downstream sediment concentrations were set as 80 g/m^3 for silt and 20 g/m^3 for sand.

All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “MIKE 21C Bishkhali meso-scale bank erosion morphological modelling study: Model development report”.(Ref-3)

2.4.3 Calibration and Validation

The well calibrated and validated hydrodynamic model is needed to develop a reliable MIKE 21C Bank erosion sediment transport model. We have calibrated for 2016, keeping in mind that the bathymetry is from 2019. The validation for 2019 was conducted using the 2019 model (the only model available), and the data collected in 2019.

This section has been left as a placeholder, as we do not yet have 2019 boundary conditions from the SWRM.

The resistance calibration was partly inherited from the MIKE 11 SWRM. The resistance model is Manning M=60 m1/3/s.

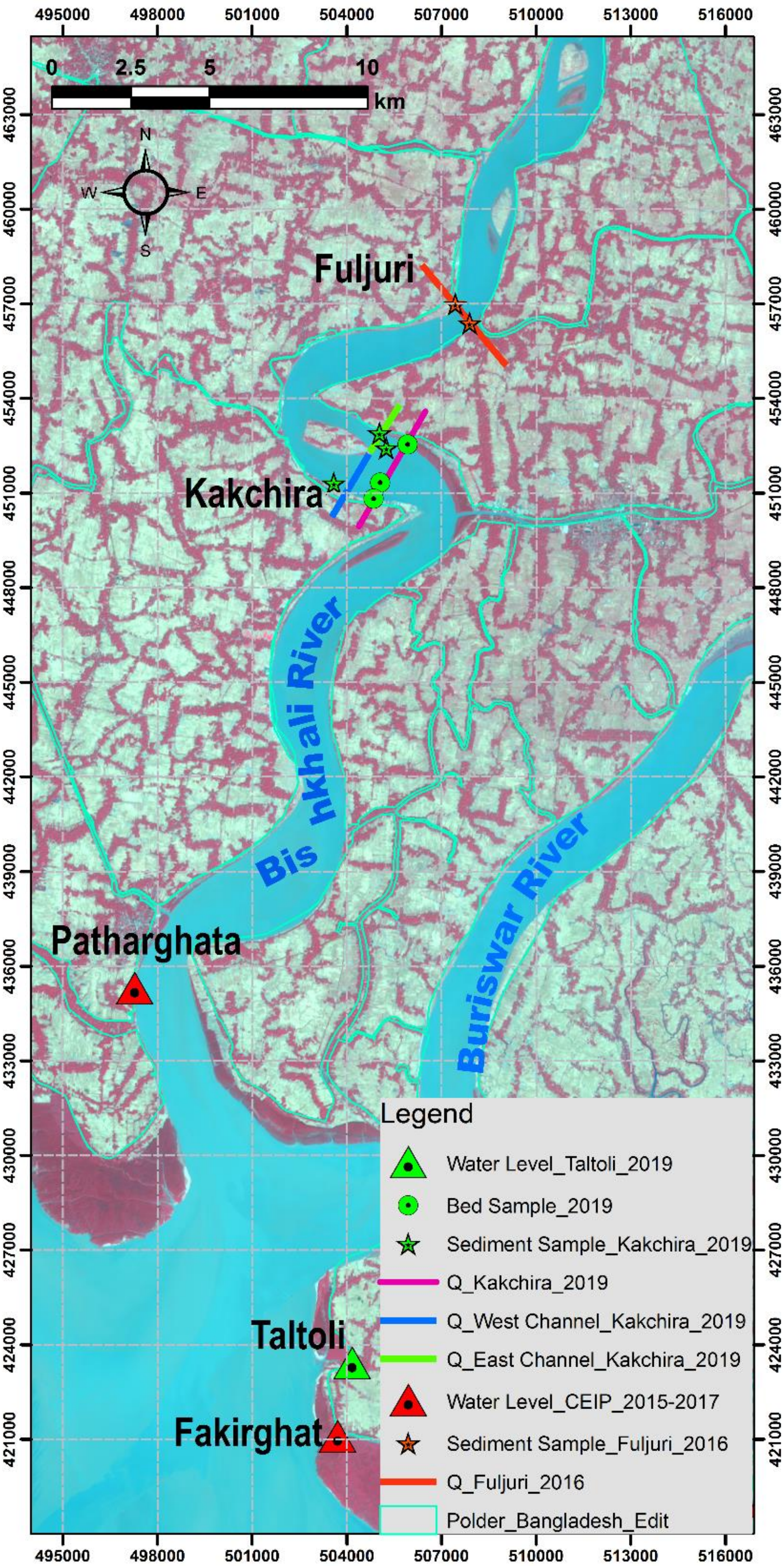

Figure 29 Discharge and water level Calibration (2016) and validation (2019) locations in Bishkhali River

The 2016 HD model calibration is presented in this section. The 2016 calibration was obviously conducted using the 2019 model, as we have no other model.

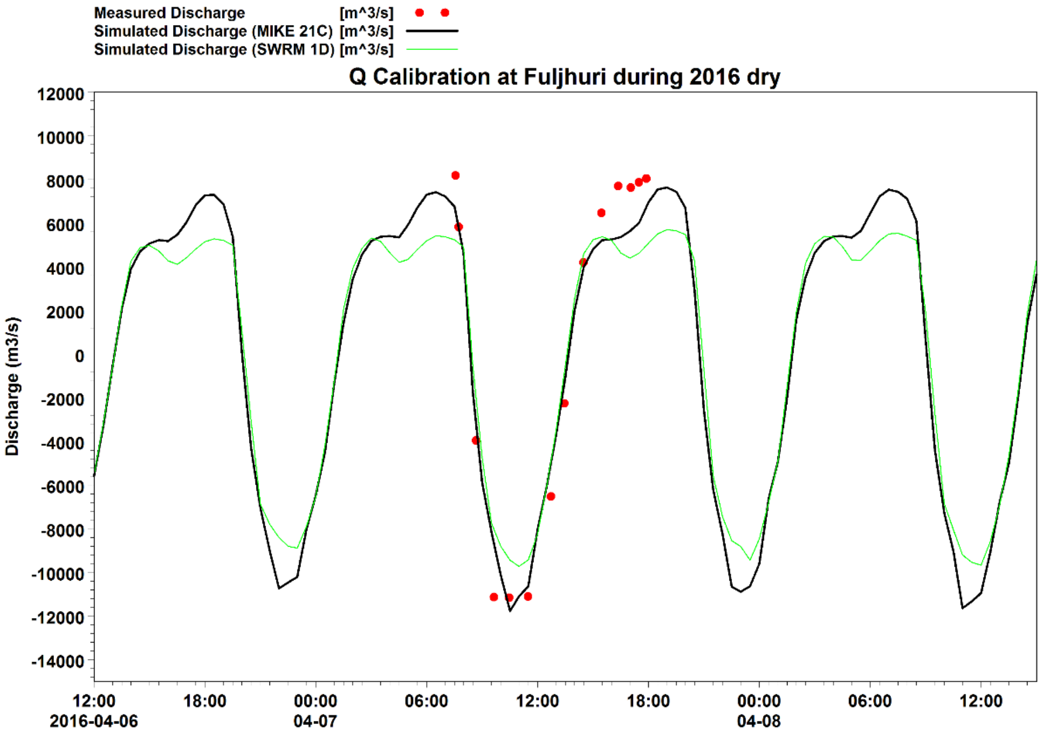

Figure 30 Discharge calibration at Fuljhuri during dry season (spring) for 2016.

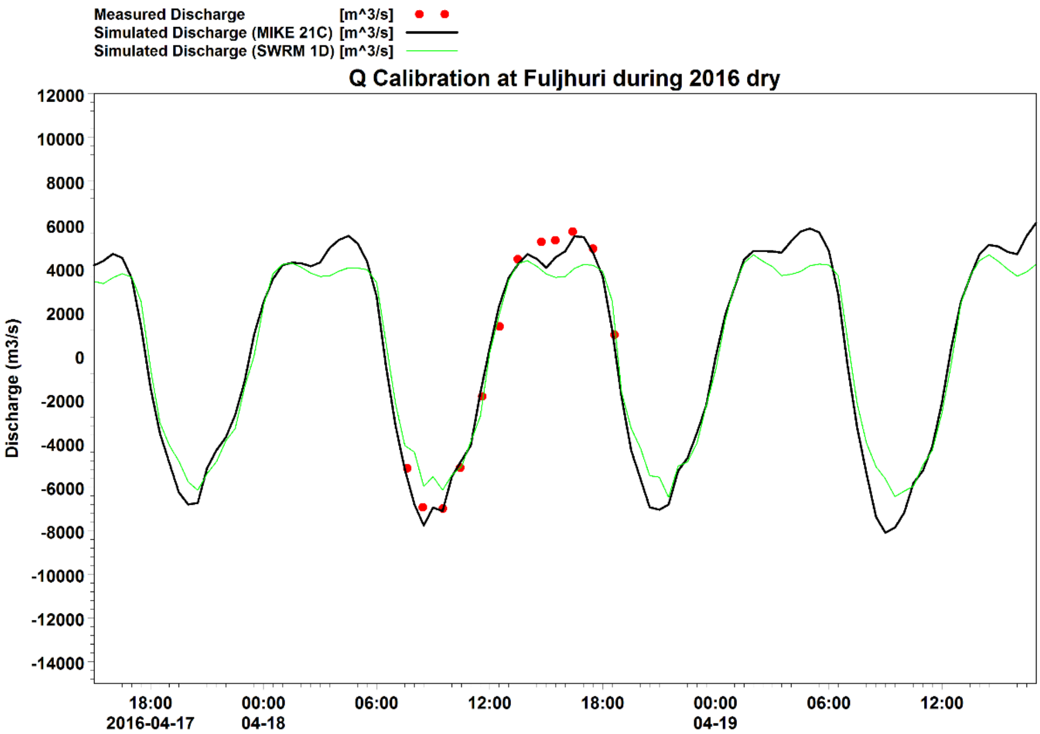

Figure 31 Discharge calibration at Fuljhuri during dry season (neap) for 2016.

The Morphological Model setup and Calibration work of Baleswar River is ongoing.

3. Boundary Conditions for Meso-Scale Models for Long Term Morphology

3.1 Passur-Sibsa River System

3.1.1 Model Setup

The Pussur-Sibsa river system is modelled in one numerical grid, combining both river systems in a single model. The river system is influenced by interaction with the adjacent floodplains (e.g., Mangrove forest and outside the polder area) as the bed level is relatively low around this area and flooding occurs. Therefore, the floodplain was incorporated on both sides of the rivers only around 250m on each side in the numerical grid. The available 2011 bathymetry data for the main river channel was interpolated on the unstructured curvilinear grid system. Figure 32 shows the grid and bathymetry for the Pussur-Sibsa river system.

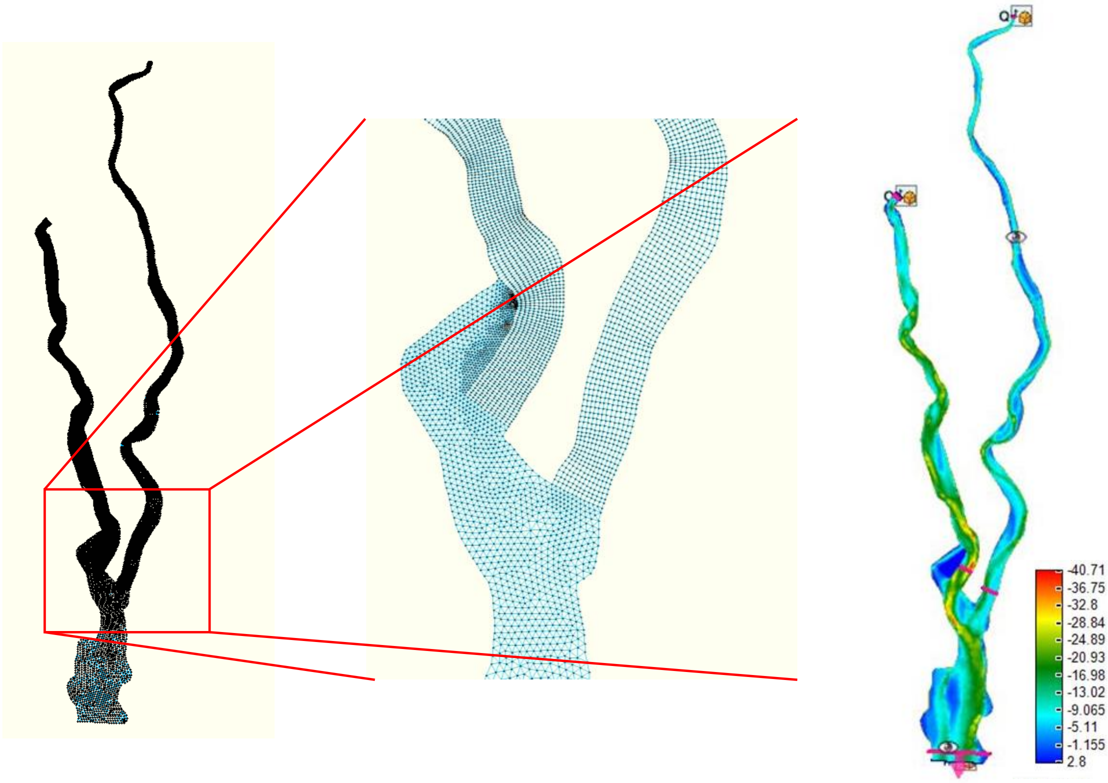

Figure 32 Computational mesh and interpolated bathymetry for the Pussur-Sibsa river system

From the bed sediment samples, it can be derived that the Pussur-Sibsa river system is cohesive in nature. However, here we used a constant manning's number (n=0.017) for the whole model domain.

3.1.2 Boundary Conditions

The Pussur-Sibsa model has two upstream boundaries and one downstream boundary. Upstream boundaries were collected from the calibrated and validated South West Regional Model (reference). The downstream boundary conditions are derived from measured water levels at Hiron Point.

Discharge from the side channels are implemented as additional boundaries in this model. The side channels are essential to include in the hydrodynamic model, as the flow exchanges with these side channels are not insignificant. Without the side channels, it becomes challenging to get the correct discharges in the Pussur-

Sibsa model. All the boundaries were extracted from the South West Regional Model. Figure 33 shows all boundaries locations in both rivers.

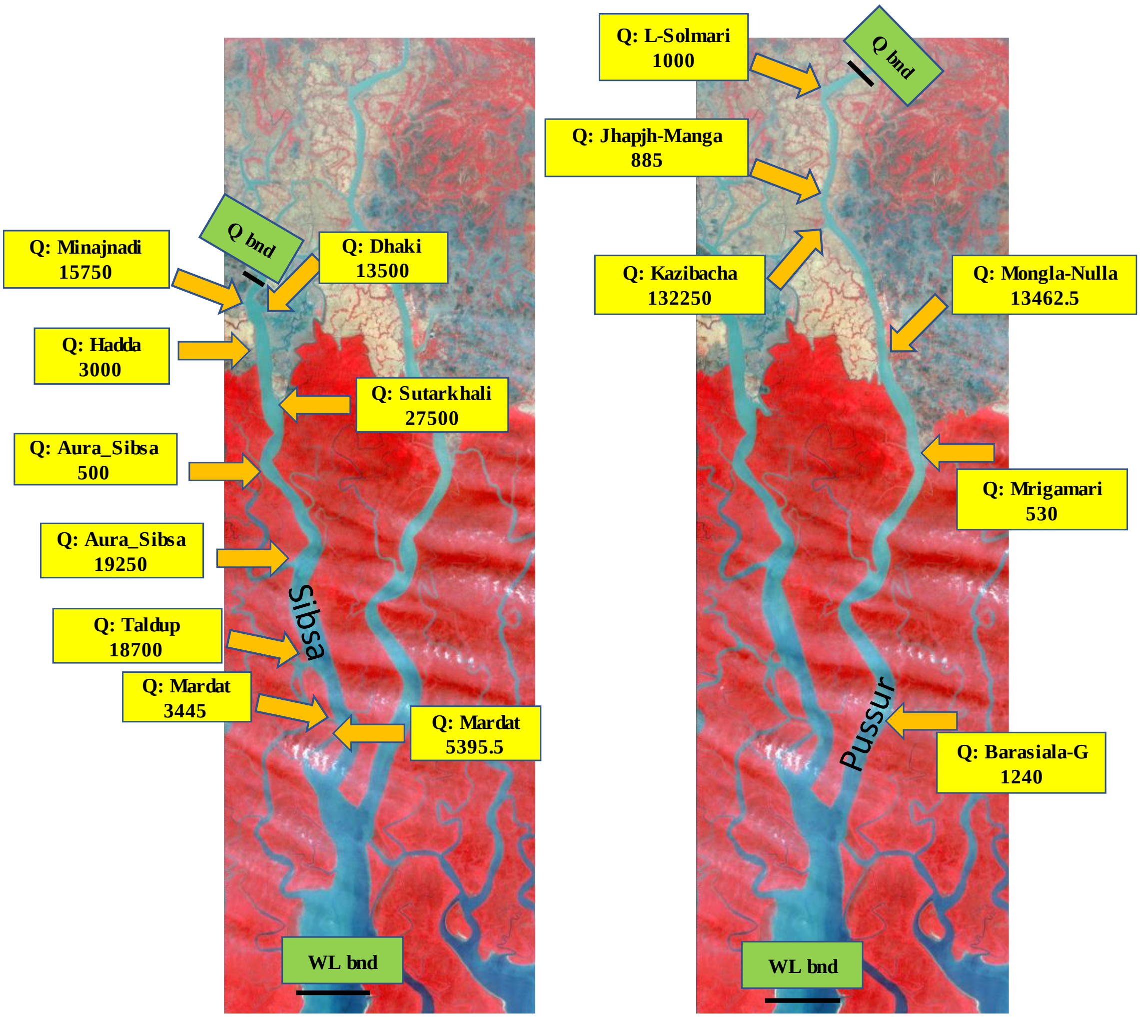

Figure 33 Boundaries location map in the Pussur-Sibsa river system. (yellow box indicate discharge from side channels from SWRM model chainage)

All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “Pussur-Sibsa morphological modelling study – Current situation”. (Ref-4)

3.1.3 Calibration and Validation

The Delft3D FM sediment transport model calculates transport rates on a flexible mesh (unstructured grid) covering the area of interest on the basis of the hydrodynamic data obtained from a simulation with the Hydrodynamic Module (HD) together with information about the characteristics of the bed material. That is why a well calibrated and validated hydrodynamic model is needed to develop a reliable sediment transport model. The model was calibrated with field data during 2011 both dry and monsoon season. The locations of the field data are shown in Figure 34.

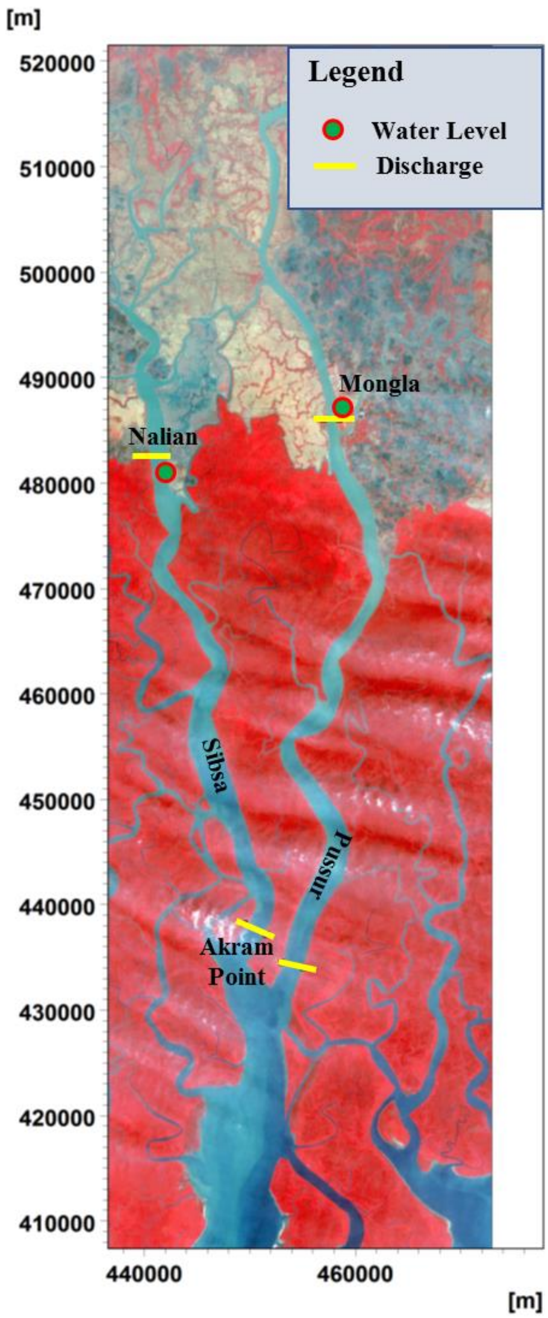

Figure 34 Field data collection map for 2011, 2015, 2016 and 2019 in Pussur-Sibsa River

The water level calibration and validation plots at Mongla Port are shown in Figure 35-38 during monsoon and dry season respectively. The computed water level is well calibrated and validated with measurement.

Figure 39-42 shows the discharge calibration at Mongla Port, Akram Point (inside Sibsa River and Pussur River during monsoon and dry season. The computed discharge is well calibrated and validated with measurement.

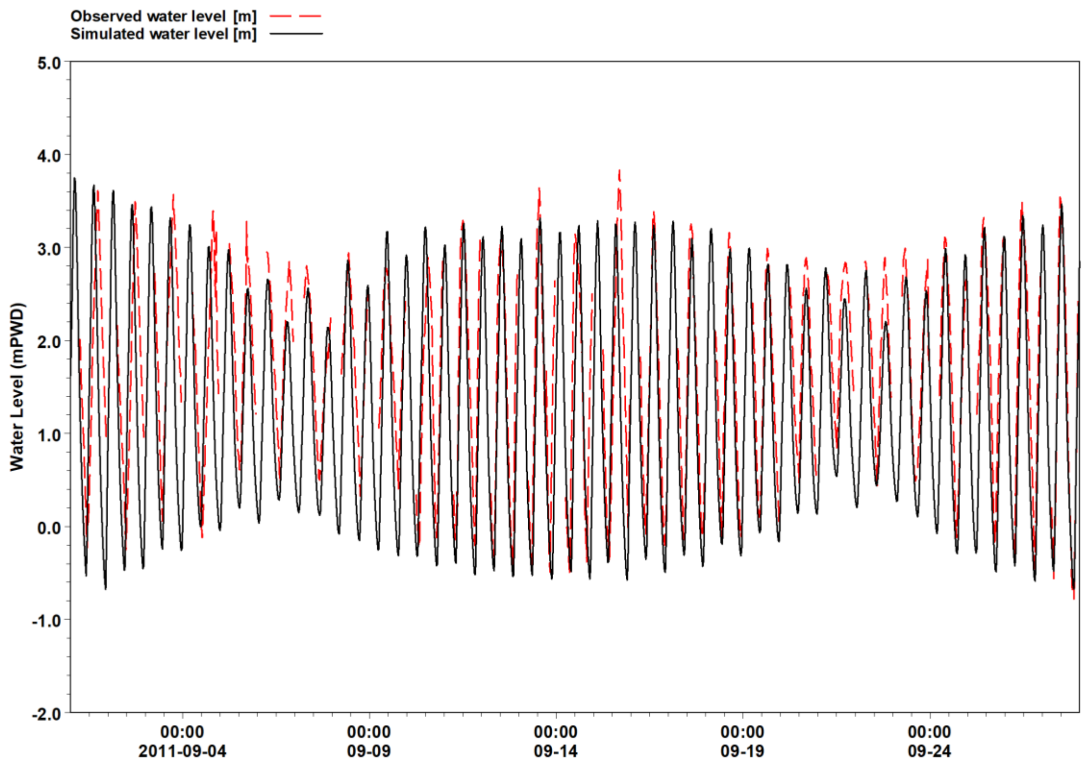

Figure 35 Comparison between observed and computed water level at Mongla Port during Monsoon

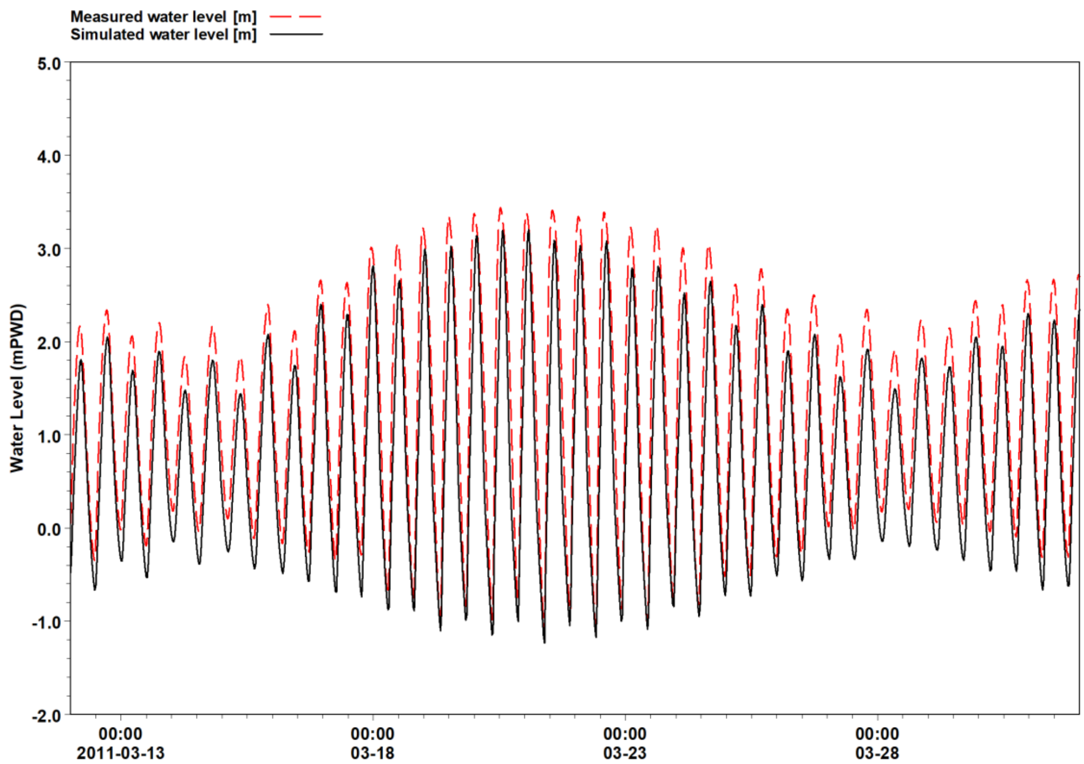

Figure 36 Comparison between observed and computed water level at Mongla Port during the dry season

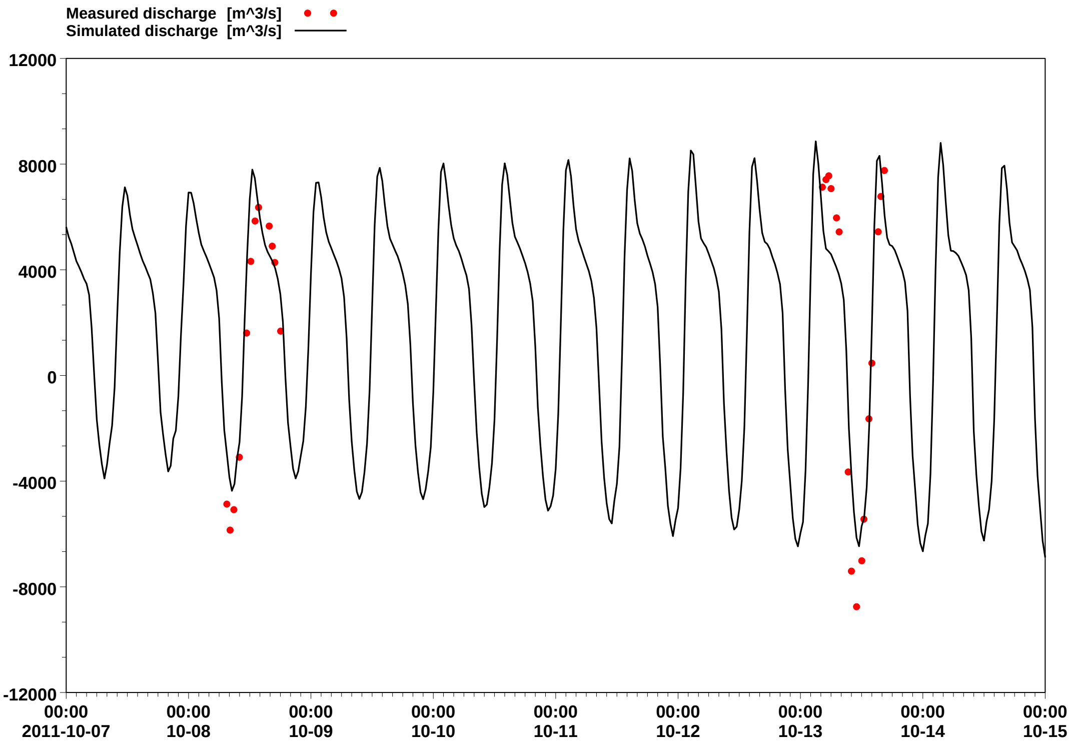

Figure 37 Discharge calibration at Mongla Port during Monsoon (ebb is positive, and flood is negative)

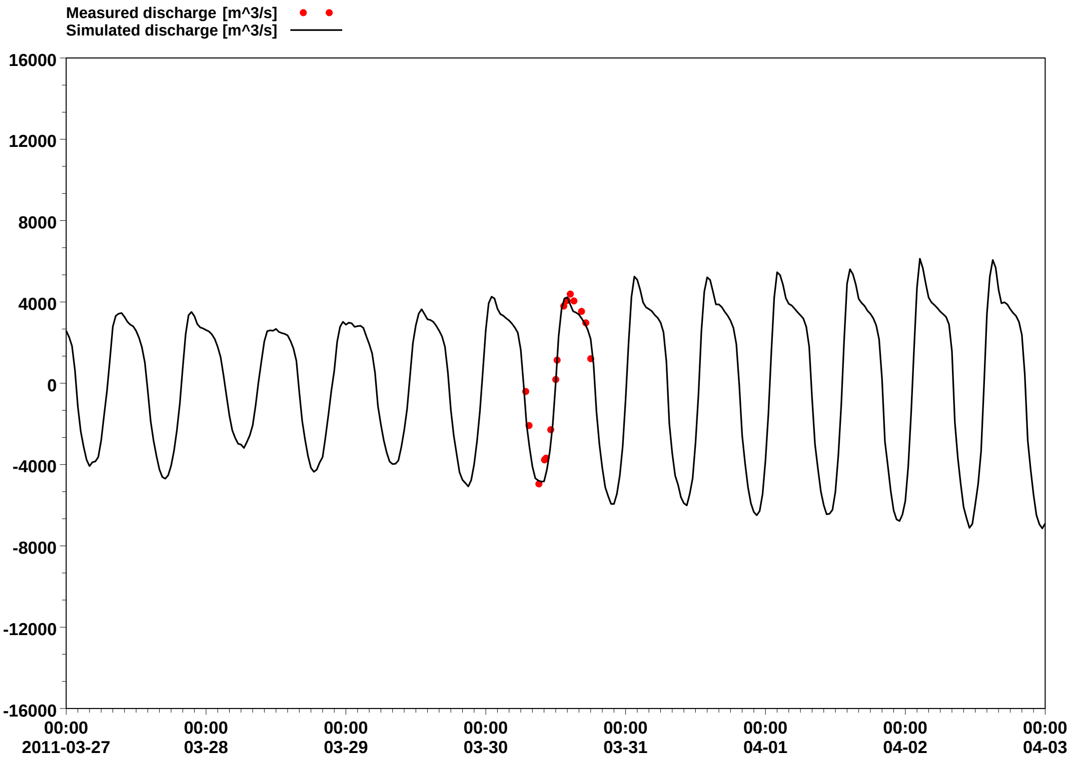

Figure 38 Discharge calibration at Mongla Port during the dry season (March)

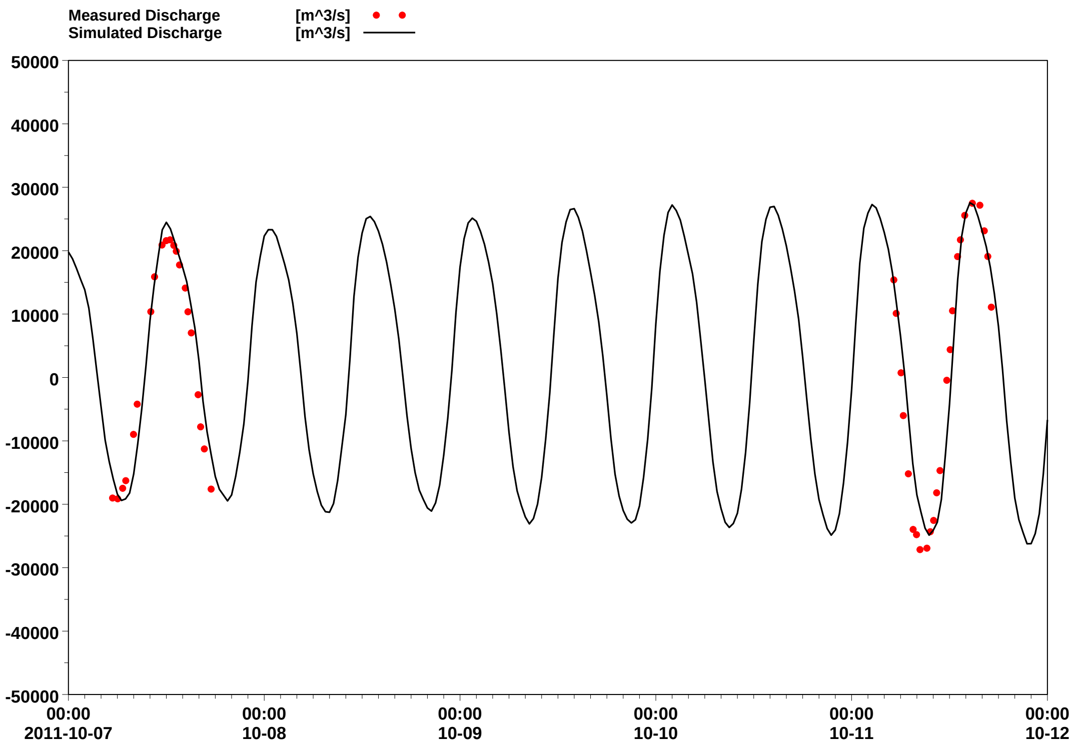

Figure 39 Discharge calibration at Akram Point in Pussur river during monsoon

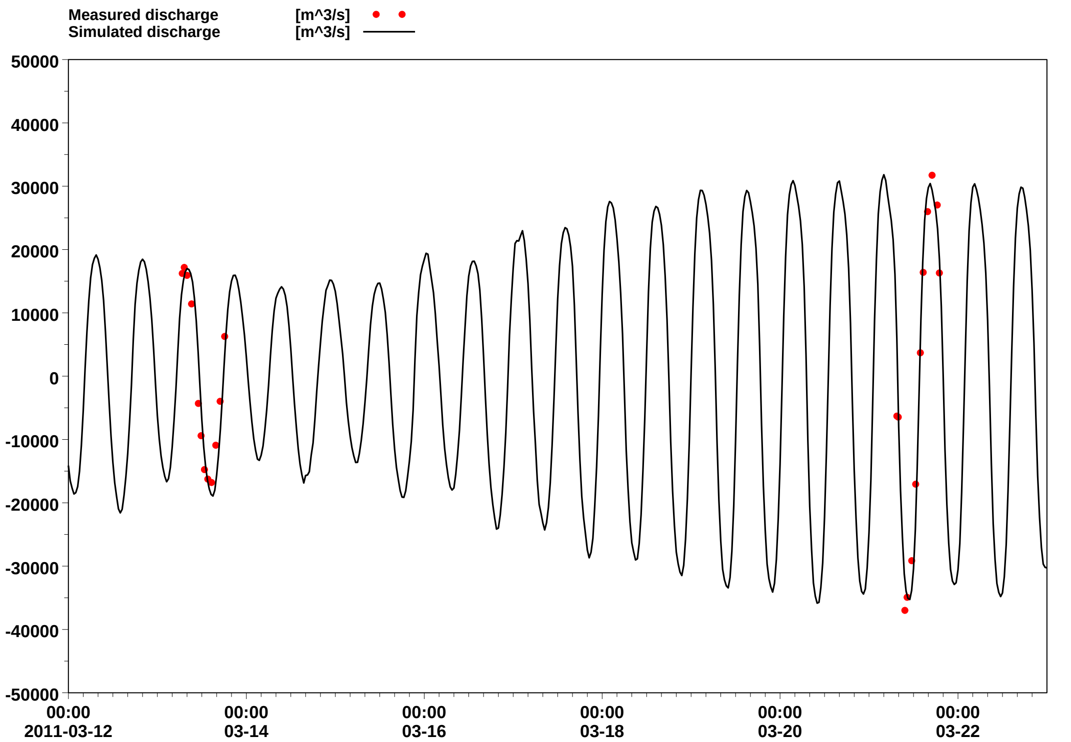

Figure 40 Discharge calibration at Akram Point in Pussur river during the dry season (March)

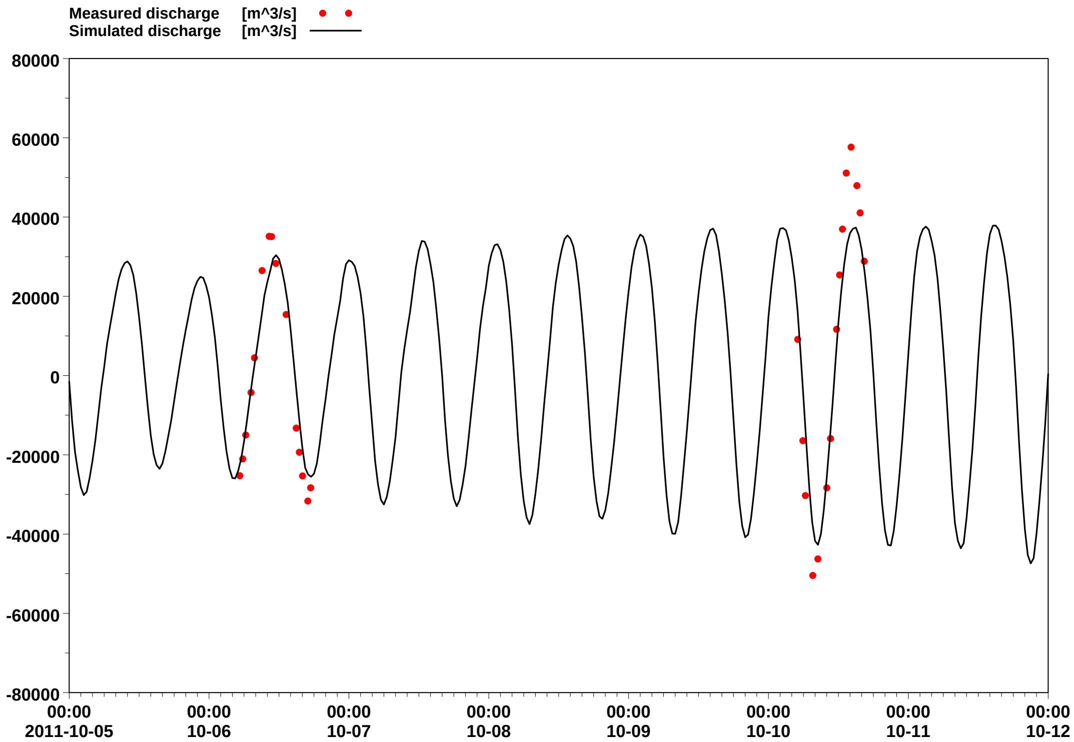

Figure 41 Discharge calibration at Akram Point in Sibsa river during monsoon

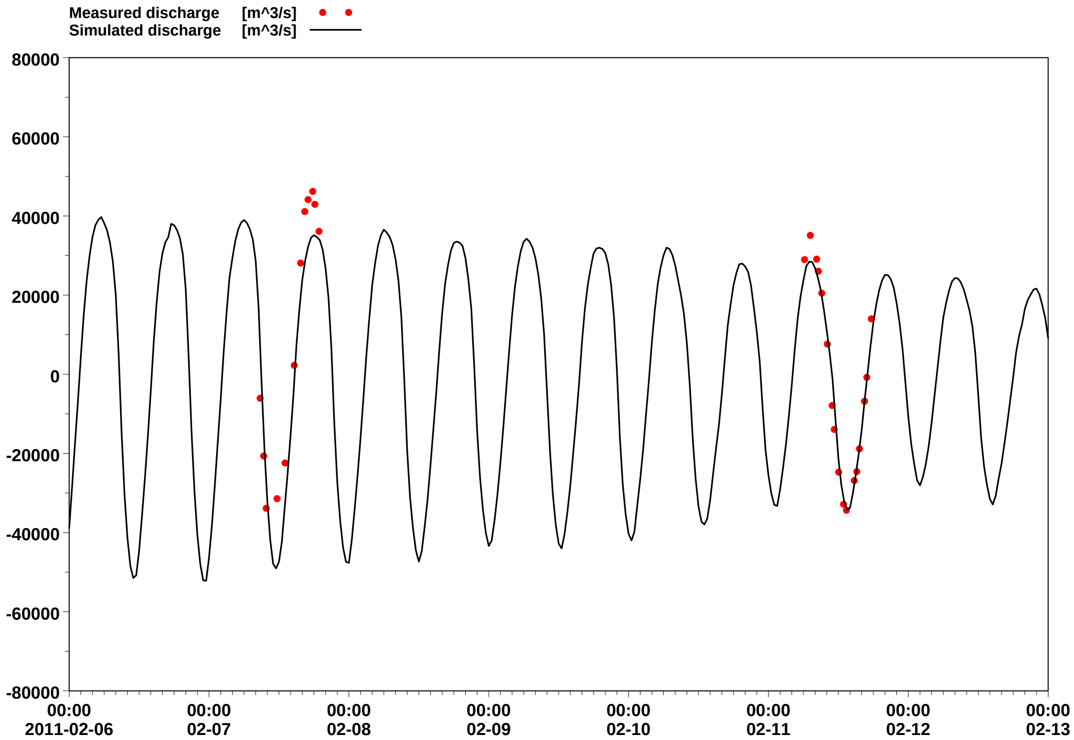

Figure 42 Discharge calibration at Akram Point in Sibsa river during the dry season

3.2 Lower Meghna- Tetulia River system

3.2.1 Model Setup

The long term meso scale model development for Lower Meghna-Tentulia river has already started by Delft3D FM modelling system.The Lower Meghna- Tetulia River system is modelled in one numerical grid, combining both Lower Meghna and Tetulia systems in a single model. The available 2009 bathymetry data for the main river channel was interpolated on the unstructured curvilinear grid system. The grid size varies between 1600m to 200m. Figure 43 shows the grid and bathymetry of the Lower Meghna-Tentulia river system for 2009. The bathymetry of the model will be further updated with the 2019 survey data.

3.2.2 Boundary Conditions

The Lower Meghna-Tentulia river system model has two open upstream boundaries and two open downstream boundaries. Four open boundaries are defined in the model, two in the north: one in the Padma River at Baruria and another one in` the Upper Meghna River at Bhairab Bazar; and two in the south of Bay of Bengal (21030’ north latitude). The northern boundaries at Baruria in the Padam river and Bhairab Bazar in the Upper Meghna river have been defined by daily rated discharge time series for the year 2009. The southern boundary has been extracted from the existing Bay of Bengal Model. Figure 44 shows all boundaries locations. Time series boundaries plot at Bhairab Bazar and at Baruria are presented in Figure 45.

All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “Lower Meghna - Tetulia River system morphological modelling study – Current situation”. (Ref-5)

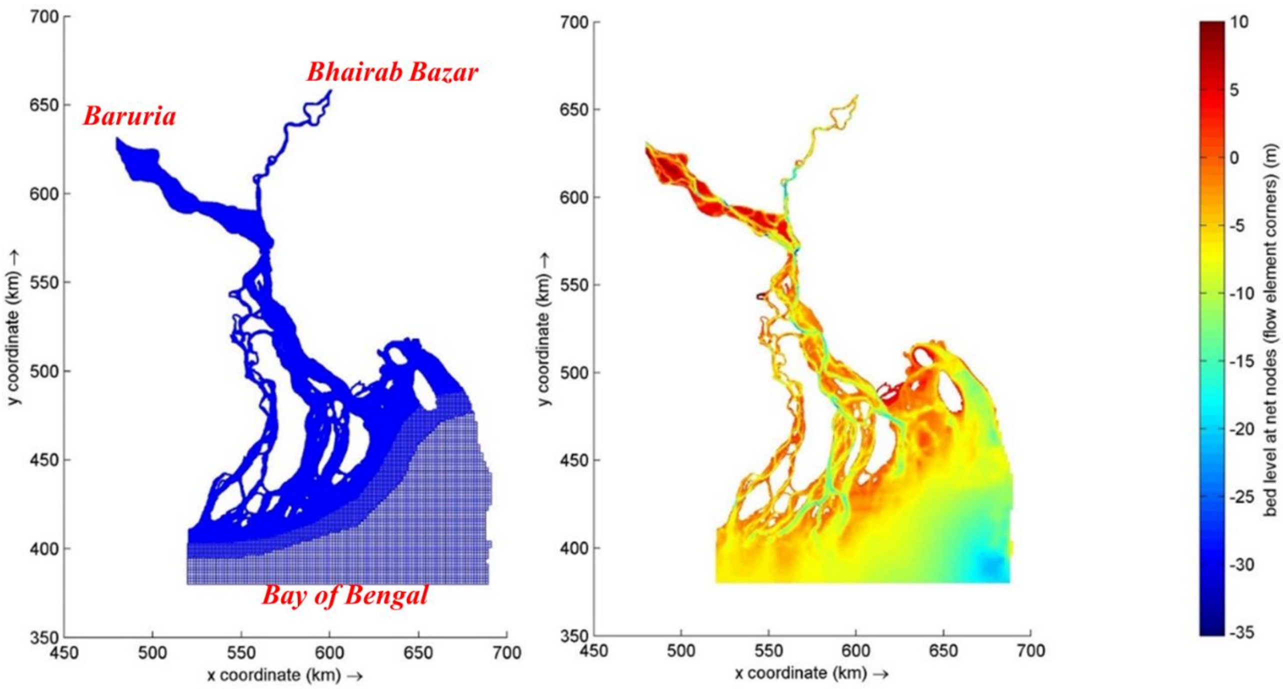

Figure 43 Model Grid, Bathymetry and Boundaries location map in the Lower Meghna-Tentulia river system

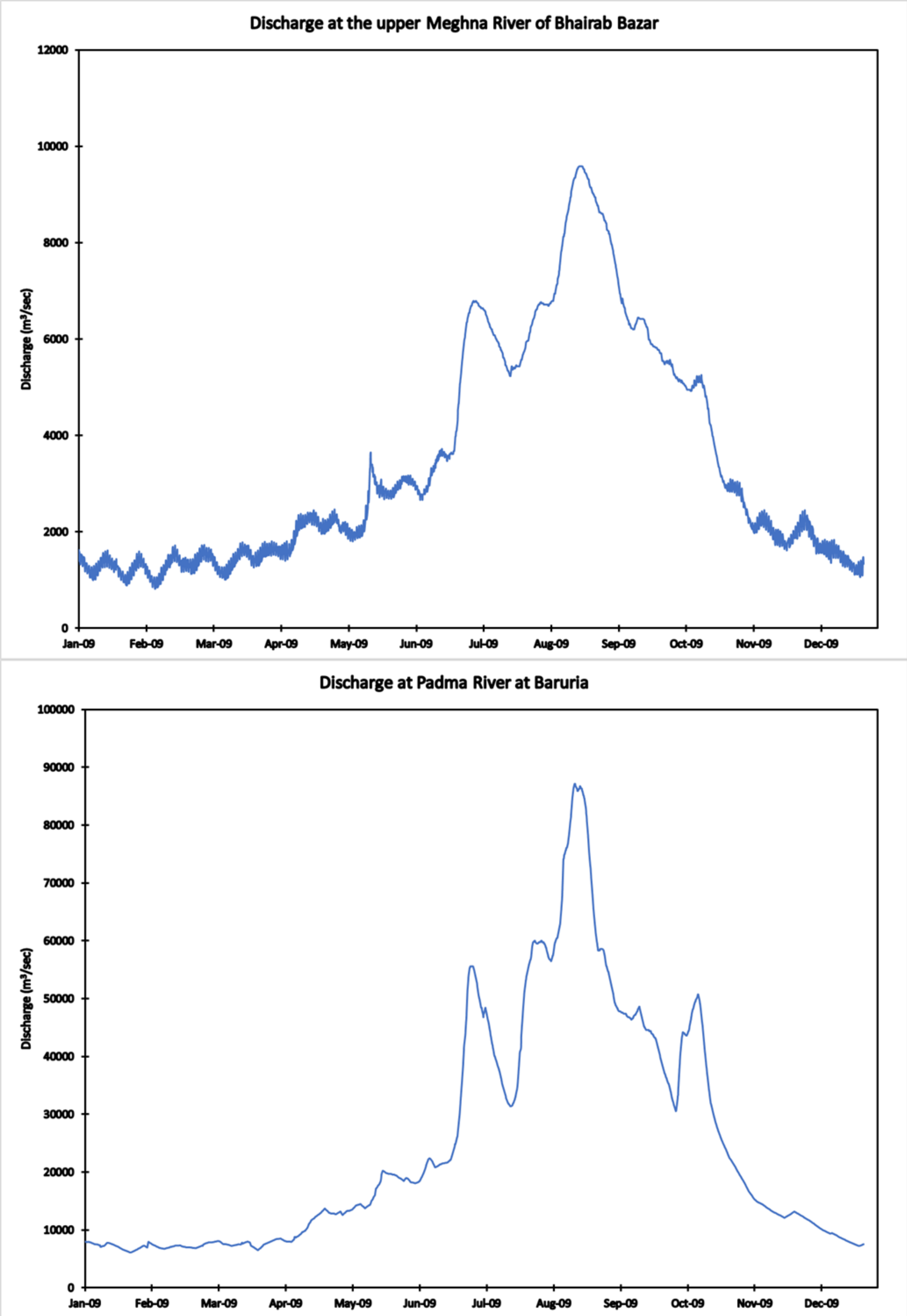

Figure 44 Discharge boundary at Bhairab Bazar of Upper Meghna River (upper panel) and Discharge boundary at Baruria of Padma River (bottom panel)

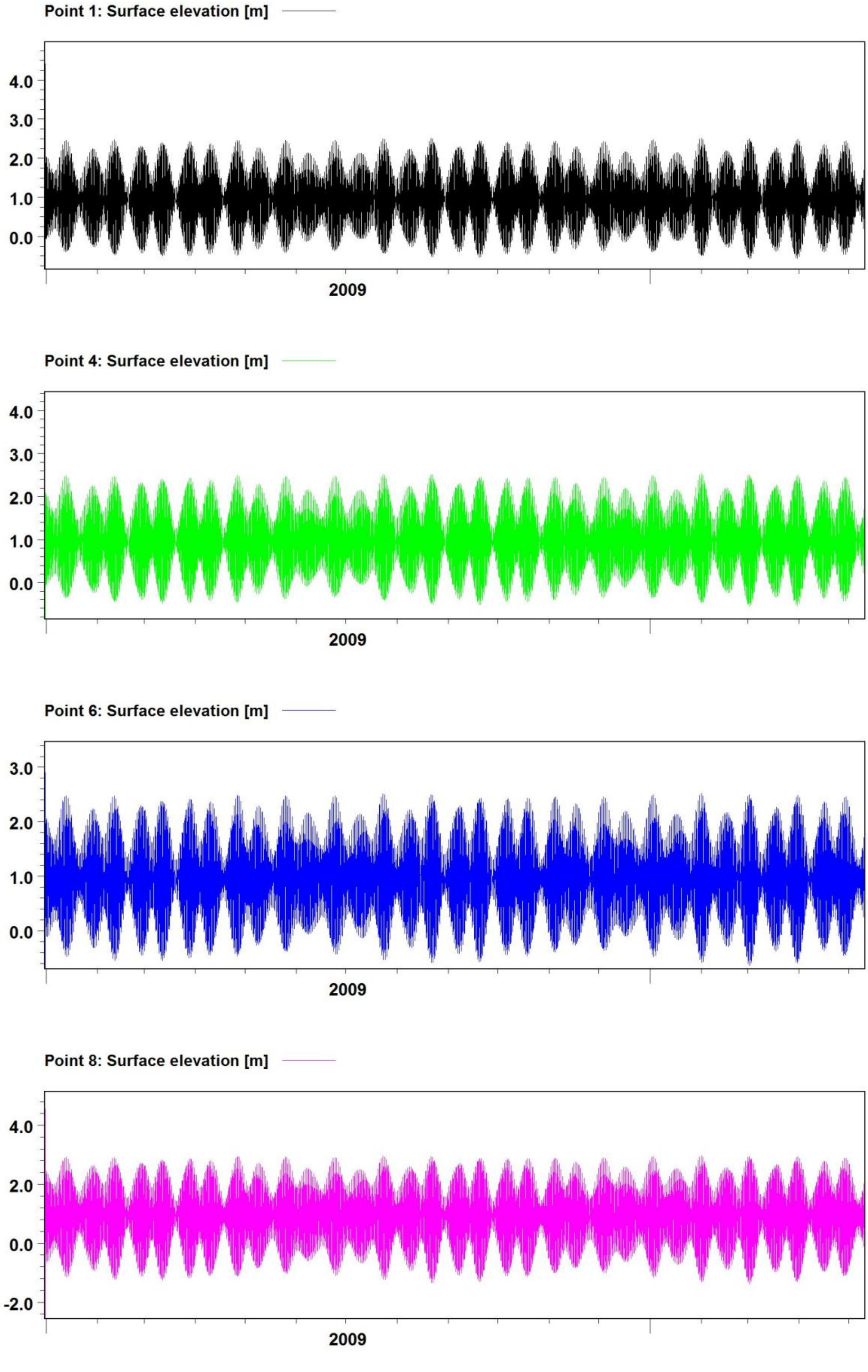

Figure 45 Southern Water Level boundaries from Bay of Bengal Model (MIKE 21 FM)

3.2.3 Calibration and Validation

The hydrodynamic model of Meghna Estuary Model was calibrated with the field data during 2009 (Figure 46) for both dry and monsoon season to make the model performance to a satisfactory level. The water level calibration at Char Langta and discharge calibration at Monpura-Jahajmara in East-Shahbazpur Channel (Jahajmara) during monsoon season are illustrated in Figure 47 and Figure 48 respectively. Water Level and discharge calibration shows good correlation with measured and simulated water level data with constant roughness (n=.010).

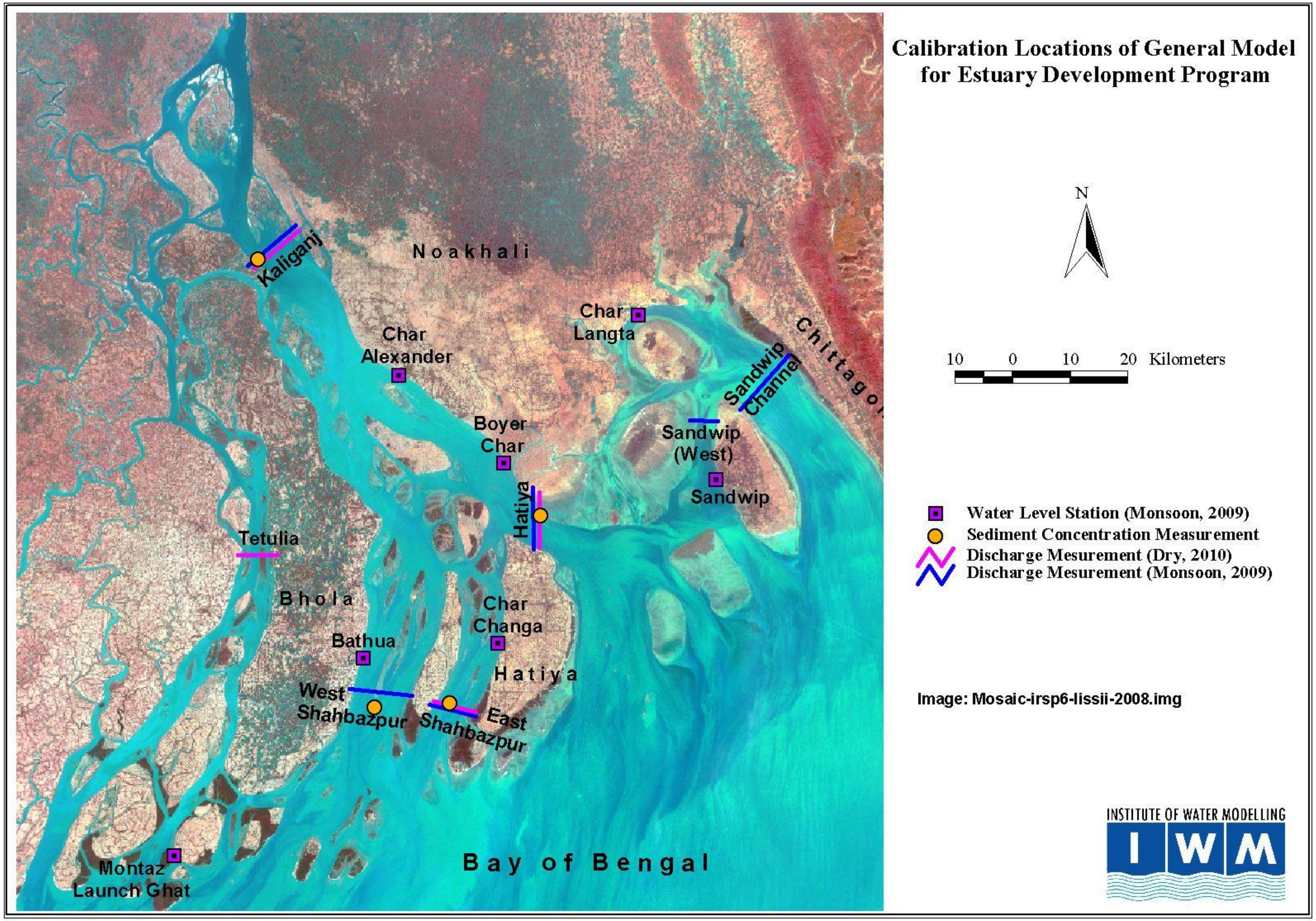

Figure 46 Locations for Lower Meghna Estuary meso model during 2009

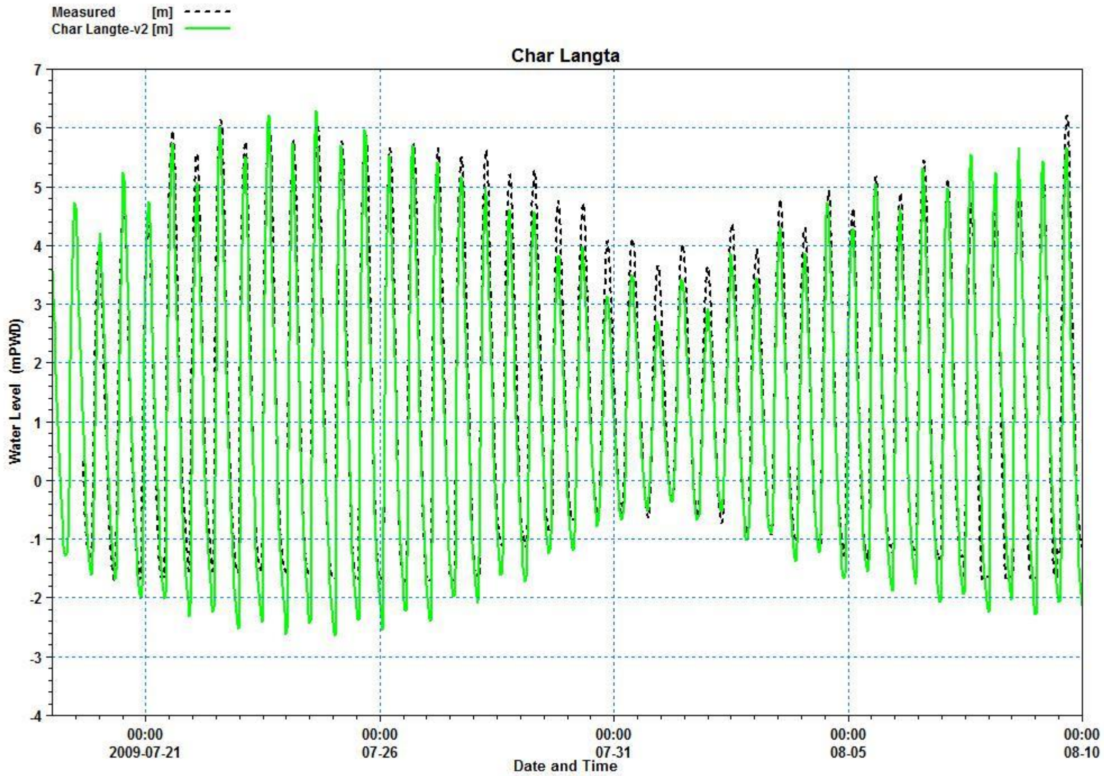

Figure 47 Water Level Calibration at Char Langta

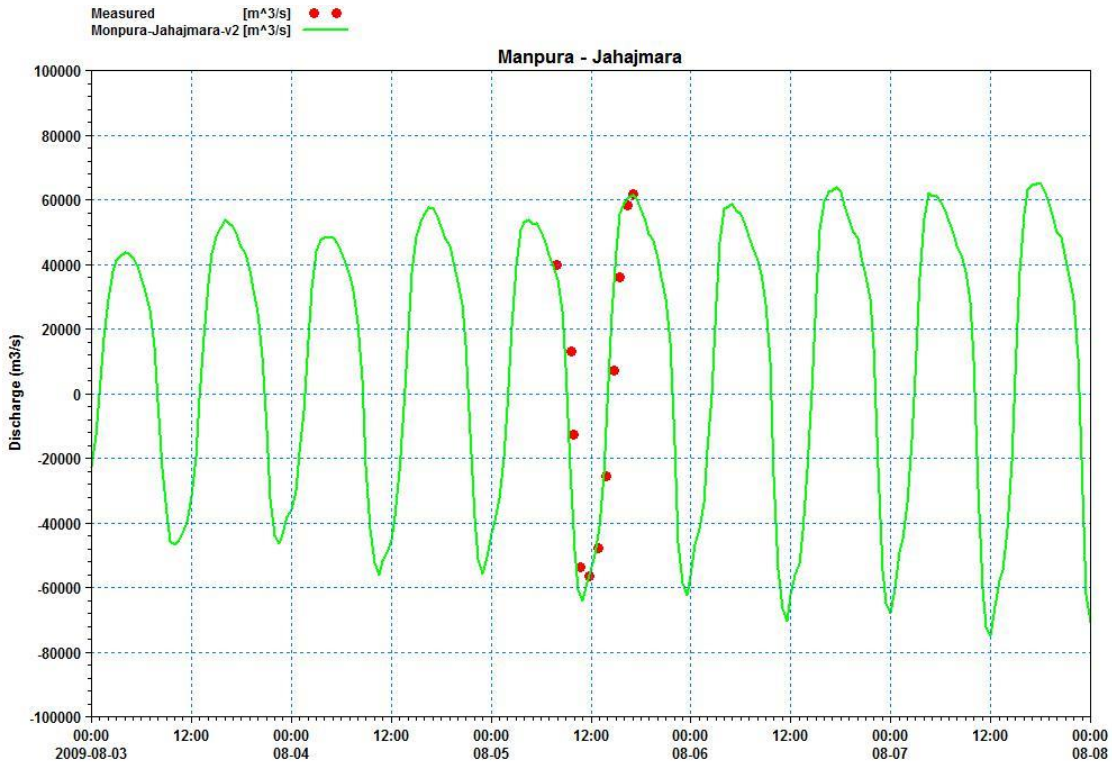

Figure 48 Discharge Calibration at Monpura-Jahajmara

3.3 Baleswar Bishkhali River System

3.3.1 Model Setup

The long term meso scale model development has already started by Delft3D FM modelling system. The Baleswar-Bishkhali river system is modelled in one numerical grid, combining both river systems in a single model. The recent 2019 bathymetry data for the main river channel was interpolated on the unstructured curvilinear grid system Figure 49 shows the grid and bathymetry of the Baleswar-Bishkhali river system for 2019. The grid size varies between 1600m to 100m.

3.3.2 Boundary Conditions

The Baleswar-Bishkhali river system model has two upstream boundary, three downstream boundary and several source points representing side channels. Upstream boundary and sources were collected from calibrated and validated South West Regional Model for year 2015. The three southern boundaries have been generated from the Bay of Bengal Model for the year 2015.Time series boundaries plot at the u/s of Baleswar and Bishkhali are presented in Figure 50. The time series boundaries extracted from the existing Bay of Bengal Model (MIKE21FM) are presented in Figure 51.

All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “Baleswar-Bishkhali morphological modelling study”. (Ref-6)

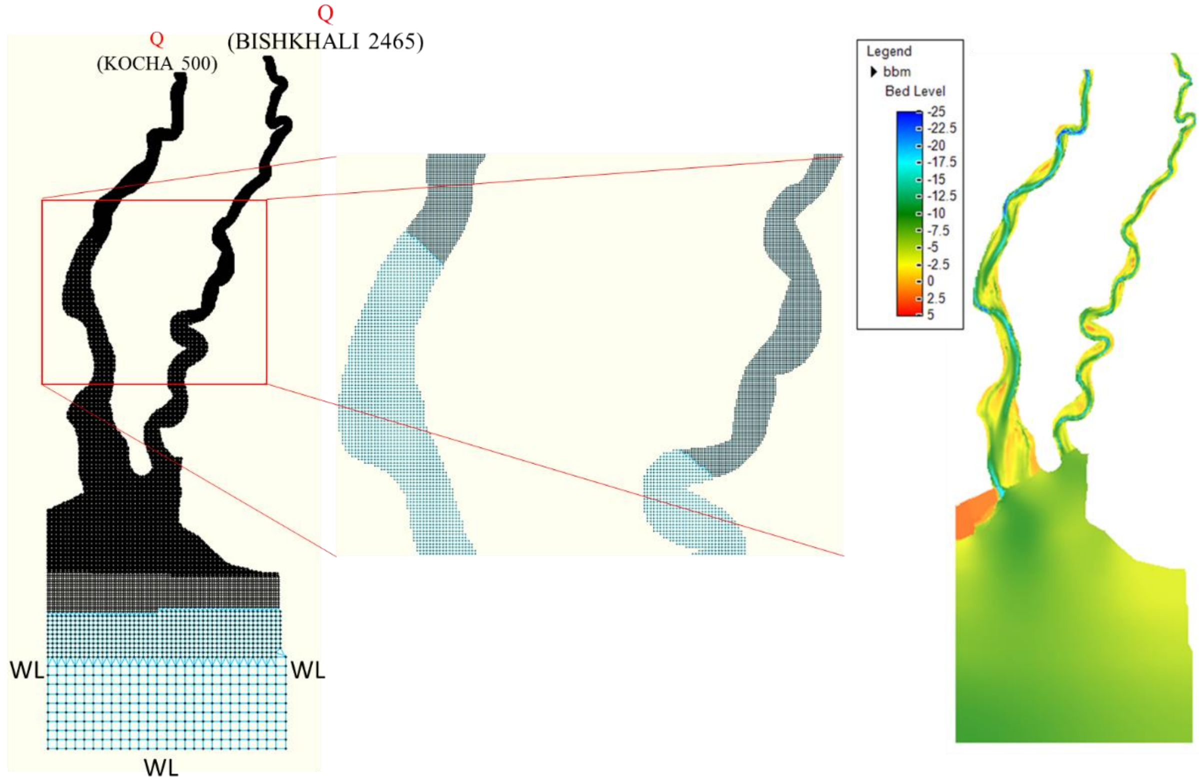

Figure 49 Computational mesh/grid (left panel) for Baleswar-Bishkhali river system and interpolated bathymetry (right panel) for 2019.

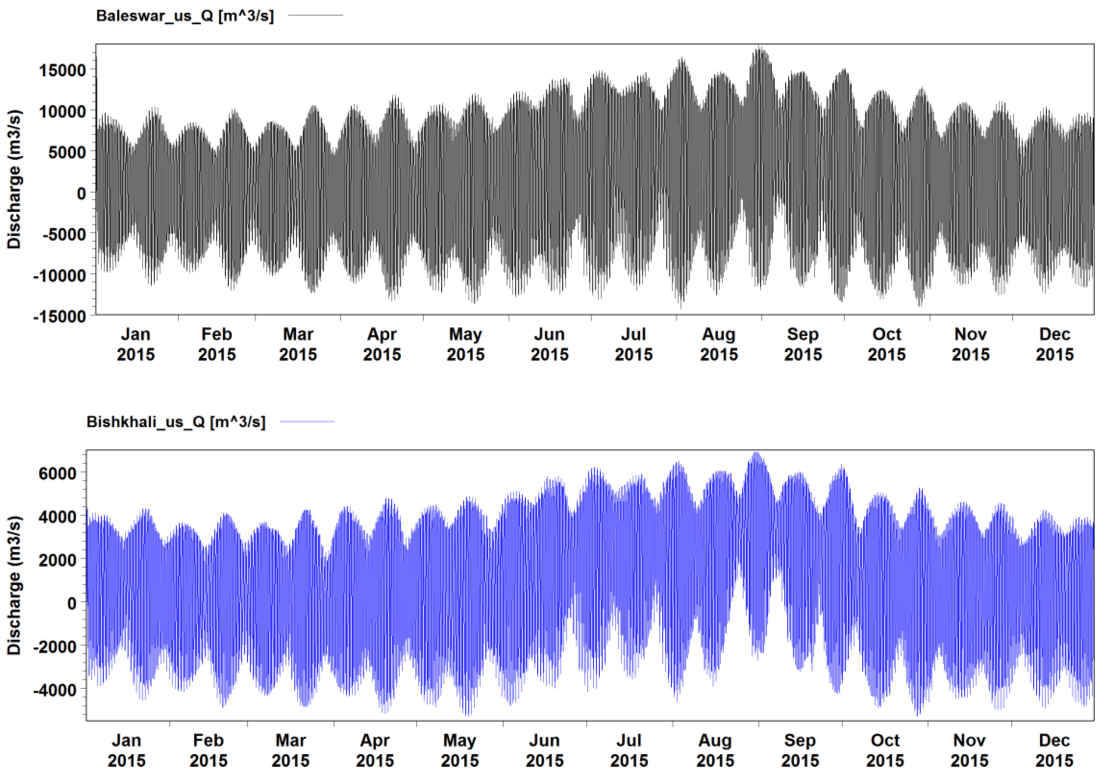

Figure 50 Discharge boundary at u/s of Baleswar River (upper panel) and u/s of Bishkhali River (bottom panel)

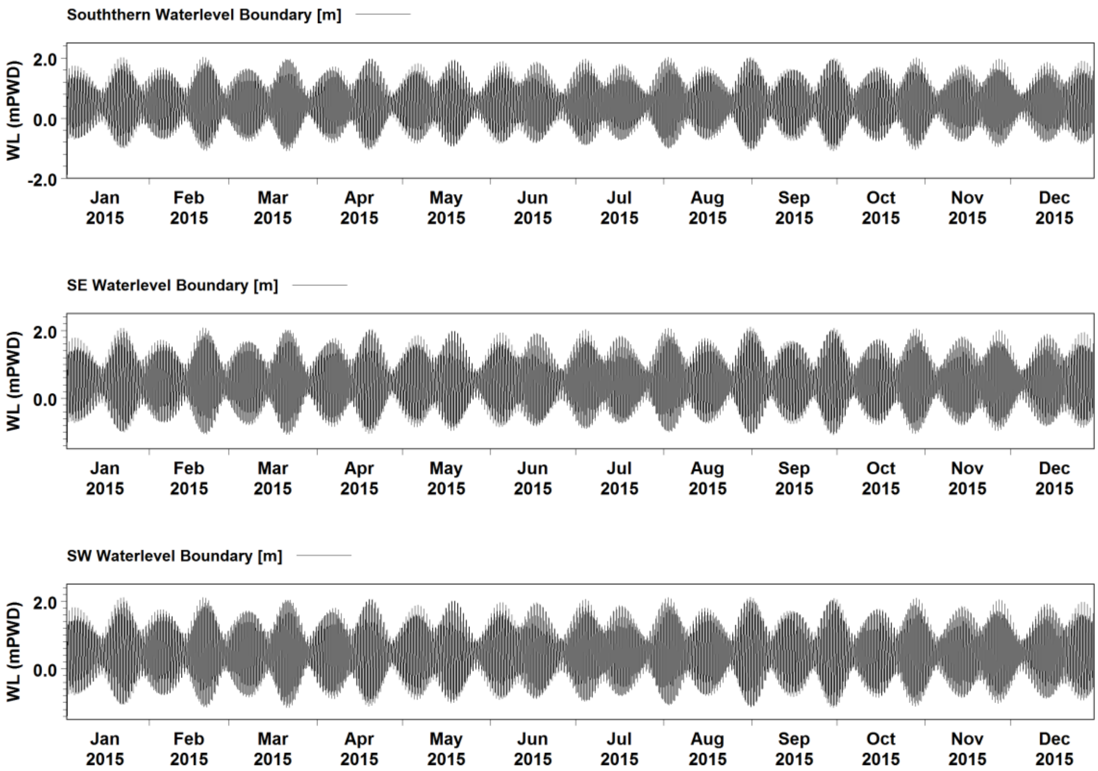

Figure 51 Southern Water Level boundaries from Bay of Bengal Model (MIKE 21 FM)

3.3.3 Calibration and Validation

Hydrodynamic model will be calibrated and validated with measure data of year 2015 and 2019. Water Level calibration shows good correlation with measured and simulated water level data. The calibration plot for the year 2015 has been shown in Figure 53 and Figure 54. The validation for 2019 was conducted using the 2019 model and the data collected in 2019.

This section has been left as a placeholder, as we do not yet have 2019 boundary conditions from the SWRM.

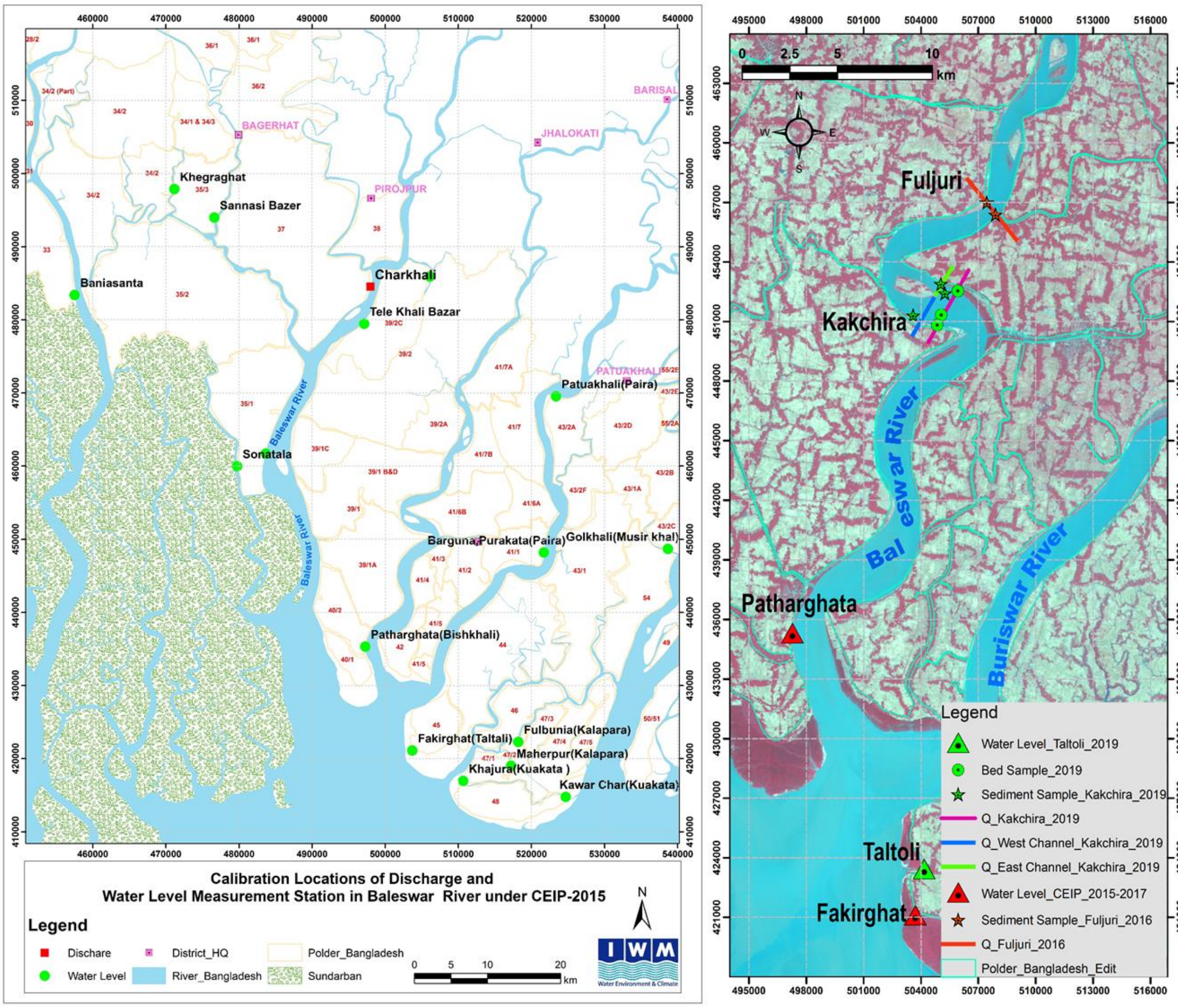

Figure 52 Discharge and water level Calibration (2015) and validation (2019) locations in Baleswar-Bishkhali River System

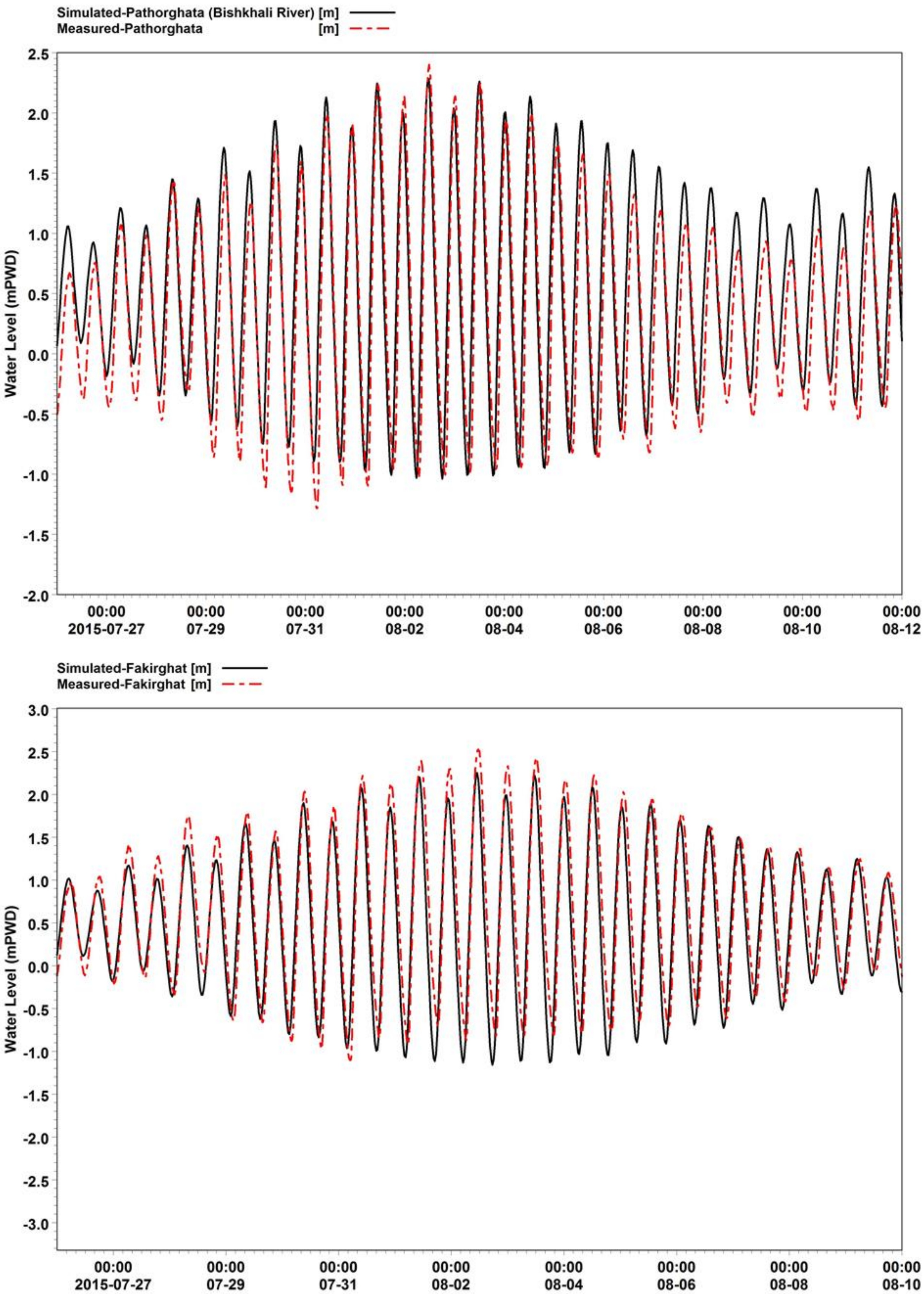

Figure 53 Water Level Calibration at Pathorghata (upper panel) and Fakirghat (bottom panel) for 2015

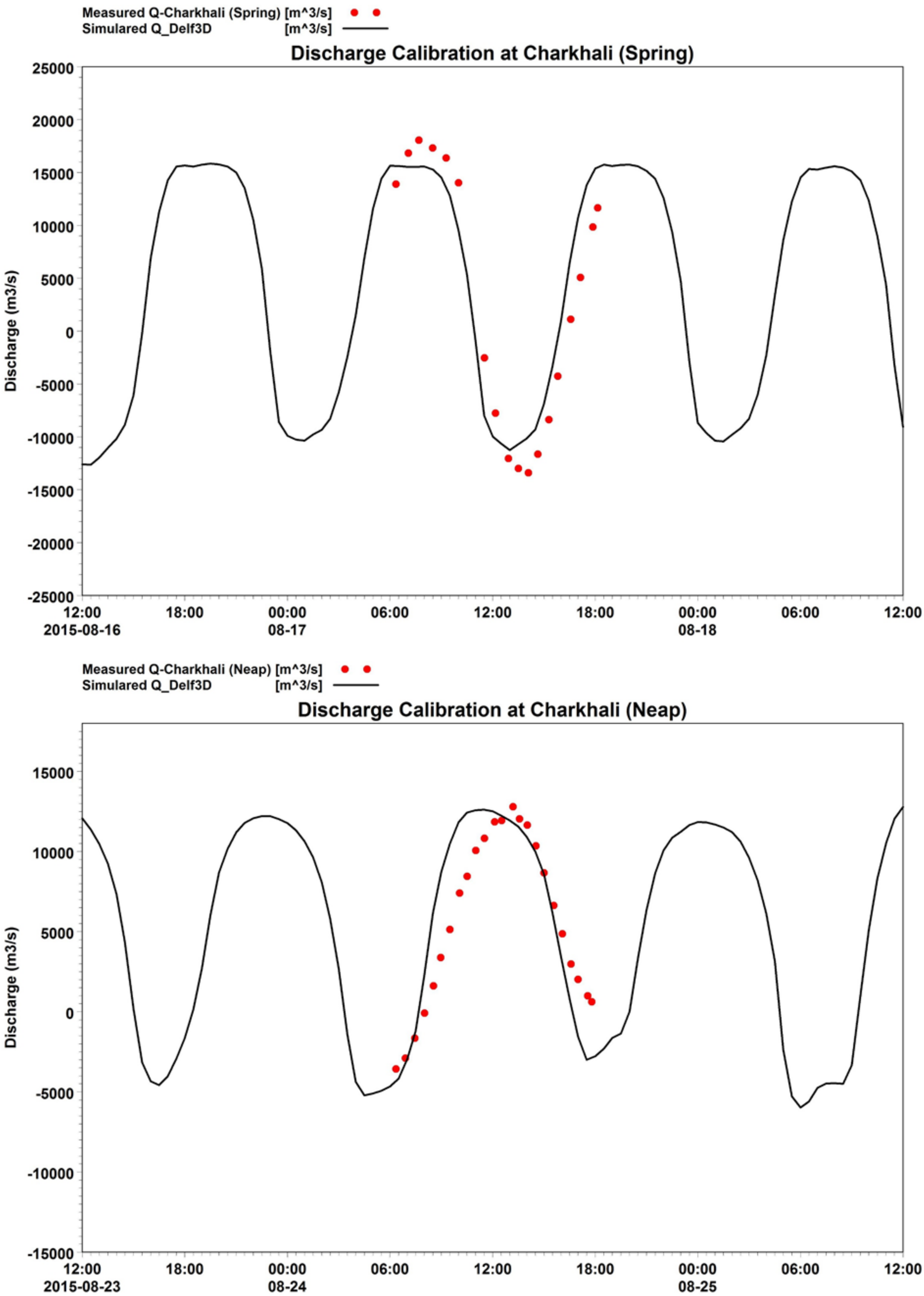

Figure 54 Discharge Calibration at Charkhali in Baleswar River

3.4 Sangu River

3.4.1 Model Setup

The Sangu river is modelled in one numerical grid in a single model. The river system is influenced by interaction with the adjacent floodplains (e.g., outside the polder area) as the bed level is relatively low around this area and flooding occurs. Therefore, the floodplain was incorporated on both sides of the rivers only around 250m on each side in the numerical grid. The available 2018 bathymetry data for the upstream part of the river channel was interpolated on the unstructured curvilinear grid and downstream was calculated using FM grid system.

3.4.2 Boundary Conditions

The Sangu model has one upstream boundaries at Puranagar and Three downstream boundary at Bay of Bengal. Upstream boundaries were collected from the calibrated and validated Eastern Hilly Regional Model. The downstream boundary conditions are derived from BOB Model.

All the boundaries were extracted from the Eastern Hilly Regional Model. Figure 55 shows all boundaries locations in both rivers. Figure 56 and 57 Shows the upstream and downstream time series data. All boundary conditions detailed descriptions are given in the report under deliverable: D-4A-2, titled as “Sangu River morphological modelling study”. (Ref-7)

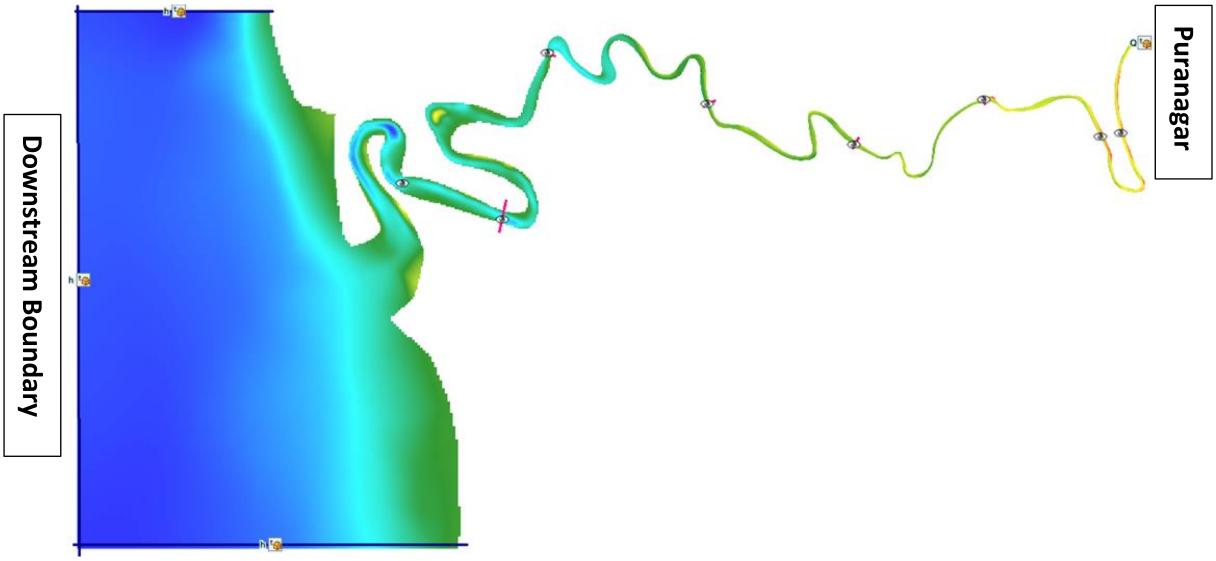

Figure 55 Boundaries location map in the Sangu river

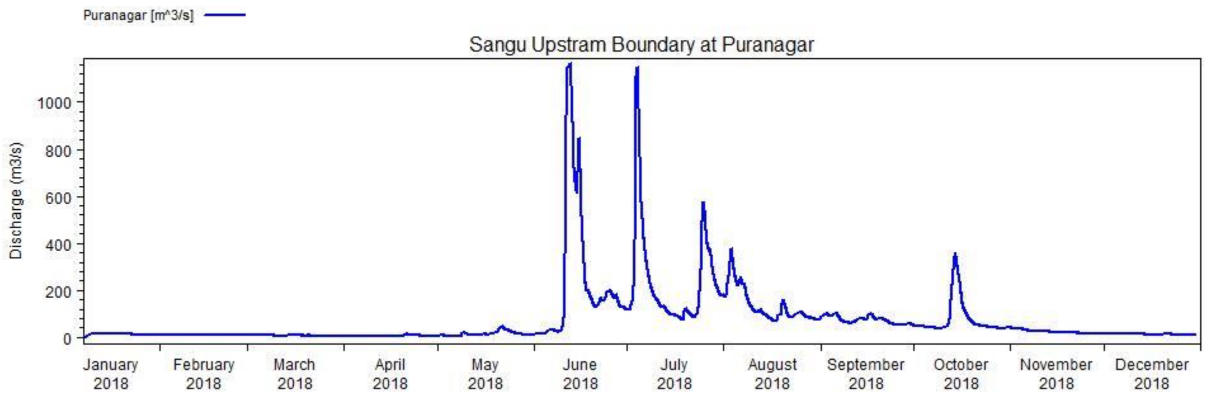

Figure 56 Upstream Discharge Boundary of Sangu at Puranagar

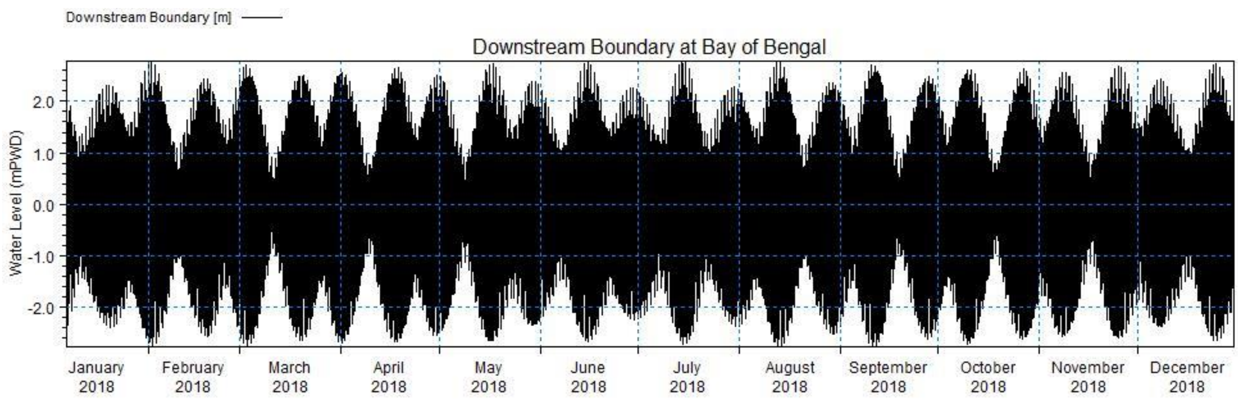

Figure 57 Downstream Water level Boundary of Sangu at Bay of Bengal

3.4.3 Calibration and Validation

The Delft3D FM sediment transport model calculates transport rates on a flexible mesh (unstructured grid) covering the area of interest on the basis of the hydrodynamic data obtained from a simulation with the Hydrodynamic Module (HD) together with information about the characteristics of the bed material. That is why a well calibrated and validated hydrodynamic model is needed to develop a reliable sediment transport model. The model was calibrated with field data during 2018 in dry season. The locations of the field data are shown in Figure 58. The Water level and Discharge calibration plot are shown in Figure 59-62.

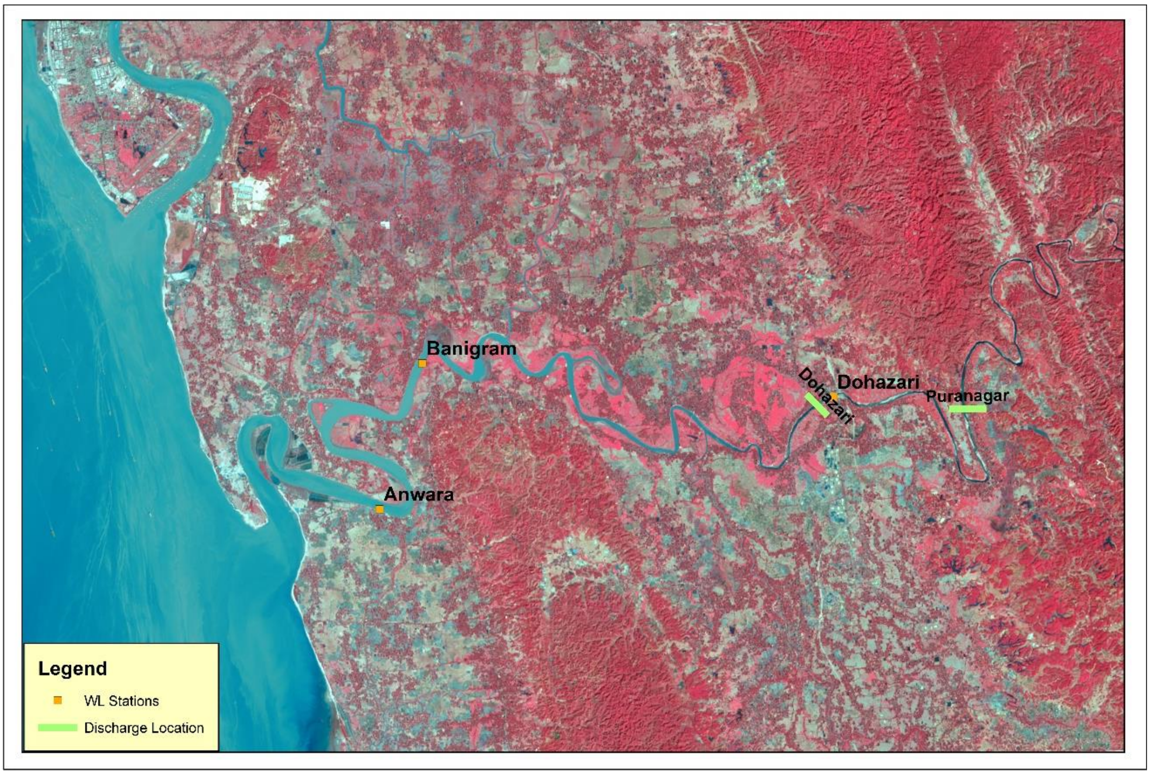

Figure 58 Locations of observed data stations for Sangu meso model

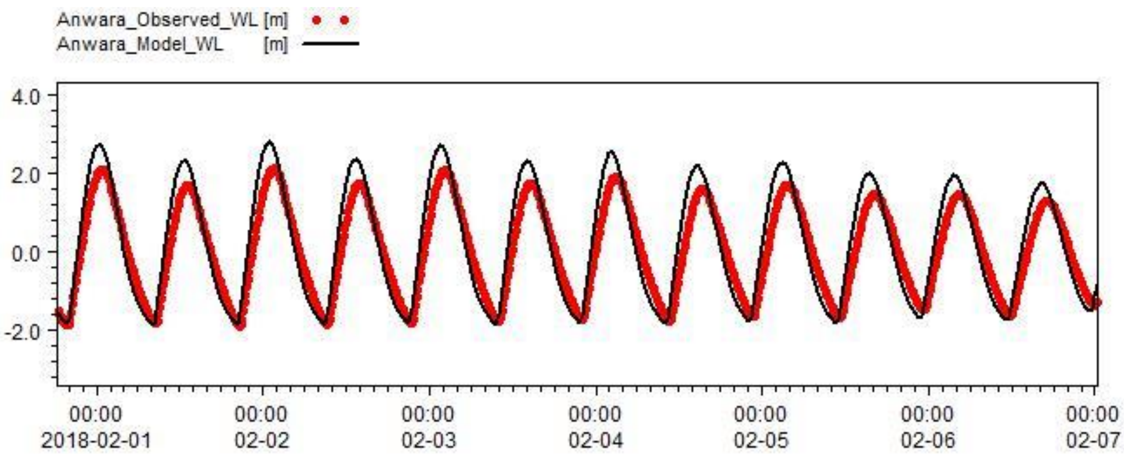

Figure 59 Water Level Calibration at Anwara (Dry 2018)

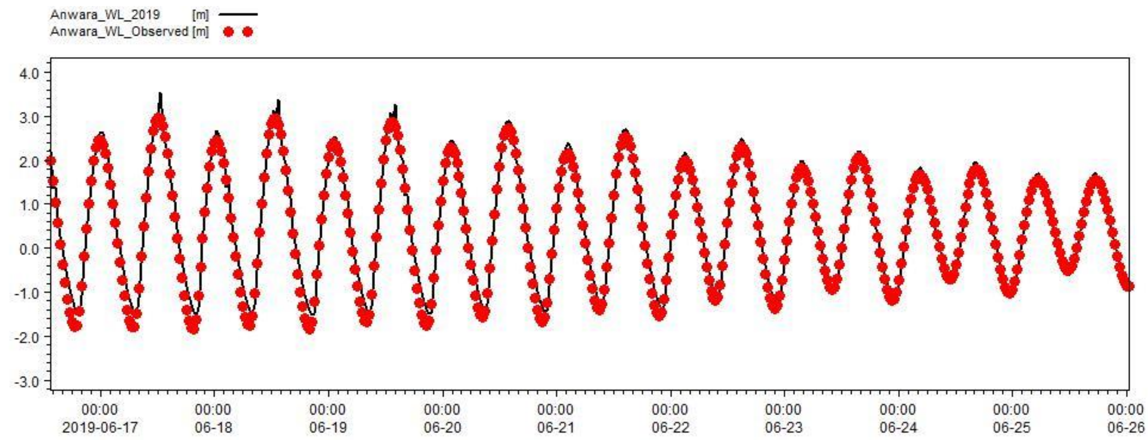

Figure 60 Water Level Calibration at Anwara (Monsoon 2019)

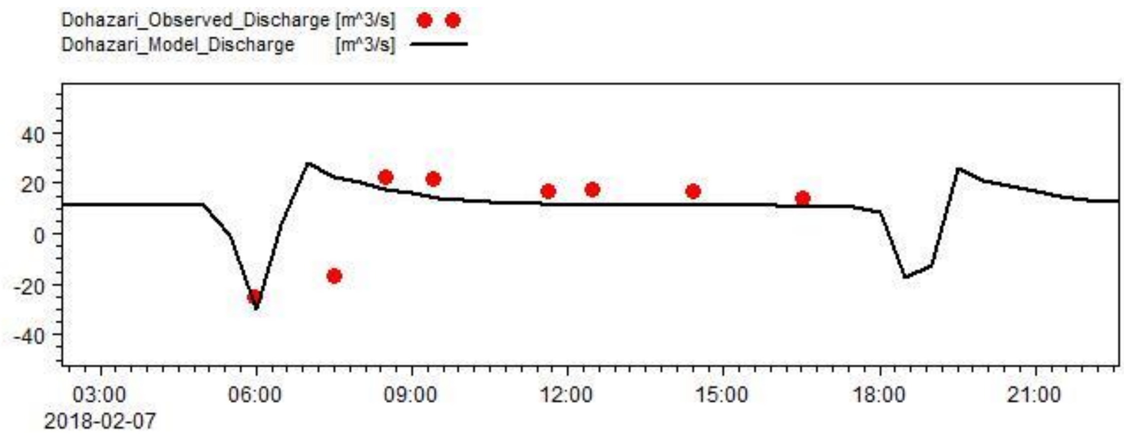

Figure 61 Discharge Calibration at Dohazari (Dry 2018)

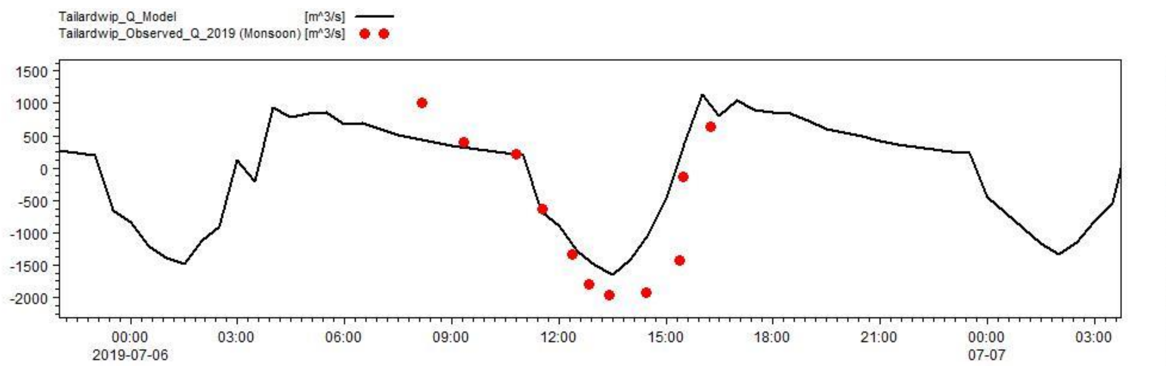

Figure 62 Discharge Calibration at Banigram (Monsoon 2019)

4. Conclusions:

All the model described in this report are at the initial setup condition and further model development, calibration and validation will be required as new data and scenario are added in the model.

The upstream and side channels boundary conditions of all meso scale models are used from the inhouse Regional Models (SWRM and EHRM) by IWM and rated discharge from measurement. The downstream boundary conditions are imposed at the seaward boundaries of the estuaries derived from the Regional models, Bay of Bengal Model (BoB) and from measured water level data where available. The sedimentation boundary derived from analysis of measured concentration data and knowledge gathered from past understanding.

Hydrometric data in the shape of water levels and discharges was used for calibrating the model. The calibration and validation quality are very convincing with the phase and magnitude correctly captured.

Future morphodynamic trends for the meso scale models will be assessed from different scenarios including climate change effect and the boundary forcing will come from the macro scale model results.

5. References:

1. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (October 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *MIKE 21C Sibsa meso-scale bank erosion morphological modelling study: Model development report*.

2. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (October 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *MIKE 21C Pussur meso-scale bank erosion morphological modelling study: Model development report*.

3. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (October 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *MIKE 21C Bishkhali meso-scale bank erosion morphological modelling study: Model development report*.

4. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (November 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *Pussur-Sibsa morphological modelling study – Current situation*.

5. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (July 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *Lower Meghna - Tetulia River system morphological modelling study – Current situation*.

6. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (December 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *Baleswar-Bishkhali morphological modelling study*.

7. DHI, Deltares, UNESCO-IHE, IWM, Universtiy of Colorado, & Columbia University. (November 2020). Coastal Embankment Improvement Project, Phase-I (CEIP-I) Long - Long Term Monitoring, Research and Analysis of Bangladesh Coastal Zone (Sustainable Polders Adapted to Coastal Dynamics). *Sangu River morphological modelling study*.

Appendix-1 Q&A

SL	Short reference to report text/figure	Comments	Reply of LTM office
1	General	Key comments: - The report describes the ***hydrodynamic boundary conditions*** of various models developed within LTM research program; it would be good to emphasize this and make a link with the D4 deliverables to which this report is connected; - This report does not touch upon sediment concentrations etc. as boundary conditions which are also needed for these models; it must either be explained why not or these must be included in this report; - To finalize this deliverable, it would be recommended to skip all text which says work in progress and put those into the D4 deliverables	-Already linked with D4 -Already included and referred to D4 -Skipped
2	Chapter 1	This chapter needs a bit more introduction to understand how this report fits into the LTM work and how this report feeds into the activities of C4.	- Chapter 1 is rewritten
3	Below Fig 42	"The Morphological Model setup and Calibration work of Baleswar River is ongoing. " => not sure what the intent of this sentence is, skip it?	-Skipped
4	Chapter 3	It is a bit confusing that in Chapter 2 mannings N is used and in chapter 3 Manning's n (inverse values).	-Mike 21C modelling system uses Manning number M instead of Manning´s n. The Manning number is the reciprocal value of the Manning´s n which is used in Delft3D-FM modelling system. - Clarified in the text
5	Fig 46	This figure cannot be read in Word by us (red cross)	-Figure has been modified
6	Section 3.4.4	Skip this section (Part of D4 deliverables)?	-Omitted
7	Chapter 4	This chapter is now very short; some reflection on the derivation of these boundary conditions and some general lessons learned would be useful here on calibration/validation of these models and what kind of issues have been encountered	-Discussion is added about these points