सत्यमेव जयते

REPORT OF THE COMMITTEE FOR CONDUCTING JOINT DETAILED TECHNICAL STUDY TO FORMULATE AN INTEGRATED PLAN TO COMBAT THREAT OF EROSION POSED BY GANGA- PADMA RIVER SYSTEM

CENTRAL WATER COMMISSION
Department of Water Resources,
River Development & Ganga Rejuvenation
Ministry of Jal Shakti

SEPTEMBER, 2024

Acknowledgement

Government of India, Ministry of Jal Shakti vide its OM No Z-16011/3/2023-FM Section MOWR dated 09.02.2023 constituted a Committee for conducting a "Joint detailed Technical Study to formulate an integrated plan to combat the threat of erosion posed by Ganga-Padma River System in West Bengal."

Six review meetings of the Committee were held in addition to several internal meetings, wherein detailed deliberations were held amongst the different stakeholders comprising of representation from the Central Government/agencies and State Government. The Committee considered a reach of 163.5 km in West Bengal along with 15 km in Bihar and reviewed the model being developed. Experiences and valuable suggestions shared by the State Government were acknowledged by the Committee. To formulate an integrated plan to combat the threat of erosion along the affected area, studies under the guidance of Committee were carried out by Tractebel Engineering Pvt Ltd. The study primarily focusses on the assessment of erosion prone vulnerable reaches and proposes mitigation measures for an integrated action plan on Ganga-Padma river system in the districts of Malda, Murshidabad and Nadia.

The Committee has carried out exhaustive studies through mathematical modelling, analysis of satellite imagery and input data from different Stakeholders for preparation of report of the Committee. Based upon 1D & 2D modelling studies, recommendations have been given for Flood Management works in various reaches to mitigate river bank erosion. I am hopeful that the recommendations of the Committee based upon the studies would be helpful in identifying the gaps and would act as guide for agencies involved in erosion abatement of Ganga-Padma river system. I express my sincere thanks and gratitude to all the members of the Committee for their significant contribution in bringing out this report. I also place on record the sincere and outstanding efforts made by officials of Department of Water Resources, River Development & Ganga Rejuvenation, Central Water Commission, Central Water and Power Research Station, State Government of West Bengal, Bihar and Jharkhand, Ganga Flood Control Commission (GFCC), National Remote Sensing Centre (NRSC), Farakka Barrage Project (FBP) in finalisation of the report. In the end, I would like to thank the Member Secretary of the Committee for his unwavering support, effective coordination among multiple agencies involved and organising meetings of the Committee.

Kushvinder Vohra
Chairman, Central Water Commission &
Ex-Officio Secretary to the Government of India and
Chairman of the Committee.

Executive Summary

Erosion & Deposition are natural geomorphic processes which happen in all alluvial reaches of rivers like Ganga and Fulhar (Mahananda). This is caused by various natural geological, geo-morphological, hydrologic, climatic, factors like floods, inflow of sediment from the drainage basin, heavy rainfall and anthropogenic activities etc. They define the river morphology which continues to change over time. Whenever, any intervention occurs in the river, it disrupts its existing equilibrium or regime. However, the river naturally regains its new regime through these processes of erosion and deposition. The issue of erosion is very rampant in the districts of Malda, Murshidabad and Nadia in the State of West Bengal. This has reportedly led to loss of agricultural land, infrastructure, and displacement of communities, reducing arable land and causing soil degradation. Erosion-induced sedimentation can degrade aquatic habitats, including riverbeds, wetlands, and riparian zones. In view of the same, Government of India, Ministry of Jal Shakti vide its OM No Z-16011/3/2023-FM Section MOWR dated 09.02.2023 constituted a Committee for conducting a "Joint detailed Technical Study to formulate an integrated plan to combat the threat of erosion posed by Ganga-Padma River System in West Bengal." The Committee was mandated to formulate an integrated plan to combat the threat of erosion along the banks of river Ganga-Padma in its entire stretch of 163.5 km in three districts, namely, Malda, Murshidabad and Nadia in West Bengal and at a stretch of 15 km in Bihar, review/ modify the existing gate regulation mechanism of Farakka Barrage, commission any technical study as deemed necessary, to obtain the requisite data/field data for the studies from the respective Organizations and look into the jurisdiction of Farakka Barrage Project.

Six meetings of the Committee were held wherein detailed deliberations were held amongst the different stakeholders comprising of representatives from the Central Government/agencies and State Government. Field experiences were shared by the State Government along with details of the past studies related to the matter carried out by Central agency like Central Water and Power Research Station (CWPRS). Studies were carried out by Tractebel Engineering Pvt Ltd under the guidance of the Committee. The Committee utilized data supplied by the State Government concerning land loss and erosion across various blocks and sites within the affected districts. The data, which includes observations of erosion and deposition over different time periods, was systematically collected by the State at various intervals.

The Committee carried out detailed study of the affected reach through setting up of mathematical models (run for different scenarios), analysis of satellite images to capture the bank-line shifting, field inputs from the State Government, Farakka Barrage Project, Tractebel Engineering Pvt Ltd etc. During the study, cross-section surveys were also carried out in a length of about 83 km upstream of Farakka barrage which includes about 68km in West Bengal and 15 km in Bihar. Similarly, cross-section surveys of river Fulhar (Mahananda) in about 22.50 km length from confluence point with river Ganga were completed. Cross-section surveys of

river Ganga downstream of Farakka barrage was also carried out in a length of about 20 km up to Nimtita for the studies. Based on the above data and analysis, critical reaches were identified and mitigation measures proposed through a combination of different strategies. The proposed measures are to be executed in co-ordination amongst the State Governments (Bihar, West Bengal and Jharkhand) and the appraisal agencies. The requisite details are included in the report.

The Committee deliberated extensively, on the issue of gate operation schedule and decided that in the present scenario the existing gate operation schedule may be adopted and suitable study to firm up the same may be awarded. The schedule should centralize the flow by symmetrical operation of gates. On the issue of jurisdiction of Farakka Barrage Project, it was suggested that the scope of Farakka Barrage Project may be addressed based on the approved EFC memo scheme for Farakka Barrage Project.

The detailed conclusions and recommendations of the Committee are presented in the report. The recommendations of the Committee will aid the State Government and other stakeholders in planning mitigation measures to combat the threat of erosion in the affected reaches and minimise the losses which occur due to the continuous problems of river bank erosion. In case of any unprecedented event, major intervention if required to be planned for undertaking in the river, suitable scientific studies should be initiated as and when required. Looking at the sensitivity of the issue in the reach, Committee recommended that suitable studies, to capture the river dynamics and suggest mitigation measures, may be carried out every 5 years.

List of Abbreviations

S No	Abbreviation Used	
1	U/S	upstream
2	D/S	downstream
3	ha	hectare
4	Sq km	Square kilometre
5	HO	Hydrological Observation
6	G&D	Gauge & Discharge
7	HD	Hydrodynamic
8	1D/2D	1 Dimensional/2 Dimensional
9	ST	Sediment Transport
10	HFL	High Flood Level
11	LWL	Lowest Water Level
12	q	Discharge intensity
13	v	Design velocity
14	MSE	Mean Square Error
15	RMSE	Root Mean Square Error
16	NSE	Nash–Sutcliffe efficiency coefficient
17	GFCC	Ganga Flood Control Commission
18	GoWB	Government of West Bengal
19	I&WD	Irrigation & Waterways Department
20	MHA	Ministry of Home Affairs
21	FM	Flood Management
22	ToR	Terms of Reference
23	FBP	Farakka Barrage Project
24	CWPRS	Central Water and Power Research Station
25	DoWR,RD&GR	Department of Water Resources, River Development and Ganga Rejuvenation
26	GP	Gram Panchayat

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Report of the Committee for Conducting a Joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga- Padma river system in West Bengal

1.0 Introduction

The Ganges forms one of the major river systems in India. One of its main headstream namely Bhagirathi originates from the ice caves at Gaumukh (N 30º55´, E 79º7´) at an elevation of 4100 m. Alaknanda, it's another main headstream in the mountainous stretch, rises beyond Manna Pass, 8 km from Badrinath at an altitude of 3123m. Both the main headstreams meet at Devprayag from where the combined flow is known as Ganga. In her course it is joined by many tributaries, important being Ramganga, Kali, Yamuna, Gomti, Ghagra, Gandak, Burhi-Gandak, Kosi, Mahanada and Sone. West Bengal is the lowermost riparian State of Ganga Basin. The river Ganga enters West Bengal at Rajmahal in Jharkhand and flows into Bangladesh near Gopalpur Ghat/ Bousmari in Nadia District of West Bengal. Due to construction of Farakka Barrage, the whole stretch of this river in West Bengal has been divided into two separate reaches (i) 68 Km upstream of the Farakka Barrage in Malda District (ii) 95. 5 Km downstream of the Farakka Barrage in Murshidabad District and Nadia District. This segment of the river has repeatedly experienced considerable changes in the sediment transport and deposition, causes wide spread flooding and undergoes frequent changes in her channel path. The complete index map of the river system in the segment with details of main river stem, its tributaries, important towns/cities, infrastructure, structures etc. is at **Annexure-I.**

1.1 Problem of Erosion in Ganga-Padma River System

Rivers, as natural channels, are intricately shaped by the dynamic processes of erosion, deposition and sediment transport. As a river progresses through the various stages of its lifecycle—namely the youthful stage, mature stage and old age stage—the gradient and size of the valley changes influencing its erosive capabilities. During these stages, the river erodes material from its banks and bed, incorporating this material into the river flow. When the river's energy decreases, it subsequently deposits this material along the river bed. The largest material i.e., boulders are deposited first, followed by pebbles, sand and silt. In India, several rivers grapple with significant erosion and siltation challenges and the Ganges is not an exception to this natural process. In the lower Ganges region i.e. broadly including the States of Jharkhand, West Bengal and Bihar, river bank erosion has become a recurrent issue posing serious problems since time immemorial. Murshidabad, Malda and Nadia districts of West Bengal are reported as severely impacted. The major concerns reported by State Government in these areas are: -

- The Ganges is a meandering river and has a general tendency to shift towards the left bank upstream of Farakka Barrage and towards the right bank downstream of the Farakka Barrage. Soil stratification of the river bank, presence of hard rocky area

(Rajmahal), high load of sediment, etc are certain factors contributing to river bank erosion.

- The areas like Mahanandatola (about 60 sq.km. in Ratua-I Block), Bilaimari, Kahla, Devipur, Uttar Dakshin Bhakuriya Gram Panchayats located around the confluence of Ganga & Fulhar (Mahananda) rivers are facing severe crisis . More than 200 sq.km. of fertile land was affected till 2004 in Malda district due to erosion as reported by the State Government.

- Due to complex hydrodynamics at the confluence of Fulhar (Mahananda) river at Manikchakghat in Manikchak block of Malda, the adjacent left bank of river Ganga and also a considerable stretch of around 4 km of Fulhar (Mahananda) often experience river bank erosion and flooding. As a result, the entire island named Bhutni diara of area approximately 51 sq.km comprising of 3 Gram Panchayats and population of 1.5 lakh in Manikchak block is affected.

- Erosion is very pronounced along left bank in the entire Manikchak and Kalichak-I blocks, at the U/S of Farakka barrage, particularly at Binnagar and Porapara

- The NH 131A, an important connectivity between Bihar and West Bengal, which stretches across this zone, is barely 1.36 km away from the river bank of Fulhar(Mahananda), which used to be 4.0 km in 2004.

- Severe erosion occurs at D/S of Farakka Barrage at both the banks at Pallarpur, Dhulian Municipality, Samserganj. The most affected areas in Samserganj Block are Nurpur GP, Giria GP of Suti-I block. In August 2020, nearly after 50 years, this region faced huge erosion which washed away dwelling places, temples, schools, agricultural lands along the right bank.

- Pronounced erosion is observed in the right bank of river Padma in Block Karimpur-II, G.P-Bausmari and Madhugari. The right bank of the river, houses many important townships as Dhulian, Nimtita, Lalgola, assests of National Importance such as NH-34, State Highway, Railway track etc. The river is only 520 m away from the railway track near the R.S. Sankopara Halt. Since, 2015 the river course has started to change its deep channel by formation of shoal towards the right bank upto Dhulian.

  In addition to above, water logging occurs frequently in this region. Flood is a big menace and agriculture is badly affected, though the land is very fertile. Looking at the gravity of the issues, planning for this massive silt is as important as the surface water flow itself in this region. It is essential that an integrated plan to combat threat of erosion posed by Ganga- Padma river system in West Bengal be prepared and implemented to save valuable lands, habitations and infrastructures, etc. from getting erased away.

Figure 1 shows reach of river Ganga passing through West Bengal.

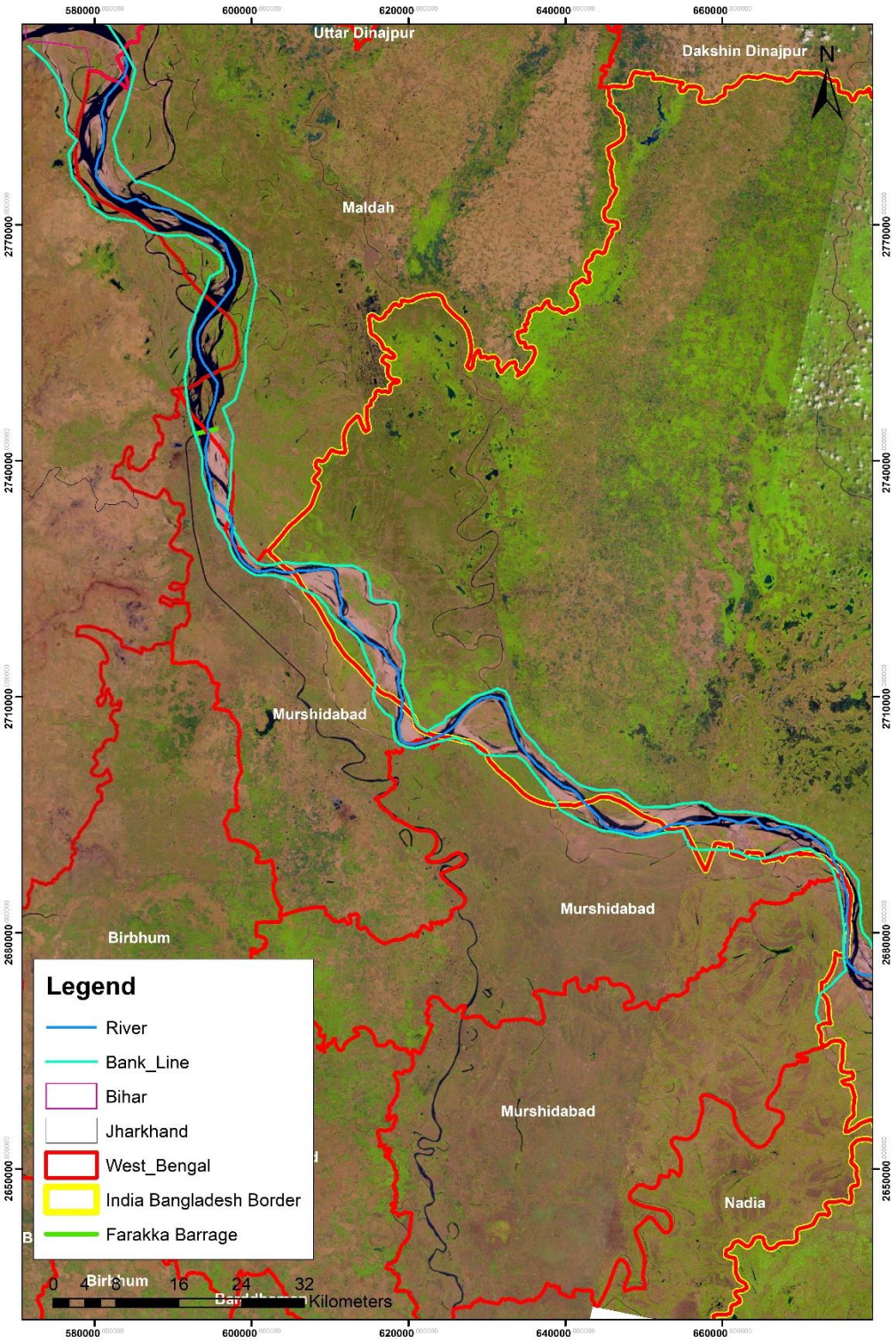


Figure 1 : Reach of river Ganga passing through West Bengal

The historical behaviour of river, as reported by the State Government, in the reach under consideration is discussed in detail below.

1.2 Historical River Changes (As reported by the Government of West Bengal)

Ganga-Padma erosion is taking place in the districts of Malda, Murshidabad and Nadia since long. The analysis of the maps of 1922-37, indicates that the direction of flow of the river Ganga-Padma between Rajmahal and Farakka was more or less straight. Subsequently, the river direction changed. The 1948-50 Survey shows that the river Ganga had a definite tendency to swing to the left below Rajmahal and to the right below Farakka. By 1967-68, the bank line had moved considerably towards the left below Rajmahal in the Rajmahal-Farakka reach. During the period 1990-2001 Hiranandapur, Manikchak, Gopalpur of Manikchak Block and Kakribandha-Jhaubona of Kaliachak- II Block of Malda district were badly affected by river bank erosion. In 2004-05 large scale erosion took place in Kakribandha-Jhaubona and Panchanandapur-I Gram Panchayats of Kaliachak II Block and Dakshin Chandipur, Manikchak and Dharampur Gram Panchayats of Manikchak Block of Malda district. Kakribandha Jhaubona, a Gram Panchayat, was totally lost by river bank erosion.

The approximate area of land eroded U/S of Farakka in district Malda from 1979 to 1996 as reported by State Government is represented in Figure 2 below.

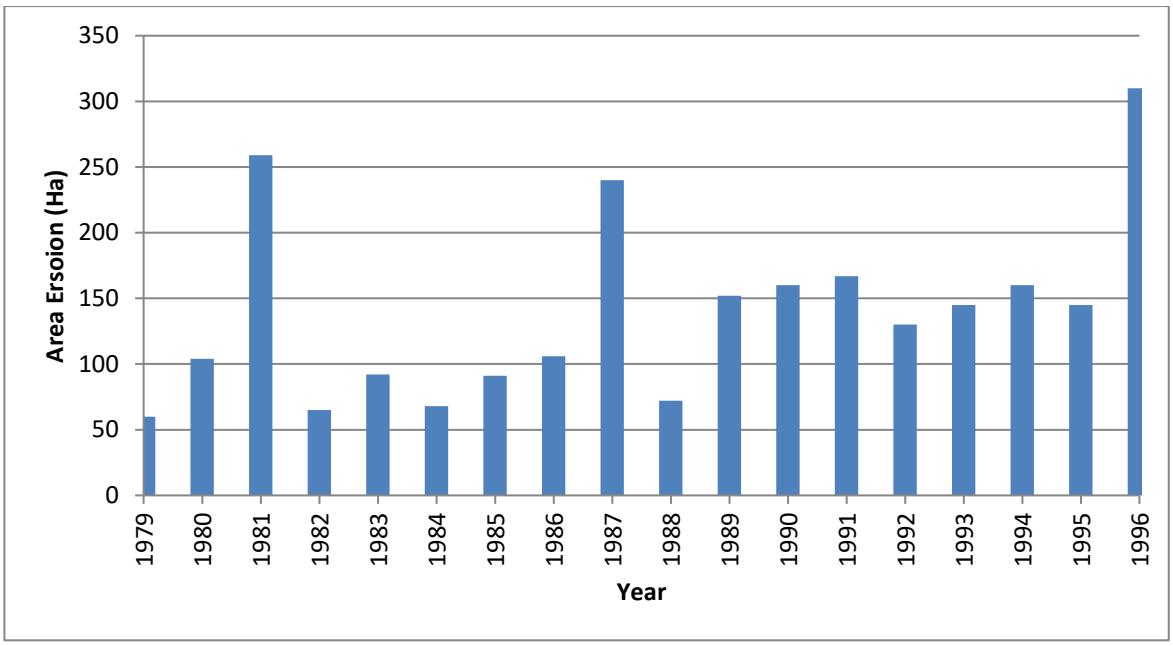


Figure 2: Plot of Area under Erosion since 1979 U/S of Farakka in Dist Malda

The river had moved considerably towards the right below Farakka and severe erosion is seen on the right bank. During the period from 1945 to 1950, there was a shift in the course of the river Ganga and it eroded about 3.2 Km width of land near Dhulian. During 1952-53, it assumed greater momentum and the old Dhulian Town was completely washed away by the river. The present Dhulian Town is at a distance of more than 1.6 Km from the location of the old town. This erosion continued up to 1956 , when the gap between the old Dhulian and the new Dhulian town was eroded away. From 1956 to 1967, there was a lull in the process of erosion at Dhulian. It started once again in 1968 and severe erosion occurred in 1969. During 1969-70, the Suti Police Station was eroded and severe damage occurred at all the places from the western bank of the river Ganga downstream of Farakka Barrage upto Jangipur. Since

1931 an area of about 282.89 sq.km. has been eroded till 1978.The reach wise statement of land erosion downstream of Farakka Barrage on the right bank (1931-77) of river Ganga as reported by State Government is represented in Figure 3 below.

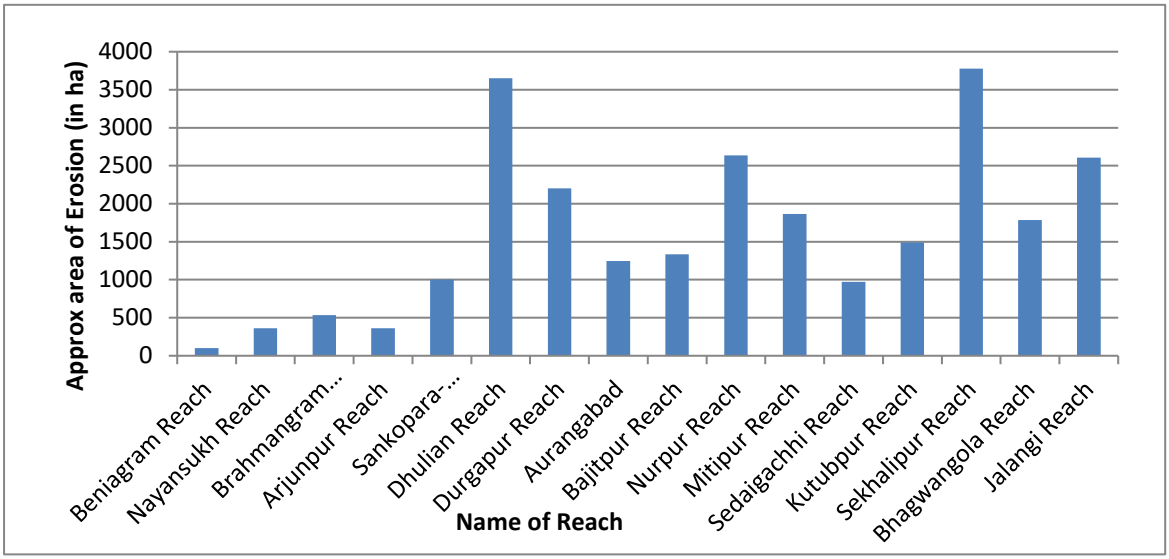


Figure 3: Plot of Approx area of Erosion D/S of Farakka on the Right Bank (1931-77)

Upto about 1972, the river Ganga downstream of Farakka flowed via two channels, with the major flow concentrated in the left channel. However, with time the left channel has got completely silted up and the river is flowing in one single deep channel along the right bank, causing continuous erosion on the right bank.

2.0 Background of the Committee

The severity of erosion and land loss, along with the consequent impacts on agricultural activity, is particularly acute in the lower reaches of the Ganga River system, prompting frequent government attention and intervention. Hon'ble Chief Minister of West Bengal vide DO letter dated February 21, 2022 and November 17, 2022 addressed to Hon'ble Prime Minister of India, flagged the issue of erosion posed by Ganga-Padma River System in the district of Malda, Murshidabad and Nadia and requested to restore the extended jurisdiction of Farraka Barrage Project (FBP). It is indicated in aforesaid DO letter that construction of Farraka Barrage has led to siltation on the river bed, spilling, flooding in adjoining areas and bank erosion in both downstream and upstream. A meeting was also taken on May 05, 2022 by Principal Secretary, Irrigation & Waterways Department (I&WD), Government of West Bengal with the officials of GFCC, FBP and I&WD, GoWB regarding the issue of Ganga erosion at interstate border and adjacent to FBP, followed by a joint site visit.

Major Concerns of the Govt of West Bengal

1. Erosion posed by Ganga-Padma River System in the districts of Malda, Murshidabad and Nadia. River bank erosion rates vary depending upon the factors like river flow, sediment transport and land use practices. Some areas experience erosion of several metres per year. This has led to loss of agricultural land, infrastructure and displacement of communities, reducing arable land and causing soil degradation. Erosion-induced

sedimentation can degrade aquatic habitats, including riverbeds, wetlands, and riparian zones.

2. Siltation on the river bed, spilling and bank erosion in both downstream and upstream and flooding in adjoining areas due to construction of Farraka Barrage.
3. Restoration of the extended jurisdiction of Farraka Barrage Project (FBP) i.e. 120 Km (40 Km upstream to 80 Km downstream).
4. Perpetual flood and erosion along the transboundary rivers like Mahananada, Fulhar (Mahananda), Tangon, Atrayee and Punarbhava at districts namely Uttar Dinajpur, Dakshin Dinajpur and Malda.
5. Threat to National Highway 131A

The government of West Bengal in collaboration with Central agencies has implemented various measures to address the issue. However, the issue continue to persist.

2.1 Composition of the Committee

In view of above, DoWR, RD & GR, Ministry of Jalshakti, GoI vide OM No Z-16011/3/2023-FM Section-MOWR dated 09.02.2023 (copy attached as **Annexure-II**) constituted a Committee under the Chairmanship of Chairman, Central Water Commission & ex-officio Secretary to Govt of India for conducting a joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma River System in West Bengal with following members and Terms of References(TOR).

Table 1: Composition of the Committee

1	Chairman, Central Water Commission	Chairman
2	Member, (D&R), Central Water Commission	Member
3	Member (RM), Central Water Commission	Member
4	Chairman, Ganga Flood Control Commission, Patna	Member
5	Commissioner (FM), DoWR, RD&GR	Member
6	General Manager, Farakka Barrage Project	Member
7	Director, Central Water & Power Research Station, Pune	Member
8	Representative of Ministry of Ports, Shipping & Waterways, Government of lndia	Member
9	Representative of State Government of Bihar	Member
10	Representative of State Government of West Bengal	Member
11	Representative of National Remote Sensing Centre, Hyderabad	Member
12	Chief Engineer (P&D), Central Water Commission	Member Secretary

2.2 Terms of Reference of the Committee

(Para 3.0 of the DoWR, RD & GR, Ministry of Jalshakti, GoI vide OM No Z-16011/3/2023-FM Section-MOWR dated 09.02.2023 order): -

1. To formulate an integrated plan to combat the threat of erosion along the banks of river Ganga-Padma at its entire stretch of 163 km in three districts, namely, Malda, Murshidabad and Nadia in West Bengal and at a stretch of 15 km near the West Bengal- Bihar Border.
2. To undertake model study required for this purpose by Central Water & Power Research Station, Pune, under the guidance of the Committee and as per timelines fixed by the Committee.
3. To review/ modify the existing gate regulation mechanism of Farakka Barrage, if required, for this purpose.
4. To commission any other technical study deemed necessary by the Committee
5. To obtain the requisite data for the studies from the respective Organizations.
6. To obtain field data required by the Committee from State Govt. of West Bengal.
7. To undertake site visits for which necessary arrangements shall be made by Govt. of West Bengal

Additional Terms of Reference as under was also given to the Committee vide this OM. Copy of OM is enclosed at **Annexure-III** with additional Terms of Reference**: -**

8. To review the original jurisdiction of Farakka Barrage Project as regards to undertaking anti-erosion/ river bank protection works, and to examine the need (if any) for extending this jurisdiction, as requested by State Government of West Bengal.

3.0 Meetings of the Committee

The Committee had six meetings dated 06.04.2023, 21.06.2023, 24.11.2023, 22.03.2024, 16.05.2024 and 03.09.2024. The summary of key deliberations & decisions taken during the meetings are given below.

3.1 1st Meeting held on 06.04.2023

- Representatives of Govt of West Bengal & Government of Bihar apprised the Committee about the issues relating to perpetual river erosion along banks of river Ganga/ Padma in upstream and downstream of Farakka barrage and action taken towards the same so far. The Government of Bihar presented few satellite images and site photographs of last year flood 2022 at different locations in between Hardev Tola to cut-end of T.C.P embankment. West Bengal also presented the vulnerable locations facing erosion in the State.

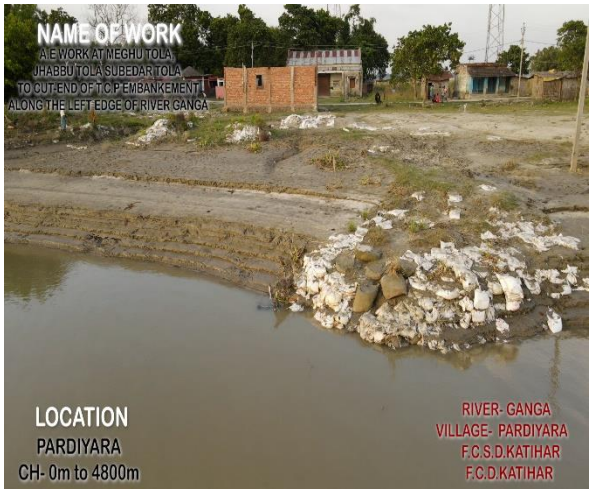


Plate 1 : Existing Works at Meghu Tola,Jhabu Tola, Subedhar Tola to cut end of TCP Embankment along the Left Edge of River Ganga (Pardiyara)

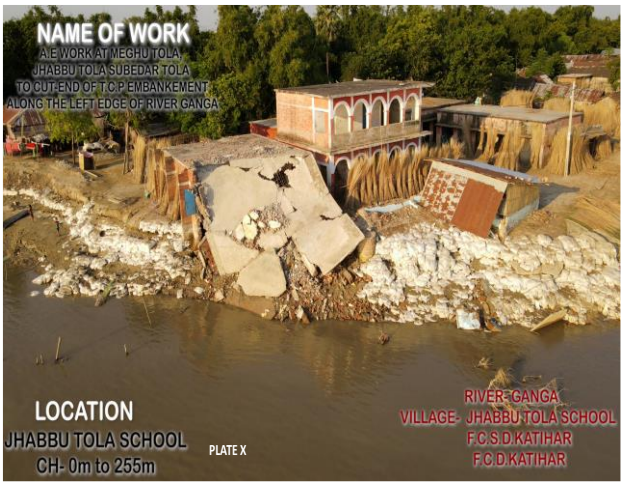


Plate 2: Existing Works at Meghu Tola,Jhabu Tola, Subedhar Tola to cut end of TCP Embankment along the Left Edge of River Ganga (Jhabu Tola School)

Plate 3: Bank Erosion at Bhutni Manikchak

Plate 4: Bank Erosion at Narayanpur, Manikchak

Plate 5: Bank Erosion at Purba Debidaspur, under Block & P.S. Samserganj

Plate 6: Bank Erosion at Maheshtola ,Block & P.S.- Samserganj

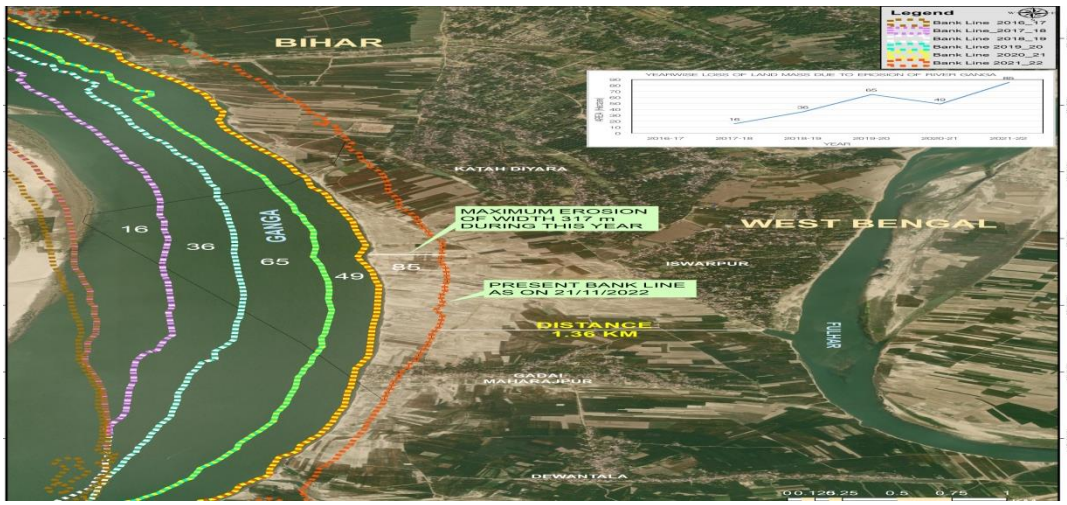


Plate 7 : Satellite Image showing year wise shifting of bankline of River Ganga towards River Fulhar (Mahananda) (2016-22)

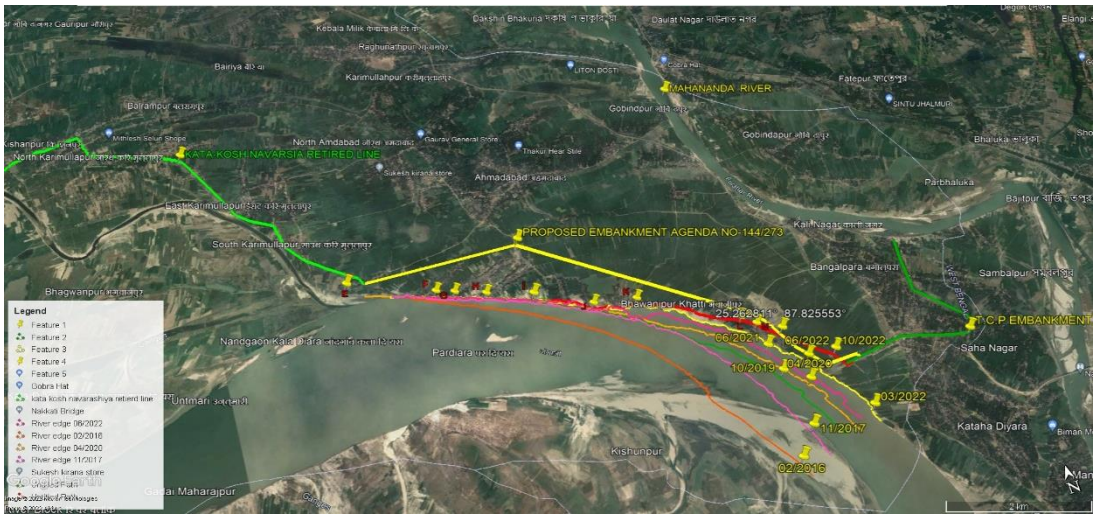


Plate 8: Satellite Image showing year wise shifting of bankline of River Ganga from Meghu Tola to Cut End of T.C.P Embankment

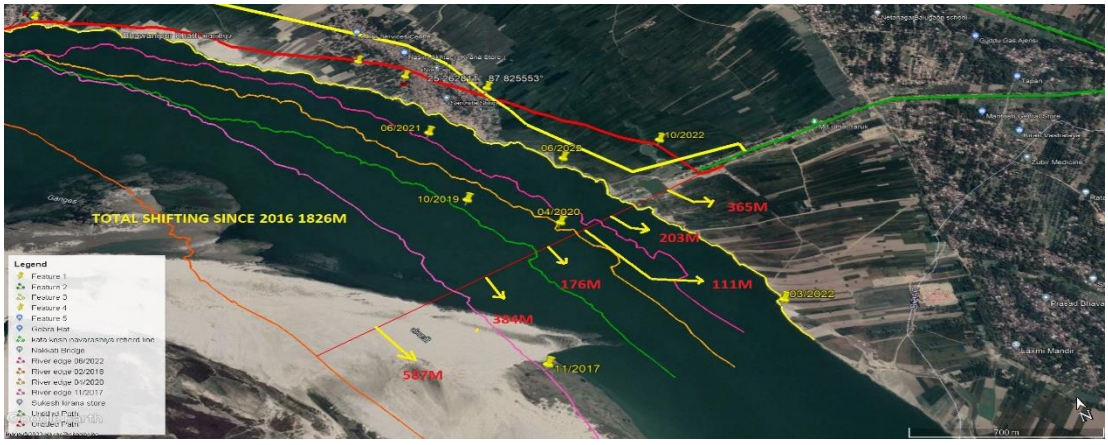


Plate 9:Satellite Image showing year wise shifting of bankline of River Ganga (2016-2022)

- Govt of West Bengal has carried out certain works, surveys and studies pertaining to erosion and appointed a consultant (Tractebel Engineering Pvt Ltd) in November, 2022 to carry out a comprehensive study through survey, model study and preparation of DPR for the entire 163.50 Km of Ganga River. River Research Institute, West Bengal has also conducted a bathymetry and topographical survey of river Ganga and Fulhar (Mahananda) at Mahanandatola and Bilaimari area of District Malda.
- Government of Bihar has undertaken anti-erosion works using boulder slope pitching with boulder apron for a length of 6300m in 2018 from Hardeo Tola to Khatti. After the flood, majority of the work proved ineffective.
- RMSI Pvt Ltd has carried out the Study in 2021 under National Hydrology Project (NHP) on the issue of Flood and Siltation in River Ganga and its tributaries due to Farakka Barrage in the State of Bihar. The study concluded that no significant changes were observed in the backwater and sediment transport “with barrage” and “without barrage” scenarios.
- Central Water & Power Research Station (CWPRS) in their presentation stated that a physical distorted model of 1:500H & I:70V was constructed and exists at CWPRS since 1963. The studies related to different stages of construction, provisions of coffer dams were studied in the said model. 1:80 Geometrically similar model was also constructed in 1994 for Farakka Hydro Electric Project. Reports on different aspects related to Farakka Barrage has been submitted to Farakka Barrage Project and other stakeholders by CWPRS. Studies on planform changes in the river Ganga U/S and D/S of barrage has been carried out from 1977 to 2009. Further, a study for proposing river training measures in river Ganga near Maharajpur, Jharkhand near Western Railway was also carried out by CWPRS.
- The Committee agreed that the study awarded by Govt of West Bengal to Tractebel Engineering Pvt Ltd (Consultant) may be an integrated study and must include the 9 km reach upstream of Farakka Barrage located in Bihar State with modified TOR, if required.
- The anti-erosion works carried out in the past at various reaches in the study area by the Government of Bihar and West Bengal shall be mapped by collecting the same from respective Govt.
- The data requirement by Tractebel Engineering Pvt Ltd will be met from available data with Central Water Commission, Govt of Bihar & West Bengal, Farakka Barrage Project, open source data and field survey, etc by following required protocols/ policy/ contractual requirements, etc.

The Minutes of the Meeting are annexed at **Annexure IV A**.

3.2 2nd Meeting held on 21.06 .2023

- Tractebel Engineering Pvt Ltd, the consultant engaged by Govt of West Bengal has surveyed cross-sections in the study reach. Bathymetry and topography details, locations & details of existing flood control works, locations of likely erosion area based on field observations, etc were collected along with cross- section survey for compilation. Satellite images from 1983 to 2023 for the study area were also analysed. Initial model set-up has been completed to be further refined with additional data.
- The Consultant scope of study would cover river Ganga 15 Km in Bihar in addition to 68 Km in West Bengal in the upstream of Farakka Barrage and 95.5 Km in West Bengal in the downstream of Farakka barrage and integration of Faraka Barrage Gate Operations parameters.
- Government of Bihar consented for bearing the financial burden of works related to cross-section survey for 15 Km (approx.) stretch in the Bihar portion by the Consultant.
- The comprehensive data requirements for the study would be prepared by the Consultant and the same to be applied by the Govt of West Bengal to respective data owning agency following existing policy.
- Commissioner(FM), DoWR, RD & GR may approach Bangladesh through proper channel for clearances to do cross-section survey in the trans-boundary reaches.
- Consultant would include the sediment load transport studies as part of their scope and make such recommendation
- The model developed by Tractebel Engineering Pvt Ltd including its set-up would be reviewed by Central Water & Power Research Station (CWPRS) and validated based on existing mathematical/ physical model.

The Minutes of the Meeting are annexed at **Annexure IV B**.

3.3 3rd Meeting held on 24.11.2023

- Farakka Barrage Project provided the requisite data comprising of salient features of Farakka barrage, Gate Operation Schedule-1997, 2007 and 2021 etc for integration of gate operation in the study. Govt of West Bengal shared the latest map/ data for all existing anti-erosion measures taken up at-least during last 10 years to the Consultant. Cross section and bathymetric surveys of 15 km reach of river Ganga in Bihar were completed by the Consultant.
- Cross-section survey work continued to be pending for the India-Bangladesh trans-boundary reach for want of permission from competent authority despite matter having been taken up with BSF & MHA.

- The Consultant was advised to explore modelling for prediction of change in morphological behaviour of the river in future, if the proposed structural work is taken up both from the perspective of hydro and sediment dynamics. The studies may focus on studying the river behaviour with present stage of existing interventions for future years.
- Committee felt that the joint study is complex in nature involving various agencies from State and Central Govt. Data acquisition for the study involves various stakeholders is taking time and lot of technical consultation from CWC and other agencies are required. In view of complexity involving several agencies and progress made by the Consultant, alteast 6 months more is required to complete the study. Accordingly, extension was sought and granted upto 31.03.2024 vide Letter No Z-16011/3/2023-FM Section MOWR dated 27.12.2023.

  The Minutes of the Meeting are annexed at **Annexure IV C**.

3.4 4th Meeting held on 22.03.2024

- Consultant shared their models/ studies with Central Water & Power Research Station (CWPRS) & Central Water Commission (CWC). Observations of CWPRS communicated in two separate tranches were complied and assimilated by the Consultant.
- Efforts for permission regarding cross-section survey work in the trans-boundary reach were continued. Pending permission, use of cross-section extracted from SRTM DEM or other credible source duly corrected for datum may be continued so that progress of studies is not affected.
- HEC 1D, 2D hydrodynamic and sedimentation models developed are showing good results during flood season (up to October). However, the results during lean season are not satisfactory perhaps due to using same gate operation schedule during flood and lean season. The result may improve if different gate operation schedule during flood and lean season is used.
- Considering importance of flood season results, 1-D integrated model for the complete study area covering upstream, downstream and Farakka Barage duly calibrated and validated at CWC HO sites with satisfactory results during flood season was considered acceptable. On the other hand, two separate 2-D models would be developed one for upstream of the Farakka barrage and another for downstream of the Farakka barrage.
- Predictive modelling for probable change in behaviour of the river morphology corresponding to planning of future structural works both from the perspective of hydro and sediment dynamics is not considered feasible with available knowledge and processing capabilities.

- Keeping in view, additional ToR regarding examination of extension of jurisdiction of Farakka Barrage Project assigned for taking up anti-erosion works, at least 3 additional months would be required to complete the study. Accordingly, extension was sought and granted upto 30.06.2024 vide Letter No Z-16011/3/2023-FM Section MOWR dated 24.04.2024.

  The Minutes of the Meeting are annexed at **Annexure IV D**.

3.5 5th Meeting held on 16.05.2024

- The total reach of study is approx. 179 km (163.5 Km in West Bengal and 15 Km in Bihar) divided into four sub-reaches i.e. Reach-A (from Sakrigali to confluence of River Fulhar (Mahananda) and River Ganga -45 km), Reach-B (from River Fulhar (Mahananda)- river Ganga confluence to Farakka Barrage -38 Km), Reach-C (from Farakka barrage to Nimtita -23 Km) and Reach-D (from Nimtita to Jalangi -73 Km). Data from various agencies i.e. Farakka Barrage Project, Govt. of West Bengal, Govt. of Bihar, CWC etc has been shared with the Consultant and is sufficient for carrying out the studies as confirmed by the Consultant.

- As a follow up of 4th meeting, integrated 1-D model from Sahibganj (Jharkhand) upto Hardinge Bridge (Bangladesh) approx. 268 Km incorporating Farakka Barrage (extended beyond Bhagwangola, West Bengal) has been calibrated and validated for three years during 2017-2019 at sites Ramayanpur (G-Bihar), Rajmahal (G-Bihar), Manikchak (G-WB), Farakka U/S Pond level (FBP), Farakka Downstream (GD-CWC), Nimtita (G-WB), Nurpur (G-WB), Geria (G-WB) and Rajshahi (G-Bangladesh-Literature) for monsoon months. Moreover, two separate 2-D model are also developed, one for upstream of Farakka (Sahibganj to Farakka Barrage) and another for downstream of Farakka Barrage (Farakka Barrage to Hardinge Bridge). The models were found to be broadly in order except minor modifications based on the observations of CWPRS & CWC modellers.

- Central Water & Power Research Station (CWPRS) pointed out that in 1-D model at chainage 45,448m of Reach-A, river cross section appears inadequate resulting in formation of vertical wall of 7m and restricting water spread on the left bank. It is also seen that in 1-D model Manning ‘n’ value in some places is taken as 0.014 which seems to be very low. Normally, Manning's ‘n’ value for open alluvial channels is taken as greater than 0.02. The consultant would review the cross-section and Manning ‘n’ value.

- Cross-section data in 1-D model for extended section i.e. Nimtita upto Hardinge Bridge (Bangladesh) has been extracted from SRTM DEM of Year 2015-16 duly corrected with satellite images of March’2024 for deepest channel/ thalweg alignment and river width. As pointed out by NRSC, consideration of two data

sets of different periods without knowing erosion and deposition in between, may be put as a limitation.

- The Committee desired that at known critical chainages, comparison of time series simulated water level from 1D & 2D may be checked to ensure validation of 2D model wrt validated 1D model. Further, validation of water spread area in 2D model may be got verified by Government of West Bengal through ground verification in addition to satellite based inundation maps which Consultant has already done.
- Bridge under construction downstream of the Farakka Barrage should be included in the model using required data as available with or to be collected from NHAI by Govt of West Bengal.
- Draft preliminary project report identifying erosion-prone reaches and suggesting mitigating measures along with cost estimate submitted by the Consultant to Govt of West Bengal would be reviewed by the Committee, once model is accepted and Preliminary Report is updated according to the model's output.

The Minutes of the Meeting are annexed at **Annexure IV E**.

3.6 6th Meeting held on 03.09.2024

Detailed deliberations were held on the contents of the report.

- The Government of West Bengal indicated some minor corrections regarding the reach of the river mentioned, certain clarifications/ modifications in the recommendations etc. of the Draft Report.
- Government of Bihar, suggested that the mitigation measures proposed in the Bihar portion may be carried out in coordination amongst Bihar, GFCC and West Bengal.
- GFCC suggested that discussion on the non-structural measures may also be incorporated in the report. However, the Committee was of the view that many nature-based recommendations have been incorporated in line with the ToR of the Committee.
- FCA Dte, CWC observed that velocity obtained from mathematical models, the exact period for which the performance scores have been calculated, additional assumptions may also be included in the Draft Report. After due deliberations, the Committee decided to incorporate the above suggestions appropriately and accepted the Report as final.

The Minutes of the Meeting are annexed at **Annexure IV F**.

4.0 Study Reach

The total reach of study is approx. 179 km (163.5 Km in West Bengal and 15 Km in Bihar) divided into four sub-reaches i.e. Reach-A (from Sakrigali to confluence of Fulhar (Mahananda) and Ganga -45 Km), Reach-B (from Fulhar (Mahananda) - Ganga confluence to Farakka Barrage -38 Km), Reach-C (from Farakka barrage to Nimtita -23 Km) and Reach-D (from Nimtita to Jalangi -73 Km).

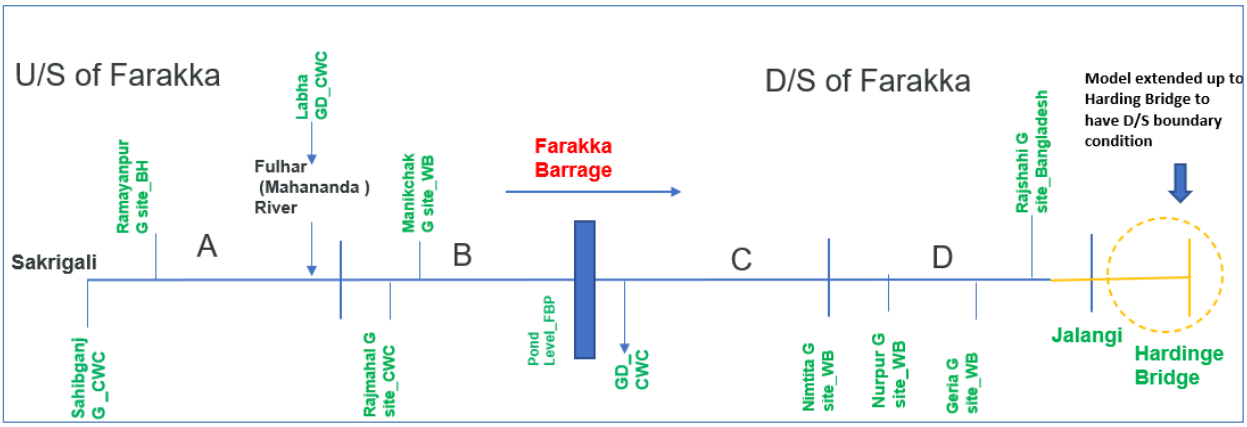


Figure 4: Line Diagram for the Study Reach

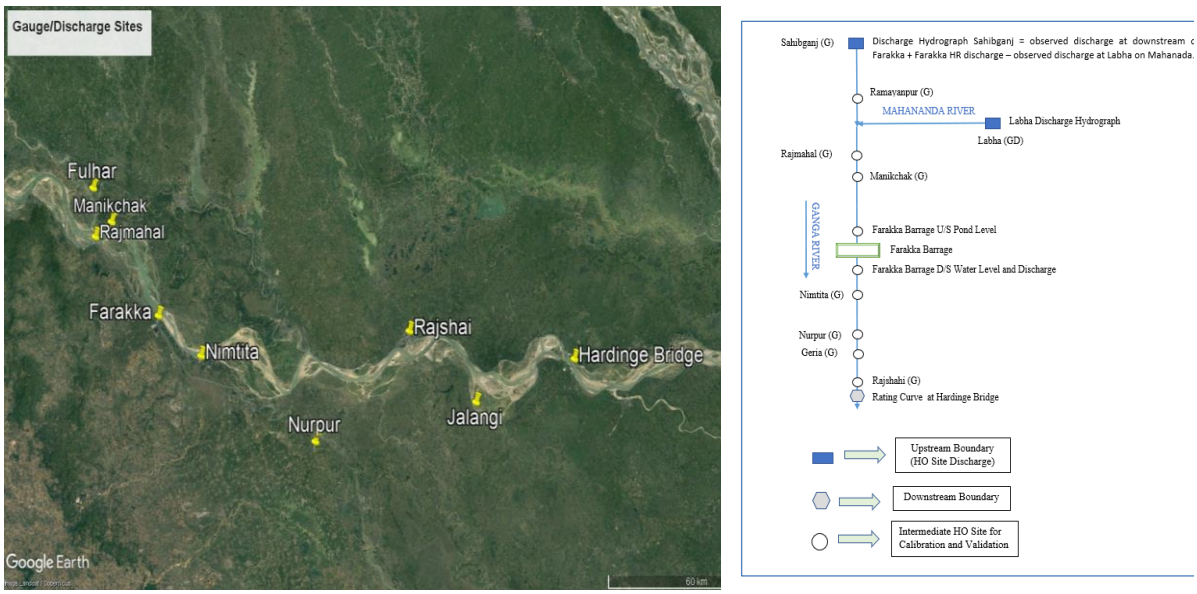


Figure 5 : Location of Gauge/Discharge Sites

For the purpose of study, following division of the study reach is considered.

A- Ratua I Reach: Sakrigali(Bihar) to confluence with Fulhar(Mahananda)

B- Manikchak-Kaliachak Reach: Fulhar (Mahananda)- Ganga Confluence to Farakka Barrage

C- Dhulian Reach: D/S Farakka Barrage to Nimtita

D-Bhagwangola Reach : D/S of Nimtita to Lalgola/Jalangi

The representation of the different reaches on Google Earth is as under.

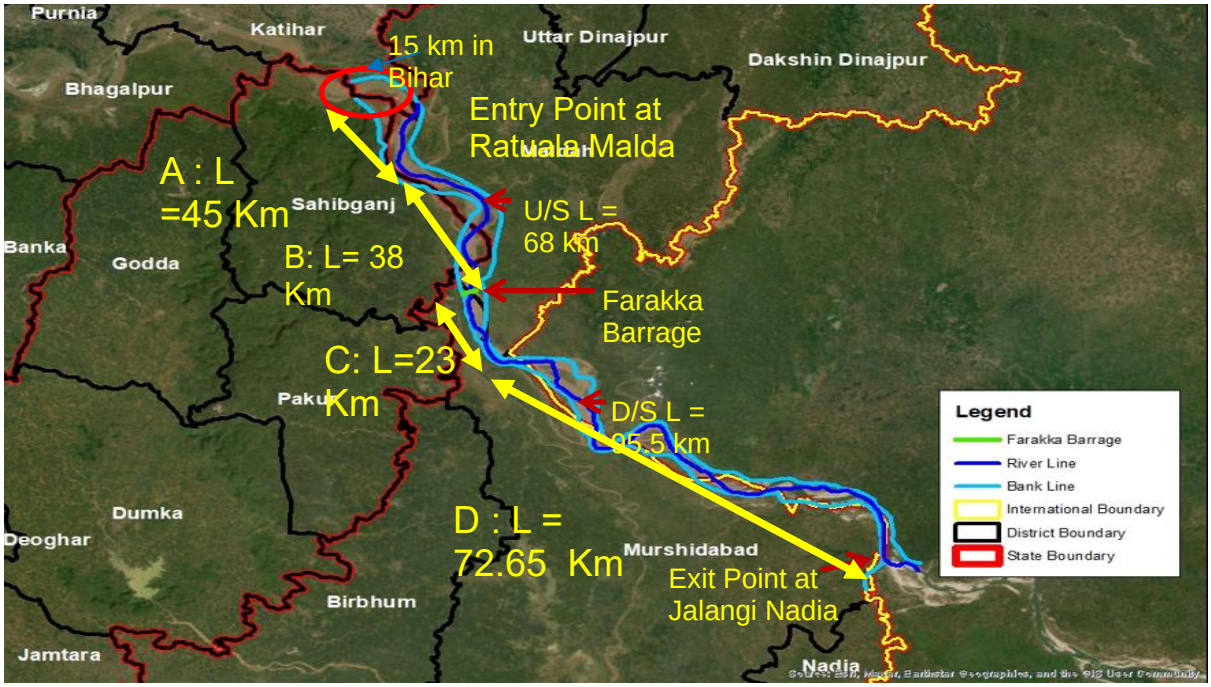


Figure 6: Study Reach

5.0 Mathematical Modelling

One of the major objective of the Committee is to formulate an integrated plan to combat the threat of erosion along the banks of river Ganga- Padma at its entire stretch of 163.5km in three districts, namely, Malda, Murshidabad and Nadia in West Bengal and at a stretch of 15 km in Bihar. In order to identify the erosion-prone areas and suggest effective management strategies, understanding the flow patterns, velocities, and interactions within the river system is crucial. The study was undertaken under guidance of CWC and Committee by a Consultant viz., Tractebel Engineering Pvt Ltd appointed by Government of West Bengal, to understand the river dynamics through comprehensive study based on mathematical model, satellite image analysis supplemented by field visits. The Report of Consultant is appended as **Appendix-I**.

In view of the same, the details of mathematical modelling and river migration studies have been carried out to analyze hydrodynamic conditions, sediment transport dynamics (M5 2D ST Model run to check for sustainability of Sakri Gali Paleo channel), and historical channel changes.

The river stretch has been divided into different reaches for the purpose of study. It is observed that in this stretch the river exhibits wide dimensions, meandering deep channels (thalwegs), and braided sections characterized by sand bars and chars. 1D and 2D HEC RAS models have been developed for different purposes and a comprehensive analysis of bank-line shifting and comparison with relevant satellite images has been done through digitization. The summary of the models run in different identified reaches with their objectives and outputs is given in the table below:-

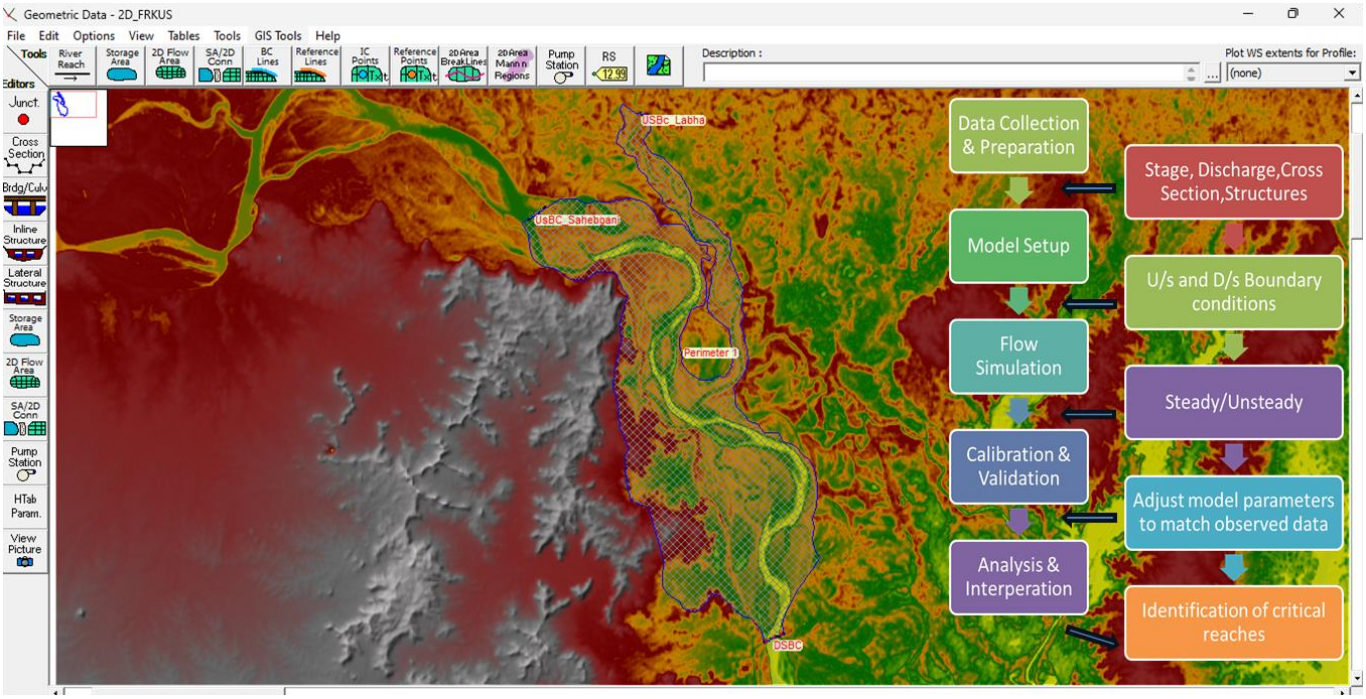
Table 2: Summary of the models run in different identified reaches

Model ID	Model Description	Purpose/ Objective	Desired Output/ Uses	Remarks
M1	1D HD Model (Sahibganj to Hardinge Bridge)	(a) Simulated Water Level and Discharge at different locations in the study reach for given design discharge, and (b) To generate boundary conditions for local scale 2D modelling of finer resolution	Design HFL and LWL.	
M2	2D HD Model (Sahibganj to Farakka)	(a) Velocity and discharge intensity (q) distribution across the length and width of the river in the study reach. (b) Identification of vulnerable locations based on simulated discharge intensity at flow cells.	2D Design velocity and Design discharge intensity (q)	Total No of Cells=5,91,162 Flow Area Cell Size=50mx50m
M3	2D HD Model (Farakka to Hardinge Bridge)			Total No of Cells=6,01,955 Flow Area Cell Size=50mx50m
M4	M2 with Spurs & Sakri Gali channel: 2D HD Model (Sahibganj to Farakka)		(a) Planning of mitigation measures (spurs, dykes) such as their no., lengths, and locations, (b) Design velocity and discharge intensity around spurs/dykes	Cell Size: 100 m x 100 m Total No. of Cells: 4,07,957
M5	2D ST Model (Sahibganj to Rajmahal)-	To understand sustainability of Sakri Gali paleo channel so as to examine longevity of activated paleo channel and also to understand it doesn't get choked with sediment and becomes inactive. For this model M4 with sediment	Sustainability assessments of pilot channels/dredging measures	

		transport function enabled has been simulated.		

5.1 General Methodology

The HEC-RAS (Hydrologic Engineering Center's River Analysis System) models are widely used for hydraulic modeling and simulation of river systems. The general methodology for using 1D and 2D HEC-RAS models involves several key steps, which differ slightly depending on using a one-dimensional (1D) or two-dimensional (2D) approach. The 1D HEC-RAS model focuses on representing the river system with cross-sectional profiles and simulates flow in a single direction along the channel. The 2D HEC-RAS model uses a grid-based approach to simulate flow in both horizontal directions, capturing more detailed spatial variability in floodplain areas. Both methodologies involve data collection, model setup, boundary condition specification, flow simulation, calibration, validation, analysis, and reporting. The choice between 1D and 2D modelling depends on the complexity of the river system and the specific objectives of the study.



5.2 Data Collection and Preparation

Table 3: Input Data for Mathematical Modelling

Sl No	Data Type	Brief details	Source	Application
1	Topographical and Bathymetric Survey Data	Cross-section surveys carried out in a length of about 83 km upstream of Farakka barrage which includes about 68km in West Bengal and 15 km in Bihar. Similarly, cross-section survey of river Fulhar (Mahananda) in about 22.50 km length from confluence point with river Ganga. Cross-section survey of river Ganga downstream of Farakka barrage carried out in a length of about 20 km up to Nimtita. Beyond Nimtita, river Ganga enters into Bangladesh and the survey along the right bank carried out for the portion accessible from India in two stretches. Cross- section survey covers bathymetric survey in river by boat and chaurs, river banks and ground surface by topography survey	River Cross sections are on actual surveyed line from bank to bank including embankments and high ground (road, highway) at intervals of about 500/ 300m. Further, the surveyed cross sections are extended to the left and right bank by rectifying the actual cross-section with SRTM DEM 30m. From Nimtita to Hardinge Bridge due to non-availability of actual river cross sections, they were generated using SRTM 30m after datum correction and terrain modification features in HEC RAS model. Remote Sensing Imagery of March' 2024 was considered for deepest	Mapping of bank-line, thalweg line, river bed line, existing embankment details, mathematical modelling

			channel/ thalweg alignment.	
2	Observed Hydrological data (Gauge Discharge & Sediment) of HO Stations	**Ganga-Azmabad(CWC)** • Daily Water Level & Discharge from 1980 to 2021 • Daily Sediment from 1993 to 2019 **Kosi-Kursela(CWC)** • Daily Water Level from 2006-2021 • Daily Discharge data from 2020-2023 **Ganga-Sahibganj(CWC)** • Daily Water Level from 1993 to 2021 **Ganga-Ramayanpur(BH)** • Daily Water Level from 2018 to 2023 **Mahananda-Labha(CWC)** • Water Level & Discharge from 1980 to 2021 **Ganga-Rajmahal(CWC)** • Water Level from 1980 to 2022 **Ganga-Manikchak(WB)** • Water Level (Seasonal) from 2007 to 2022 **Ganga-Farakka HR(FBP)** • Water Level & Discharge from 1980 to 2021 **Ganga-Farakka –DS (CWC)** • Water Level & Discharge from 1980 to 2021 • Sediment from 1995 to 2022 **Ganga-Nimtita(WB)** • Water Level (Seasonal) from 2010 to 2022	From different organisations like CWC, State of West Bengal, Farakka Barrage Project	Mathematical Modelling. These hydrological data were prepared in daily time series format and plotted in graphs. Outliers, consistency, completeness, quality etc were checked. Then data were prepared in model input formats.

		Ganga-Farakka Pond Level(FBP) • Water Level from 2003 to 2005 & 2007 to 2023 **Ganga –Nurpur (WB)** • Water Level (Seasonal) from 2017 to 2022 **Ganga -Geria(WB)** • Water Level (Seasonal) from 2017 to 2022 **Padma Rajshahi (Literature Review)** • Water Level 2017,2019,2020, 2022 and 2023		
3	Gate operation Data	• 1997 Rising and Falling flood gate operation charts • 2007 Rising and Falling flood gate operation charts • 2021 Gate Operation Schedule Draft report of Farakka barrage operation schedule prepared by Central Water & Power Research Station (CWPRS)	From Farakka Barrage Project / Central Water & Power Research Station	Mathematical Modelling
4.	Existing river bank protection works executed in the last ten years in the study reach		From State Government of West Bengal & Bihar ,Farakka Barrage Project	These works comprised of flood embankments, bank revetments by sand bag/ stone/ gabion pitching, porcupine etc
5.	Satellite Images	Landsat I Images	Downloaded from ESRI's Earth Explorer website	Estimate bank shifting and understand river dynamics

Flood Frequency Analysis has been carried out for assessing the probability of encountering a specific discharge in a river, especially during peak discharge events and corresponding to a particular return period. Three commonly used statistical methods in flood frequency analysis are Gumbel's Extreme Value Distribution, Log Pearson Type III Distribution and Log Normal Distribution. These three methods have been used in this study. The D-INDEX method is employed to compare the relative fit of distributions to hydrological data. The distribution with the lowest D-index is seen as the best fit. Design discharge as established based on Flood Frequency Analysis of long term annual maximum discharge observed at D/S of Farakka, Labha and Sahibganj (estimated discharge) is given below.

Table 4: Flood Frequency Analysis

G&D Station	Flood Value for 50 year Return Period (m^3/s)	Flood Value for 100 year Return Period (m^3/s)
Sahibganj	70596	76305
Labha	6523	7259
Farakka Barrage D/S	77119	83554

The details of the type of model, boundary conditions, flow simulations are given below.

5.3 Model Configuration, Calibration & Validation

5.3.1 1D HD Model (Sahibganj to Hardinge Bridge)-M1

The model includes the stretch from Sahibganj to Hardinge Bridge, incorporating the Farakka Barrage and Fulhar (Mahananda) River from Labha HO Site. The model developed predicts Water Level and Discharge at different locations/ cross- sections in the study reach for given design discharge. This would also provide the input boundary conditions for 2D modelling. Depending on the Hydrological Data (GD) at various sites of CWC, I&WD West Bengal and WRD Bihar as available and detailed above, the boundary conditions has been decided as under:-

- Design Discharge from Flood Frequency Analysis
- Discharge Hydrograph at Sahibganj (river Ganga) and Labha (river Fulhar (Mahananda)) was used as U/S Boundary Condition
- Rating Curve at Hardinge Bridge as the downstream boundary condition
- Farakka Barrage is included as an inline structure in the 1D model. The gate operation schedule has been adopted w.r.t upstream water level to maintain the pond level at 22m. When pond level rises above 22m due to inflow, the gates start opening. Similarly, when inflow recede the gates start closing so that pond level does not go below 22m.
- Manning's n is considered varying from 0.018 to 0.025. The value of Manning's coefficient 'n' considered is based upon the data from literature review and field study. The value of Manning 'n' as observed in River Ganga at Azmabad site of CWC in different months is annexed at **Annexure V**.

- The model sensitivity analysis has been carried out for different Manning's value, n=0.014, n=0.016, n=0.018, n=0.020, n=0.022 and distributed n (0.014-0.025). The results for different simulations for different values of 'n' at Rajmahal and Nimtita sites are shown in Figure 7 & 8 below.

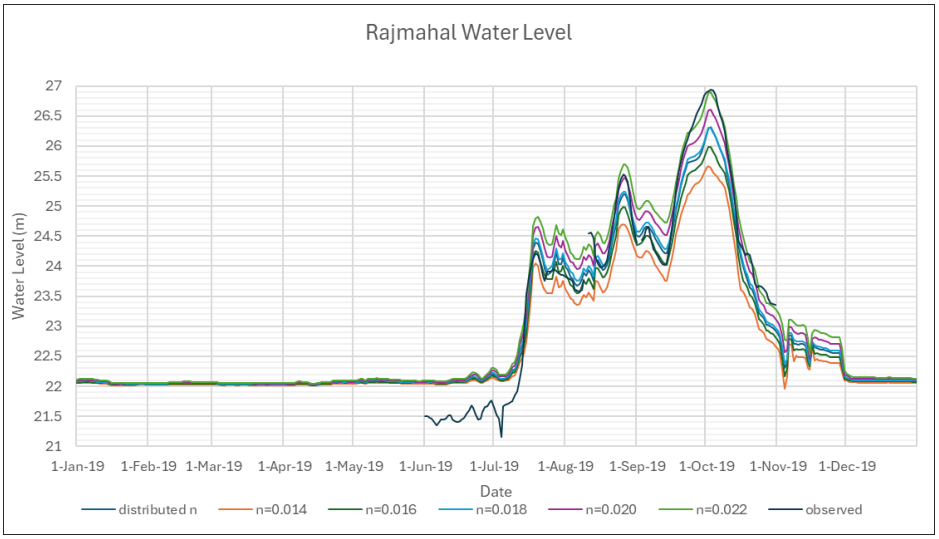


Figure 7 : Simulated water level at Rajmahal for different Manning's value

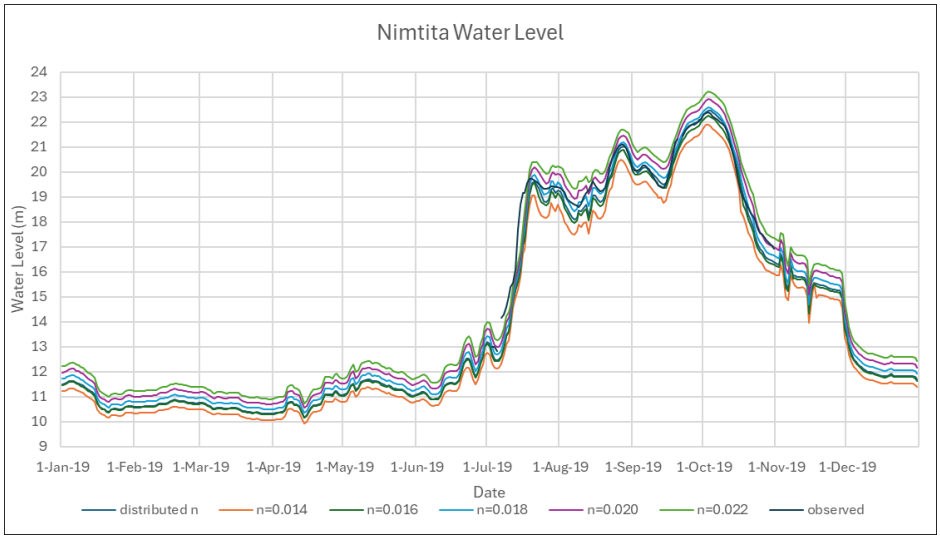


Figure 8 : Simulated water level at Nimtita for different Manning's value

It is seen from the above analysis that the simulated water level is increasing with the increasing value of Manning's 'n'. The model is well calibrated and validated with the distributed value of Manning's 'n' ranging from 0.018 to 0.025 across the width of a cross-section. Higher Manning coefficient for sand bar, flood plain area and comparatively lower values has been adopted for deep channel of the river.

The model has been calibrated with Manning's 'n' for simulated v/s observed water level at Ramayanpur, Rajmahal, Manikchak, Farakka Pond Level, Farakka Downstream, Nimtita, Nurpur and Geria sites for monsoon period (July to October) during 2018-2020 and validated for monsoon period (July to October) during 2021-2023. 1D HD Baseline simulation for 100

year and 50 year return period, 1D HD Scenario Simulation with NHAI Bridge Downstream of Farakka are run for determining HFL and LWL.

5.3.2 2D HD Model (Sahibganj to Farakka) & (Farakka to Hardinge Bridge)- M2 & M3

2D HD Models have been developed for the reaches between Sahibganj to Farakka (M2) and Farakka to Hardinge Bridge (M3) respectively. Bhutani Diara surrounded by ring bund has also been included in the 2D model domain. The models developed give an overview of the velocity and discharge intensity distribution across the length and width of the river reach. The various conditions used in the model are:-

- Discharge Hydrograph at Sahibganj and Labha (Fulhar (Mahananda)) as U/S boundary condition and the Farakka Barrage pond level stage hydrograph as the downstream boundary in M2
- Farakka downstream discharge hydrograph as U/S boundary condition and the rating curve at Hardinge Bridge as the downstream boundary in M3
- Manning's value for the cell is taken as 0.018 for the entire geometry in M2 & M3.
- The model (M2 & M3) is simulated for the period 1st July 2019 to 31st October,2019.
- Bhutani Diara surrounded by ring bund has also been included in the model domain.

The Model (M2) has been calibrated with Manning's 'n' for simulated vs observed water level at Rajmahal and the Model (M3) at Nimtita. The models have been simulated for 100 year and 50 year return period and simulated design velocity and discharge intensity extracted at critical reaches or cells. The Statistical analysis such as R^2, Root Mean Square Error (RMSE), Nash-Sutcliffe efficiency (NSE) and Percentage Bias (% bias) have been calculated for simulated and observed water level and discharge at the calibration and validation locations. The value of R and R^2 is observed to be 0.97 and 0.95 at Rajmahal and 0.95 and 0.90 at Nimtita.

5.3.3 2D HD Scenario Simulation with Spurs and Sakrigali Paleo Channel- M4 & M5

In order to identify critical reaches in the study segment and plan mitigation measures, different 2D HD scenario simulations have been carried out with fine mess size. The M2 model is modified (M4) by incorporating activated Sakri Gali paleo channel along with spurs at 12 locations and then the model M4 is simulated for 50 year & 100 year return floods at Sahibganj. In order to verify sustainability of the activated Sakri Gali paleo, the Model M4 with sediment transport function enabled (i.e., M5- 2D ST Model) is simulated. The model was simulated for about three years from Nov 2017 to Nov 2020. The model indicates that on flow diversion from the main channel into Sakri Gali activated channel (through dredging), has kept its section and has not been filled with sediment.

5.4 Results

a) For the mathematical models developed on the range of events to be modelled, to check its performance, the statistical analysis such as R^2, Root Mean Square Error (RMSE), Nash-Sutcliffe efficiency (NSE) and Percentage Bias (% bias) have been calculated for simulated and

observed water level and discharge at the calibration and validation locations. The scores have been calculated for monsoon period except at Farakka pond level and Farakka Downstream Water level and discharge in Table 5 & 6 and comparison presented in Figures 9 to 18.

Table 5: Simulated vs Observed Water Level for 1D Model

Site	R	R^2	MSE	RMSE	NSE	% bias
Ramayanpur	0.98	0.96	0.18	0.43	0.94	0.39
Rajmahal	0.97	0.93	0.11	0.33	0.98	-0.06
Manikchak	0.98	0.96	0.41	0.64	0.93	2.47
Farakka Pond Level	0.93	0.86	0.08	0.28	0.80	-0.25
Farakka Downstream	1.00	0.99	0.90	0.95	0.88	-4.63
Nimtita	0.98	0.96	0.31	0.56	0.97	-0.80
Nurpur	0.96	0.93	0.64	0.80	0.94	-2.30
Geria	0.97	0.94	0.38	0.62	0.92	-0.40
Rajshahi	0.99	0.99	0.11	0.33	0.98	0.67

Table 6: Simulated vs Observed Discharge for 1D Model

Site	R	R^2	MSE	RMSE	NSE	% bias
Farakka Downstream	1.00	1.00	1543700.84	1242.46	0.99	5.04

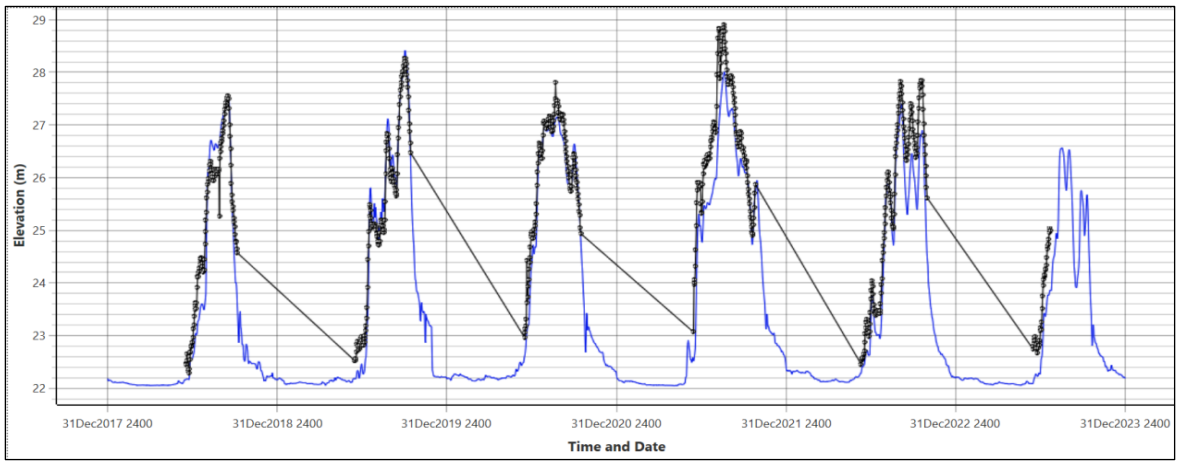


Figure 9 :Comparison of observed water level (seasonal) and simulated water level for the simulation period, 2018-2023, at Ramayanpur

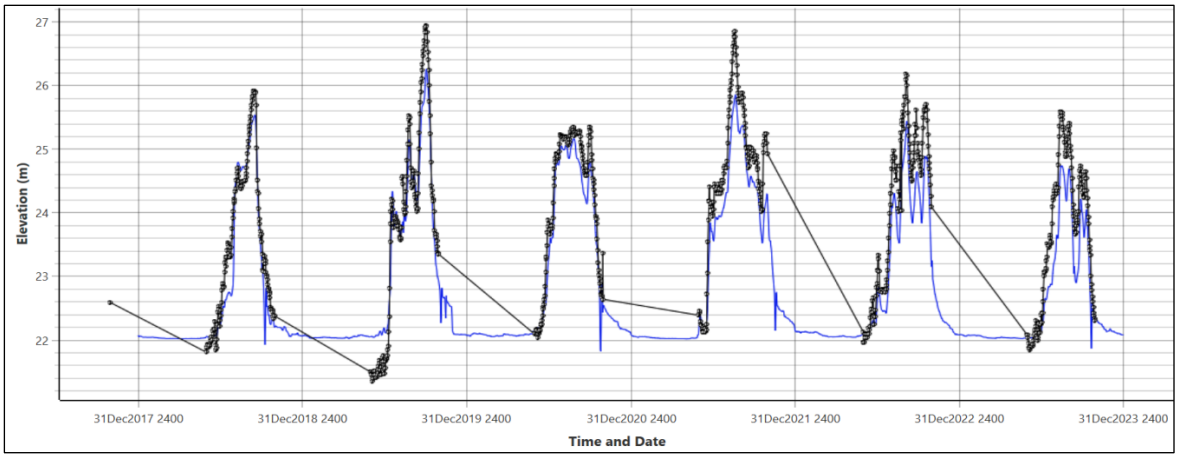


Figure 10 : Comparison of observed water level (seasonal) and simulated water level for the simulation period, 2018-2023, at Rajmahal

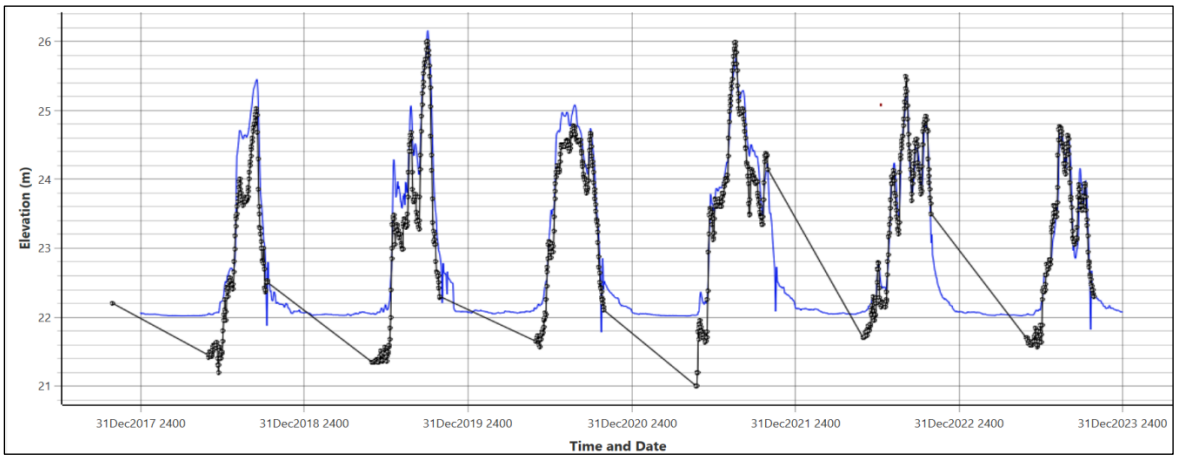


Figure 11: Comparison of observed water level (seasonal) and simulated water level for the simulation period, 2018-2023, at Manikchak

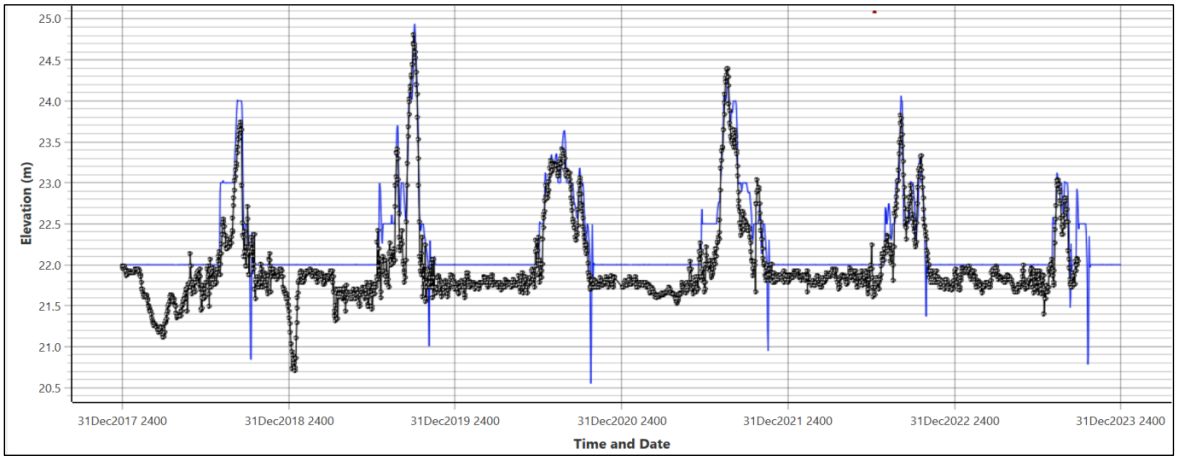


Figure 12: Comparison of observed water level and simulated water level for the simulation period, 2018-2023, at the upstream of Farakka Barrage, i.e., pond level

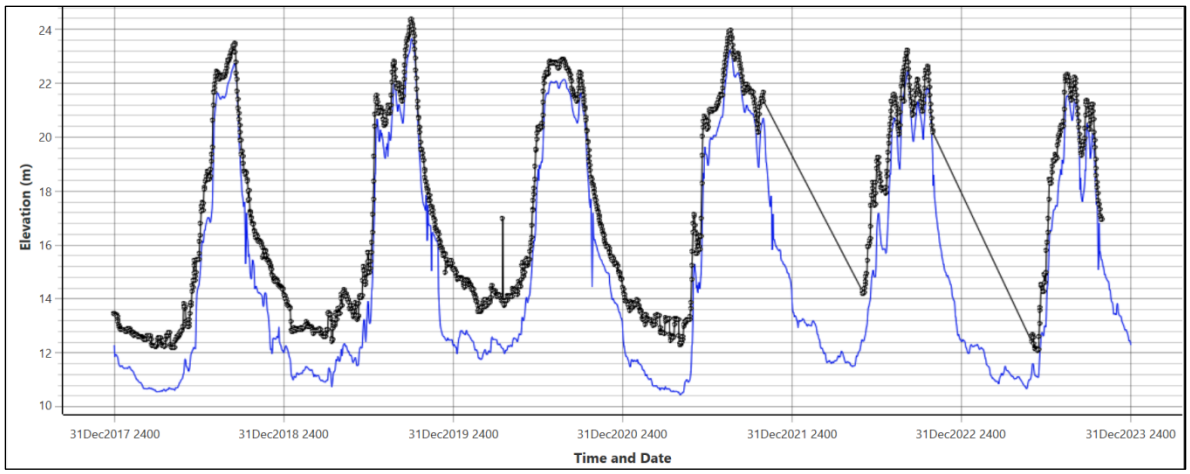


Figure 13: Comparison of observed water level and simulated water level for the simulation period, 2018-2023, at Farakka Barrage Downstream

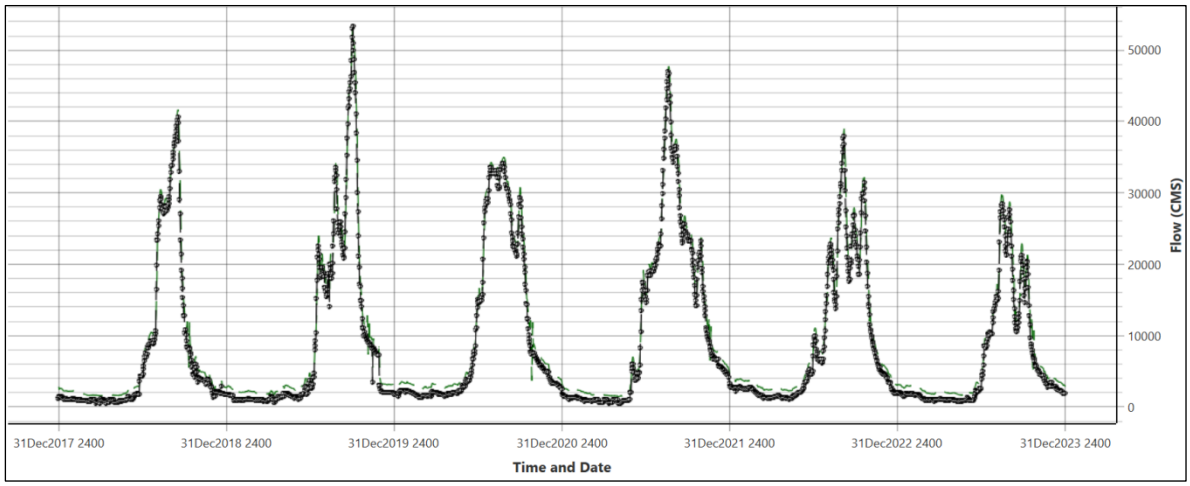


Figure 14: Comparison of observed discharge and simulated discharge for the simulation period, 2018-2023, at Farakka Barrage Downstream

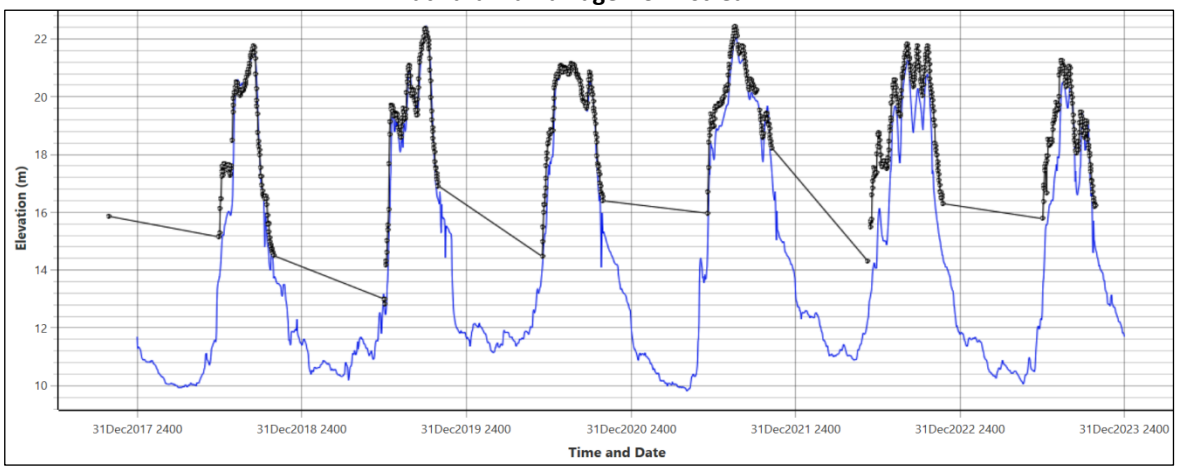


Figure 15 :Comparison of observed water level (seasonal) and simulated water level for the simulation period, 2018-2023, at Nimtita

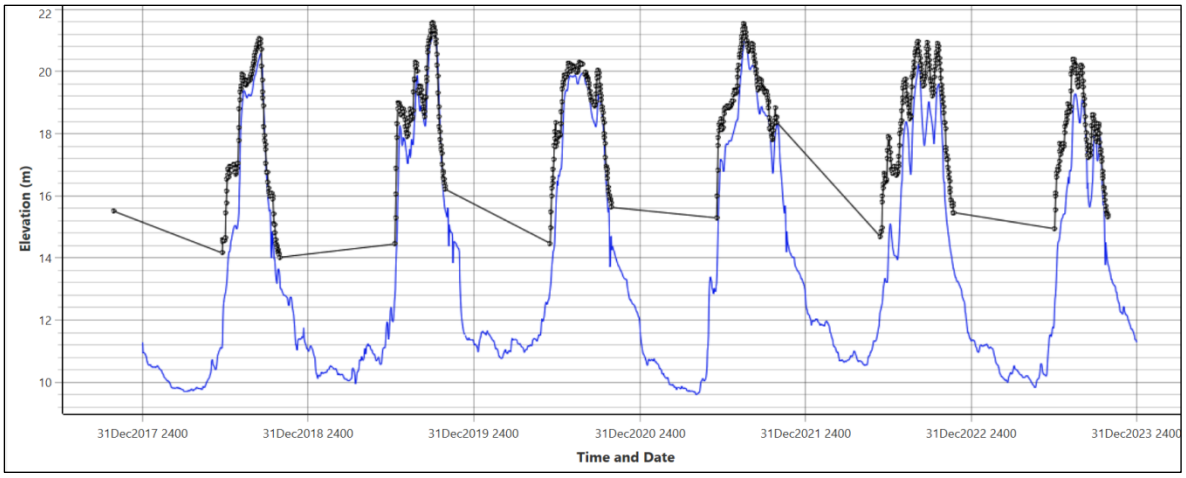


Figure 16: Comparison of observed water level and simulated water level for the simulation period, 2018-2023, at Nurpur(G)

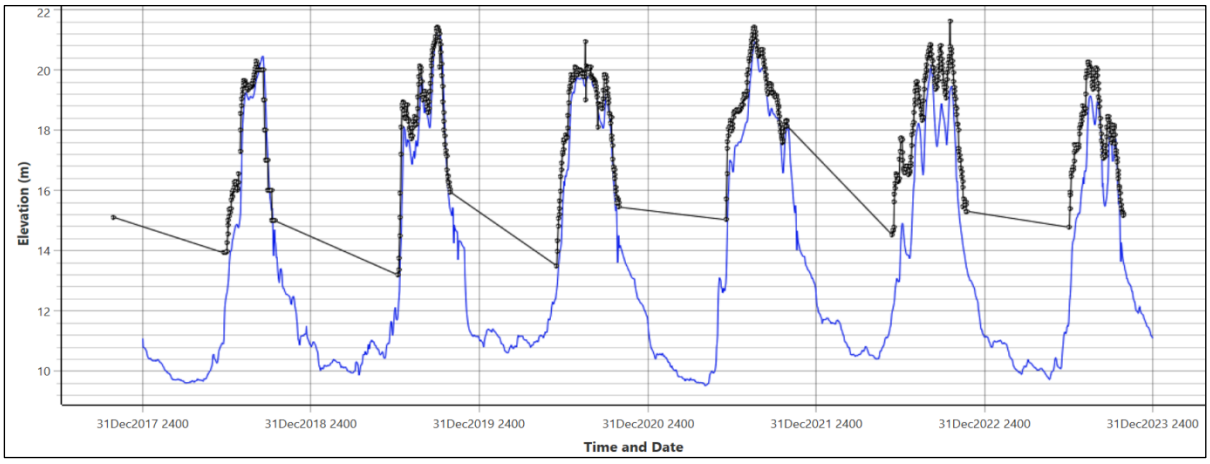


Figure 17: Comparison of observed water level (seasonal) and simulated water level for the simulation period, 2018-2020, at Geria

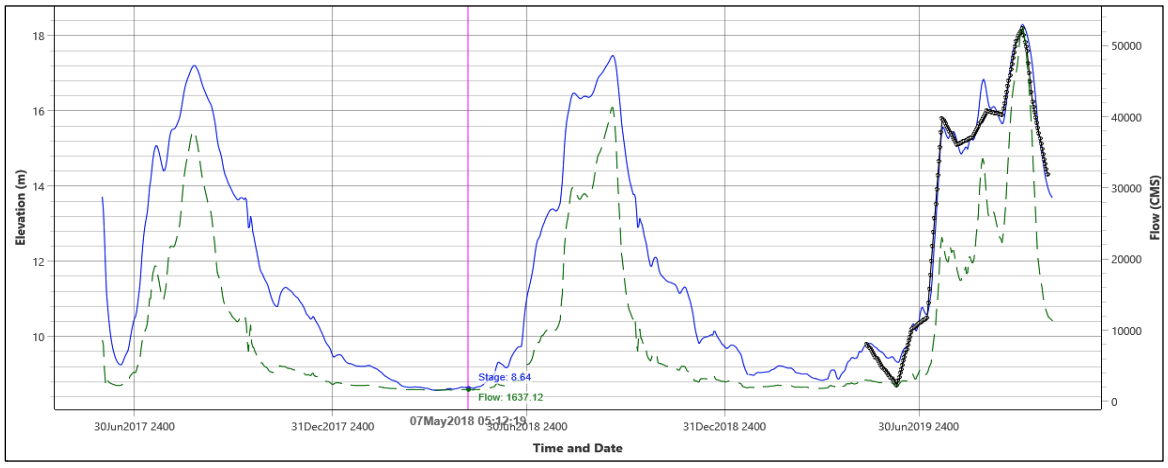


Figure 18: Comparison of observed water level (seasonal) and simulated water level for the monsoon period of 2019 at Rajshahi

Further, the results of the statistical analysis for simulated and observed water level at Rajmahal and Nimtita for M2 and M3 is given in Table 7 and Table 8.

Table 7 : Simulated vs Observed Water Level at Rajmahal

R	R^2	MSE	RMSE	NSE	% bias
0.97	0.95	0.11	0.32	0.99	-0.15

Table 8: Simulated vs Observed Water Level at Nimtita

R	R^2	MSE	RMSE	NSE	% bias
0.95	0.90	0.16	0.40	0.97	0.47

Further, comparison of results of simulated 1D and 2D model for the period 1st July 2019 to 31st Oct 2019 at different locations have also been carried out and shown in Figure 19, 20 and 21.

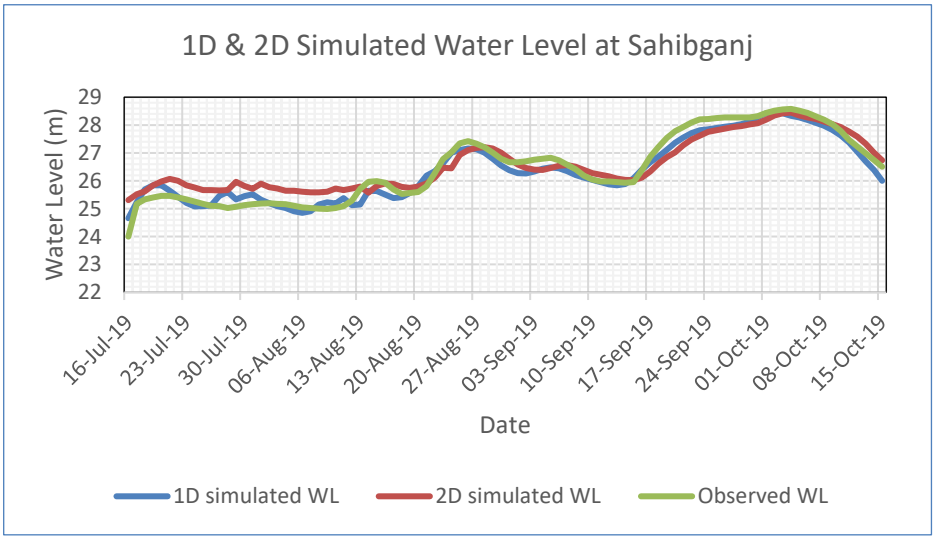


Figure 19: Comparison of 1D & 2D simulated water level at Sahibganj

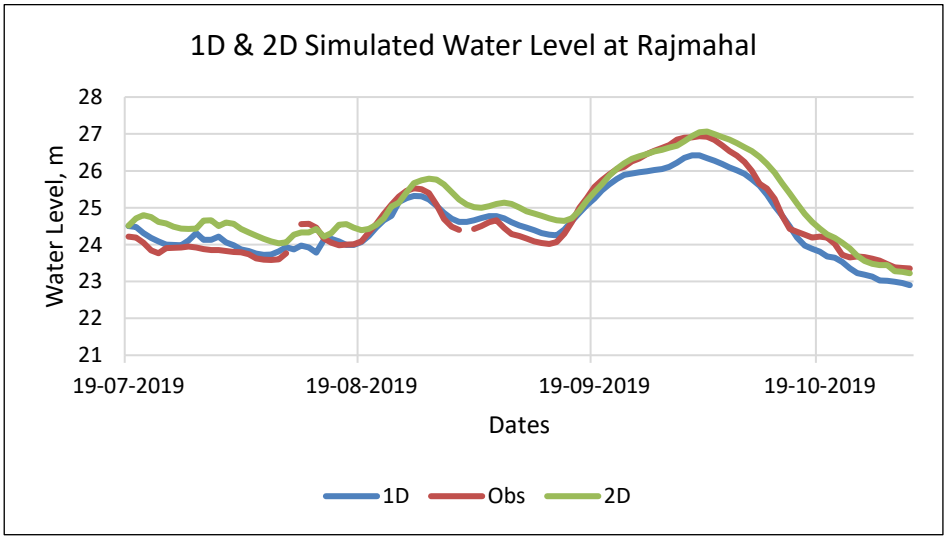


Figure 20: Comparison of 1D & 2D simulated water level at Rajmahal

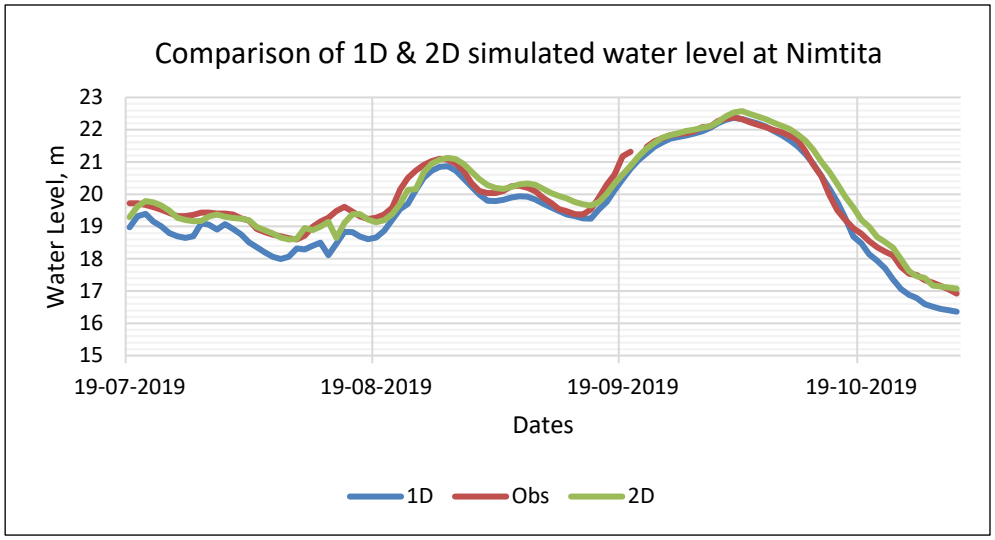


Figure 21 : Comparison of 1D & 2D simulated water level at Nimtita

It is seen from the above analysis that performance of the models are stable.

- The design HFL, LWL, velocity and discharge intensity as obtained from simulation of 1D HD and 2D HD models are key hydraulic parameters in planning of mitigation measures such as spurs, revetments etc. their number, length and location in the study. The design HFL, LWL, velocity and discharge intensity for different design discharge (reach wise) as obtained from the models are tabulated in table placed at **Annexure VI.**
- 1D HD Scenario Simulation carried out with NHAI bridge in the downstream of Farakka indicates that the simulated pond level of Farakka Barrage is about 10-12cm higher for peak discharge of 100 year return period.
- 2D HD Scenario simulation has been carried out with spurs at few locations in the study segment. The velocity profiles as obtained from the model are indicated in table placed at **Annexure VI**. The differences in velocity and discharge intensity with and without spurs can also be seen.
- From the model results, it can be inferred that the Sakri channel if activated through dredging will be an effective mitigation measure to divert flow from the current main channel of river Ganga. The activation of the channel will result in reduction of pressure on the left bank near Bhutani area. It is also expected that the water carrying capacity of the activated Sakri Gali channel will further increase with time, i.e., redistribution of flow through main river channel and Sakri Gali channel will take place.

5.5 Assumption and Limitations

There are some assumptions and limitations in the study and the same are summarised below.

- HEC RAS 2D model have been used for hydrodynamic (HD) simulations in which curvilinear flow and secondary current have not been taken into consideration.

- In the study reach, the radius of curvature is very large, for example, near Bhutani Diara, the radius of curvature is more than 8 km. Therefore, at local modelling scale, the riverbank line is almost straight (not curvilinear). As a result, the helical flow and secondary velocity will not be significant.
- Morphological simulation viz., simulation of sediment transportation process is computation intensive which requires very long simulation time and high computing machine. Stability of model is another important consideration while carrying out morphological simulation. Accordingly, morphological simulation has been carried out on limited scale in limited reaches only.
- Morphological simulation, i.e., simulation of sediment transport has been carried out at local scale and short time, say 2-3 years only especially, to understand the efficacies and sustainability of activation of old paleo channel.
- Morphological simulations for long period, say, 15-20 years to understand possible morphological changes in a large, wide and braided river like river Ganga in the study reach is not practically feasible as on date, if not impossible mathematically.
- 2D HD simulations give velocity distribution across the length and breadth of a river in base line as well as scenario simulations through the changes in velocity distribution due to physical intervention such as spurs, embankment etc. HEC RAS 2D model is quite capable for simulations of physical interventions. Accordingly, for planning and designing of anti-erosion and flood management mitigation measures, 2D hydrodynamic simulations normally serves the purpose and has been carried out.
- The discharge data at Sahibganj (upstream inflow boundary) has been used for validation and calibration of model results. The discharges at Sahibganj are measured at daily time step. Therefore, in the calibration and validation of model, the peak flow lag time could not be analyzed in the study as the measured discharge and water level data is on daily time step, whereas the travel time between Sahibganj (upstream inflow boundary) to Farakka D/S discharge observation location is 8 hours only.
- Contribution from Kosi at Kursela has been found to be small fraction of discharge of river Ganga at Azamabad. Moreover, discharge data of Kosi at Kursela is available from 2020-2023 only. Accordingly, contribution of Kosi has not been considered as one of the upstream boundary condition in the models.
- Cross-section data in 1-D model for extended section i.e. Nimtita upto Hardinge Bridge (Bangladesh) has been extracted from SRTM DEM of year 2015-16 duly corrected with satellite images of March'2024, deepest channel/ thalweg alignment and river width. Efforts for permission regarding cross-section survey work in the trans-boundary reach were made but due to pending permission, use of cross-section extracted from SRTM DEM duly corrected for datum was used.
- Central Water & Power Research Station (CWPRS) Pune, had carried out physical model studies of the study reach including Farakka barrage in the past (1999). Measured velocities for different discharges at different locations from the physical model studies have also been studied vis-a-vis 2D HD numerical simulations in the

current assignment. As such, comparison of two studies (1999 physical model study and 2024 mathematic model studies) does not provide any insight of the velocity distributions pattern as the river is morphologically dynamic and it is understood that the key input data of the studies, i.e., river geometry/ bathymetry has been changed significantly over the years.

- Keeping in view availability of online data, the year 1988 is considered as the reference year and erosion/ deposition has been analysed based on the bankline that existed in 1988.

6.0 Remote Sensing Image Analysis to assess the present condition of reach

In order to conduct a thorough analysis of bank line shifting in West Bengal, relevant satellite images were obtained for digitization, primarily sourced from ESRI's Earth Explorer website. These images predominantly comprised Landsat I data captured during the dry season, specifically in March and April from year 1988-2023 except 2002, 2003 and 2012 as images with cloud cover less than 40% is not available. These images were downloaded in Geotiff format and directly imported to ArcGIS platform for digitization of river banks and associated features like sand bars. Looking at the areas prone to erosion, the left bank in the upstream and right bank in the downstream was digitized starting from upstream to downstream of the study area for multiple images and the changes in riverbank lines measured. The erosion prone areas and chars/ islands were identified. For the purpose of study, the entire reach is divided into 5 zones:-

U/S of Farakka

- Reach 1 – Ratua I Reach (From 15km upstream of Bihar-West Bengal Border to confluence of river Fulhar (Mahananda) with river Ganga)
- Reach 2 – Manikchak-Kaliachak Reach (From confluence of river Fulhar (Mahananda) with river Ganga to Farakka Barrage)

D/S of Farakka

- Reach 3 – Dhulian Reach (From Farakka Barrage to Nimtita)
- Reach 4 – Lalgola Reach (D/S of Nimtita)
- Reach 5 – Bhagwangola Reach (D/S of Lalgola)

The year 1988 is considered as the reference year and erosion/ deposition has been analysed based on the bank-line that existed in 1988. The results obtained are as under:-

- In reach-I i.e from 15km upstream of Bihar-West Bengal Border to confluence of river Fulhar (Mahananda) with river Ganga, the river has shifted towards the left about 3.9km between chainage 48,900m to 57,400m upstream of Farakka Barrage that caused erosion in West Bengal resulting in loss of agricultural land. In Bihar, between chainage 61,400m to 64,000m U/S of Farakka Barrage, the river shifted 4.2Km towards the right.

- In reach-II i.e Manikchak-Kaliachak Reach (From confluence of river Fulhar (Mahananda) with river Ganga to Farakka Barrage), the river has shifted towards the left about 2.3km between chainage 17,000m to 26,500m upstream (U/S) of Farakka Barrage. However, deposition is observed between the chainage 5,000m to 17,000m due to the river shifting towards right.
- In reach-III i.e In Dhulian Reach (From Farakka Barrage to Nimtita), bank was almost stable just below Farakka Barrage, while significant shifting occurred between chainage 8,000m to 23,000m downstream (D/S) of the barrage, predominantly leading to erosion.
- In reach IV i.e Lalgola (D/S of Nimtita) and reach V i.e Bhagwangola, deposition was primarily observed, indicating the river's movement away from the West Bengal border and towards Bangladesh.
- The chainage/reach wise observed Deposition/ Erosion area as identified from the satellite images U/S and D/S of Farakka in the study are as follows.

Table 9: Erosion Area (1988-2023)

Erosion Area			
Sl. No.	**Name**	**Chainage (m) Ch 0 is Farakka**	**Area (sq. km)**
1	Ratua I Reach	42,924 – 77,442	61.43
2	Manikchak Kaliachak Reach	20,950 – 40,957	26.90
3	Manikchak Kaliachak Reach	6,221 – 20,950	4.00
4	Dhulian Reach	500 – 6,221	2.13
5	Lalgola	14,516 – 20,177	2.38
6	Bhagwangola	52,225 – 61,195	5.59
		Total	**102.44**

Table 10 : Deposition Area (1988-2023)

Deposition Area			
Sl. No.	**Reach Name**	**Chainage (m) Ch 0 is Farakka**	**Area (sq. km)**
1	Ratua I Reach	77,442 – 83,714	18.96
2	Manikchak Kaliachak Reach	6,221 – 21,436	24.98
3	Dhulian Reach	4,979 – 14,976	2.29
4	Nimtita	19,592 – 24,103	1.40
5	Lalgola	42,246 – 52,225	44.76
6	Bhagwangola	85,523 – 95,922	31.72
		Total	**124.11**

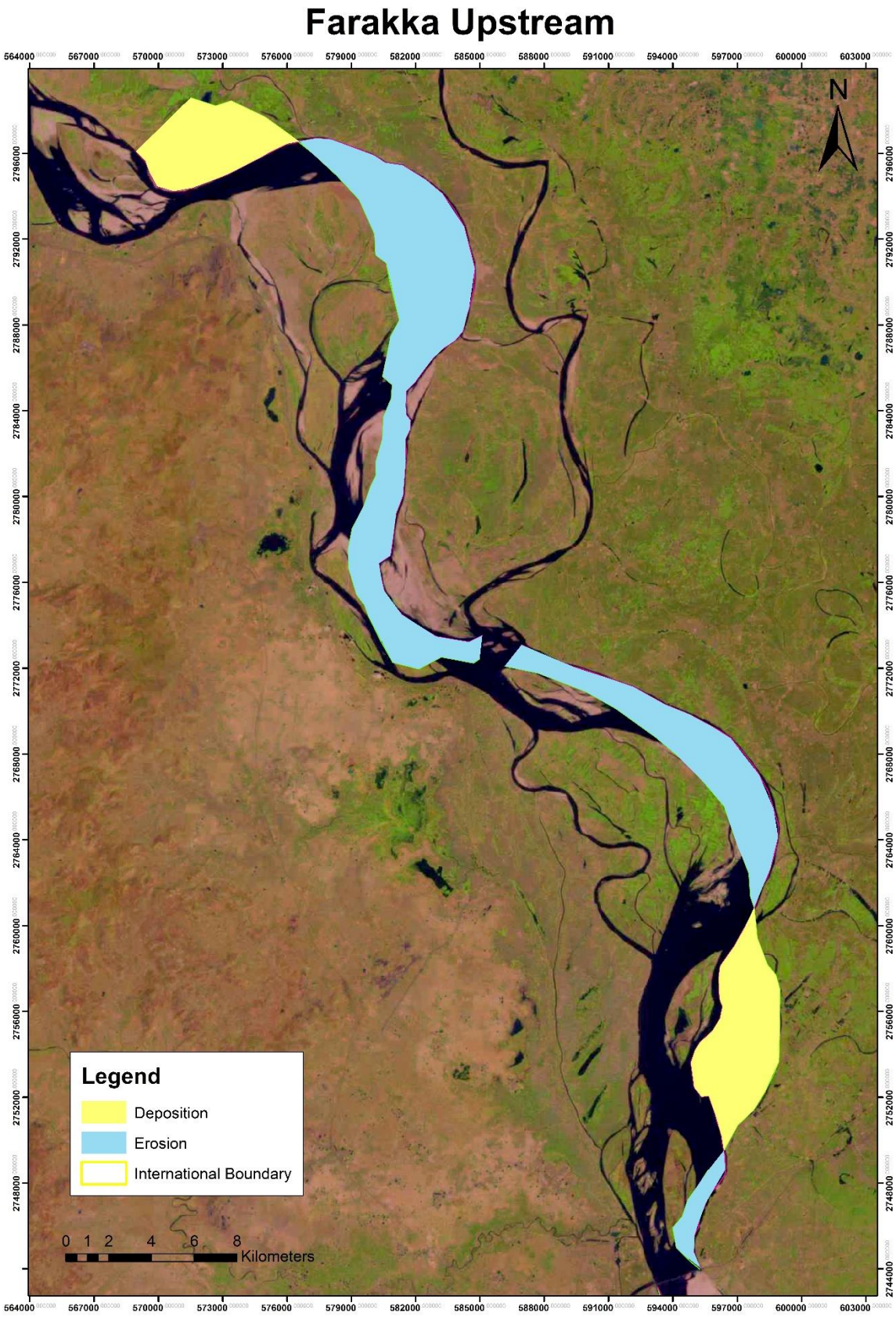


Plate 10: Erosion and Deposition observed in Ratua-I and Manikchak Kaliachak Reach (U/S of Farakka)

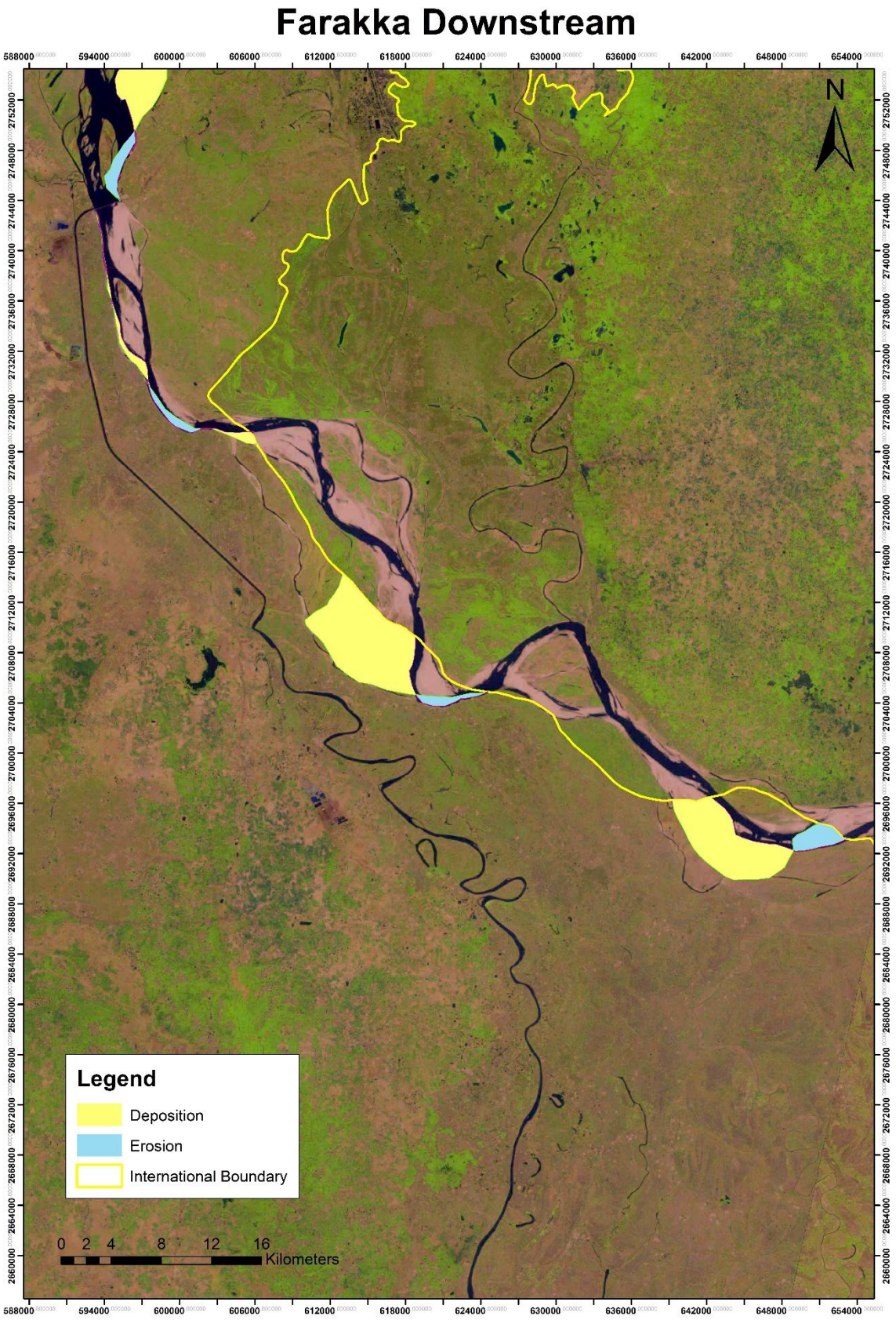


Plate 11: Erosion and Deposition observed in Dhulian, Lalgola and Bhagwangola Reach (D/S of Farakka)

7.0 Identification of Critical Reaches for Planning and Design of Riverbank Anti-Erosion Measures and Training Works

Based on the findings of the mathematical model set-up, the river migration studies carried out using remote sensing, the site characteristics and field visits, critical reaches/ locations have been identified.

- In Ratua-I reach (from 15km upstream of Bihar-West Bengal Border to confluence of river Fulhar (Mahananda) with river Ganga) continuous shifting of the river towards left bank has been observed. The thalweg is also observed to be near the left bank. Hence, this is identified as the most vulnerable reach.
- In Manikchak-Kaliachak Reach (From confluence of river Fulhar (Mahananda) with river Ganga to Farakka Barrage), bank erosion is the major issue on the left bank. The top level of existing embankment along the left bank is below the HFL in the reach (Ch 4,000-6,000; 25,500-26,500 and 34,500-36,000) i.e. near village Palgachhi, Khaskol Chandipur and Manikchand respectively. Along the right bank (in Jharkhand) it is vulnerable to erosion due to high stream velocity.
- In the area near the Dhulian town along both the left and right banks, erosion is observed. Most of the river reach from Dhulian town to Nimtita, had undergone erosion during the flood season 2022. The river bank is made up of sand, silt and clay in different proportions. Higher flow velocities and pulsating flows resulted in toe erosion and consequent sluffing and sliding of the bank. The excessive height of the bank (8m above LWL), may destabilize the river bank.
- Severe bank erosions have been observed in the right bank of river Ganga starting from downstream of Farakka barrage up to Nimtita due to concentration of flow along the right bank on account of char formation in the downstream of Farakka barrage along left bank. The river bank in Nimtita near Bangladesh border is mostly made of alluvial type soil with moderate clay contents. The free-standing soil slope looks steeper than the bank slopes observed in the upstream reach. Most of the bank is unprotected making it highly vulnerable to erosion during floods. Only some emergency works, executed during floods made by sandbags were observed at few locations. The right bank of the river is protected by revetment and six spurs laid up to the border.

The reach wise site characteristics at these locations is summarised in Table 11 below.

Table 11: Site characteristics U/S & D/S of Farakka

River Stretch	Approximate Chainage (m) U/S of Farakka Barrage	Riverbank Side	Nearest Village	Bankline shifting in last 10 years, m	Riverbank Plan Form	Riverbank Slope upto thalweg, %	Distance of thalweg line from riverbank, m	Country Side Land Use/Builtup Area
Ratua-I Stretch	81,470	Left	Sakari Galiurf Kala Diara	467 right	Straight	1.9	649.0	Agriculture land
	80,732	Left	Sakari Galiurf Kala Diara	450 right	Straight	1.9	820.8	Agriculture land
	80,080	Left	Sakari Galiurf Kala Diara	307 right	Straight	2.1	699.8	Agriculture land
	79,272	Left	Untmari	957 right	Concave	1.8	661.0	Agriculture Land
	78,437	Left	Untmari	1,212 right	Concave	0.9	1066.0	Agriculture Land
	77,442	Left	Nandgaon Kala Diara	785 right	Concave	1.0	1008.0	Agriculture Land
	76,742	Left	South Karimullapur	304 right	Concave	0.8	1485.0	Village
	76,003	Left	Pardiara	147 left	Concave	4.8	220.0	Village
	75,177	Left	Pardiara	369 left	Concave	2.5	581.0	Village
	74,280	Left	Ahmedabad	676 Left	Concave	4.0	560.0	Village
	73,318	Left	Ahmedabad	878 left	Concave	9.1	201.0	Village
	72,371	Left	Bhawanipur Khatti	1,802 left	Concave	5.3	370.0	Village
	71,528	Left	Bhawanipur Khatti	2,282 left	Concave	6.8	292.0	Village
	69,788	Left	Kataha	2,373 left	Concave	0.5	2697.0	Agriculture land
	69,198	Left	Kataha	2,448 left	Concave	4.4	270.1	Agriculture land
	68,631	Left	Kataha	2,441 left	Concave	4.3	300.0	Agriculture land
	68,150	Left	Gadai Maharajpur	2,479 left	Concave	5.6	260.2	Agriculture land

	67,563	Left	Gadai Maharajpur	2,533 left	Concave	14.2	100.0	Agriculture land
	66,986	Left	Maniknagar	2,653 left	Concave	9.1	174.1	Agriculture land
	66,367	Left	Maniknagar	2,565 left	Concave	11.9	130.2	Agriculture land
	65,690	Left	Gadai Maharajpur	2,494 left	Concave	11.2	110.2	Agriculture land
	65,195	Left	Gadai Maharajpur	2,452 left	Concave	9.8	126.4	Agriculture land
	64,562	Left	Gadai Maharajpur	2,312 left	Concave	0.7	3496.0	Agriculture land
	63,911	Left	Gadai Maharajpur	2,038 left	Concave	0.4	2420.0	Agriculture land
	63,058	Left	Paschim ratanpur	1,605 left	Concave	0.3	3845.0	Agriculture land
	62,187	Left	Paschim ratanpur	56.5 left	Concave	0.8	1409.7	Agriculture land
	61,561	Left	Bhubantola	63 left	Concave	1.0	1339.9	Agriculture land
	60,913	Left	Bhubantola	260 right	Concave	1.5	824.0	Agriculture land
	60,282	Left	Naobarar Jaigir	555 right	Concave	1.8	702.0	Agriculture land
	59,681	Left	Naobarar Jaigir	766 right	Concave	6.0	275.8	Agriculture land
	59,070	Left	Naobarar Jaigir	850 right	Concave	4.0	275.5	Agriculture land
	58,482	Left	Katihar	571 right	Concave	0.6	1893.3	Agriculture land
	57,822	Left	Harachandapur	88 right	Concave	1.1	1281.5	River bank builtup area
	57,183	Left	Harachandapur	196 left	Concave	26.3	961.0	River bank builtup area
	56,665	Left	Harachandapur	180 left	Straight	1.9	685.0	Agriculture land
	56,141	Left	Harachandapur	250 left	Concave	5.8	209.6	Agriculture land
	55,636	Left	Kesarpur	272 left	Straight	4.1	420.0	Agriculture land
	55,114	Left	Bagdukra	218 left	Straight	5.7	261.0	Agriculture land
	54,568	Left	Bagdukra	266 left	Straight	4.8	366.0	Agriculture land
	54,001	Left	West Chandipur	554 left	Concave	6.3	296.0	Agriculture land

	53,420	Left	Chandipur tafir	830 left	Concave	3.7	506.5	Agriculture land
	52,848	Left	Balutola	503 left	Concave	4.2	449.3	Agriculture land
	52,507	Left	Balutola	325 left	Concave	4.3	449.3	Agriculture land
	52,158	Left	Chandipur	106.2 Left	Concave	1.0	820.4	Riverbank builtup area
	51,821	Left	Chandipur	60.9 Right	Concave	1.8	380.2	Riverbank builtup area
	51,503	Left	Chandipur	219.2 Right	Straight	2.7	277.3	Riverbank builtup area
	51,181	Left	Chandipur	356.7 Right	Straight	3.6	326.1	Riverbank builtup area
	50,826	Left	Chandipur	550.1 Right	Straight	5.4	266.6	Riverbank builtup area
	50,525	Left	Chandipur	695 Right	Straight	2.2	678.5	Riverbank builtup area
	50,198	Left	Chandipur	890.9 Right	Straight	1.4	1257.7	Riverbank builtup area
	49,866	Left	Chandipur	1,658.8 Right	Straight	10.3	189.2	Riverbank builtup area
	49,538	Left	Chandipur	1,786 Right	Concave	3.8	474.8	Riverbank builtup area
	49,180	Left	Chandipur	1,894.9 Right	Concave	2.2	745.1	Riverbank builtup area
	48,841	Left	Chandipur	1,967.5 Right	Concave	4.2	363.8	Riverbank builtup area
	48,501	Left	Chandipur	2,028.3 Right	Concave	2.4	570.8	Riverbank builtup area
	48,154	Left	Chandipur	2,034.5 Right	Concave	2.7	723.6	Riverbank builtup area
	47,786	Left	Chandipur	1,999.5 Right	Concave	2.3	852.0	Riverbank builtup area
	47,434	Left	Chandipur	2,067.3 Right	Concave	3.1	734.9	Riverbank builtup area
	47,096	Left	Chandipur	2,141.8 Right	Concave	2.5	919.9	Riverbank builtup area
	46,753	Left	Chandipur	2,057.3 Right	Concave	1.9	1058.9	Riverbank builtup area
	46,439	Left	Chandipur	2,122.6 Right	Concave	2.3	838.4	Riverbank builtup area
	46,130	Left	Chandipur	2,208.2 Right	Concave	1.5	1175.5	Riverbank builtup area
	45,790	Left	Chandipur	2,234.9 Right	Concave	1.2	1315.2	Riverbank builtup area

	45,448	Left	Chandipur	2,280.7 Right	Concave	1.5	1111.0	Riverbank builtup area
	45,127	Left	Chandipur	2,310.3 Right	Concave	1.8	897.8	Riverbank builtup area
	44,566	Left	Jankiramtala	2,195.6 Right	Concave	1.2	1612.0	Riverbank builtup area
	44,093	Left	Jankiramtala	1,943.4 Right	Concave	0.7	1213.7	Riverbank builtup area
	43,505	Left	Jankiramtala	1,334.6 Right	Concave	5.7	259.2	Riverbank builtup area
Manikchak Kaliachak	42,904	Left	Jankiramtala	1,300 Left	Concave	6.6	274.0	Agricuture Land
	42,285	Left	Jankiramtala	1,400 Left	Concave	1.1	1206.0	AgricutureLand
	41,626	Left	Narayanpur	600 Left	Concave	0.8	1827.0	Agricuture Land
	40,957	Left	Narayanpur	1,000 Left	Concave	3.2	427.0	AgricutureLand
	40,210	Left	Narayanpur	628.4 Left	Straight	7.1	265.1	Agricuture Land
	39,725	Left	Narayanpur	182.8 Left	Straight	13.3	184.2	Builtup Area
	39,186	Left	Narayanpur	33 Left	Straight	9.0	223.0	Builtup Area
	38,659	Left	Manikchak	86.9 Right	Straight	13.9	143.0	Riverbank Builtup Area
	38,206	Left	Manikchank	73.1 Right	Straight	5.7	210.7	Agricutural Land
	37,679	Left	Manikchak	27.1 Right	Straight	3.9	387.5	Agricutural Land
	37,224	Left	Manikchak	5.6 Left	Straight	3.7	390.7	Agricutural Land
	36,675	Left	Manikchak	25.8 Left	Straight	2.6	521.7	Agricutural Land
	36,078	Left	Manikchak	48.6 Left	Straight	8.7	176.4	Agricutural Land
	35,642	Left	Manikchak	50.3 Left	Straight	4.7	314.4	Builtup Area
	35,126	Left	Manikchak	56.9 Left	Straight	2.9	550.5	Agricuture Land
	34,565	Left	Manikchad	34.6 Right	Straight	1.3	1028.5	Agricuture Land
	33,986	Left	Manikchak	115.1 Right	Straight	1.5	1010.3	Agricuture Land
	33,386	Left	Manikchak	83.9 Right	Straight	1.5	990.7	Agricuture Land

	32,756	Left	Khanpur	57.8 Left	Straight	1.6	910.4	Agricuture Land
	32,085	Left	Khanpur	161.4 Left	Straight	1.5	836.7	Riverbank builtup area
	31,218	Left	Khanpur	307.2 Left	Straight	3.9	368.2	Riverbank builtup area
	30,419	Left	Gopalpur	492 left	Concave	9.7	207.0	Agriculture land
	29,716	Left	Gopalpur	700 left	Concave	5.8	288.0	Agriculture land
	29,076	Left	Gopalpur	878 left	Concave	9.0	192.0	Agriculture land
	28,340	Left	Gopalpur	1,050 left	Concave	8.3	207.0	Agriculture land
	27,638	Left	Gopalpur	1,263 left	Concave	4.7	289.0	Agriculture land
	26,918	Left	Gopalpur	1,637 left	Concave	2.0	595.0	Agriculture land
	26,077	Left	Khaskol Chandipur	2,118 left	Concave	1.9	544.0	Flood plan/Builtup Area
	25,291	Left	Khaskol Chandipur	2,549 left	Concave	1.0	920.0	Flood plan/Builtup Area
	24,469	Left	Khaskol Chandipur	2,743 left	Concave	0.8	1481.0	Flood plan /Builtup Area
	23,797	Left	Majhia Saran	2,751 left	Concave	1.3	741.0	Flood plan /Builtup Area
	23,098	Left	Jotkasturi	2,694 left	Concave	1.3	951.0	Ghat/Builtup Area
	22,497	Left	Bindu Road,Jotkasturi	2,522 left	Concave	5.7	288.0	Riverbank Builtup Area
	21,931	Left	Shukurullapur	2,356 left	Concave	14.4	131.0	Riverbank Builtup Area
	21,436	Left	Panchanandapur	2,254 left	Concave	4.5	368.0	Riverbank Builtup Area
	20,950	Left	Panchanandapur	2,137 left	Concave	5.7	302.0	Riverbank Builtup Area
	20,447	Left	Panchanandapur	1,994 left	Concave	3.7	399.0	Agriculture land
	19,860	Left	Panchanandapur	1,533 left	Concave	2.1	461.0	Agriculture land
	18,862	Left	Panchanandapur	1,547 left	Concave	1.0	952.0	Agriculture land
	17,925	Right	Panchanandapur	1,271 lleft	Concave	5.8	207.0	Agriculture land
	17,056	Right	Panchanandapur	1,025 left	Concave	9.5	228.0	Agriculture land

	16,156	Right	Panchanandapur	528 left	Convex	7.1	306.0	Agriculture land
	15,568	Right	Panchanandapur	273 left	Convex	7.3	368.0	Agricultureland
	15,015	Right	Kaliachak	245 left	Convex	7.2	332.0	Agriculture land
	14,495	Right	Kaliachak	537 left	Convex	8.8	293.0	Agriculture land/Builtup Area
	14,001	Right	Kaliachak	678 left	Concave	9.4	247.0	Agriculture land /Builtup Area
	13,497	Right	Kaliachak	518 left	Concave	11.3	272.0	Builtup Area/Agriculture land
	12,993	Right	Kaliachak	0	Concave	6.8	363.0	Builtup Area/Agricultureland
	12,483	Right	Kaliachak	413 Right	Convex	8.3	232.0	Riverbank builtup area
	11,967	Right	Kaliachak	649 Right	Convex	6.5	302.0	Riverbank builtup area
	11,407	Right	Kaliachak	457 Right	Convex	3.6	516.0	Riverbank builtup area
	10,817	Right	Kaliachak	0	Convex	5.3	350.0	Riverbank builtup area
	10,259	Right	Kaliachak	144 left	Convex	3.6	513.0	Riverbank builtup area
	9,656	Right	Kaliachak	557 left	Concave	1.7	947.0	Riverbank builtup area
	9,012	Left	Kaliachak	473 left	Concave	1.2	1039.0	Riverbank builtup area
	8,045	Left	Kaliachak	326 left	Concave	0.7	1660.0	Riverbank builtup area
	7,276	Left	Kaliachak	218 left	Concave	12.4	160.0	Riverbank builtup area
	6,743	Left	Sultanganj Palgachhi	186 left	Concave	10.0	161.0	Riverbank builtup area
	6,221	Left	Palgachhi	264 left	Concave	5.4	229.0	Riverbank builtup area
	5,682	Left	Palgachhi	235 left	Concave	9.1	164.0	Riverbank Builtup Area
	5,166	Left	Palgachhi	295 left	Concave	5.5	234.0	Riverbank Builtup Area
	4,572	Left	Palgachhi	98 left	Concave	10.6	231.0	Riverbank builtup area
	3,992	Left	Palgachhi	91 Right	Convex	13.7	212.0	Riverbank Builtup Area

	3,423	Left	Jagannathpur	100 Right	Convex	27.2	110.0	Riverbank Builtup Area
	2,791	Left	Jagannathpur Baishnabnagar,	112 Right	Convex	5.0	328.0	Riverbank Builtup Area
	2,176	Left	Jagannathpur Baishnabnagar,	115 Right	Convex	5.3	449.0	Riverbank Builtup Area
	1,574	Left	Jagannathpur Baishnabnagar,	175 Right	Convex	10.6	244.0	Guide Bund

Downstream of Farakka

River Stretch	Approximate Chainage (m) D/S of Farakka Barrage	Riverbank Side	Nearest Village	Bankline shifting in last 10 years, m	Riverbank Plan Form	Riverbank Slope upto thalweg, %	Distance of thalweg line from riverbank, m	Countary Side Land Use/Builtup Area
Dhulian Reach	**566**	Right	Benia Gram	885 Right	Straight	0.9	509.8	Riverbank Builtup Area
	1,051	Right	Benia Gram	1,000 Right	Straight	0.7	440	Riverbank Builtup Area
	1,591	Right	Benia Gram	1,100 Right	Straight	2.3	362.3	Riverbank Builtup Area
	2,059	Right	Benia Gram	1,100 Right	Straight	1	348.4	Riverbank Builtup Area
	2,571	Right	Benia Gram	1,300 Right	Straight	1.1	377.6	Riverbank Builtup Area
	3,061	Right	Benia Gram	1,200 Right	Straight	0.4	286.4	Riverbank Builtup Area
	3,548	Right	Benia Gram	1,100 Right	Straight	0.8	450.2	Riverbank Builtup Area
	4,019	Right	Benia Gram	950 Right	Straight	0.6	536.4	Riverbank Builtup Area
	4,505	Right	Benia Gram	600 Right	Straight	0.4	547.3	Riverbank Builtup Area
	4,979	Right	Baikunthapur	250 Right	Straight	2.2	353.3	Riverbank Builtup Area
	5,458	Left-Right	Brahmangram, Kuli	180 Right	Convex	1.2	1872	Riverbank Builtup Area
	5,978	Left-Right	Brahmangram, Kuli	120 Right	Convex	1.7	1367	Riverbank Builtup Area

6,491	Left-Right	Brahmangram, Kuli	60 Left	Convex	2.4	955.3	Riverbank Builtup Area
7,005	Left-Right	Kuli gram , Farakka	10 Left	Convex	6.1	372	Riverbank Builtup Area
7,488	Left-Right	Kuli	15 Left	Convex	5.0	452.3	Riverbank Builtup Area
8,023	Left-Right	Arjunpur	80 Left	Convex	5.9	364	Riverbank Builtup Area
8,470	Left-Right	Sibnagar	156 Left	Convex	6.2	387	Riverbank Builtup Area
8,955	Left-Right	Khodabandpur	280 Left	Convex	7.2	329.02	Agriculture land
9,532	Left-Right	Khodabandpur	190 Left	Convex	5.3	407	Riverbank Builtup Area
10,044	Left-Right	Khodabandpur	280 Left	Convex	4.3	508	Riverbank Builtup Area
10,632	Left-Right	Mahadeb Nagar,	350 Left	Convex	4.5	503	Riverbank Builtup Area
11,177	Left-Right	New Krishnapur	450 Left	Convex	6.1	387	Riverbank Builtup Area
11,867	Left-Right	Ferryghat Road	600 Left	Straight	3.7	589.2	Riverbank Builtup Area
12,457	Left-Right	Bhakti Dham Road	850 Left	Straight	3.7	581.4	Riverbank Builtup Area
13,008	Left	Lalpur, Dhulian	870 Left	Straight	6.0	374.2	Riverbank Builtup Area
13,490	Left	Lalpur, Dhulian	650 Left	Straight	3.1	696.5	Riverbank Builtup Area
14,000	Right	Dhulian,Lalupur ,Murshidabad	450 Left	Concave	8.5	300	Riverbank Builtup Area
14,516	Right	Raiganj, Lalupur	220 Left	Concave	5.5	422	Riverbank Builtup Area
14,976	Right	Samserganj	5 Left	Concave	3.9	630	Riverbank Builtup Area
15,468	Right	Tirangamore	250 Right	Concave	4.2	590	Riverbank Builtup Area
16,025	Right	Ghaneshyampur	370 Right	Concave	4.9	440	Riverbank Builtup Area
16,536	Right	Ghaneshyampur,	350 Right	Concave	4.1	500	Riverbank Builtup Area
17,006	Right	Purba Debidaspur	480 Right	Concave	5.3	450	Riverbank Builtup Area
17,504	Right	Kankuria, Anantpur	780 Right	Concave	4.9	490	Riverbank Builtup Area
18,015	Right	Shikdarpur, Nimtita	1,000 Right	Concave	4.9	480	Riverbank Builtup Area

	18,509	Right	Madrasa Ghat	1,180 Right	Concave	4.3	520	Riverbank Builtup Area
	19,060	Right	Chachanda	1,280 Right	Concave	7.1	330	Builtup area & Agriculture land
	19,592	Right	Dhusaripara,	1,360 Right	Concave	7.1	346	Builtup area & Agriculture land
	20,177	Right	Dhusaripara,	1,360 Right	Concave	5.4	480	Riverbank Builtup Area
	22,859	Right	Radha Nagar	188 Left	Convex	3.9	320.4	Riverbank Builtup Area
	24,103	Right						
	25,652	Right						
	26,983	Right						
	28,181	Right						
	29,373	Right						
	32,166	Right						
	33,616	Right						
	35,313	Right						
	36,617	Right						
	38,264	Right						
	40,412	Right						
	42,246	Right						
	43,965	Right						
	45,683	Right						
	47,271	Right						
	48,425	Right						
	49,453	Right						
Lalgola Reach	**50,620**	Right	Barashimul	6,020.5 left	Straight	3.2	288.6	Builtup area & Agriculture land
	52,225	Right	Teghari	3,533.9 left	Straight	2.5	445.2	Agriculture land
	58,228	Right	Lalgola	224.3 right	Convex	4.7	145.3	Builtup area & Agriculture land
Bangladesh	**61,195**	Right						
	66,195	Right						
	69,030	Right						
	75,005	Right						
	76,836	Right						
	78,500	Right						
	80,736	Right						
	82,636	Right						
	85,523	Right						
	87,155	Right						
Bhag	**89,064**	Right	Babupur	3,806.4 left	Concave	4.4	197.0	Agriculture land

	90,789	Right	Nashipur	3,348.1 left	Straight	0.8	1061.7	Agriculture land
	93,722	Right	Munsurpur	3,092.6 left	Straight	2.9	516.6	Agriculture land
	95,922	Right	Jazira Char Dumuria	1,595.3 right	Straight	4.5	291.4	Agriculture land
	98,977	Right	Dakshin Jajira Char Dumuria	382.7 left	Straight	3.4	173.7	Agriculture land
Bangladesh	**1,02,977**							
	1,07,277							
	1,12,078							
	1,18,771							
	1,23,617							
	1,27,188							
	1,30,072							
	1,33,993							
	1,36,399							
	1,38,395							
	1,41,918							
	1,49,966							
	1,54,326							
	1,56,928							
	1,60,345							
	1,62,446							
	1,71,103							
	1,73,406							
	1,74,773							

indicates region in Bangladesh

8.0 Gate Operation Schedule

Farakka Barrage is 2245m long with 109 bays of width 18.3m each. Out of the 109 bays there are 3 silt excluder bays, 21 under sluice bays, 1 fish lock bay and 84 spillway bays. Barrage bays are numbered from right to left bank. The feeder canal head regulator is located on the right bank. The design discharge of the feeder canal is 1,132m^3/s. The design pond level of barrage is 21.94m. Barrage is designed for passing a maximum discharge of 76,455m^3/s. The barrage gates are partially operated upto a discharge of 39,643 m^3/s and the gates are fully open for the discharge beyond. Central Water & Power Research Station (CWPRS) has conducted studies for gate operation schedule and submitted the recommendations for change in the gate operation schedule for different pond levels during rising and falling floods in August 2007. In 2017, existing conditions in the upstream and downstream of barrage were reviewed by the Farakka Barrage Project, and it was observed that a big sized shoal is formed at the centre of pond, upstream of Farakka Barrage. This upstream shoal is dividing the flow

through two channels, one along the left bank and other along the centre of the pond. The left bank channel is creating adverse flow conditions by eroding/ attacking the embankments, guide bunds and spurs. In addition, a large shoal was also noticed on downstream right bank of the barrage, which pushed flow to develop a channel directed at critical angles to the left bank. Considering, these facts, the Farakka Barrage Project opined to study the revision of the existing gate operation schedule to mitigate the effects of shoals both upstream and downstream of Farakka Barrage.

Farakka Barrage Project awarded this study to CWPRS. A report titled *Hydraulic Model Studies for Revision of Gate Operation Schedule of Farakka Barrage, West Bengal June' 2022* was submitted by CWPRS in June, 2022. For the review of the existing gate operation schedule, studies were carried out on an existing 1:80 geometrically similar scale model at CWPRS. The river reach from 5km upstream to 3km downstream of Farakka Barrage was reproduced in the model as per the latest survey (post flood 2016 and 2017) provided by the Farakka Barrage Authorities. All 109 bays of barrage were reproduced in the model. The study was carried out with discharge stages 14,158 and 22,653 m^3/s with existing and proposed gate operation schedules. In addition, 2D mathematical model of barrage pond was also developed to understand the flow conditions with alternative gate operation schedules for discharge ranging from 14,158 to 39,644m^3/s. Following observations emerged thereto.

- In the present scenario, it is observed that a skewed gate operation schedule along the right side of the barrage wherein a few group of gates are operated for a maximum period of time for the floods to pass even during the lean season flow is being followed. The horizontal jet of flow issuing out of these groups of barrage gates has resulted in the development of scour bulb downstream of the protected portion of the barrage along the right bank.
- The scour bulb has a tendency to scour from the central portion and deposit sediments along the edges. In this case, the scour bulb has strong tendency for right side deposition due to the presence of protection works while left and front side deposits are weaker. Hence, it is observed that many chute channels have formed on the left side after the breach of the deposited sediments. These chute channels are directed towards the left bank at critical angles and are causing large scales erosion of the left bank. These chute channels are observed to be formed only on the left side thereby causing more flow towards the left, resulting in erosion of the left bank.
- In order to reduce the intensity of flow in the left bank, the flow condition is needed to be moderated by allowing the development of scour bulb downstream of the barrage at the centre of the river.
- In view of the above, the gate operation schedule to be adopted should centralize the flow by symmetrical operation of gates. However, the sluices are to be kept open as the channel leading water to the head regulators for diversion should be active even during

the lean season. The same gate operation schedule should be practiced for both rising as well as falling flood but in a reverse direction.

Thus, Gate operation chart which is based on downstream water level as control level is being used by Farakka Barrage Authorities.

In the 1D mathematical model under the present study, gate operation schedule has been adopted w.r.t upstream water level in barrage to maintain the pond level at 22.00 m. While simulating the gate operation using mathematical model, it was ensured that when pond level rises above 22m due to inflow, the gates start opening. Similarly, when inflow recedes, the gates start closing so that pond level does not go below 22 m. The different gate groups have been assigned different threshold upstream water levels at which the gates in the given group start opening and closing as shown in Figure 22 below.

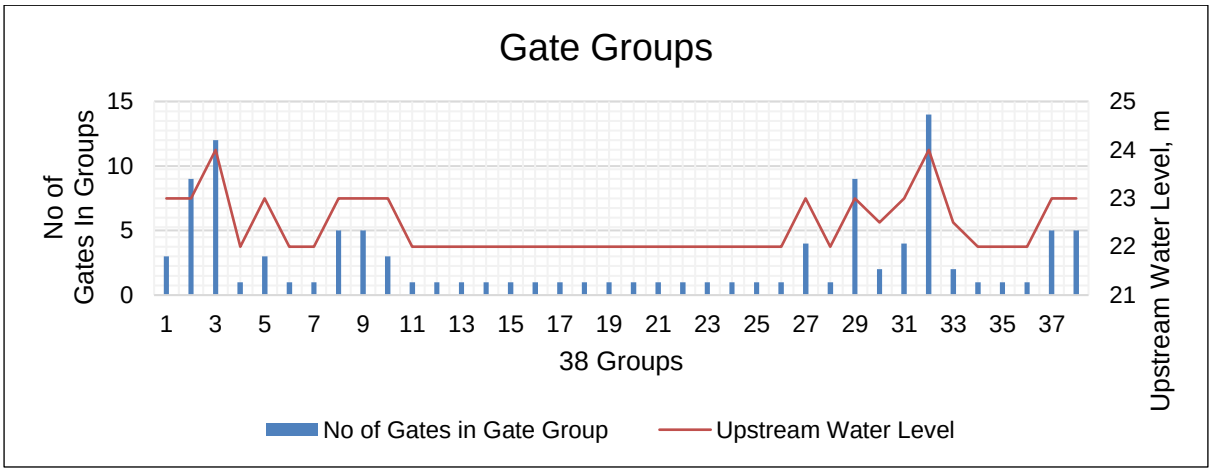


Figure 22: Reference Level at which gates of Farakka Barrage start to open and close

The gate operation schedule may not be unique but suggestive piano type gate operation exhibits that upstream pond level remain stable at El22.0 m through systematic and clubbed operation of gates.

It was informed to the Committee that the work of revival of two existing physical models viz., composite distorted mobile bed model having horizontal scale of 1:5OO, vertical scale of 1:70 having a reach of about 50 km upstream to 15 km downstream of Farakka Barrage; and Geometrically similar rigid bed model to a scale of 1:80 having a reach of about 8 km upstream to 3 km downstream of Farakka Barrage has been entrusted to CWPRS vide DoWR,RD&GR order no Z-15013/3/2021-FM Section -MOWR dated 26.02.24. The physical model studies will further assist towards assessment of impacts of gate operation on various morphological features viz., shoal and hydraulic concentration of flow velocities both upstream and downstream of barrage. The Committee therefore agreed that these physical model studies at CWPRS may be utilised for review of gate operation schedule, if required. As of now, the gate operation schedule/ protocols provided by CWPRS have been informed to be functioning satisfactorily.

The Technical Report on," Hydraulic Model Studies for Revision of Gate Operation Schedule of Farakka Barrage, West Bengal, June 2022" submitted by CWPRS is placed as **Appendix-II.**

9.0 Mitigation Measures

9.1 Existing River Bank Protection Measures

The mapping of existing bank protection works was carried out from the information received from the State Government and the field visit carried out by the Consultant. It has been observed that the existing mitigation measures majorly comprised of spurs, bed bars, bank revetment and embankments.

In **Ratua-I reach,** bank protection works on the left bank for a length of 400m of river Ganga at Keshorpur; for a length of 600m at Koshighat, block-Manikchak; protection & strengthening of embankment for a length of 800 m & construction of ring bund for a length of 400 m at Boro Kalutontola in Block- Manikchak have reportedly been carried out in earlier years. However, most of these works are presently damaged/ partially damaged. Further downstream, bank protection work on the left bank of river Ganga at Saheba-more, Mannutola & Srimantatola for a length of 675m; at Kalutontola and Nanditola for a length of 550m; at Bagedantola for a length of 575m; at Rajkumartola for a length of 875m; at Nilkantatola for a length of 500m in block Manikchak were also reportedly carried out. Presently, these are also in damaged/ partially damaged condition.

In **Kaliachak reach,** bank protection work on the left bank of River Ganga at Sukurullahapur for a length of 100m; D/S of Balukhara Kali mandir for a length of 1150m; at JoteKosturi for a length of 500m (in the upstream of Balukhara Kalimandir in Block-Kaliachak-II) are reported to be in damaged/ partially damaged condition. Spurs, mostly in the damaged condition, existed.

In **Dhulian reach**, porcupine, stone pitching, spurs and bank revetments exists at different sites, mostly in damaged/ partially damaged state. Bank protection works executed earlier on the left bank of river Ganga from Parlalpur ferry ghat to Golapmandalpara for a length of 2100m; for a length of 1000m at downstream of Farakka Barrage at Parlalpur from Safar Ali Park to Par Anup Nagar Primary School, in Malda are also damaged.

In **Lalgola-Bhagwangola** reach spurs and bank revetments were found to be in damaged/partially damaged condition.

The status of existing protection works is tabulated in Table 12 below.

Table 12: Status of existing protection works

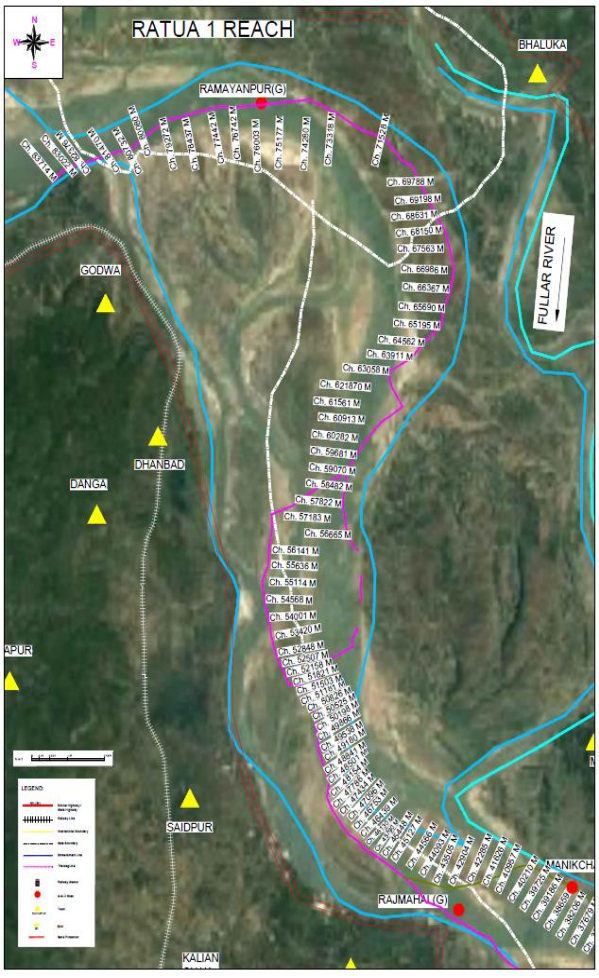
Ratua I Reach			
S.No.	**Chainage**	**Anti-Erosion Works**	**Status**

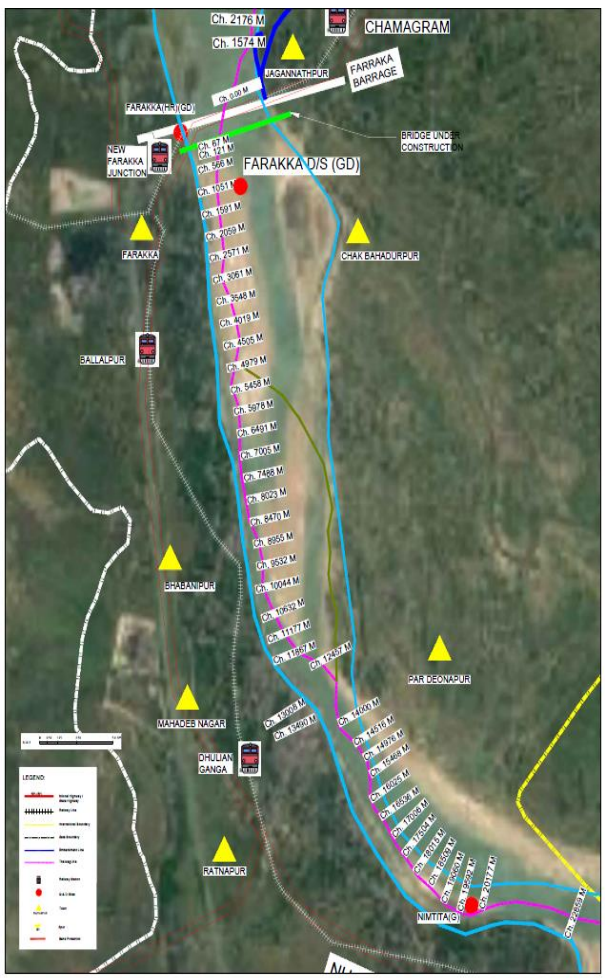
	(From- To)		
1	**60,913-63,058 (Left Bank)**	• Bank protection work to left bank of river Ganga at Keshorpur for length 400m under Mouza Keshorpur in Block Manikchak, P.S.- Bhutni. • Protection to left bank of river Ganga for length of 600m at Koshighat, P.S- Bhutni, block- Manikchak, dist-Malda under Malda Irrigation Division. • Protection & Strengthening of Panchayat embankment for a length of 800 m & construction of ring bund for a length of 400 m at Boro Kalutontola in the left bank of river Ganga under G.P. - Uttar Chandipur, P.S. - Bhutni, Block- Manikchak, Dist- Malda	Damaged Damaged Partially Damaged
2	**56,665-59,681 (Left Bank)**	• Bank protection works to the left bank of river Ganga at Saheba-more, Mannutola & Srimantatola for a length of 675m in Block Manikchak, P.S- Bhutni, Dist- Malda under Malda Irrigation Division. • Bank protection works to the left bank of river Ganga at Kalutontola and Nanditola for a length of 550m in Block Manikchak, P.S Bhutni, Dist- Malda. • Bank protection works to the left bank of river Ganga at Bagedantola for a length of 575m, in Block Manikchak, P.S- Bhutni, Dist; Malda. • Bank protection works to the left bank of river Ganga at Rajkumartola for a length of 875m under Mouza Nawararjaigir in Block Manikchak, PS Bhutni, Dist.- Malda under Malda Irrigation Division. • Construction of retired embankment including provision of inspection path on the left bank of river Ganga at Bhutnidiara in P.S-Manikchak Dist-Malda. • Bank Protection works to the left bank of river Ganga at Nilkantatola for a length of 500m in Block-Manikchak, P.S-Bhutni, Dist- Malda.	Damaged Damaged Damaged Partially Damaged Partially Damaged Partially Damaged
Manikchak-Kaliachak Reach			

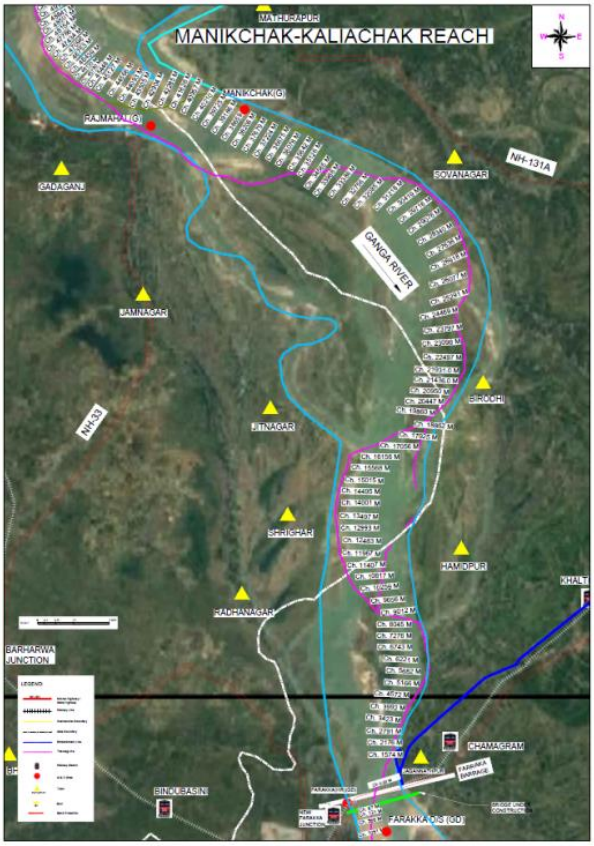
3	**23,000-1,750 (Left Bank)**	24 Spurs	Damaged
4	**21,931-24,469 (Left Bank)**	• Bank protection works to the left bank of River Ganga at Sukurullahapur adjoining to Dwar Bund in G.P Bangitola for a length of 100m in Block-Kaliachak-II, Dist-Malda. • Bank protection works in the left bank of river Ganga at Sukurullahpur for a length of 1,150(in the d/s of Balukhara Kali mandir) along with strengthening and raising of dwarf embankment(2100m) in G.P Bangitola. • Bank protection works in the left bank of river Ganga at JoteKosturi for a length of 500m (In the upstream of Balukhara Kalimandir) in G.P-Bangitola, Block-Kaliachak-II, P.S-Mothabari, dist-Malda. • Improvement on the L/B of river Ganga U/S of Farakka Barage at offtake of old Bhagirathi river from 0.00 km to 0.25 km at Mahadevpur In P.S-English Bazar , Dist.- Malda.	Partially Damaged
5	**1,500-4,572 (Left Bank)**	Bank Protection and improvement of marginal embankment	Partially Damaged
		Dhulian Reach	
6	**400-23,000(Right Bank)**	S1 (Ch 240m) ,S2 (Ch 353m), S3 (Ch 426m) ,S4 (Ch. 603m), S5 (Ch. 635m) ,S6 (Ch. 706m) ,S7 (Ch 795m), S8 (Ch 1,200m) ,S9 (Ch 4,857m) ,S10 (Ch 8,200m) ,S11 (Ch 11,905m),S12 (Ch. 12,225m) ,S13 (Ch 12,650m), S14 (Ch 13,020m) BB 1 (Ch 6,810m), BB2 (Ch 7,550m), BB3 (Ch 7,180m) ,BB4 (Ch 7,295m) ,BB 5 (Ch 13,075m) ,BB6 (Ch 13,130m) ,BB7 (Ch 13,190m) ,BB8 (Ch 13,250m), BB 9 (Ch 13,390), BB 10 (Ch 13,430m) ,BB 11 (Ch 13,495m) ,BBH12, (Ch 13,590m) ,BB 13 (Ch 13,690m) ,BB 14 (Ch 21,160m) ,BB 15 (Ch 21,265m), BB 16 (Ch 21,450m) ,BB17 (Ch 21,540) ,BB 18 (Ch 21,650m), BB 19 (Ch 21,757m)	Spurs 1 to 9 (Damaged) BB1 to 4 (Damaged) Other spurs and bed bars are partially damaged
7	**566-1,051 (Right Bank)**	Porcupine	Damaged

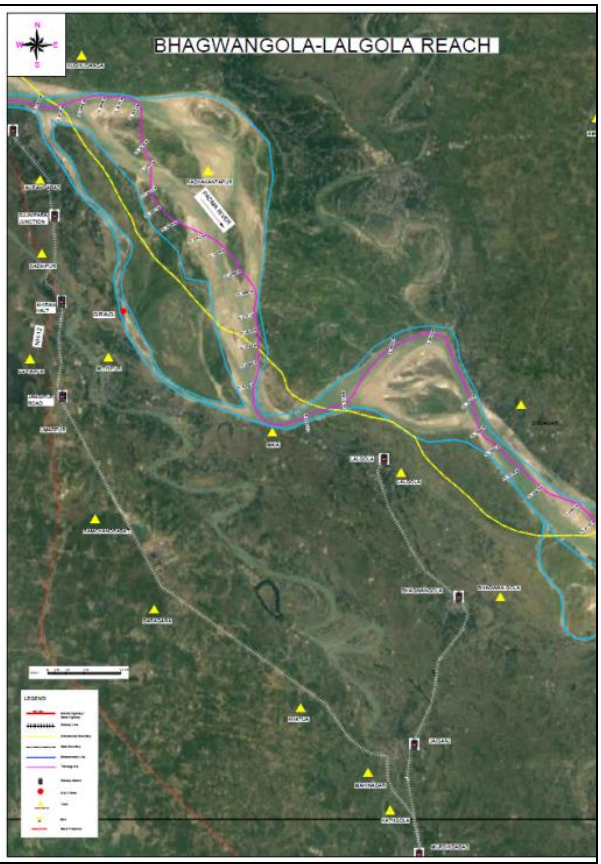
8	**2,571-3,061 (Right Bank)**	Stone Pitching	Partially Damaged
9	**3,700-5,000 (Right Bank)**	Stone Pitching	Partially Damaged
10	**7,700-9,100 (Right Bank)**	Stone Pitching and Porcupine	Partially Damaged
11	**9,400-12,457 (Right Bank**	Stone Pitching	Partially Damaged
12	**13,008-22,859 (Right Bank)**	Stone Pitching	Damaged
13	**3,250 – 7,500 (Left Bank)**	Bank Revetment	Partially Damaged
14	**10,600-13,008 (Left Bank)**	• Bank protection works to the left bank of river Ganga from Parlalpur ferry ghat to Golapmandalpara for a length of 2,100m in G.P –Pardeonapur-Sovapur, block-Kaliachak-III, P.S - Baisnabnagar , Dist.- Malda • Bank protection work to the left bank of river Ganga for a length of 1000 m at downstream of Farakka Barrage at Parlalpur from Safar Ali Park to Par Anup Nagar Primary School in Block-Kaliachak-III, P.S. - Baisnabnagar Dist.- Malda. • Bank protection work to the left bank of river Ganga for a length of 460 m adjoining to Par Aunpnagar under Par Anupnagar mouza in Perdeonapur-Sovapur G.P & Block- Kaliachak-III P.S- Baishnabnagar, Dist- Malda	Damaged
Lalgola Bhagwangola Reach			
15	**23,000-24,103**	14 Spurs and bank protection (on off-shoot of river Ganga)	Damaged
16	**54,000-58,500**	Bank Revetment	Damaged
17	**87,155-87,790**	Bank Revetment	Damaged

18	**91,100-91,560**	Bank Revetment	Damaged
19	**91,560-92,295**	Bank Revetment	Damaged
20	**1,14,268-1,15,439**	Bank Revetment	Partially Damaged
21	**1,23,617-1,24,062**	Bank Revetment	Partially Damaged
22	**1,33,241-1,34,555**	Bank Revetment	Partially Damaged
23	**1,36,399-1,36,749**	Bank Revetment	Partially Damaged
24	**1,39,643-1,40,263**	Bank Revetment	Partially Damaged









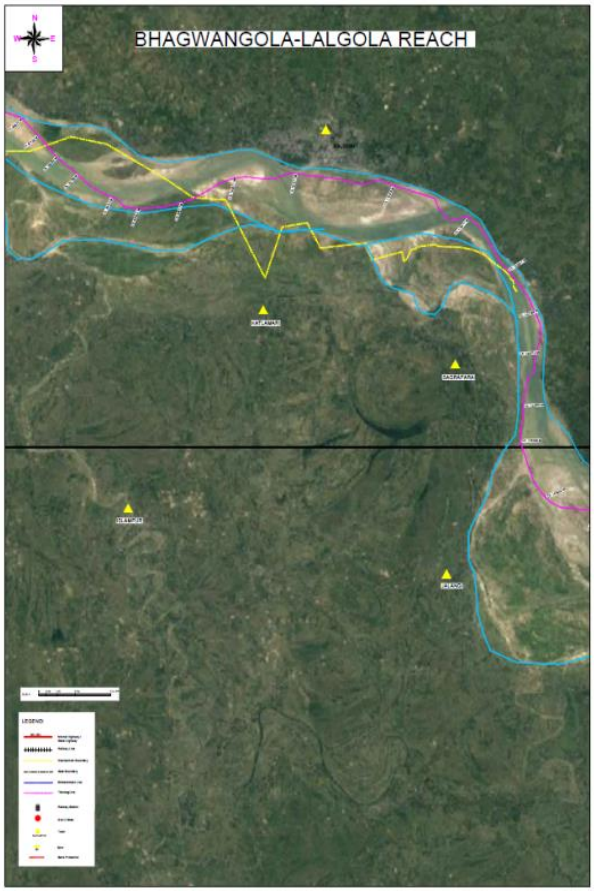


Plate 12: Status of Existing Anti-Erosion Works U/S & D/S of Farakka in the Ganga-Padma River System

9.2 Proposed Mitigation Measures

On the basis of the position of thalweg line, results of mathematical models run in different scenarios, location and status of already existing river bank protection works, net velocity plots, nature of area near the bank, river shifting etc. (the various parameters as indicated under Table 11) certain critical reaches have been identified and mitigation measures to combat the issues have been proposed.

IS 8408:1994 code provides for adoption of design discharge equal to that adopted for design of any structure in close proximity is designed or 50 year flood whichever is higher. It was observed that values of Q_{DT}=100 and Q_{DT}=50 do not have significant differences Thus, in view of the criticality of the reach, the presence of persistently eroding banks in the vicinity of the reach, safety aspects of existing barrage, recurring issue of erosion in the reach, flood of 1 in 100 year is adopted for design of planned mitigation measures as a special case for the purpose of the study reach. The special consideration for this study reach may not be quoted as a reference for other situation without carrying out detailed study.

Reach wise proposed mitigation measures are as under.

A. Reaches U/S of Farakka

Reach-I : Ratua Reach & Bhutani reach

Issues: Erosion of left bank of river leading to shift in bank line forming a concave bend.

Proposed Works:

12 spurs (7 spurs in Bihar & 5 in West Bengal) have been proposed at chainages (from Farakka barrage) 62,178m; 63,911m; 65,289m; 66,218m; 67,563m; 68,838m; 69,788m; 71,158m; 72,728m; 73,835m; 74,931m; 75,787m and 76,314m at the left bank of the river to divert the flow of bank away from left bank. Design of spurs may be done as per BIS code IS 8408:1994. Further, bank revetment along with launching apron is provided from chainage 62,100 to 76,350 (for a reach length of 14.25 km) covering the entire reach length of proposed spurs to protect the river banks from embankment as well as erosion due to possible vortex formation near spurs of the river.

The bank pitching and launching apron may be provided with boulders in cage as per the BIS code IS 14262:8408 . Further, core of spurs may be constructed using sand filled Geo-bags and outer layer of spurs to be provided with boulders in cage.

Bhutani area: RCC/PSC Porcupine screens are proposed in Bhutani area from chainage 45,000 m to 50,000 m with short screens of length 50 m and spacing between screens as 150m c/c. The layer of screens is to be decided based on depth of flow and height of the screen is

provided upto 50% of depth of flow with 5 rows in bottom layer. Subsequently 4 row/3 rows may be provided in middle layer and top layer as per depth of flow.

Paleo Channel Activation (Jharkhand – 15.00 km) at right bank

Issues: Along the right bank, Sakrigali paleo channel exists along which main course of river Ganga used to flow. With the passage of time the course of river Ganga continue to shift toward the left bank and flow through the Sakrigali channel ceased to exist. The mouth of the channel subsequently was blocked due to silt deposition.

Proposed works: It is proposed to clear the mouth of the channel and also clear the obstruction in the existing channel along with deepening the channel in 50m width to reduce the flow pressure on left bank.

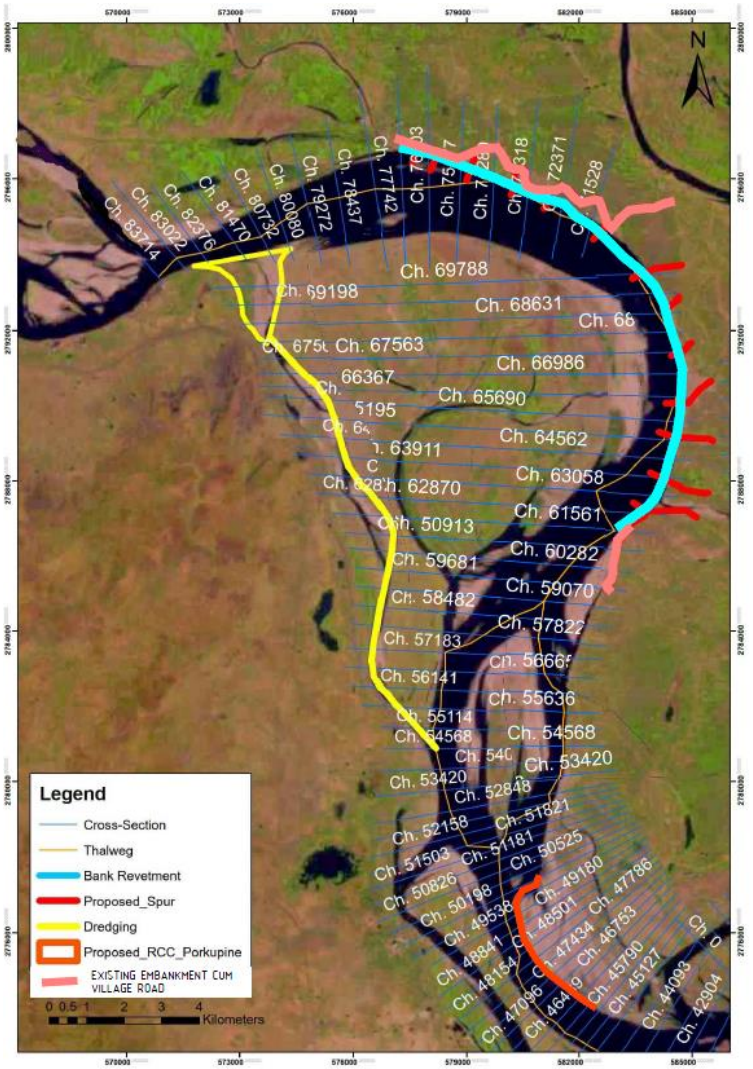


Plate 13: Layout of Proposed River Bank Protection Works in Ratua-I reach of Ganga-Padma River System

Reach-II : Kaliachak Reach

Issues: Erosion & flooding at left bank and erosion on right bank

Proposed Works:

Raising & Strengthening of existing embankment on left bank along with bank revetment with launching apron

Raising & strengthening of existing embankment is proposed at 3 locations (Ch. 4,000 – 6,000; 25,500 – 26,500 and 34,500 – 36,000) along with bank revetment with launching apron using sand filled geo-bags for a total length of 4.5 km to prevent flooding as well as bank erosion. Works for raising & strengthening of existing embankment may be done as per BIS code 12094:2000. Further bank revetment with launching apron using sand filled geo-bags is proposed at 2 locations on left bank (chainage 31,200-30,200 & 1,500-3,500) for a total length of 3.5 km.

Bank revetment with launching apron at right bank

Bank revetment with launching apron is provided at 1 location on right bank (chainage 13,000-15,500) for total length of 2.5 km using sand filled geo-bags.

Plate 14: Layout of Proposed River Bank Protection Works in Kaliachak reach of Ganga-Padma River System

B. Reaches D/S of Farakka

Reach-III : Dhulian Reach

Issues: Erosion on right bank of river in downstream of Farakka barrage and further on both banks in downstream area.

Proposed Works:

Bank revetment with launching apron using sand filled geo-bags is proposed at 6 locations on right bank (2,200-2,500; 4,500-6,000 ; 6,500 – 7,000; 8,900-11,867; 15,000- 16,500; 18,500-19,000) for a total length of 7.3 km and at 3 locations on left bank (5,600-7,000; 7,200-7,600; 12,500-14,000) for a total length of 3.3 km. Gabion wall is proposed at 3 locations on right bank (12,000 – 13,000; 17,000 – 17,400; 20,000 – 20,200) for a total length of 1.6 km. Bank Stabilised Ghat is proposed at 2 locations on right bank (7,500-8,500 and 13,000-14,500) for a total length of 1.6 km. Short RCC/ PSC Porcupine screens of length 50m at spacing 150m c/c to be provided at 4 locations on right bank (1,600 – 2,000; 17,500 – 18,500; 19,000-19,500; 20,000-21,000). The layer of screens is to be decided based on depth of flow and height of the screen is provided upto 50% of depth of flow with 5 rows in bottom layer. Subsequently 4 row/3 rows may be provided in middle layer and top layer as per depth of flow.

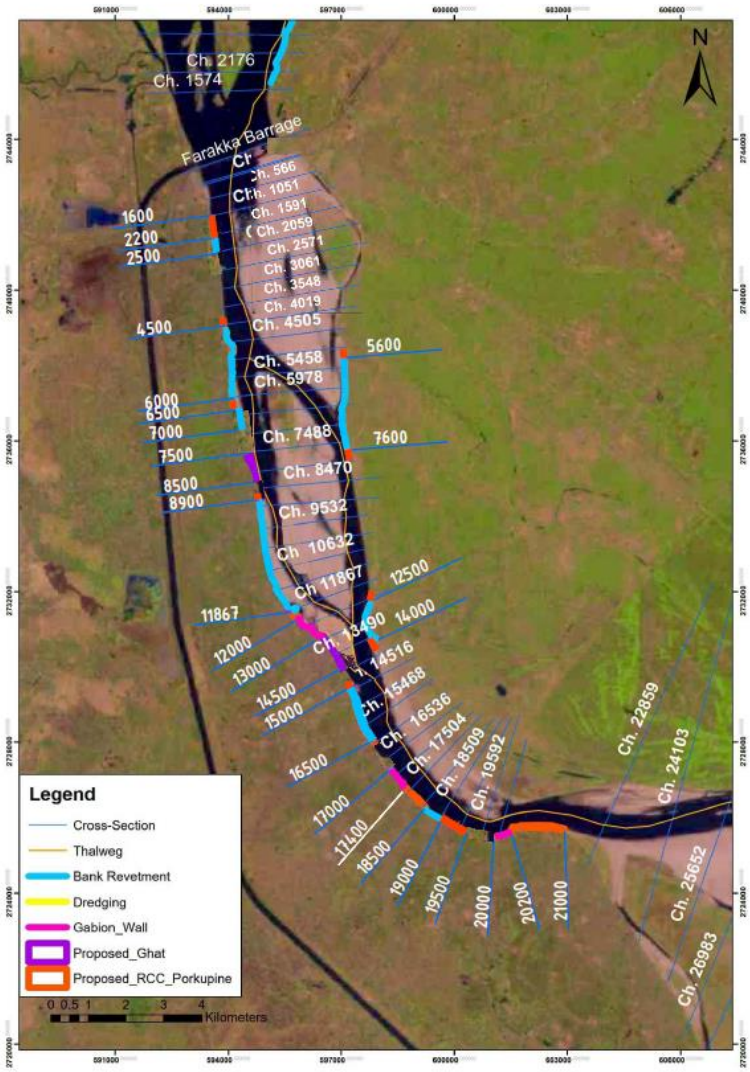


Plate 15: Layout of Proposed River Bank Protection Works in Dhulian reach of Ganga-Padma River System

Reach-IV: Bhagwangola Reach

Issues: Erosion on right bank of river

Proposed Works: Bank revetment with launching apron using sand filled geo-bags is proposed at 4 locations on right bank (56,000-57,000; 73,000-75,000; 87,150-87,650; 91,000-92,000) for a total length of 4.5 km. RCC/PSC Porcupine screens are proposed at 2 locations on right bank (55,000-56,000; 57,000-57,500) for total length of 1.5 km. The layer of screens is to be decided based on depth of flow and height of the screen is provided upto 50% of depth of flow with 5 rows in bottom layer. Subsequently 4 row/3 rows may be provided in middle layer and top layer as per depth of flow. Further, the reaches where standalone bank revetments are proposed; a provision of 2-3 RCC/PSC porcupine short screens of length 50 m @ 150 m spacing at U/S and D/S of revetment reaches is proposed to prevent revetment from outflanking.

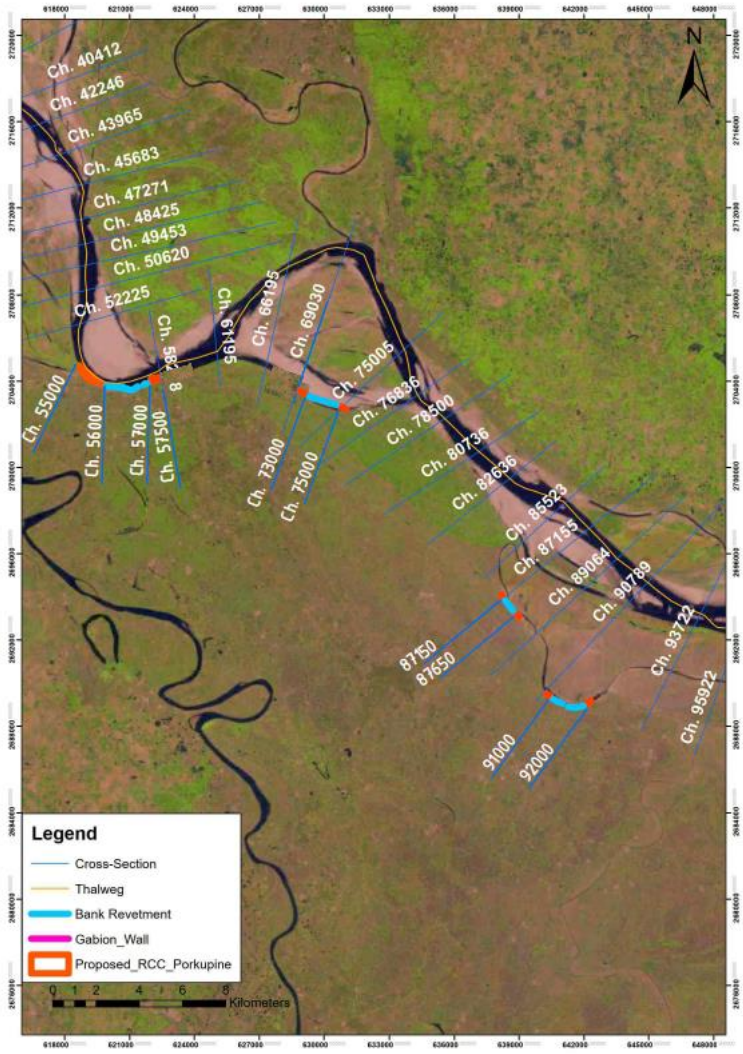


Plate 16: Layout of Proposed River Bank Protection Works in Lalgola-Bhagwangola reach of Ganga-Padma River System

Note: The above mitigation measures are proposed based on the findings of the mathematical models, field input provided by the State Government, Consultant and Farakka Barrage Project, processing and analysis of satellite imageries for studying bank-line shifting. The

mathematical models have been set-up based on certain assumptions/ limitations. With the advent of additional data, it may be required to revalidate the models/ capture the bank-line river dynamics to combat erosion. The above said proposed works along with detailed design are to be revisited and firmed up by the concerned agencies at the time of preparation of Detailed Project Report and appraisal of Detailed Project Report for execution of works. The recommendations of Committee thereof do not suggest to bypass the due appraisal process following existing relevant guidelines and prevalent field conditions. Further, Central Water and Power Research Station (CWPRS) has been mandated to revive two existing physical models viz., composite distorted mobile bed model having horizontal scale of 1:5OO, vertical scale of 1:70 having a reach of about 50 km upstream to 15 km downstream of Farakka Barrage; and ii. Geometrically similar rigid bed model to a scale of 1:80 having a reach of about 8 km upstream to 3 km downstream of Farakka Barrage. These revived physical models, in future, will assist in reviewing the results of present studies as well as assessment of impacts of gate operation on various morphological features viz., shoal and hydraulic concentration of flow velocities both upstream and downstream of barrage.

The indicative drawings of proposed measures are enclosed at **Annexure-VII**. Structural detailing and specifications will be finalised at DPR stage by the State Government considering prevailing site conditions. A line diagram incorporating the details of proposed and existing mitigation measures is placed at **Annexure-VIII.**

The Committee recommended that the design aspects of above proposed works as well as extent of works shall be finalised by the appraising agency in State as well as Centre as per relevant guidelines and prevailing site conditions.

10.0 Jurisdiction of Farakka Barrage Project

West Bengal is a lower riparian State, with severe erosion along both the banks of the Ganga-Padma river system in the entire stretch of 163.50km in Malda, Murshidabad and Nadia districts. This has resulted in severe loss of public utilities, private property and agricultural land over a period of time. This has attracted attention of government from time to time to combat the issue and plan remedial measures. The remedial measures are usually taken-up by the respective State Governments and Farakka Barrage Project (FBP) in their areas of jurisdiction respectively. A brief history of the jurisdiction of FBP is as under: -

- Originally, the jurisdiction of Farakka Barrage Project was 12.5km upstream to 6.9km downstream of Farakka Barrage. The FBP was mandated to undertake anti erosion works and other mitigation measures within their jurisdiction.
- A DO letter dated 16.12.2004 from Farakka Barrage Project addressed to Hon'ble Chief Minister, Government of West Bengal was written requesting the consent/ no-objection of Government of West Bengal on extending the jurisdiction of Farakka Barrage Project up to 40km U/S of Farakka Barrage and

80km D/S of barrage. In response, Hon'ble Chief Minister, Government of West Bengal vide DO letter dated 02.12.2004 and 7.01.2005 gave "*No objection*" to the extension of the jurisdiction of Farakka Barrage project up to Jalangi.

- The jurisdiction of FBP was accordingly, extended in January 2005 vide MOWR letter No 12/24/2004-GB-FBP/90-100 dated 19.1.2005 as regards to taking up anti-erosion and bank protection works.
- Later, the issue of jurisdiction of FBP was discussed in the TAC meetings of FBP in the presence of the representatives of the Government of West Bengal. 112th TAC meeting of FBP held on 17.11.2016 and 18.11.2016 strongly recommended for restoration of the original jurisdiction FBP. Eventually, in July' 2017 the original jurisdiction of FBP was restored.
- Hon'ble Chief Minister, West Bengal had brought the matter before the Hon'ble Prime Minister, on several occasions, vide letter No 1255-CM/2017 dated 10.08.2017, Letter No 80-CM/2022 dated 21.02.2022 and letter No 153-CM/2022 dated 17.11.2022 requesting the jurisdiction of FBP upto 40km and 80km by rescinding the aforesaid decision.
- A DO letter No 169-CS/2023 dated 17.11.2023 was sent to Secretary, DoWR,RD&GR, MoJS by Chief Secretary, Government of West Bengal requesting the same stating that the stretch of 163.5km in Malda, Murshidabad and Nadia is long. If it is divided into multiple agencies, it will be difficult to adopt a technically holistic approach and results will not be optimal.

Detailed deliberations were held in the Committee meeting on the issue of jurisdiction of Farakka Barrage Project. In view of above facts, it was observed that the jurisdiction reach of Farakka Barrage Project (FBP) may be considered as per the scope approved in relevant EFC Memo.

11.0 Conclusions & Recommendations

The Committee addressed the preparation of integrated plan to combat the threat of erosion along banks of River Ganga-Padma in said reach. The conclusion/ recommendations of the Committee are as below:

1. As discussed in section 1.2, the river has morphologically been behaving differently in upstream as well as downstream of barrage. This has led to dynamically evolving different conditions, both in upstream as well as downstream of the barrage. The same has been extensively documented, studied and made part of modelling for the study purpose.

2. Govt of West Bengal appointed a Consultant (Tractebel Engineering Pvt Ltd) in November, 2022 to carry out a comprehensive study through survey, model study and preparation of DPR for the entire 163.50 km of river Ganga in West Bengal. Earlier, CWC got a study commissioned on the issue of Flood and Siltation in River Ganga and its tributaries due to Farakka Barrage in the State of Bihar in 2021 through RMSI Pvt Ltd. The study inter-alia concluded that no significant changes were observed in the backwater and sediment transport "with barrage" and "without barrage" scenarios. CWPRS has also carried out studies on Ganga-Padma River System using physical modelling along with analysis of satellite imageries. The secondary information together with the ongoing study awarded by Govt of West Bengal to Tractebel Engineering Pvt Ltd (Consultant) has now been integrated to formulate an integrated plan to combat the threat of erosion along the banks of river Ganga-Padma at its entire stretch of 163.5 km in three districts, namely, Malda, Murshidabad and Nadia in West Bengal and at a stretch of 15 km in Bihar.

3. In order to identify the erosion-prone areas and suggest effective management strategies, understanding the flow patterns, velocities, and interactions within the river system is crucial. In view of the same, mathematical modelling and river migration studies have been carried out to analyze hydrodynamic conditions, sediment transport dynamics, and historical channel changes. 1D and 2D HEC RAS models have been developed for different purposes and a comprehensive analysis of bank-line shifting with, pertinent satellite images has been done through digitization. The summary of the models in different identified reaches with their objectives and outputs has been presented under section 5.0.

4. Design velocity, discharge intensity, HFL and LWL are key hydraulic parameters which are required in planning and design of anti-erosion measures. Various model scenarios are run to obtain the same. The reach wise estimated parameters are presented at **Annexure VI**.

5. In order to combat the threat of erosion posed along the banks of river Ganga-Padma, mitigation measures are proposed to be executed. The suggested measures are as summarised in Table 13 below.

Table 13: Summary of Proposed Mitigation Measures

SNo		Location	Suggested Mitigation Measures
		Ratua Reach	12 **spurs** including 7 spurs in Bihar have been proposed at chainages (from Farakka barrage) 62,178m; 63,911m; 65,289m; 66,218m; 67,563m; 68,838m; 69,788m; 71,158m;

1	Upstream of Farakka		72,728m; 73,835m; 74,931m; 75,787m and 76,314m at the left bank of the river. **Bank Revetment** Bihar – 7.683 km (76,350 to 68,631) West Bengal – 6.530 km (68,631-62,100) **Porcupine Screen in Bhutani Area** 5.00 km (50,000-45,000)
		Along the Right Bank	**Paleo Channel Activation** (Jharkhand – 15.00 km)
2		Kaliachak Reach	**Embankment Raising / Strengthening with Bank Revetment** West Bengal – 4.5 km (4,000-6,000; 25,500 – 26,500; 34,500 – 36,000) **Bank Revetment (left Bank)** West Bengal – 3.5 km (31,200 – 30,200 & 1,500 – 3,500) **Bank Revetment (Right Bank)** Jharkhand – 2.5 km (13,000 – 15,500)
3	Downstream of Farakka	Dhulian Reach	**Bank Revetment** Right Bank – 7.3 km (2,200-2,500; 4,500-6,000; 6,500 – 7,000; 8,900-11,867; 15,000- 16,500; 18,500-19,000) Left Bank – 3.30 km (5,600-7000; 7,200-7,600; 12,500-14,000) **Gabion Wall** Right Bank – 1.60 km (12,000 – 13,000; 17,000 – 17,400; 20,000 – 20,200) **Bank Stabilised Ghat** Right Bank-2.5km (7,500-8,500;13,000-14,500) **Porcupine Screens** Right Bank – 2.90 km (1,600 – 2,000; 17,500 – 18,500; 19,000-19,500; 20,000-21,000)
4		Bhagwangola Reach	**Bank Revetment** Right Bank – 4.5 km (56,000-57,000; 73,000-75,000; 87,150-87,650; 91,000-92,000) **Porcupine Screens** Right Bank – 1.50 km (55,000-56,000; 57,000-57,500)
The reaches where standalone bank revetments are proposed; a provision of 2-3 RCC/PSC porcupine short screens of length 50 m @ 150 m spacing at U/S and D/S of revetment reaches to prevent revetment from outflanking.			

The Committee recommended that the design aspects of above proposed works as well as extent of works including some other works required in this regard shall be finalised by the appraising agency in State as well as Centre as per relevant guidelines and prevailing site conditions. Accordingly, the proposed works may be taken up by the State Government in phased manner on priority. The Committee further recommended that the works in Bihar portion and in the 6km stretch of Ganga near the Bengal Bihar border may be taken up in co-ordination amongst Bihar, West Bengal & Ganga Flood Control Commission.

6. The proposed mitigation measures are designed by adopting 100-year return period flood as design flood against the usually adopted BIS code provision of 50-year return period flood as design discharge for anti-erosion/river protection measures. It was observed that values of Q_{DT}=100 and Q_{DT}=50 do not have significant differences. Further, IS 8408:1994 code also provides for adoption of design discharge equal to that adopted for design of any structure in close proximity or 50 year flood whichever is higher. The State Government was also of the view that higher return period flood may be adopted as design flood as the critical situation so warrants. In view of the criticality of the reach, the presence of persistently eroding banks in the vicinity of the reach, safety aspects of existing barrage, recurring issue of erosion in the reach, Committee felt that a design flood of 1 in 100 year return period be adopted for design of planned mitigation measures as a special case for the purpose of the study reach. However, the hydrologic design considerations are treated as special case purely on merit and may not be quoted as a precedence in any future design consideration elsewhere in other cases.

7. The details of river bank protection works executed in the last ten years in the study reach were identified through field visits by the consultant, information provided by State Government and Farakka Barrage Project. It was observed that these works majorly comprised of flood embankments, bank revetments by sand bag/ stone/ gabion pitching, porcupine etc. Abstract of data collected can be seen in Table 3. The location and status of the existing river bank protection works in the reach under study are discussed in Section 9.1.

8. Mathematical models are effective in simulating fluvial hydrodynamics but may not fully capture the complexities of sediment transport processes. Therefore, to conduct a thorough analysis, it is recommended that gate operation protocols be developed using a combination of mathematical models and results from physical modelling experiments. It was informed to the Committee that the work of revival of two existing physical models viz., composite distorted mobile bed model having horizontal scale of 1:5OO, vertical scale of 1:70 having a reach of about 50 km upstream to 15 km downstream of Farakka Barrage; and Geometrically similar rigid bed model to a scale of 1:80 having a reach of about 8 km upstream to 3 km downstream of Farakka Barrage has been entrusted to CWPRS vide DoWR,RD&GR order no Z-15013/3/2021-FM Section -MOWR dated 26.02.24. The physical model studies will further assist towards assessment of impacts of gate operation on various morphological features viz., shoal and hydraulic concentration of flow velocities both upstream and downstream of barrage. The Committee therefore agreed that these physical model studies at CWPRS may be utilised for review of gate operation schedule, if required. As of now, the gate operation schedule/ protocols provided by CWPRS have been informed to be functioning satisfactorily.

9. In the long term, non-structural measures such as implementing floodplain zoning should be considered. Additionally, nature-based interventions in form of vetiver grass, coir mat etc. may be explored on a pilot basis in select sections of the affected area, subject to feasibility to bring out their longevity and maintenance cost. Provision for extensive use of sand filled geo bags has already been recommended. These interventions may be developed by the State Governments in consultation with relevant apprising agencies. These measures can be further evaluated and potentially expanded owing to its effectiveness and sustainability.

10. During the course of working of this Committee, a detailed technical study for proposing mitigation measures in the study segment was carried out backed by scientific model studies, migration study through remote sensing. However, it is necessary to keep a close watch on the river dynamics and the performance of the existing and proposed (completed) structures on the river. In case of any unprecedented event, major intervention may be required to be planned for undertaking in the river for which suitable scientific studies should be initiated as and when necessary. Looking at the sensitivity of the issue in the reach, suitable studies to capture the river dynamics and further to suggest mitigation measures may be done every 5 years.

11. Regarding jurisdiction of Farakka Barrage Project, the Committee observed that the jurisdiction reach of Farakka Barrage Project may be considered as per the scope approved in relevant EFC Memo.

12. The mathematical model developed for the studies have undergone extensive deliberations during the Committee meetings, capturing exhaustive field data and river hydro-dynamics. The model has also undergone calibration and validation procedure before the output from the model was utilised for drawing an integrated plan to combat erosion in Ganga-Padma system. Keeping in view the facts that considerable efforts have been invested in finalising the model and arriving at the conclusions, Committee recommends that the State may preserve the mathematical model developed for future uses as appropriate. The copy of the model may also be kept with CWC and CWPRS for future reference.

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RATUA 1 REACH

ANNEXURE- I

N
W E
S

GANGA RIVER

NH-33

SAHIBGANJ(G)

SAHIBGANJ

GODWA

DHANBAD

DANGA

SOLAPUR

SAHIBGANJ

SAIDPUR

KALIAN CHAK

GADAGANJ

KATIHAR

RAMAYANPUR(G)

BHALUKA

FULLAR RIVER

MALDA

BAHARAL

MALDAH

MATHURAPUR

MANIKCHAK(G)

RAJMAHAL (G)

SOVANAGAR

NH-31

NH-131A

Ch. 83714 M
Ch. 82376 M
Ch. 81470 M
Ch. 80732 M
Ch. 80080 M
Ch. 79272 M
Ch. 78437 M
Ch. 77442 M
Ch. 76742 M
Ch. 76003 M
Ch. 75177 M
Ch. 74280 M
Ch. 73318 M
Ch. 71528 M

Ch. 69788 M
Ch. 69198 M
Ch. 68631 M
Ch. 68150 M
Ch. 67563 M
Ch. 66986 M
Ch. 66367 M
Ch. 65690 M
Ch. 65195 M
Ch. 64562 M
Ch. 63911 M
Ch. 63058 M
Ch. 621870 M
Ch. 61561 M
Ch. 60913 M
Ch. 60282 M
Ch. 59681 M
Ch. 59070 M
Ch. 58482 M
Ch. 57822 M
Ch. 57183 M
Ch. 56665 M
Ch. 56141 M
Ch. 55636 M
Ch. 55114 M
Ch. 54568 M
Ch. 54001 M
Ch. 53420 M
Ch. 52848 M
Ch. 52507 M
Ch. 52158 M
Ch. 51821 M
Ch. 51503 M
Ch. 51181 M
Ch. 50826 M
Ch. 50525 M
Ch. 50198 M
Ch. 49866 M
Ch. 49538 M
Ch. 49180 M
Ch. 48841 M
Ch. 48501 M
Ch. 48154 M
Ch. 47786 M
Ch. 47434 M
Ch. 47096 M
Ch. 46753 M
Ch. 46439 M
Ch. 46130 M
Ch. 45790 M
Ch. 45448 M
Ch. 45727 M
Ch. 44566 M
Ch. 44093 M
Ch. 43505 M
Ch. 42904 M
Ch. 42285 M
Ch. 41626 M
Ch. 40957 M
Ch. 40210 M
Ch. 39725 M
Ch. 39186 M
Ch. 38659 M
Ch. 38206 M
Ch. 37679 M
Ch. 37224 M
Ch. 36675 M
Ch. 36078 M
Ch. 35642 M
Ch. 35126 M
Ch. 34565 M
Ch. 33986 M
Ch. 33386 M
Ch. 32756 M
Ch. 32085 M
Ch. 31218 M
Ch. 30419 M

SCALE 0 0.4 1.0 2.0 4.0KM

LEGEND:

- NH-/SH- Ntional Highway / State Highway
- Railway Line
- International Boundary
- Sate Boundary
- District Boundary
- ThalwegLine (2023)
- Railway Station
- G & D Sites
- Town RATNAPUR

MANIKCHAK-KALIACHAK REACH

N
W E
S

MANIKCHAK(G)
RAJMAHAL(G)
KALIAN CHAK
GADAGANJ
SOVANAGAR
NH-131A
JAMNAGAR
SAGARBHANGA
GANGA RIVER
BIRODHI
SAHIBGANJ
NH-33
JITNAGAR
SAHIBGANJ
MALDAH
SHRIGHAR
HAMIDPUR
KHALTIPUR
RADHANAGAR
BHATBHAGA
BARHARWA JUNCTION
NH-133A
BHATBHAGA
BINDUBASINI
CHAMAGRAM
JAGANNATHPUR
FARRAKA BARRAGE
FARAKKA(HR)(GD)
BRIDGE UNDER CONSTRUCTION
NEW FARAKKA JUNCTION
FARAKKA D/S (GD)
JHARKHAND

Ch. 44405 M
Ch. 43505 M
Ch. 42904 M
Ch. 42283 M
Ch. 41626 M
Ch. 40957 M
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Ch. 20950 M
Ch. 20447 M
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Ch. 16156 M
Ch. 15568 M
Ch. 15015 M
Ch. 14495 M
Ch. 14001 M
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Ch. 12483 M
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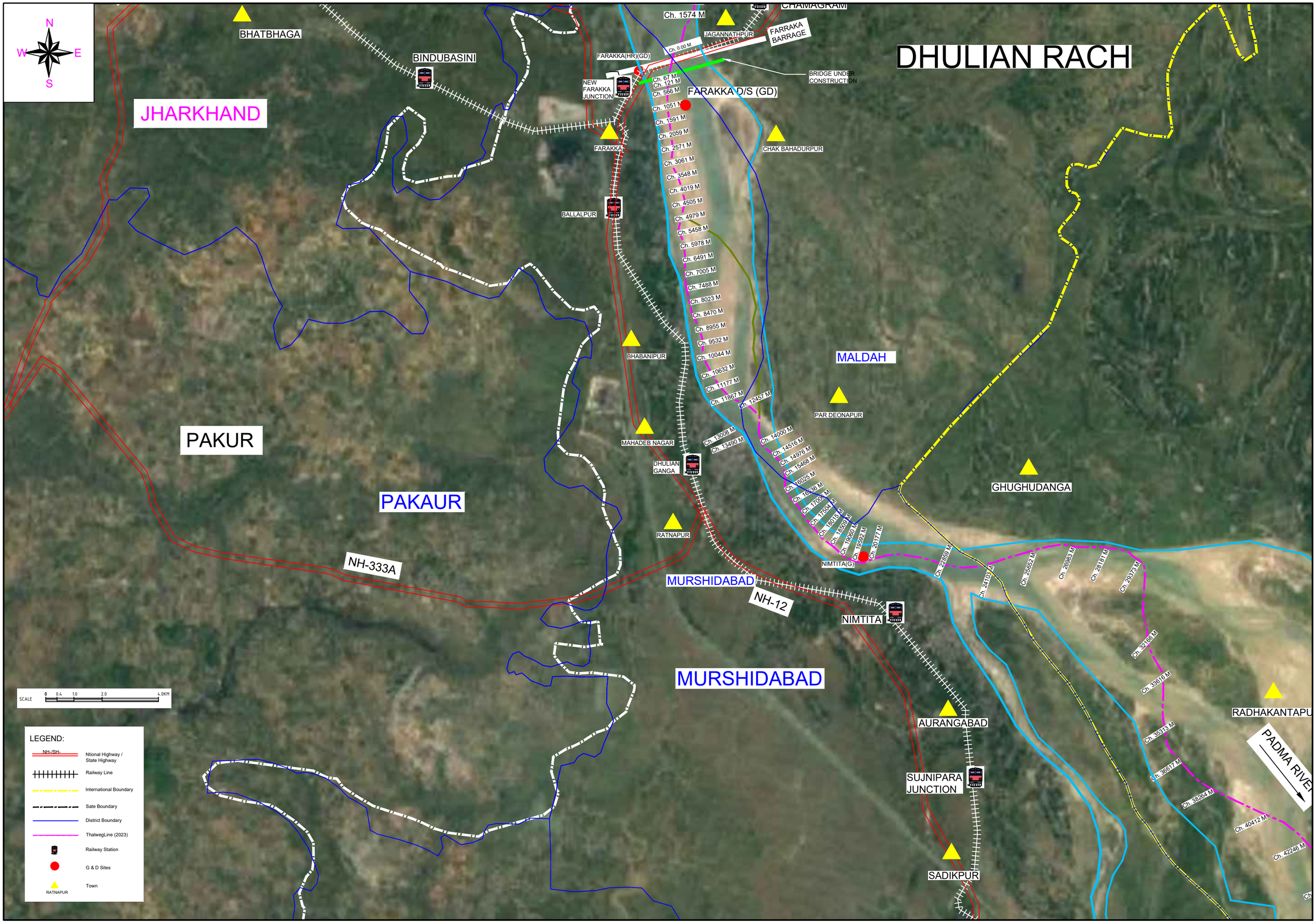
Ch. 11407 M
Ch. 10817 M
Ch. 10259 M
Ch. 9656 M
Ch. 9012 M
Ch. 8045 M
Ch. 7276 M
Ch. 6743 M
Ch. 6221 M
Ch. 5682 M
Ch. 5166 M
Ch. 4572 M
Ch. 3992 M
Ch. 3423 M
Ch. 2791 M
Ch. 2176 M
Ch. 1574 M
Ch. 0.00 M
Ch. 67 M
Ch. 121 M
Ch. 566 M
Ch. 1051 M
Ch. 1591 M
Ch. 2059 M

SCALE 0 0.4 1.0 2.0 4.0KM

LEGEND:

- NH-/SH- — Ntional Highway / State Highway
- Railway Line
- International Boundary
- Sate Boundary
- District Boundary
- ThalwegLine (2023)
- Railway Station
- G & D Sites
- Town (RATNAPUR)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JHARKHAND
Ch. 1574 M
JAGANNATHPUR
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FARRAKA BARRAGE
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FARAKKA(HR)(GD)
Ch. 0.00 M
BRIDGE UNDER CONSTRUCTION
NEW FARAKKA JUNCTION
Ch. 67 M
Ch. 121 M
Ch. 566 M
FARAKKA D/S (GD)
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Ch. 7488 M
Ch. 8023 M
Ch. 8470 M
Ch. 8955 M
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Ch. 10044 M
Ch. 10632 M
Ch. 11177 M
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Ch. 12457 M
FARAKKA
CHAK BAHADURPUR
BALLALPUR
BHABANIPUR
MALDAH
PAR DEONAPUR
MAHADEB NAGAR
Ch. 13008 M
Ch. 13490 M
Ch. 14000 M
Ch. 14516 M
Ch. 14976 M
Ch. 15468 M
Ch. 16025 M
Ch. 16536 M
Ch. 17004 M
Ch. 17504 M
Ch. 18015 M
Ch. 18569 M
Ch. 19060 M
Ch. 19592 M
Ch. 20177 M
DHULIAN GANGA
GHUGHUDANGA
PAKUR
PAKAUR
RATNAPUR
NIMTITA(G)
Ch. 22659 M
Ch. 24103 M
Ch. 25652 M
Ch. 26983 M
Ch. 28181 M
Ch. 29373 M
NH-333A
MURSHIDABAD
NH-12
NIMTITA
Ch. 32166 M
Ch. 33616 M
Ch. 35315 M
Ch. 36617 M
Ch. 38264 M
Ch. 40412 M
Ch. 42246 M
MURSHIDABAD
AURANGABAD
SUJNIPARA JUNCTION
SADIKPUR
RADHAKANTAPU
PADMA RIVER
SCALE 0 0.4 1.0 2.0 4.0KM
LEGEND:
NH-/SH- Ntional Highway / State Highway
Railway Line
International Boundary
Sate Boundary
District Boundary
ThalwegLine (2023)
Railway Station
G & D Sites
Town
RATNAPUR

BHAGWANGOLA-LALGOLA REACH

N
W E
S

RATNAPUR

MURSHIDABAD

NH-12

NIMTITA

MURSHIDABAD

AURANGABAD

SUJNIPARA JUNCTION

SADIKPUR

AHIRAN HALT

MURSHIDABAD

NH-12

NAZIRPUR

JANGIPUR ROAD

UMARPUR

RAMCHANDRABATI

MURSHIDABAD

GIRIA(G)

MITHIPUR

RADHAKANTAPUR

PADMA RIVER

MAIA

LALGOLA

MURSHIDABAD

Ch. 18015 M
Ch. 18509 M
Ch. 18980 M
Ch. 19522 M
Ch. 20177 M
Ch. 22359 M
Ch. 24163 M
Ch. 25852 M
Ch. 26983 M
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Ch. 45683 M
Ch. 47271 M
Ch. 48425 M
Ch. 49453 M
Ch. 50620 M
Ch. 52225 M
Ch. 53228 M
Ch. 61195 M

SCALE 0 0.4 1.0 2.0 4.0KM

LEGEND:

- NH-/SH- — Ntional Highway / State Highway
- Railway Line
- International Boundary
- Sate Boundary
- District Boundary
- ThalwegLine (2023)
- Railway Station
- G & D Sites
- RATNAPUR — Town

BHAGWANGOLA-LALGOLA REACH

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Ch. 48425 M
Ch. 49455 M
Ch. 50620 M
Ch. 52225 M
Ch. 52828 M
Ch. 61195 M
Ch. 66195 M
Ch. 69030 M
Ch. 75005 M
Ch. 76836 M
Ch. 78500 M
Ch. 80736 M
Ch. 82536 M
Ch. 85523 M
Ch. 87155 M
Ch. 89064 M
Ch. 90769 M
Ch. 93722 M
Ch. 95922 M
Ch. 98974 M

MAIA
LALGOLA
LALGOLA
GODAGARI
MURSHIDABAD
MURSHIDABAD
MCHANDRABATI
BHAGWANGOLA
BHAGWAN GOLA
BARAGARA
KHATUA
JAIGANJ
MAHINAGAR

SCALE 0 0.4 1.0 2.0 4.0KM

LEGEND:

- NH-/SH- Ntional Highway / State Highway
- Railway Line
- International Boundary
- Sate Boundary
- District Boundary
- ThalwegLine (2023)
- Railway Station
- G & D Sites
- Town (RATNAPUR)

BHAGWANGOLA-LALGOLA REACH

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Ch. 89084 M
Ch. 90789 M
Ch. 93722 M
Ch. 95927 M
Ch. 98977 M
Ch. 102977 M
Ch. 107277 M
Ch. 112078 M
Ch. 118741 M
Ch. 123617 M
Ch. 127188 M
Ch. 130072 M
Ch. 133993 M
Ch. 136399 M
Ch. 140532 M
Ch. 144918 M

MURSHIDABAD

KATLAMARI

SAGRAPARA

ISLAMPUR

JALANGI

SCALE 0 0.4 1.0 2.0 4.0KM

LEGEND:

- NH-/SH- Ntional Highway / State Highway
- Railway Line
- International Boundary
- Sate Boundary
- District Boundary
- ThalwegLine (2023)
- Railway Station
- G & D Sites
- Town (RATNAPUR)

ANNEXURE-II

Z-16011/3/2023-FM Section-MOWR

I/80560/2023

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD & GR
(Flood Management Wing)

Block-11, 8th Floor, CGO Complex,
Lodhi Road, New Delhi-110003.
Dated: 24 February, 2023

Office Memorandum

Subject: Constitution of a Committee for conducting a joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga- Padma river system in West Bengal.

The undersigned is directed convey that, with the approval of the Competent Authority of DoWR, RD&GR, Ministry of Jal Shakti, a Committee is constituted for conducting a ***joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga- Padma river system in West Bengal*** , as per the following details:

2. **Composition of the Committee**:

1.	Chairman, Central Water Commission	Chairman
2.	Member, (D&R), Central Water Commission	Member
3	Member (RM), Central Water Commission	Member
4	Chairman, Ganga Flood Control Commission, Patna	Member
5.	Commissioner (FM), DoWR, RD&GR, MoJS	Member
6.	General Manager, Farakka Barrage Project	Member
7.	Director, Central Water & Power Research Station, Pune	Member
8.	Representative of Ministry of Ports, Shipping & Waterways, Government of India	Member
9.	Representative of State Government of Bihar	Member
10.	Representative of State Government of West Bengal	Member
11.	Representative of National Remote Sensing Centre, Hyderabad	Member
12.	Chief Engineer (P&D), Central Water Commission,	Member-Secretary

CE (P&D)

3. Terms of Reference :

i. To formulate an integrated plan to combat the threat of erosion along the banks of river Ganga-Padma at its entire stretch of 163 km in three districts, namely, Malda, Murshidabad and Nadia in West Bengal and at a stretch of 15 km near the West Bengal- Bihar Border (9 km in Bihar +6 km in West Bengal).

ii. To undertake model study required for this purpose by Central Water & Power Research Station, Pune, under the guidance of the Committee and as per timelines fixed by the Committee.

iii. To review / modify the existing gate regulation mechanism of Farakka Barrage, if required, for this purpose.

iv. To commission any other technical study deemed necessary by the Committee.

v. To obtain the requisite data for the studies from the respective Organizations.

vi. To obtain field data required by the Committee from State Govt. of West Bengal.

vii. To undertake site visits for which necessary arrangements shall be made by Govt. of West Bengal.

4. The Committee will submit its report within a period of six months from the date of its constitution. The Committee may co-opt other members, if required, and may invite any officer from expert organization to present their outcome of related technical studies carried out.

5. The expenditure on TA/DA etc. of the officials for participating in meetings / visits shall be borne by the respective Organizations. The expenditure in respect of the technical studies authorized by the Committee shall be borne by Farakka Barrage Project (FBP) and shall be chargeable to relevant Budget Head of FBP scheme.

9/2/2023

(R.R. Sambharia)
Sr. Joint Commissioner-1 (FM)
Ph. No. 011-24362160
e-mail: sjcer1-mowr@nic.in

To
The Members of the Committee

Copy to:

1. Chief Secretary, Government of West Bengal
2. Chief Secretary, Government of Bihar.
3. Secretary, MoPS&W, Government of India
4. Director, NRSC, Hyderabad.

With a request to nominate a senior officer for the Committee

Sr. Joint Commissioner-1 (FM)

Copy for information to:

1. PS to Hon'ble Minister for Jal Shakti
2. Sr. PPS to Secretary (WR,RD&GR)
3. Sr. PPS to Special Secretary (WR, RD&GR)

Sr. Joint Commissioner-1 (FM)

I/91204/2023

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD&GR
(Flood Management Wing)
****

Block-11, 8 Floor, CGO Complex,
Lodhi Road, New Delhi-110003.
Dated: 27 December, 2023

Office Memorandum

Subject: Committee constituted for conducting a Joint detailed technical study on erosion caused by Ganga-Padma river system- Extension of tenure alongwith additional ToR-reg.

A Committee was Constituted by this Department vide O.M. Z-16011/3/2023-FM Section-MOWR dated 9.2.2023, as per the request of Govt. of West Bengal, for conducting a Joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma river system in West Bengal. In this context, in continuation to this office O.M. Z-16011/3/2023-FM Section-MOWR dated 9.2.2023, and as per the request of Member Secretary of the Committee, vide letter T-38075/1/2023-MORPH-CC dated 15.12.2023, the approval of competent authority is hereby conveyed for extending the tenure of this Committee **upto 31.3.2024 for submission of the report.**

2. Further, approval of competent authority is also conveyed for revising the Terms of Reference(ToR) of the above Committee by including the following para as para 3 (viii) in the ToR:

"To review the original jurisdiction of Farakka Barrage Project as regards to undertaking anti-erosion / river bank protection works, and to examine the need (if any) for extending this jurisdiction, as requested by State Govt. of West Bengal"

3. The request of Govt. of West Bengal, as above, vide D.O. letter No.169-CS/2023 dated 17.11.2023 from Chief Secretary, is enclosed herewith.

Encl: As above

27/12/2023

(R. R. Sambharia)
Sr. Joint Commissioner-I (FM)
Tel. No. 011-24362160
E-mail: sjcer1-mowr@nic.in

To,
Shri D P Mathuria
Chief Engineer (P&DO)
Central Water Commission
Sewa Bhawan, New Delhi-110066

Copy for information to:

Chairman, Central Water Commission, Sewa Bhawan, New Delhi-110066

ANNEXURE-IV A

Minutes of first (1st) Meeting of the Committee for conducting Joint Detailed Technical Study to formulate an integrated plan to combat threat of erosion posed by Ganga Padma River System in West Bengal

The first (1st) Meeting of the Committee for conducting Joint Detailed Technical Study to formulate an integrated plan to combat threat of erosion posed by Ganga- Padma River System in West Bengal was held under the Chairmanship of Sh. Kushvinder Vohra, Chairman, CWC on April 06, 2023 at Sewa Bhawan, New Delhi. The list of participants is appended at **Annexure-I.**

Chairman, CWC welcomed the participants and took a brief introduction of members of the committee. Thereafter, Chief Engineer (P&DO), CWC made a brief presentation on the ToR of the committee and issues pertaining to erosion in Ganga-Padma River System raised by the Government of West Bengal.

I. **Key Deliberations and Issues**

Sh. B Mukherjee, Joint Secretary (Works), I&W Directorate, Govt of West Bengal made a presentation informing the Committee on the issues relating to perpetual river erosion along banks of river Ganga/Padma in upstream and downstream of Farakka barrage.

The State has carried out certain works, survey and studies pertaining to erosion issues and also appointed a consultant (M/s Tractebel Engineering P Ltd) in November, 2022 to carry out a comprehensive study through survey, model study and preparation of DPR on the entire 163.50 KM of Ganga River. Commissioner (FM) advised the Govt of West Bengal to comply to CWC guidelines for preparation of DPR by consultant.

River Research Institute, W.B has also conducted a bathymetry and topographical survey of river Ganga and Fulhar at Mahanandatola and Bilaimari area of Dist.- Malda. Moreover, it has been suggested by a West Bengal Government appointed Dutch expert that by providing a cut-off between two flow lines of Ganga at the reach in Jharkhand in Sahibganj, the threat of erosion in that area can be minimized. Further, it was also informed that presently there is no policy of regulations of the settlements in diaras in the State of West Bengal. Copy of presentation is appended as **Annexure-II**.

Sh. Anil Kumar, Chief Engineer, Flood Control and Drainage, Katihar, WRD, Government of Bihar made a presentation informing the Committee about the gradual shifting of river edge of Ganga river with time. He informed that government of Bihar has carried anti-erosion works using boulder slope pitching with boulder apron for a length of 6300 respectively in 2018 from Hardeo Tola to Khatti. After the flood, majority of the work proved ineffective. Copy of presentation is appended as **Annexure-III.**

Dr Pratap Singh, Vice President, RMSI Pvt Ltd gave an overview on the Study carried out in 2021 under *National Hydrology Project (NHP)* on the issue of Flood and Siltation in River Ganga and its Tributaries due to Farakka Barrage in the State of Bihar. The objective of this project was to study the effect of Farakka Barrage on backwater and siltation of River Ganga and its major tributaries joining river Ganga between Buxar to Farakka Barrage.

Hydraulic and sediment transport models were set up using HEC-RAS software. The analysis and modeling of the study area was carried out using one-dimensional (1D) hydraulic modeling. In conclusion of the study, it was informed that no significant changes were observed in the backwater and sediment transport with changes in barrage" and "without barrage' scenarios. Copy of presentation is appended as **Annexure-IV**.

Dr R.S. Kankara, Director, **CWPRS** made a presentation on the overview of past studies carried out on Ganga-Padma River System using physical modelling along with analysis of satellite imageries. The findings of the study were also presented. Copy of presentation is appended at **Annexure V**.

II. **Agreed actions and way forward.** Number of suggestions were made by Chairman, CWC for way forward. In this regard, the following were agreed by all the members of the Committee:

1. Integrated study awarded by Govt of West Bengal to M/s Tractabel Engineering P Ltd (Consultant) may be an integrated study and must include the 9 Km reach upstream of Farakka barrage located in Bihar state. This reach in Bihar has location of nose from where the river Ganga flows tend to erode the left bank as is decipherable from the times series of satellite imageries data plot presented by Bihar and WB. Non-inclusion of this reach may defeat the purpose of the integrated study. Requirement of river morphology and cross-section data by M/s Tractabel Engineering P Ltd may be met as part of existing contract of Govt of West Bengal with Consultant for which Bihar may make requisite payments while the field work of generating cross-sections etc may be carried out by Consultant itself. Govt of West Bengal may share requisite information with Govt of Bihar so as to facilitate an administrative and financial decision at end of Govt of Bihar. Modelling cost for the entire stretch including the stretch in Bihar would be borne by the Government of West Bengal. ATR to be submitted within 15 days.

(Action: Govt of West Bengal and Govt of Bihar)

2. Government of Bihar and West Bengal would share the details of the anti-erosion works carried out in the past at various reaches in the region of interest and their subsequent effects. Detailed map showing the same may be prepared and presented in the next meeting.

(Action: Govt of West Bengal and Bihar)

3. Comm(FM), DoWR,RD&GR to examine the issue of providing data (daily data) being shared with Bangladesh as part of JRC framework to Govt of West Bengal. Further, DoWR,RD&GR to examine the request of the Govt of West Bengal for sharing of gate regulation data or other related data of the Farakka Barrage required for their study.

(Action: Commissioner (FM)

4. Government of West Bengal is advised to make request for seeking relevant discharge and gauge data of CWC through an online portal for the study purpose.

(Action: Govt of West Bengal)

5. In next meeting, officials from Govt of Jharkhand may also be invited in view of West Bengal informing that implementation of decisions as per recommendations made by Dutch team may require taking on board Jharkhand state as well.

(Action: CWC)

6. ToR of studies proposed by M/s Tractabel Engineering P Ltd (Consultant) for Govt of West Bengal may be shared with all Committee members for their consideration, views and review, if any.

(Action: Govt of West Bengal)

7. M/s Tractabel Engineering P Ltd (Consultant) appointed by Govt of West Bengal may give a presentation in virtual mode on studies undertaken by them towards integrated erosion studies for upstream and downstream reach of Ganga-Padma system.

(Action: Govt of West Bengal)

****

1ST MEETING OF THE COMMITTEE FOR CONDUCTING JOINT DETAILED TECHNICAL STUDY TO FORMULATE AN INTEGRATED PLAN TO COMBAT THREAT OF EROSION POSED BY GANGA-PADMA RIVER SYSTEM IN WEST BENGAL ON 06.04.2023 AT NEW DELHI

COMMITTEE CONSTITUTED BY MOJS, GOI ON 09.02.2023

REPRESENTATION BY GOVERNMENT OF WEST BENGAL

GOVERNMENT OF WEST BENGAL
IRRIGATION AND WATERWAYS DEPARTMENT

INTRODUCTION

- Entry of Ganga/Padma in West Bengal ----At Bilaimari G.P. in Ratua block of Malda
- The districts of Bihar and Jharkhand at the interstate border near the entry point of Ganga in West Bengal ----- Katihar and Sahebganj of Bihar and Jharkhand
- Exit point of Ganga/Padma into Bangladesh ----- Bousmari G.P. of Jalangi block in Nadia
- Total length of Ganga/Padma in West Bengal ---- 163.50 KM. (65 KM U/S of Farakka Barrage + 98.5 KM D/S of Farakka Barrage)
- Off-take point of Bhagirathi from Ganga/Padma ----- At Ahiron in Suiti-I block of Mushidabad at about 40 D/S of Farakka Barrage.
- The main course of Ganga, after 22 KM D/S of Farakka Barrage is commonly known as Ganga/Padma.

WEST BENGAL -BIHAR BORDER EROSION GOOGLE IMAGE FOR THE YEAR 1985 AND 2022

GOOGLE BASED ALIGNMENTS OF GANGA / PADMA FOR REACH DOWNSTREAM OF FARAKKA BARRAGE

ISSUES RELATING TO PERPETUAL RIVER EROSION ALONG BOTH BANKS OF RIVER GANGA/PADMA LEADING TO LAND LOSS, FLOOD DAMAGES ENDANGERING PUBLIC AND PRIVATE PROPERTIES

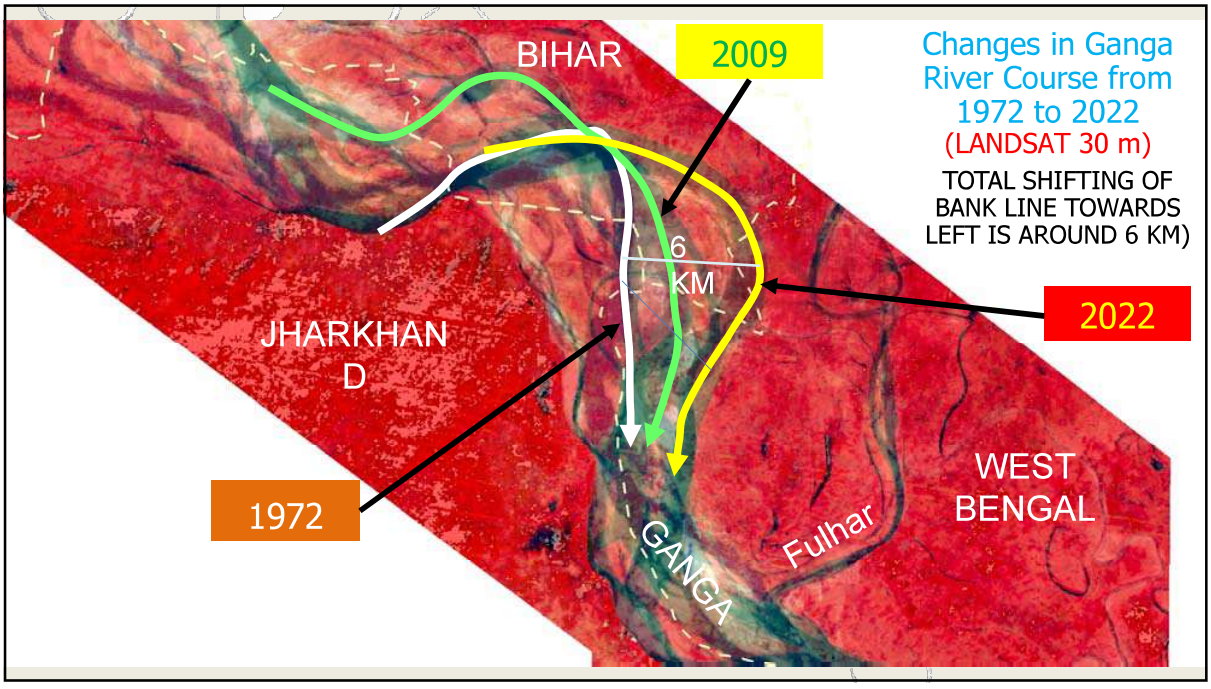
- The river Ganga/Padma has a general tendency to shift towards the left bank upstream of the Farakka Barrage and towards the right bank below the Farakka Barrage.
- Erosion along both banks of the river takes place almost in every year ,mostly during monsoon and even in non-monsoon periods.
- Around 400 SQ KM area adjacent to the river course in 15 blocks and 1 Municipality of 3 districts are the worst sufferer.
- During the period from 2005 to 2021 , almost 3374 hectare of land has been engulfed by the river due to erosion. Such loss of land during 1931-2004 was to the tune of 46,871 hectare. The district wise details are in the next slides.
- The damages to the Public and Private properties due to erosion and flooding during 2005-2021 is to the tune of Rs. 1200 Crore.
- The deposition of mostly cohesion less soil on the entire river bank buttresses the erosion problem.
- Moreover, severe erosion has been observed at immediate d/s of Farraka Barrage during release of flood discharge from the said barrage in monsoon.
- The erosion is still continuing & average 600 hectare of land is engulfed annually by the river in West Bengal.

STATEMENT OF LAND LOSS IN MALDA DISTRICT DUE TO EROSION OF RIVER GANGA

- FROM THE YEAR 1931-1996 ---------- 16861 Hectare
- From the year 1997- 2004 ---------- 2598 Hectare
- From the year 2005-2020 ---------- 1467 hecrare
- From the year 2021-2022 ---------- 297.5 hectare

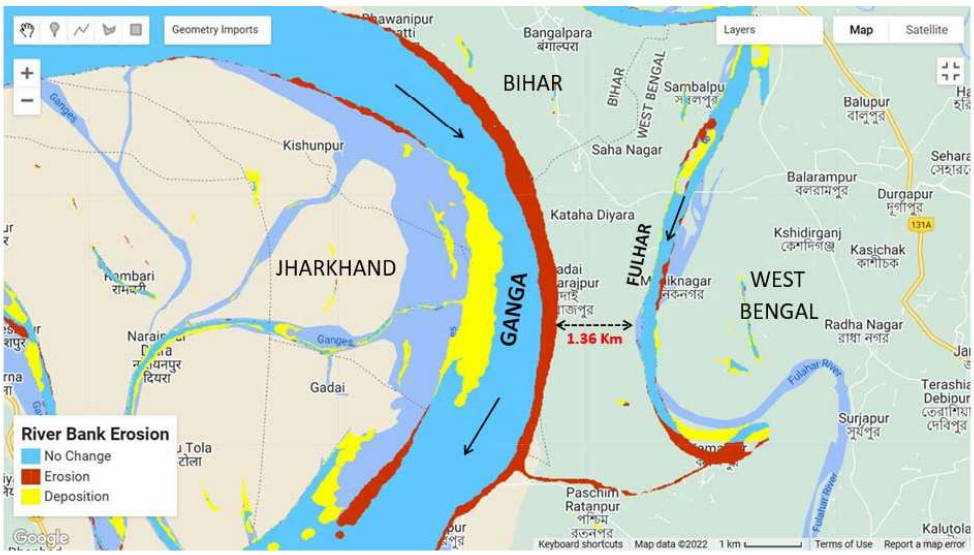
STATEMENT OF LAND LOSS IN MURSHIDABAD & NADIA DISTRICT DUE TO EROSION OF RIVER GANGA

- FROM THE YEAR 1931-1996 ---------- 15990 Hectare
- From the year 1997- 2004 ---------- 11422 Hectare
- From the year 2005-2020 ---------- 1333 hecrare
- From the year 2021-2022 ---------- 276 hectare



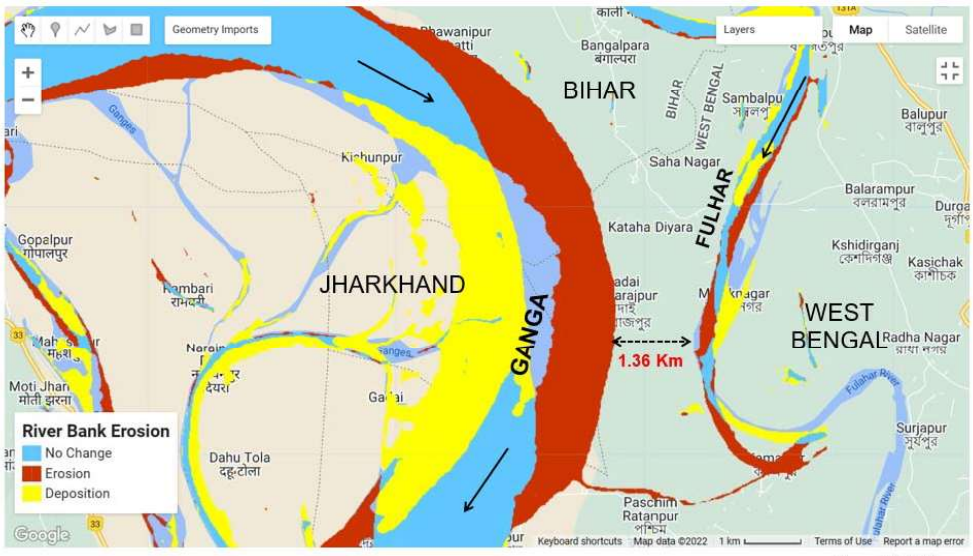
EROSION OF RIVER GANGA BETWEEN NOVEMBER 2021 TO NOVEMBER 2022

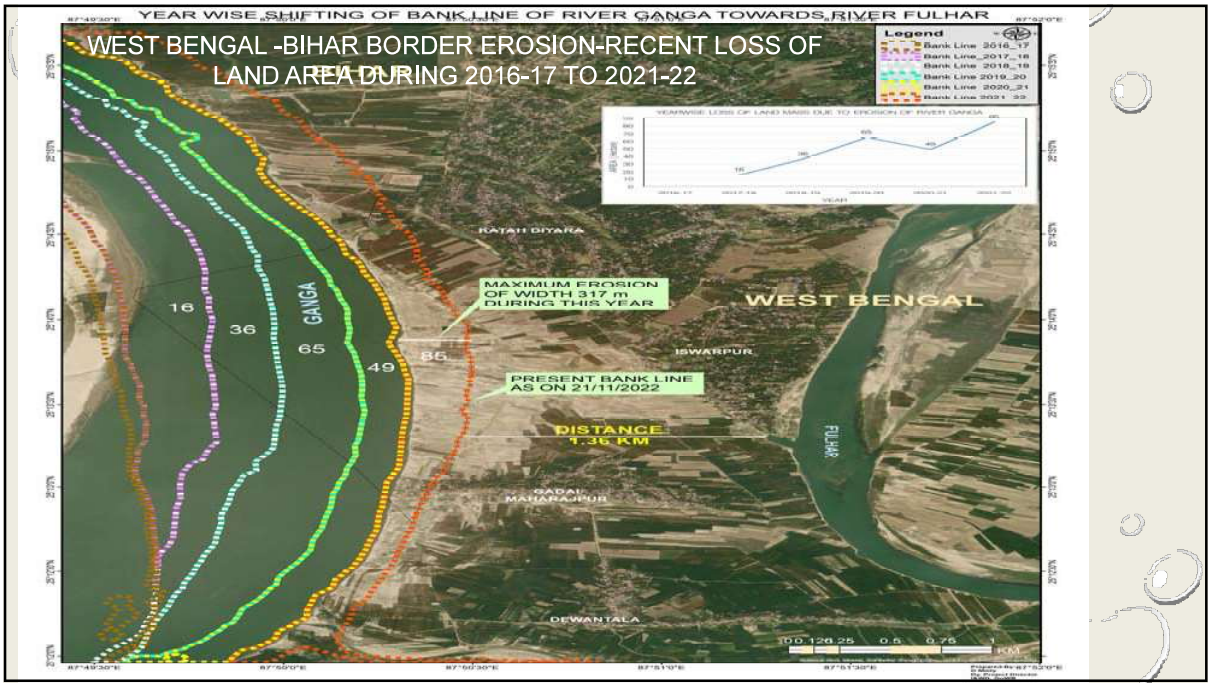
Total Length of Erosion: 11 Km (Within West Bengal (6.00 Km)



EROSION OF RIVER GANGA BETWEEN NOVEMBER 2016 TO NOVEMBER 2022

Total Length of Erosion: 11 Km (Within West Bengal (6.00 Km)





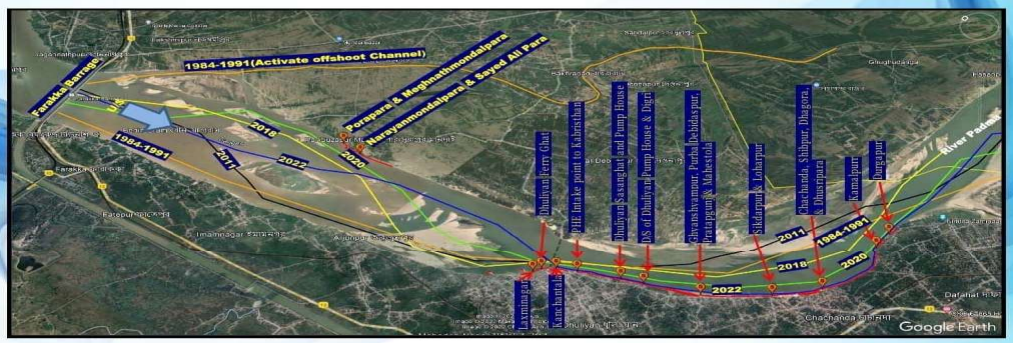
Keshorpur, Bhutni, Manikchak

Photos of erosion in river Ganga at the confluence of Koshi channel

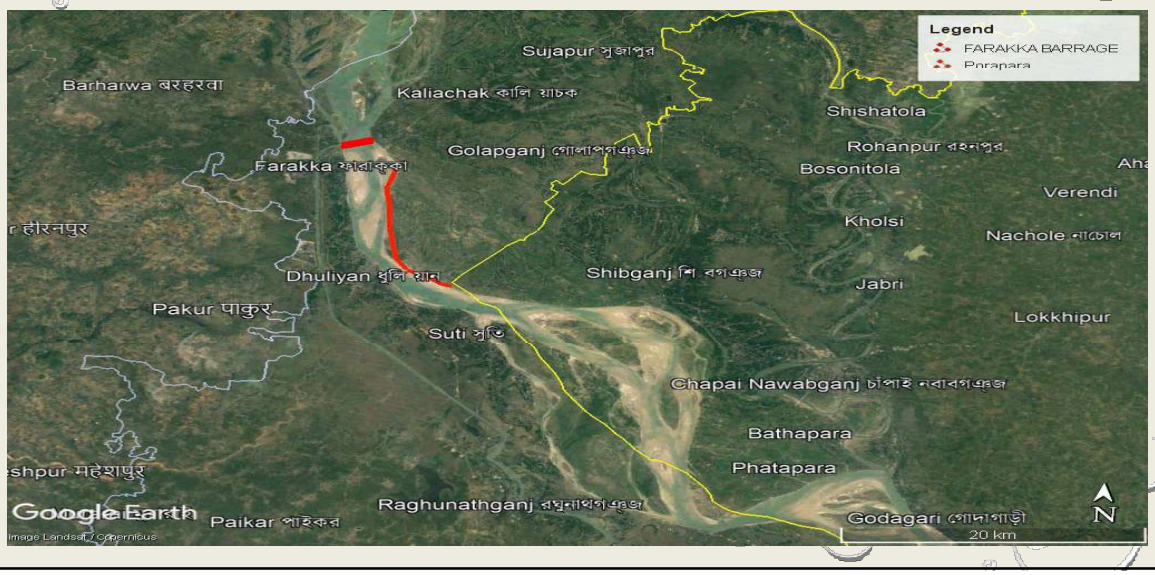
Some Photographs of vulnerable reaches (District: Malda)

Narayanpur, Manikchak

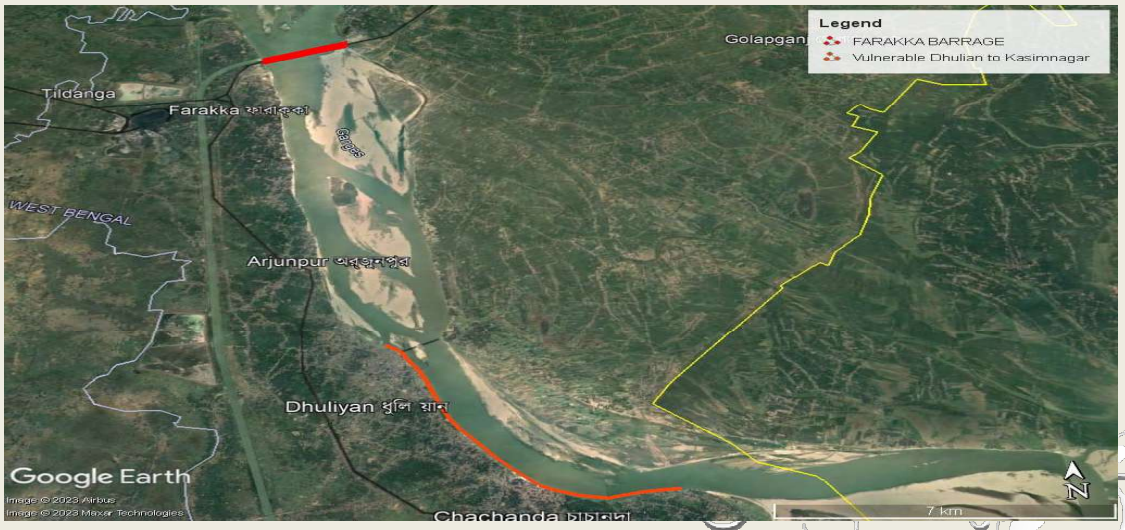
Bank line shifting erosion maps at d/s of Farakka Barrage from 1984 to 2022



GOOGLE MAP OF MOST VULNERABLE REACH AT L/B OF RIVER GANGA IMMEDIATE D/S OF FARAKKA BARRAGE AT PORAPARA



GOOGLE MAP OF MOST VULNERABLE REACH AT R/B OF RIVER GANGA IMMEDIATE D/S OF FARAKKA BARRAGE AT DHULIAN, SAMSHERGUNJ , BAISHNAB MANDIR UPTO KASHIM NAGAR



Golapmondal_Para & Khas Para, Block- Kaliachak-III

Some Photographs of vulnerable reaches (District: Murshidabad)

Purba Debidaspur, under Block & P.S.-Samserganj

Maheshtola ,Block & P.S.-Samserganj

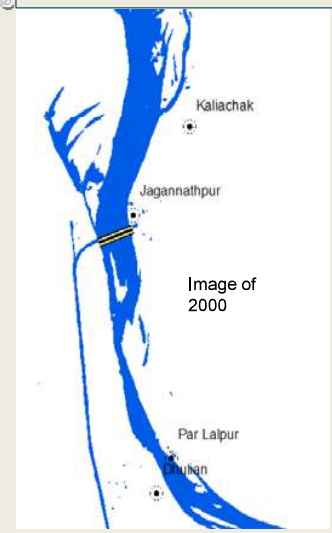
Loharpur, Block & P.S.-Samserganj

Chachanda, Block & P.S.-Samserganj

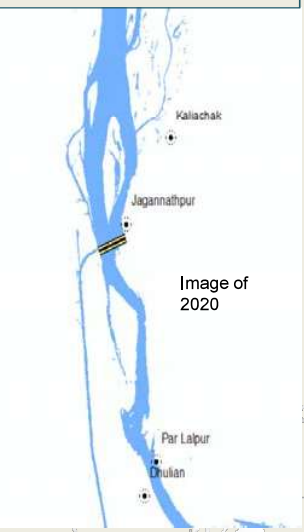
IMMEDIATE CONCERNS

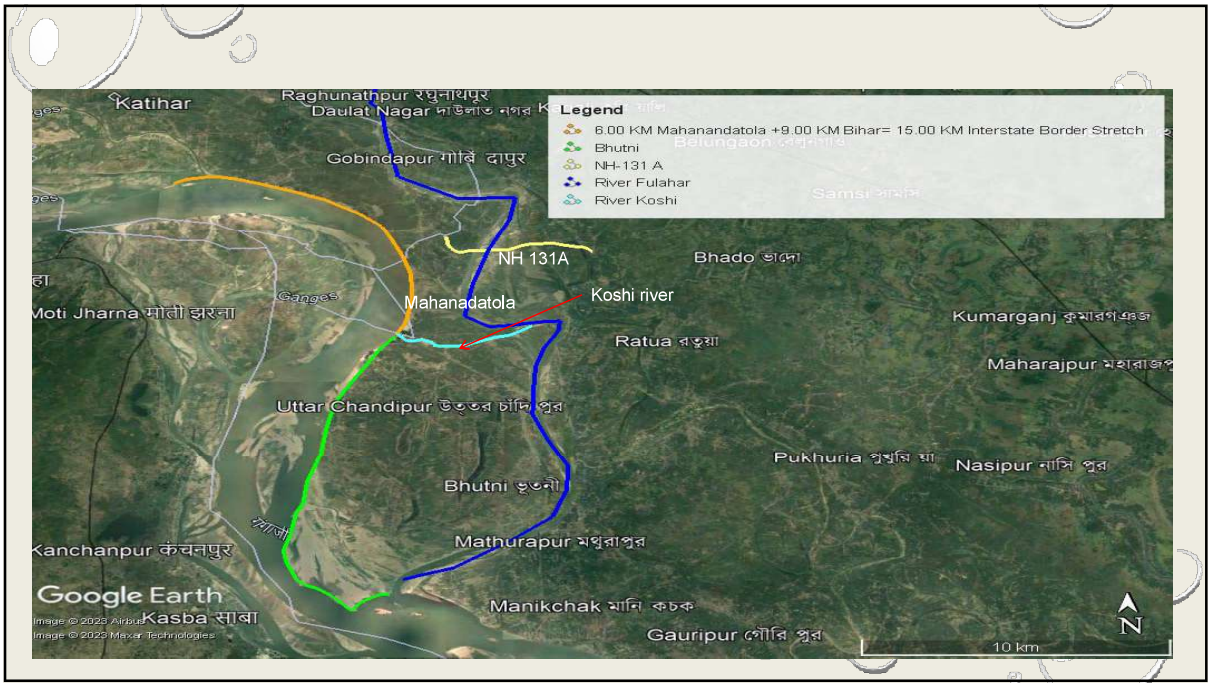
- A stretch of 15 KM (9 KM in Bihar in Katihar + 6 KM in West Bengal in Malda) near interstate border requires taking up anti erosion works simultaneously, having its specifications derived through a joint study under the aegis of GFCC.
- An area of 60 SQ KM , named as Mahanadatola, in Ratua-I block, in between river Koshi, Fulhar , Ganga and Bihar is prone to perpetual river erosion endangering 3 GPs with population of 1.6 Lakh. Moreover the NH 131A, an important connectivity between Bihar and West Bengal, which stretches across this zone, is barely 1.36 KM away from the river bank of Fulhar, which used to be 4.0 KM in 2004.
- Due to complex hydrodynamics at the confluence of Fulhar river at Manikchakghat in Manikchak block of Malda, the adjacent left bank of river Ganga and also a considerable stretch of around 4 KM of Fulhar often experience river erosion and flooding. As a result the entire island named Bhuitnidiara of area 51 SQKM of 3 GPs and population of 1.5 Lakh in Manikchak block is endangered.
- Erosion along left bank in the entire Manikchak and kalichak-I blocks, at the u/s of Farakka barrage, particularly at Binnagar and Porapara is very pronounced.
- Severe erosion occurs at d/s of FB at both the banks at Pallarpur, Dhulian Municipality, Samserganj. At about 13.3 km d/s of FB river with is less than 1 km, whereas the main barrage itself has a length of 2.245 km with 109 Gates having 18.30 m span.
- It is observed from the satellite imageries, the river flow at D/S of the Barrage is concentrated towards the right bank. The Gates should be ideally operated in such a manner that the flow is through the central region of the barrage proper.

FARAKKA BARRAGE GATE OPERATION



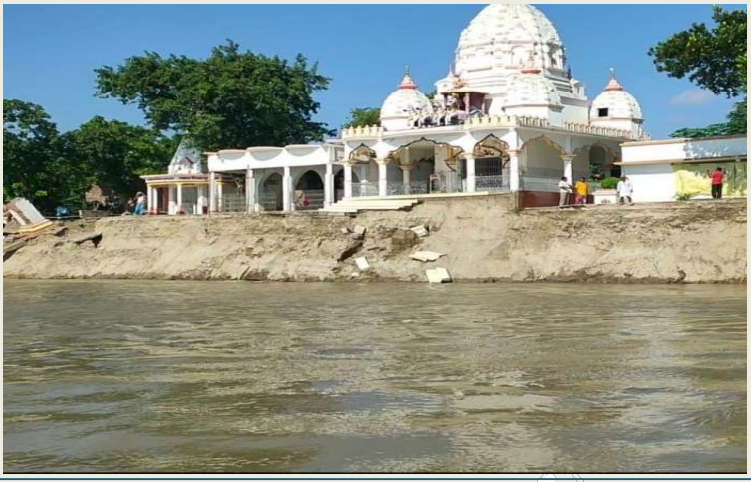
By analyzing the image of Landsat 5 Data of 21st March, 2000 (Left Image) and Landsat 8 Data of 28th March, 2020 (Right Image) it is observed that while water is flowing throughout the gate in 2000 but water is only flowing through right side only in 2020. Gate should be operated in such a manner that the flow is through central region of the river.





Protection work of Radha Gobinda Mandir at Parlalpur in 2018

Parlalpur, Radha Gobinda Mandir, Kaliachak-III



RECENT ACTIVITIES

- A joint site visit, at 15 KM river reach at interstate border with Bihar, was conducted on 05.05.2022 followed by a joint meeting with the officials of West Bengal, Bihar, Farakka Barrage Project Authority.
- As per the discussions of that meeting, West Bengal carried out river survey in 6 KM stretch in West Bengal, designed the specifications of the required anti-erosion works and shared the same with Bihar on 22.09.2022 for obtaining their views. The same is still awaited.
- A consultant has been engaged by the State Government in November, 2022 to carry out a comprehensive study through proper survey, model study and preparation of DPR on the entire 163.50 KM of Ganga river. To facilitate such model study, barrage regulation and release data and report of any previous study by FBPA/CWPRS/CWC were asked from FBPA in May, 2022 and January, 2023. The same are still awaited from FBPA.
- The recent study by Central Design Office, IWD, WB suggests that problem of bank erosion continuing for decades may be deterred if the char land formed near Sahebgunj side in the river Ganga is cut by excavation and or by controlled blasting along the narrow existing flow line of branches of Ganga and the deepest main flow path is shifted.

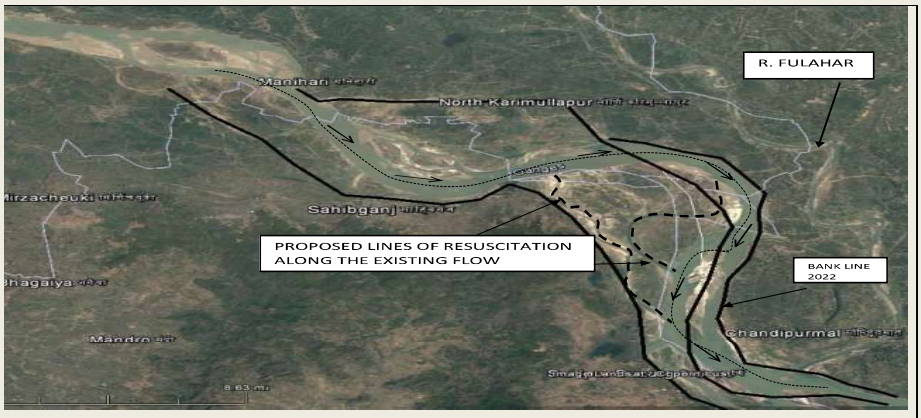
RECENT ACTIVITIES

- River Research Institute, W.B has also conducted a bathymetry and topographical survey of river Ganga and Fulhar at Mahanandatola and Bilaimari area of Block- Manikchak, Dist.-Malda and prepared a comprehensive report in January, 2022. The same may be shared with the Committee if asked for.
- At two locations, Rajmahal and Farakka, river cross section, discharge, gauge, silt data requirement was placed by the Chief Engineer (North), I&W Directorate to the Chief Engineer , CWC Vide Memo No- 999-CI(N) 4D-11/15 Dated 27.12.2022 & Vide Memo No. 62/2 CI(N) 4D-11/2015 Dated 31.01.2023. The same is still awaited.
- GFCC was requested earlier in May, 2022 and again in December, 2022 to take a lead role for coordination between stakeholder states and organizations in formulating a comprehensive DPR of Ganga/Padma erosion abatement both in West Bengal and adjoining stretches in Jharkhand and Bihar. But no response has been received till date.
- Moreover, it has been suggested by a Dutch expert that by providing a cut-off between two flow lines of Ganga at the reach in Jharkhand in Sahebganj, the threat of erosion in that area can be minimized.
- Apart from completing bank protection works at 31 identified vulnerable stretches during the period from 2017-2021 at a cost of Rs. 168.47 Crore, the State Government has also taken up further such works at 14 Kilometre at a total cost of Rs. 80.14 Crore during last one year.

Terms of Reference of the Consultant engaged for "'remedial measures on "Ganga-Padma" erosion abatement in the districts of Malda, Murshidabad and Nadia in the State of West Bengal, India

- **To undertake soil investigation & Survey (bathymetry by ADCP,DGPS& RTK), Total Station (TS) as found to be necessary.**
- **To study the erosion problem by analysing Remote sensing imageries and GIS technique & mathematical Model study considering Farakka Barrage Gate operation.**
- **Assessment of present structural conditions of the various existing damaged infrastructures.**
- **Identification of critically vulnerable components of the existing erosion & flood control infrastructures and suggesting remedial measures by design and analysis.**
- **Preparation of a " Detail Project Report (DPR) for the proposed remedial measures on Ganga – Padma erosion abatement in the districts of Malda, Murshidabad and Nadia" for submission to GFCC .**
- **Preparation of Rough cost estimate of the proposed measures for investment purposes**

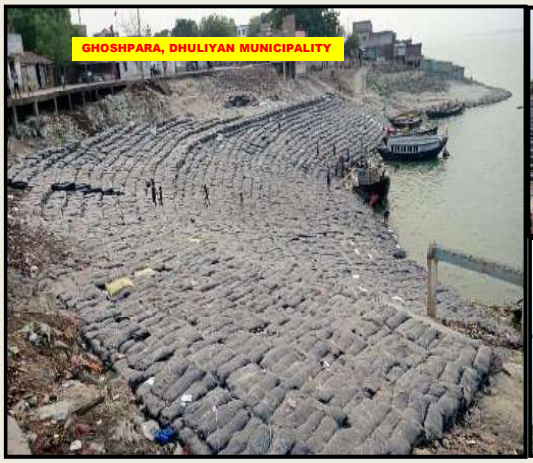
PROPOSED LINES OF RESUSCITATION ALONG THE EXISTING DORMANT FLOW



GOOGLE IMAGE FOR THE YEAR 2022.

Some of the Photographs of Achievements

Some of the Photographs of Achievements



HYDRO METEOROLOGICAL DATA REQUEST BY CE-NORTH, I&W DTE. FROM CE-CWC

Site Name	Type	Frequency	Monsoon From	Monsoon To	Non-Monsoon From	Non-Monsoon To	Data Type
Rajmahal (Seasonal)	Cross	Monthly Average	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified
Rajmahal (Seasonal)	Discharge	Daily	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified
Rajmahal (Seasonal)	Gauge	Hourly	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified
Rajmahal (Seasonal)	Meteorological	Daily	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Unclassified
Rajmahal (Seasonal)	Silt	Monthly Average	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified

HYDRO METEOROLOGICAL DATA REQUEST BY CE-NORTH, I&W DTE. FROM CE-CWC DATED. 27.12.2022

Site Name	Type	Frequency	Monsoon From	Monsoon To	Non-Monsoon From	Non-Monsoon To	Data Type
C.S-97 A , Farakka	Cross	Monthly Average	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified
C.S-97 A , Farakka	Discharge	Daily	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified
C.S-97 A , Farakka	Gauge	Hourly	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified
C.S-97 A , Farakka	Meteorological	Daily	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Unclassified
C.S-97 A , Farakka	Silt	Monthly Average	15/May/1995	31/October/2022	01/January/1995	31/December/2022	Classified

SUBMISSION TO THE COMMITTEE

i. Coordination between Bihar and West Bengal in fixing the specifications of the anti erosion works at 15 KM most vulnerable interstate border stretch with Bengal and Bihar.

ii. Ensuring availability of discharge and other hydro-meteorological data from CWC and FBPA.

iii. Siltation at the bed of Ganga due to Farraka Barrage is a long pending contentious issue. The Report of such earlier study, carried out by CWC/FBPA/CWPRS may be shared with the State Government. However, the CWPRS may also carry out a fresh model study to affirm the causes of siltation, bank erosion. The barrage gate operation may also be reviewed through such study in the background of severe erosion observed at the right and left bank immediate d/s of the barrage.

iv. The suggestion on dredging of river in Jharkhand, as proposed by Dutch expert may be considered.

v. The outcome of the study being carried out by the Consultant will be shared with the Committee to obtain their valuable comments and suggestions.

vi. After finalization of the DPR in next four months the same will be placed before GFCC for recommendation to MOJS, GoI to include the envisaged works under the funding of FMBAP. It would be the endeavor of the State to take up the anti erosion works emerged from the DPR from the next working season with Central funding since such anti erosion works are capital intensive , sometimes to the tune of Rs. 30 crore/KM and very difficult for the State Government to accommodate the same within the State's own budget.

THANK YOU

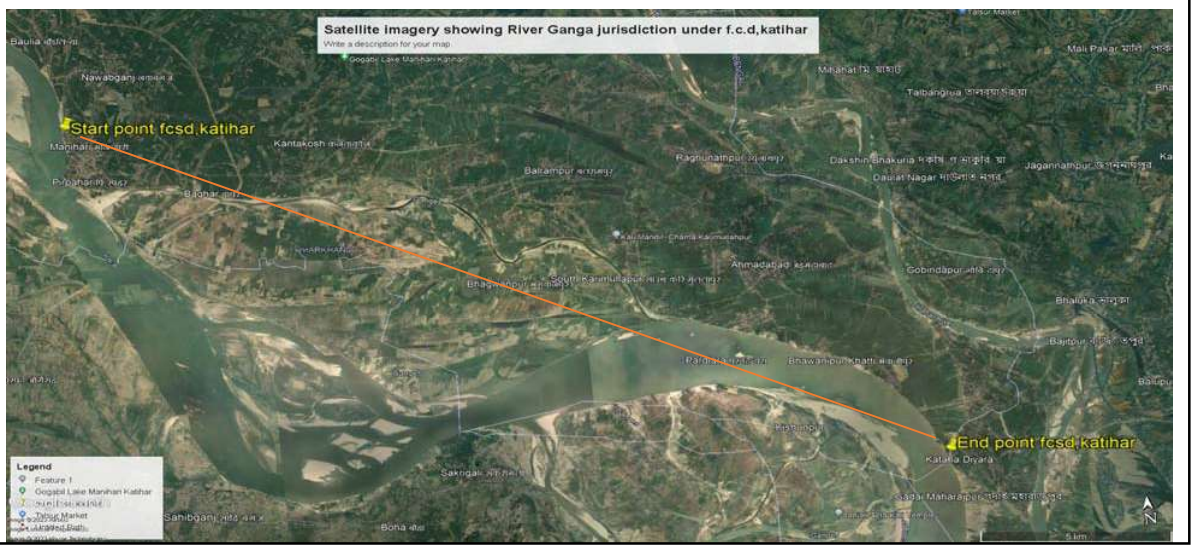
जल संसाधन विभाग,
बिहार

CHIEF ENGINEER
FLOOD CONTROL & DRAINAGE
WATER RESOURCES DEPARTMENT, KATIHAR

PRESENTATION
ON
PROTECTION AND STABILIZATION OF RIVER BANK FROM MEGHU TOLA, JHABBU TOLA, SUBEDAR TOLA, BABLA BANNA TO DINARAM TOLA UP TO WEST BENGAL BORDER ALONG LEFT EDGE OF RIVER GANGA
BLOCK : AMDABAD
DIST : KATIHAR
RIVER : GANGA

RIVER GANGA JURISDICTION UNDER F.C.D,KATIHAR

Under F.C.D, Katihar river ganga start from signal tola (Block – manihari) to Dinaram tola (Block-Amdabad)up to west Bengal Border.



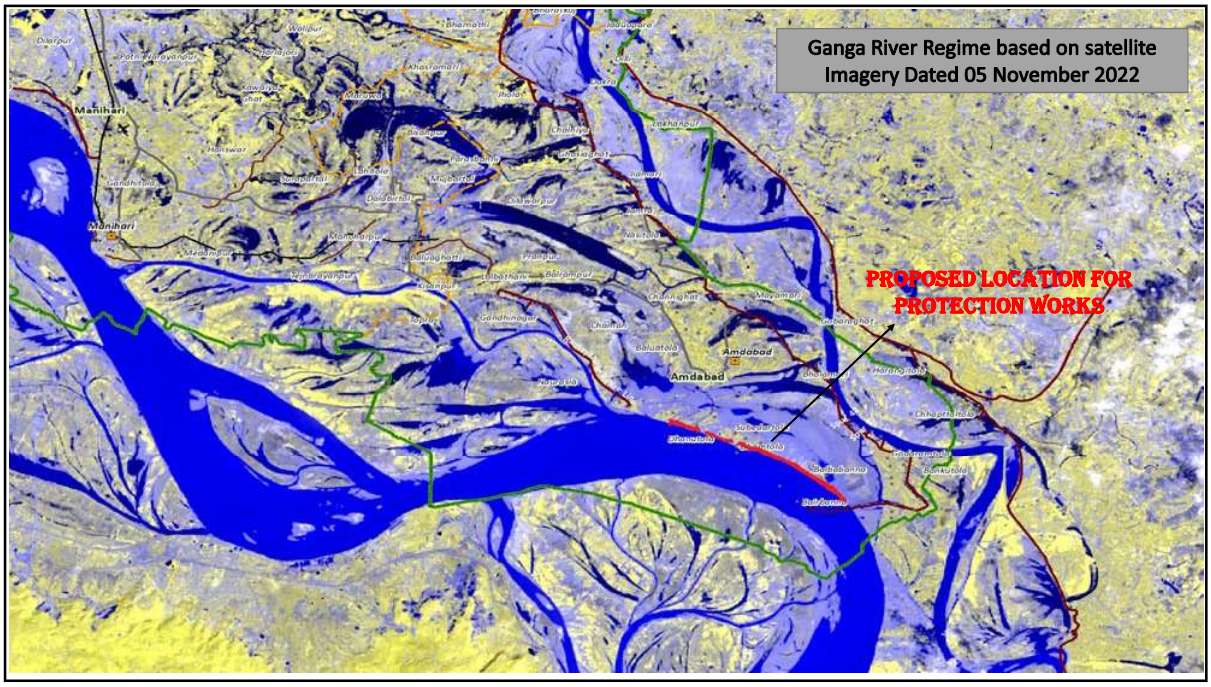
BRIEF HISTORY OF SITE

- Under flood control division, Katihar River Ganga start from Signal Tola (Block:-Manihari)To Dinram tola (Block:-Amdabad) up to West Bengal border.
- From Manihari ship wharf,River splits into two parts. Left part of River Ganga flow through Mednipur, Aazampur,Gola, Kata-Kosh, Ramayanpur, Hardeo Tola, Pardiyara Via Babla Banna up to West Bengal Border,and Right part of River Ganga after Manihari ship wharf, enter in Jharkhand . After covering a distance of about 19 KM through the state of Jharkhand ,it joins the left stream near Hardeo Tola to form the main stream of river Ganga.
- Due to which water pressure increases excessively in this reach. There are 7 thickly populated village's Meghu tola, Jhabbu tola , Kriti tola, Subedar tola, Pardiyar, Yusuf tola and Babla Banna just situated on the left edge of river ganga.
- It is often seen that every year in this reach during the flood period ,many houses and important structure's are eroded due to heavy erosion.

BRIEF HISTORY OF SITE..continued.

In year 2022 Babla Banna was the most affected area by the flood , Where the river has entered 100 metre to 250 metre at a length of 992 metres and a big loop has been formed. Due to formation of this loop about 200 to 250 houses and many important structure like school building road and Masjid eroded at village Babla Banna .

- In D/S of Babla Banna river Ganga reaches very close to the last portion of Mahananda right embankment. In this reach The shortest distance between river Ganga and Mahananda is about 2 km. And it is also observed that since 2016 near cut-end of T.C.P Embankment the Left Bank of river Ganga gradually shifted about 1800 metres towards left.
- **The present scenario in regards with safety of villages and important structure's protection work is essentially required.**



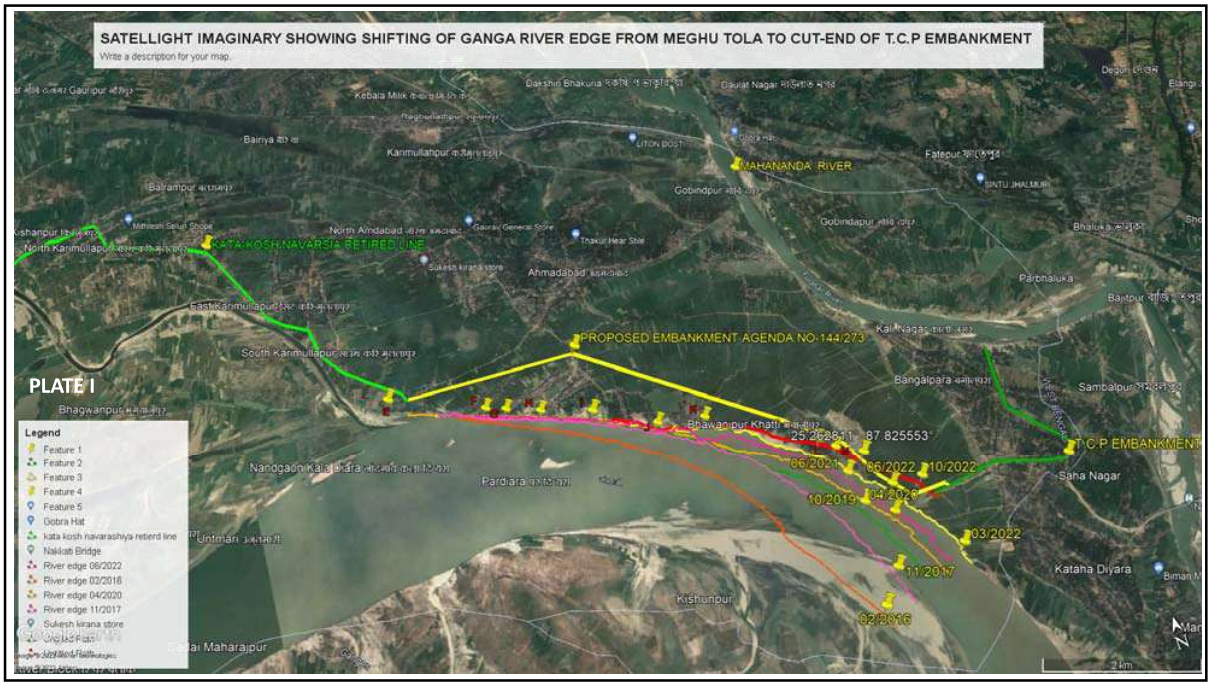
DETAIL OF PREVIOUS ANTI EROSION WORK DONE BY FLOOD CONTROL DIVISION, KATIHAR SINCE 2018

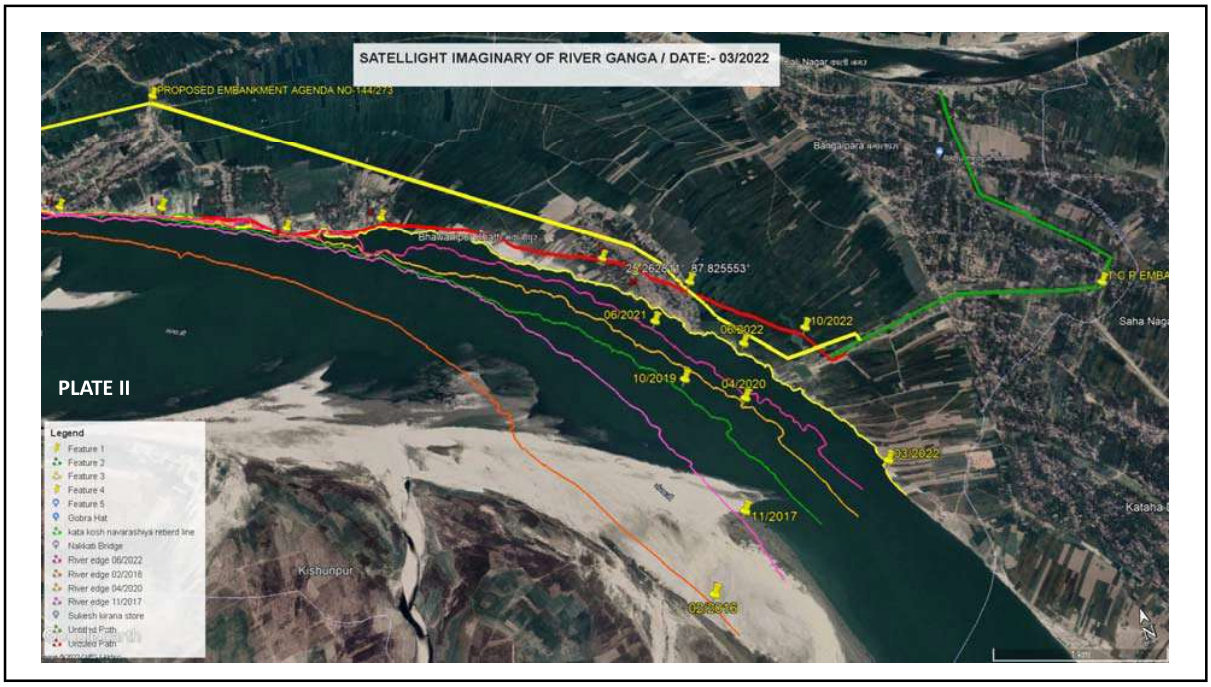
In year 2018 before flood On the Left Bank of river Ganga. Boulder slope pitching with boulder apron (size 22.50 M Wide × 1.2M Thick) work has been done at a length of 6300 meters from Hardeo Tola to Khatti. Out of which the of length of 1500 metre work is Intact/safe and the rest of work is not effective.

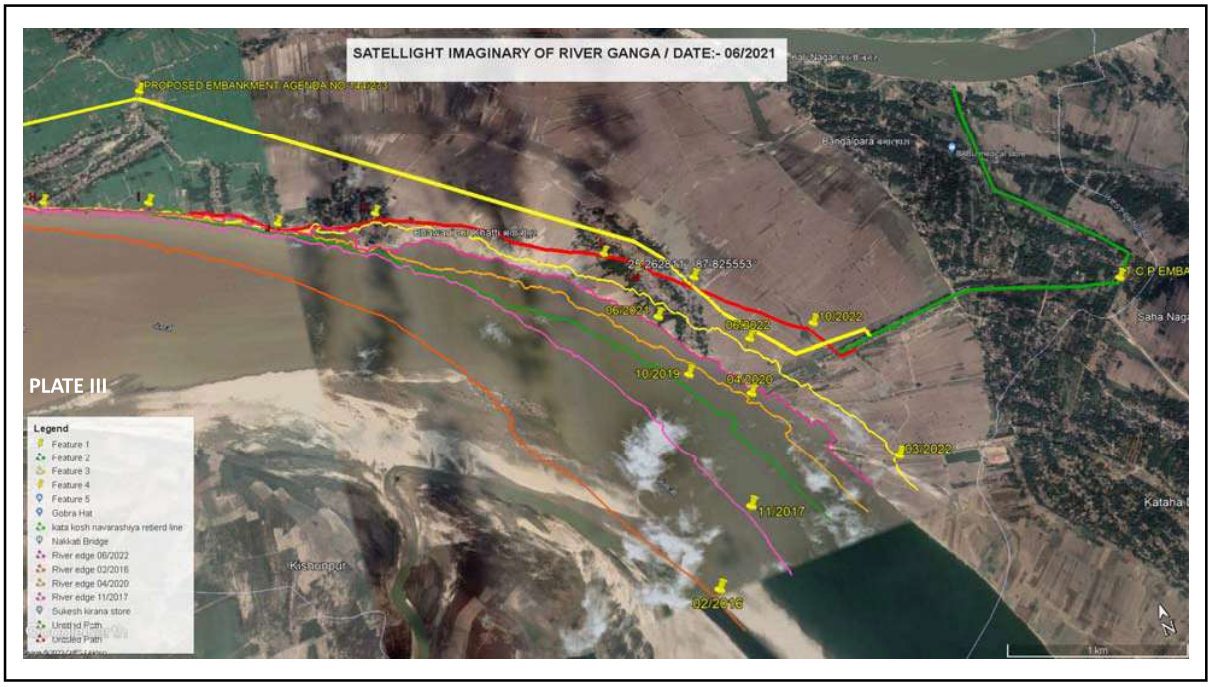
Again before flood 2020 at a length of 6700 metres at Meghu Tola to cut-end of T.C.P Embankment Geobag slope pitching with two row of ballah piling in toe.at has been done whose 1500 meters work is Intact/safe and the rest of work is not effective.

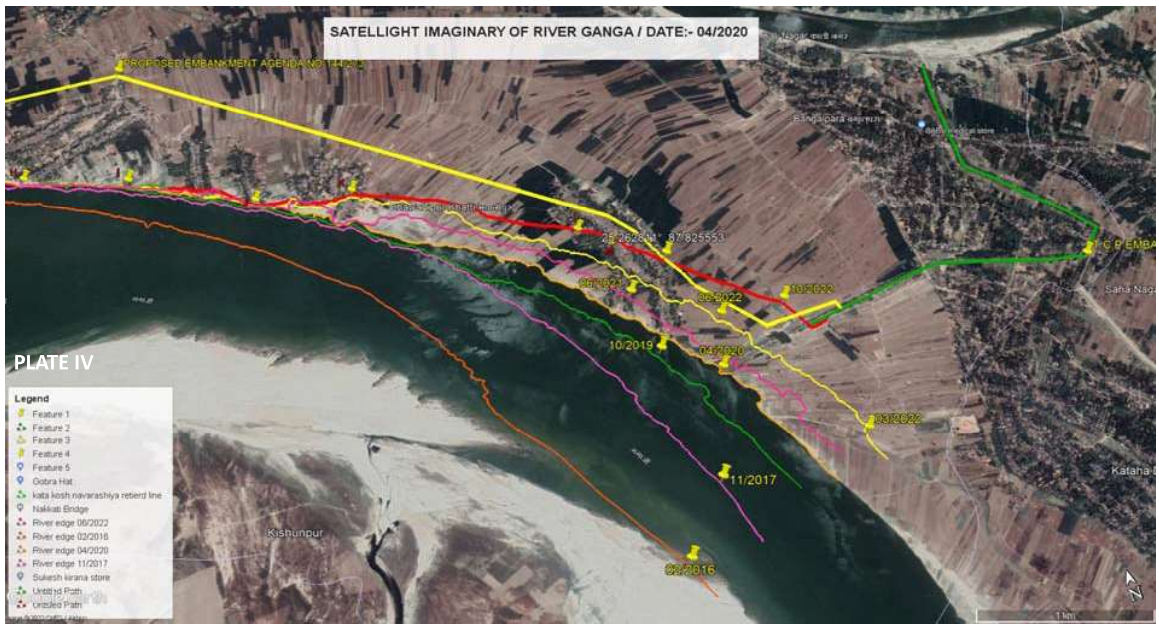
Note:-After 2020, no any anti-erosion work has been done in this reach.

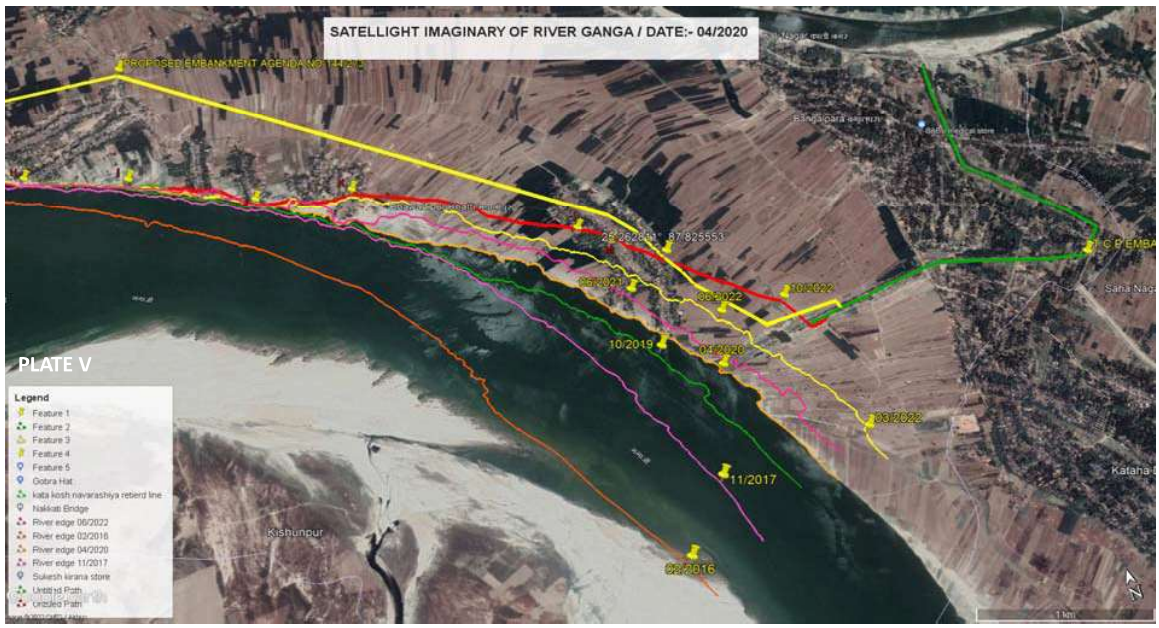
GRADUAL SHIFTING OF RIVER EDGE OF GANGA RIVER IN BETWEEN HARDEV TOLA AND TCP CUT POINT IN LAST 7 YEARS .

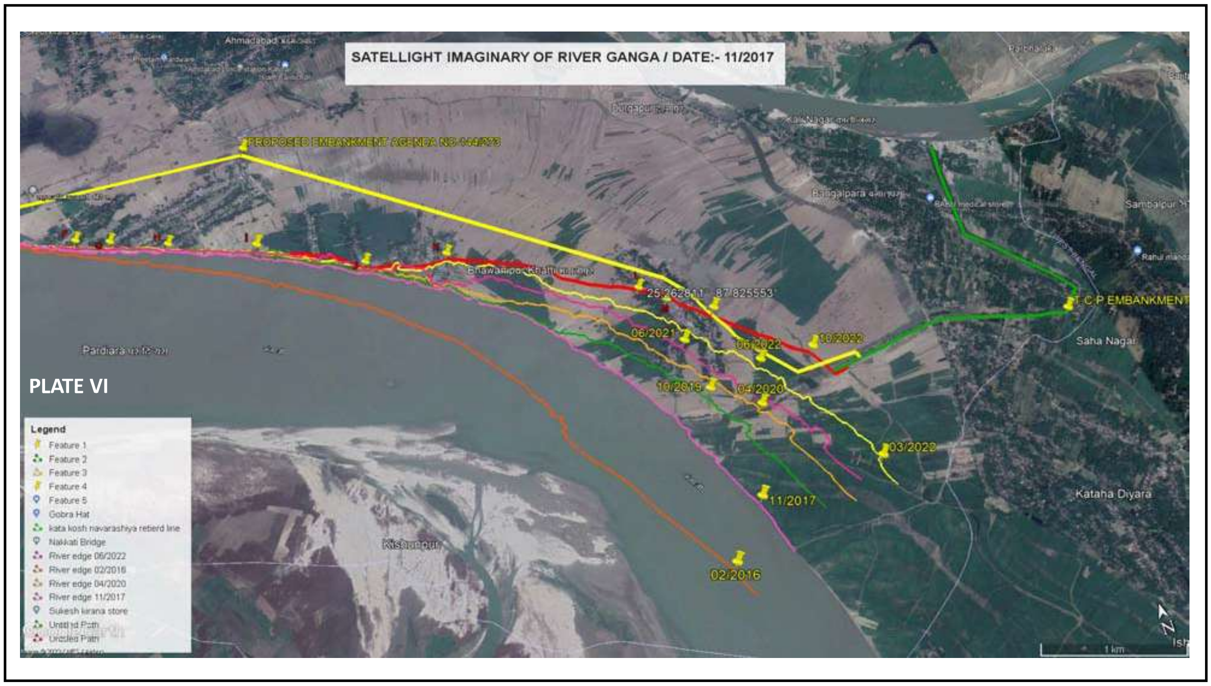


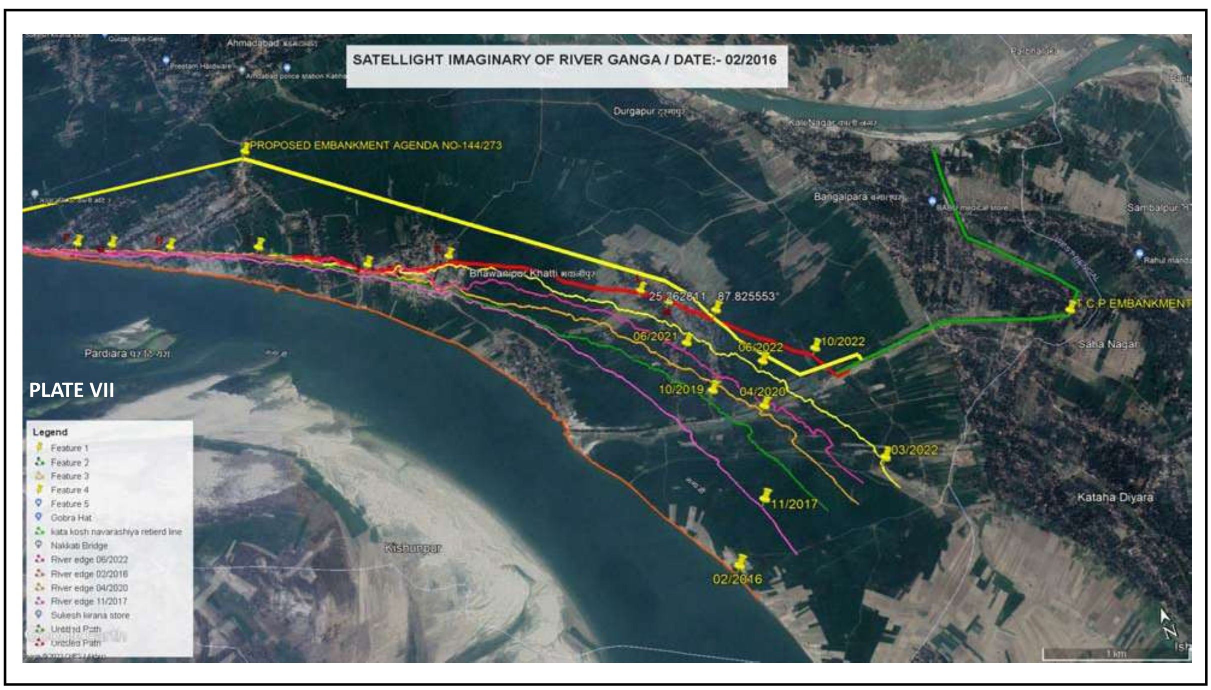

SATELLIGHT IMAGINARY OF RIVER GANGA / DATE:- 03/2022
PROPOSED EMBANKMENT AGENDA NO-1142/23
87.825553'
06/2021
06/2022
10/2022
10/2019
04/2020
03/2022
11/2017
02/2016
Kishunpur
PLATE II
Legend
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Gobra Hat
kata kosh navarashiya retierd line
Nakkati Bridge
River edge 06/2022
River edge 02/2016
River edge 04/2020
River edge 11/2017
Sukesh kirana store
Untitled Path
Untitled Path

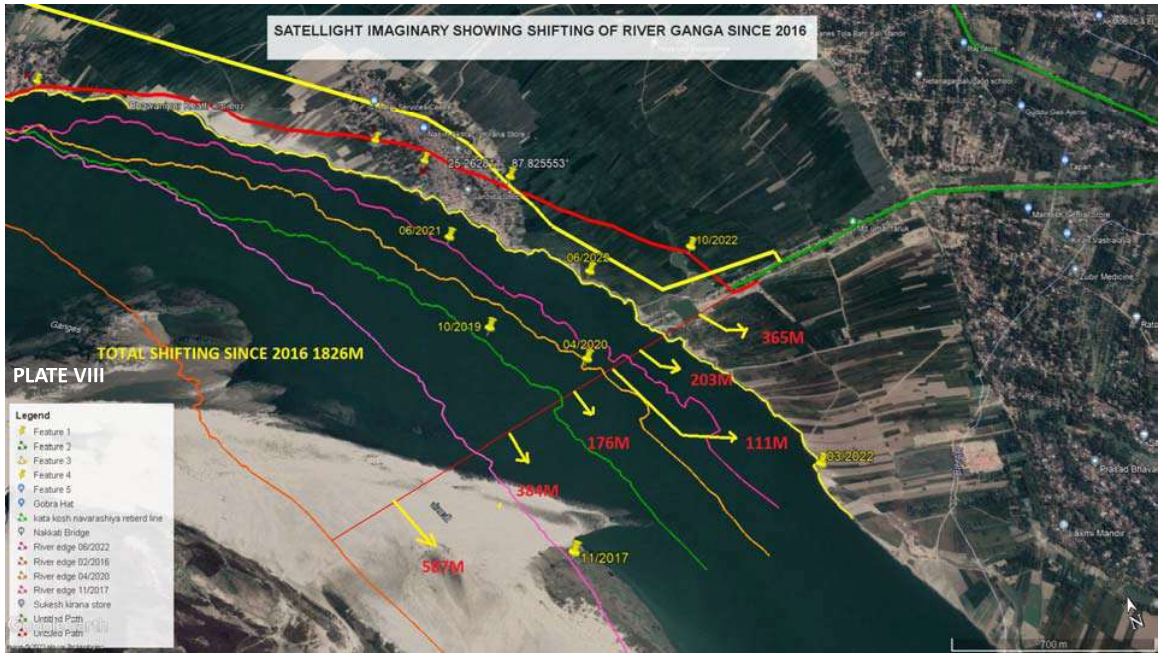

SATELLIGHT IMAGINARY OF RIVER GANGA / DATE:- 06/2021
PROPOSED EMBANKMENT AGENDA NO-1142/23
87.825553'
06/2021
06/2022
10/2022
10/2019
04/2020
03/2022
11/2017
02/2016
Kishunpur
PLATE III
Legend
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Gobra Hat
kata kosh navarashiya retierd line
Nakkati Bridge
River edge 06/2022
River edge 02/2016
River edge 04/2020
River edge 11/2017
Sukesh kirana store
Untitled Path
Untitled Path


SATELLIGHT IMAGINARY OF RIVER GANGA / DATE:- 04/2020
PROPOSED EMBANKMENT AGENDA NO 11/2015
PLATE IV
Legend
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Gobra Hat
kata kosh navarashiya retierd line
Nalkati Bridge
River edge 06/2022
River edge 02/2016
River edge 04/2020
River edge 11/2017
Sukesh kirana store
Untitled Path
Untitled Path
Kishunpur
10/2019
11/2017
02/2016
1 km


SATELLIGHT IMAGINARY OF RIVER GANGA / DATE:- 04/2020
PROPOSED EMBANKMENT AGENDA NO 11/2015
PLATE V
Legend
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Gobra Hat
kata kosh navarashiya retierd line
Nalkati Bridge
River edge 06/2022
River edge 02/2016
River edge 04/2020
River edge 11/2017
Sukesh kirana store
Untitled Path
Untitled Path
Kishunpur
10/2019
11/2017
02/2016
1 km


SATELLIGHT IMAGINARY OF RIVER GANGA / DATE:- 11/2017
PROPOSED EMBANKMENT AGENDA NO-144/273
PLATE VI
Bhawanipur Khatti
25.262811 87.825553
T.C.P EMBANKMENT
10/2022
06/2022
06/2021
10/2019
04/2020
03/2022
11/2017
02/2016
Pardiara
Kishunpur
Saha Nagar
Kataha Diyara
Legend
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Gobra Hat
kata kosh navarashiya retierd line
Nakkati Bridge
River edge 06/2022
River edge 02/2016
River edge 04/2020
River edge 11/2017
Sukesh kirana store


SATELLIGHT IMAGINARY OF RIVER GANGA / DATE:- 02/2016
PROPOSED EMBANKMENT AGENDA NO-144/273
PLATE VII
Bhawanipur Khatti
25.262811 87.825553
T.C.P EMBANKMENT
10/2022
06/2022
06/2021
10/2019
04/2020
03/2022
11/2017
02/2016
Pardiara
Kishunpur
Saha Nagar
Kataha Diyara
Legend
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Gobra Hat
kata kosh navarashiya retierd line
Nakkati Bridge
River edge 06/2022
River edge 02/2016
River edge 04/2020
River edge 11/2017
Sukesh kirana store



DETAILS OF FLOOD FIGHTING WORKS IN LAST THREE YEARS

- FF YEAR 2020 – 95.22 LACS

  MATERIALS USED : E.C BAG, N.C, BAMBOO ROLL

- FF YEAR 2021 – 60.17 LACS

  MATERIALS USED : E.C BAG, N.C, BAMBOO ROLL, B.A. WIRE CRATE

- FF YEAR 2022 – 99.35 LACS

  MATERIALS USED : E.C BAG, N.C, BAMBOO ROLL, B.A. WIRE CRATE

SITE PHOTOGRAPHS OF LAST YEAR FLOOD 2022 OF DIFFERENT LOCATIONS IN BETWEEN HARDEV TOLA TO CUT-END OF T.C.P EMBANKMENT.

PLATE X

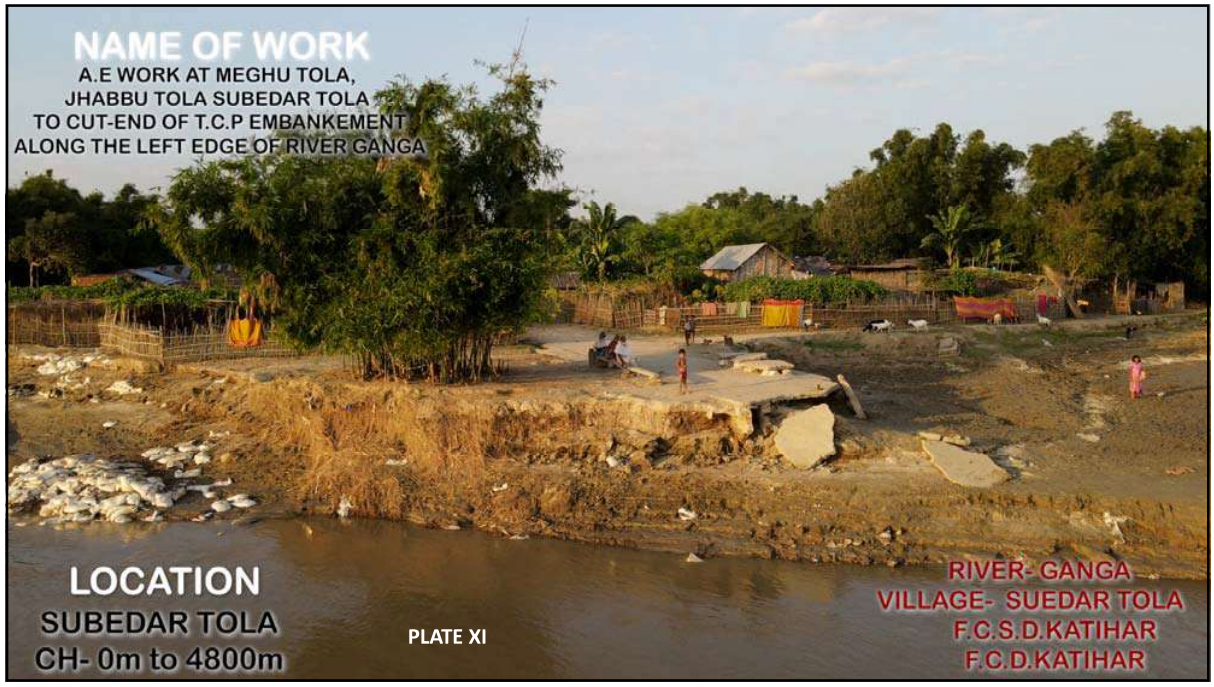


PLATE XI


NAME OF WORK
A.E WORK AT MEGHU TOLA,
JHABBU TOLA SUBEDAR TOLA
TO CUT-END OF T.C.P EMBANKEMENT
ALONG THE LEFT EDGE OF RIVER GANGA
LOCATION
PARDIYARA
CH- 0m to 4800m
PLATE XII
RIVER- GANGA
VILLAGE- PARDIYARA
F.C.S.D.KATIHAR
F.C.D.KATIHAR


NAME OF WORK
A.E WORK AT MEGHU TOLA,
JHABBU TOLA SUBEDAR TOLA
TO CUT-END OF T.C.P EMBANKEMENT
ALONG THE LEFT EDGE OF RIVER GANGA
LOCATION
PARDIYARA
CH- 0m to 4800m
PLATE XIII
RIVER- GANGA
VILLAGE- PARDIYARA
F.C.S.D.KATIHAR
F.C.D.KATIHAR

PLATE XIV

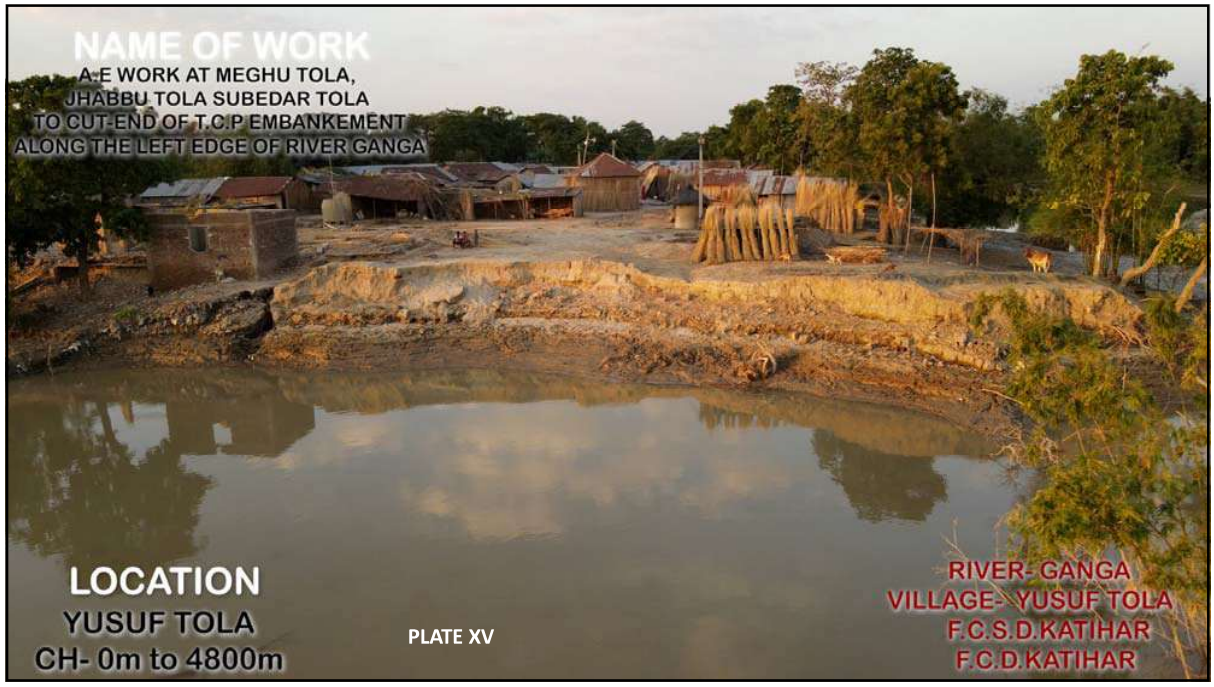


PLATE XV


NAME OF WORK
A.E WORK AT MEGHU TOLA,
JHABBU TOLA SUBEDAR TOLA
TO CUT-END OF T.C.P EMBANKEMENT
ALONG THE LEFT EDGE OF RIVER GANGA
LOCATION
YUSUF TOLA
CH- 0m to 4800m
PLATE XVI
RIVER- GANGA
VILLAGE- YUSUF TOLA
F.C.S.D.KATIHAR
F.C.D.KATIHAR


NAME OF WORK
A.E WORK AT MEGHU TOLA,
JHABBU TOLA SUBEDAR TOLA
TO CUT-END OF T.C.P EMBANKEMENT
ALONG THE LEFT EDGE OF RIVER GANGA
LOCATION
BABLA BANNA
CH- 0m to 4800m
PLATE XVII
RIVER- GANGA
VILLAGE- BABLA BANNA
F.C.S.D.KATIHAR
F.C.D.KATIHAR


NAME OF WORK
A.E WORK AT MEGHU TOLA,
JHABBU TOLA SUBEDAR TOLA
TO CUT-END OF T.C.P EMBANKEMENT
ALONG THE LEFT EDGE OF RIVER GANGA
LOCATION
BABLA BANNA
CH- 0m to 4800m
PLATE XVIII
RIVER- GANGA
VILLAGE- BABLA BANNA
F.C.S.D.KATIHAR
F.C.D.KATIHAR


NAME OF WORK
A.E WORK AT MEGHU TOLA,
JHABBU TOLA SUBEDAR TOLA
TO CUT-END OF T.C.P EMBANKEMENT
ALONG THE LEFT EDGE OF RIVER GANGA
LOCATION
BABLA BANNA
CH- 0m to 4800m
PLATE XIX
RIVER- GANGA
VILLAGE- BABLA BANNA
F.C.S.D.KATIHAR
F.C.D.KATIHAR

PLATE XX

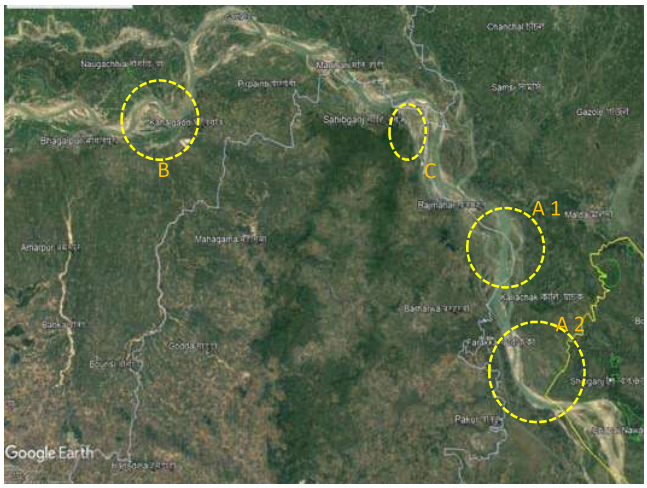
PLATE XXI

THANKS

OVERVIEW OF THE PAST STUDIES CARRIED OUT ON RIVER GANGA

By

CWPRS, Pune



Past studies carried out by CWPRS on river Ganga

A. Studies for river Ganga upstream (A1) and downstream (A2) of Farakka Barrage for Farakka Barrage Project, West Bengal.

B. Studies for river Ganga in the vicinity of Bhagalpur for WRD, Bihar.

C. Studies for river training measures in river Ganga near Maharajpur, Jharkhand for Western railway.

1. Farakka Barrage Project

a) Physical Model

View of 1/80 GS scale Farakka Hydro-electric model

Farakka Barrage

Coffer dam studies for Farakka barrage at CWPRS, Pune

View of 1/500 H & 1/70 V distorted model

- Distorted model of 1:500 H & 1:70 V was constructed at CWPRS in the year 1963.
- Studies related to different stage of construction, provisions of cofferdams were studied in the said model.
-
- 1/80 Geometrically similar model constructed in 1994 for proposed Farakka Hydo-electric Project

1/36 GS scale model of Farakka Head Regulator

Photo-elastic studies for web sheet piles of Farakka barrage

1/45 scale sectional model of Farakka barrage spillway

1/15 GS scale model of Jangipur Navigation lock

Other studies

- Spillways/ under sluice
- Divide wall, guide bunds
- Head regulator, navigation lock
- Jangipur barrage,
- Photo elasticity studies, etc.,

Pre - Barrage studies

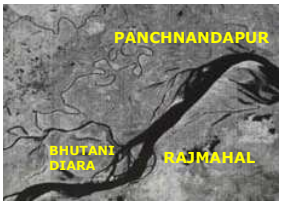
- Bhagmari syphon across Farakka Feeder Canal
- Water availability studies for NTPC Super Thermal Power Plant
- Vibration studies for Farakka barrage road & railways,
- **Total 102 Technical Reports submitted to FBP and other stake holders.**

b) Studies for Planform changes in river Ganga

Upstream of Farakka Barrage

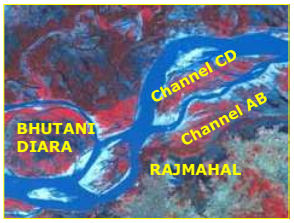
1998

- ❖ Flood of 75,900 cumecs observed in river Ganga in the year 1998
- ❖ Flood spills over Pagla rivers inundated almost of the district in Malda

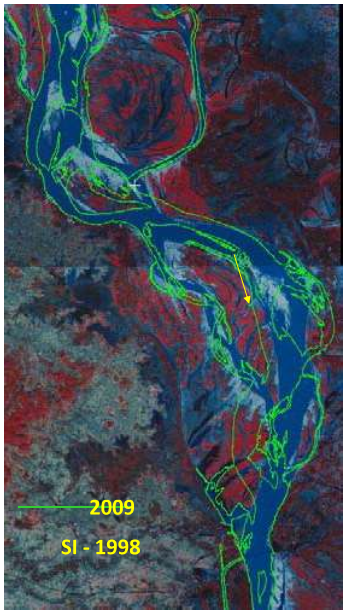


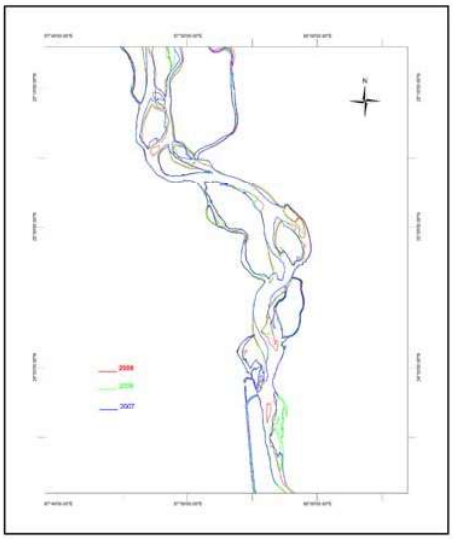
RIVER GANGA - YEAR 1977

RIVER GANGA - YEAR 1988



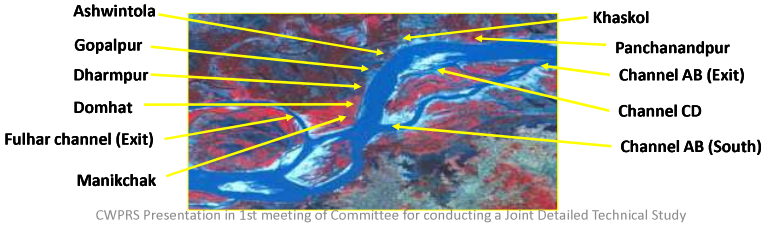
RIVER GANGA - YEAR 1998





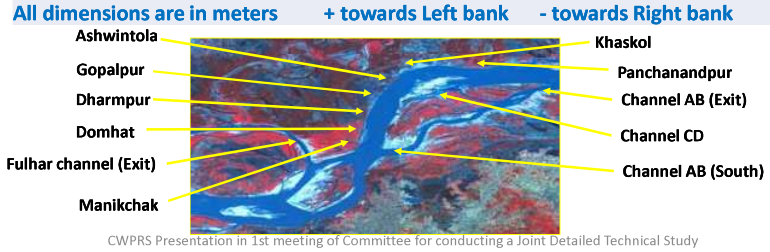
Estimation of Bank line changes at different locations												
Places	1977 to 1988	1988 to 1998	1998 to 2000	2000 to 2001	2001 to 2002	2002 to 2003	2003 to 2004	2004 to 2005	2005 to 2006	2006 to 2007	2007 to 2008	2008 to 2009
Manikchak	293	-166	0	204	114	272	169	34	0	62	116	45
Domhat	943	452	-770	0	201	510	216	146	24	145	0	0
Dharmpur	2005	1106	0	-433	106	231	238	123	78	192	188	56
Gopalpur	3094	1995	112	14	0	0	0	0	0	0	0	0
Aswintola	2056	1877	227	22	14	0	0	0	0	0	0	0
Khaskol	1372	1591	760	65	31	0	0	0	0	0	0	0
Panchanandapur	-376	285	-636	325	34	263	231	0	0	0	0	0
Channel AB (South)	-165	-630	-121	0	0	0	0	0	47	-76	0	-42
Channel AB (Exit)	-1602	-730	586	-54	0	0	-147	-199	57	-151	-106	-23
Channel CD			260	-67	-26	-121	-105	-135	-144	-579	-198	-45
Fulhar channel (Exit)	-511	554	145	-90	-711	65	-196	-108	45	-61	-196	-263

All dimensions are in meters, + towards Left bank - towards Right bank



Estimated Average Annual Rate of erosion at different locations in meter			
Places	1977 to 1998	1998 to 2005	2005 to 2009
Manikchak	6	113	56
Domhat	66	43	42
Dharmpur	148	38	129
Gopalpur	242	18	0
Aswintola	187	38	0
Khaskol	141	122	0
Pachanandapur	-4	31	0
Channel AB (South)	-38	-17	-18
Channel AB (Exit)	-111	27	-56
Channel CD	0	-28	-242

All dimensions are in meters + towards Left bank - towards Right bank



Major findings

- **Studies indicated that the bank erosion near Panchanandpur is halted.**
- **Comparison of satellite imageries from year 1998 to 2009 reveal that the central channel is fully developed presently.**
- **The trend shows that the river has a tendency to attack some portions near Manikchak/Domhat area. Close watch on river behaviour in this area may be kept during flood.**

Downstream of Farakka Barrage

- **Heavy sediment influx collects in a (alluvial) fan (arc) shape**
- **Main channel continue carrying flood**
- **As the discharge increases main channel is unable to carry all the flood**
- **The fan shaped sediment is overtopped at low level point creating a chute flow which carries flow at very high velocity resulting in erosion d/s.**

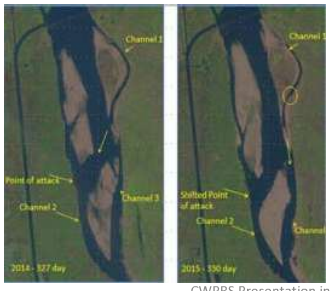
Imagery Used : from USGS site

Dec 1976

Mar 2000

Mar 2003

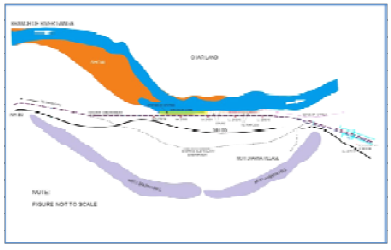
Oct 2013



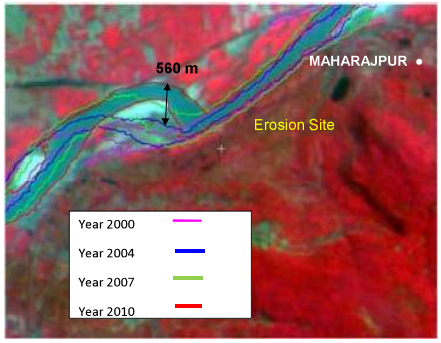
Major findings:

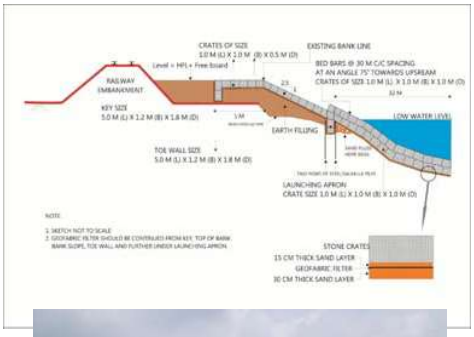
- **Heavy sediment influx created sedimentation along downstream of barrage (After year 1992) due constriction at Dhulian.**
- **During rising floods, the chute channel cause erosions along both the banks.**

2. PLANFORM CHANGES NEAR MAHARAJPUR AND REMEDIAL MEASURES FOR RIVER TRAINING, JHARKHAND



- **In 2011 river Ganga attacked the eastern railway embankment.**
- **Right bank of river reduced the gap between the river edge and the railway embankment (~ 6-12 m)**

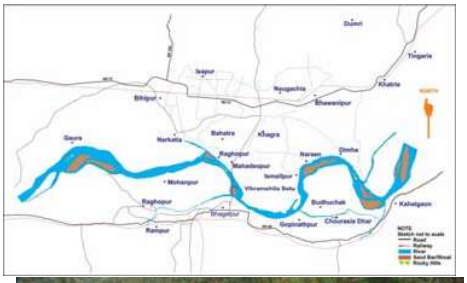


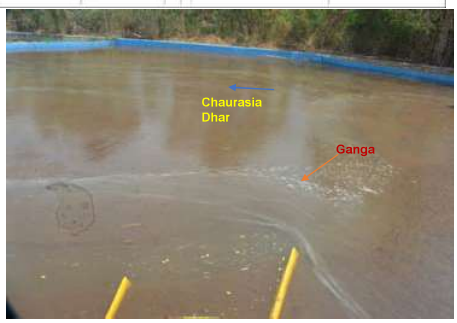


Year 2011

Year 2021

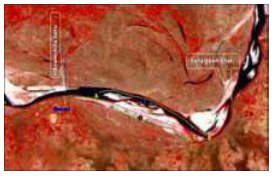
3. PLANFORM CHANGES OF RIVER GANGA NEAR BHAGALPUR for WRD BIHAR

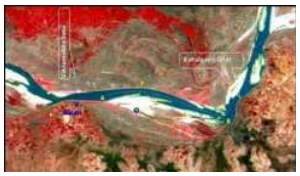


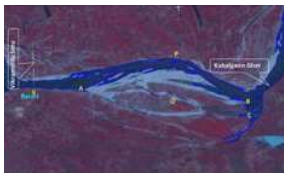


PROTECTION WORKS NEAR BINDTOLI

- **High tortuosity at Bindtoli/ Ismailpur created erosion causing distress to the habitats in the area.**
- **As a river training measures, it was proposed to activate an alternative channel (in the vicinity of Chaurasia Dhar).**
- **Hydraulic model to a scale of 1 : 550 H and 1: 65 constructed to assess the possibility of activation of Chaurasia Dhar.**


Year 1990


Year 1995


Year 2000

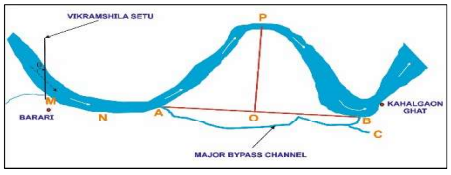

Year 2005


Year 2010


Year 2015


Year 2021

Imagery date	Bypass channel length AOB	River Valley length APB	Distance of apex of river curvature from AOB (=PO)	Ratio of AOB to PO	Arc Chord ratio APB/AOB
	Km	Km	Km		
16.04.90	11	13.55	1.84	5.97	1.23
19.5.95	12.59	13.91	2.01	6.26	1.10
15.9.98	13.49	12.83	2.79	4.83	0.95
17.3.2000	16.14	17.34	4.14	3.89	1.07
3.11.04	13.95	15.42	4.37	3.19	1.10
5.11.05	13.89	15.41	4.81	2.88	1.10
11.1.08	14.25	17.48	5.64	2.52	1.22
16.01.09	14.97	18.67	6.61	2.26	1.24
2.12.09	14.21	17.91	6.56	2.16	1.26
20.2.10	14.03	18.1	6.43	2.18	1.29
10.04.13	12.01	18.09	6.78	1.77	1.50
8.1.14	11.34	18.18	7.02	1.61	1.60
15.5.14	12.38	20	6.73	1.84	1.61
15.3.15	12.32	20	7.05	1.74	1.62
9.4.2016	11.26	21.31	7.2	1.56	1.89
28.4.17	11.66	20.63	7.31	1.59	1.76
8.4.18	11.5	20.72	7.2	1.59	1.80
1.3.19	10.66	21.68	7.2	1.48	2.03
3.3.20	10.62	20.41	7.62	1.39	1.92
15.3.21	10.79	20.73	7.23	1.49	1.91



10-09-2024
CWPRS Presentation in 1st meeting of Committee for conducting a Joint Detailed Technical Study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma river system

Major findings: -

- ✓ **Planform studies based on remote sensing application indicated the activation of Chaurasia Dhar with four alternative channels possible in near future**
- ✓ **Unorganized human interventions, should be stopped.**

Major Lacuna in the studies:

- **Lack of proper data, providing need based solutions based upon expertise and past info.**
- **The studies on existing composite model of 1:500 H and 1:70 V which discontinued since 1998 due to either not referring the studies to CWPRS or non-availability of funds to CWPRS for maintaining the model.**
- **CWPRS has tried to give the technical solutions based on the limited available data and plan form analysis of freely available satellite imageries in the TAC of FBP.**
- **For precise and quantifying morphological outputs, the data such as sediment inflow, rainfall pattern, geotechnical parameters of river banks, yearly bathymetric data, etc., are essential which are very much difficult to acquire with the concerned agencies in addition to the monitory support.**

Thank You

Vision of CWPRS

- **The stretch wise mathematical model for the river Ganga is proposed to be developed after receipt of bathymetric, hydrological, sediment and other relevant data.**
- **This will be integrated with the physical model at CWPRS (40 km upstream and 15 km downstream of Farakka barrage) for the prediction of planform changes in the reach under consideration**
- **The erosion / deposition pattern will be assessed at various locations in river Ganga.**
- **The short term and long term river training measures will be evolved based on the different hydraulic parameters obtained from physical/mathematical model and the assessment of river planform changes.**
- **E-flow quantum based on biodiversity habitat and draft for inland navigation requirement will be assessed.**

Minutes of Second (2nd) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga Padma River System in West Bengal

The Second (2nd) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga Padma River System in West Bengal was held under the chairmanship of Shri Kushvinder Vohra, Chairman, CWC on June 21, 2023 at Sewa Bhawan, New Delhi. The list of participants is appended at **Annexure-I.**

Chairman, CWC welcome all the members and took a brief round of introduction of the members, who joined physically as well as virtually. Thereafter, Chief Engineer (P&DO), CWC and Member Secretary of the Committee appraised the committee of the current status on the action points of the first meeting held on April 06,2023. After that M/s Tractabel Engineering P Ltd was requested to make presentation on the studies undertaken by them.

I. Key Deliberations and Issues

Representative of M/s Tractabel Engineering P Ltd informed that 328 cross-sections have been surveyed, so far in the studied reach. Their bathymetry and topography details have been fully captured. Also, the locations of existing flood control works and their details have been collected during field survey. Moreover, the locations of likely erosion area based on field observations have also been collected. The complete data base is under compilation. They have also analysed satellite images from 1983 to 2023 for the study region. Initial model set up has also been completed. However, based on availability of more data, the model set up will be further refined. Some initial results were also shown. The PPT of M/s Tractabel Engineering P Ltd is attached herewith as **Annexure-II.**

Sh. B Mukherjee, Joint Secretary (Works), I&W Directorate, Govt of West Bengal informed that scope of work also involves sediment analysis. Further he emphasized the need of Farakka data for development of integrated model for understanding its impact on both upstream and downstream.

Sh. Anil Kumar, Chief Engineer, Flood Control and Drainage, Katihar, WRD, Government of Bihar informed that necessary approval is being obtained for the work related to cross section survey for 15 Km (approx.) stretch in the Bihar portion to be under taken by the consultant engaged by West Bengal.

II. Agreed actions and way forward

1. Consultant scope of study includes 68 Km of river Ganga in WB and 15 KM in Bihar in upstream of Farakka barrage. Further it also includes 95.65 Km in West Bengal in downstream of Farakka barrage. The Gate operations parameters shall be integrated with the study.

(Action: Govt of West Bengal/Consultant)

2. Consultant M/s Tractabel to provide an updated inventory of sites for which hydrological data is required. The details may include parameters and duration for which data is required for the studies currently being undertaken by them. The requisition for data shall be provided to Govt of WB who shall be providing requisite undertaking for consideration of CDRC as per guidelines.

(Action: Govt of West Bengal)

3. Consultant shall map all existing anti erosion measures implemented by states in requisite scale and keep an inventory of same as part of study.

(Action: Govt of West Bengal/Consultant)

4. CDRC meeting may be convened urgently to enable sharing of hydrological data with the State Govt of WB immediately once proposal from them is received.

(Action: CWC)

5. The15 Km reach of Ganga lying in Bihar will also be included in the scope of study of consultant for which cross section and bathymetric surveys will be got carried out from the consultant under the terms of existing contract arrangements with G/o WB. The requisite payment issues are being coordinated and settled by G/o Bihar. Pending this, Bihar to formally communicate to G/o West Bengal that consultant may henceforth start completing the field surveys for generation of DEM

(Action: Govt of Bihar)

6. Government of Bihar has already provided annual maximum flows data to consultant M/s Tractabel. They will also provide the time series data requisitioned by consultant urgently.

(Action: Govt of Bihar)

7. Farraka barrage project to provide data of releases from barrage to consultant

(Action: FBP)

8. IWAI informed that they are also carrying out topographical and bathymetry surveys upto Varanasi at interval of 50m c/c. It was directed that this data may also be shared with consultant and CWC.

(Action: IWAI)

9. For the trans boundary reach, where cross section survey work is pending due to clearance issues from BSF and Bangladesh Riffles. It was suggested ministry may request MHA for getting requisite clearances for which proposal shall be forwarded by the GoWB.

(Action: FM Wing)

10. Consultant must include the sediment load transport studies as part of their scope and make such recommendation so that integrated plan to combat threat of erosion is addressed from futuristic considerations.

(Action: Govt of West Bengal/Consultant)

11. The finding of the model developed by M/s Tractabel including its set up will be reviewed by CWPRS. Further, CWPRS may also validate the model outputs based on their existing mathematical/physical model.

(Action: CWPRS)

12. The Report of RMSI on the issue of Flood and Siltation in River Ganga and its Tributaries due to Farakka Barrage in the State of Bihar to be shared with Government of West Bengal for use in present study

(Action: CWC)

ANNEXURE IV C

Minutes of Third (3rd) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma River System in West Bengal

The Third (3rd) Meeting of the Committee for conducting Joint Detailed Technical Study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma River System in West Bengal was held under the Chairmanship of Shri Kushvinder Vohra, Chairman, CWC & ex officio Secretary to Govt of India on November 24, 2023 at Sewa Bhawan, New Delhi. The list of participants is attached at **Annexure-I.**

Chairman, CWC welcomed all the members of the Committee who participated physically as well as virtually. Thereafter, Chief Engineer (P&DO), CWC and Member Secretary of the Committee appraised about the brief background of the study and the agenda wise discussion/deliberation took place during course of meeting. The decisions taken are as under:

Agenda 1: Confirmation of the minutes of 2nd meeting

The minutes of 2nd meeting of the Committee held on 21.06.2023 was circulated among the members of the Committee. No comments/observations were received from the members of the Committee before the meeting as well as during the meeting. The minutes of 2nd meeting as circulated were confirmed .

Agenda 2: Review of the data collection from various sources for the study and follow up on decisions taken during 2nd meeting of the committee

1. FBP has already provided the requisite data comprising of salient features of Farraka barrage, Gate Operation Schedule-1997, 2007 and 2021 etc vide their letter dated 27.10.2023. FBP will also share upstream pond level time series data (for past 10 years), gate position of Farakka Barrage with the Govt of West Bengal/Consultant under intimation to CE(P&D), CWC within 3 days for integration of gate operation in the study.

(Action: FBP/Govt of WB/Consultant)

2. Govt of West Bengal have already shared the latest map/data for all existing anti-erosion measures taken up at least during last 10 years. WB will further share the **planned anti-erosion measures** with the Consultant for mapping. Govt of Bihar and Farakka Barrage Authority

will also share the details of anti-erosion measures being planned in addition those which have already been implemented.

(Action: Govt of West Bengal/Bihar/FBP/Consultant)

3. Cross section and Bathymetric surveys of 15 Km reach of Ganga in Bihar has already been carried out by the Consultant. Necessary payment to the Consultant by Govt of Bihar is under process.

(Action: Govt of Bihar/Consultant)

4. IWAI will share the latest topographic and bathymetric survey data with the consultant within 3 days for integration in the study.

(Action: IWAI/Consultant)

5. Cross section survey work is pending for the India-Bangladesh trans-boundary reach for want of permission from competent authority despite matter having been taken up with BSF & MHA. Comm(FM), DoWR, RD & GR will expedite the required permission by taking up the matter with the concerned office.

(Action: FM Wing, DoWR, RD & GR)

6. All data required for the sediment load transport studies has been received and the same has been included in the study. Consultant will share the studies performed so far with CWPRS & CWC immediately. CWPRS & CWC will review it and proovide feedback for further improvement.

(Action: Consultant/CWPRS/CWC)

Agenda 3: Review of progress of study by the consultant

1. Various data collected have been analysed. HEC-based 1D 2D modelling for sedimentation and critical parameters for planning of anti-erosion measures has been developed separately for upstream and downstream reaches. Remote Sensing based morphological changes has also been completed. Identification of measures is in progress. Consultant may also explore to set up single model for both u/s. barrage and d/s reaches. The model been set-up may also be reviewed by CWC/ CWPRS and suggestions thereto incorporated within next week. **(Action:**

Consultant)

2. Consultant will explore modelling for prediction of change in behaviour of the river in future if the proposed structural work is taken up both from the perspective of hydro and sediment dyanamics. Such scenario prediction may not only focus in the existing erosion-prone reaches but beyond these reaches possibly for entire reach in study. **(Action: Consultant)**
3. Consultant may adapt the model beyond planning and design of anti-erosion measures. The studies may focus on studying the river behaviour with present stage of existing interventions for future years, appropriately incorporating planned measures and their progressive impact on river behaviour. **(Action: Consultant)**
4. Consultant has to consider flow data of Kosi at Kursela alongwith Ganga at Azmabad & Fulhar at Labha upstream of Farakka . Government of West Bengal will request CWC through online data portal for providing discharge data of Kosi at Kursela HO site. CWC will convene special CDRC online meeting for approval of the request on priority.

(Action: Govt of WB/CWC)

Agenda 4: Time extension for the committee to submit its report

Committee felt that the joint study is complex in nature involving various agencies from State and Central Govt. Data acquisition for the study involves various stakeholders is taking time and lot of technical consultation from CWC and other agencies are required. In view of this and progress made by the Consultant, it will require alteast 6 months to complete the study. Accordingly, extension upto 31.03.2024 may be requested from the competent authority.

(Action: CWC)

Meeting ended with a vote of thanks to the Chair.

ANNEXURE IV D

Minutes of Fourth (4th) Meeting of the Committee for conducting Joint Detailed Technical study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma River System in West Bengal

The Fourth (4th) Meeting of the Committee for conducting Joint Detailed Technical study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma river system in West Bengal was held under the Chairmanship of Shri Kushvinder Vohra, Chairman, CWC & ex-officio Secretary to Govt of India on March 22, 2024 at Sewa Bhawan, New Delhi. The list of participants is attached at **Annexure-I.**

Chairman, CWC welcomed all the members of the Committee who'd joined physically as well as virtually. Thereafter, agenda wise discussions took place during course of meeting. The decisions taken are as under:

Agenda 1: Confirmation of the minutes of 3rd meeting

The minutes of 3rd meeting of the Committee held on 24.11.2023 was circulated among the members of the Committee. No comments/ observations has been received from the members of the Committee before the meeting as well as during the meeting. The minutes of 3rd meeting as circulated are accordingly confirmed .

Agenda 2: Review of progress of study by the consultant and follow up on decisions taken during 3rd meeting of the committee

1. Farakka Barrage Project has shared all the requisite data like salient features of Farraka barrage, Gate operation schedule, upstream pond level etc with the Govt of West Bengal & Consultant for integration in the study.
2. Govt of West Bengal and Bihar has shared the existing and planned anti-erosion measures with the consultant for mapping in the project. Farakka Barrage Project has also shared the executed as well as planned anti-erosion measures within their jurisdiction.
3. Govt of Bihar has informed that payment for cross-section and bathymetric surveys of 15 Km reach of Ganga lying in Bihar has been made to consultant.
4. Consultant has informed that study has already been carried out with the available topographic and bathymetric survey data from various sources. Therefore, data from IWAI will not be required.
5. DO letter regarding cross-section survey work in the trans-boundary reach has been issued on 08.12.2023 by Commissioner (FM), DoWR,RD&GR. However, it emerged that obtaining permissions from Bangladesh may take some time. In absence of such permission and survey data, Consultant proposed to utilize the SRTM sourced information or information from other credible source so that progress of studies are not affected. The same was accepted.
6. Consultant has informed that they have already shared their models/studies with CWPRS & CWC. Two separate meetings were held with concerned officials from

CWC and CWPRS respectively on 19.12.2023 and 02.02.2024 towards improvement of model. Observations of CWPRS on the model set-up were explained and discussed. Consultant informed that observations of CWPRS communicated in two separate tranches have already been complied and assimilated. The observations would be taken into consideration while finalsing the model set-up.

(Action: Consultant/CWPRS/CWC)

7. Consultant has also informed that they have submitted the draft preliminary project report identifying erosion-prone reaches and suggesting mitigating measures along with cost estimate with Govt of West Bengal. It was decided that this draft report will be finalized once studies are accepted by committee.

(Action: Consultant/CWPRS/CWC)

7. Consultant has informed that HEC 1D, 2D hydrodynamic and sedimentation modelling has been done for the project. He informed that the model is showing good results during flood season (up to October). However, the result during lean season is not accurate because the same Gate operation schedule has been used during flood and lean season. The result may improve after adding different operation schedule during flood and lean season. It was decided that consultant will set-up 1-D integrated model for the project incorporating the Farakka barrage duly calibrated during flood season, as the model results during flood season are satisfactory. This model will be validated and calibrated using available data at CWC HO sites. Two separate 2-D model will be developed one u/s from the Farraka barrage and one d/s of the barrage. All these models will be vetted in consultation with CWC and CWPRS modellers by 30th April 2024.

(Action: Consultant/CWPRS/CWC)

8. Consultant has informed that predictive modelling for probable change in behaviour of the river morphology in future if the proposed structural works are taken-up both from the perspective of hydro and sediment dynamics is not feasible with available knowledge and processing capabilities which was also confirmed by CWPRS. Morphological studies conducted by CWC for 15 rivers through IIT's/NIT's also could not provide predictive analysis as regard to erosion prone reaches.
9. Discharge Data of Kosi at Kursela was requested by Government of West Bengal for incorporation in the model. CWC has provided discharge data (only two years data available) after taking concurrence in 61st CRDC meeting held on 05.12.2023.
10. The tenure of Committee was extended up-to 31st March 2024 vide DoWR, RD & GR (FM wing) OM dated 27th Dec 2023 along with additional TOR *"To review the original jurisdiction of Farakka Barrage Project as regards to undertaking anti-erosion / river bank protection works, and to examine the need (if any) for extending this jurisdiction"*, as requested by State Govt. of West Bengal. It was decided that this ToR will be discussed separately in smaller group consisting of Commissioner (FM), FBP, Govt of West Bengal.

(Action: CWC/FBP/WB/ FM Wing, DoWR, RD & GR)

11. The field visit of the Committee will be undertaken in due course for which Govt of

West Bengal may inform their convenience.

(Action: CWC)

Agenda 3: Time extension for the committee to submit its report

Committee felt that the joint study is complex in nature involving various agencies from State and Central Govt. Data acquisition and examination for the study involves various stakeholders taking time and lots of technical consultation from CWC and other agencies are required. Moreover, additional ToR has been assigned to the Committee while giving extension up to 31.03.2024 which required extra effort. In view of this and progress made by the consultant, it will require at least 3 months to complete the study. Accordingly, extension up to 30.06.2024 may be requested from the competent authority.

(Action: CWC)

Meeting ended with a vote of thanks to the Chair.

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ANNEXURE IV E

Minutes of Fifth (5th) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga Padma River System in West Bengal

The Fifth (5th) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga Padma River System in West Bengal was held under the chairmanship of Shri Kushvinder Vohra, Chairman, CWC & ex officio Secretary to Govt of India on May 16, 2024 at Sewa Bhawan, New Delhi. The list of participants is attached at **Annexure-I.**

Chairman, CWC welcome all the members of the committee who joined physically as well as virtually. Thereafter, agenda wise discussion/deliberation took place during course of meeting. The actionable decisions taken are as under:

Agenda 1: Confirmation of the minutes of 4th meeting

The minutes of 4th meeting of the Committee held on 22.03.2024 was circulated among the members of the Committee. No comments/observations were received from the members of the Committee before the meeting as well as during the meeting. The minutes of 4th meeting is accordingly deemed to be confirmed as circulated.

Agenda 2: Review of progress of study by the consultant and follow up on decisions taken during 4th meeting of the Committee

1. Data from various agencies i.e. Farakka Barrage Project, Govt. of West Bengal, Govt. of Bihar, CWC etc has been shared with the Consultant and is sufficient for carrying out the work as confirmed by the Consultant.
2. The total reach of study is approx. 179 km (164 Km in West Bengal and 15 Km in Bihar) divided into four sub-reaches i.e. Reach-A (from Sakrigali to confluence of Mahanada and Ganga -45 Km), Reach-B (from Mahananda- Ganga confluence to Farakka Barrage -38 Km), Reach-C (from Farakka barrage to Nimtita -23 Km) and Reach-D (from Nimtita to Jalangi -73 Km).
3. As a follow up of 4th meeting, integrated 1-D model from Sahibganj (Jharkhand) upto Hardinge Bridge (Bangladesh) approx. 268 Km

incorporating Farakka Barrage (extended beyond Bhagwangola (West Bengal)) is calibrated and validated for three years during 2017-2019 at sites Ramayanpur (G-Bihar), Rajmahal (G-Bihar), Manikchak (G-Bihar), Farakka u/s Pond level (FBA), Farakka Downstream (GD-CWC), Nimtita (G-WB), Nurpur (G-WB), Geria (G-WB)and Rajshahi (G-Bangladesh-Literature) for monsoon months. Moreover, two separate 2-D model are also developed, one for upstream of Farakka (Sahibganj to Farakka Barrage) and another for downstream of Farakka Barrage (Farakka Barrage to Hardinge Bridge). The models were found to be broadly in order except minor modifications based on the observations of CWPRS & CWC modelers.

4. CWPRS pointed out that in 1-D model at chainage 45448m of Reach-A, river cross section appears inadequate resulting in formation of vertical wall of 7m and restricting water spread on the left bank. It is also seen that in 1-D model manning 'n' value in some places is taken as 0.014 which seems to be very low. Normally, Manning's 'n' value for open alluvial channels are greater than 0.02. The consultant will review the cross section and manning 'n' value.

(Action: Consultant/CWPRS/CWC)

5. Cross-section data in 1-D model for extended section i.e. Nimtita upto Hardinge Bridge (Bangladesh) has been extracted from SRTM DEM of Year 2015-16 duly corrected with satellite images of March 2024 deepest channel/thalweg alignment and river width. As pointed out by NRSC, consideration of two data sets of different periods without knowing erosion and deposition in between, may be put as a limitation.

(Action: Consultant)

6. Simulated water level from 1-D and 2-D model at chainage 41956m and -19876m on 2nd Oct 2019 presented to be matching. It was desired that at known critical chainages, comparison of time series simulated water level from 1D & 2D may checked to ensure validation of 2D model wrt validated 1D model. Further, validation of water spread area in 2D model may be got verified by Government of West Bengal through ground verification in addition to satellite based inundation maps which consultant has already done.

(Action: Consultant/WB)

7. It came to know that a bridge is under construction downstream of the Farakka Barrage which should be included in the model using required data as available with or to be collected from NHAI by Govt of West Bengal.

(Action: Consultant/WB)

8. Draft preliminary project report identifying erosion-prone reaches and suggesting mitigating measures along with cost estimate submitted by the consultant to Govt of West Bengal would be reviewed by the committee, once model is accepted and Preliminary Report is updated according to the model's output.

(Action: Consultant/CWPRS/CWC)

9. Analysis in critical reaches to determine the velocity profile and the position of the thalweg line, assessing the severity of the issues posed by the river may be carried out from model output. The analysis will be key inputs for proposed anti-erosion measures.

(Action: Consultant/WB)

10. Morphological studies carried out by CWC for the rivers of West Bengal may be shared with Govt of West Bengal for their reference.

(Action: CWC)

11. The field visit of the committee will be taken up after accepting the model and examining the updated preliminary report. Govt of West Bengal will share a tentative itinerary for consideration of the committee.

(Action: CWC/WB)

Agenda 3: Meeting of CWPRS and CWC modellers with consultant

It was decided to schedule an in-person meeting of the consultant with CWPRS and CWC modellers next week preferably on 22nd May 2024 (FN) to finalize and freeze the 1-D and 2-D models, taking into account the modelling limitations and striving for optimal accuracy. Participation from the Government of West Bengal in this meeting will be via video conferencing. As desired, the reports and updated models may be shared once again with CWPRS & CWC modellers for review and sharing their valuable suggestions by email latest by 21-05-2024 for necessary action by the consultant before next meeting on 22nd May 2024.

(Action: CWC/CWPRS/WB/Consultant)

Meeting ended with a vote of thanks to the chair.

Minutes of Sixth (6th) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga Padma River System in West Bengal

The Sixth (6th) Meeting of the Committee for conducting joint detailed technical study to formulate an integrated plan to combat threat of erosion posed by Ganga-Padma River System in West Bengal was held under the Chairmanship of Shri Kushvinder Vohra, Chairman, CWC & ex-officio Secretary to Govt of India on September 3rd, 2024 at Sewa Bhawan, New Delhi. The list of participants is attached at **Annexure-I.**

At the outset, Chairman, Central Water Commission, extended a warm welcome to the Committee members who'd joined physically as well as virtually. It was informed that the draft report of the Committee has already been circulated to all Members of the Committee. Accordingly, all the members were requested to give their suggestions, if any, on the Draft Report.

Detailed deliberations were held on the contents of the report. Some suggestions were offered which are as below:

1. Government of West Bengal indicated some minor corrections regarding the reach of the river mentioned, certain clarifications/ modifications in the recommendations etc. of the Draft Report.
2. Government of Bihar, suggested to incorporate that the mitigation measures proposed in the Bihar portion. Further that these measures in the 6km reach in West Bengal from Bihar border may be carried out in coordination amongst Bihar, GFCC and West Bengal.
3. GFCC suggested that discussion on the non-structural measures may also be incorporated in the report. However, the Committee was of the view that many nature based recommendations have been incorporated in line with the ToR of the Committee.
4. The FCA Dte, CWC observed that velocity obtained from mathematical models, exact period for which the performance scores have been calculated, additional assumptions may also be included in the Draft Report.

After due deliberations, the Committee decided to incorporate above suggestions appropriately. Subject to above, Committee accepted the Report as final.

In his concluding remarks Chairman, CWC expressed his appreciation for the co-operation and contribution of all the members of the Committee in providing all input, data, reports, finalization of model and formulation of the report. Chairman further commended the Committee Members for

fulfilling the tasks outlined in the Terms of Reference (ToRs) of the Committee. He also commended the CWC team and the Consultant for their efforts in data interpretations and performing the various studies and finalizing the report as per the discussion in the Committee meetings.

Meeting ended with a vote of thanks to the chair.

ANNEXURE-V

Analysis of Manning's Coefficient 'n' as observed in River Ganga at Azmabad

The analysis of data for Manning's Coefficient 'n' as observed in River Ganga at CWC site Azmabad was carried out for monsoon and non-monsoon period for the year 2021, 2022 and 2024 respectively is as below.

2021 (Manning's n)												
Date	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1	0.038	0.038	0.043		0.056	0.036			0.016		0.021	0.027
2	0.052	0.039	0.042			0.031	0.029	0.024	0.015		0.021	0.027
3		0.041	0.042		0.057	0.031	0.026	0.021	0.016			0.026
4	0.042	0.04	0.039		0.053	0.033	0.026		0.013			0.025
5	0.043	0.041	0.044		0.058	0.033	0.027					
6	0.04	0.043	0.044	0.045	0.05		0.027		0.017	0.015		0.026
7	0.04			0.051	0.051	0.035	0.027	0.017	0.019	0.016		0.026
8	0.045	0.04	0.044	0.05	0.041	0.036			0.016	0.017	0.022	
9	0.041	0.041	0.045	0.057		0.039	0.026	0.016	0.02	0.017	0.023	0.027
10		0.044		0.056	0.052	0.037	0.027		0.02			
11	0.04	0.043	0.052		0.059	0.039		0.016	0.019	0.018		0.027
12	0.042	0.043	0.049	0.049	0.039				0.019	0.017	0.023	
13	0.042	0.044	0.046	0.049	0.052		0.025		0.019	0.018	0.024	0.028
14	0.045			0.049								0.028
15			0.048	0.056	0.069		0.027		0.019		0.025	0.027
16	0.042	0.043	0.048	0.048		0.043	0.026		0.019	0.022	0.024	0.027
17		0.042	0.045	0.05	0.054	0.038			0.019			0.026
18			0.046		0.054	0.032	0.026		0.02	0.02		0.029
19	0.039	0.039	0.05		0.053	0.016	0.027				0.024	
20		0.044	0.047		0.052		0.028	0.014	0.018		0.024	0.028
21				0.047	0.06	0.026			0.016	0.023		
22	0.041	0.041	0.049	0.047	0.055	0.021	0.027		0.017	0.024	0.025	
23		0.044	0.046			0.021	0.027		0.016	0.023	0.024	
24		0.046	0.044		0.05	0.021	0.028	0.014	0.016		0.025	0.03
25	0.04		0.046	0.05	0.4	0.021		0.013		0.021	0.026	
26			0.044	0.05		0.022	0.026	0.014		0.02		
27			0.05	0.048	0.039		0.025	0.016		0.019		0.029
28	0.039			0.054		0.021	0.025	0.015		0.02		0.03
29	0.042			0.053	0.047		0.024			0.02		
30			0.054	0.049				0.016		0.019	0.024	
31			0.047		0.044		0.025	0.016				0.02

2022 (Manning's n)								
Date	**Mar**	**April**	**May**	**June**	**Jul**	**Aug**	**Sept**	**Oct**
1	0.03	0.041		0.03	0.03	0.03	0.03	0.03
2	0.03	0.036	0.03		0.03	0.03	0.03	
3	0.03			0.04		0.03	0.03	0.03
4		0.034	0.03		0.03	0.03		
5		0.038			0.03	0.03	0.03	
6			0.03	0.04	0.03	0.03	0.03	0.024
7	0.03	1.018	0.03		0.03		0.03	0.026
8		0.039		0.04	0.03	0.03	0.03	0.025
9		0.039	0.03	0.03	0.03		0.03	
10	0.03		0.03	0.04		0.03	0.03	0.022
11	0.03	0.037	0.03	0.04	0.03	0.03		0.018
12		0.037	0.03		0.03	0.03	0.03	0.017
13		0.034	0.03		0.03	0.03	0.03	0.018
14			0.03	0.04	0.03		0.03	
15				0.03	0.03		0.03	
16		0.039			0.03	0.03	0.03	0.022
17				0.03		0.03	0.03	
18					0.03	0.03		0.02
19	0.03	0.035	0.03		0.03	0.03	0.03	
20		0.039	0.03	0.04	0.03	0.03	0.03	
21	0.03	0.036	0.047	0.04	0.03			0.03
22	0.03			0.04	0.03	0.03		0.03
23	0.03		0.045	0.04	0.03	0.03		
24			0.046	0.038		0.03		
25	0.03			0.038	0.03	0.03		0.03
26	0.03	0.037	0.039		0.03	0.03		0.03
27		0.037	0.041	0.04	0.03	0.03		0.03
28	0.03		0.038		0.03			0.03
29				0.04	0.03	0.03		0.03
30	0.03			0.04	0.03			
31	0.03					0.03		

2024 (Manning's n)			
Date	**Jan**	**Feb**	**Mar**
1		0.021	0.012
2		0.013	0.014
3		0.014	
4			0.013
5	0.012	0.013	0.013
6	0.012	0.013	0.013
7		0.012	0.014
8		0.012	
9		0.012	0.011
10	0.011	0.014	
11			0.013
12		0.013	0.013
13		0.012	0.014
14		0.011	0.014
15			0.014
16		0.012	0.014
17	0.012	0.013	
18	0.018		
19	0.014	0.013	
20	0.013	0.012	
21		0.012	
22	0.01	0.016	
23		0.012	0.013
24	0.002	0.013	
25	0.022		
26		0.01	0.013
27	0.023	0.013	0.013
28		0.01	0.014
29	0.026	0.012	
30	0.014		0.014
31	0.012		

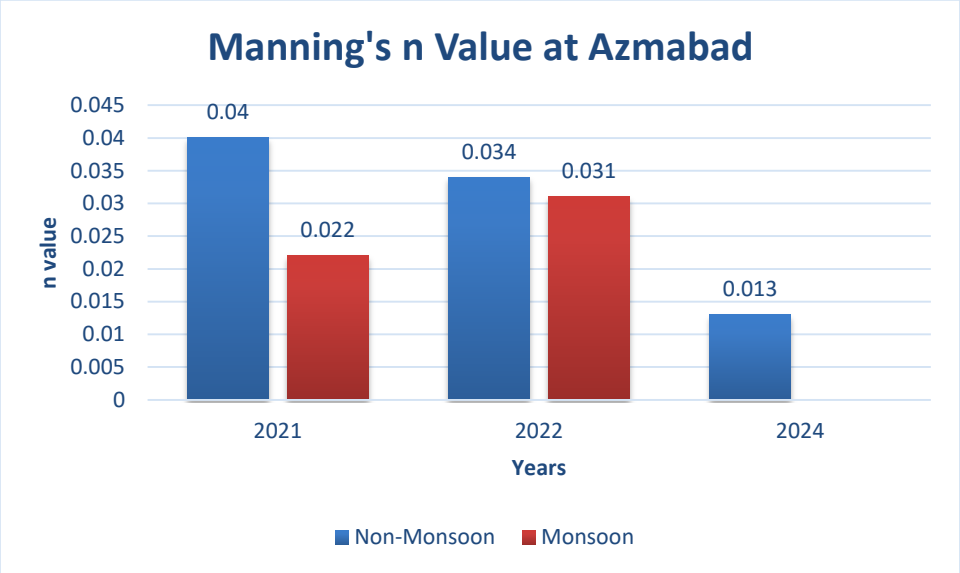


Fig: Plot of Manning's 'n' value as observed at CWC site Azmabad in monsoon and non-monsoon period

It is observed that the value of the Manning's coefficient 'n' varies from 0.013 to 0.04.

RATUA 1 REACH

Design HFL, LWL, Velocity and Discharge Intensity for different design discharge for Ratua 1 Reach

Design Parameters- Farakka Upstream								
River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s (Baseline)		Design Discharge Intensity, m2/s (Baseline)	
		100 years Return Period	50 years Return Period		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Ratua Reach	81470	30.388	29.900	21	2.29	2.29	55.49	52.54
	80732	30.380	29.892	21	2.15	2.15	32.04	30.52
	80080	30.374	29.892	21	1.95	1.95	30.33	39.00
	79272	30.365	29.892	21	2.57	2.57	26.12	25.02
	78437	30.357	29.892	21	2.51	2.50	27.14	26.10
	77442	30.346	29.892	21	2.58	2.57	29.79	28.74
	76742	30.339	29.848	21	2.19	2.17	29.31	28.26
	76003	30.302	29.811	21	2.33	2.31	28.43	27.43
	75177	30.260	29.769	21	2.37	2.35	33.83	32.70
	74280	30.215	29.724	21	2.26	2.24	41.51	40.28
	73318	30.166	29.675	21	2.32	2.32	40.90	39.96
	72371	30.119	29.628	21	1.81	1.80	36.42	35.47
	71528	30.076	29.585	21	2.12	2.11	40.42	39.88
	69788	29.989	29.498	21	2.53	2.52	55.29	54.46
	69198	29.959	29.468	21	2.76	2.74	58.81	57.82
	68631	29.930	29.439	21	2.70	2.68	59.42	58.24
	68150	29.906	29.415	21	2.51	2.48	52.78	51.63
	67563	29.876	29.385	21	2.53	2.52	50.94	49.92
	66986	29.847	29.356	21	2.32	2.31	42.39	41.48
	66367	29.816	29.325	21	2.21	2.19	42.80	41.90
	65690	29.782	29.266	21	2.37	2.35	42.50	41.61
	65195	29.732	29.202	21	2.36	2.35	34.62	33.73
	64562	29.708	29.174	21	2.28	2.22	33.22	32.29
	63911	29.693	29.157	21	2.18	2.14	30.07	29.36

River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s (Baseline)		Design Discharge Intensity, m2/s (Baseline)	
		100 years Return Period	50 years Return Period		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Ratua Reach	63058	29.657	29.119	21	2.03	2.02	27.58	26.77
	62187	29.631	29.088	21	2.26	2.24	26.39	25.51
	61561	29.608	29.063	21	2.24	2.22	35.58	34.50
	60913	29.587	29.040	21	2.07	2.04	31.86	30.76
	60282	29.584	29.037	21	2.14	2.11	33.09	31.86
	59681	29.550	29.001	21	2.25	2.2	34.41	33.10
	59070	29.519	28.967	21	2.34	2.28	31.92	30.57
	58482	29.479	28.923	21	2.33	2.27	27.9	26.60
	57822	29.462	28.904	21	2.34	2.29	27.74	26.57
	57183	29.441	28.880	21	2.55	2.49	43.86	42.11
	56665	29.404	28.840	21	2.78	2.71	43.77	42.01
	56141	29.317	28.747	21	2.87	2.80	47.13	45.18
	55636	29.277	28.703	21	3.62	3.54	47.77	45.87
	55114	29.245	28.671	21	3.24	3.19	50.76	48.82
	54568	29.211	28.627	21	3.26	3.17	63.00	60.50
	54001	29.186	28.598	21	3.05	2.97	68.42	65.79
	53420	29.195	28.602	21	3.06	2.99	58.67	56.54
	52848	29.195	28.602	21	2.48	2.54	44.21	42.50
	52507	29.189	28.595	21	2.48	2.42	38.14	36.64
	52158	29.198	28.602	21	2.47	2.41	36.34	34.92
	51821	29.198	28.602	21	2.45	2.4	38.62	37.13
	51503	29.186	28.589	21	2.54	2.49	36.89	35.42
	51181	29.165	28.565	21	2.55	2.49	44.9	43.14
	50826	29.142	28.539	21	2.86	2.79	59.2	57.07

River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s (Baseline)		Design Discharge Intensity, m2/s (Baseline)	
		100 years Return Period	50 years Return Period		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Ratua Reach	50525	29.125	28.519	21	2.96	2.89	65.27	62.97
	50198	29.121	28.515	21	3.08	3.02	70.43	68.13
	49866	29.110	28.502	21	4	3.93	102.8	99.94
	49538	29.094	28.484	21	3.43	3.36	80.74	78.12
	49180	29.083	28.473	21	3.56	3.48	79.77	77.17
	48841	29.073	28.460	21	3.46	3.38	71.22	68.11
	48501	29.043	28.424	21	3.5	3.43	64.53	62.24
	48154	28.992	28.370	21	3.22	3.14	65.39	62.99
	47786	28.974	28.349	21	3.2	3.12	71.42	68.79
	47434	28.949	28.321	21	3.35	3.26	82.42	79.51
	47096	28.942	28.312	21	3.15	3.09	81.85	78.93
	46753	28.942	28.308	21	3.35	3.26	74.92	72.24
	46439	28.942	28.308	21	3.15	3.07	72.03	69.43
	46130	28.942	28.307	21	3.28	3.2	72.48	69.9
	45790	28.933	28.296	21	3.2	3.12	63.42	61.09
	45448	28.944	28.303	21	3.18	3.1	62	59.73
	45127	28.940	28.299	21	3.27	3.2	59.29	57.1
	44566	28.933	28.292	21	2.83	2.76	63.47	61.14
	44093	28.927	28.286	21	2.79	2.72	42.02	40.28
	43505	28.920	28.279	21	2.99	2.9	41.01	39.17

MANIKCHAK-KALIACHAK REACH

Design HFL, LWL, Velocity and Discharge Intensity for different design discharge for Manikchak -Kaliachak Reach

River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s (Baseline)		Design Discharge Intensity, m2/s (Baseline)	
		100 years Return Period	50 years Return Period		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Manikchak-Kaliachak Reach	42904	28.912	28.271	21	2.77	2.68	34.69	33.05
	42285	28.905	28.264	21	2.79	2.69	35.81	33.89
	41626	28.897	28.256	21	3.09	3	41.72	39.77
	40957	28.888	28.247	21	3.15	3.06	42.28	40.24
	40210	28.879	28.237	21	3.08	2.99	39.18	37.4
	39725	28.855	28.209	21	3.08	3.01	62.74	60.37
	39186	28.845	28.197	21	3.98	3.91	59.67	57.7
	38659	28.838	28.189	21	4.28	4.2	59.05	57.08
	38206	28.830	28.179	21	3.35	3.29	61.42	59.47
	37679	28.824	28.171	21	3.6	3.53	61.63	59.64
	36675	28.824	28.171	21	3.78	3.69	59.02	56.92
	36078	28.790	28.132	21	3.43	3.36	48.46	46.65
	35642	28.782	28.120	21	2.82	2.74	42.2	40.41
	35126	28.770	28.106	21	2.67	2.6	41.27	39.63
	34565	28.763	28.096	21	2.58	2.52	35.47	34.09
	33986	28.760	28.093	21	2.68	2.62	42.73	41.23
	33386	28.753	28.086	21	2.87	2.82	45.79	44.24
	32756	28.745	28.078	21	2.85	2.81	47.15	45.91
	32085	28.737	28.070	21	2.69	2.66	42.15	41.07
	31218	28.726	28.059	21	2.65	2.62	41.45	40.36
	30419	28.716	28.049	21	2.79	2.76	46.36	45.41
	29716	28.707	28.040	21	3.07	3.06	50.56	49.75
	29076	28.699	28.032	21	2.71	2.69	48.4	47.54
	28340	28.690	28.023	21	2.6	2.57	47.9	46.83

River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s (Baseline)		Design Discharge Intensity, m2/s (Baseline)	
		100 years Return Period	50 years Return Period		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Manikchak-Kaliachak Reach	27638	28.682	28.015	21	2.39	2.37	41.53	40.72
	26918	28.673	28.006	21	2.05	2.03	32.33	31.62
	26077	28.662	27.995	21	1.9	1.88	25.59	24.97
	25291	28.653	27.986	21	2.15	2.13	26.21	25.53
	24469	28.642	27.975	21	2.25	2.23	32.43	31.73
	23797	28.634	27.967	21	2.35	2.33	34.11	33.36
	23098	28.626	27.959	21	2.37	2.35	36.08	35.28
	22497	28.618	27.951	21	2.27	2.24	40.89	39.96
	21931	28.611	27.944	21	2.39	2.36	44.43	43.37
	21436	28.605	27.900	21	2.38	2.34	44.48	43.33
	20950	28.570	27.859	21	2.38	2.34	45.4	44.14
	20447	28.565	27.854	21	2.13	2.09	33.54	32.53
	19860	28.560	27.847	21	2.05	2.02	28.64	27.75
	18862	28.554	27.841	21	2.7	2.67	28.85	27.97
	17925	28.552	27.837	21	2.61	2.57	33.57	32.53
	17056	28.534	27.816	21	2.82	2.81	57.86	56.3
	16156	28.527	27.808	21	3.18	3.13	64.45	62.73
	15568	28.509	27.786	21	2.97	2.92	62.78	61.15
	15015	28.507	27.783	21	3.35	3.31	67.57	65.89
	14495	28.502	27.777	21	3.55	3.51	70.53	68.91
	14001	28.498	27.773	21	3.58	3.53	81.59	79.77
	13497	28.492	27.765	21	3.82	3.77	89.02	87.01
	12993	28.488	27.760	21	3.84	3.78	93.88	91.54
	12483	28.486	27.757	21	3.41	3.35	71.84	69.88
	11967	28.483	27.753	21	3.29	3.24	64.06	62.12

River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s (Baseline)		Design Discharge Intensity, m2/s (Baseline)	
		100 years Return Period	50 years Return Period		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Manikchak-Kaliachak Reach	11407	28.482	27.751	21	3.48	3.41	67.98	65.87
	10817	28.479	27.748	21	3.72	3.64	66.83	64.63
	10259	28.473	27.740	21	3.44	3.37	55.74	53.81
	9656	28.471	27.738	21	3.13	3.07	48.13	46.45
	9012	28.468	27.735	21	2.89	2.83	45.99	44.37
	8045	28.465	27.730	21	2.9	2.82	36.5	35.01
	7276	28.459	27.723	21	3.04	2.96	40.53	38.6
	6743	28.454	27.718	21	2.33	2.3	65.47	62.64
	6221	28.448	27.710	21	2.45	2.29	53.41	51.01
	5682	28.441	27.702	21	2.7	2.67	47.27	44.91
	5166	28.434	27.694	21	3.21	3.18	59.1	56.23
	4572	28.427	27.685	21	3.63	3.58	62.84	60.41
	3992	28.417	27.673	21	4.8	4.75	78.27	75.32
	3423	28.401	27.655	21	5.35	5.26	97.27	93.29
	2791	28.401	27.654	21	5.46	5.33	103.41	98.48
	2176	28.399	27.651	21	5.23	5.04	111.23	105.13
	1574	28.388	27.637	21	4.02	3.83	99.18	92.95

DHULIAN REACH

Design HFL, LWL, Velocity and Discharge Intensity for different design discharge for Dhulian Reach (Farakka to Nimtita)

Design Parameters- Farakka Downstream								
River Stretch	**Approximate Chainage (m) downstream of Farakka Barrage**	**Design HFL, m**		**Design LWL, m**	**Design Velocity, m/s**		**Design Discharge Intensity, m2/s**	
		100 Year Return Period	50 Year Return Period		100 Year Return Period	50 Year Return Period	100 Year Return Period	50 Year Return Period
Dhulian Reach	67	25.462	25.008	12.450	2.81	2.68	74.65	70.25
	566	25.237	24.895	12.438	2.97	2.84	69.62	65.47
	1051	25.192	24.859	12.427	3.49	3.37	73.6	69.66
	1591	25.103	24.771	12.415	4	3.88	86.39	82.23
	2059	25.023	24.691	12.405	3.77	3.65	65.73	62.53
	2571	24.935	24.605	12.393	3.69	3.6	75.62	72.36
	3061	24.886	24.556	12.383	3.92	3.81	62.73	60.18
	3548	24.836	24.506	12.372	3.74	3.65	81.89	78.82
	4019	24.789	24.453	12.361	3.39	3.33	65.36	62.71
	4505	24.765	24.425	12.350	3.04	2.97	63.38	60.72
	4979	24.759	24.425	12.340	2.71	2.62	59.99	57.42
	5458	24.753	24.411	12.329	2.77	2.69	60.25	57.68
	5978	24.746	24.404	12.317	2.87	2.79	66.16	63.65
	6491	24.739	24.397	12.306	2.41	2.35	53.69	51.47
	7005	24.728	24.386	12.294	1.86	1.79	42.42	40.38
	7488	24.718	24.375	12.283	2.07	2.03	40.3	38.53
	8023	24.704	23.262	12.271	2	1.95	44.9	43.31
	8470	24.686	24.344	12.261	2.23	2.21	45.1	43.58
	8955	24.655	24.313	12.251	2.17	2.17	42.51	41.35
	9532	24.654	24.303	12.238	1.87	1.85	42.29	41.42
	10044	24.622	23.286	12.226	2.09	2.08	41.55	40.76
	10632	24.609	24.266	12.213	2.59	2.57	48.07	47.47
	11177	24.596	24.253	12.201	2.41	2.4	49.22	48.82

River Stretch	Approximate Chainage (m) downstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s		Design Discharge Intensity, m2/s	
		100 Year Return Period	50 Year Return Period		100 Year Return Period	50 Year Return Period	100 Year Return Period	50 Year Return Period
Dhulian Reach	11867	24.579	24.236	12.185	2.45	2.41	44.69	44.05
	12457	24.564	24.221	12.172	2.39	2.38	53.81	53.49
	13008	24.550	24.207	12.160	4.11	4.03	75.04	74.77
	14976	24.502	24.158	12.116	3.09	3.03	50.07	50
	17006	24.301	23.956	12.070	3.03	2.98	52.54	52.53
	19592	24.204	23.861	12.013	2.54	2.51	48.91	49.82
	22859	23.966	23.615	11.939	2.7	2.67	61.05	59.61
	24103	23.704	23.358	11.912	2.28	2.27	51.39	50.72
	25652	23.703	23.355	11.877	1.86	1.86	41.69	40.91
	26983	23.676	23.326	11.847	1.98	1.96	44.67	43.6
	28181	23.651	23.300	11.820	2.01	1.98	45.22	43.92
	29373	23.627	23.275	11.794	1.8	1.76	37.28	35.92
	32166	23.587	23.236	11.731	1.88	1.86	42.19	40.93
	33616	23.550	23.198	11.699	1.93	1.9	42.88	41.68
	35313	23.518	23.166	11.661	1.81	1.78	40.09	38.89
	36617	23.479	23.126	11.632	1.85	1.82	40.72	39.45
	38264	23.452	23.099	11.595	1.61	1.58	35.78	34.75
	40412	23.415	23.061	11.547	1.55	1.52	33.84	32.9
	42246	23.385	23.031	11.506	1.79	1.76	39.62	38.29
	43965	23.351	22.997	11.467	2	1.96	43	41.91
	45683	23.321	22.966	11.429	1.77	1.75	37.42	36.34
	47271	23.291	22.935	11.393	1.95	1.95	43.15	42.49
	48425	23.258	22.901	11.367	2.12	2.1	46.42	46.01
	49453	23.233	22.874	11.344	2.12	2.09	44.05	44.01

River Stretch	Approximate Chainage (m) downstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s		Design Discharge Intensity, m2/s	
		100 Year Return Period	50 Year Return Period		100 Year Return Period	50 Year Return Period	100 Year Return Period	50 Year Return Period
Dhulian Reach	50620	23.214	22.855	11.318	1.67	1.66	36.22	35.98
	52225	23.186	22.826	11.282	1.64	1.61	35.22	35.18
	58228	23.062	22.708	11.148	3.19	3.18	69.22	68.38
	61195	22.164	21.840	11.082	3.06	3.04	65.55	63.96
	66195	21.695	21.387	10.970	1.73	1.69	29.56	28.28
	69030	21.655	21.346	10.906	1.56	1.52	27.82	26.67
	75005	21.560	21.252	10.773	3.1	3.06	63.2	61.28
	76836	21.063	20.749	10.732	2.7	2.65	56	54.16
	78500	20.952	20.637	10.694	2.64	2.6	55.49	53.69
	80736	20.849	20.533	10.644	2.57	2.52	54.02	52.19
	82636	20.650	20.334	10.602	2.64	2.59	54.77	52.82

BHAGWANGOLA_JALANGI REACH

Design HFL, LWL, Velocity and Discharge Intensity for different design discharge for Bhagwan Gola -Jalangi Reach

River Stretch	Approximate Chainage (m) downstream of Farakka Barrage	Design HFL, m		Design LWL, m	Design Velocity, m/s		Design Discharge Intensity, m2/s	
		100 Year Return Period	50 Year Return Period		100 Year Return Period	50 Year Return Period	100 Year Return Period	50 Year Return Period
Bhagwan Gola Reach	85523	20.484	20.173	10.537759	1.85	1.79	37.42	35.6
	87155	20.478	20.167	10.50124	1.85	1.8	38.53	36.76
	89064	20.463	20.150	10.458522	1.88	1.85	39.19	37.79
	90789	20.444	20.132	10.419922	1.69	1.66	34.76	33.63
	93722	20.394	20.081	10.354291	1.83	1.82	34.56	33.51
	95922	20.330	20.017	10.305062	1.35	1.33	27.77	26.77
	98977	20.297	19.985	10.2367	1.38	1.35	28.47	27.41
	102977	20.222	19.910	10.147193	1.49	1.45	30.59	29.35
	107277	20.157	19.846	10.050972	2.14	2.1	44.05	42.48
	112078	19.901	19.592	9.9435405	1.36	1.32	26.77	25.55
	118771	19.900	19.592	9.7937719	1.5	1.46	30.07	28.77
	123617	19.798	19.490	9.6853335	1.55	1.5	31.36	29.77
	127188	19.750	19.444	9.6054256	1.91	1.85	38.45	36.63
	130072	19.635	19.329	9.5408906	2.62	2.55	52.92	50.66
	133993	19.489	19.187	9.4531507	2.52	2.43	48.67	46.09
	136399	19.407	19.106	9.3993119	1.75	1.67	34.25	32.36
	138395	19.401	19.101	9.3546476	1.34	1.29	26.27	24.2
	141918	19.397	19.095	9.2758138	1.07	1.04	18.56	17.52
	149966	19.385	19.084	9.0957245	0.8	0.7	15.48	14.61
	154326	19.364	19.063	8.9981612	0.81	0.77	15.05	14.21
	156928	19.343	19.043	8.9399365	1.1	1.05	21.46	20.25
	160345	19.308	19.010	8.8634747	1.36	1.29	17.95	16.83
	162446	19.291	18.994	8.8164608	1.36	1.29	24.46	22.83
	171103	19.274	18.978	8.622744	1.32	1.25	24.93	23.34
	173406	19.242	18.948	8.57121	1.28	1.22	23.31	21.82
	174773	19.233	18.940	8.5406208	1.33	1.27	22.37	20.91

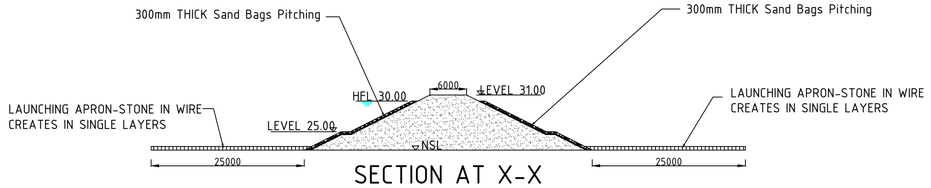
DESIGN VELOCITY AND DISCHARGE INTENSITY AT THE NOSE OF SPURS IN THE RATUA-1 REACH

Design velocity and discharge intensity for design of Spurs in the Ratua-I reach

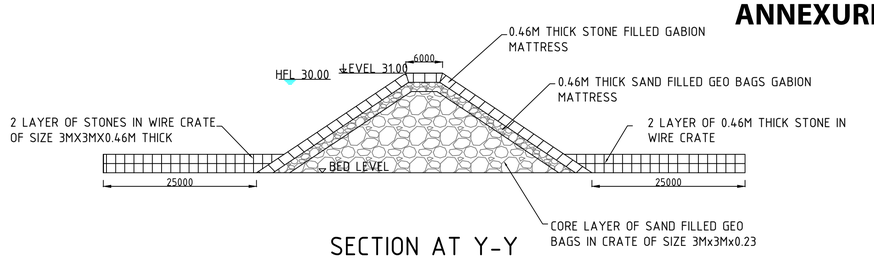
Design Parameters with Spurs

River Stretch	Approximate Chainage (m) upstream of Farakka Barrage	Design Velocity, m/s		Design Discharge Intensity, m^2/s	
		100 years Return Period	50 years Return Period	100 years Return Period	50 years Return Period
Ratua Reach	76314	5.75	5.65	55.84	55.78
	75787	6.42	6.33	54.54	53.73
	74931	7.23	7.13	90.22	90.13
	73835	6.22	6.18	69.73	69.05
	72728	5.27	5.09	53.2	52.52
	71528	6.84	6.51	83.32	82.25
	69788	8.57	8.22	83.32	82.25
	68631	3.86	3.23	47.42	46.56
	67563	7.13	6.75	102.4	102.28
	66218	8.97	8.68	99.98	99.84
	65289	6.71	6.52	94.56	93.32
	63911	5.45	4.55	61.41	60.52
	62178	4.18	3.63	46.18	45.8

ANNEXURE VII



SECTION AT X-X



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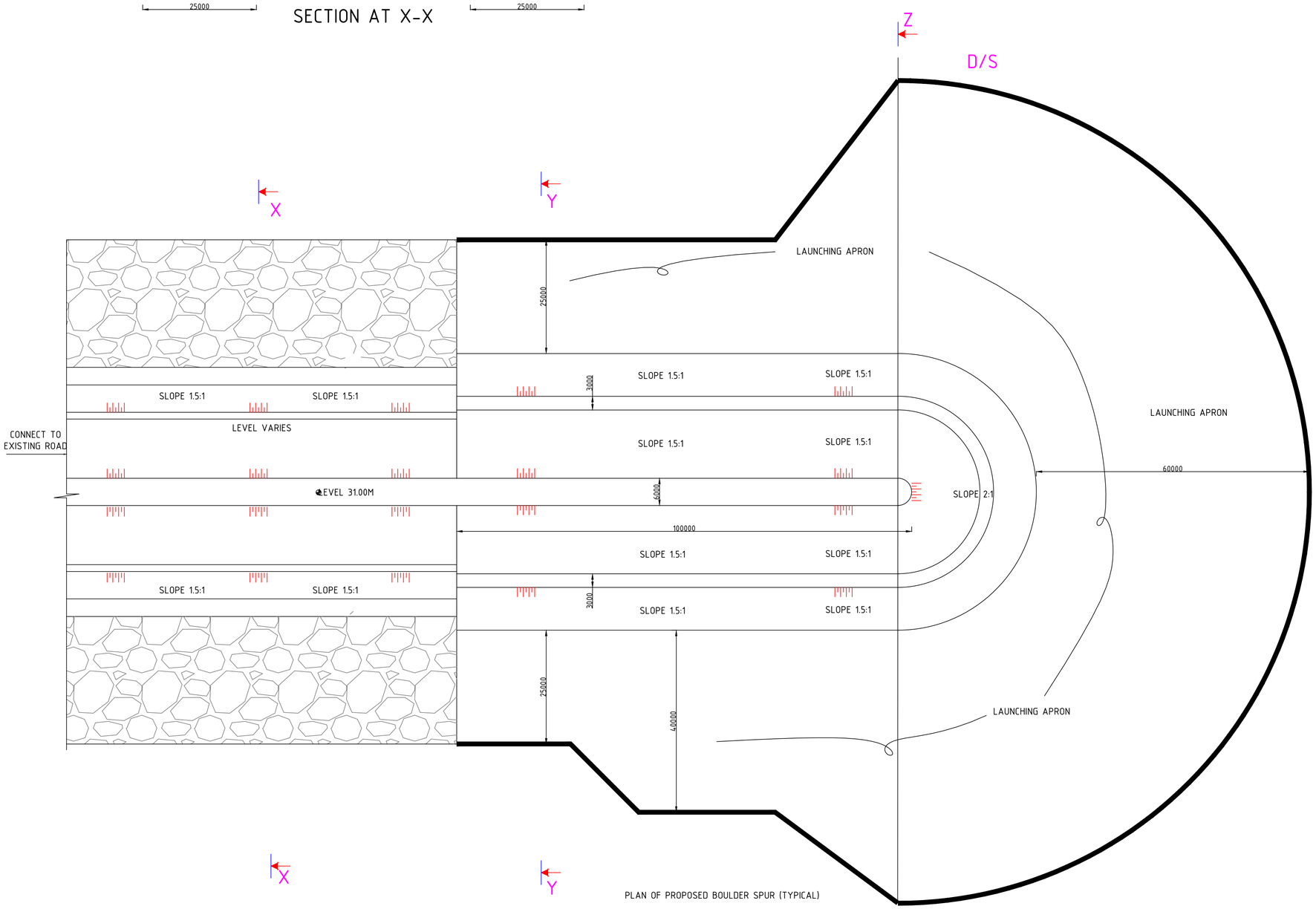
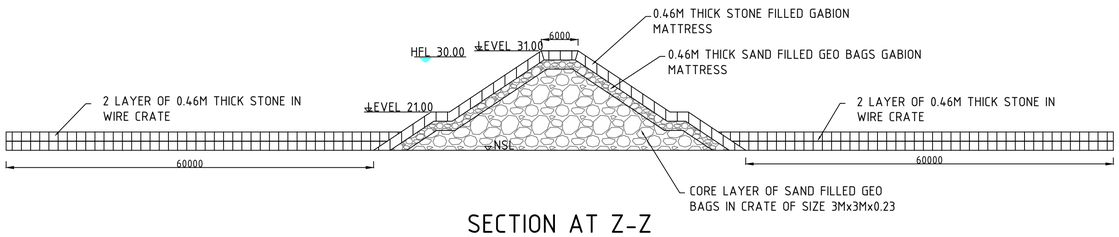


PLAN OF PROPOSED BOULDER SPUR (TYPICAL)



SECTION AT Z-Z

SCALE 0 5.0 12.5 25.0 50.0M

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Rev.	Y	M	D	Modifications	Status	Drawn	Checked	Approved	Validated
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-	-	-	-		-	-	-	-	-
-	-	-	-		-	-	-	-	-
-	-	-	-		-	-	-	-	-

Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL DETAIL OF BOULDER SPUR

CONSULTANT

TRACTEBEL ENGIE

TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
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Status Of Drawing: FOR DETAIL PROJECT REPORT

Scale: As Shown | Size: A1

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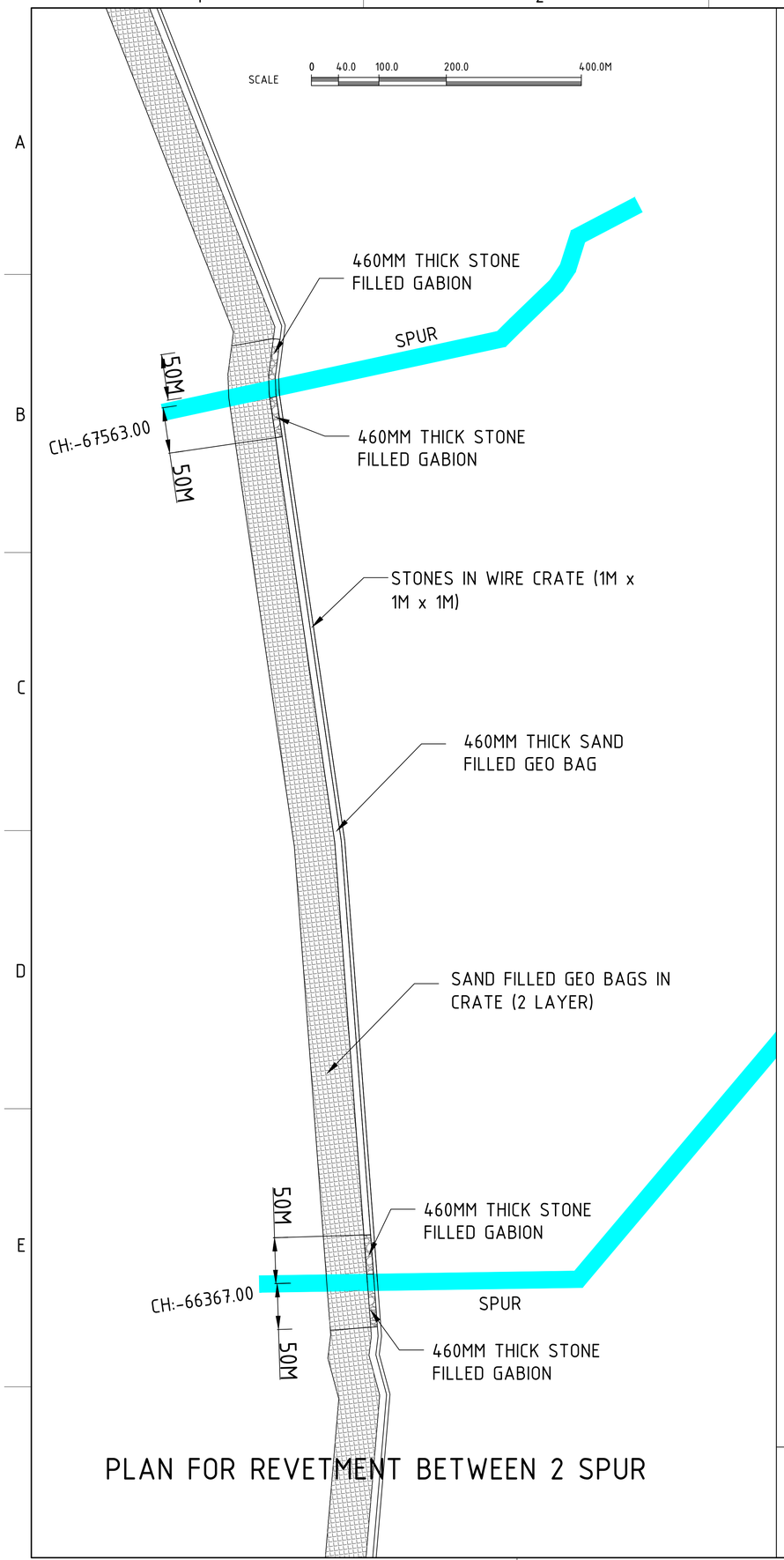
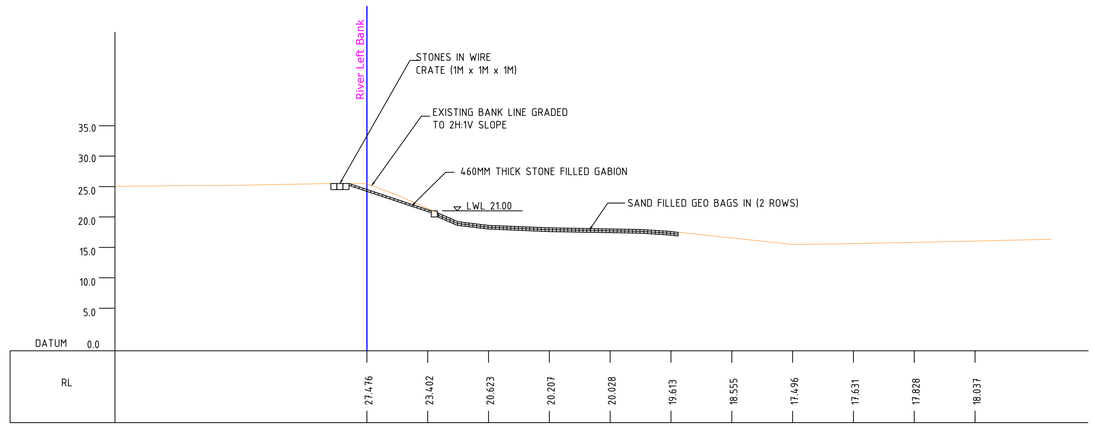
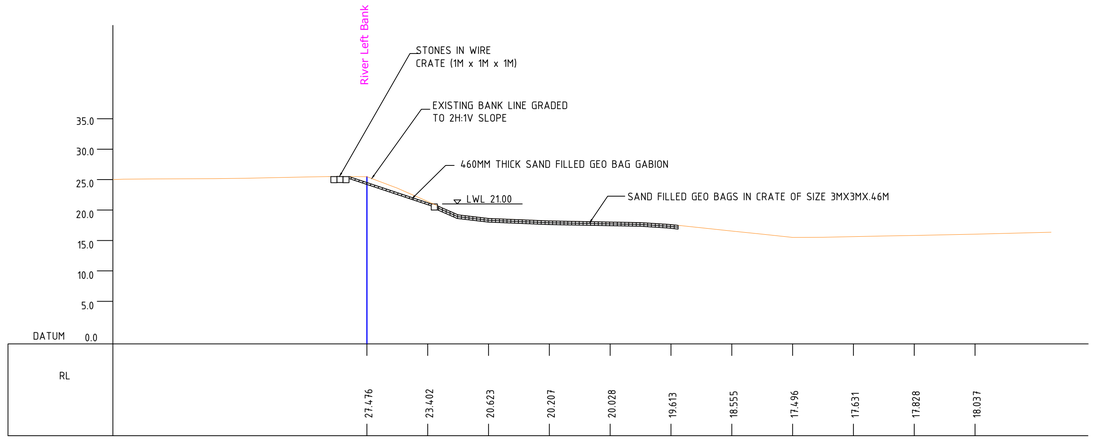


PLAN FOR REVETMENT BETWEEN 2 SPUR



SECTION FOR BANK REVETMENT FOR 50 M IN U/S AND D/S OF SPUR



SECTION FOR REVETMENT FOR IN BALANCE PORTION OF BETWEEN TWO SPUR

SCALE 0 5.0 12.5 25.0 50.0M

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.

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Rev.	Y	M	D	Modifications	Status	Drawn	Checked	Approved	Validated
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-	-		-		-	-	-	-	-
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-	-		-		-	-	-	-	-

Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL PLAN AND SECTION FOR BANK REVETMENT DETAIL BETWEEN TWO SPURS

CONSULTANT

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Status Of Drawing: FOR DETAIL PROJECT REPORT

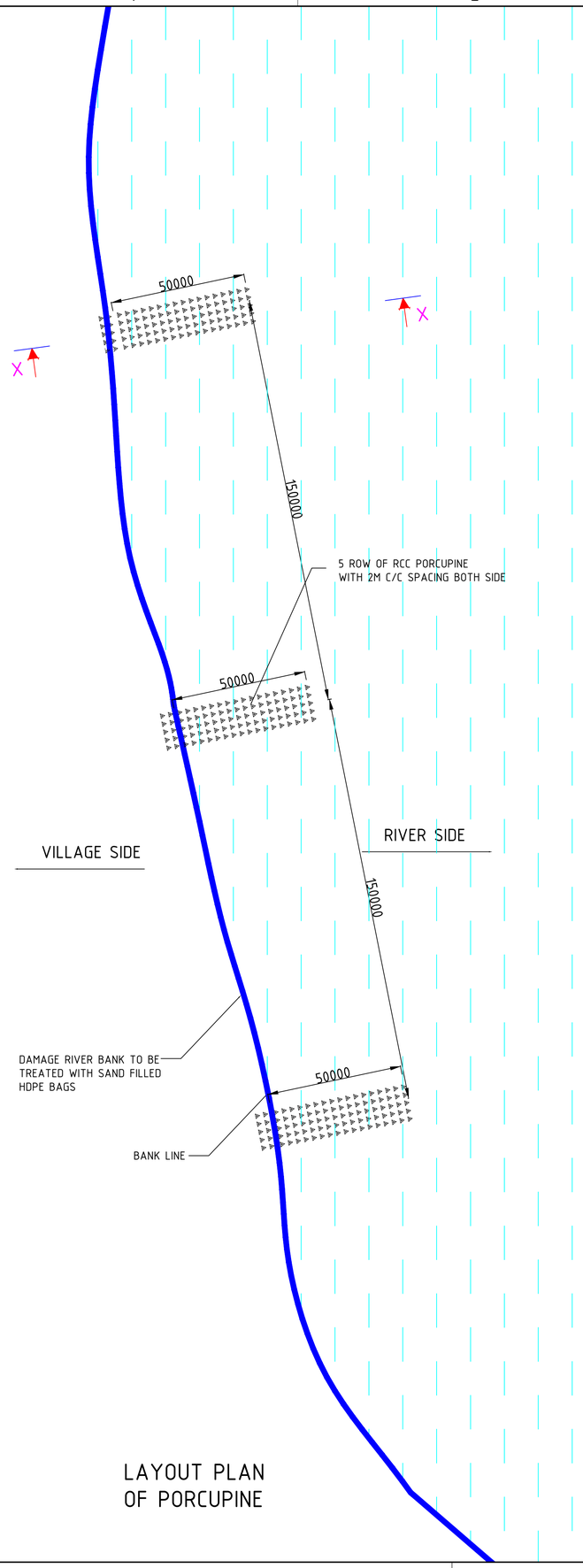
Scale: As Shown | Size: A1

DRG N°: P.020985-V-20315-007 | Rev.: 00 | Sheet: 1 OF 1

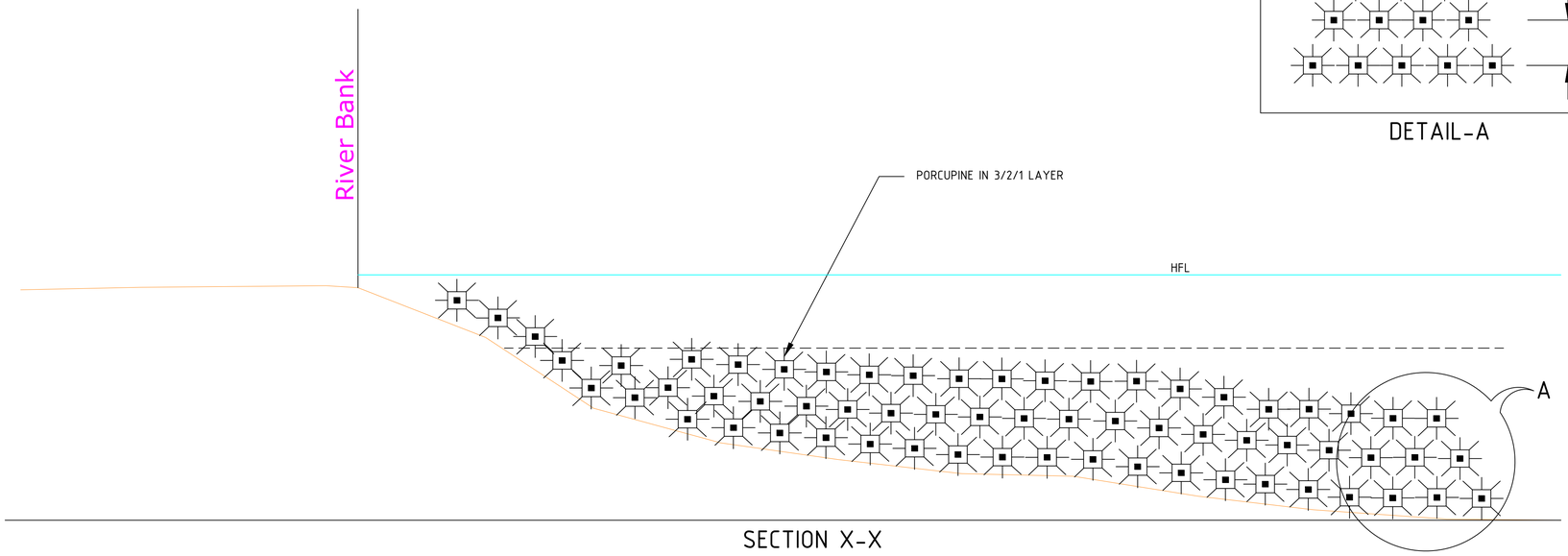
TYPICAL CROSS SECTION OF BANK REVETMENT

NOTES:-

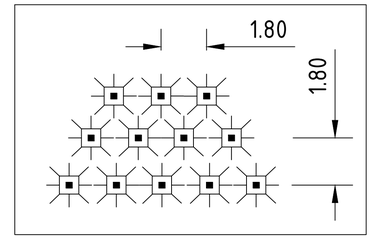
1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.



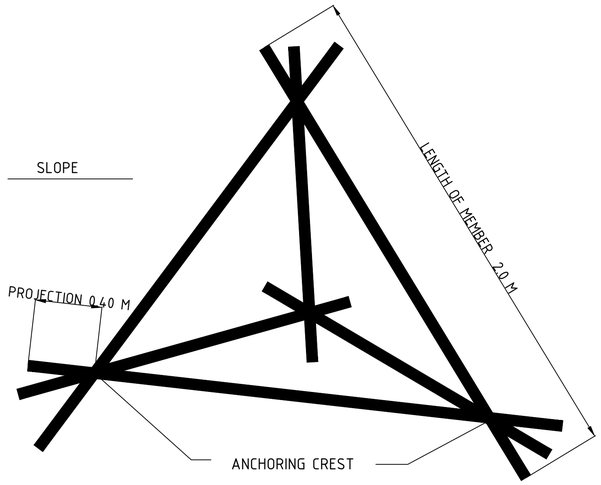
LAYOUT PLAN
OF PORCUPINE



SECTION X-X
(1:125)



DETAIL-A



RCC PORCUPINE DETAIL
(NTS)

SCALE 0 10.0 25.0 50.0 100.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

SURVEYED BY

Rev.	Y	M	D	Modifications	Status	Drawn	Checked	Approved	Validated
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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL DETAIL FOR RCC PORCUPINE

CONSULTANT

TRACTEBEL ENGIE

TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT
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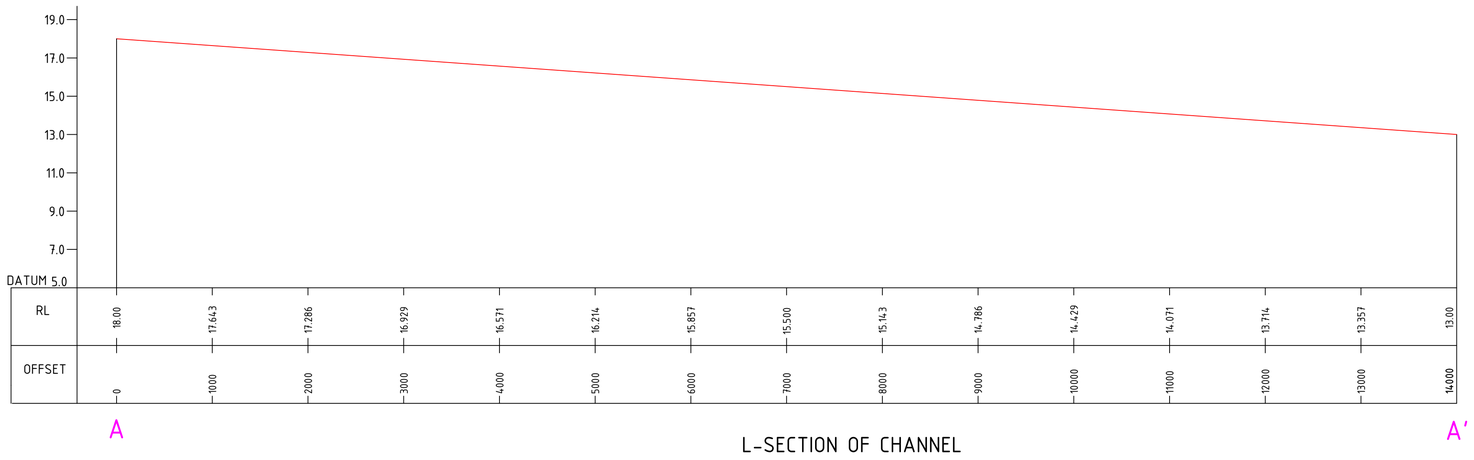
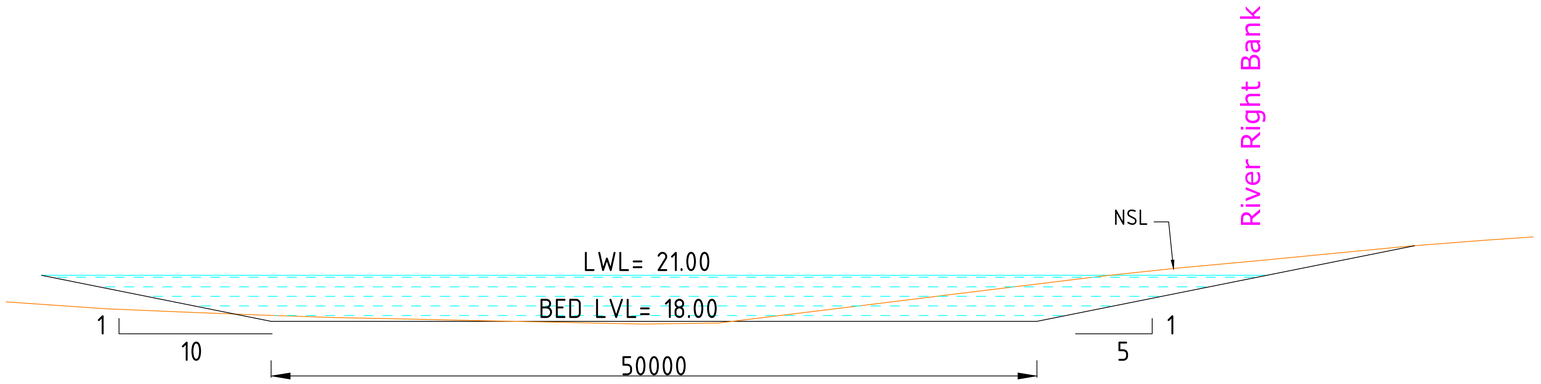
DRG N°: P.020985-V-20315-013 | Rev.: 00 | Sheet: 1 OF 1

PLAN



L-SECTION OF CHANNEL



CROSS SECTION OF CHANNEL ACTIVATION
CH:-65690.00
(U/S OF FARAKKA BARRAGE)

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

SURVEYED BY

Rev.	Y	M	D	Modifications	Status	Drawn	Checked	Approved	Validated
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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

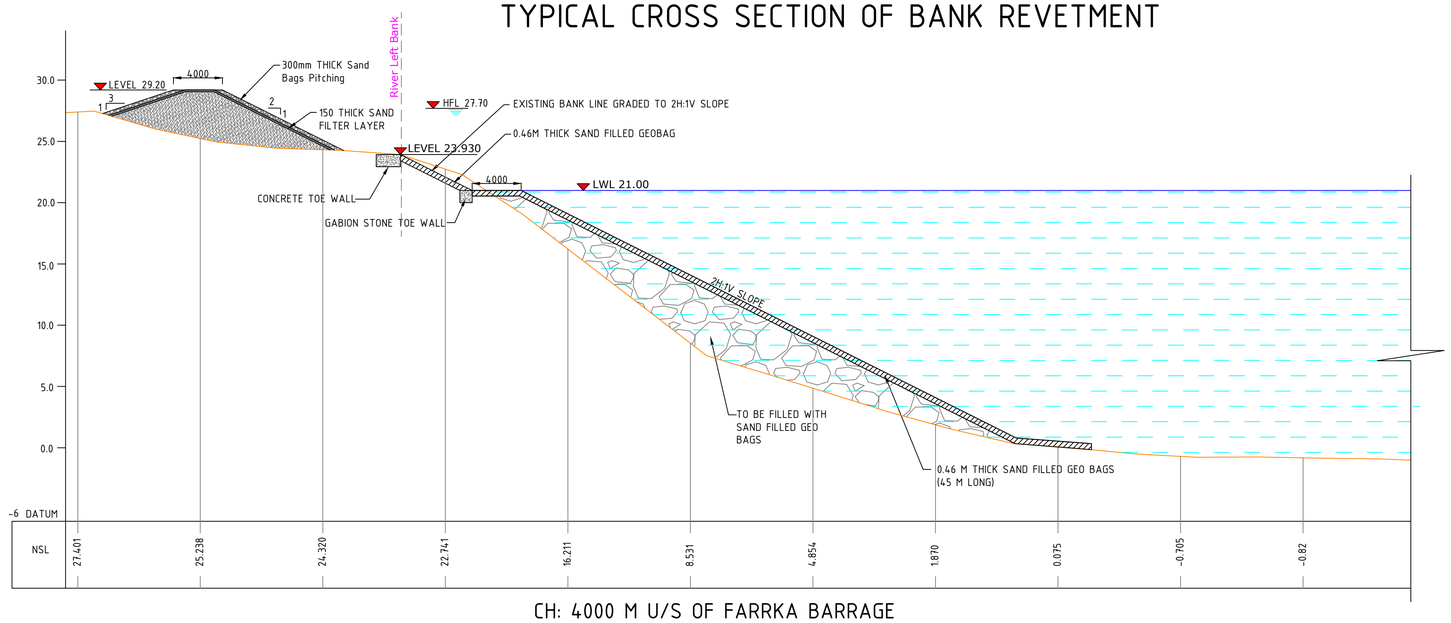
GANGA-PADMA RIVER
CROSS SECTION FOR CHANNEL ACTIVATION

CONSULTANT

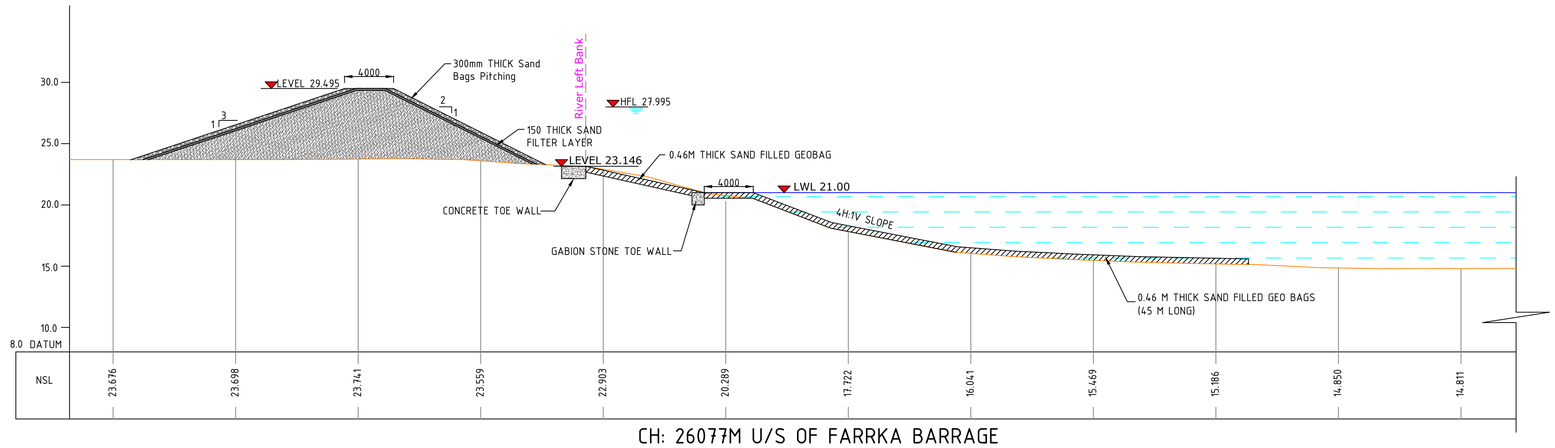
TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT
Scale: As Shown
Size: A1
DRG N°: P.020985-V-20315-010
Rev.: 00
Sheet: 1 OF 1

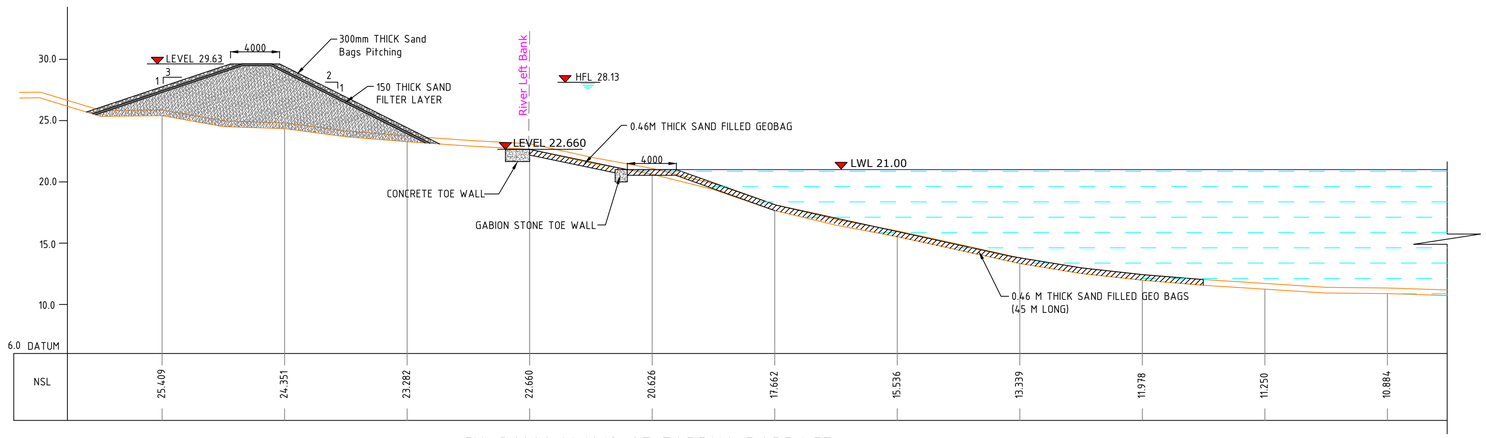
TYPICAL CROSS SECTION OF BANK REVETMENT



CH: 4000 M U/S OF FARRKA BARRAGE
(TYPICAL FOR CH: 4000 TO 6000)



CH: 26077M U/S OF FARRKA BARRAGE
(TYPICAL FOR CH: 25500 TO 26500)



CH: 36000 M U/S OF FARRKA BARRAGE
(TYPICAL FOR CH: 34500 TO 36000)

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.

SCALE 0 2.5 6.25 12.5 25.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL CROSS SECTION FOR EMBANKMENT COSTRUCTION WITH BANK REVETMENT IN MANICHAK-KALIACHAK REACH

CONSULTANT

TRACTEBEL ENGIE

TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT

Scale: As Shown | Size: A1

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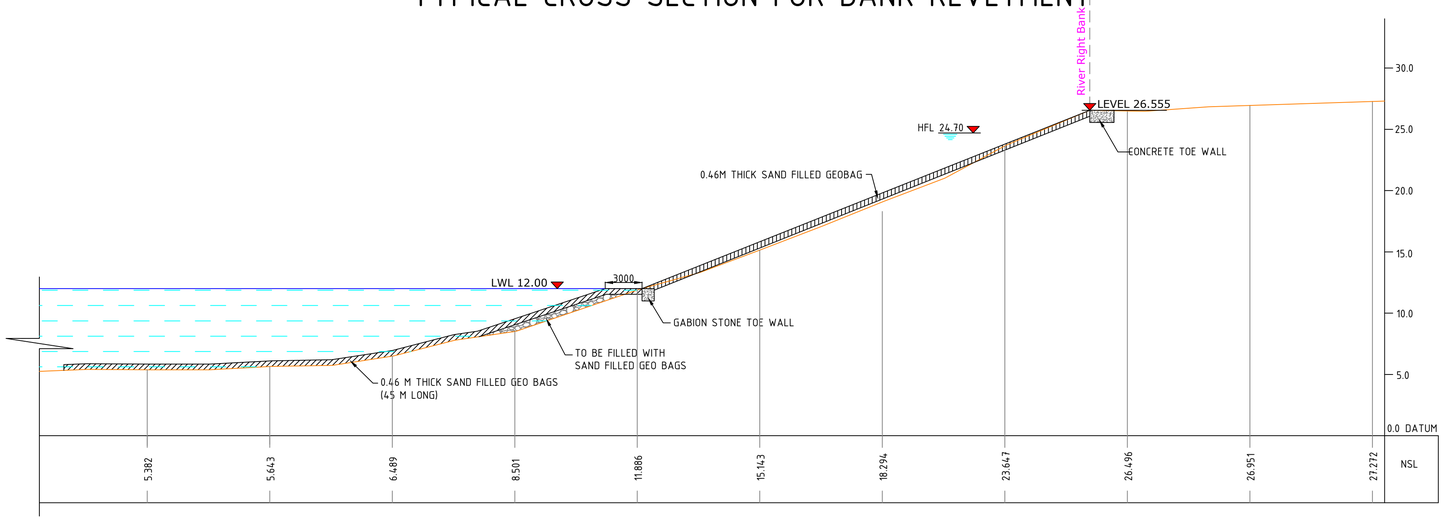
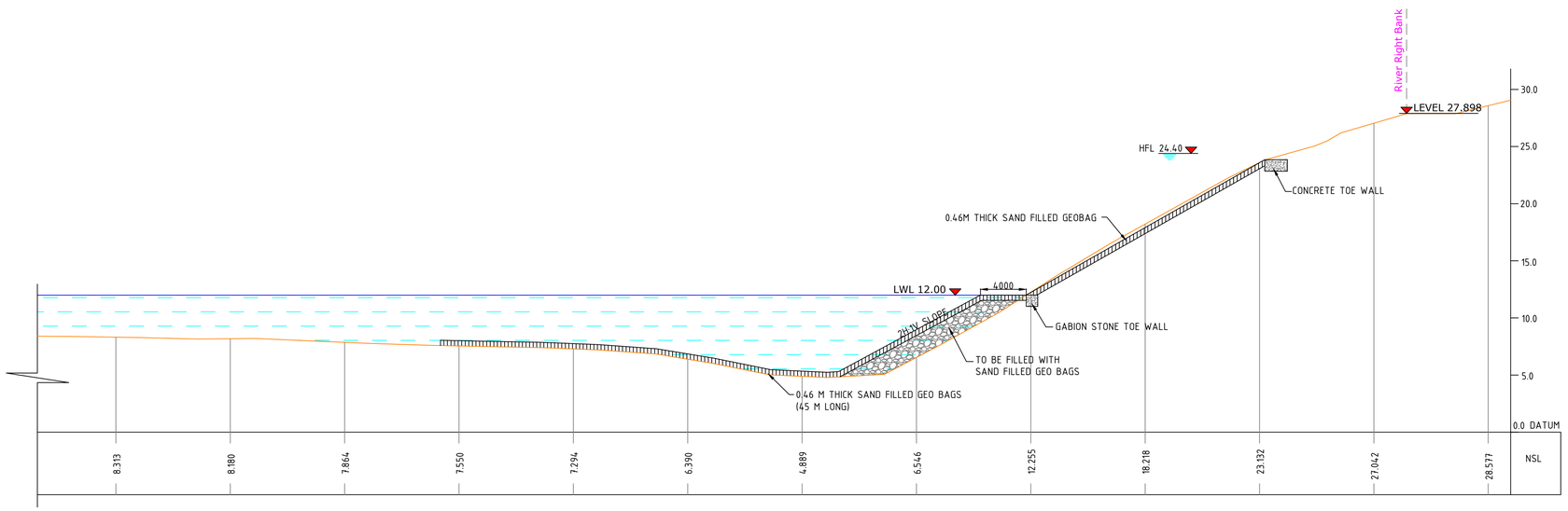
TYPICAL CROSS SECTION FOR BANK REVETMENT



CH: 2500 M D/S OF FARRKA BARRAGE
(TYPICAL FOR 2200-2500 & 4500 TO 6000)



CH: 7000 M D/S OF FARRKA BARRAGE
(TYPICAL FOR 6500-7000 & 8900 TO 11867)

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.

SCALE 0 2.5 6.25 12.5 25.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL CROSS SECTION FOR REVETMENT IN DOWN STREAM OF FARAKKA BARRAGE

CONSULTANT

TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT

Scale: As Shown | Size: A1

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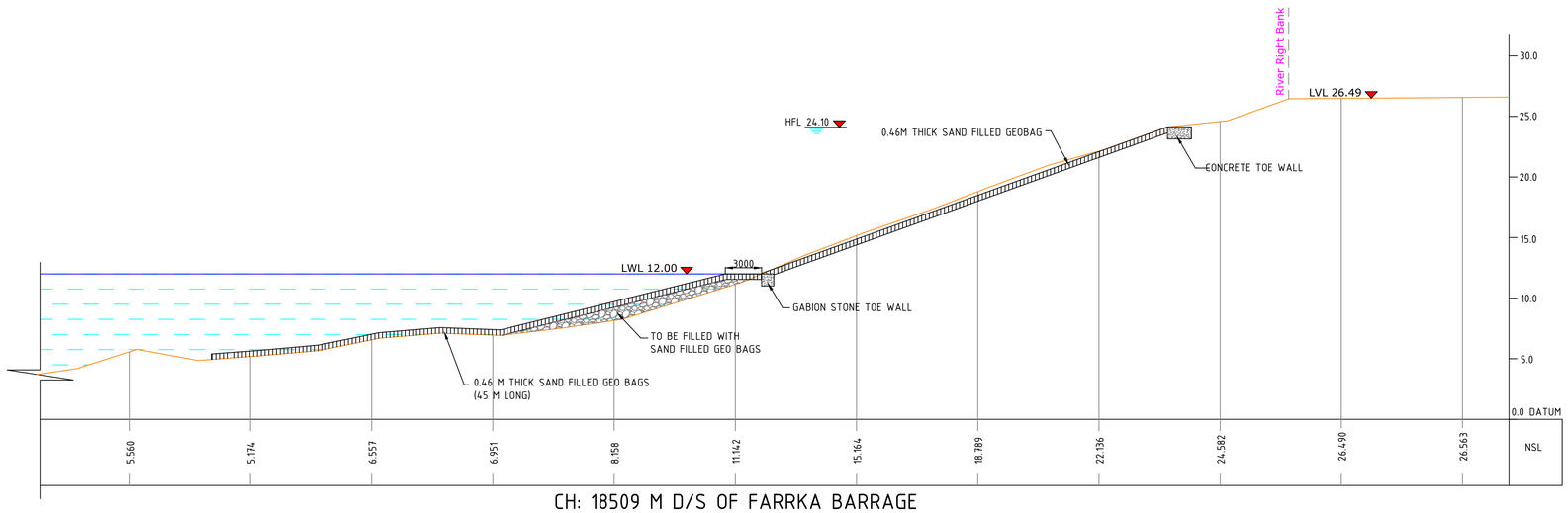
TYPICAL CROSS SECTION FOR BANK REVETMENT



CH: 18509 M D/S OF FARRKA BARRAGE
(TYPICAL FOR 15000-16500 & 18500 TO 19000)

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
2. DO NOT MEASURE DIMENSIONS ON THE DRAWING. ONLY WRITTEN DIMENSION SHOULD BE FOLLOWED.

SCALE 0 2.5 6.25 12.5 25.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Rev.	Y M D	Modifications	Status	Drawn	Checked	Approved	Validated
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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL CROSS SECTION FOR BANK REVETMENT

CONSULTANT

TRACTEBEL ENGIE

TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT
Scale: As Shown | Size: A1
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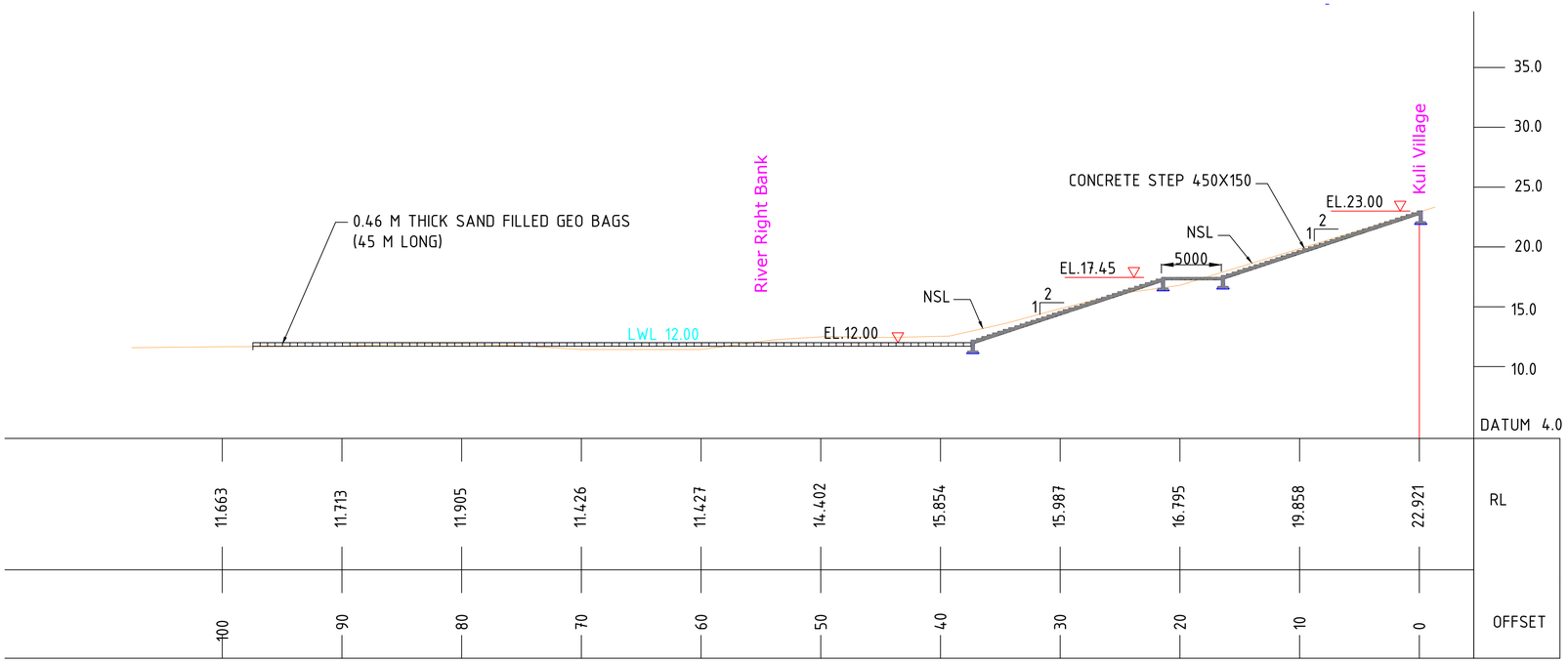
TYPICAL CROSS SECTION FOR GHAT



CH:-8023.0

(D/S OF FARAKKA BARRAGE)

NOTES:-

1. ALL DIMENSIONS AREA IN MILIMETER AND LEVEL ARE IN METERS UNLESS NOTED OTHERWISE.
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SCALE 0 2.5 6.25 12.5 25.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL CROSS SECTION FOR GHAT DEVELOPMENT

CONSULTANT

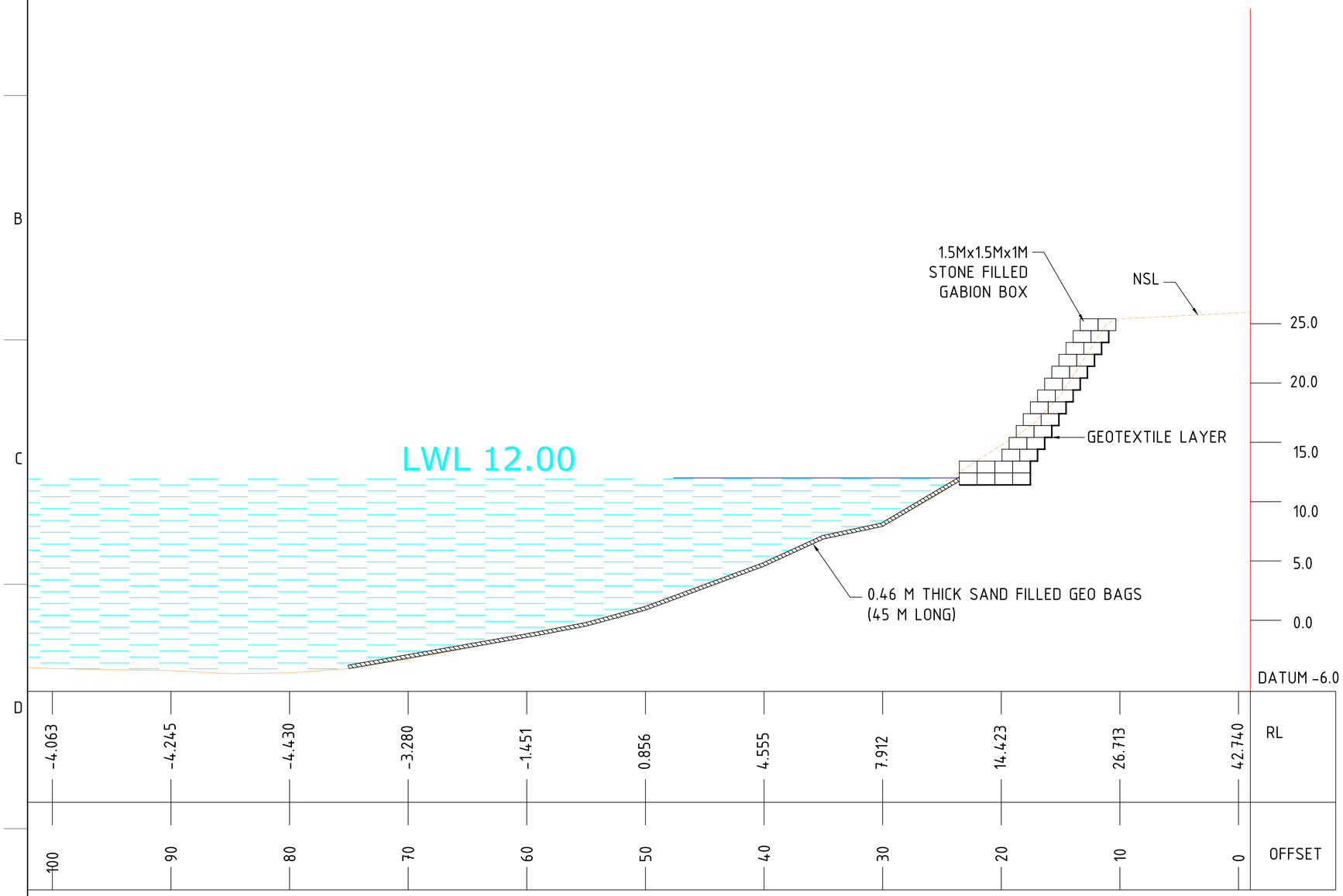
TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT

Scale: As Shown | Size: A1

DRG N°: P.020985-V-20315-017 | Rev.: 00 | Sheet: 1 OF 1

TYPICAL CROSS SECTION OF GABION WALL



(D/S OF FARAKKA BARRAGE)

NOTES:-

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SCALE 0 2.0 5.0 10.0 20.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL CROSS SECTION FOR GABION WALL

CONSULTANT

TRACTEBEL ENGIE

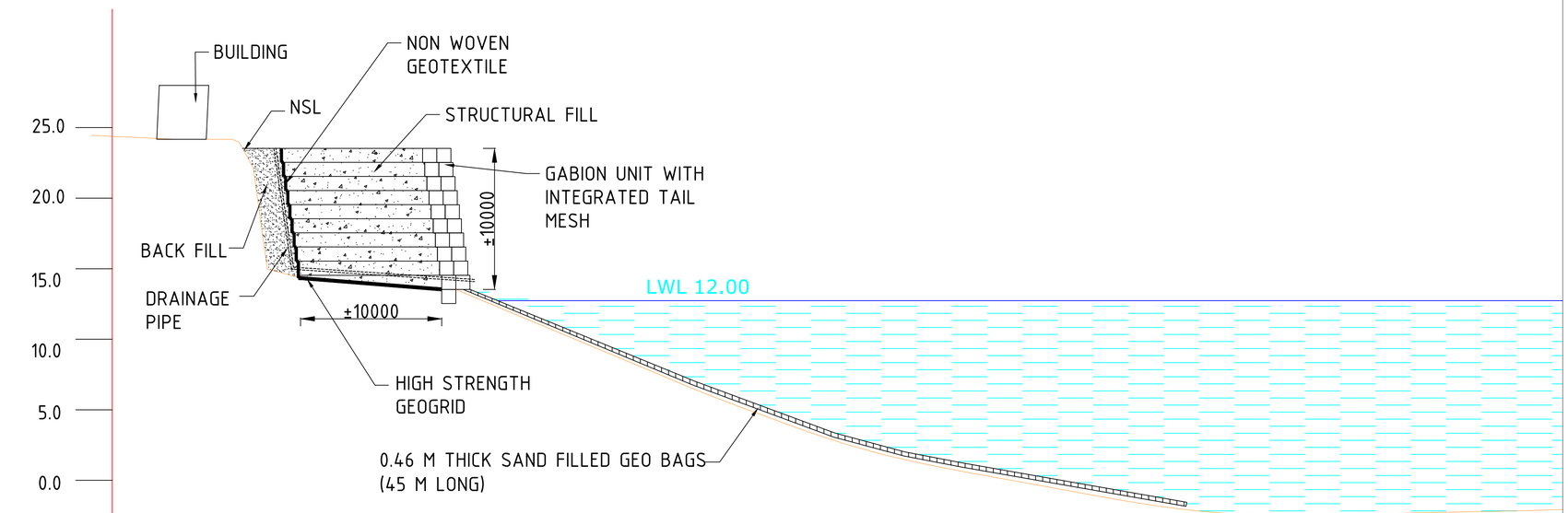
TRACTEBEL ENGINEERING PVT. LTD.
Infec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

Status Of Drawing: FOR DETAIL PROJECT REPORT

Scale: As Shown | Size: A1

DRG N°: P.020985-V-20315-018 | Rev.: 00 | Sheet: 1 OF 1

TYPICAL CROSS SECTION OF GABION WALL IN BUILT-UP AREA
(D/S OF FARAKKA BARRAGE)



RL	42.740	26.713	14.423	7.912	4.555	0.856	-1.451	-3.280	-4.430	-4.245	-4.063
OFFSET	0	10	20	30	40	50	60	70	80	90	100

(D/S OF FARAKKA BARRAGE)

NOTES:-

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SCALE 0 2.0 5.0 10.0 20.0M

CLIENT

IRRIGATION & WATERWAYS DIRECTORATE
GOVERNMENT OF WEST BENGAL

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Rev.	Y	M	D	Modifications	Status	Drawn	Checked	Approved	Validated
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Project

PREPARATION OF DPR FOR REMEDIAL MEASURES ON GANGA-PADMA EROSION ABATEMENT IN THE DISTRICTS OF MALDA, MURSHIDABAD AND NADIA IN WEST BENGAL

Subject

GANGA-PADMA RIVER
TYPICAL CROSS SECTION OF GABION WALL IN BUILT-UP AREA

CONSULTANT

TRACTEBEL ENGIE

TRACTEBEL ENGINEERING PVT. LTD.
Intec House, 37
Institutional Area, Sector 44
122002 Gurgaon-INDIA

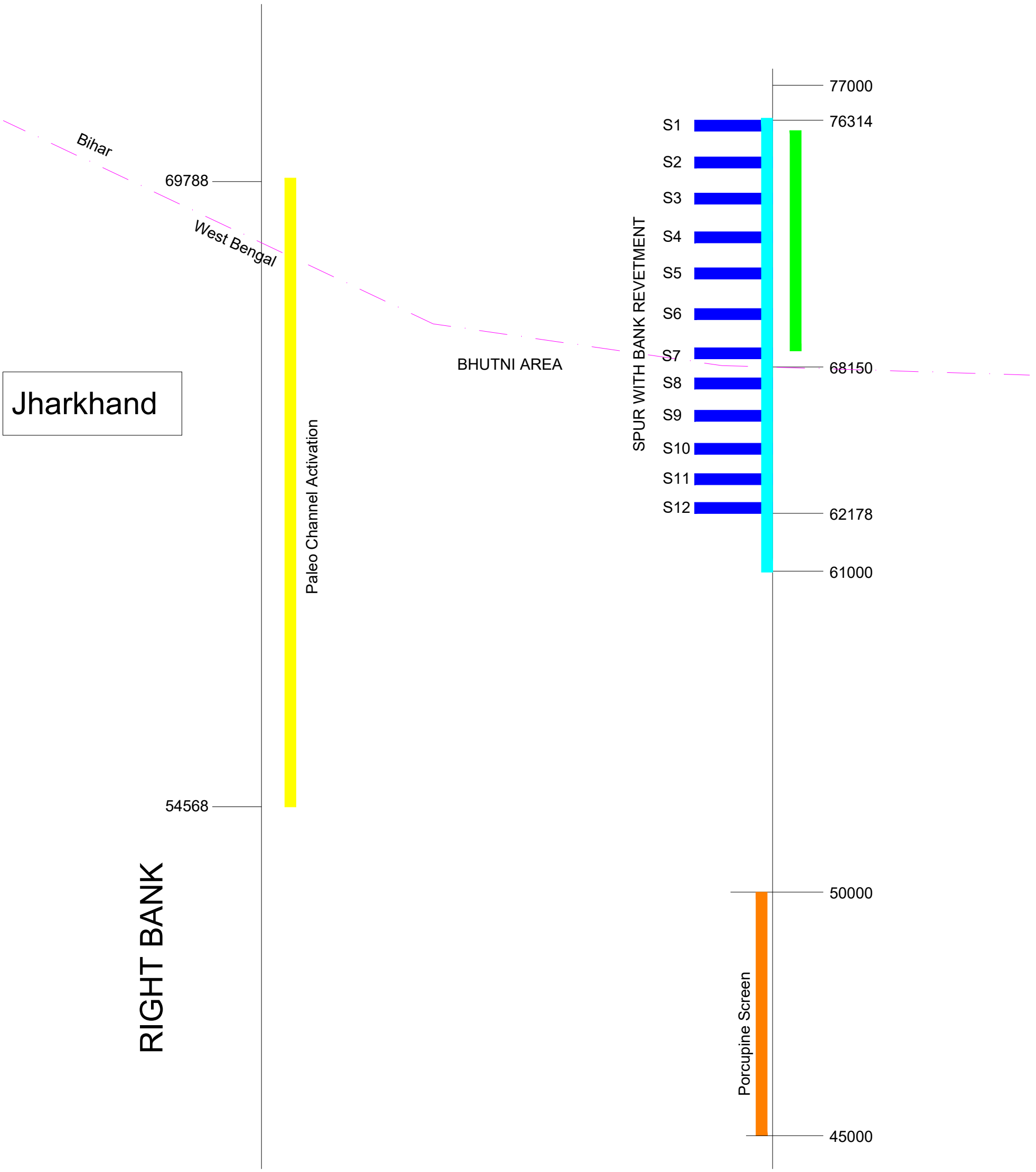
Status Of Drawing: FOR DETAIL PROJECT REPORT

Scale: As Shown | Size: A1

DRG N°: P.020985-V-20315-019 | Rev.: 00 | Sheet: 1 OF 1

ANNEXURE- VIII

RATUA 1 REACH



LEGEND:-

- EXISTING PROTECTION WORK
- PALEO CHANNEL ACCTIVATION
- Porcupine Screen
- SPUR

PROPOSED PROTECTION WORK

MANIKCHAK-KALIACHAK REACH

Jharkhand

RIGHT BANK

LEFT BANK

45000

36000

Embankment Raising

34500

31200

Bank Revetment

30200

26500

Embankment Raising

25500

24000

21000

15500

Bank Revetment

13000

6000

Embankment Raising

4000

3500

Bank Revetment

2100

1500

FARAKKA BARRAGE

00.00

LEGEND:-

EXISTING PROTECTION WORK

PROPOSED PROTECTION WORK

BANK REVETMENT

Porcupine Screen

EMBANKMENT RAISING

DHULIAN REACH

FARAKKA BARRAGE

0.00

RIGHT BANK

1600 Porcupine Screen

2000

2200 Bank Revetment

2500

4500 Bank Revetment

6000

6500 Spur

Bank Revetment

7000

7500 Ghat

8500

8900 Bank Revetment

11867

12000 Gabion Wall

13000 Ghat

14500

15000 Bank Revetment

16500

17000 Gabion Wall

17400

17500 Porcupine Screen

18500 Bank Revetment

19000 Porcupine Screen

19500

20000 Gabion Wall

20200 Porcupine Screen

21000

LEFT BANK

5600 Bank Revetment

7000

7200

7600

12500 Bank Revetment

14000

19000

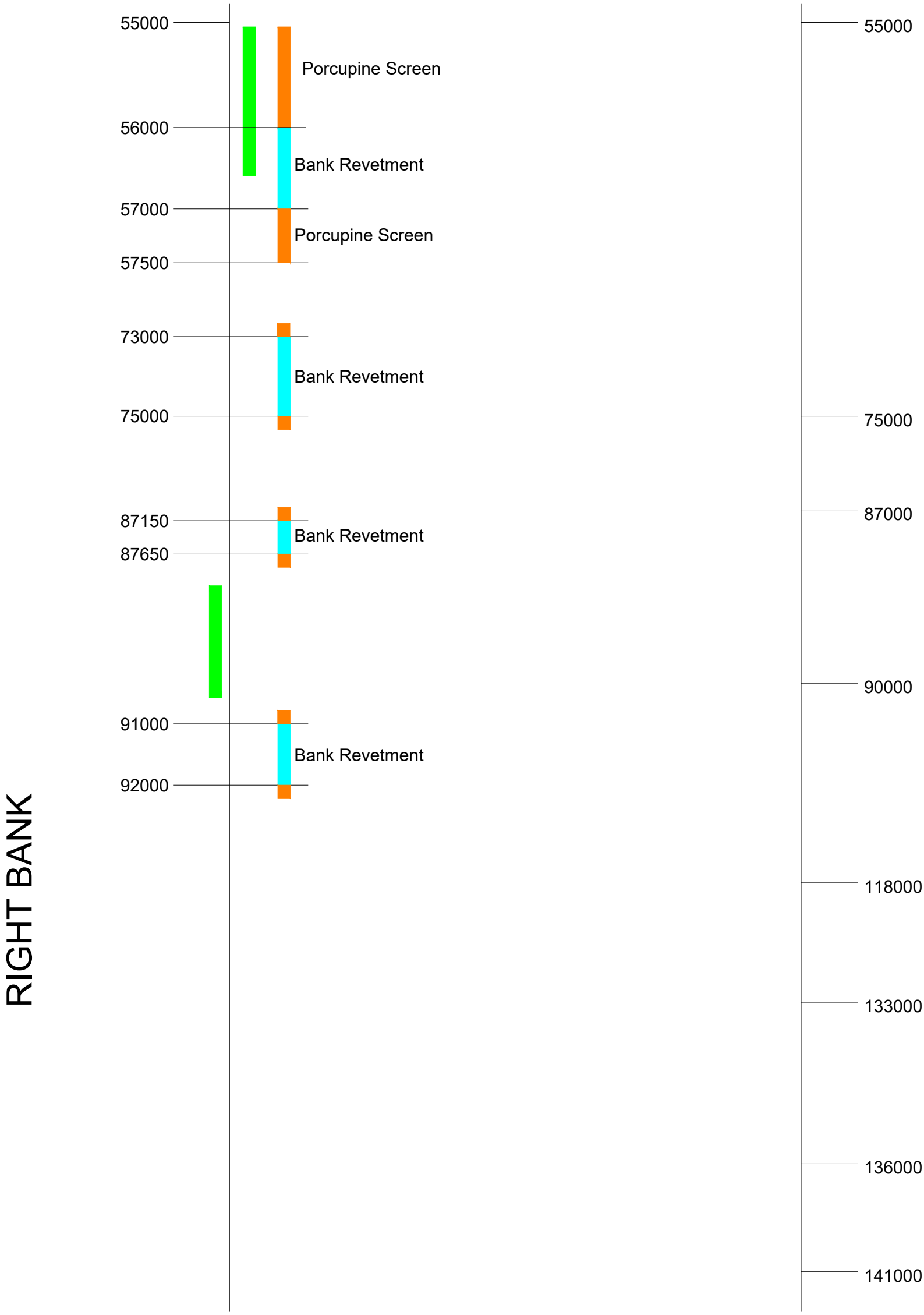
LEGEND:-

EXISTING PROTECTION WORK

PROPOSED PROTECTION WORK

- BANK REVETMENT
- Porcupine Screen
- GABION WALL
- GHAT

LALGOLA - BHAGWAN GOLA



LEGEND:-

EXISTING PROTECTION WORK

BANK REVETMENT

Porcupine Screen

PROPOSED PROTECTION WORK

CWC.GOV.IN

CWCOfficial.GoI

CWCOfficial_GoI

CWCOfficial.GoI

c/CWCOfficialGoI

CENTRAL WATER COMMISSION
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION
NEW DELHI