HYDRO-MORPHOLOGICAL STUDY FOR FIXATION OF THE ALIGNMENT OF COASTAL CLOSURE – A CASE STUDY OVER MAINKA-MONTAZ CHANNEL IN THE COASTAL AREA

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CERTIFICATE OF APPROVAL

We hereby recommended that the M.Engg. research work presented by Shyamal Kumar Ghosh, Roll No. 1009162001P, Session: October 2009, entitled **“Hydro-morphological study for fixation of the alignment of coastal closure – A case study over Mainka-Montaz Channel in the coastal area”** be accepted a fulfilling this part of the requirement for the degree of Master of Engineering in Water Resources Engineering on 29 September 2014.

Dr. Umme Kulsum Navera Professor Department of Water Resources Engineering BUET, Dhaka.	Chairman (Supervisor)
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DECLARATION

This is to certify that this project work entitled **“Hydro-morphological study for fixation of the alignment of coastal closure – A case study over Mainka-Montaz Channel in the coastal area”** has been done by me under the supervision of Dr. Umme Kulsum Navera, Professor, Department of Water Resources Engineering (WRE), Bangladesh University of Engineering and Technology (BUET), Dhaka. I do hereby declare that this project work or any part of it has not been accepted elsewhere for the award of any degree or Diploma from any other institution.

(Shyamal Kumar Ghosh)

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BRTC	Bureau of Research and Testing Centre
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CDSP	Char Development and Settlement Project
CEGIS	Centre for Environmental and Geographical Information Services
CEIP	Coastal Embankment Improvement Project
CERP	Coastal Embankment Rehabilitation Project
DWRE	Department of Water Resources Engineering
EDP	Estuary Development Programme
EIP	Early Implementation Programme
HWL	High Water Level
HWN	High Water Neap
HWS	High Water Spring
ICZMP	Integrated Coastal Zone Management Project
IWM	Institute of Water Modeling
JMREMP	Januma-Meghna River Erosion Mitigation Project
LRP	Land Reclamation Project
LWN	Low Water Neap
LWS	Low Water Spring
MES	Meghna Estuary Study
ML	Mean Level
MSL	Mean Sea Level
M & M	Mainka and Montaz
MOWR	Ministry of Water Resources
OIDB	Offshore Island Development Board
O & M	Operation and Maintenance
PWD	Public Works Department

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ABSTRACT

The present study has been conducted to hydrological analysis and find out the zone of tidal meeting points for fixation of alignment of the closure over Mainka and Montaz channel. The Mainka and Montaz channel is connected channel of Bura Gauranga River (branch of Tetulia Channel) and kukri-Mukri Channel (branch of Shabazpur Channel) which both finally flows to the Bay of Bengal.

Analysis of cross-section of Mainka and Montaz channel and selection of the closure sites (16 no. cross section of Mainka Channel and 25no. cross section of Montaz channel). Those stretches of both Channels have a regular shape with very constant width and depth. The closure over Montaz channel already constructed last monsoon by BWDB.

The maximum and minimum design water level was calculated and got 3.5m and -0.80m. The tidal range varies from less than 1.0 meter during neap to 2.5 meter during spring. It is envisaged to execute final closures in three days from 13-15 February and from 27 February-1March. The maximum discharge of Montaz channel is 425 m3/see on 28/12/09 and 700m3/see on 2/1/10. Similarly the maximum discharge of Mainka channel is 775 m3/see on 29/12/09 and 600m3/see on 3/1/10. The critical velocities during final closure (gap considered 100m) are 1.2 m/sec in the Mainka Channel and 1.4 m/sec in the Montaz Channel.

The conclusions on the main morphological developments observed in the period from 1973 to 2008 are presented this study. The planform of the chars and channels in the cross dam area has changed significantly during the period from 1984 to 1996. The area of south Bhola has been accreting rapidly in the last 25 years. At present a number of channels between Bhola and the chars to the south of Bhola have more or less stabilized.

The construction of closure in the coastal area, the selection of timing during final closure is the most vital issue. In this study it has been find out the closing time by analysis of water level. A suitable period around neap has been selected; in this case the first neap in February seems adequate.

Innovative techniques and new construction materials have been developed in the past decades for constructing dams, embankments and slope protection structures. Geo-textile tube (shortly called geo-tube) technology is one of these new features that have been successfully used to create sustainable sea defense structures, retaining structures, slope reinforcement and erosion protection. They are also cost effective and time saving when compared to traditional construction methods.

Chapter 1

INTRODUCTION

1.1 General

Bangladesh with an area of 147570 sq. km [DHV-Haskoning, 2007] is one of the greatest deltas in the world. Majority of the coast line of Bangladesh represents deltaic complex of the major River system- Ganges – Brahmaputra – Meghna having a catchments area of 1.75 million sq. km [BWDB, 2007]. About 380 km represents deltaic fringes connected to major rivers out of total estimated coastline of 710 km [EDP, 2007]. Due to tidal fluctuations, coastal area of Bangladesh is very much vulnerable to tidal flooding, occasional cyclones and tidal surges. Crops productions are severely restricted due to saline intrusion as well as making lives and livings of peoples at stake.

A vast network of river systems, an ever-dynamic estuary and a saline water front penetrating island from the sea marks the coastal zone. The coastal zone includes a number of small islands in addition to the coastal plains. The Coastal Zone of Bangladesh is generally perceived to be a zone of multiple vulnerabilities. It is the combination of natural disasters and man-maid hazards with realized and untapped development potentials that sets the unique stage where the coastal people pursue their livelihoods. The coastal zone needs special attention and requires distinctive approaches because of the vulnerabilities and potentials in combination with the remoteness of part of this zone [MOWR. 2003]. Coastal Cross dam is playing as a main role for part of land reclamation from the estuary. To protect the coastal area of Bangladesh from tidal floods and saline water intrusion, Bangladesh Water Development Board so far implemented 123 polders up to second phase of Coastal Embankment Rehabilitation Project [CERP-II, 2003]. These polders involved construction of 5017 km embankment and 1293 nos. of closures [CERP-II, 2000]. The closures were constructed mainly on tidal channels. The closures apart from being used as flood protection measures also induced land reclamation. Many big closures have been constructed in the polder projects of Bangladesh.

Experiences show that some new lands are coming up as per natural accretion, but these are coming up at a slower pace and take a lot of time to be usable for agriculture and human living. The learning experiences of the past dictate us that the process of land accretion could be accelerated through effective intervention like construction of cross dam over flowing channels.

1.2 Background of the Study

The national policy and activities of Governments of Bangladesh for management of the coastal zone are aimed at improving the management of natural resources; mitigation and/ or better management of natural disasters, human induced natural resources degradation, bio-diversity/ habitat loss, climate change, environmental pollution as well as creation of opportunities for sustainable economic development. Land reclamation has been recognized as an important activity as a part of coastal management in Bangladesh, and has been studied and planned in various previous projects.

The Dutch funded Land Reclamation Project (LRP) spanning over a period of 14 years from 1977 to 1991 was one of the early systematic efforts in the field of land reclamation and estuary control. Initially the objectives of LRP had major emphasis of land reclamation only. With the progress of the project activities consolidation, protection and development the new accreted land also become prominent [LRP, 2009], [LRP,1990] and [LRP, 1987].

After the completion of the LRP project in July 1991, the distinct sets of activities of LRP were continued as 2 separate projects. The Char Development and Settlement Project (CDSP) was started to look after the land-based activities of LRP and Meghna Estuary Study (MES) was designed to take care of hydrological and morphological aspects of the estuary [CDSP III ,2009].

Meghna Estuary Study (MES) prepared a long-term plan for the project area covering the next 25 years. MES also prepared a list of priority projects and possible interventions for the next 5-10 years, which was indicated as “Development plan”. MES carried out marine surveys as well as implementation of a number of erosion control and accelerated land accretion projects on pilot basis [MES II (2007), Technical note of Meghna Estuary Studies-01, Bangladesh Water Development Board and MES II, 2007].

Bangladesh Water Development Board (BWDB) Task Force submitted its report in June 2003. The Task Force identified 19 potential cross dam sites for assisting and accelerating the natural processes of land accretion in the coast of Bangladesh in Figure-1.1. The Task Force also prepared a proposed action plan for implementation, in phases, of identified priority works [EDP, 2007].

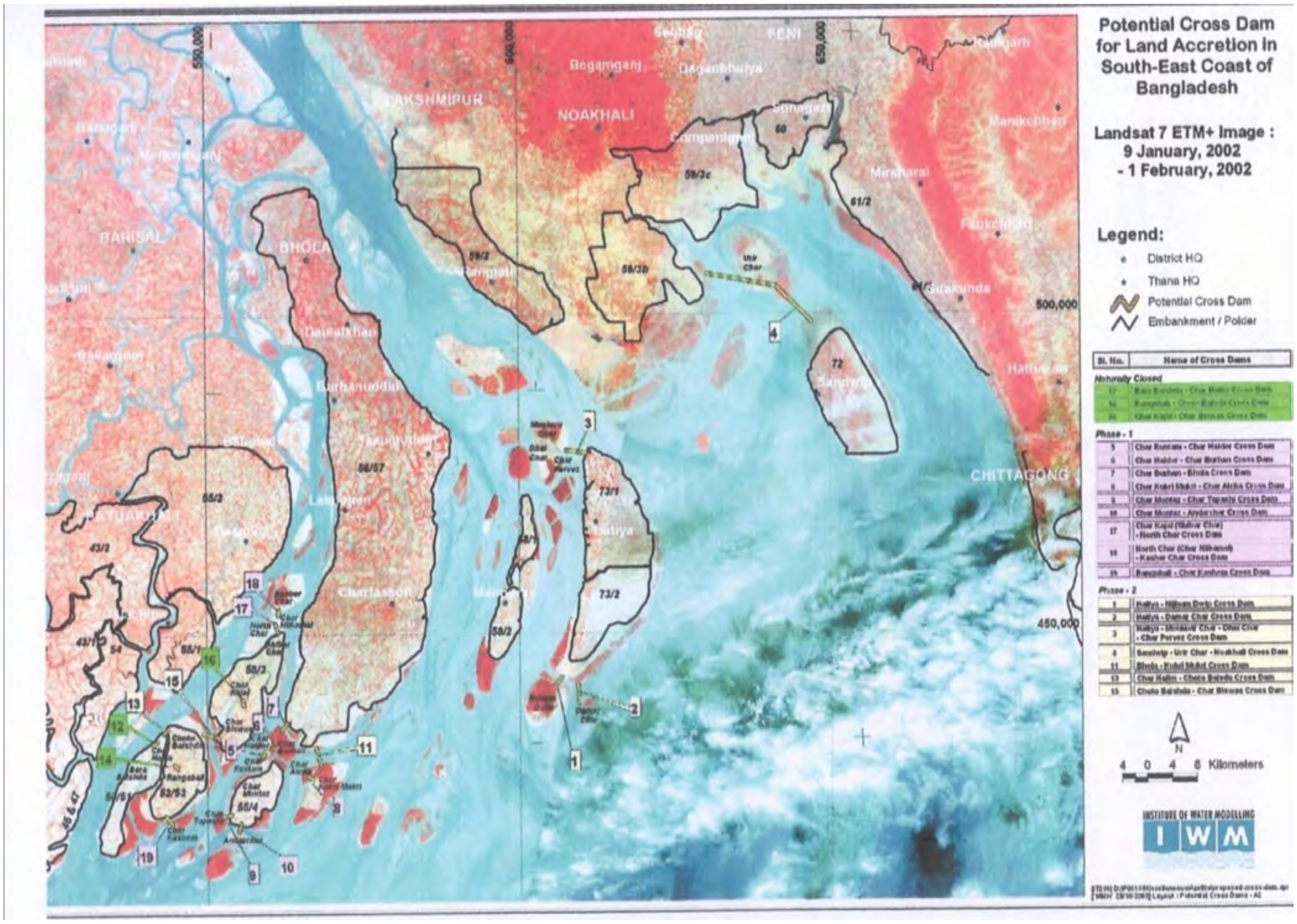


Figure -1.1: Potential closures sites (19 nos.) identified by BWDB. (Source: IWM, 2003).

The Estuary Development Programme (EDP) commenced on the 1st March 2007 as essential follow up of LRP, MES and the Task Force activities. EDP carried out the updating of bathymetric surveys, investigation and design of potential cross dams and investigation and implementation of potential land accretion schemes [EDP, 2010].

The Closures in between Char Mainka and Char Islam over Mainka Channel and Montaz Channel in between Char Islam and Char Montaz are taken into account in this study. The above two smaller channel have width of about 1 km and depths around 5meter to 6meter and located at the south-western end of West Shahbajpur Channel, which is the channel that discharges the largest portion of net flow from the lower Meghna to the outer delta area. The study area consists of islands with larger rivers on both sides Bura Gouranga River & Kukri Mukri Channel and smaller channels in between Mainka & Montaz channel. About 3500 hactor land will be reclaimable for implementation of the cross dam over Manika-Montaz Channel and also would be connected the Bhola to Patuakhali district as well as char land to main land.

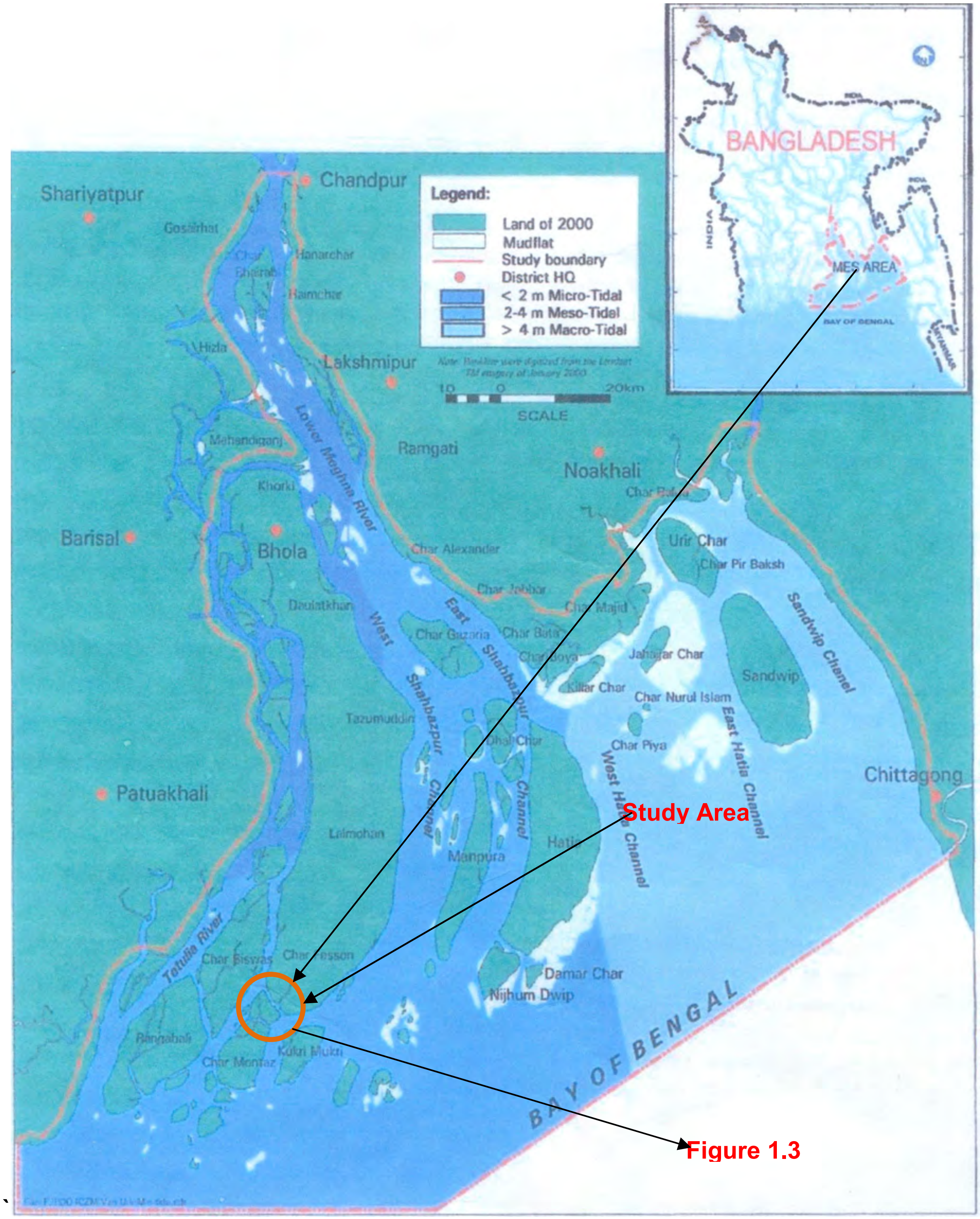


Figure - 1.2: Location of Study Area (Source-EDP, 2007)

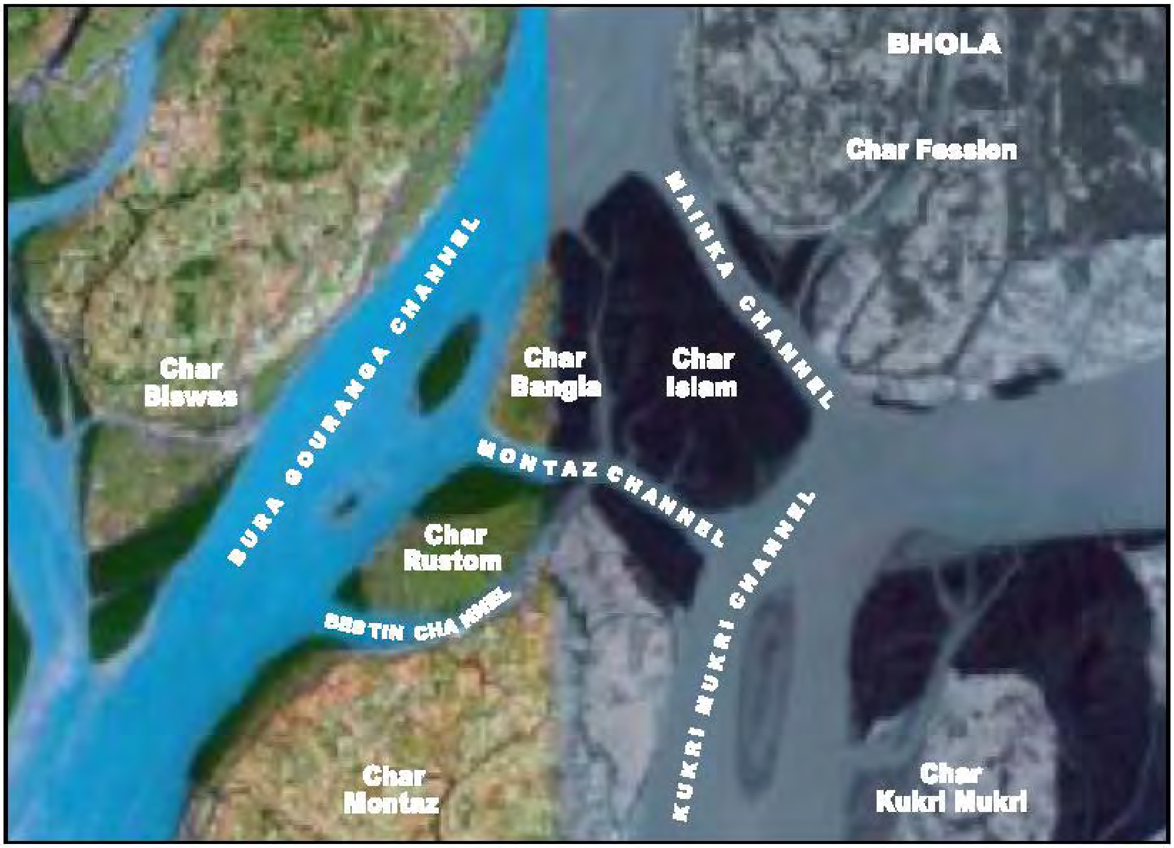


Figure-1.3: Location Map (Source- Google)

1.3 Objectives and Scope of the Study

Specific objectives of the study are as follows:

1. Selection of the design discharge and water level of the study area and locate the tidal meeting point of proposed channels.
2. Planning and fix up the alignment of the closures on the basis of survey data with the river bathymetry. The latest bathymetric data will be analyzed and use as output for the update of the morphological study.

1.4 Outline of the Report

This study has been presented in five (5) Chapters, they are:

Chapter-1 of this report contains the background of the study, objectives and scope of the study.

Chapter -2 a brief history is given of the construction of previous cross-dams in Bangladesh and their principles, review of techniques and methods as well as applicability.

A description of general approach and different information sources used for this study is included in Chapter-3. This will include an assessment of the latest status and the reliability of different information sources.

Results and discussion of the project are included in chapter-4

The conclusion with outcome of the study and also focus on the recommendations and limitation of the project in addition recommendation of new techniques for construction of coastal closure is included in Chapter-5.

Chapter 2

LITERATURE REVIEW

2.1 General

Accretions of new land have much importance and serious implication on the physical and social security for the population in the coastal areas and on the islands. Land Reclamation Project (LRP), Meghna Estuary Studies (MES)-I and II and Estuary Development Programme (EDP) have already worked to exploit the potentials for reclamation and development of new and along the coastal fringes. Meghna Estuary Studies prepared a phased long term Master Plan for possible coastal closures in the estuary for the next 25 years. Bangladesh water Development Board (BWDB) in 2003 reviewed the past LRP and MES studies and identified 19 potential closures priority land reclamation interventions. The EDP (2009) has been conducted the marine survey throughout the lower Meghna and also identified, investigated and designed as well as implemented some potential closures for land accretion schemes.

2.2 Closures an overview

In Bangladesh, land reclamation by closure construction in order to promote accretion process first started in 1956-57 [BWDB, 2006]. The first closure was built over the drying branch of Meghna River, which is known as Noakhali closue-1 that resulted rapid siltation in an area of 21000 ha [BWDB, 2007]. The second closure was constructed in 1964 connecting char Jabbar Island to the Noakhali mainland. Subsequently one closure was constructed at Batir Tek in Noakhali district over Daria Nadi during 1980 [BWDB, 2007] that finally resulted in accretion of contiguous land of about 1000 sq.km in greater Nokhali district. During 1970, this additional area was brought under development by embankment. Later on the area was brought under full protection against tidal and cyclone surge under the project CERP during 1996-2003. Under Muhuri Irrigation Project, Feni River was closed during 1988, resulting accretion of approximately 3315 ha [Euroconsult et. Al, 1987]. This new area has been brought under comprehensive development including flood protection and human settlement under CDSP-II [CERP-II, 2003].

In 1976, a closure was constructed between Jahajmara and char yunus in Hatiya island popularly known as "kalam Bund", which reclaimed a considerable amount of land. Two small dams have been built in Monpura Island, one in 1978 and the other one in 1989 and together they resulted in an accretion of 200 ha of new land [DHV-Haskoning, 2007]. The cross dam in between Monpura and Char Fayazuddin was constructed during 1980 by Offshore Island Development Board (OIDB). This resulted in the silting up of the channel and continuous land development [LRP, 1990].

In 1982, as part of the accretion trial programme, an older branch of the Noakhali khal, the daria Nadi was closed, which induced siltation in area of 200 ha. Due to this dam, the channel cross-sectional area was reduced by about 650 sqm per year [DHV-Haskoning, 2007]. Besides, some small dams have been constructed by local initiative in different places of the coastal areas which have reclaimed lands and also checked localized erosions.

Under MES a pilot closure was constructed over the Bestin khal in Char Montaz (Polder-5/4) in 1999 [MES II, 2001]. It consisted of a permeable closure using geo-textile material and pre-fabricated elements. Scouring was controlled by applying geo-textile bed protection. The low under water dam consisted of concrete blocks and finally a pre-cast A-frame and geo-textile screen. The geo-textile screens were fitted to the A-frame. The closure dam had initial success in inducing some sedimentation but the final earthen closure was never done. Moreover, the functioning of the A-frame was found to be complicated by irregular settlements and has been suggested to delete the A-fame from the standard design in the EDP. In 2010, a solid closure was constructed with geo-textile bed mattresses including bamboo core filled with earth filled gunny bags under EDP [EDP, 2010].

2.3 Review of Previous closures in Bangladesh

Construction of major closures started in Bangladesh as early as 1957 [DHV-Haskoning, 2010] with the implementation of closure-1 in the dying eastern branch of the Meghna River. The purpose of the closure was to reclaim land for agriculture. The length of the closure was 14km. The dam was made of local sediments replaced by labour. Only for the final closure gap of he main channel chambers were constructed of wood and bamboo and filled with brushwood and gunny bags filled with clay.

In view of some failures with local methods much attention has been concentrated on the design and the construction methodology of closure. A few big closures have successfully been implemented with combination of horizontal and vertical method of closing incorporating cofferdam over sill and bottom mattresses. Now-a-days BWDB has standardized the design with the chamber of wooden bullah and bamboo; to be filled with clay filled gunny bags vertically up to the design level. This procedure is followed for small and medium size channel with lower tidal range up to 3m. For big size channels with tidal range from 3 to 5m, improved methods of closing are followed. Amtali khal closure, Chakamaya khal Closure, Madargong Khal Closure are important closures that have constructed following improved techniques, using Netherlands experience, using local manpower and local materials.

The success of such closing depends of labour strength, labour movement facilities, material stock channel section and depth, current velocity, tidal fluctuation back water effect, site situation, materials and labour movements facilities equally from both banks and time of final closing. Most of the closures in coastal area are closed following this procedure. The materials used are local earth, straw, brush wood, Golpata, tree branches, earth filled gunny bags, bamboo pins, wooden bullah, bamboo tarja (mat) and mata.

Closures/ cross dams executed in Noakhali, Chkamaya khal, Amtali khal, Madargong, Feni River and Bestin Channel being representative of the closure/ cross dam construction in Bangladesh, are described in the following.

2.3.1 Noakhali (Meghna) Cross Dam-1

In the year 1956-57, Irrigation Department of Govt. of East Pakistan (Present BWDB) implemented a closure construction across the abundant course of this channel connecting Lakshamipur main land with North Hytia Island (Ramgati) in order to reclaim land from the bed of the Bay. The objective was achieved; an alluvium land strip of 13-16 km wide was added to the coast line of Noakhali district and added North Hatiya with main land. A net area of 21000 hactor [DHV-Haskoning, 2007] was reclaimed and was ready for agriculture development by 1965 [EIP, BWDB, June 1982].

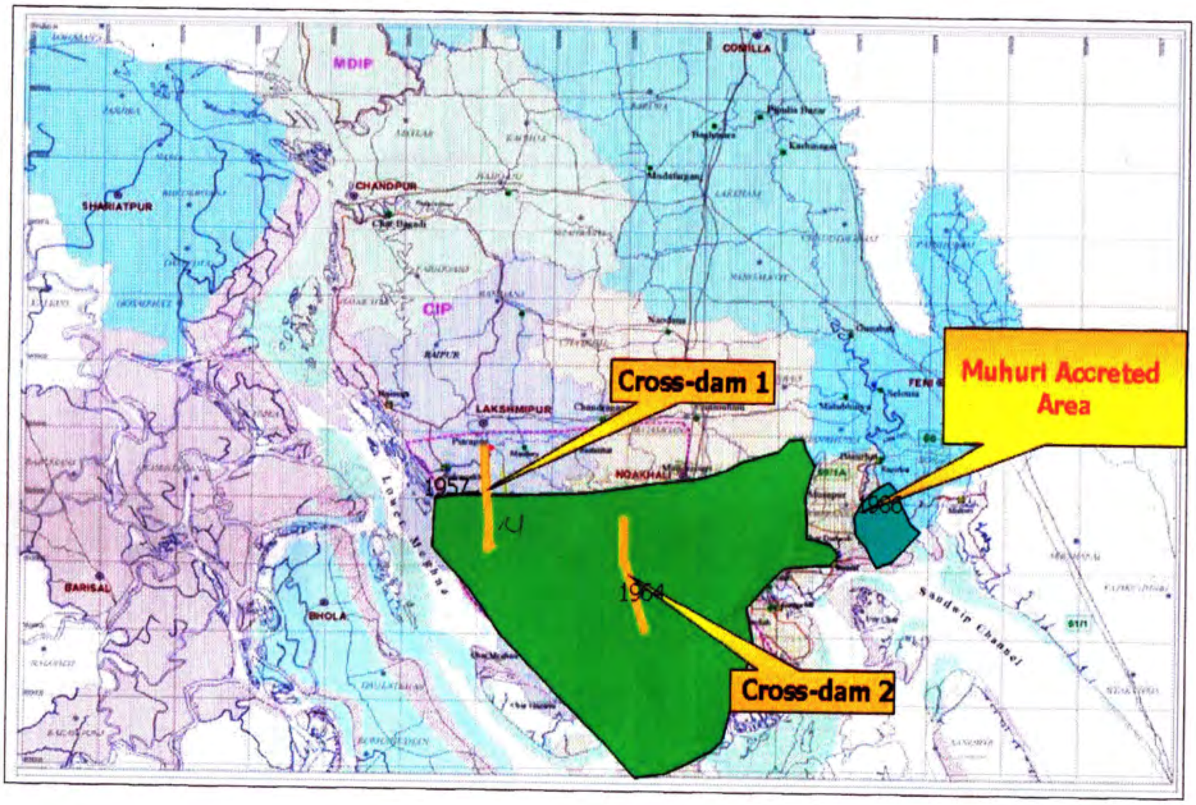

Noakhali Cross Dams and Feni River Closure Dam

Figure 2.1- Noakhali closure and Feni River closure

2.3.2 Noakhali (Meghna) Cross Dam-2

The Noakhali (Meghna) closure no-2 is about 16 km [EDP, 2007] long connecting Noakhali main land with Char Jabbar Island. Tide caused to flow from east through Bamni River, Meghna River and Petkata khal and also from the west through Baggar Donna khal. The two flows met near the closure alignment at the south main channel and at North main channel. Eastern tide comes about half an hour earlier than western tide. A large part of the dam alignment is located on char and on the shoals which dry up during low tide. The actual closures connected two main channels (i,e. north main channel and south main channel) and three shallow channels. The closure passed along the high ridges in the char and stopped the tides moving to and from. The closure-2 has been constructed in 1963-64 providing an account of 31,000 hactor [EIP, BWDB, June 1982].

2.3.3 Chakamara Khal Closure

The Chakamara Khal is a tidal channel from Andhamanik River near Khepupara in Polder-44 under Patuakhali WD Division of BWDB, Kalapara. The width of the channel at the closure site is 210m with an average depth of 5.5 m below mean water level. The tide range of the channel is 1.5m to 3.3 m. The closure was successfully executed during 1978-79 [DHV-Haskoning, 2007] and [EDP, 2007].

2.3.4 Amtali Closure

The Closure is located on Amtali khal in polder 43/1 under Barguna O & M Division located in the district of Barguna. The western embankment of the polder borders before the Balsher River which is one of the Major fresh water arteries coming from Barisal-Patuakhali area and finally flows into the Bay of Bengal. The Closure was implemented by Dutch aided Early Implemented Programme (EIP). The Closure work was taken up for execution in 1979-80 construction season through contractor following traditional Bengali Mata method but failed to complete that season and also the attempt failed in the following the 1980-81 season [EIP, BWDB, June 1982].

2.3.5 Madargong Closure

The Madargong Closure is located in Shyamnagar Upazila in Satkhira district and is under administrative control of Satkhira O & M Division-1 of BWDB. The channel cross section at the closure was about 6.5m below average water level with a width at waterline as 140m. The tidal range at the site is about 5.2m at spring tide and 1.9m at neap tide. The tidal prism at spring tide is about 7X106 m3 [EIP, BWDB, June 1982].

The closure as attempted in 1970 without success [DHV-Haskoning, 2007]. The closue was again tendered out and work order was given in 1976. The closure works by means of local mata method was started in January 1976.The site was abandoned in March 1976 because of disproportionate progress of works of the contractor. Later it was decided to take up the closure works in 1979-80 under Dutch aided under EIP. After two earlier failures utilizing local mata method, a team of Dutch experts assisted BWDB with the implementation. The third attempt in March 1980 also had the same fate.

2.3.6 Feni River (Muhuri) Closure

Feni River Closure Dam is situated in the Sonagazi Upazila of Feni district. It was constructed during February 1985 [DHV-Haskoning, 2010] at the mouth of the Feni River as a major component of Muhuri Irrigation Project. Topographic surveys by the Land Reclamation Project indicate that the closure resulted in an accretion of about 4000 hector of new land. The dam project was aimed at preservation of water for irrigation purposes and to form a barrier between the sea and the conservation reservoir. Prior to the construction of the closure the estuary was subjected to daily flooding by tides. The volume of tidal prism was very much dependent on tidal water levels. This closure also served as a protection of Muhuri Irrigation Project against tidal waves of extreme height.

2.3.7 Nijhum Dwip Closure Pilot Scheme by MES

The first closure trial in Nijhum Dwip was executed in 1987 [EDP (2007), Inception Report of Estuary Development Programme, Bangladesh Water Development Board] by MES Project. The main purpose was to investigate the feasibility of reducing the cost of classic design of closure by reducing the earth filled bags. In the classic design, the cost of dam body consisting of clay filled bags was 83% of the total cost. The number of bags was proved insufficient to face high tide and wave action in monsoon because of fine-grained local soil filling the bags.

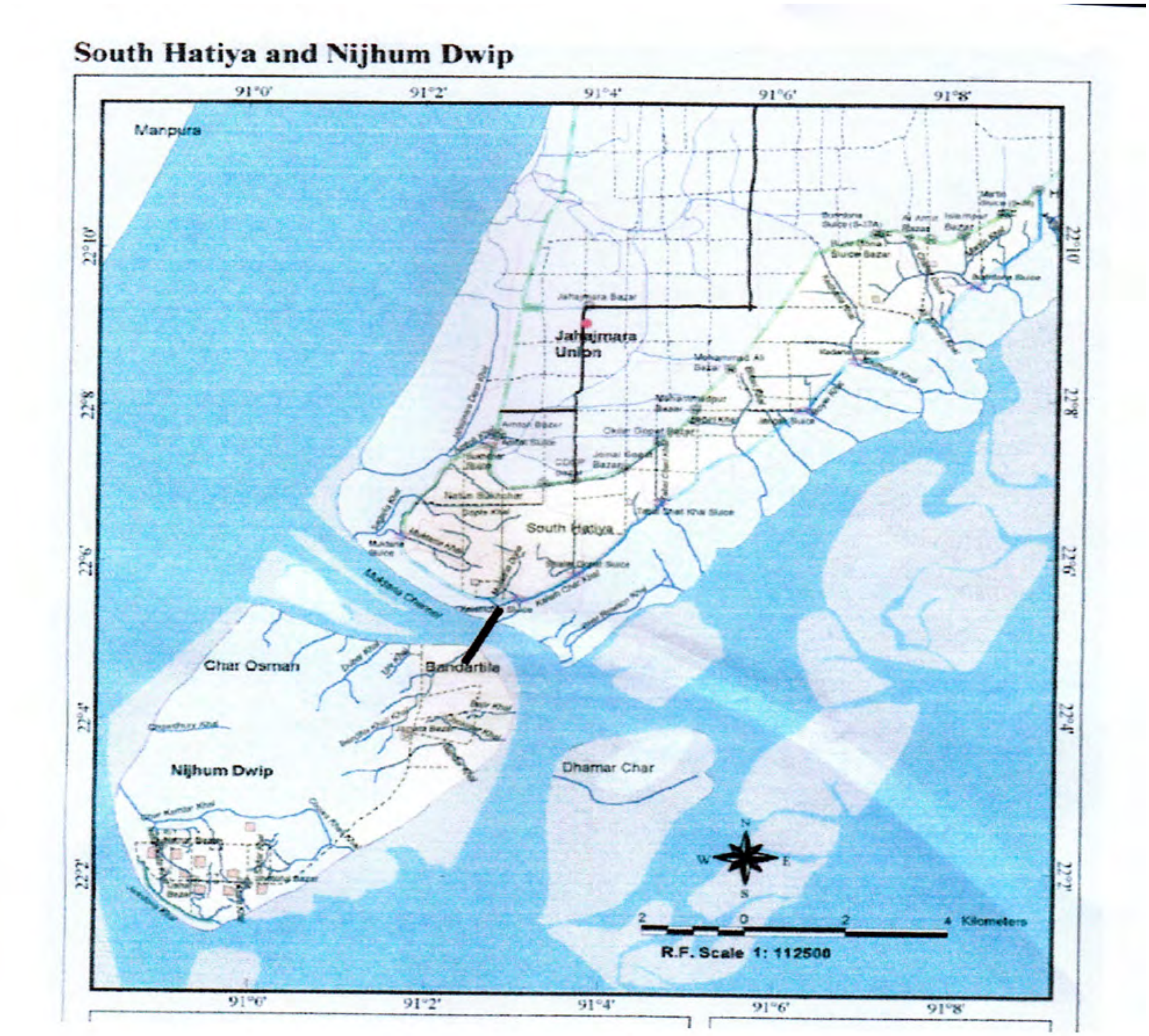


Figure 2.2: Hatiya and Nijhum Dwip Closure

2.3.8 Char Montaz Permeable closure Pilot Scheme by MES

The second pilot was semi permeable closure based on completely new concept. A low under water dam was made on geo-textile mattress ballasted with concrete blocks. The under dam provide stability to steel A-frames and woven geo-textile screen that are fixed to A-frame made of Galvanized Iron pipes. Both the construction and the impact were successful. The exposure to waves was limited because of location of the structure. So another pilot was planned to test the construction in heavier circumstances. One of the conclusions of the test was that the functioning of A-frames is made complicated by irregular settlements and it is suggested to delete them from the standard design [MES II, 2001]. The size of the Bestin Channel has been reduced substantially as a result of the construction of a permeable cross-dam in 1999 under MES-II [MES II, 2001] in figure 2.3.

Figure 2.3: Permeable cross-dam constructed during MES-II on Bestin Channel in 1999.

2.3.9 Nijhum Dwip Permeable Closure (Trial Section)

The third Pilot cross dam was at Muktaria Channel in order to test the construction as applied in Char Montaz in more severe hydrological situation. In particular exposure to higher waves was tested with A-frame with geo-textile screens by putting it on a small section in the channel [BWDB, 2007].

2.3.10 Bestin Closure by EDP

The Bestin Channel is separating Char Montaz from Char Rustom and is connecting the east branch of the Tetulia River with the Montaz Channel in the north. In 1999 a permeable dam (A-frame type) has been constructed in the Bestin Channel along Char Montaz (under MES) [EDP, 2009]. In 2010 after 10 years later it appeared that as a result more than ¾ of the channel has been silted up. The closure has been completed by constructing a solid cross-dam as part of the EDP in 2010 [EDP, 2010] in figure 2.4. This cross dam provided a road communication between both chars. Due to construction this dam at about 1750 ha land will be reclaimed [EDP, 2010].

Figure 2.4: A solid cross-dam constructed during EDP on Bestin Channel in 2010.

2.4 Challenges of Closure

The closing of tidal channels closure definitely involve specialized techniques and expertise. A very judicious hydraulic analysis with past experience is a prerequisite for any project. Experiences with completed projects are major guidelines for planning and designing future projects. There are some local constructions methods are mentioned in the followings:

1. Horizontal closure method of construction
2. Vertical closure method of construction
3. Combined method (horizontal and Vertical) of construction

The Bangladeshi Mata closure method is essential a horizontal closure method and the improved employed in bigger channels like Chakamya and Amtali is vertical closure method. Application of entirely horizontal closures will result in high velocity in the last part of tidal channel and is to be closed in the low tide period i.e winter season. Alternatively the application of purely vertical closure methods will create an almost unmanageable situation during construction in view of the substantial length of the dam section to be constructed. To avoid the disadvantages a combination of vertical and horizontal method has to be adopted. The most attractive combination of horizontal and vertical closure method requires the following components:

1. Bed protection
2. Low cross dam on shoals
3. Construction of sill
4. Cross dam construction on top of sill

Sub-structure area covers all works up to the level of low water level and super-structure covers works above low water level. The cross dam or sill may consist of gunny bags.

Innovative techniques and new construction materials have been developed in the past decades for constructing dams, embankments and slope protection structures. Geo-textile tube (shortly called geo-tube) technology is one of these new features that have been successfully used to create sustainable sea defense structures, retaining structures, slope reinforcement and erosion protection. One of the benefits of using geo-tubes is that they are easy to install providing that the new construction and placing method has been adopted. Once in place these products are very durable, deliver high performance, while minimally impacting the environment. They are also cost effective and time saving when compared to traditional construction methods.

Two alternative options have been considered during EDP study:

1. Closure structure with 3 geo-tubes of which two geo-tubes are placed on top of the sill. The third tube is to be placed on top of the sand fill between the two filled geo-tubes as shown the Figure 2.5, Alternative I.

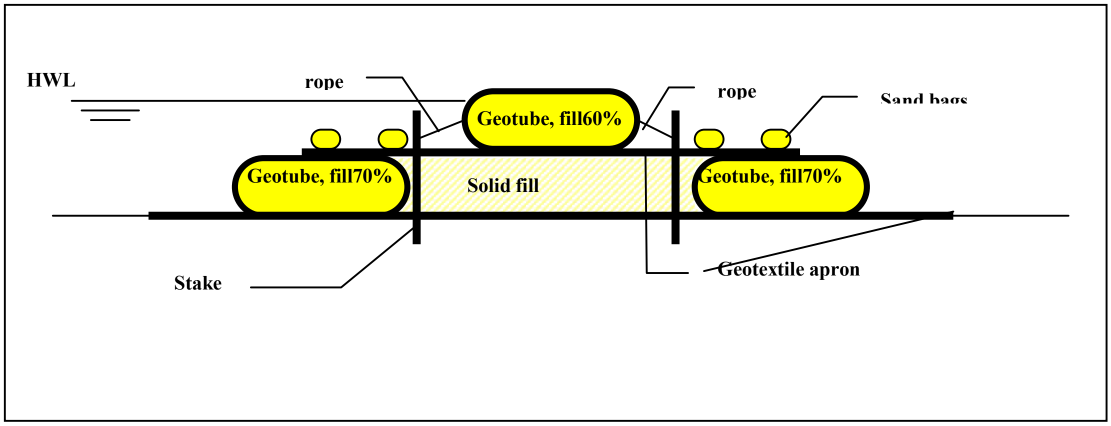


Figure- 2.5: Alternative I, 3 geo-tubes, (Source: EDP, 2007)

2. Closure structure with 1 geo-tube would sit on top of a scour apron, held in place by anchor tubes or sand bags (Figure 2.6), Alternative II.

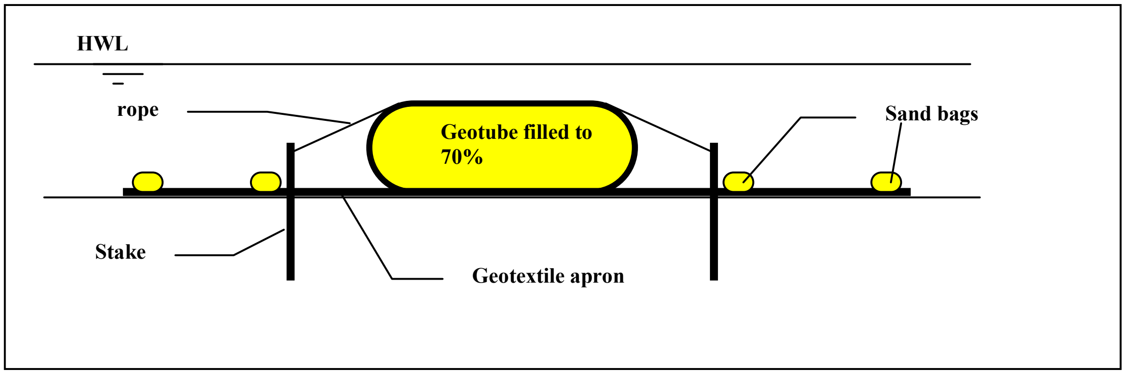


Figure 2.6: Alternative II, 1 geo-tube (Source: EDP,2007)

After a thorough evaluation of possible risks during placement of the tubes in tidal areas taking into account the lack of experience with placement of geo-tubes it has been decided to option for the construction with one geo-tube. The advantage of the system with one tube is that in case placing of the geo-tube should fail due to for example sliding of the geo-tube as a result of current forces on the tube, then as back-up system sand bags can be placed in the closure gap to the complete closure operation within reasonable time.

2.5 Major Causes of failure of Cross dam

1. Backwater effect
2. Overtopping due to tide after flow closing
3. Unplanned closing time (suitable closing dates are middle of new moon to full moon or middle of full moon to new moon) in January-February, when tides levels are yearly lowest.
4. Failure to build a reasonable section of cross dam immediately after closing date i.e sufficient cross section to withstand pressure of new moon or full moon tides.
5. Physical exhaustion of labourers.
6. Labour strike for extra wage behind flow closing date
7. Non-availability of earth nearby
8. During closing time earth is borrowed in an unplanned way from wherever it is available nearby. This may cause scarcity of earth from nearby places to meet the need just after flow closure. Thus backwater or tide water may overtop the cross dam and cause failure.
9. Failure to property addresses the geotechnical aspect of foundation materials and cross dam materials.

2.6 Remedial measures for prevention of failure

1. Proper Hydro-morphological study
2. Selection the method of closure construction
3. Erosion control of closure approach head and river bed.
4. Proper planning of time of execution
5. Flow closing date should be on the day of lowest tide of the year.

6. Proper location of Closure alignment
7. Proper geo-technical investigation
8. Proper planning of closure site for material collection, placing, labour movement etc.
9. Labour procurement and timely engagement
10. Reserve labour force after closing date
11. Sufficient reserve labourers should be kept for making proper section with proper height to cope with the rising tide and back water effect.

2.7 Summary

It is apparent that the kind of closure to be employed for a particular channel depends on the following criteria:

1. Tidal volume
2. Tidal range the cross section at closure side
3. Channel bottom materials
4. Availability of materials
5. Availability of labour

This is obviously trickily demarcate line of division for choosing the type to be employed as small and bigger channels need to be defined. Dutch engineers have suggested it on the basis of tidal volumes; Final closure will have to be under taken in the gullies after first blocking the flow over shoals. However, general criteria for horizontal mata method may be as stated below.

1. The initial narrowing of channel on the shoal reducing cross-sectional area may not lead to more difficult flow situation during subsequent closure operation in the channel
2. Initial rising of channel bed by constructing sill, will lead to uniform flow situation over the entire width of channel.

Chapter 3

THEORY AND METHODOLOGY

3.1 General

This study will follow the approach as set up during Meghna Estuary Studies-II and Estuary Development Programme. It is indicated in the Meghna Estuary Studies-II study that numerical modeling of hydraulic and morphological changes in the complex coastal delta area of Bangladesh (despite of significant effort and improvement in the last decade) has not yet resulted in sufficiently reliable predictions at mid and long-term. Therefore during the MES II study an approach was chosen in which numerical modeling is used in combination with a process-based approach (statistical / empirical techniques and physical interpretation of developments).

The result from the Meghna Estuary Studies-II study has been used as a starting point and this study is also focus on updated and additional information obtained. Where relevant, information from Meghna Estuary Studies-II (MES-II) and Estuary Development Programme (EDP)study has been summarized and repeated in this report.

Several sources of updated and additional information have been obtained in this study.

1. Survey data from survey campaign Anwesha 2009-2010 (by BWDB)
2. Survey data from survey campaigns at Mainka-Mintaz locations 2009-2010 (by Institute of Water modeling)
3. Information from previous studies (e.g. MES II, LRP) and literature.

In this chapter, a general overview is given of the availability and reliability of data. Furthermore, a description is given of data processing methodologies and analysis applied with the available data.

3.2 Methodology

First the present hydraulic conditions have been analyzed using the results of the flow measurements. From the mean flow velocities and the head over the channels the hydraulic resistance in the channels has been computed. A set of conditions expected to prevail during the construction of the cross-dam and particularly during the final closure has been estimated in steps. In order to simulate the impact of the closure operations on the hydraulic conditions in the channels a spreadsheet model has been developed. This model has been used to simulate the partial horizontal closure, narrowing the channel at the dam site. The impact of this narrowing on the flow conditions is essential for determining the width of the final closure gap.

The impact of the sill in the closure gap on the flow over the sill is mainly dependent on the level of the sill crest relative to the water level. A lower sill gives lower flow velocities but a higher sill is preferred to limit the volumes needed for final closure. Hence the flow over the sill has been computed to determine the crest level of the sill. Finally the spreadsheet model is used to determine the flow velocities in channel and closure gap during final closure operations.

3.3 Hydraulic Resistance

A preliminary assessment of the hydraulic resistance (C) of the channel by using the formula based on Krytian W. Pilarczyk , 1990

$C=18\log(12R/D_{50})$……………………………………….. (i)

Where gives $C> 100\ m^{1/2}/s$, which is far too high.

A high value means smooth channel with low resistance. The reason of the too high values is that in case of very fine sediments ($D_{50} < 40$) the hydraulic resistance is probably more determined by the irregularities in channel bed and banks than by the grain sizes.

With the results of the flow measurements during spring, the hydraulic resistance has been computed from the Chézy formula

$v = C \sqrt{R.I}$………………………………………………..(ii)

Where
v = the average velocity in the cross-section
R = the hydraulic radius (=wet x-sectional area A/wet boundary length p)
I = water level slope in the Channels (= dh/L = head/channel length)

For the days of the spring flow measurements the C-values computed on an hourly basis. For each hourly water level the values of A and R have been computed. Then the water level slope (I) has been computed from dh and L.

And finally from the mean velocities $v=(Q/A)$……………(iii)

and the values for R and I the hydraulic resistance is determined from

$C = v/\sqrt{(R.I)}$……………………………………………….(iv)

Extreme Chezy numbers are found when the flow velocities and/or the heads are small. During slack the computed C-values become zero and during about zero head the computed C-values become very large. This has no physical meaning; therefore the extreme values have been neglected.

Perhaps an exception is the high C values found in Mainka channel. They occur during the combination of max velocities and nearly zero heads. There is probably a datum error in the heads. Another option is that the hydraulic conditions are far from steady then and C-computations are not valid anymore.

3.4 Spreadsheet model

The spreadsheet model has been developed to enable computation of the changing hydraulic conditions in the Mainka and Montaz Channels during closure operations. The boundary conditions of the model consist of the water levels at both ends of the channel. The principles of the modeling are as follows: The water level difference over the channel (head) generates the flow (discharge, velocity). The flow depends on the hydraulic resistance of the channel and the effect of the decreasing closure gap. The resistance losses in the channel stretches at both sides of the dam plus the hydraulic losses through the closure gap should equal the total head over the channel. This approach leads to the following mathematical descriptions:

The split of the total hydraulic losses over the channel (dh) is described by

$dh = dh_{channel} + dh_{gap}$ ………………………………………………….(v)

The hydraulic losses in the channel:

$dh_{channel} = L/R * v^2/C^2$…………………………………………………..(vi

Where,

$v = Q/A$ = the mean velocity in the channel in m/s……………………….(vii

Here,

L = the total length of the channel in m

R = the hydraulic radius in m

C = the Chezy number in $m^{1/2}/s$

Q = the discharge in m^3/s

A = the wet cross-sectional area of the channel in m^2

The losses through the closure gap are

$dh_{gap} = m.u^2 /2g$……………………………………………………….(viii)

in which

$u = Q/A_{gap}$ = the mean sub-critical velocity in the closure gap in m/s……..(ix)

Where

m = loss coefficient in the gap (-)

g = acceleration of gravity in m/s^2.

So the total head can be rewritten as:

$dh = LQ^2/RA^2C^2 + m\ Q^2/A_{gap}^2.2g$ ………………………………………..(x)

This relation between the head and the discharge can also be written as

$Q = \sqrt{}\ dh /[\ L/RA^2C^2\ + m/A_{gap}^2.2g\ ]$…………………………………….(xi)

It should be noted that this formula holds for quasi-stationary conditions supposed to prevail during each moment during the tidal cycle. This is about true as long as inertia forces are negligibly small. In case of the Montaz and Manika channels are applicable as the channels are very short (4 to 5 km only).

The formula shows that during closure activities, when the size of the closure gap is decreasing, the discharge through channel and gap can be computed for every time step, viz. for every combination of water levels and head over the channel.

3.5 Survey data

A general survey campaign was executed by Anwesha in the period of 2009/2010. Accordingly, more detailed local surveys were executed at the cross dam locations by IWM in 2009 and 2010. The IWM survey campaign for Bhola-Montaz area consisted of bathymetry measurements, water level measurements, discharge measurements and flow velocity measurements in figure 3.1. The survey was executed in 2009. The above surveyed has been analyzed and reviewed in this study.

3.5.1 Topographic Survey

During EDP project topographical survey executed along the alignment of the Approach Dams and the Connecting Dam. The survey comprised a longitudinal profile from embankment to embankment, with cross-sections at an interval of 50m; these cross-sections are 100m wide. Along these long sections and cross-sections surface levels have been taken at intervals of maximum 20m. Also a few cross-sections of the embankments have been taken. In this study the survey result has been analyzed and find out the alignment of the approach and connecting embankments of the cross dams.

3.5.2 Hydrographic Survey

The hydrographic survey data has been plotted and analyzed which was conducted by IWM during 2009-2010 consists of two parts during EDP projects:

1. Hydrographic survey in the Montaz and Manika channels comprising bathymetry and water levels and flow velocities in wet and dry conditions
2. Hydrographic survey in the main channels (Bura Gouranga Channel and Kukri Mukri Channel) comprised bathymetry, flow and sediment concentrations.

The wet cross-sections were completed with the dry parts such as the levels of banks and adjacent flood plains, coming from the topographic survey executed simultaneously. The water levels of the hydrographic survey measured at both ends of the Montaz and Manika channels. Results have been presented in later. The locations of the flow measurements are indicated on the following map Figure 3.1.

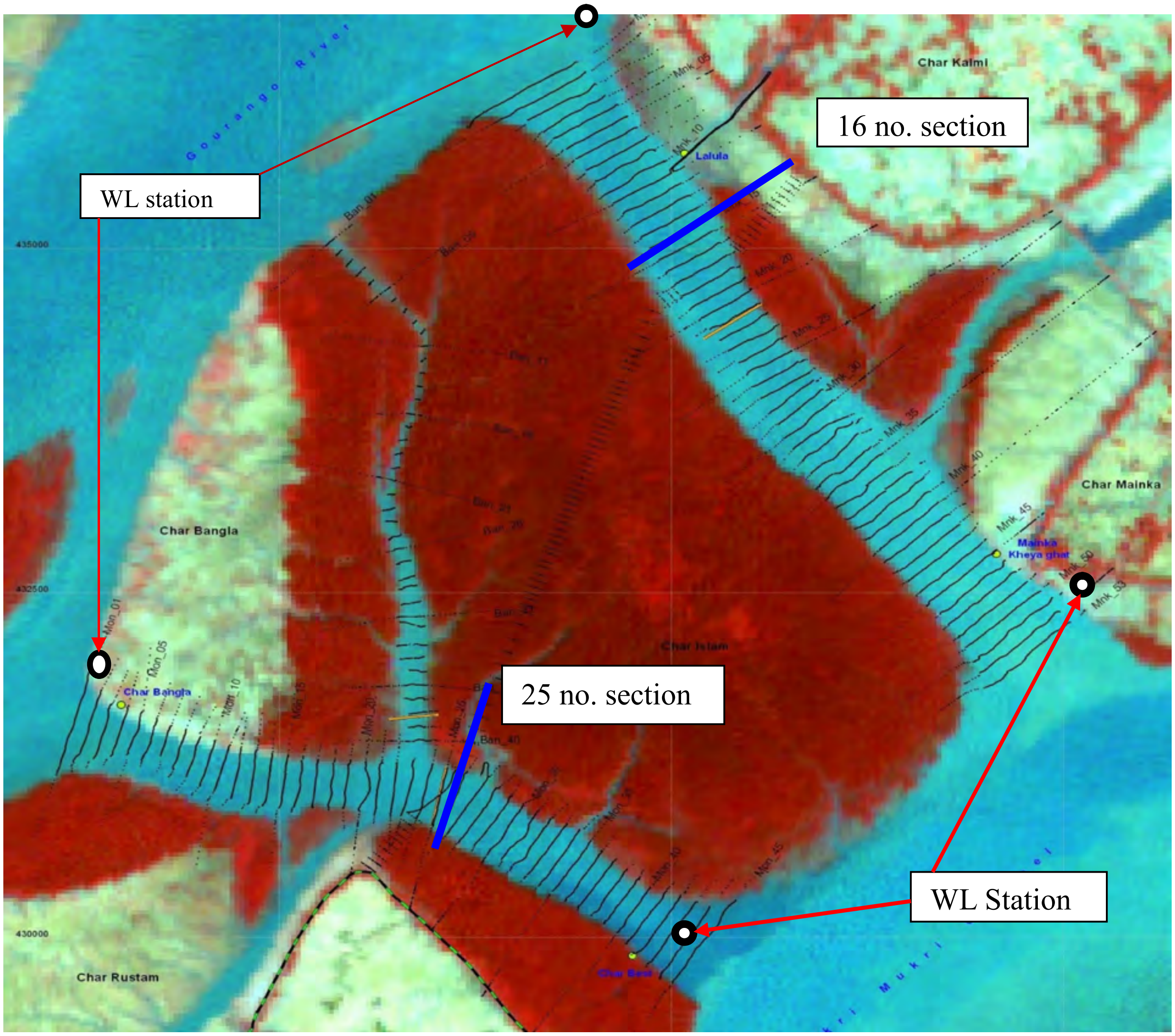


Figure 3.1: Locations of hydrographic measurements (Source: IWM)

3.5.3 Water Level

Water levels have been plotted against time and analysis which were measured at both ends of the Mainka & Montaz channels by IWM. There are 4 water level stations were operational. The location of the Water Level stations was presented in figure 3.1. For the first campaign staff gauges have been read. During night time hourly measurements were taken and during day time at least half-hourly readings have been performed. The second campaign was done using pressure-cell type of transducers and a sampling interval of 5 minute. Survey results were presented in the figure in the next chapter.

3.5.4 Discharge

The discharge measurement data has been plotted against water level and analyzed which were measured by IWM. In October 2009, total six times the flows were measured in the Montaz and Manika channels, 2 times in each channel during neap and during spring in table 3.1. In the Mainka and Montaz channels this programme has been repeated in the second campaign, during neap and during spring.

Table- 3.1: Discharge measurement

Location	**Mainka Channel**	**Montaz Channel**
neap tide	12 Oct 09 28 Dec 09	13 Oct 09 29 Dec 09
spring tide	19 Oct 09 2 Jan 10	18 Oct 09 3 Jan 10

3.6 Analysis of shoreline changes

In the MES-II study shoreline development and changes in land use were analyzed for a period from 1974 up to 2000 based on data from satellite pictures. Shorelines were delineated based on the satellite pictures and imported in GIS environment. In this study the 2008 shoreline (based on the available 2008 satellite picture) has been delineated in the same way by CEGIS. Furthermore, some additional GIS analysis of shoreline changes was executed by EDP for some specific special areas. The Shoreline changes in the period from 2000 to 2008 has been analyzed and described under this study. Furthermore, the conclusions about historical shoreline changes as well as identified trends in the MES-II study has been evaluated again and updated.

During MES-II, also a forecast method based on extrapolation of shoreline movement was developed. Despite its shortcomings, especially the lack of physical background, it is the only method at hand for long term predictions of shoreline changes in the Meghna Estuary. In order to evaluate the quality of predictions and the usefulness of the method for the EDP, the forecast prepared in 2001 (15 and 30 years ahead) has been compared with the position of the shoreline in 2008, as delineated by CEGIS.

The update of identified trends in the shoreline changes and physical processes may lead to a qualitative update and important of the forecast produced by Meghna Estuay Studies -II.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 General

In this chapter the available relevant images, maps and topographical data, Water level, Discharge, are summarized and analyzed. The selection of the location of the alignment of the dams to be constructed has been described in the last section of this chapter.

4.2 Study Area

For the project area a working map has been made using a suitable satellite image. The study area is located in figure 4.1.

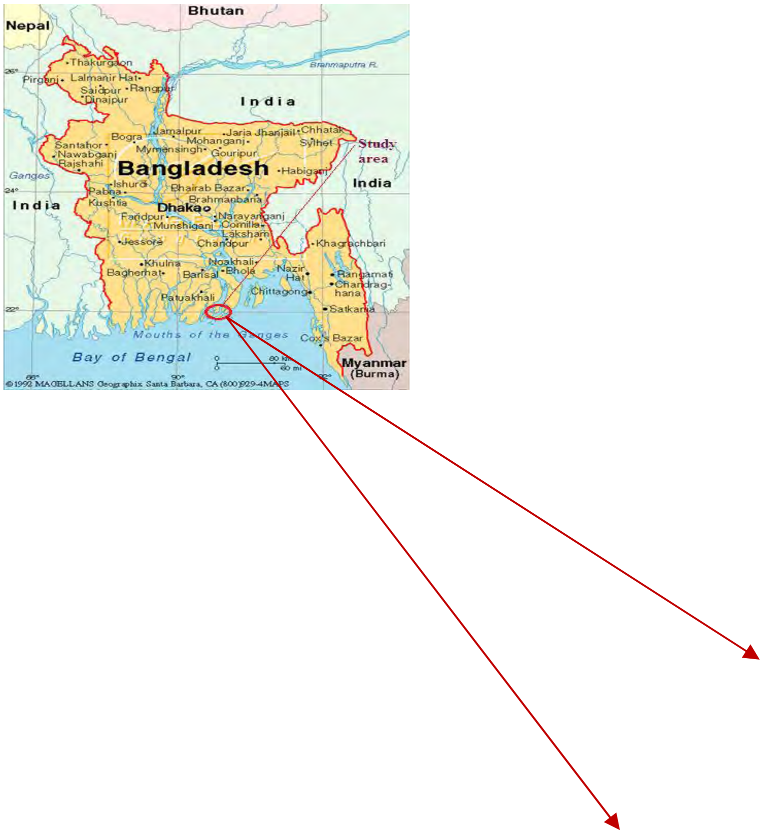


Figure 4.1: Location of Study area (Source: EDP, 2009)

The image presented in figure 4.2 has been traced to obtain the working map as depicted. On the map some particulars of the site can be seen:

1. the Mainka Channel and the Montaz Channel, are both connecting the main channels Bura Gouranga and Kukri Mukri
2. the embankment system on the chars
3. the selected alignment of all dams
4. Location of the photographs

The study area is located at the south-western end of West Shahbajpur Channel, which is the channel that discharges the largest portion of net flow from the Lower Meghna to the outer delta area. In the monsoon period about 50 % of the net flow is transported out by

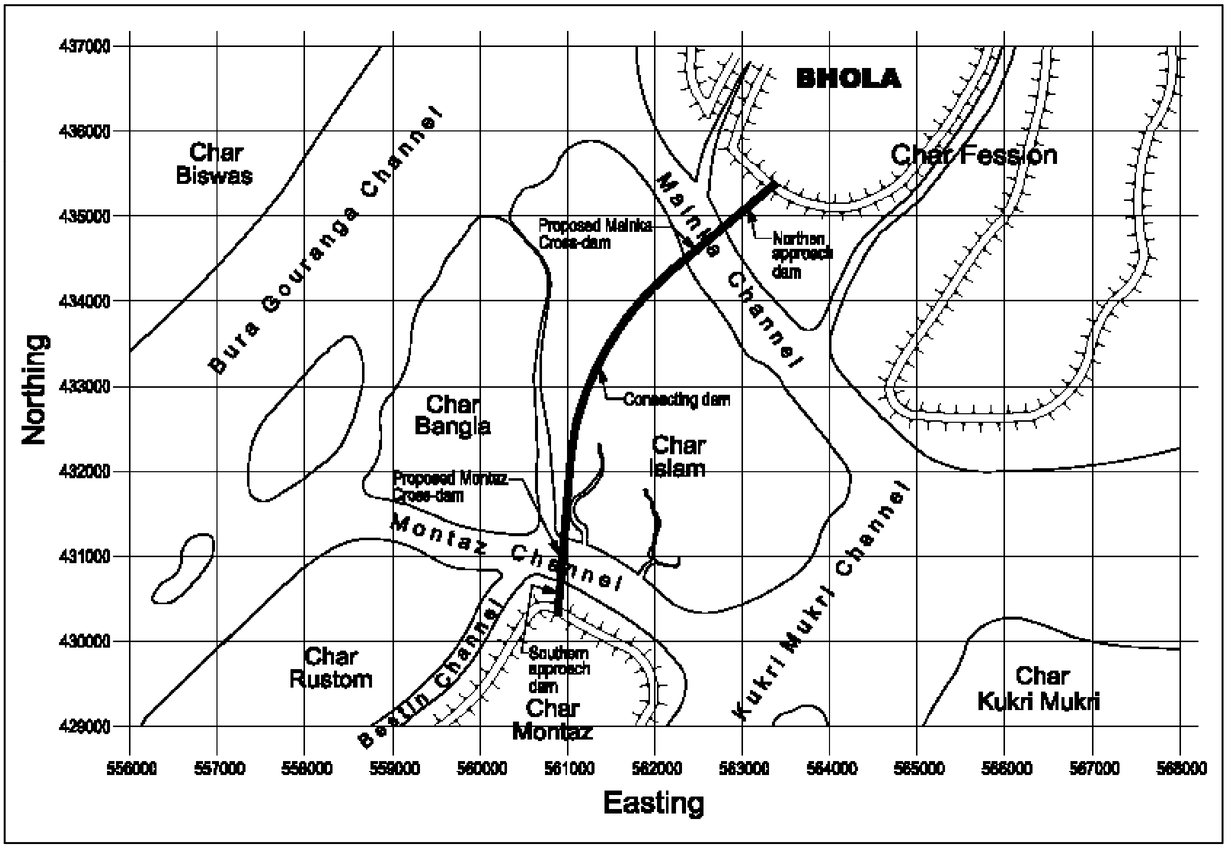


Figure 4.2: Map with proposed alignment of Closure and connecting embankment (Source: EDP, 2009)

West Shahbazpur Channel, in the dry period this increases to about 75 % of the total net flow (because net flow is reversed in Hatiya Channel by incoming tidal action). On the eastern side of the pilot area, the Tetulia Channel discharges a smaller but still significant portion of net flow (15- 20 %). Both channels can influence the conditions in the pilot area, supplying sediment and generating the flow.

The project area consists of islands with larger rivers on both sides (Bura Gouranga Channel, Kukri Mukri Channel) and smaller channels in between (Mainka Channel, Montaz Channel, Bestin Channel). The closures taken into account in this study are planned at the following locations:

1. Between Bhola and Char Islam: Mainka Channel
2. Between Char Islam and Char Montaz: Montaz Channel

3. The smaller channels have widths of several hundred meters up to 1 km and depths around -2 to -3 m PWD

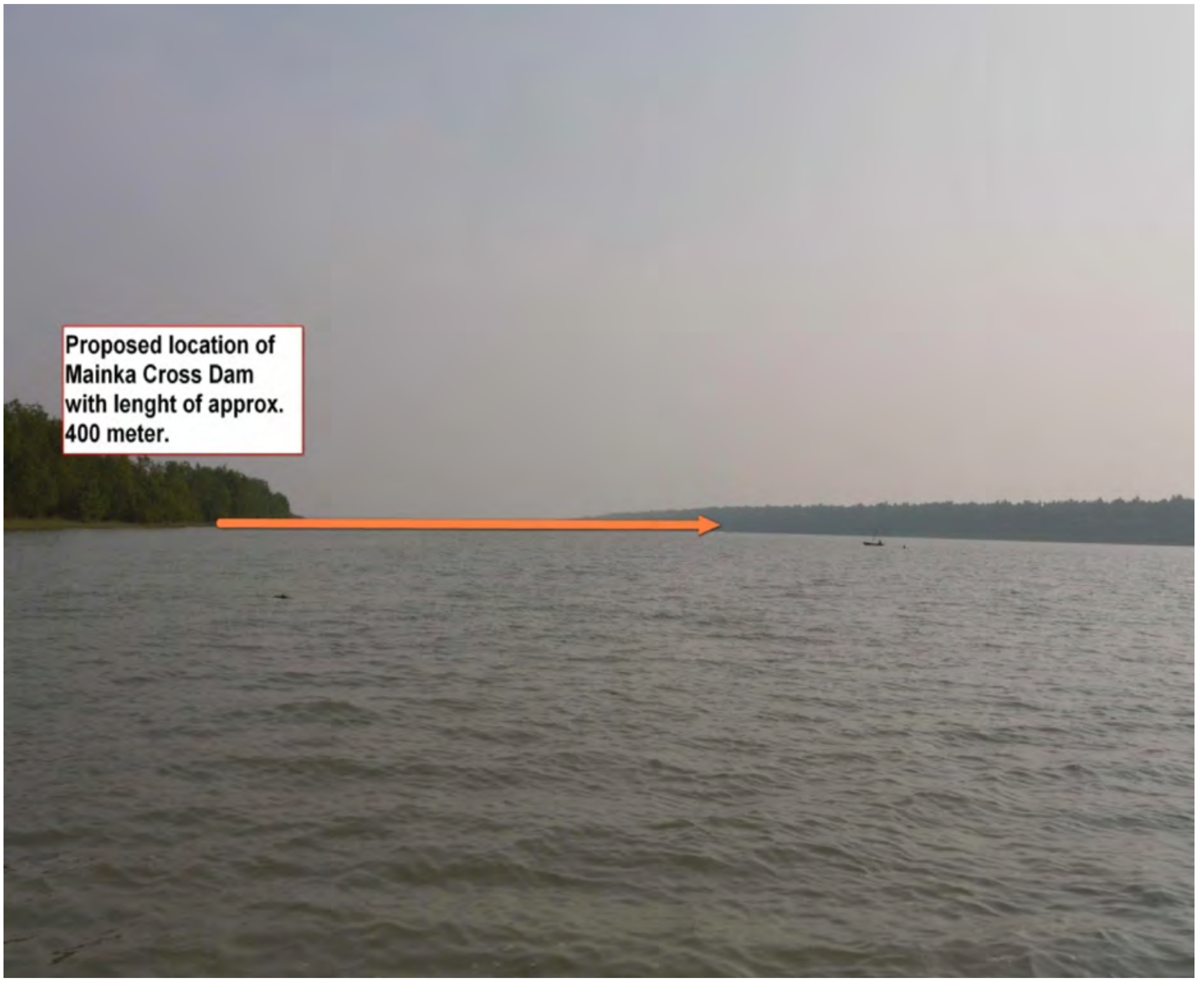


Figure 4.3: Location of proposed closure over Mainka Channel (Looking towards Bura Gauranga Channel)

Figure 4.4: Location of proposed closure over Montaz Channel(Looking towards Bura Gauranga Channel)

The on-going construction of closure over Montaz channel follows the alignment recommended by EDP. The recent photographs are given figure-4.5 and figure-4.6.


Figure-4.5: On-going closure over Montaz Channel (Looking towards Char Montaz)

Figure-4.6: Closure over Montaz Channel (Looking towards Char Islam)

4.3 Topographic Survey

From the hearings of the local people it became clear that for them the main function of the proposed cross-dam will the road connection between Bestin Bazar and Bhola. Therefore the cross-dams in the Mainka Channel and in the Montaz Channel will not only be connected to the nearby embankments (Approach Dams), but also the cross-dams will be connected with the so-called Connecting Dam, which is crossing over Char Islam.

The results of the topographic survey have been summarized in the following figures:

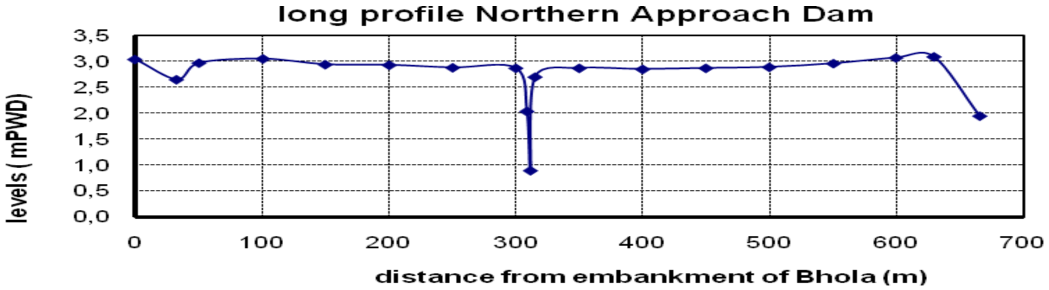


Figure-4.7: Long profile from Bhola embankment to Mainka Channel (Northern approach dam): Data (source : IWM, 2010)

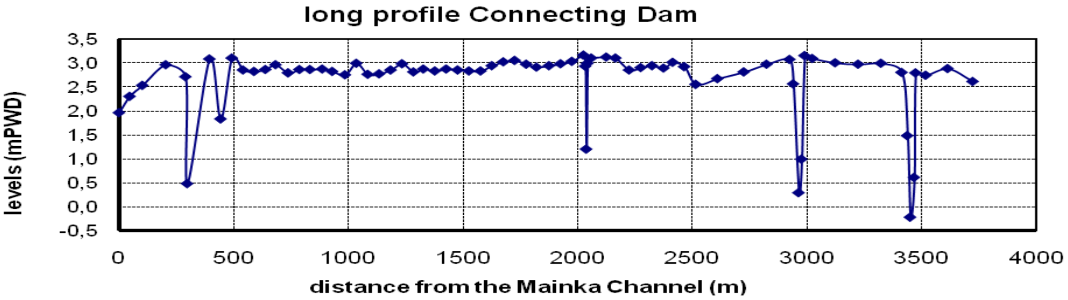


Figure 4.8: Long profile in between Mainka and Montaz Channels (Connecting Dam), Data (Source-IWM,2010)

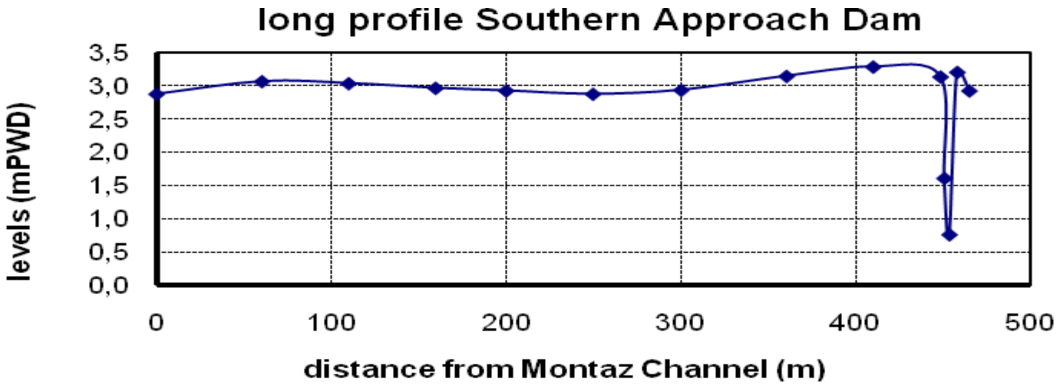


Figure 4.9: Long profile from Monatz channel to Montaz existing embankment (Southern approach dam), Data (Source-IWM,2010)

From the above long profiles Figures 4.7, 4.8 and 4.9 it can be seen that the main part of the flood plain has a level between 2.5 to 3 m PWD (which is just below to the HW level. The local roads in the area have a level of 4 to 4.5 m PWD. The embankment level at the Montaz side is about 1m lower than the embankment level at the Bhola side.

It should be noted that part of the topographical work consists of leveling the dry part of the bathymetric cross-sections of the channels.

4.4 Hydrology around the Project area

The area is in the meso-tidal range, with tidal ranges varying from 2- 4 m (2 - 2.5 measured in Mainka and Montaz channels during spring). During the monsoon period, the tidal action is slightly less explicit, however the difference is small.

Flow velocities in the area are in the range of 1- 1.5 m/s. The smaller channels are very sheltered and no significant water level differences have been measured over these channels (maximum about 0.2m). Therefore flow velocities are somewhat lower in these channels (where the closures are planned). Measurements of flow velocities in the small channels in Oct 2009 and Jan 2010 revealed max velocities up to 1.2 and 0.8 m/s respectively.

The salt intrusion reaches beyond this area during dry season and beginning of monsoon season (December to June), meaning that some salt intrusion occurs in the project area (salinity ≈ 2 to 10 pt). Salinity remains however significantly lower than in the outer Bay of Bengal (salinity ≈ 20 to 30 pt), also during the dry season. During the monsoon season (June to November), no salt intrusion is observed in the pilot area (salinity < 2 pt).

4.5 Hydrography

4.5.1 Hydrographic Survey

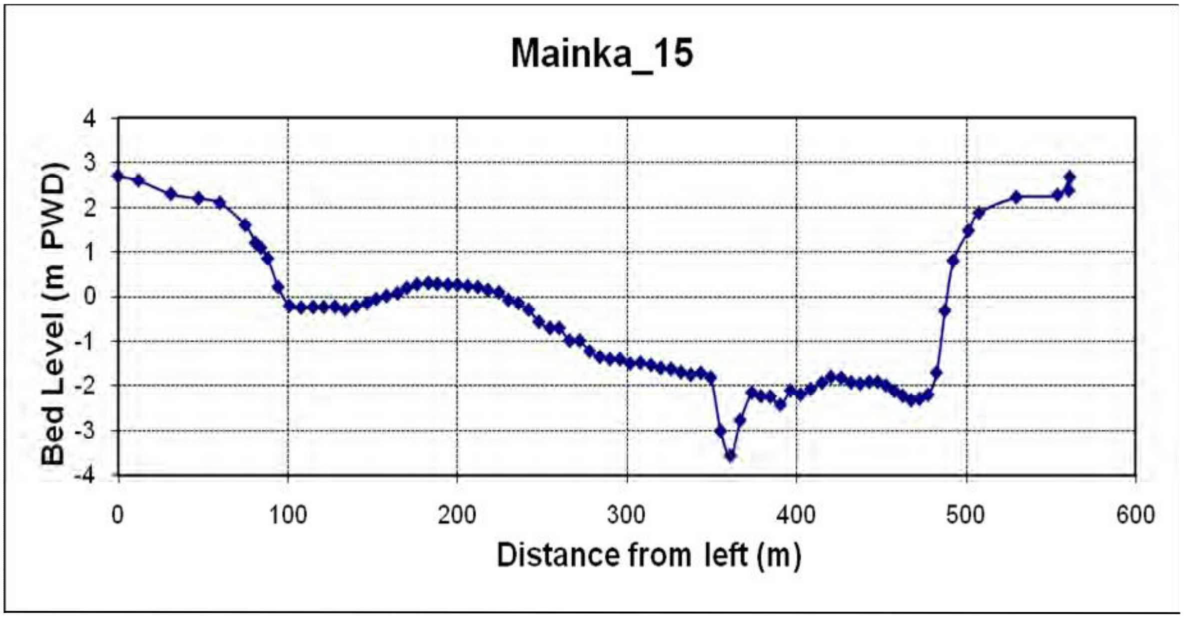
The bathymetric measurements have been executed in the third week of October 2009 by IWM.

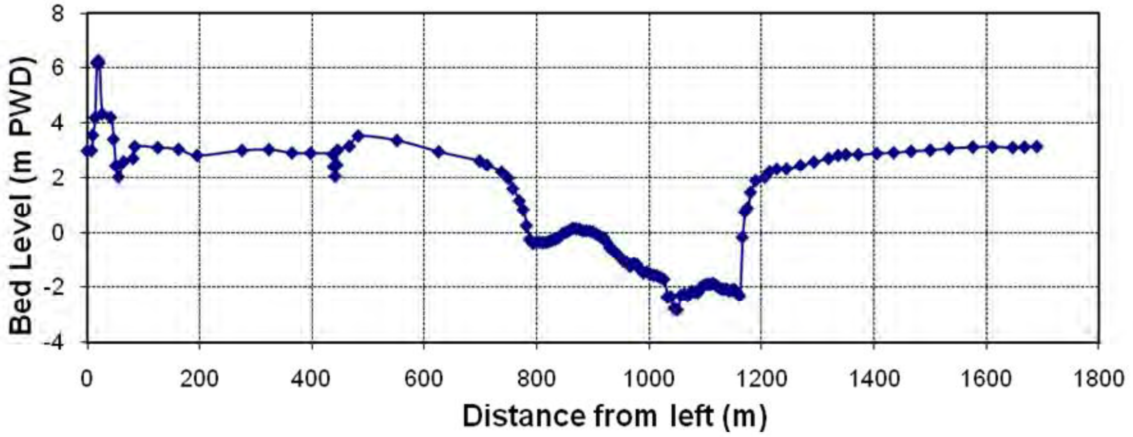
The wet cross-sections were completed with the dry parts such as the levels of banks and adjacent flood plains, coming from the topographic survey executed simultaneously. For location of hydrographic survey has been referred in figure 3.1. The main results of the hydrographic measurements are presented and discussed in the following sections.

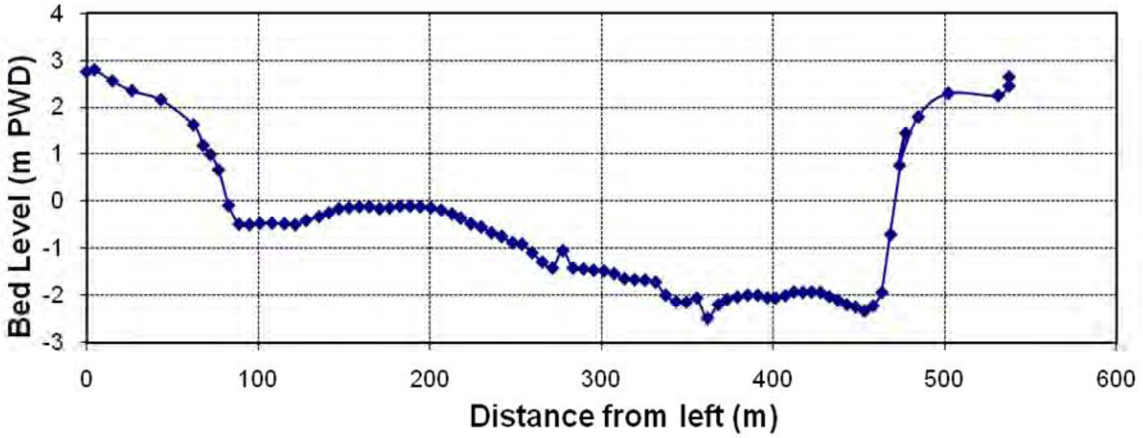
4.5.2 Channel Dimensions, bathymetry

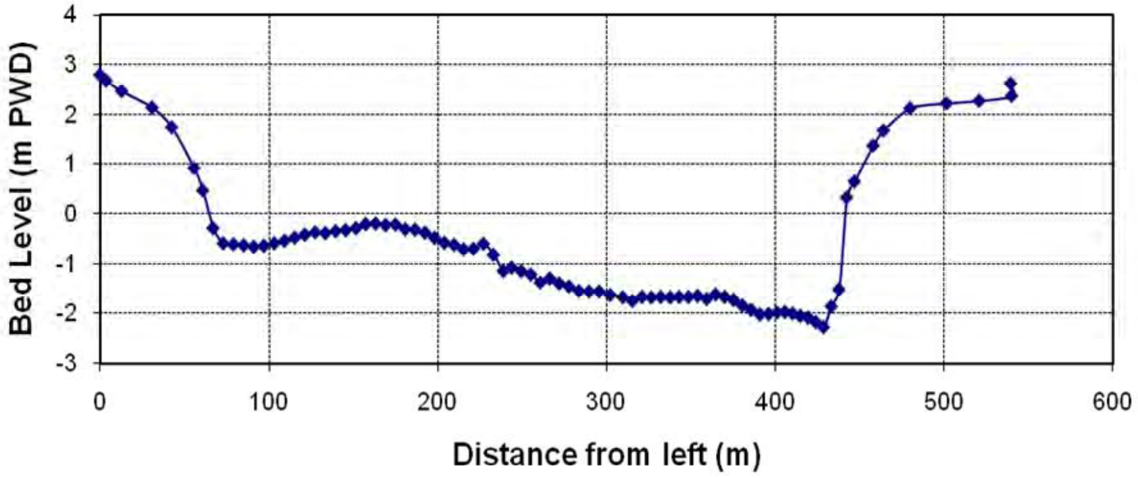
The results of the bathymetric survey have been combined with results of the topographic survey in order to get a complete cross-sectional profile. Moreover, each fifth cross-section has been extended to both sides to include more surface levels of the flood plain into the sections. The measurements comprised 53 cross-sections in the Mainka Channel and 45 cross-sections in the Montaz Channel.

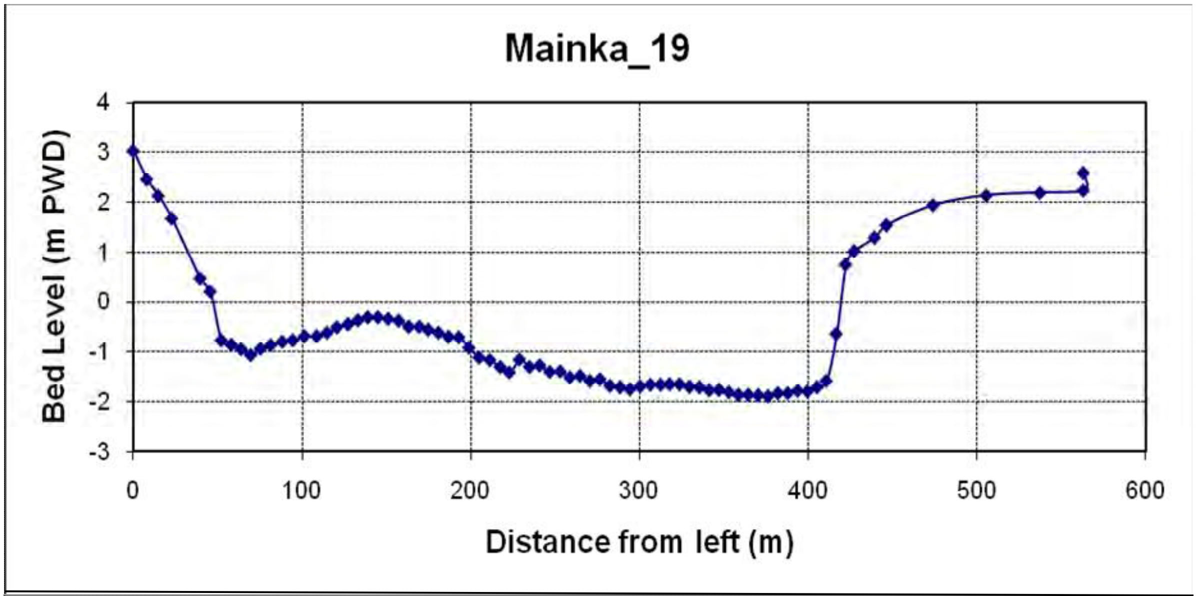
Here 11 numbers selected cross-section (15 to 25) of Mainka Channel have been analyzed.

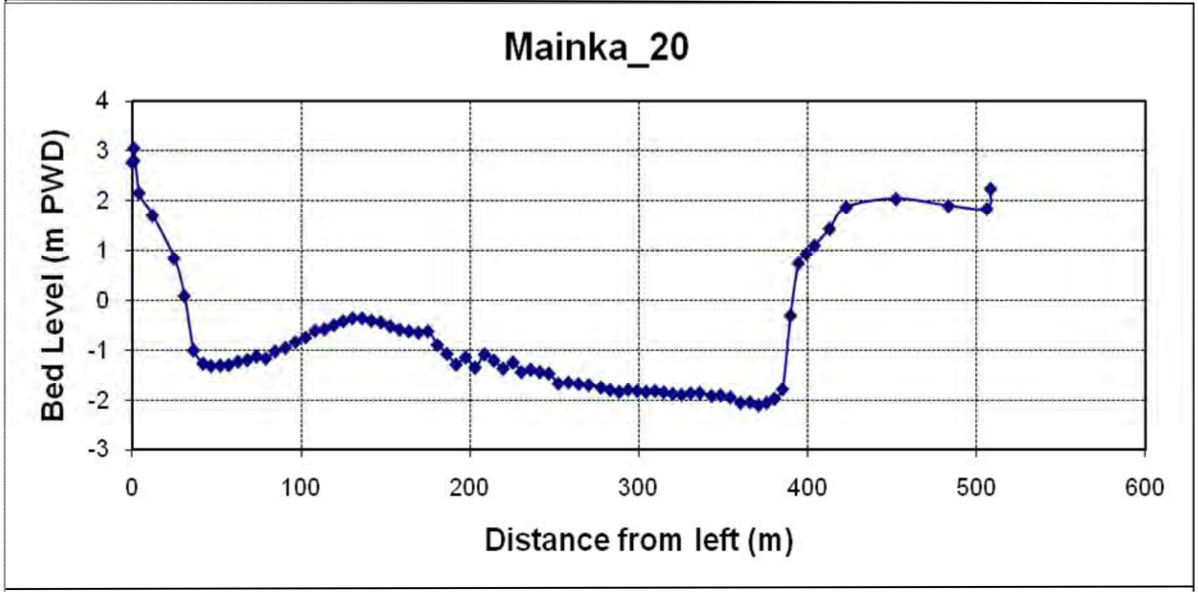


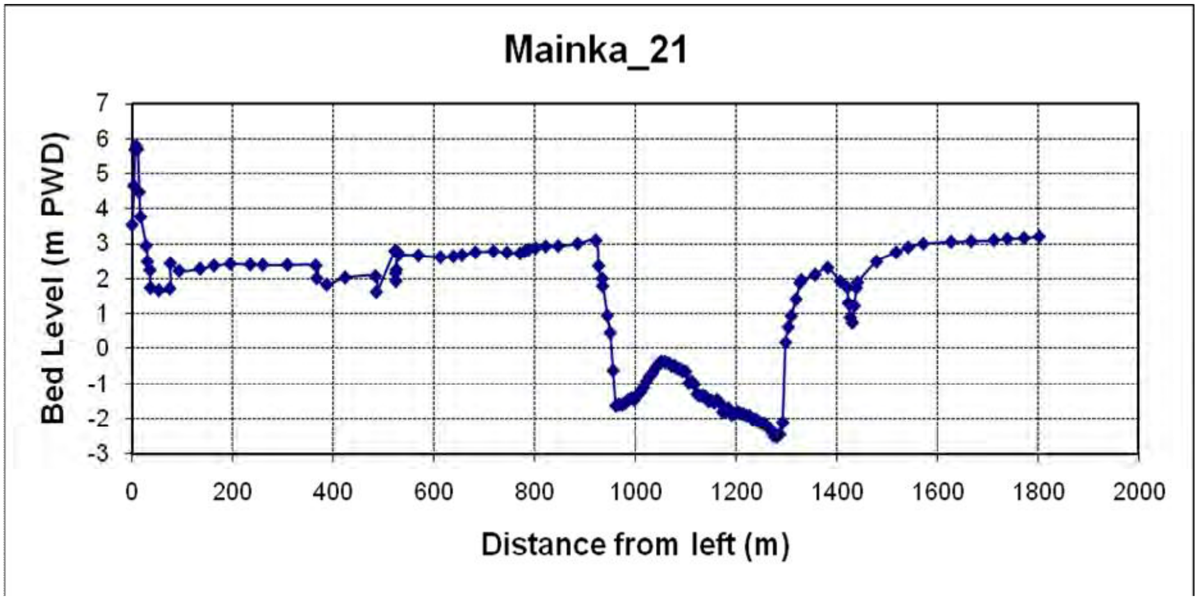

Mainka_16

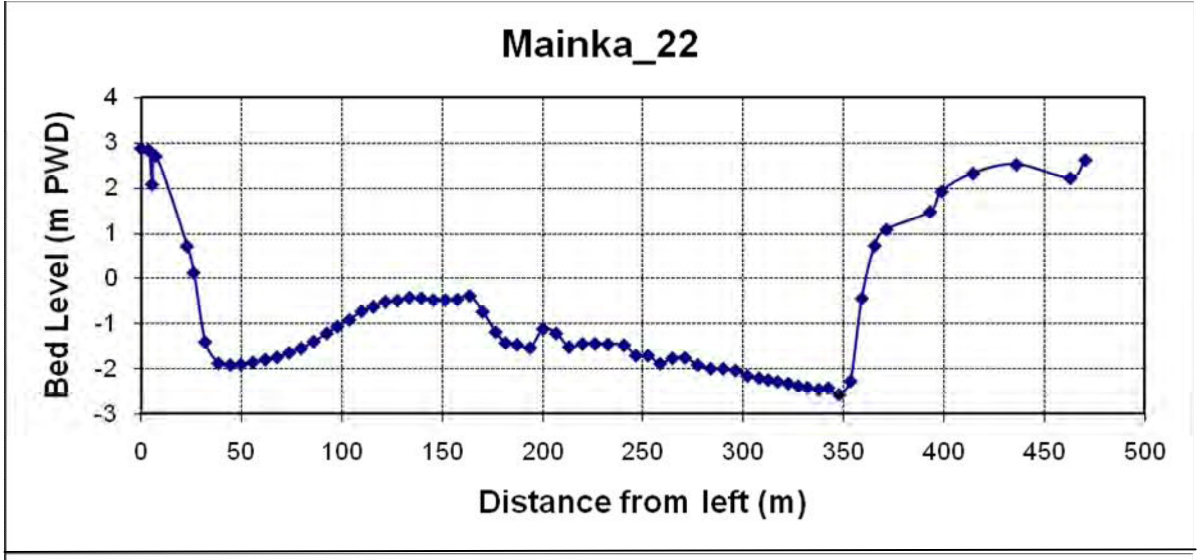

Mainka_17

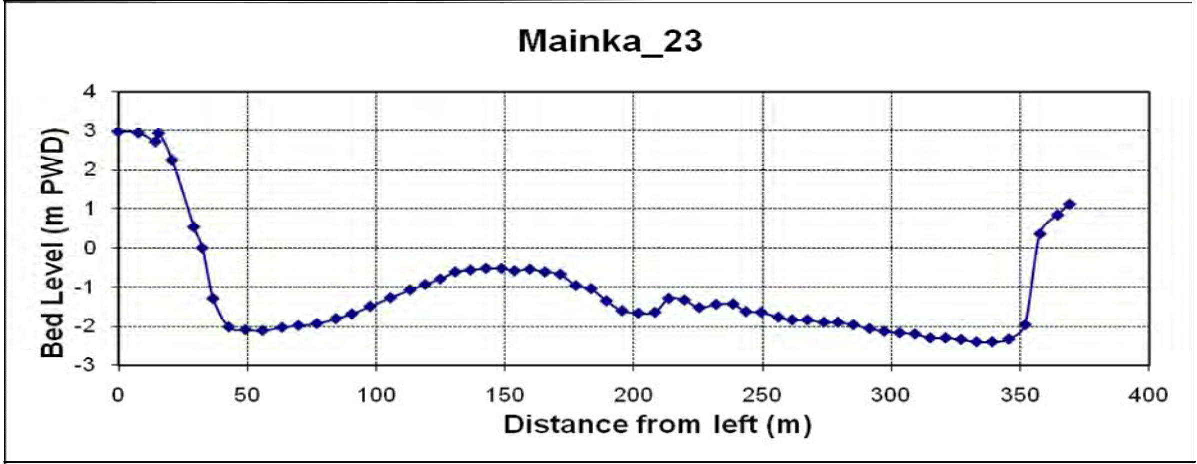

Mainka_18


Mainka_19
Bed Level (m PWD)
4
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Distance from left (m)


Mainka_20
Bed Level (m PWD)
4
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Distance from left (m)


Mainka_21
Bed Level (m PWD)
7
6
5
4
3
2
1
0
-1
-2
-3
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from left (m)


Mainka_22
Bed Level (m PWD)
4
3
2
1
0
-1
-2
-3
0
50
100
150
200
250
300
350
400
450
500
Distance from left (m)


Mainka_23
Bed Level (m PWD)
4
3
2
1
0
-1
-2
-3
0
50
100
150
200
250
300
350
400
Distance from left (m)

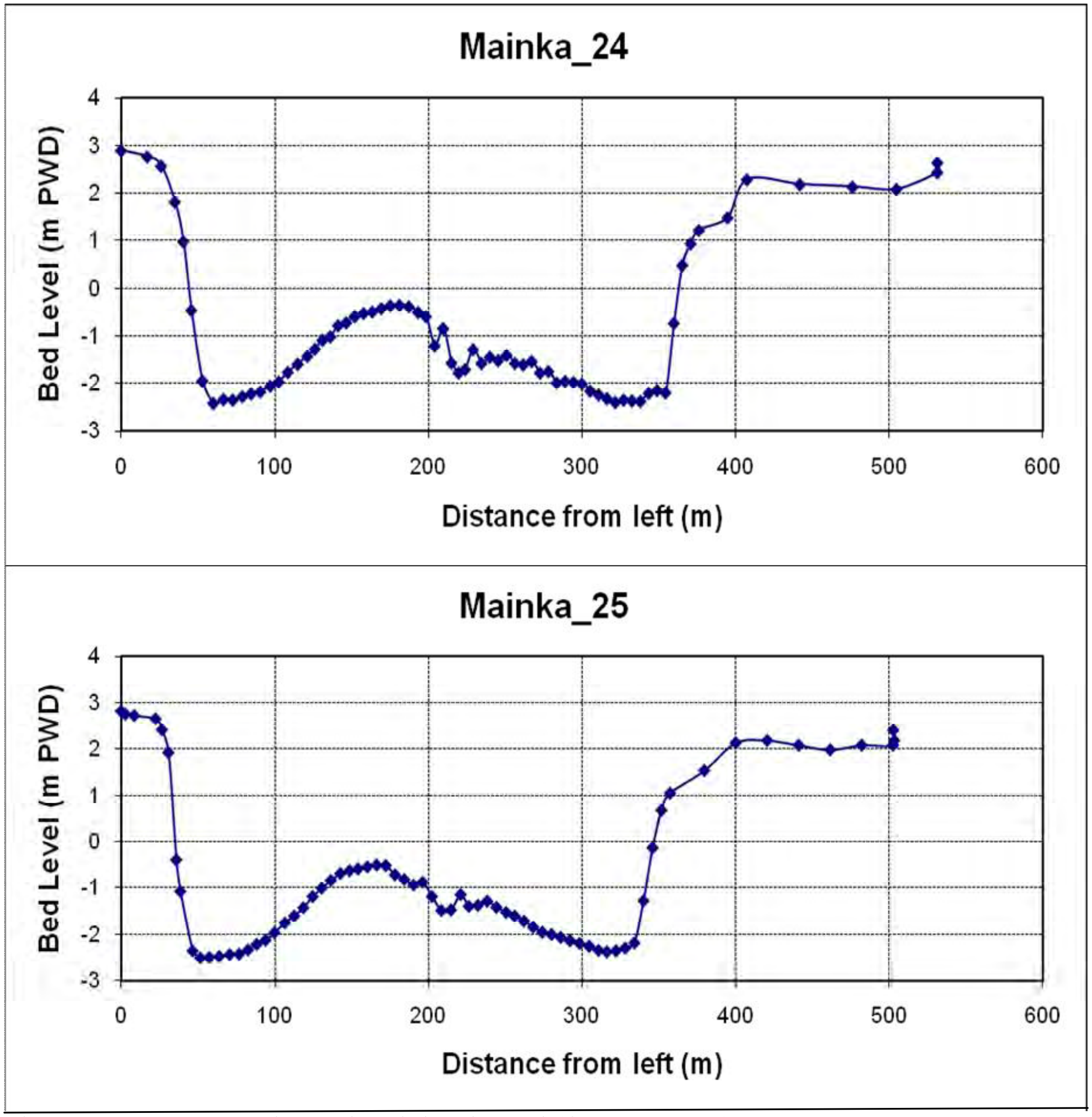
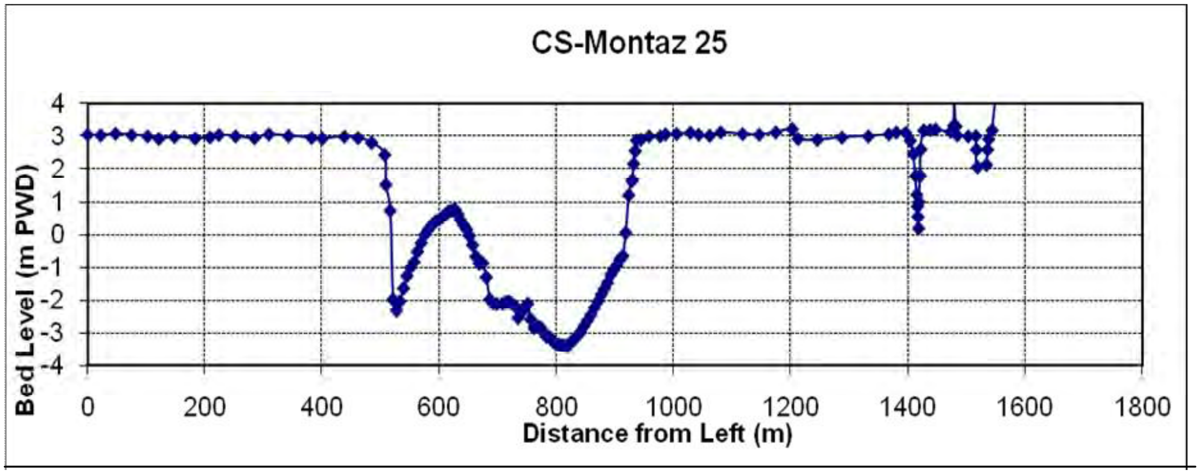


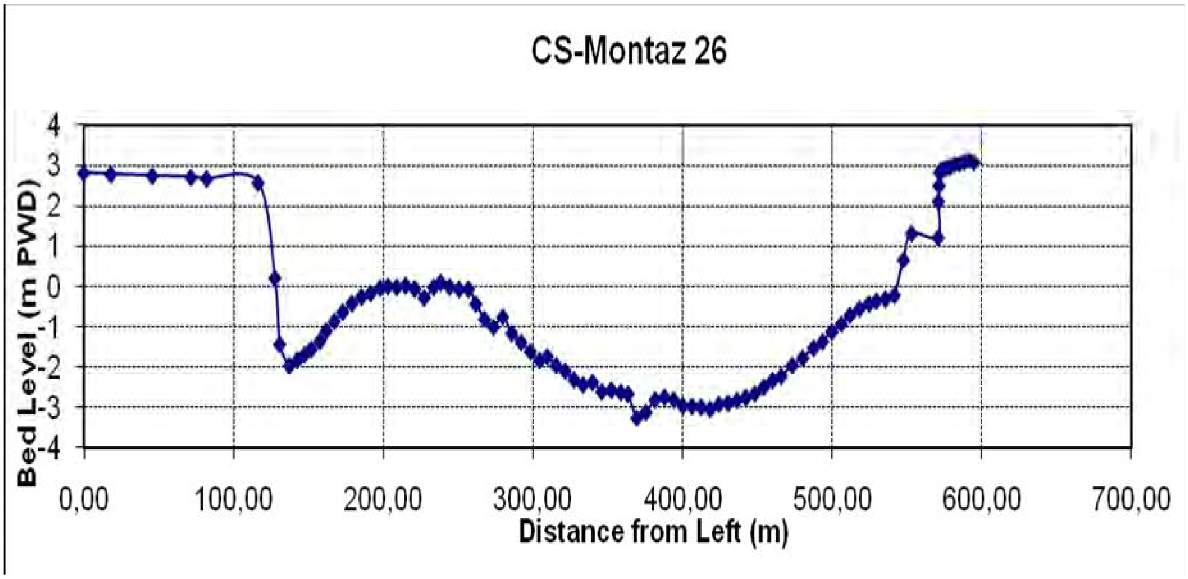
Figure 4.10: Cross sections of Mainka channel (from 15 to 25)

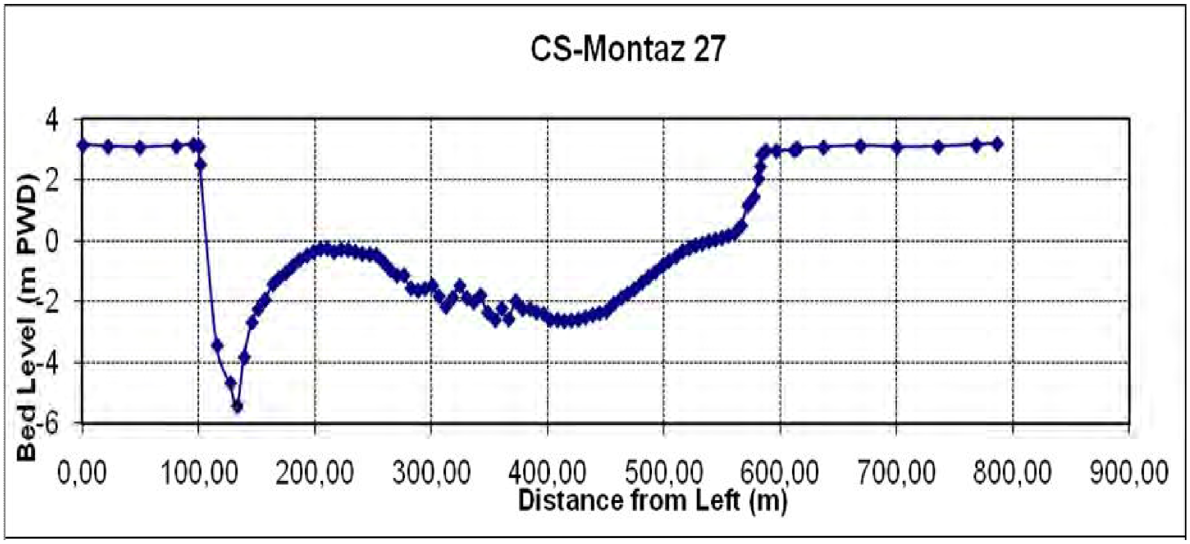
Analysis of above cross sections (Mainka Channel)

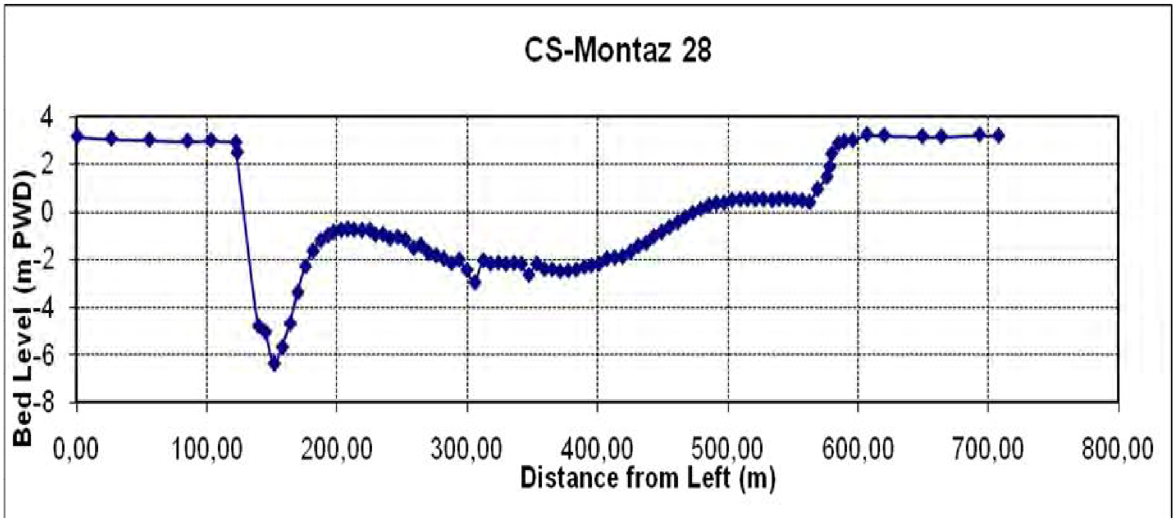
This approach led to a selection of the closure site in the Mainka Channel varying from cross section 15 to cross section 25 see in figure 3.1. That stretch of the Mainka Channel has a regular shape with very constant width and depth. Outside the cross-section15 to cross-section 25 in figure-4.10 stretches is less desired because of the distance to open waters and the existing drainage channels. The minimum bed level is found of the above cross section. The cross section of outside of section 15 to 25 is more. The maximum bed of section of 15 to 16 is -2.5 meter.

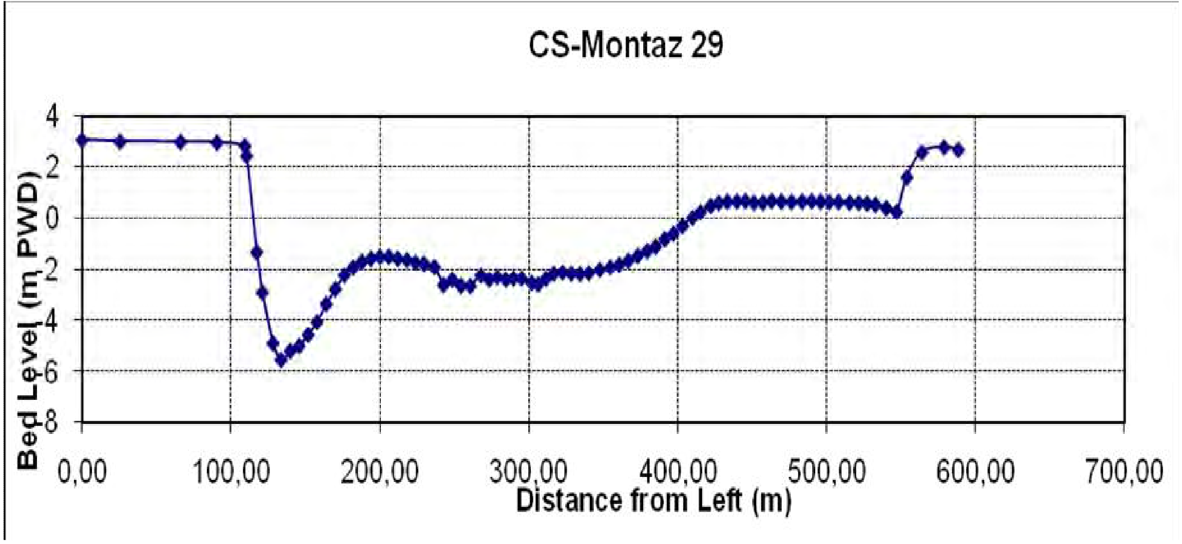
Here analyzed selected 6 numbers cross –section from 25 to 30 of Montaz Channel.






CS-Montaz 27


CS-Montaz 28


CS-Montaz 29

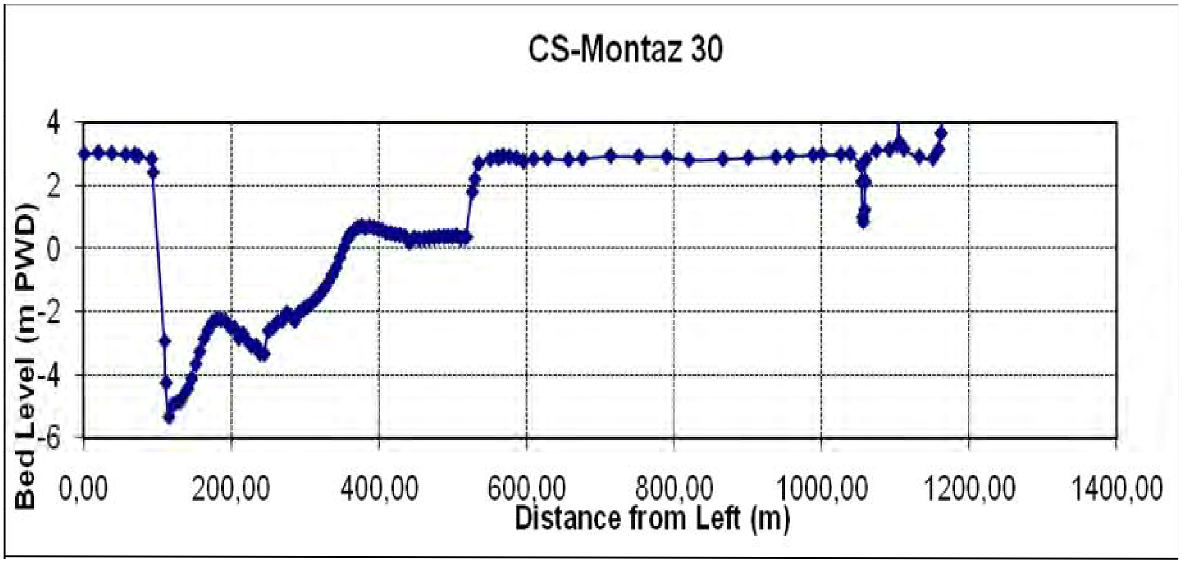


Figure 4.11: Cross-sections of Montaz Channel (from 25 to 30)

Analysis of above cross sections (Montaz Channel)

For the selection of the closure location in the Montaz Channel, the situation is quite different (in comparison with the Mainka Channel). Connecting the people of Bestin Bazar to Bhola means that the closure in the Montaz channel needs to connect Char Montaz with Char Islam (rather than Char Rustom with Char Bangla). Hence the closure in the Montaz Channel should be located east of the northern entrance of the Bestin Channel, but not too far eastwards, to keep sufficient distance to the open waters of the Kukri Mukri Channel. This limits the potential dam site to the cross section 24 to cross section 30 stretch, see figure 4.11**.** The Montaz Channel has a rather irregular shape, especially along the cross section-24 to cross section-30 stretch. Only the cross-section 25 and 26 have bed levels of -3 m PWD, the other sections are deeper. This limits the selected stretch to cross section-25 to cross section-26.

Conclusions latest status and quality IWM survey data Bhola- Montaz area:

- Bathymetry and water levels need to be corrected for identified benchmark error at Montaz (input for calibration dedicated flow model Bhola- Montaz and for design).
- Measured discharges and flow velocities are considered reliable and can be used for calibration dedicated flow model and design purposes.

4.5.3 Wave Conditions

The dams in the Montaz and Mainka channels are located very sheltered for the incoming extreme waves from offshore. This can be seen from figure 4.12. It should be noted here that extreme waves are the highest wind waves (mainly sea) and don’t include the storm surges under cyclonic conditions.

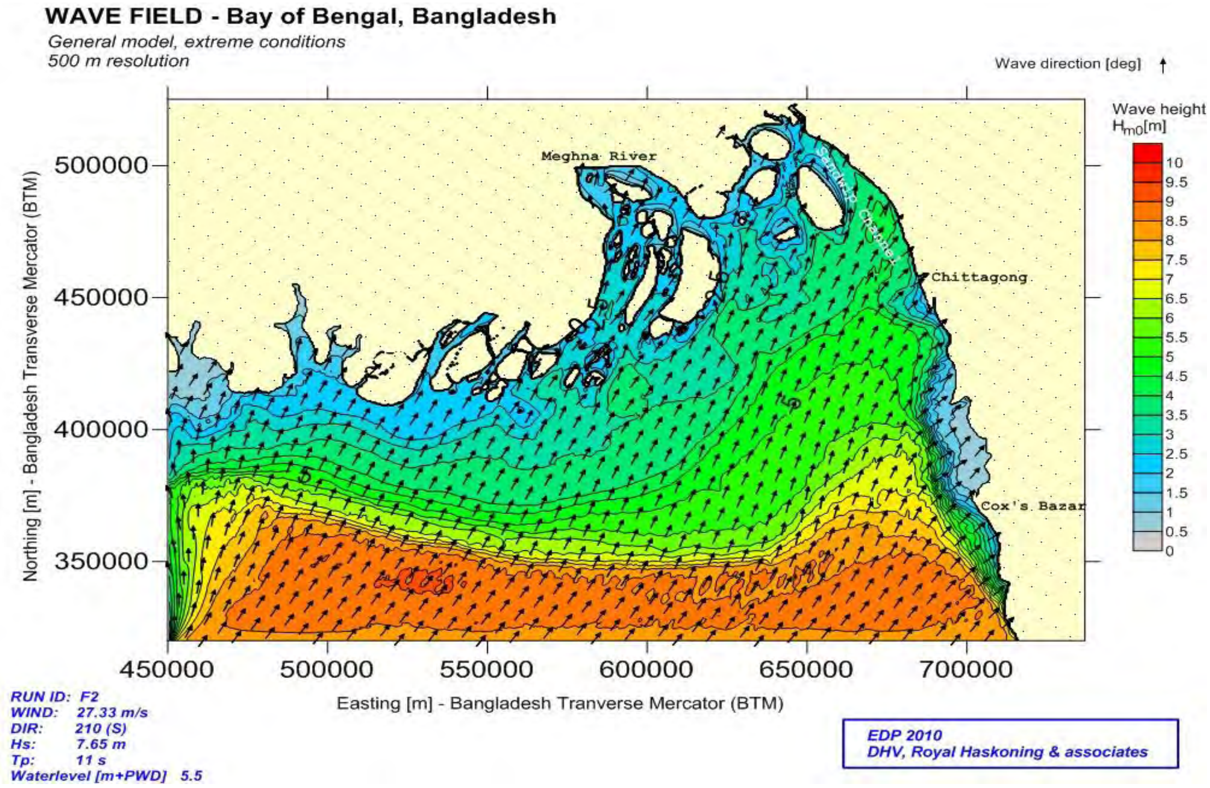


Figure- 4.12: Extreme waves from SSW (return period 5 years), (Source: EDP,2010)

The figure shows that the significant wave height offshore of 7.65 meter is increasing first to above 8meter and then decreasing going near shore to about 3.1 meter near the southerly entrance of the Kukri Mukri Channel (depth 9.2 meter; period 5 second direction 200 degree). This wave will further reduce due to the shoaling in the Kukri Mukri channel and will hardly enter the Montaz and Mainka channels which are nearly perpendicularly oriented to the wave direction.

The locally generated waves can be calculated with the Brettschneider formula. The following input is chosen:

- Channel direction is NW- SE for Mainka Channel. Channel direction is WNW- ESE for Montaz Channel. The yearly maximum wind speed from SE- ESE is around 17.5 meter/second, reaching up to 20 meter/second every 5 years. The yearly maximum wind speed from NW- NNW is around 15 meter/second, reaching up to 17.5 meter/second every 5 years.
- The water depth in the channel is around 3 meter.

Simple Brettschneider calculations in the Mainka Channel lead to the following range of expected wave heights:

> from SSE side: *Hs= 0.5 to 0.8 meter* (fetch ranging from 5 to 8 kilometer 1/1 to 1/5 per year return period)

> from WNW side: *Hs= 0.4 to 0.7meter* (fetch ranging from 3 to 5 kilometer, 1/1 to 1/5 per year return period)

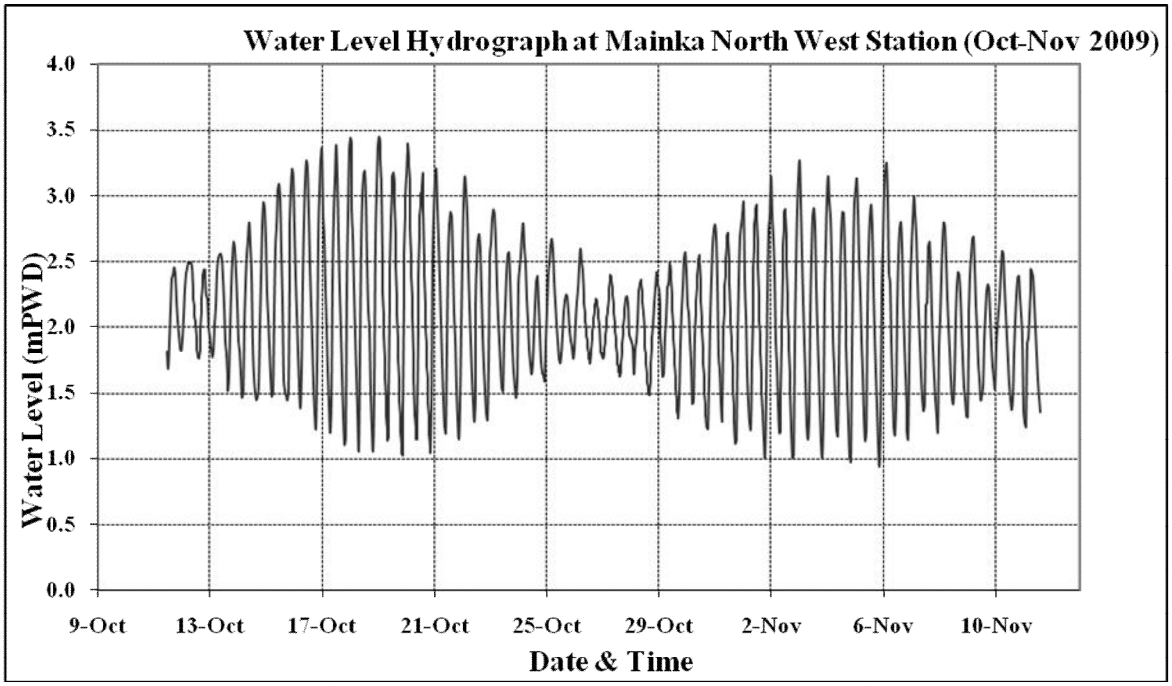
Simple Brettschneider calculations in the Montaz Channel lead to the following range of expected wave heights:

> from SSE side: Hs= *0.6 to 0.7 meter* (fetch 4 kilometer, 1/1 to 1/5 per year return period)
> from WNW side: Hs= *0.5 to 0.6 meter* (fetch 3 kilometer, 1/1 to 1/5 per year return period)

It can be concluded that the design wave height is in the order of 0.5 -0.8 meter from each side. The water depth is varying a lot over the fetch area thus the calculations the above have clear limitations. For a more detailed calculation of design wave heights, a dedicated 2D SWAN wave model would be required for the closure area of Bhola -Montaz.

4.5.4 Water Levels

Water levels readings of Mainka and Montaz closure' location are plotted against time and analyzed. The survey results of above noted is presented in figures 4.13 and 4.14.



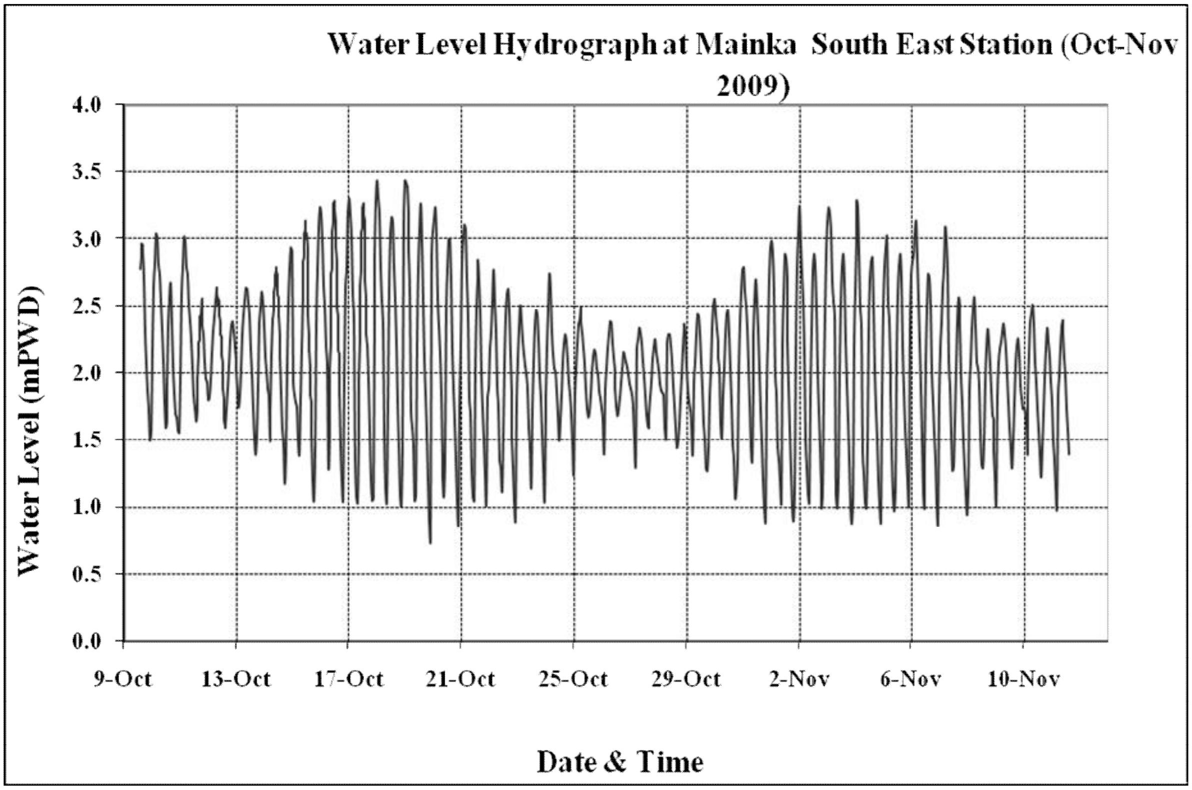
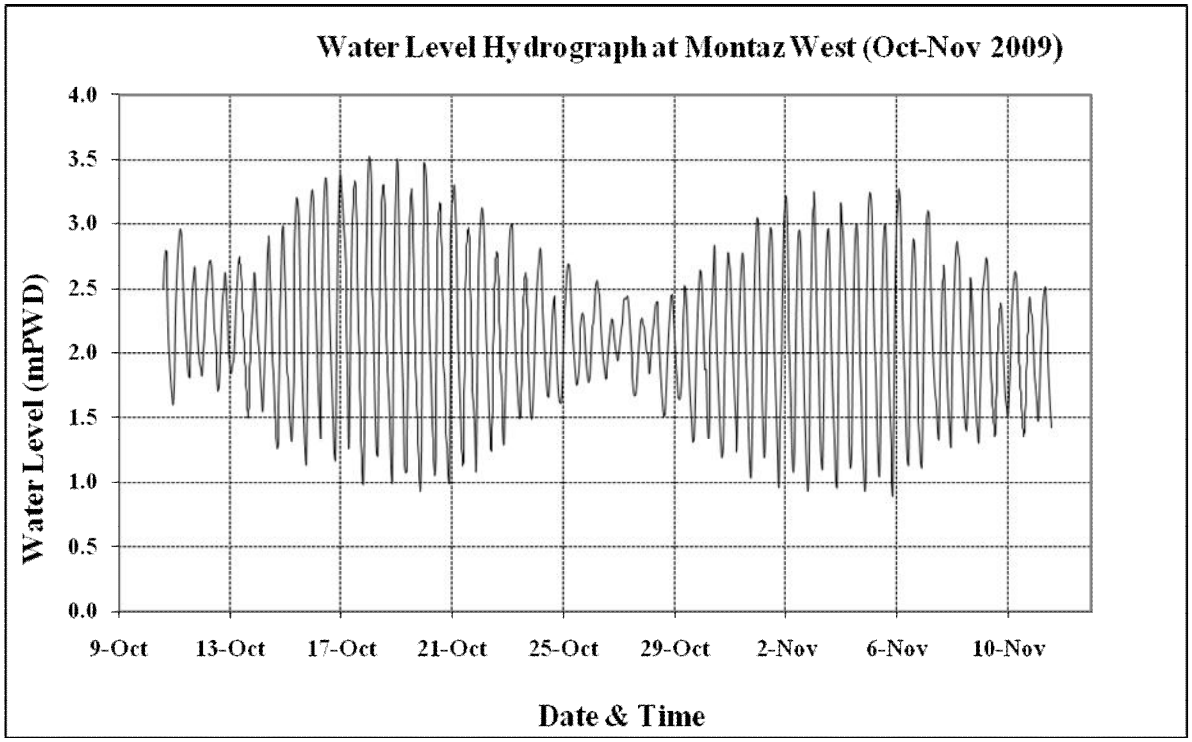


Figure 4.13: Water levels at both ends of Mainka Channel



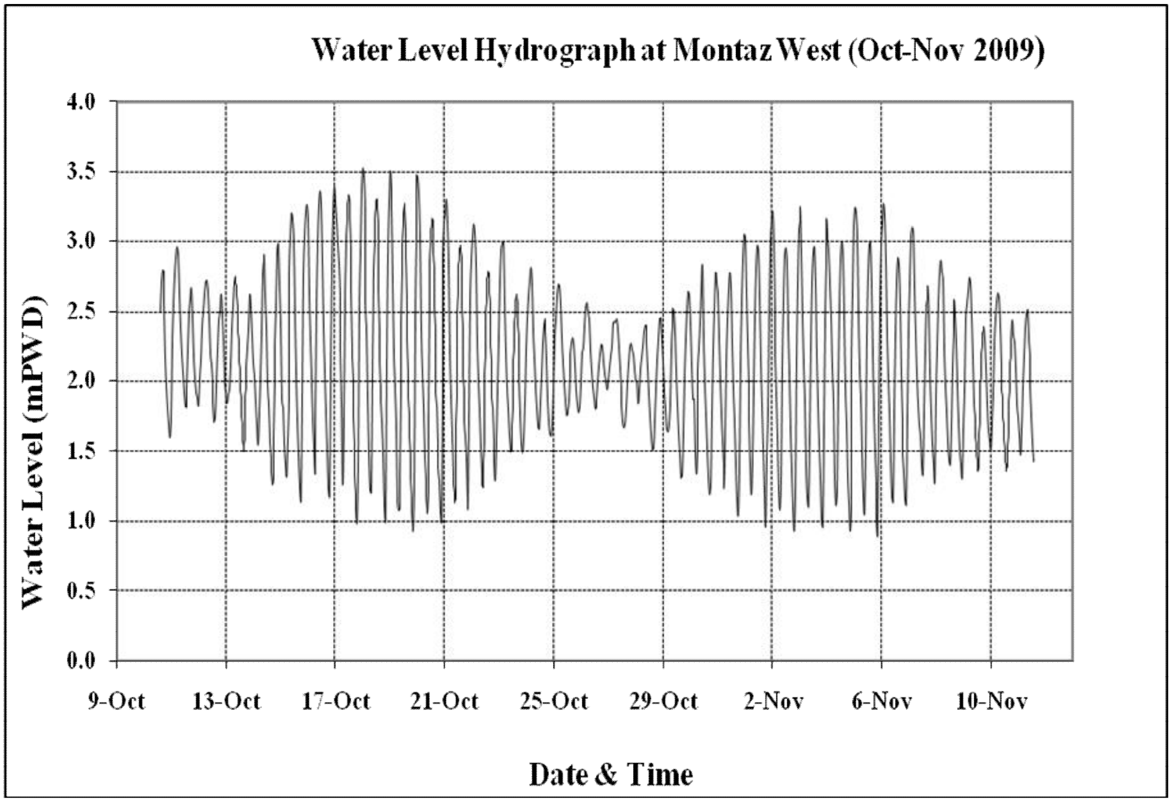


Figure 4.14: Water levels at both ends of Montaz Channel

Summary of results

In the graphs it can be seen that the measurements of October/November show a mean level of about 2.1 meter PWD. The tidal range varies from less than 1.0 meter during neap to 2.5 meter during spring. During spring the max levels are about 3.4 meter PWD and the minimum levels are about 0.9 meter PWD. A few months later these levels are 0.3 to 0.5meter lower due to the seasonal effect (impact of Meghna flows on the water levels in the Bay of Bengal). It should be noted that the water level variation around neap is rather different from neap to neap, complicating the comparison.

Table 4.1: Tidal characteristics of Montaz and Mainka channels (levels in m PWD):

Period	**LWS**	**LWN**	**ML**	**HWN**	**HWS**
October/November	0.9	1.7	2.1	2.5	3.4
December/Jananuary	0.6	1.2	1.8	2.4	3.0

4.5.5 Design water level

A design water level must be determined for stability calculations for the dam. Note that extreme events such as cyclones are not included in the design water level. The dam will be exposed to hydraulic forces for only a few years, until it is covered in sediment. Chance of occurrence of an extreme cyclone in these years is very small.

Based on the available water level measurements and other data from the MES report about seasonal variation an estimate of the design water level to take into account for stability calculations can be made. Because there are doubts about the reference level in the most recent IWM measurements at Mainka and Montaz, the results from MES studies will be used.

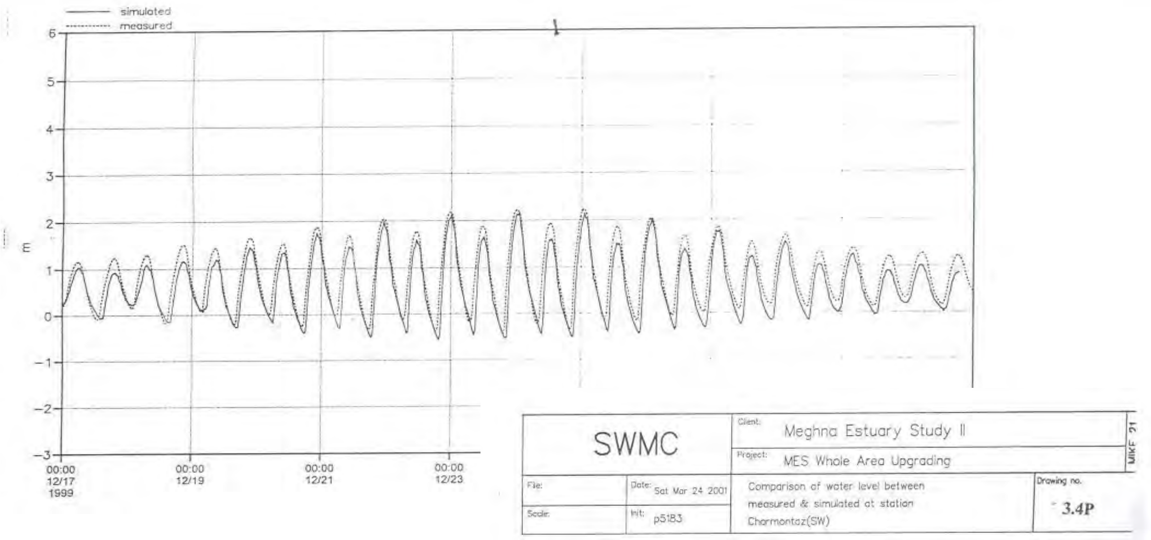


Figure 4.15: Measured water levels Char Montaz (source: MES II)

The following parameters are determined based on that information from above figure:

- Maximum water level spring tide: + 2.2 m PWD
- Minimum water level spring tide: - 0.5 m PWD
- Mean sea level estimate: + 0.7 m PWD

The seasonal variation at Mainka and Montaz area is estimated at 1 m. The measurements were executed in the dry season, as a conservative approach the full 1 m is added to the maximum spring tide level. Furthermore, to take into account long-term water level variations, based on expert judgment it is advised to include an addition to the design water levels of 0.3 m. This results in:

- Maximum design water level: + 3.5 m PWD
- Minimum design water level: -0.8 m PWD

The maximum water level measured at Kepupara (a close by water level station) measured over the period from 1990 to 2008 is + 3.03 m PWD. Kepupara water level station is located on a side river stretch so the tidal characteristics are likely to be a bit different than in Montaz. However the maximum water level measured is in the same order as indicated above. When corrected water level measurements are available for Montaz, the maximum design water levels can be updated.

4.5.6 Discharge

The discharge measurements in the Montaz and Mainka channels have been executed in the centre line of the closure. During the Oct measurements traditional propeller current meters have been deployed, whereas for the second campaign an ADCP has been used.

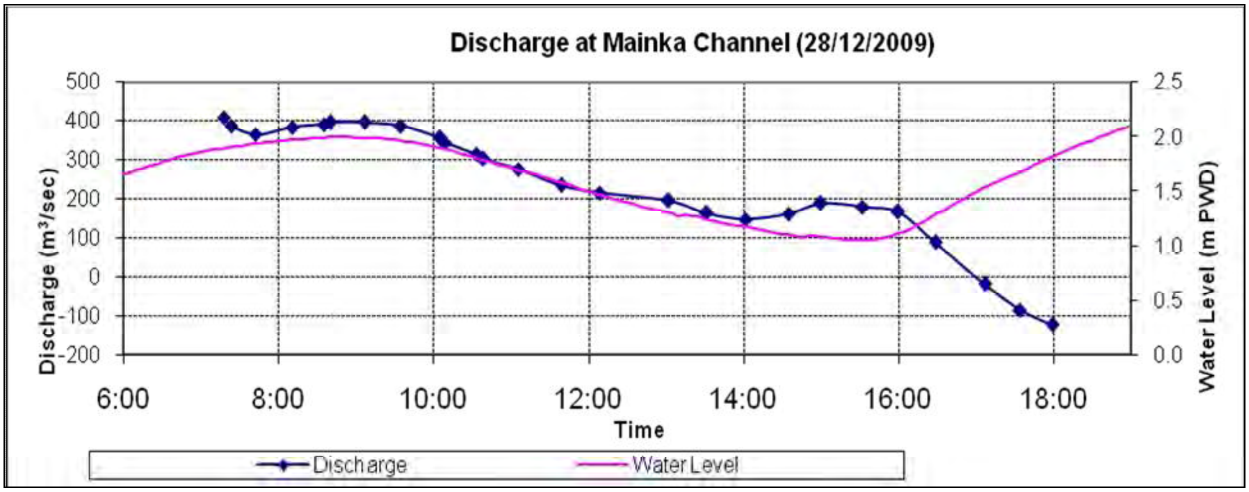
Table- 4.2: Programme flow measurements

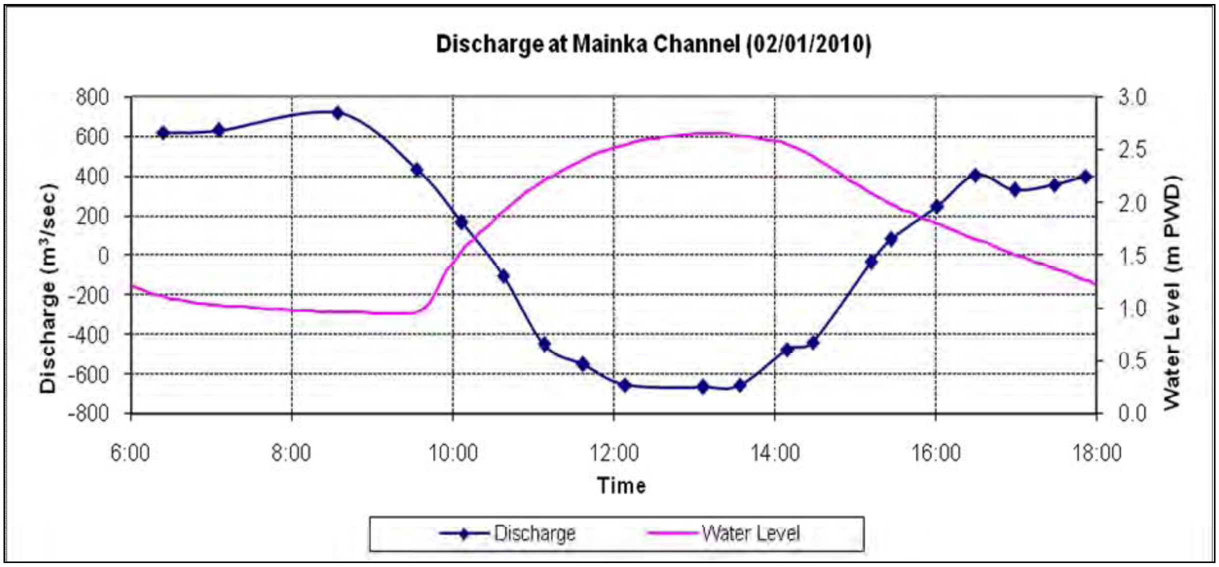
location	**Mainka Channel**	**Montaz Channel**
neap tide	12 Oct	13 Oct
spring tide	19 Oct	18 Oct

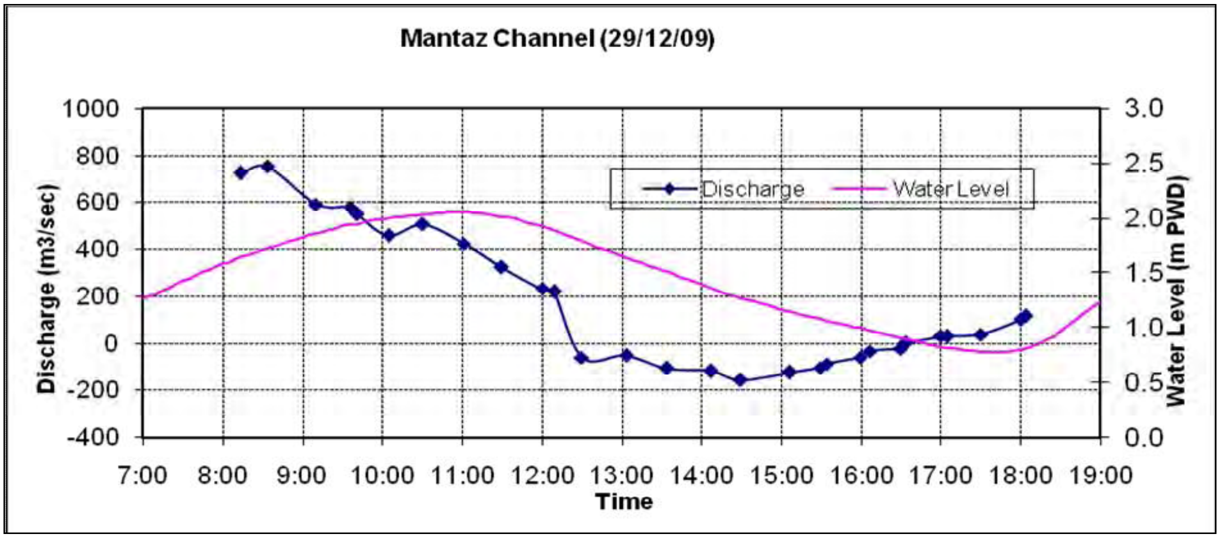
The measurements have been taken on an half-hourly basis during one tidal cycle of approximately 13 hours. Per cross-section the measurements have been done in two measuring verticals with at least 3 points per vertical depending on the water depth. In one vertical a directional current-meter and in the other vertical a non-directional current-meter has been deployed'. Per point the revolutions of the propeller of the current-meter were recorded.

From the measured revolution of the propeller/cup the flow velocities have been calculated using the available calibration equations. The velocities have been averaged per measuring vertical. From these values and the wet cross-section (from cross profile and water level) the hourly discharge has been computed, using a special programme. The programme distributes the flow velocities of the vertical over the full wet cross-section taking the different water depths of the cross-section into account. In fact it is assumed that Chezy's law is valid and v:√h. The total discharge computed in this way has been devided by the total wet cross-sectional area to obtain the mean flow velocities.

The results of the survey and the data processing are summarized in the charts below. The discharges are presented in Figure- 4.16. In chart the water levels have also been depicted in order to show the correlation between horizontal (discharge) and vertical (water levels) tide.


Discharge at Mainka Channel (28/12/2009)
Discharge (m³/sec)
500
400
300
200
100
0
-100
-200
Water Level (m PWD)
2.5
2.0
1.5
1.0
0.5
0.0
6:00
8:00
10:00
12:00
14:00
16:00
18:00
Time
Discharge
Water Level


Discharge at Mainka Channel (02/01/2010)
Discharge (m³/sec)
800
600
400
200
0
-200
-400
-600
-800
Water Level (m PWD)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
6:00
8:00
10:00
12:00
14:00
16:00
18:00
Time
Discharge
Water Level


Mantaz Channel (29/12/09)
Discharge (m3/sec)
1000
800
600
400
200
0
-200
-400
Water Level (m PWD)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
Time
Discharge
Water Level

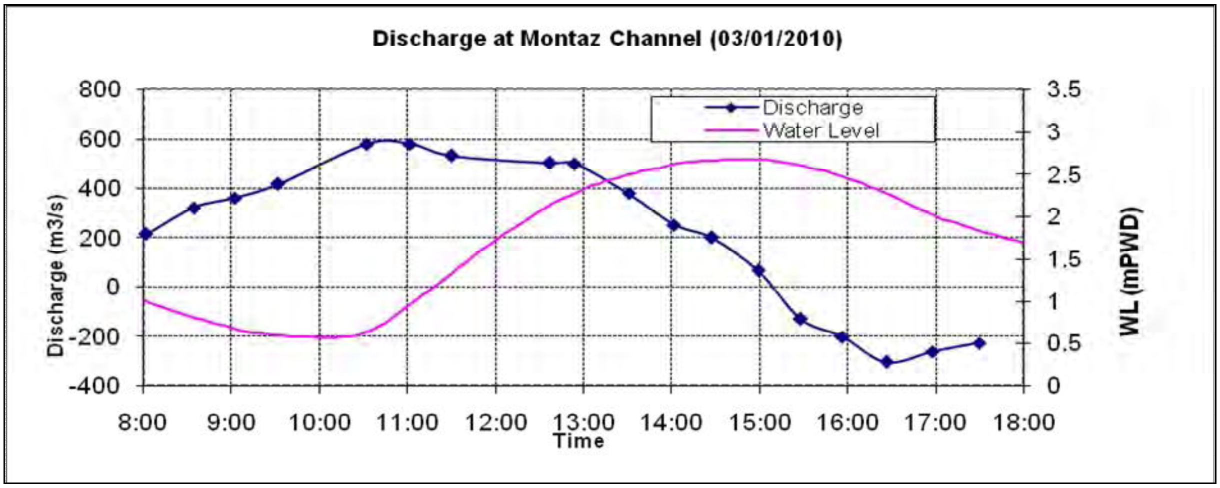


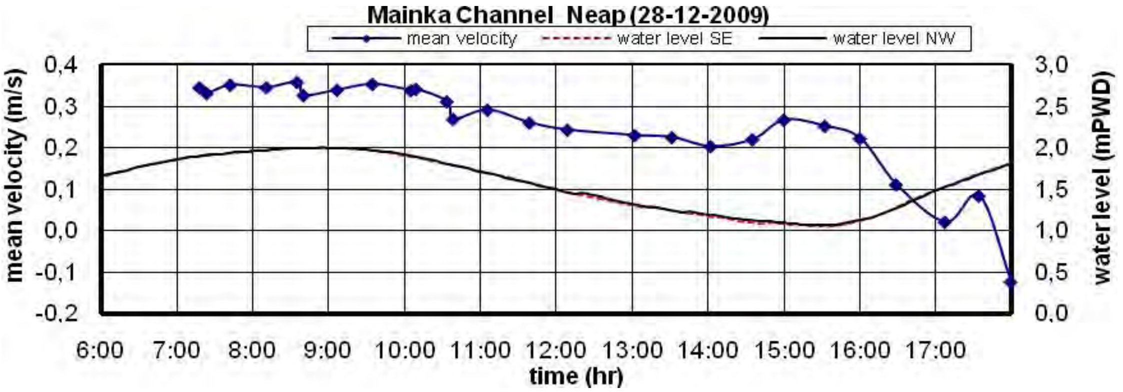
Figure-4.16: Discharge of Mainka and Montaz Channels

4.5.7 Velocity

For the October measurements it holds that along 2 measuring verticals (per cross-section) at a number of measuring points the flow velocities were determined. From the measured wet cross-section (bathymetry combined with water levels) and the flow velocities the discharges have been computed.

The ADCP measures the velocities in the core of the cross-section and computes the velocities near the boundary, viz. near surface, near channel bed and near banks. Total discharge and flow direction become online available during the measurements. The main results are presented in the graphs and tables hereafter.

Survey results



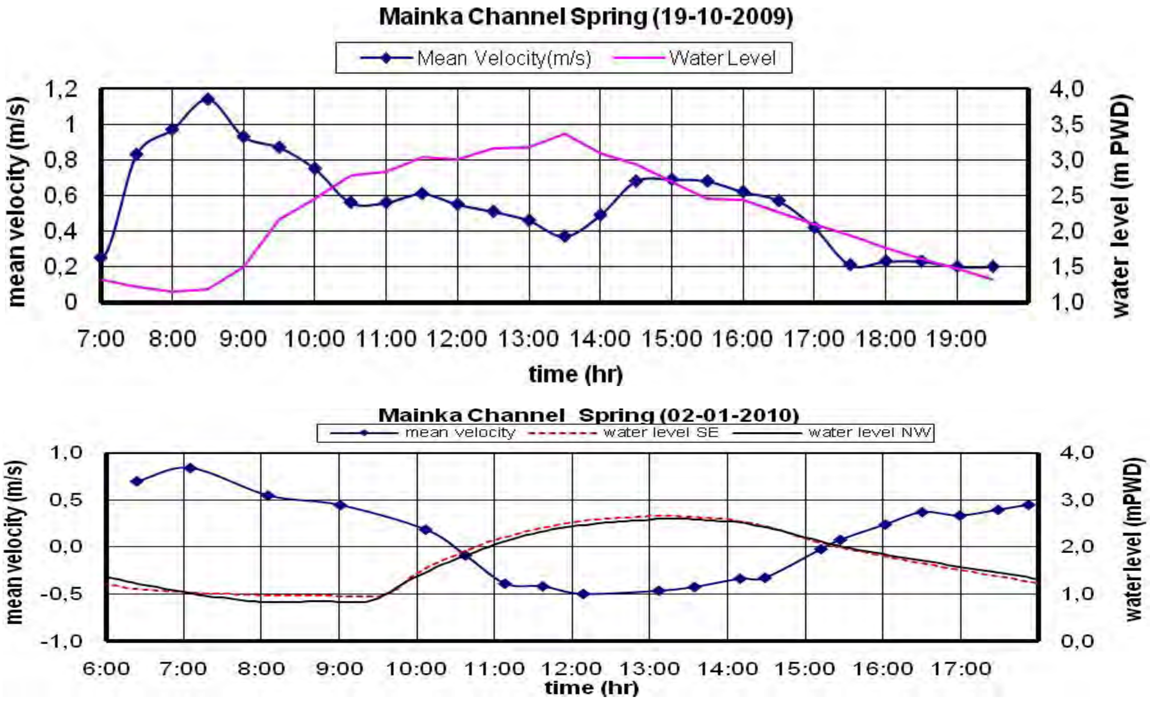
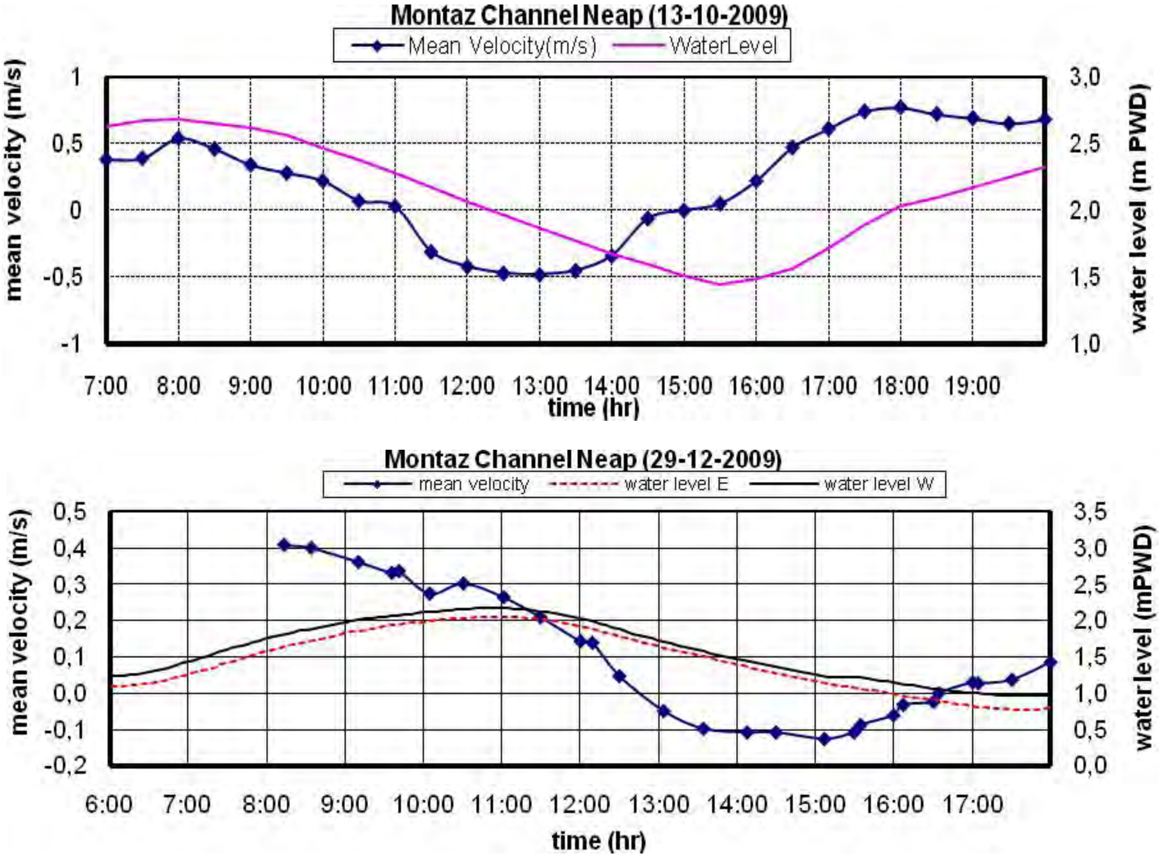


Figure 4.17: Flow velocities in the Mainka Channel



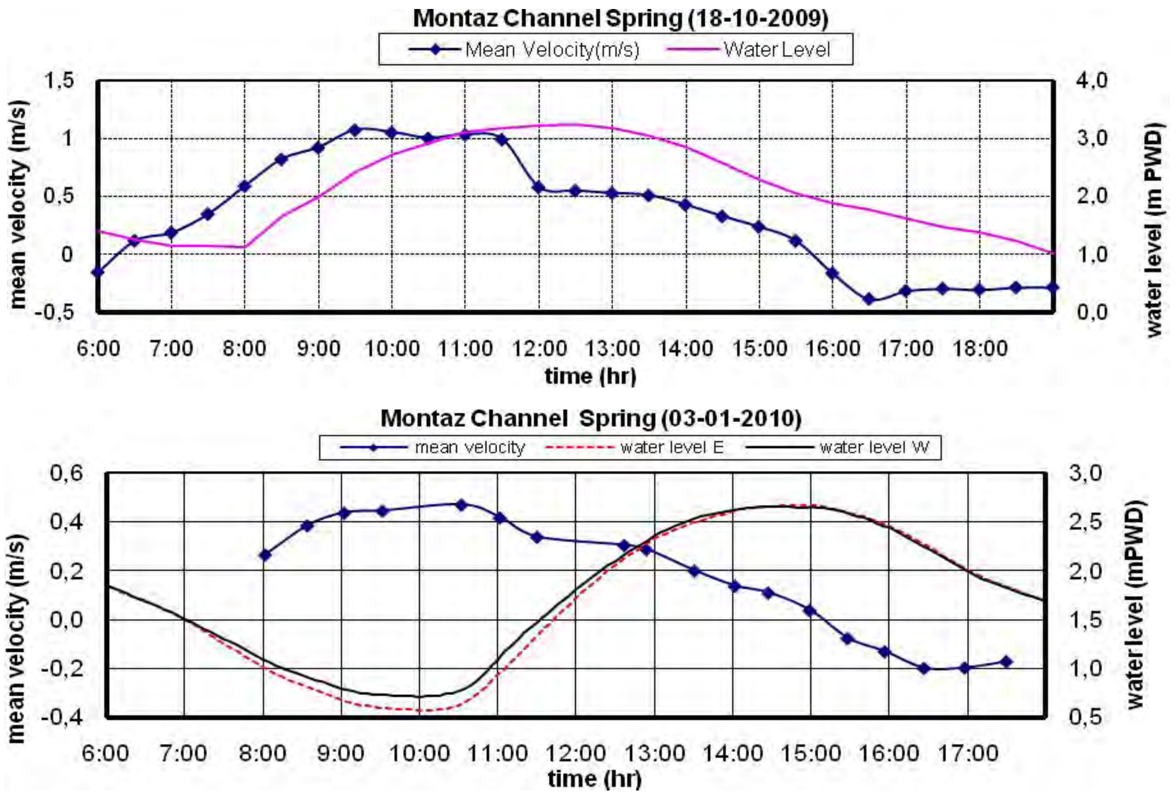


Figure 4.18: Flow velocities in the Montaz Channel

Conclusions

From the figure 4.17 and figure 4.18 the maximum and minimum flow velocities have been compiled in the table below.

Table 4.3: Maximum/minimum velocities at closure sites in October respectively December/January (meter/second)

Flow measurements	**Mean velocity in Mainka Channel**		**Mean velocities in Montaz Channel**	
	minimum	maximum	minimum	maximum
Neap	-0.57 --	0.75 0.36	-0.50 -0.11	0.79 0.41
Spring	0.20 -0,50	1.17 0.83	-0.40 -0.20	1.05 0.47

Note: For Mainka flow towards SE is positive and towards NW is negative; for Montaz flow towards the E is positive and towards the W is negative.

Summary of the Table

1. The negative flows, viz. the flows towards the Bura Gouranga Channel, are sometimes stronger during neap than during spring.
2. During spring tide in October the flows in the Mainka channel are constantly directed towards the Kukri Mukri Channel and do not change direction/sign. In December the same happened there during neap in figure 4.18.
3. During neap the maximum velocities halved at the end of the year (compared with October conditions) with max values in the order of 0.4 meter/second (about closure conditions).
4. During both survey campaigns the max velocities occurred in the Mainka Channel during spring. The maximum spring velocity of 0.83 meter/second.

For the works in the channel it is important to note that favorable periods with zero flow (slack) during low water levels are scarce. Some of such periods occurred 19 Oct 17:30-19:30 in the Mainka Channel, 13 October 14:30-15:30 and 29 December 16:00-18:00 in the Montaz Channel.

4.5.8 Location of tidal meeting point

There are two proposed closure one is on the Maink Channel and another on the Montaz channel. The both channels are connected with Bura Gouranga Chaneel in the west and Kukri Mukri Channel in the east. So we have to find out the flow meeting point of both Mainka and Montaz Channel.

Mainka Channel

For finding out the flow meeting point of Mainka channel consider water level stations of western point (Char Kalmi) and eastern point (Mainka Kheya Ghat) and discharge u/s of Bura Guranga and Kukri Mukri channel both spring and neap (Use Fugure-4.19 to Figure-4.24).

Montaz Channel

For finding out the flow meeting point of Montaz channel consider water level stations of western point (Char Bangla) and eastern point (Char Bestin) and discharge d/s of Bura Guranga and Kukri Mukri channel both spring and neap.

In the analysis use the figure- 4.19 to figure-4.24.

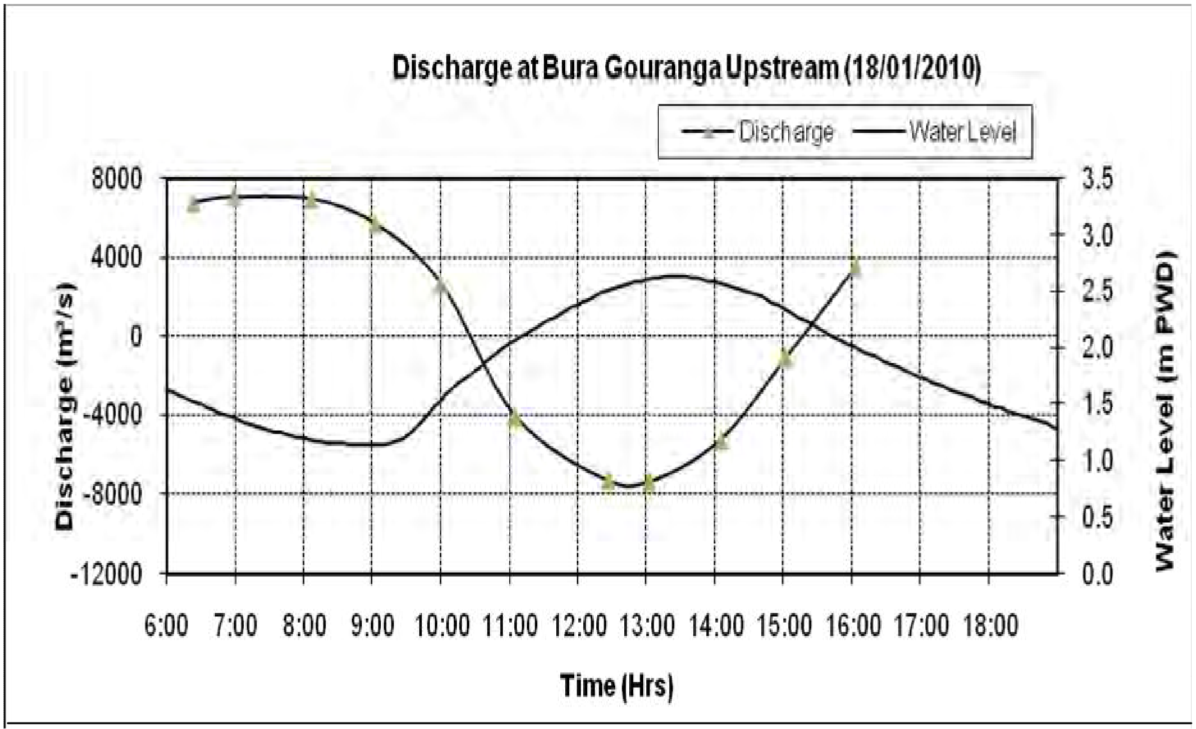


Figure-4.19: Discharge Observation at Gura Gouranga Channel (U/S) located at Char Kalmi (during spring)

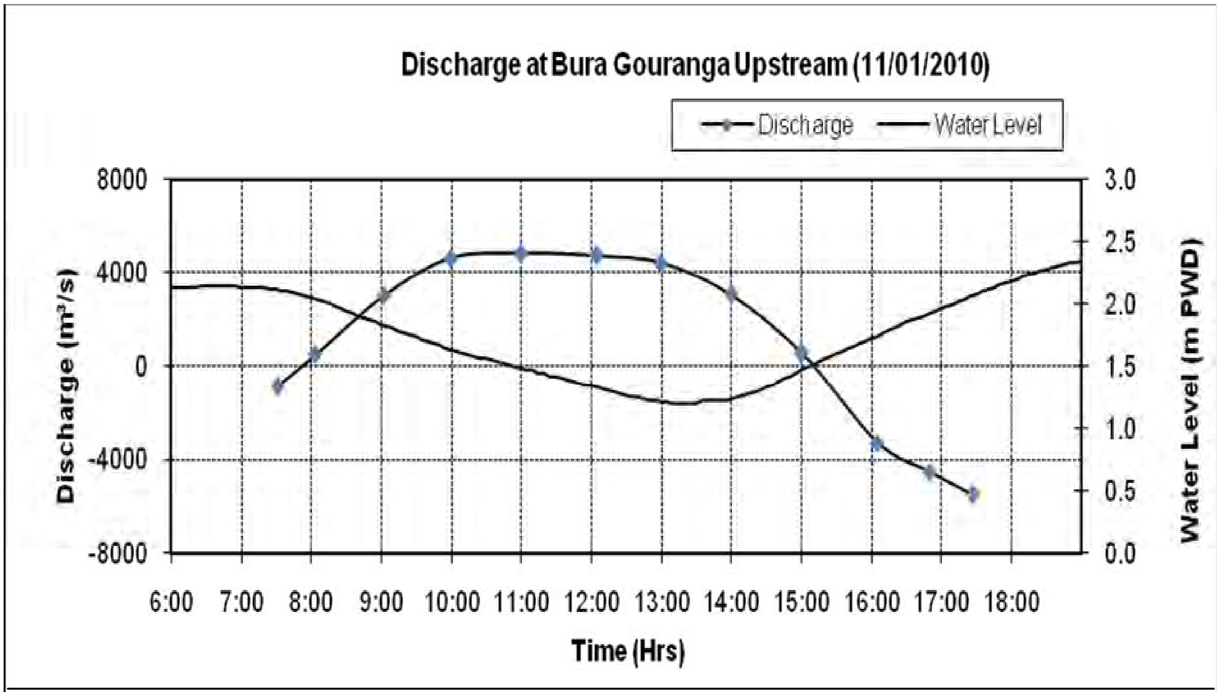


Figure-4.20: Discharge Observation at Gura Gouranga Channel (U/S) located at Char Kalmi (during neap)

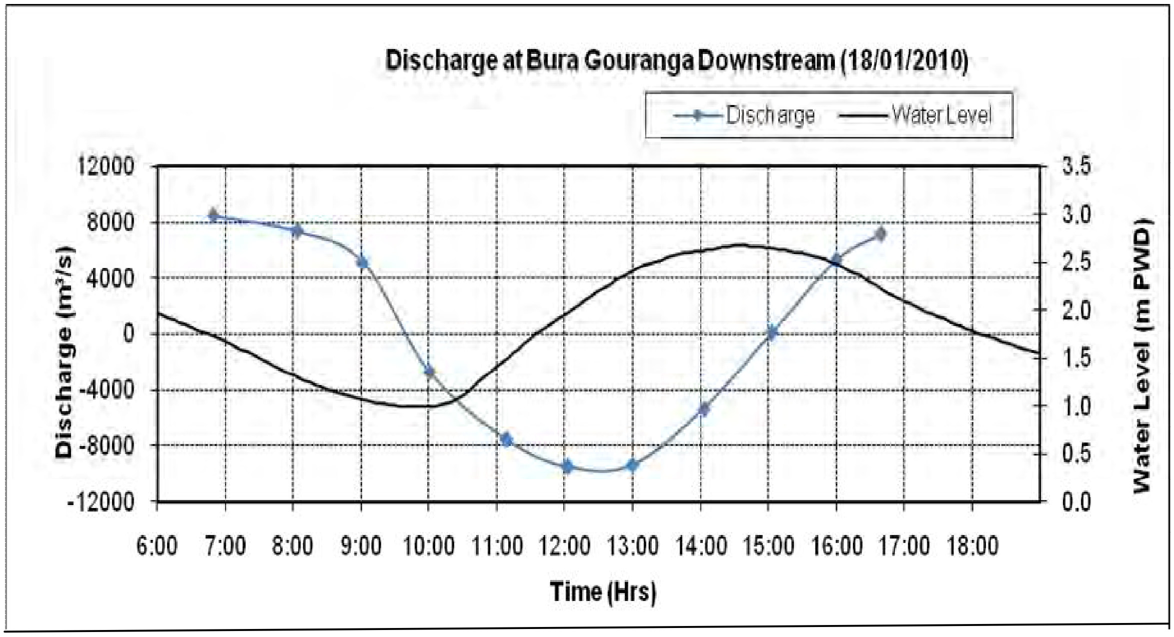


Figure-4.21: Discharge Observation at Gura Gouranga Channel (D/S) located at Char Bangla (during spring)

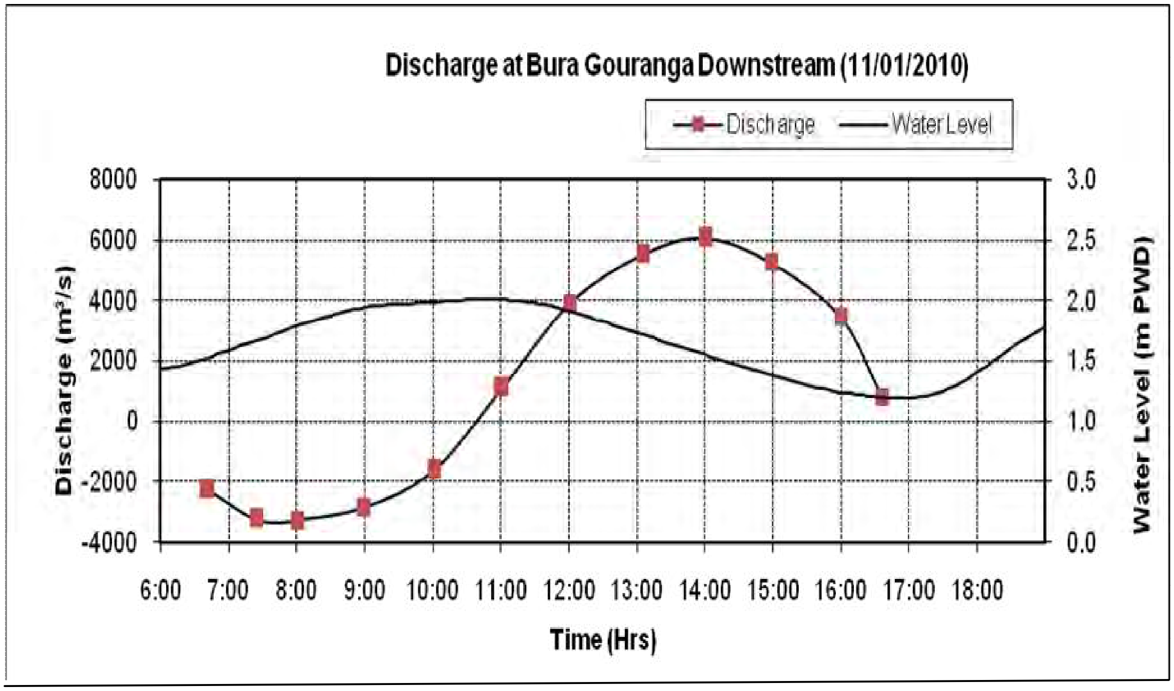


Figure-4.22: Discharge Observation at Gura Gouranga Channel (D/S) located at Char Bangla (during neap)

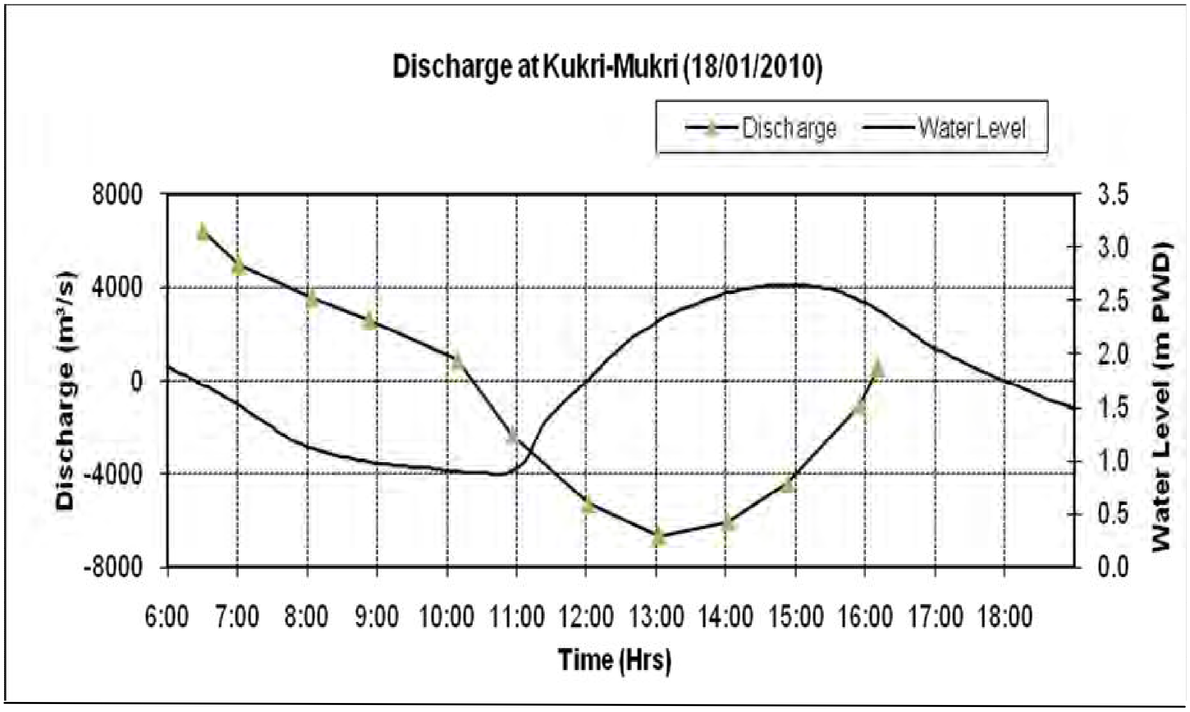


Figure-4.23: Discharge Observation at Kukri Mukri Channel (during spring)

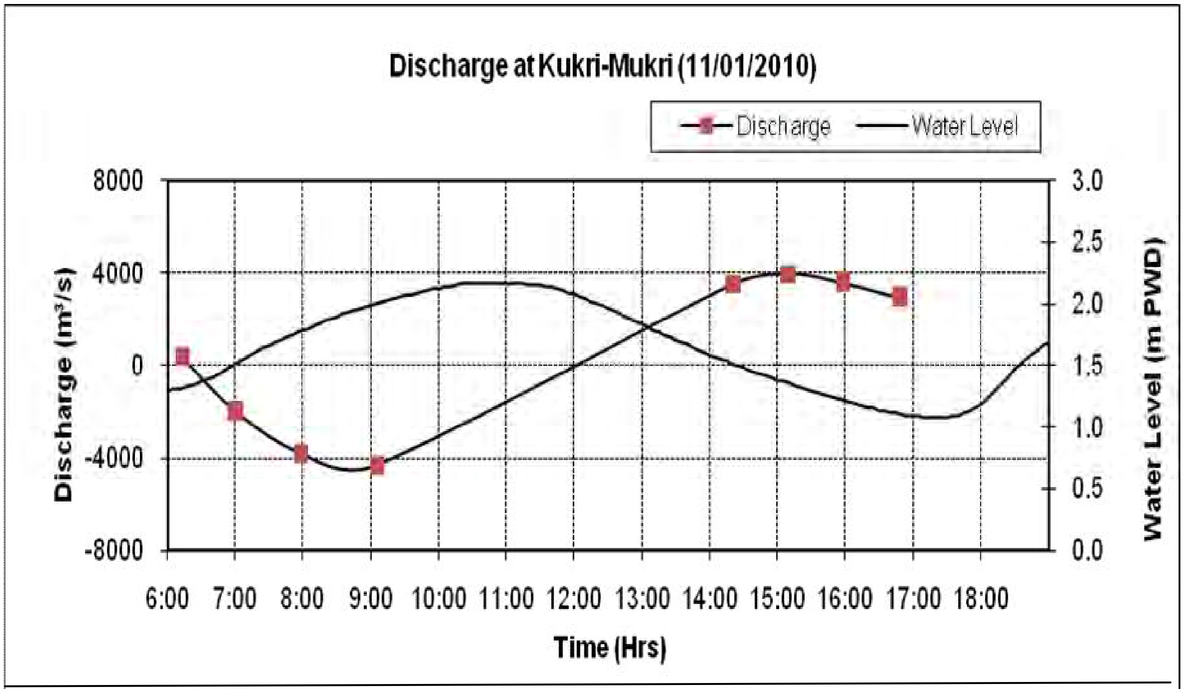


Figure-4.24: Discharge Observation at Kukri Mukri Channel (during neap)

Flow Meeting Zone of Montaz Channel
Distance between two stations = 4 km

During Spring tide (High tide)						
Montaz west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	18/01/2010	2.951	8448	10560	0.80	-4.15
Montaz east point						
	18/01/2010	2.954	6414	10022	0.64	-4.40
Flow meeting Point						
Distance from West		**2.222**	**km**			

During Spring tide (Low tide)						
Montaz west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	18/01/2010	1.075	-5316	14368	-0.37	-4.15
Montaz east point						
	18/01/2010	0.991	-4400	11579	-0.38	-4.40
Flow meeting Point						
Distance from West		**1.973**	**km**			

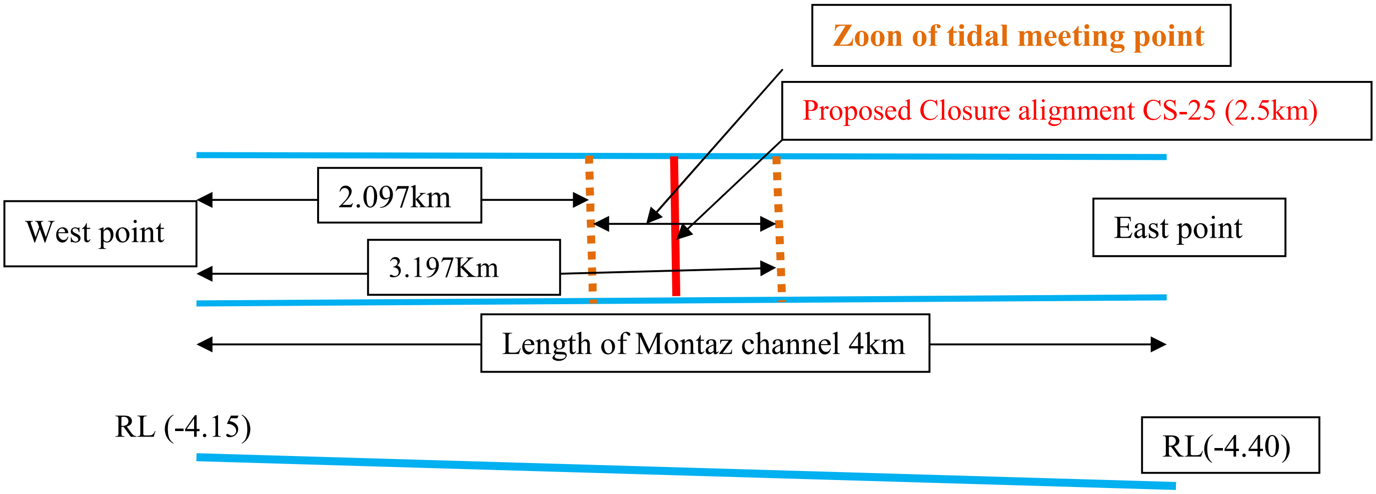
Area of Neutral Zone (Zone of neutral point of flow):

1.973 km to 2.222 km from west point of Montaz Channel

During Neap tide (High tide)						
Montaz west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	11/01/2010	2.609	6059	11016	0.55	-4.15
Montaz east point						
	11/01/2010	2.607	3956	7928	0.499	-4.40
Flow meeting Point						
Distance from west		**2.097**	**km**			
During neap tide (Low tide)						
Montaz west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	11/01/2010	1.184	1098	15686	0.07	-4.15
Montaz east point						
	11/01/2010	1.196	2015	7435	0.271	-4.40
Flow meeting Point						
Distance from west		**3.197**	**km**			

Area of Neutral Zone (Zone of neutral point of flow):
2.097 km to 3.197 km from west point of Montaz Channel

Consider the flow meeting point during neap (high and low tide)



Here found that the slope of the Montaz Channel is gentle slope from west to east. The zone of flow meeting point ranging 2.097km to 3.197 km from west point of the channel and the alignment of closer was fixed at 2.500km from west based on cross-section and discussed with local people.

Flow Meeting Zone of Mainka Channel
Distance between two stations = 5 km

During Spring tide (High tide)						
Mainka west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	18/01/2010	2.907	5698	7213	0.79	-5.17

Mainka east point						
	18/01/2010	3.021	6414	10022	0.64	-2.18
Flow meeting Point						
Distance from West		**2.762**	**km**			
During Spring tide (Low tide)						
Mainka west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	18/01/2010	1.097	-5238	16897	-0.31	-5.17
Mainka east point						
	18/01/2010	0.878	-4400	11579	-0.38	-2.18
Flow meeting Point						
Distance from West		**2.246**	**km**			

Area of Neutral Zone (Zone of neutral point of flow):

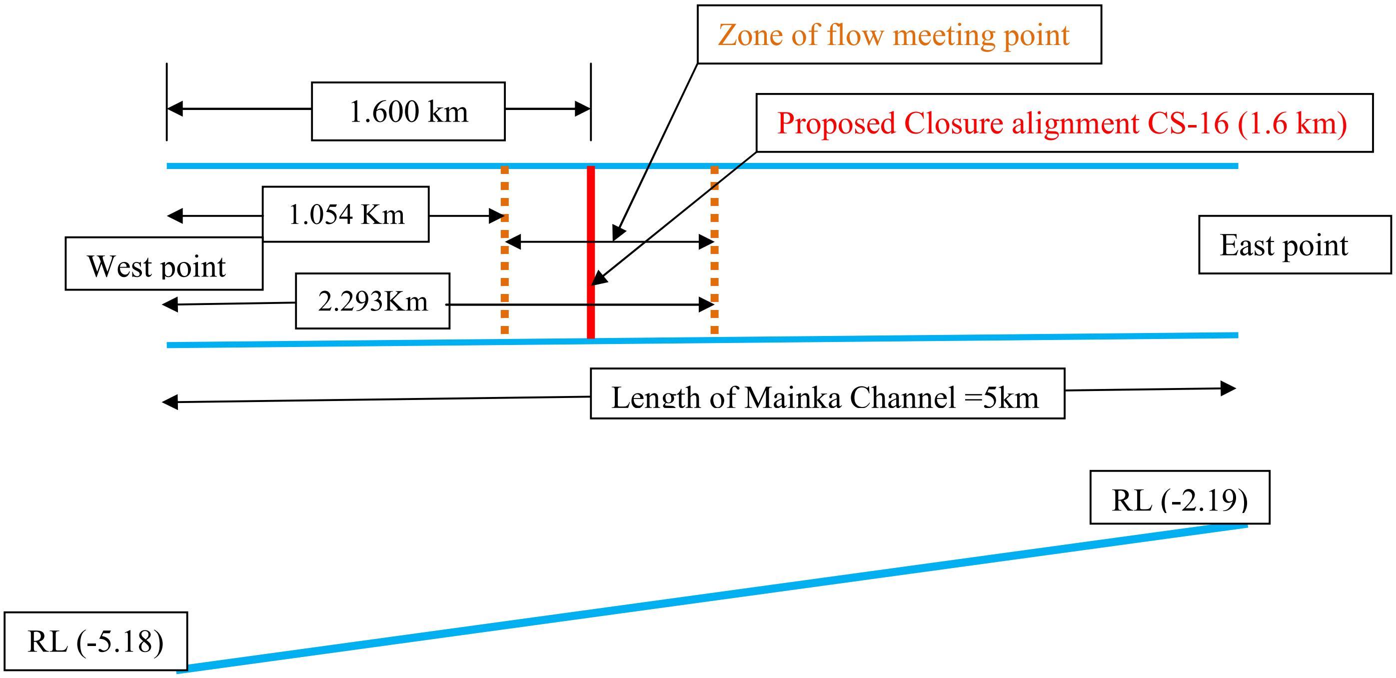
2.246 km to 2.762 km from west point of Montaz Channel

During Neap tide (High tide)						
Mainka west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	11/01/2010	2.436	4824	9549	0.67	-5.17
Mainka east point						
	11/01/2010	2.435	3955	9080	0.499	-2.18
Flow meeting Point						
Distance from west		**2.293**	**km**			
During neap tide (Low tide)						
Mainka west point						
	Date	WL (m)	Q(m3/s)	Area (m2)	Velocity (m/s)	Bed level (m)
	11/01/2010	1.193	-868	8949	-0.097	-5.17
Mainka east point						

	11/01/2010	1.292	-2015	7435	-0.271	-2.18
Flow meeting Point						
Distance from west		**1.054**	**km**			

Area of Neutral Zone (Zone of neutral point of flow):
1.054 km to 2.293 km from west point of Mainka Channel

Consider the zone of tidal meeting point during neap (high & low tide) which is 1.054 km to 2.293 km from west point of Mainka Channel



Here found that the slope of the Montaz Channel is steep slope from west to east. The zone of flow meeting point ranging 1.054km to 2.293 km from west point of the channel and the alignment of closer was fixed at 1.600km from west based on cross-section and discussed with local people.

4.6 Selection the Alignment of Closure

The Cross dam Site Selection has been based upon the following criteria:

1) Based on tidal meeting point Mainka & Montaz Channel

Mainka Channel: Zone of tidal meeting point **1.054 km to 2.293 km** (during neap high and low tide) from west point of the Channel

Montaz Channel: Zone of tidal meeting point **2.097 km to 3.197 km** (during neap high and low tide) from west point of Montaz Channel

2) Based on Channel sections

This approach led to a pre-selection of the cross-dam site in the Mainka Channel varying from cross section15 to cross section 25, see Figure-3.1. That stretch of the Mainka Channel has a regular shape with very constant width and depth. Outside the cross section 15 to cross section 25 stretches is less desired because of the distance to open waters (waves) and the existing drainage channels.

For the pre-selection of the cross-dam location in the Montaz Channel, the situation is quite different (in comparison with the Mainka Channel). Connecting the people of Bestin Bazar to Bhola means that the cross-dam in the Montaz channel needs to connect Char Montaz with Char Islam (rather than Char Rustom with Char Bangla). Hence the cross-dam in the Montaz Channel should be located east of the mouth of the Bestin Channel, but not too far eastwards, to keep sufficient distance to the open waters of the Kukri Mukri Channel. This limits the potential dam site to the cross section 24 to cross section 30 stretches, see figure-3.1. The Montaz Channel has a rather irregular shape, especially along the cross section 24 to cross section 30 stretches. Only the cross-section 25 and 26 have maximum bed levels of -3 mPWD, the other sections are deeper. This limits the pre-selected stretch to sc25 to cs26.

The total length of the Mainka and Montaz channels is about 4 to 5 kilometer each, as can be seen from Figure 3.1. The dam site in the Mainka Channel (**cross-section16)** is located at **1.6 kilometer** from the western channel entrance and 3.4 kilometer from the Eastern entrance of the closure site. On the other hand the Montaz Channel **(cross-section 25)** is located at **2.5 kilometer** from the western channel entrance and 2 kilometer from the eastern end of the channel. The following sections are presented below in Figure 4.25 and 4.26.

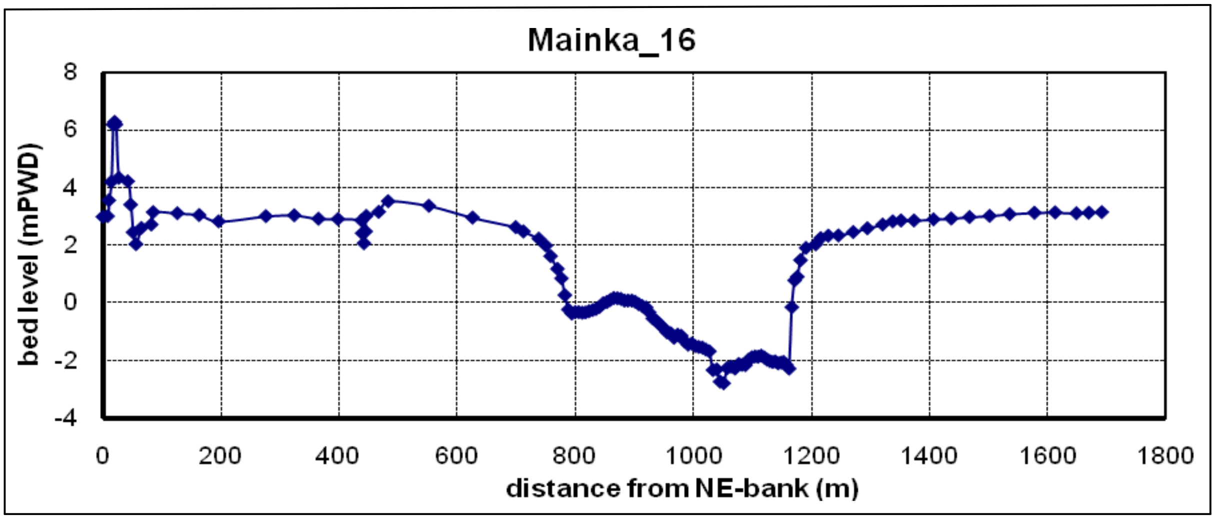


Figure-4.25: Cross-section of proposed closure location over Mainka Channel

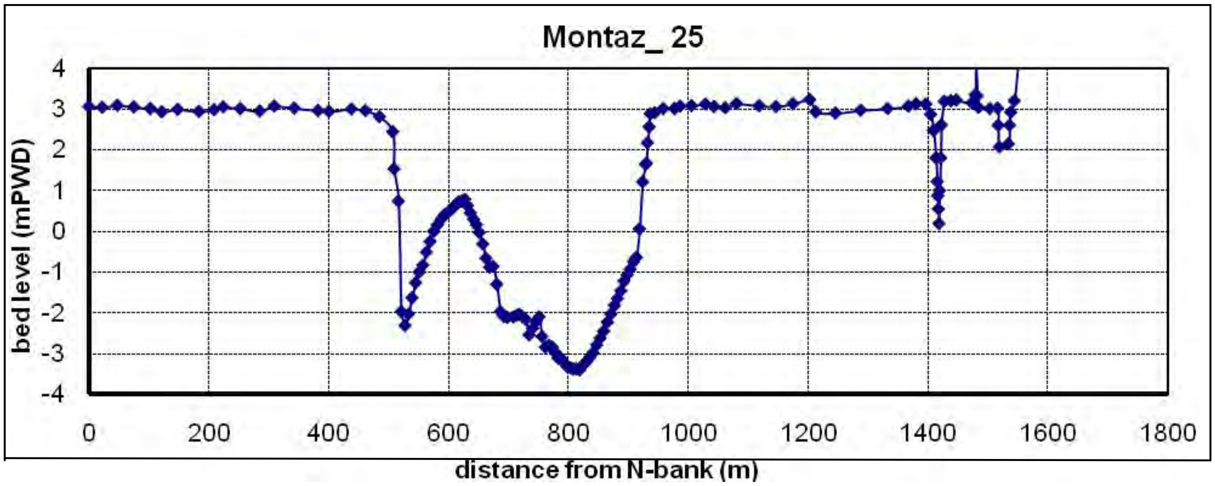


Figure- 4.26: Cross-section of proposed closure location over Montaz Channel

3) Based on discussion with the Local people

The selected potential sites of the closures have been discussed with the local people. From the discussions with the local community it came out that they clearly prefer to have the cross-dam in the Mainka Channel near cross section-15 or cross section-16 rather than cross section-24 or cross section-25. For the cross-dam site in the Montaz Channel the people agreed with the cross section-25 or cross section-26 locations.

Finally it has concluded that the closure in the Mainka Channel along **cross-section 16** and the closure in the Montaz Channel along **cross-section 25** may be proposed.

The Cross dam Site Selection has also been based upon optimizing the functionality of the dams and the discussions about the site preference of the local people. The functionality of the dams is for instance:

- Facilitate local transport
- Appropriate connection (the alignments of the dams should fit into the existing road network in order to enabling use of the dam for road construction in the future)
- Improving safety in this cyclone prone area
- Maximum accretion in the channels
- Favorable channel profile (minimizing closure works)
- Other physical aspects regarding hydro-morphology
- Sufficient sheltering in view of waves (Not too close to the open waters of the Bura Gouranga and Kukri Mukri channels)
- Minimum hindrance of the existing drainage pattern.

4.6.1 Timing of final closing

From the graph below it was concluded that the closure could be executed over a few days (say maximum 3 to 4 days) and that the final closure should take place in half a day around a tidal cycle with minimum head over the Montaz and Mainka channels (if possible during daytime).

To elucidate this timing, the predicted water levels of February at the proposed dam site should be taken. From these figures a suitable period around neap has been selected, in this case the first neap in February seems adequate.

The graph also indicates that a suitable period with minimum head and flows is expected to occur during the period of 10/11 and 25/26 February. This is the appropriate time for the final closure. (in figure-4.27).

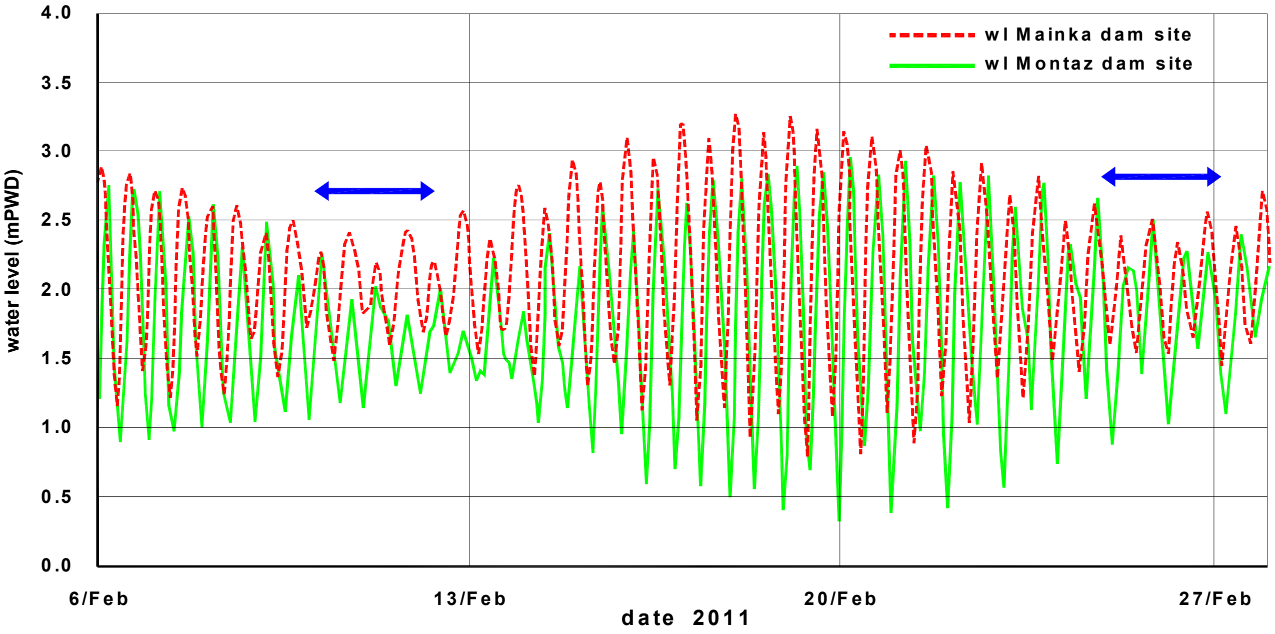


Figure 4.27: Selecting the period of closing of Closure

4.6.2 Consequences of partial horizontal closure

After construction of the approach dams and connecting dam on the flood plain, the remaining gap consists more or less of the low water channel. Then the dams are extended gradually, thus narrowing the wet cross-section at the dam site (the closure gap). This horizontal closure continues until the flow velocities in the closure gap become unacceptable high. Then the temporary heads of the extended dams will be protected with a layer of bags. This determines the width of the final closure gap. For the horizontal closure the maximum flow conditions in January 2011 are decisive.

During horizontal closure the formulation of the dimensions of the closure gap is as follows:

$A_{gap} = d'(b-\partial b/\partial t*t)$ in which
$d' = d - 0.2$

With d = the actual water depth and 0.2 is the thickness of the bed protection (75 kg geo-bags).

d = water level minus the bed level (= h_{dam} + 2 mPWD) for the Mainka Channel and (h_{dam} + 3 mPWD) for the Montaz Channel

d' = h_{dam} + 1.8 respectively d' = h_{dam} + 2.8

h_{dam} = the water level in the gap has been estimated, see table -4.4
It should be noted that h_{dam} is also affected by the partial closure but these effects are small and therefore neglected here, thus avoiding an iterative computation.
b = channel width for a certain water depth.

In order to simplify the computations b is schematized here to be the wet cross-sectional area of the channel/ the water depth in the final closure gap; b = A/d.
∂db/∂t = horizontal closing speed e.g. 5m/hour. This speed is depending on the construction method and capacity applied to extend the dams e.g. by head-load or using the dredger, etc.

In case of closure from both channel banks, the closure speed per bank is 2.5 m/hour.
As a first estimate the gap has been defined to be

A_{gap} = (h_{dam} + 1.8) (283-5*t) with (t in hours) for the Mainka Channel and
A_{gap} = (h_{dam} + 2.8) (308-5*t) with (t in hours) for the Montaz Channel.

With this definition of the size of the closure gap the development of the discharge could be computed for a series of tidal cycles during the days of partial closing. However, for the purpose of defining the minimum width of the final closure gap it is sufficient to select the most unfavourable combination of water levels and head, leading to the highest flow velocities. During a tidal cycle these conditions occur 6 hrs before HW (= around LW) in the Mainka Channel and 4 hrs before HW in the Montaz Channel, see Table 4.9 (spring measurements of 2/3 Jan 2010). These conditions are:

Table -4.4: Maximum flow conditions in January/February 2011 during spring tide

Channel	**h_W**	**h_e**	**dh**	**h_{dam}**	**d**	**$A_{channel}$**	**b**	**A_{gap} in m^2**
	(m)	(m)	(m)	(m)	(m)	(m^2)	m	t in hours
Mainka	1.00	1.03	-0.035	1.01	2.81	724	258	2.81(258-5*t)
Montaz	0.77	0.62	0.142	0.68	3.48	923	265	3.48(265-5*t)

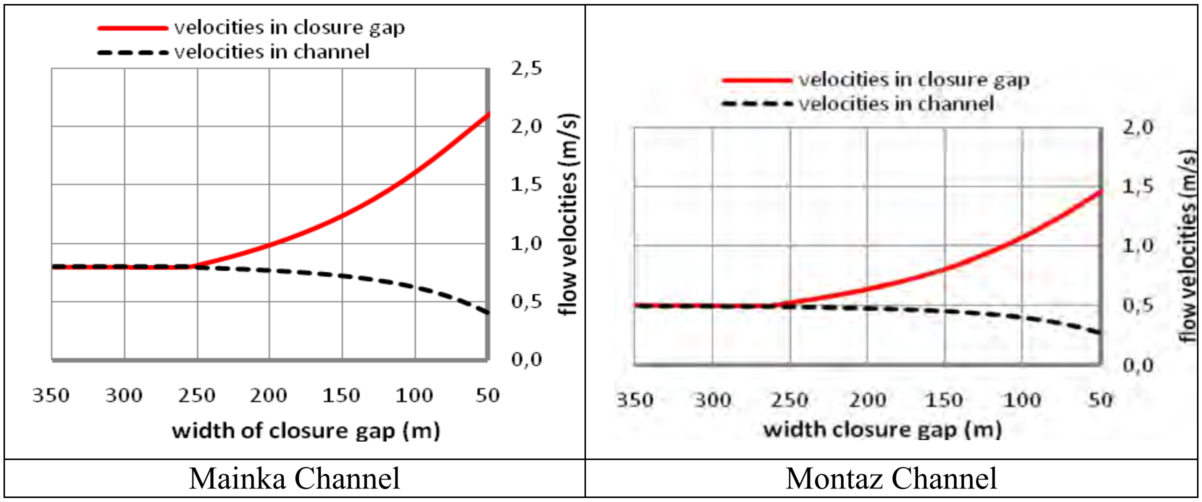
Under these conditions the flow velocities during partial horizontal closure have been computed. For these computations the following assumptions have been made:

$R_w = R_e = R$; $A_w = A_e = A$; $C_w = C_e = C$ For the considered water level in the closure gap, the assessed parameters read:

Table-4.5: Parameters for flow computations (spring)

Channel	**h_{dam}**	**R**	**A**	**C**	**Q(0)**	**v**
Mainka	1.01	2.04	724	65	580	0.8
Montaz	0.68	2.21	923	55	462	0.5

The results are depicted in the Figure below:



Mainka Channel	Montaz Channel

Figure- 4.28: Maximum flow velocities during partial horizontal closure (spring January, 2011)

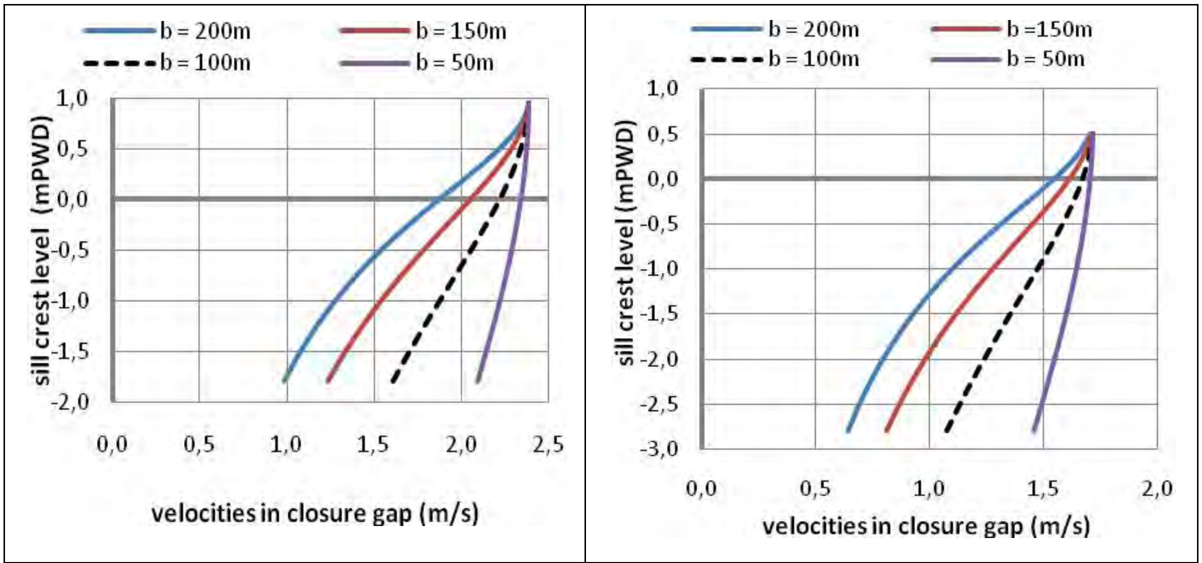
The figure shows that narrowing of the channel width from 350 to 100 meter are causing double flow velocity in the gap. For the Mainka Channel this means max spring velocities of 1.6 meter/second and for the Montaz Channel this is 1.1 meter/second. These velocities are high enough to erode the unprotected heads of the dams for the partial horizontal closure, but too low to damage heads protected with soil bags. This also implies that the last part of the partial horizontal closure should be constructed during neap and head protection should be implemented before spring conditions prevail. This holds especially for the Mainka cross-dam.

4.6.3 Level of sill crest

After the partial horizontal closure a sill will be constructed. The sill is further reducing the wet area of the closure gap, leading to a further increase of the flow velocities. The reduction of the gap is obviously depending on the crest level of the sill. For varying sill levels the wet area of the gap is by:

$A_{gap} = b_0 * (h_{dam} - h_{sill})$ in which
b_0 = the initial width of the gap at the start of constructing the sill
h_{dam} = the water level above the sill
h_{sill} = the level of the sill crest

With this formulation of A_{gap} the discharge and the velocities in channels and gap have been computed for combinations of gap width and sill crest levels. The results have been depicted in the Figure below.



Mainka Channel | Montaz Channel

Figure-4.29: Impact of sill construction on maximum flow velocities (spring January, 2011)

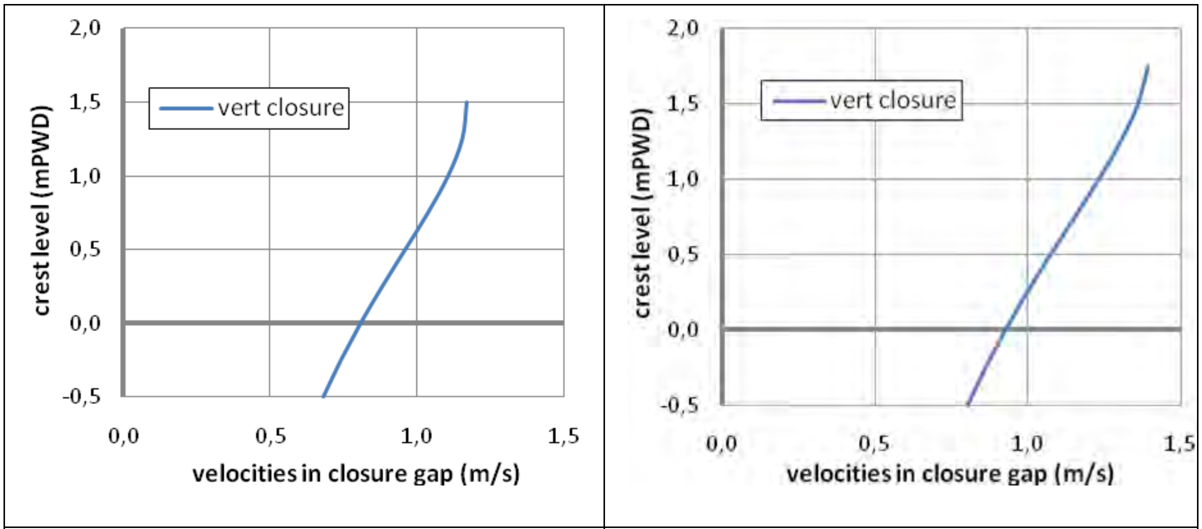
The figure shows how the mean flow velocities in the closure gap are further increasing while raising the sill level. When in closure gaps with a width of 100m a sill is constructed with a crest level of -0.5 meter PWD, the maximum flow velocities in the closure gap are increasing from 1.6 to 2.1 meter/second in the Mainka dam and from 1.1 to 1.6 meter/second in the Montaz dam. However, the increase is limited for the higher crest levels as velocities come near to the critical velocity, which amounts to 2.4 meter/second and 1.7 meter/second (Froude number =1) at respectively the Mainka Channel and Montaz Channel under maximum flow conditions during spring.

4.6.4 Flow velocities during final closure

The final closure will consist of two steps

- Raising the sill crest from about -0.5 meter PWD to about 1.0 meter PWD
- Installing (placing, fixing and filling) the geo-tubes

The first step is done using synthetic bags. The bags can be dumped from the dam heads (horizontal closure) or from a barge (vertical closure). The impact of the vertical closure on the hydraulic conditions is comparable to the impact of the sill construction, see previous section. However, as the final closure will be implemented during neap, the velocities will remain lower (compare Figure-4.29 and Figure-4.30).



Mainka Closure (gap width 100 m)

Montaz Closure(gap width 100 m)

Figure-4.30: Impact of vertical closure on maximum flow velocities (neap February, 2011)

The second step is closing the remaining gap by installing a geo-tube, which should take place during neap conditions. During filling, the crest level of the tube will be raised from 1.0 meter PWD to 2.5 meter PWD. During neap the water levels are varying around 1.8meter PWD with a range of about 1.2 meter. During LW the dam crest at 1meter PWD is nearly dry. The flows will become then critical. However, the max heads during neap will be smaller, so the critical velocities become then 1.2 meter/second in the Mainka Channel and 1.4 meter/second in the Montaz Channel.

4.6.5 Bottom protection

The flow velocities in the closure gap are increasing significantly during the various steps of the closure. After the channels are partially closed to widths in the order of 100m, the mean velocities in the closure gap may reach values of about 1.6 m/s as can be seen from Figure-4.30. Flow contraction around the heads of the dams (for partial horizontal closure) gives locally quite higher velocities. The strong flow will generate a vortex street downstream of the dam heads with strong erodible power. The highest velocities will occur in the final closure gap when raising the sill crest level. Then critical flow conditions will occur over the width of the gap. The maximum velocity will reach then values in the order of 2.4 meter/second, see Figures 4.29 and 4.30. Therefore the channel bed will be protected with a mattress.

The mattress will not only cover the area with high velocities, but also the surrounding areas, for reasons of safety. Therefore the channel bed will be protected over the full width of the closure gap (100m) plus an extra width of 20m at both sides. Hence, the total width of the bed protection will amount to 140m.

The mattress should be strong enough to remain stable during the required period of 1 to 2 months during the lean season. In these months the maximum velocities over the mattress will remain below 0.8 meter/second before the closure operations. Under these conditions the bags remain certainly stable and scouring at the edges of the mattress will be small. This also means that a relatively light geo-textile may be applied, e.g. 250 gm/m^2, thickness 2 mm.

The length of the mattress (the horizontal dimension in the flow direction) should be such that the stability of the mattress will also be secured during the closure activities. The high turbulence just downstream of the closure gap should reduce somewhat before reaching the edge of the mattress. This could be verified by scour computations. However, in case of the

Montaz and Mainka channels, these computations are not needed in view of the short duration of the closure and the considerable length of the mattresses.

4.7 Morphological Analysis

During the MES II studies an extensive morphological analysis was executed, based on historical shoreline developments, recent bathymetrical changes and cross-sectional analyses up to 2000. This chapter describes the update of the morphological analysis with various new data for the present situation (2010). Furthermore the shoreline change forecast as prepared under the MES II studies is evaluated and extended where possible.

4.7.1 Approach

The approach for the EDP studies is to update the morphological analysis as finalized for the MES II study in 2001 where possible. The main conclusions from the MES II study will be repeated in this chapter, however the complete extensive study of historical developments on which these conclusions were based can be found in the MES II report and will not be completely repeated here.

The new data available for the morphological analysis consists of:

1. Satellite picture and delineated shoreline 2008
2. Bathymetry 2009/ 2010
3. Survey data hydraulic conditions 2009/ 2010
4. Wave modeling results

Based on the new data and information, the developments from 2001 up to now are analyzed. These are compared to the historical development for the period from 1974 up to 2000 as analyzed and described in the MES II study. Identified trends in the MES II study are evaluated based on the new developments, and the morphological analysis is updated and improved where possible.

The following developments are analyzed (following the approach in the MES II study):

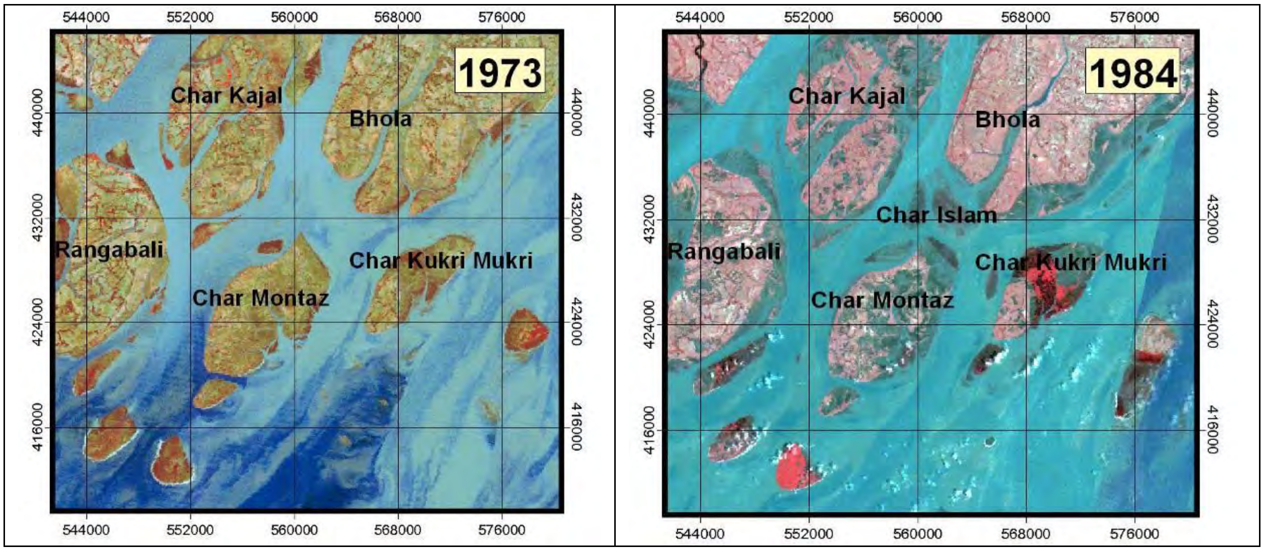
1. Shoreline changes
2. Bathymetry changes, sediment volume changes
3. Changes in selected cross-sections

4. Thalweg changes

Updated numerical modeling results (simulation of flow diversion over the main channels in the estuary, morphological simulations) for the current situation can support this update of the morphological analysis further. Unfortunately these results are not available at the time of writing of this. When they become available the analysis can be extended with that information.

4.7.2 Shoreline Changes (Planform Development)

Planform development in the Meghna Estuary in general, and the project area Bhola- Char Islam- Char Montaz specifically has been studied very recently by CEGIS based on satellite pictures from 1973 to 2008. The satellite pictures for the pilot area, as prepared by CEGIS, are shown in the Figure 4.31. The general change and development of the chars southeast of Bhola can be observed.



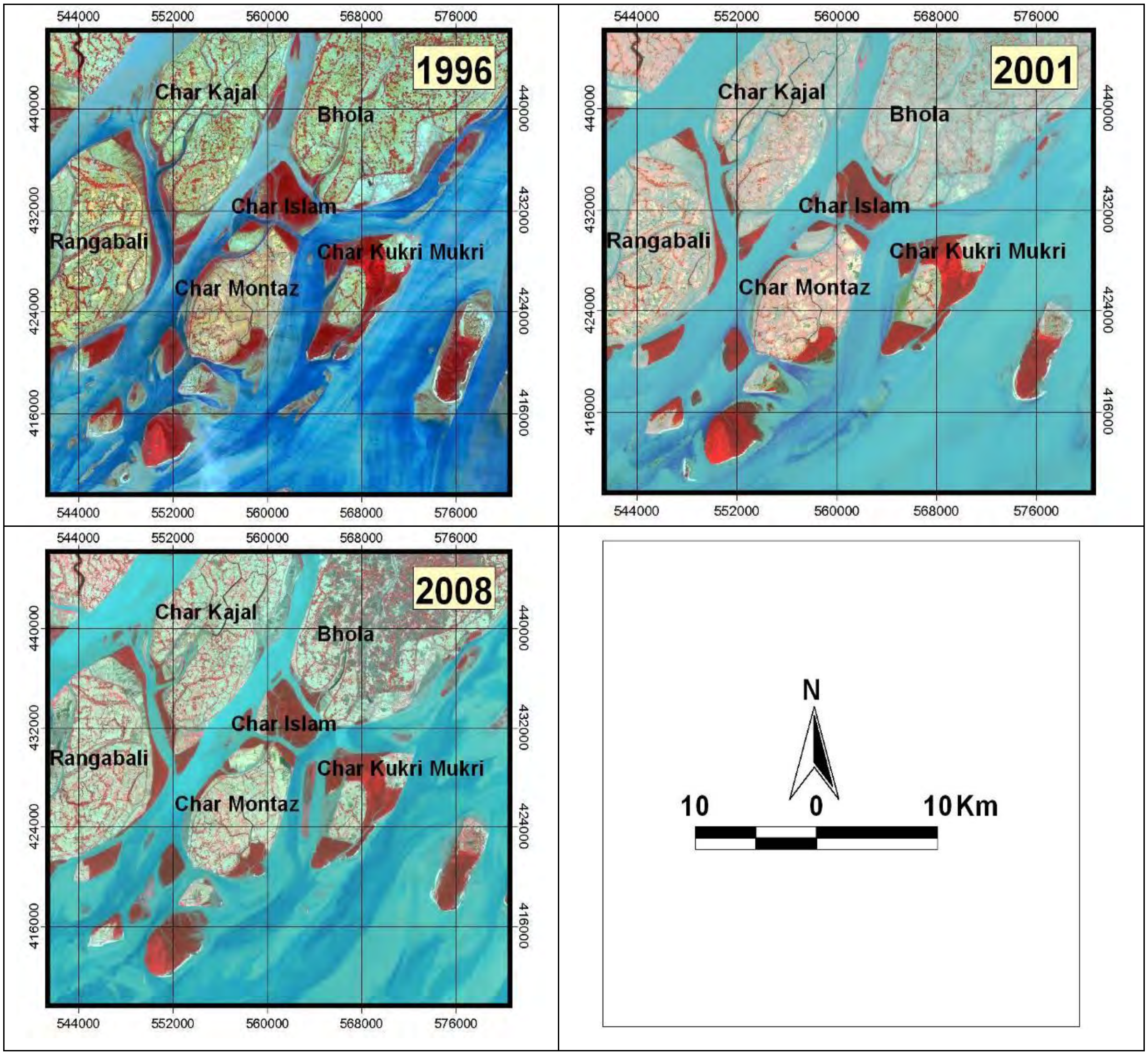


Figure 4.31: Satellite pictures of Bhola –Char Islam – Char Montaz (Source: CEGIS)

It can be observed that during the 1973- 1984 period new chars emerged in the area. The initial development of these chars with sparse vegetation can be seen in the 1984 picture. The development of these chars clearly continues in the period up to 1996, the chars have grown significantly, heightened and have been covered by developed vegetation. Consequently the channel widths have decreased a lot in this same period. Mangroves cover the boundaries of the newly developed chars. The satellite pictures for 2001 to 2008 do not show significant changes in char shape or land use compared to 1996 anymore. Smaller scaled changes might have occurred but these cannot be seen in the satellite pictures.

4.7.3 Erosion and accretion land area

From those pictures it is confirmed that the largest part of accretion and the most significant shoreline changes have occurred between 1973 and 1996. After 1996 the area has been relatively stable, though some local erosion/ sedimentation still occurred along the edges of the islands. Furthermore, a new small char has emerged between Char Montaz and Char Kukri Mukri between 2001 and 2008. Apparently accretion is occurring in the Kukri Mukri Channel. Some very small chars have also emerged/ grown between 2001 and 2008 in between southeast Bhola and Char Kukri Mukri.

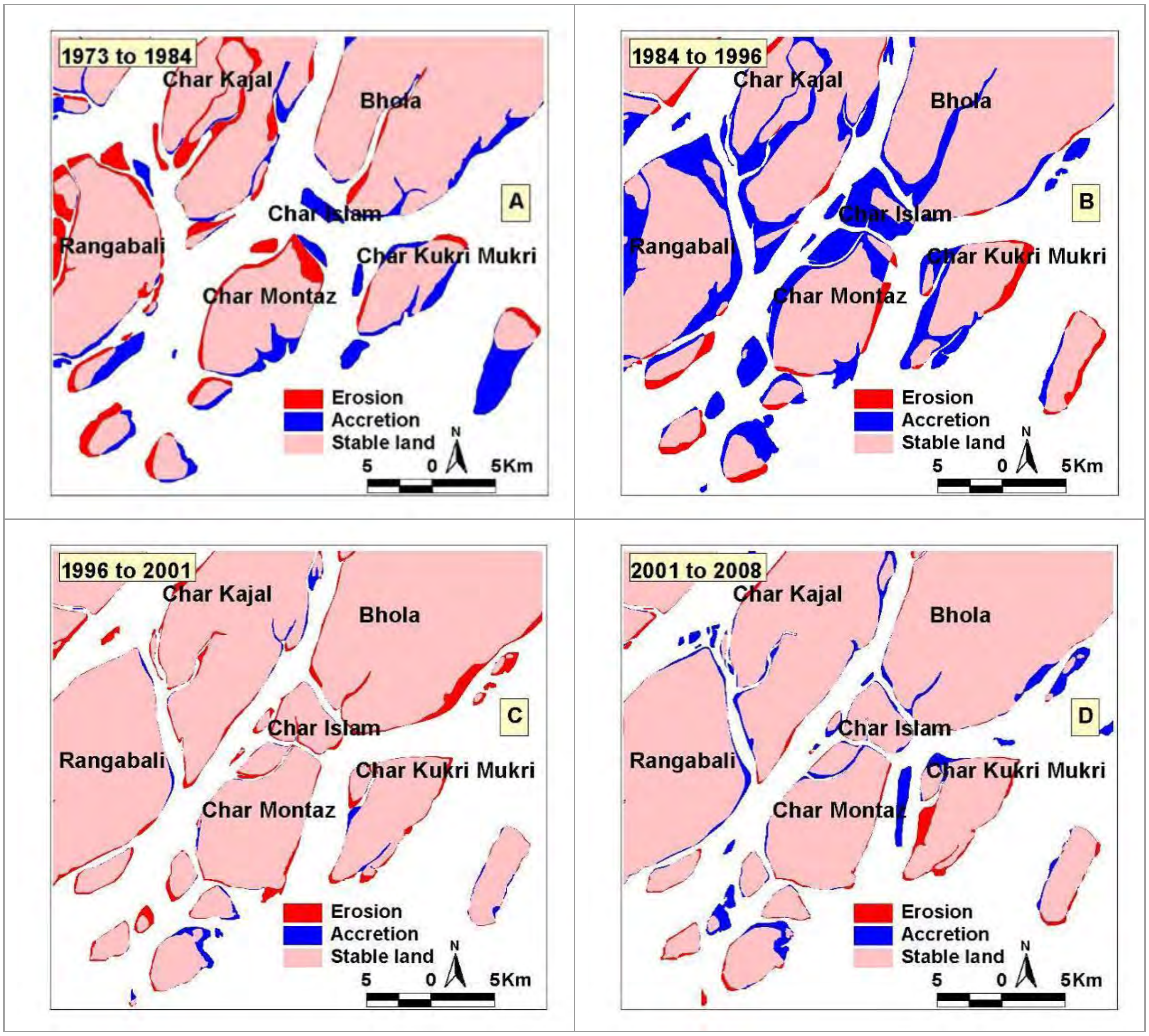


Figure-4.32: Erosion and accretion Bhola – Char Islam-Char Montaz (Source: CEGIS)

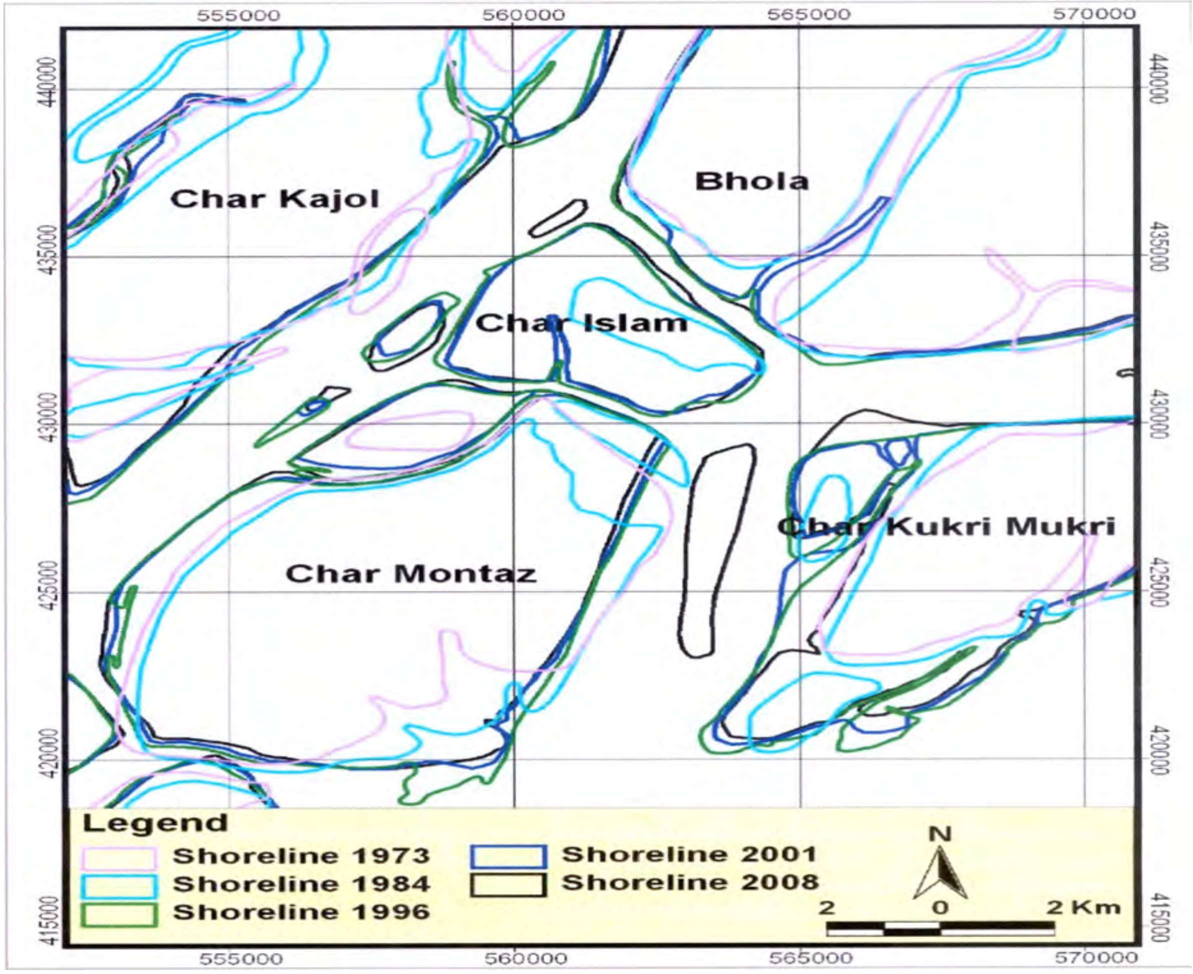


Figure-4.33: Detail planform development for area Bhola-Char Islam-Char Montaz (Source: CEGIS).

For the locations where the cross dams are planned, a more detailed analysis have been executed. Below the development of islands (chars) and channels are described in more detail.

Islands (chars)

The development of sizes of Char Montaz and Char Islam are summarized in the table below. Similar patterns can be observed as for the overall development described above; the main change occurred between 1984 and 1996. After that the island sizes are relatively stable.

Table 4.6: Development Char sizes Char Montaz (Left) & Char Islam (Right), Source: CEGIS

Char Montaz		Char Islam	
Year	**Size (Sq. km)**	**Year**	**Size(Sq. km)**
1973	61	1973	0
1984	60	1984	5
1996	79	1996	19
2001	70	2001	18
2008	78	2008	18

Channels

Mainka and Montaz Channels seem to have narrowed a little bit in the last decade, through the observed change can also be interpreted as being within the error margin of the shoreline digitizing method. The current narrowest point of Mainka Channel and Montaz Channel are around 500meter and 400meter respectively. The morphological development of the channels is analyzed further in the next section about developments of the bed level under water.

Bed Level Development

Besides an analysis shoreline changes, additionally the change of bathymetry (bed level) was analyzed to gain more insight in the morphological developments. The bathymetry is available only until 2000/2001 from the previous MES II study. From detailed analysis of the change in bathymetry in channels around Char Manika (Bhola) –Char Islam- Char Montaz, it turns out that the bed level changes were mostly between -1meter and +1meter and therefore relatively small. It is expected that the cross sections and bed levels in these channels have been relatively stable in the last decade.

Summary

Based on the different types of analysis executed, the conclusions on the main morphological developments observed in the period from 1973 to 2008 are presented here. The planform of the chars and channels in the cross dam area has changed significantly during the period from 1984 to 1996. The dominant process was accretion in this period, chars were growing and heightening at rapid rates and consequently channels widths were decreasing. The last decade in general the shoreline as well as bed levels have been rather stable. Only in the Kukri Mukri Channel, accretion has occurred between 2001 to 2008, with one char emerging between Kukri Mukri and Char Montaz and some smaller chars growing/ emerging between south-east

Bhola and Char Kukri Mukri. These findings need additional verification based on a new bathymetry when this becomes available.

4.7.4 Effects of closure

An analysis of effects of the planned cross-dams (1. Mainka Channel, 2. Montaz Channel) is executed based on available information. Note that in this study, only the potential hydraulic and morphological effects of the cross-dams are assessed. There might be other (positive or negative) effects that determine the feasibility and purpose of these cross-dams (e.g. road connection, fishery, livelihood, ecological aspects, drainage, navigation etc.).

Unfortunately no numerical modelling including these cross-dams has been executed until now. Dedicated modelling of this area will be executed later and may provide additional and more detailed insights into the effects of the cross dams. The following potential effects of the realization of cross-dams in the Meghna Estuary will be assessed here:

- Change in (tidal) flow patterns
- Increase of accretion/ erosion patterns
- Increase of water levels in the channel
- Change in salinity intrusion

Change in (tidal) flow patterns

From an analysis of flow patterns in larger scaled hydraulic models (MES II), it is concluded that in the present situation no significant water level differences exist over the east-west directed channels where the closures have been planned. Therefore, the flow velocities are also low in these channels in the present situation. Closing the channels off is expected to decrease the flow velocities in the channels even further. The (tidal and river) flow can still follow its preferred path in north-south direction through the larger channels east and west of Char Montaz- Char Islam and Bhola after realization of the cross-dams. The net flow directions and velocities are not expected to change as a result of the cross-dams. No large-scale impact is expected on the flow conditions in the estuary.

Increase of accretion/ erosion patterns

Because the flow velocity is expected to decrease only locally in the small channels (where the cross-dams are planned), the expected additional accretion by realization of the cross-dams is also expected to be mostly in the channels itself. The realization of the cross-dams will most likely also decrease inflow in the Kukri Mukri Channel further, leading to some acceleration of naturally occurring accretion in this channel. No large-scale impact is expected on the morphological development and accretion patterns in the estuary.

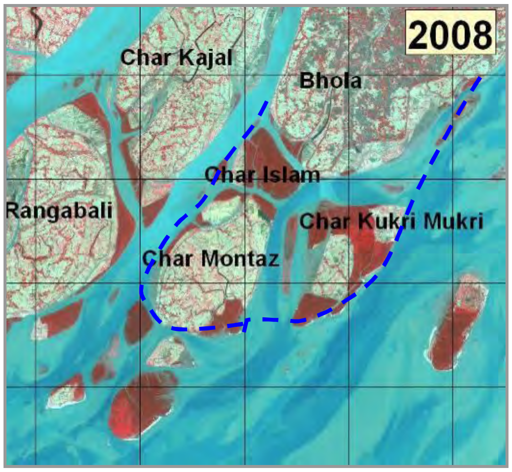


Figure 4-34: Potential landform development in the Bhola- Montaz area in the coming decade(s)

Increase of water levels in the channel

Because no strong tidal flow is closed off by realization of the cross-dams, significant water level increase at either side of the cross-dam is not expected.

Change of salinity intrusion

Because the large scaled flow patterns are not influenced, no impact is expected on the salinity intrusion in the estuary.

4.8 Geo-technical Aspects

4.8.1 Design requirements

There are a number of geotechnical aspects which may affect the design of the cross dams:

1. Subsoil characteristics along the alignment of the dam need to be determined for various reasons:

- to assess the bearing capacity and macro stability of the dams. This is primarily a check whether the selected location is suitable for constructing a cross dam
- to estimate the subsidence and its progress with time. This enables the addition of a surplus height when constructing the dams
- to assess the natural underwater slope
- to assess the subsoil characteristics as a potential source of fill material

2. Soil characteristics of the channel bed, especially the grain size distribution, as it may be used for selecting the type of geo-textile to be applied for bed protection and for scouring computations if any

3. Soil characteristics of the borrow areas are to be determined for a number of reasons
    - to assess the suitability of the material for dam construction
    - to select the appropriate type of bag (used for closing the channel)
    - to assess the suitability of the sediments for usage in a sand/cement mixture needed for side-slope protection

4.8.2 Geo-technical Site Investigation

The following investigation may be followed for design of cross dams.

(a) Boreholes and sampling
(b) Laboratory analysis for test results
(c) Classification and consistency of the cohesive layers
(d) Settlements
(e) Stability

4.9 Design of Closure

4.9.1 Design Approach

For the design of the cross-dams three phases can be distinguished:

1. The conceptual design

2. The preliminary design and
3. The final or detailed design

The conceptual design phase started with a reconnaissance trip to get a first impression of the project area and to collect or estimate some elementary data on channel dimensions, water levels and flow. This was leading to a first estimate of the type of closure to be applied in the channels; especially the method of closing has been indicated. In this phase it was decided to investigate the use of geo-tubes for closure in order to gain insight and experience needed in view of large closures envisaged to come in the near future. The data requirements for the following two design phases were outlined and converted into a set of survey programmes to measuring topographic, geotechnical and hydrometric data during wet and dry seasons.

The preliminary design phase started after completing the initial estimates regarding the method of closure and the possibilities of using geo-tubes have been elaborated. Preliminary assessments of lean season conditions have been made. The hydraulic conditions during construction of the closure dams have been simulated using a spreadsheet model.

The final design phase started with taking care of comments. The results of the lean season survey have been added and used to review the preliminary assessed lean season conditions .The simulation of hydraulic conditions has been reviewed with the aid of a 2D model, recalibrated with fresh data as far as available. The chapters on morphology and waves have been elaborated.

For the required field data three survey programmes have been outlined.

1. Topographic and hydrometric survey in the project area for design purposes
2. Hydrometric survey incl. sediment transport in the main channels around the project area for 2D model calibration
3. Geotechnical investigations and laboratory testing

4.9.2 Size and level of the proposed closures' alignments

The Approach Dams will connect the cross-dams in the Montaz and Mainka Channels with the nearby embankments. The Connecting Dam is connecting the closures of the Montaz and

Mainka Channels. The length of the main, connecting and approach dams are to be proposed in the table below:

Table 4.7: Length of Main, Approach and Connecting Dams

Proposed construction element	**location**		**length**
	From	**to**	**m**
Northern approach	Bohla embankmemnt	Mainka closure	700
Mainka Closure	Char Mainka	Char Islam	500
Connecting Dam	Mainka Closure	Montaz Closure	4000
Montaz cross-dam	Char Islam	Char Montaz	400
Southern approach	Montaz Closure	Montaz embankment	600
		Total:	**6200 m**

The Main, approach and connecting dam in figure 4.2 is running over the floodplain. Along the closure alignment the floodplain levels are rather constant and vary in between 2.5 to 3.0 meter PWD, for details see the longitudinal profiles presented in figure 4.7 and figure 4.8.

The crest level of the approach dams and road should at least be the same as the level of the local roads to be connected, viz. 4 to 4.5 meter PWD. The dams don't need the levels of the nearby embankments (5.4 meter PWD at the Montaz side and 6.4 meter PWD at the Bhola side, Herewith it should be noted that the main functions of the closures are acceleration of accretion and local connection. Others than with an embankment, the hydraulic conditions at both sides of the cross-dam remain tidal and the hydraulic head over the dam will be very small (say <0.5m). Therefore the crest level of the cross-dam is not based on tidal characteristics (water level exceedence) but on crest levels of existing local roads. The considered 4.5 meter PWD level gives a clearance of 1meter during high water spring of 3.5 meter PWD.

The crest level of the dams will be constructed higher than the existing roads, as some over-height is needed to compensate beforehand for subsoil subsidence and dam consolidation. An over-height of 20% of the height of the approach dams of 4.50-2.75= 1.75m means an over-height of 0.35meter. The crest level of the existing polder of both Charfession and Galachipa is considered as 5meter PWD as per design level of BWDB. But in Cyclone Aila May 2009, the maximum water level recorded were 5.5meter PWD. So the crest level of the proposed cross dam is to be considered 6.00meter PWD.

It is envisaged that the low embankment at the Char Montaz side will be raised to at least the 6m PWD level and that in future the dam levels may also be raised to the 6m PWD level in view of road construction. Therefore all dams will be given an extra width. Raising the dam crest with one meter, with side slopes 1 in 3 means an extra width of 6m will be consider. Therefore the dams have been given an extra width of 6m to accommodate the higher crest level in future.

The height of the Approach Dams and Connecting Dam on the floodplains will initially amount to 2.25m. The width of the crest will be 6m (normal) + 6m (extra) = 12m (at the 5 mPWD level). The side-slopes will be constructed 1 in 3. For the profile see figure 4.37.

Before construction work will be started the footprint of the dams must be cleared over a width of 27m from vegetation. Construction of Approach dams and Connecting Dam will be done by manual earthwork using plain soil from nearby borrow areas. It means that no bags or other materials are needed. On the side-slopes grass will be planted

4.9.3 Closure method, sequence of work

The closure method applied will be the same for both Mainka and Montaz channels. The closure method will consist of a maximum of horizontal and vertical closures. First a horizontal partly closure will be realized by extending the dams at both sides of the channel into the channel to obtain a final closure gap with a width of 100m. The final gap will coincide with the deepest part of the low water channel. Then the vertical closure method is applied to close the final closure gap in three steps: by constructing a sill, then raising the sill crest level to about Mean Sea Level (MSL) and finally installing a geo-tube on top. The method is schematized in the figure 4.35 (the numbers in the figure refer to the step numbers listed below).

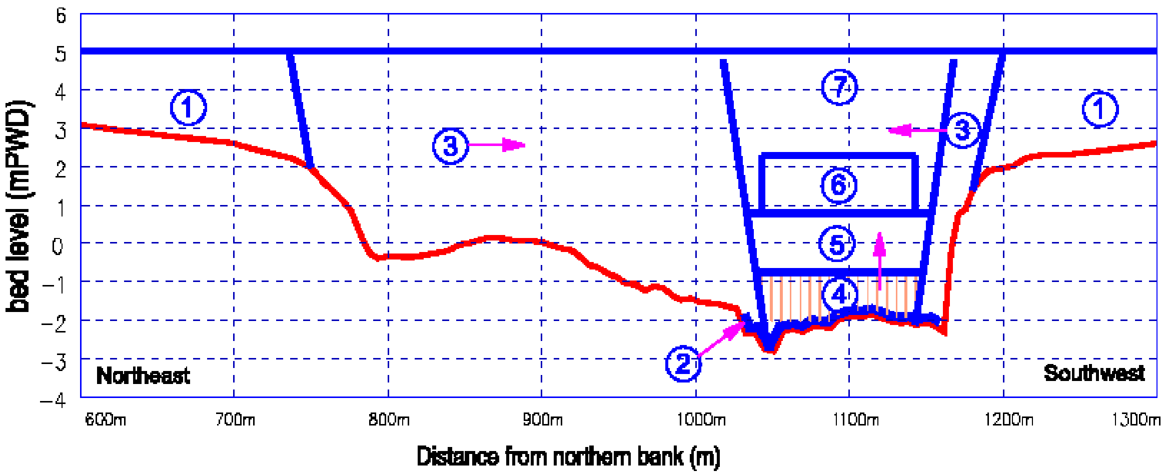


Figure 4.35: Sequence of works

In the beginning of the closure works the channel bed around the final closure gap need to be protected to reduce the scour during construction and shift the scour sufficiently away from the closure dam. After closure the cross-dam will get its final shape by profiling and by providing a slope protection.

The sequence of the works is indicated by the following steps:

1. construction of approach dams and connecting dam (earthwork)
2. bed protection in the LW channel (geo-textile with bags)
3. extension of dams into the channel thus defining the final closure gap (earthwork with dam heads protected by bags)
4. construction of a sill (2 bunds of bags with sand in between, covered by a geo-textile and/or bags) with a crest level of about -0.5 meter PWD
5. raising the sill crest level till about the LWN level (1 meter PWD) using bags
6. installation and filling of a geo-tube on top (or alternatively deploying bags)
7. final profiling of dam (earthwork)
8. slope protection works (new gunny-bags with sand/cement mixture).

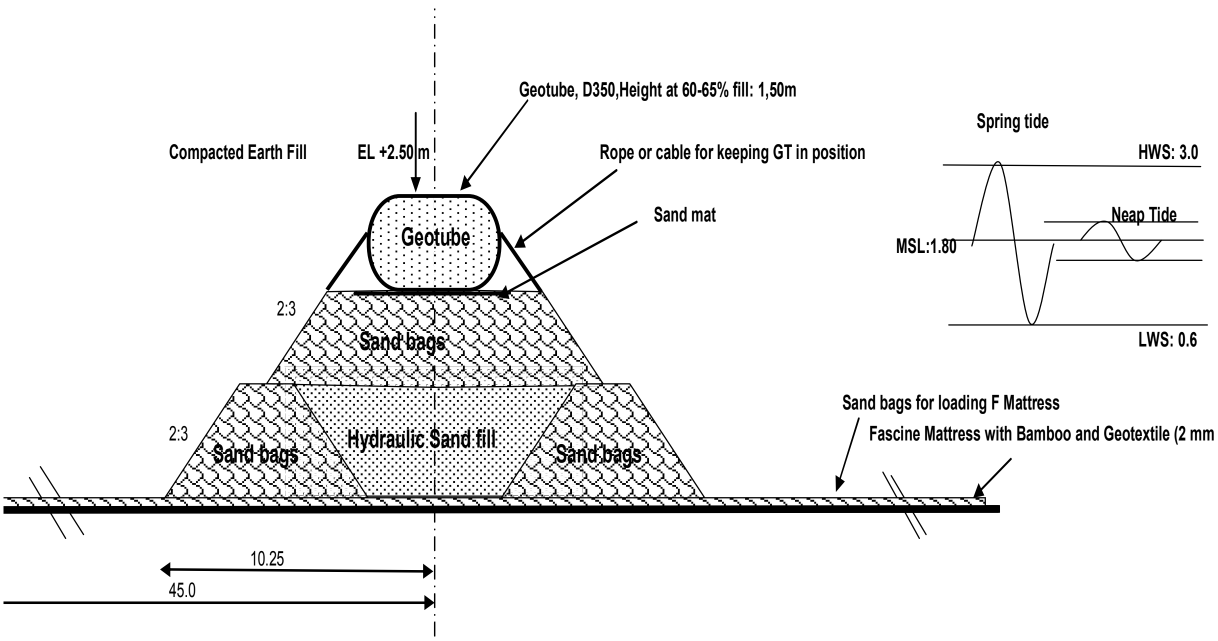


Figure 4.36: Typical cross-section of closure without profiling

It should be noted that for the filling of the geo-tube dredger is required. Having a dredger at site, it should be considered to use the dredger for all earthworks to the maximum extent.

Several times stockpiles of gunny bags have to be made. The stockpiles should be made on both banks during construction in following purpose.

1) ballasting bed protection
2) head of dams of partial horizontal closure
3) constructing sill
4) raising sill
5) extra bags for final closure without tubes
6) constructing slope protection

Timely preparation of the stockpiles is prerequisite for a smooth execution of closure works.

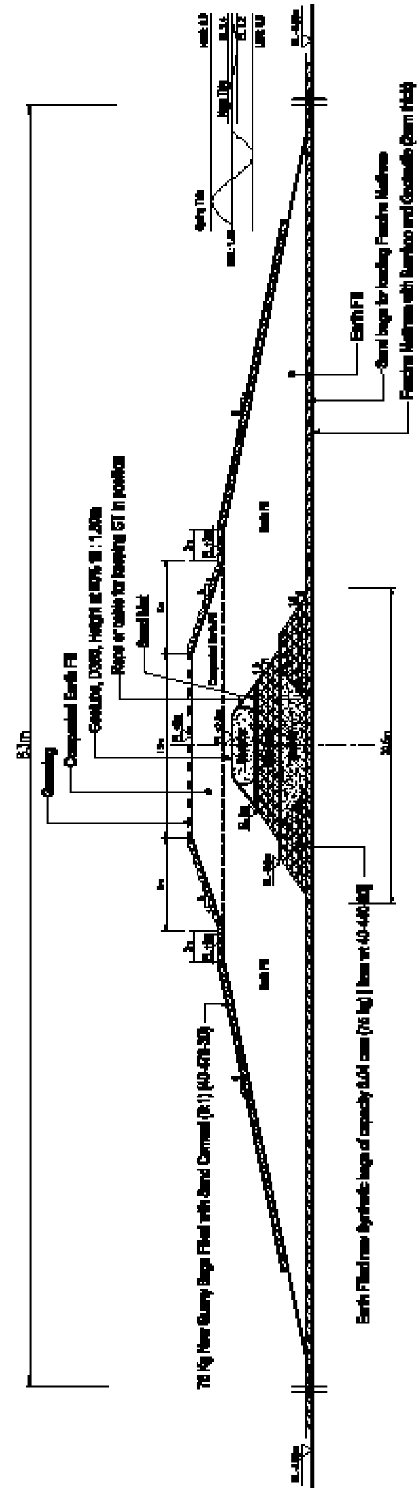


Figure 4.37: Typical cross-section of closure with profiling

4.9.4 Final Closure dimensions

Often the closure dam forms just a section of an important bund just like an embankment or a polder dike with primary flood preventing functions. Then the final profile of the dam will be the same as the profile of the important bund. This is not the case for the cross-dams in the M&M channels. The main functions of the dam are stimulation of land accretion, local transportation and safety. This means that the final profile of the dam is on the one hand determined by the requirements of the land transport. On the other hand the dam should be solid enough to survive monsoon conditions.

It seems reasonable to give the dam the crest level and the crest width of nearby roads (and not necessarily the nearby embankment). Also extra height is needed to compensate beforehand for subsoil plus dam consolidation. This leads to a final profile as indicated in figure 4.37.

The crest level will be the same as the crest levels of the approach dams, being 5 mPWD. The crest width amounts to 12 m. The side slopes above the berms (at the level of 3 mPWD) are 1 in 3. The berm width is taken to be 3m. The underwater slopes will be 1 in 5. Herewith it is assumed that the natural underwater slope of the used soil is the same or steeper.

4.9.5 Side-slope protection

The completed cross-dams need some side-slope protection, mainly in view of wave action. It is estimated that the wave height in front of the dams is very limited (H_s= 0.5 to 0.7m. Normal wave action will not affect the slope areas above floodplain level, as these levels are close to normal HW. Hence, only in the LW channel the water depths are sufficient for (wind) waves to reach the dam. The accretion process in the channel is stimulated by the dam. Therefore the wave action against the dam will reduce in the years after closing.

4.10 Risk of Closure due to different condition

4.10.1 Identifying of risks

In general it may be stated that for various reasons there is always a chance of damage and ultimately of failure of a cross-dam in the Bay of Bengal. Identification of these reasons and assessment of the chances of occurrence are the heart of this risk analysis. During the various phases of implementing the dam, errors could be made leading to serious damage or failure of the dam, viz.

1. errors in the data collection phase
2. errors in the design phase
3. mistakes during construction

These errors are often man-induced, but in some cases also nature may spoil the implementation, as can be seen from the elaboration hereafter. During the data collection phase, baseline data will be collected from literature and dedicated surveys. Inconsistencies in published data indicate errors. Possible errors in survey results may be caused by the instruments, the measuring method and/or the data processing. The errors in this phase affect directly the design work.

Mistakes in the design work may occur in the chosen methodology, resulting in applying the wrong design graphs. Besides errors in baseline data, errors in schematization occur, often due to lack of knowledge of the basic physics. Another source of errors comes from mathematical modeling activities, where transparency is usually insufficient (software capabilities, schematizations, curve fitting, validation). The design may prescribe the wrong materials and/or the wrong method of construction (e.g. method of closure).

Possibly the most serious error to be made during construction is a substantial underestimation of the work, by which the strict time schedule cannot be met. As a result conditions (wind, waves, water levels, currents) will become more difficult, ultimately leading to failure of the closure. So, some reasons of failure are e.g. insufficient labour, delays in procurement of materials, etc.

After a successful realization of the dam things may ultimately go wrong because:

1) lack of maintenance
2) human induced failure (social unrest)
3) nature induced damage (storm surges)

4.10.2 Consequences of the risk and measures

From some of the errors identified above the possible consequences are indicated and measures are suggested to reduce the chance of occurrence.

Datum errors always occur, to overcome this; a fresh topo-bathy-hydraulic survey of the dam area is needed. As long as all levels are tied up to the same benchmark, the dam design will be all right. The crest level of the dam in relation with the high water levels will be correct. The dam height and volumes are correct. Only all dam levels contain the datum error of the used benchmark

To overcome datum uncertainties the water level predictions, needed for appropriate timing of the works, should be based on fresh water level data collected in the dam area.
This will lead to encountering the wrong conditions during closure and will generate further delays when conditions (weather, waves, currents) deteriorate in the pre-monsoon (April/May).

The lack of maintenance is an ongoing problem. However, it may be expected that the amount of annual maintenance work is decreasing as initial deformations due to subsidence and consolidation will decrease and siltation will increase, by which the dam will become better protected against wave action. Monitoring during the first year and providing then the required maintenance should be made part of the implementation contract.

Accretion implies creating new farmland and ownership related issues, which often sparked social unrest. To prevent this, solutions can be found in the experiences of previous reclamation related projects as LRP, CDSP, MES and EDP.
The Bay of Bengal is infamous for the severe tropical cyclones, which enter the bay from the Indian Ocean and hit the chars and dams before running ashore. The cyclones occur in the pre- and post-monsoon, viz. April/May and October/November respectively. Therefore the dam needs to be completed by March.

The dam is used by the local people to reach the nearest cyclone shelter. In the context of this risk analysis the main questions are:

- what is the chance a cyclone hit the dam?
- what is the chance the dam survives a cyclone?

From the above considerations it is concluded that most errors can be avoided or it is at least possible to minimize the negative consequences.

4.10.3 Storm Surges

A cyclone entering the Bay has a heavy impact on the local conditions. Besides the high wind velocities, heavy rain and low air pressure, a so-called ‘storm surge’ is generated. The storm surge is the water level rise due to storm and low pressure, which travels in the footprint of the cyclone. So it is in fact a kind of long wave running with the cyclone over chars and dams towards the coast. The wave height, deformed by morphological features, will increase towards the coast due decreasing water depths, and will damp by mangroves, etc. The wave height can be considerable up to 4 to 7meter is reported. The surge is considered to be the main reason for the tremendous damage a cyclone can give. About 90% of the casualties are attributed to the storm surge.

Unfortunately not much is known about the shape of the storm surge. The propagation of the surge equals probably the propagation of the cyclone. Especially the speed of the landfall is of interest. In general a cyclone will pass an area (e.g. a char) in hours not in days. This is also confirmed by observations that damage is considerably less when the landfall coincides with low water. So the surge comes fast and the wave length is probably a few hours only. However, after the landfall the surge runs inshore and there the high waters remain much longer, as it takes time (perhaps days) for the huge volumes of water to retreat. From these considerations a shape of the storm surge can be estimated. Especially the steepness of the wave front determines the hydraulic load when the surge hits a dam. The worst case is when the surge gets a steep front, breaks and rolls like a tsunami over the dam and chars.

The frequency of the severe cyclones entering the Bay is 0 to 4 per year. On average perhaps 2, according to the Bay of Bengal Pilot. About 2/3 of the cyclones hit the coast between Noakhali and Cox's Bazar. Statistics indicate that less than 10% of the cyclones hit the Barisal-Patuakhali coast, say on average once in 5 years. From some of these cyclones the max height of the storm surge has been published (the highest recorded surge near Barisal occurred in 1973 and amounted to 4.55meter). The way and place of this observation is not known, so it is difficult to 'translate' this height to the dam site. As a first guess it is assumed that for a wave height of 4 to 5meter ashore a wave height on deep water in the Bay will be in the order of 0.5 to 1meter growing to 1 to 2meter when hitting the first chars.

25 May 2009 the cyclone Aila hits the coast of Bangladesh and West Bengal over an unusual wide front. Damages were reported from Noakhali to Khulna to Kolkata.

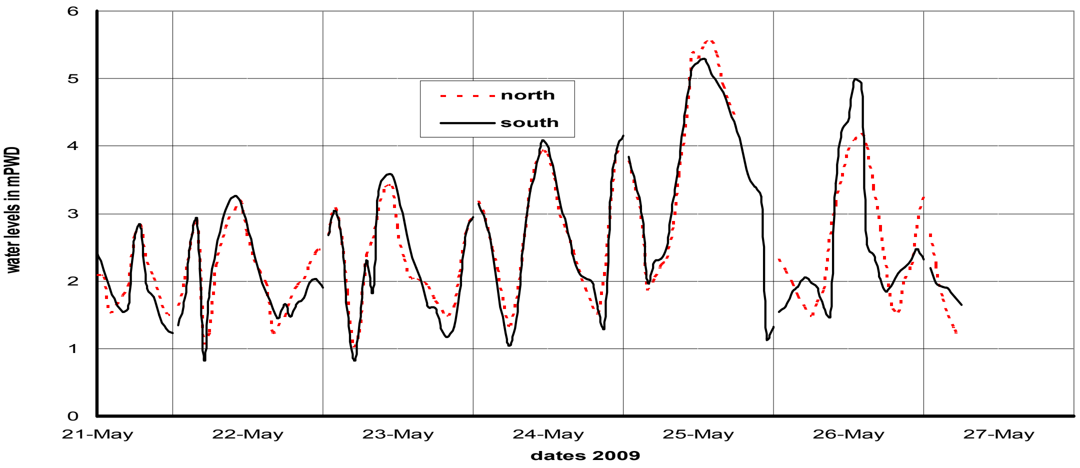


Figure 4.38: Cyclone Aila in Bestin Channel

Water level readings at both ends of the Bestin Channel continued during the cyclone; see the storm surge on 25 May, 2009. The max water levels recorded were 5.5 meter PWD which is about 2 meter above the normal spring tide levels. Interestingly the graphs show already a considerable rise of the high waters one day before the storm surge passed the project area. Also a steep wave front seems visible over about half the wave height, but that could be a reading error.

Another aspect is that most cyclones crossing the Bay area are coming from the south-west. The dam site seems to be ‘protected’ in the south and east by Char Montaz. It means that the surge has to cross (part of) the char before reaching the dam site. In case of Aila this aspect is not clear.

As a worst case (perhaps once in a century) it is assumed that a surge with height of 2meter and a steep front will hit the dam during high water. So the floodplains are flooded and the water level is about 3.5 meter PWD, which is 1.5meter below the dam crest level. When the wave hits the dam it will be partly reflected. If it were a pure long wave, the wave height would double in front of the dam and would become 3.5meter (with levels of 7 meter PWD). Due to reduced reflection the water levels rises to say 6 - 6.5 meter PWD, the closure will be flooded. Initially there will be an overflow with a hydraulic head of 1.5m and critical velocities of more than 3 meter/second. Gradually the water levels will fall, the overflow velocities will decrease and a few hours later the floodplains are dry again.

In this scenario the cross dam may be endangered by two phenomena.

1. The hydraulic load on the dam will be considerable at the moment the surge hits the dam. The dynamic horizontal force will tend to shift the closure.
2. The high overflow velocities will scour the dam rapidly.

First rough computations reveal that the first phenomenon is unlikely, as the maximum impact is only possible when the propagation speed of a steep surge front is high enough (e.g. > 7 meter/second). So the dam will most probably survive the dynamic impact of the surge front, however, the overflow starts damaging the dam. The flow will erode the downstream unprotected part of the slope of the dam .The scour hole will ‘travel’ in upstream direction, which is going fast, also because the dam is made of highly erodible material. First order computations indicate that under these conditions it is quite possible that a section of the closure and especially the unprotected parts (the approach dams) will be washed away before the water levels fall below dam crest level.

The preliminary conclusion is that in extreme cyclone conditions the dam (especially the unprotected approach dams) may seriously be damaged, but chances are too low to take extra protective measures.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions of the Study

The conclusions of the present study are the following:

1. In study find out that Zone of tidal meeting point 2.097 km to 3.197 km (during neap high and low tide) from west point of Montaz Channel and 1.054 km to 2.293 km (during neap high and low tide) from west point of Mainka Channel.

2. It has concluded that the closure in the Mainka Channel along cross-section 16 which is located at 1.6 kilometer from the Western channel entrance and 3.4 kilometer from the Eastern entrance of the closure site. On the other hand the closure in the Montaz Channel along cross-section 25 may be selected which is located at 2.5 kilometer from the western channel entrance and 2 kilometer from the eastern end of the channel.

3. The maximum and minimum design water level was calculated and got 3.5meter and -0.80meter respectively. But during construction the maximum and minimum water will be varied.

4. Most critical during the construction of the cross-dams is obviously the final closure to be implemented during the neap tides of February. It is envisaged to execute final closures in three days from 13-15 February and from 27 February-1March.

5. The maximum discharges of Montaz channels are 425 cum/see on 28/12/09 and 700 cum/see on 2/1/10 respectively. Similarly the maximum discharges of Mainka channels are 775 cum/see on 29/12/09 and 600 cum/see on 3/1/10 respectively.

6. The critical velocities during final closure (gap considered 100m) are 1.2 m/sec in the Mainka Channel and 1.4 m/sec in the Montaz Channel.

7. The conclusions on the main morphological developments observed in the period from 1973 to 2008 are presented this study. The planform of the chars and channels in the cross dam area has changed significantly during the period from 1984 to 1996.

8. The acceleration of accretion in the estuary area, it can be observed that construction of proposed cross dam over Char Mainka and Char Montaz will extend the Bhola island up to south of Char Montaz as well as Char Montaz will be connected to the main land of Bhola.

9. BWDB already closed the Montaz channel in the last year and used sand filled synthetic bags as a core material but in this study recommended the hydraulic sand filled geo-tube.

5.2 Recommendations of the Study

The following recommendations have been made based on the present study:

1. Though the closure over Montaz Channel already constructed, so the remaining closure over Manika channel may be constructed for land reclamation as well as connecting the isolated Dwip Char Montaz under Patuakhali to the main land Char Mainka under Bhola.
2. Conduct close monitoring during construction of the cross dams to observe the exact placement of underwater gunny bags, identification of any uncovered area, movement of any thalweg line and any adverse morphological changes shall have to be continued before, during and after construction.
3. Special emphasis should be given in maintaining geo-tubes specifications for volume of hydraulic fill, fineness modulus value of sand to be used, jointing or stitching quality, proper dumping /placing activities.
4. A monitoring to be established during execution of the cross dams to tackle any adverse situation that may arise and to immediately address it by adaptive approaches. The cell will maintain close liaison with the local execution authority.
5. It is also recommended the new procedure for construction of coastal cross dam which is much better and economic as well as time consuming than the procedure of previous cross dams constructed of coastal areas in Bangladesh. The procedure is using Geo-tube in place of gunny bags.

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