CHAPTER 5

PLANNING OPTIONS AND SCENARIO

5.1 Planning Units

For comprehensive regional planning, the whole NW region has been divided into fifteen planning units based on the geographical and hydraulic characteristics as shown in Figure 5.1 and summarized below ;

No.	Planning Unit Name	Gross Area (ha)	Sub-unit
1.	Thakurgaon	421,312	-
2.	Upper Atrai	189,553	-
3.	Teesta Right Bank	131,732	-
4.	Teesta Left Bank	94,036	-
5.	Kurigram	166,612	Kurigram North, Kurigram South
6.	Upper Karatoya	379,803	-
7.	Gaibandha	73,034	-
8.	Middle Bangali	225,431	-
9.	Joypurhat	250,955	Little Jamuna Right & Left
10.	Barind Tract	268,532	-
11.	Mohananda Basin	138,834	Upper & Lower Basins
12.	Atrai Left Bank	201,866	Naogoan Polder, Bogra Polder 2,3,4
13.	Atrai Right Bank	300,649	Chalan Beel Polder A,B,C,D
14.	Lower Bangali	181,874	SIRDP, Hurasagar
15.	Pabna	215,000	-

Planning unit 1 (Thakurgaon) has its own drainage basin extending to India. Hence, the improvement of the area may have the direct impact to India since the downstream reach of the Tangon, the major river in the area, again flows into India across the international border.

Planning unit 2 (Upper Atrai) has rather wide drainage basin in India and is directly influenced by the flooding situation in India in terms of flood control. Thus, the improvement of the area may have the direct impact to India since the downstream area belongs to India. The area of this unit is characterized by the rather steep land slope as compared with the downstream areas of the NW region.

Planning unit 3 (Teesta Right Bank) is the area located the most upstream of the internal rivers originated in the NW region and have no drainage basin extending to India from the hydrological point of view. Accordingly, there would not take place any flooding problem which has an adverse effect on the India territory regarding flood control. Due to the frequent breaches of the Teesta Right Embankment (TRE), on the other hand, the area as well as the adjacent and southern areas have suffered the habitual flooding damage. Therefore, the improvement of the area will not have any adverse effect to downstream areas and moreover will contribute to the alleviation of the flooding damages in the adjacent and southern areas of the unit.

Planning unit 4 (Teesta Left Bank) has a linkage with wide drainage basin in India from the hydrological point of view. The area is bounded on the south by the Teesta river, on the other hand the improvement of the area will not have any adverse effect to other areas.

Planning unit 5 (Kurigram) has the same characteristics with the Planning unit 4. The area is bounded by such major rivers in the NW region as the Teesta, Darlah and Brahmaputra.

Planning unit 6 (Upper Karatoya) has the linkage with a small drainage basin in India but the rainfall runoff taking place in the area is drained through the Bangali river. Therefore, the improvement of the area may have adverse effect to the downstream areas.

Planning unit 7 (Gaibandah) is bounded by the Teesta, Brahmaputra and Ghagot, and has the downstream area that is influenced by the flooding situation of the area.

Planning unit 8 (Middle Bangali) has an influence on the downstream areas concerning the flooding conditions. The area is not affected by the backwater of the Brahmaputra through the Hurasagar and Lower Bangali.

Planning unit 9 (Joypurhat) is the area just upstream of the Atrai Left Bank and outside the backwater area from the Brahmaputra but the improvement of the area may affect the downstream area where serious flooding is taking place.

Planning unit 10 (Barind Tract) is a rather high land and not affected by other areas. In adition, it basically does not suffer flooding problem.

Planning unit 11 (Mohananda Basin) is linked with a wide drainage basin in India from the hydrological aspect and much affected by the flooding situation in India. Since the downstream reach outfalls to the Ganges, the improvement of the area will not have any adverse effect to other areas.

Planning unit 12 (Atrai Left Bank) is of very low-lying area and the improvement of upstream or adjacent areas may affect the planning unit area in view of rise in the flood water levels.

Planning unit 13 (Atrai Right Bank) is also of very low-lying area and the improvement of upstream or adjacent areas may affect the planning unit area as well as the aforesaid Atrai Left Bank.

Planning unit 14 (Lower Bangali) is also of very low-lying area and much affected by the backwater of the Brahmaputra.

Planning unit 15 (Pabna) can be categorized independent area with little inter-relation with the flooding situation in other areas owing to the successful completion of the FCD components and the further developments planned. It is not basically affected by the improvement of the other areas.

Among the above planning units, planning units 8 (Middle Bangali), 12 (Atrai Left Bank), 13 (Atrai Right Bank) and 14 (Lower Bangali) are covered by the sub-regional hydrodynamic model used by the NWRS study team.

Flooding and drainage problems in the region and conceivable structural measures against them are categorized by the planning units as tabulated in the following page;

Planning Unit No.	Name of Planing Unit	Major Causes of Flooding	Conceivable structural measures
1 & 2	Thakurgaon & Upper Atrai	Flash floods	No option due to border problem except Town Protection Project
3	Teesta Right Bank	Breach of TRE due to bank erosion and its poor quality.	Strengthening of embankment/river training works against bank erosion
4	Teesta Left Bank	Breach of TLE due to bank erosion and its poor quality	Strengthening of embankment/river training works against bank erosion
5	Kurigram	Breach of flood due to bank erosion and/or public-cut	Strengthening of embankment/river training works against bank erosion
6	Upper karatoya	Insufficient conveyance capacity of the rivers	Construction of embankment/Bangali floodway or provision of flood retention area
7	Gaibandha	Breach of BRE/TRE due to bank erosion, insufficient conveyance capacity of the Ghagot and insufficient capacity of Manas drainage regulator.	Strengthening of TRE/river training works against bank erosion/Strengthening of Ghagot embankment/new Manas drainage regulator.
8	Middle Bangali	Breach of Brahmaputra embankment and insufficient conveyance capacity of Bangali.	Bangali floodway.
9	Joypurhat	Insufficient conveyance capacity of Little Jamuna upstream of Badalgachi	Extension of embankment upstream of Badalgachi town.
10	Barind Tract	No flooding problem except that in relation to the flooding in the Shib river	To be covered by those in Lower Atrai.
11	Mahananda	Prolonged inundation due to high backwater stage of the Ganges and insufficient conveyance capacity of the Mahananda and Pagla.	Construction of embankment along the Mahananda and Pagla.
12	Atrai Left Bank	Prolonged inundation due to high back water stage with long duration of the Brahmaputra and insufficient conveyance capacity of river channels.	Construction of embankment for CFD area and/or provision of flow area for Green River.
13	Atrai Right Bank	Prolonged inundation due to high back water stage with long duration of the Brahmaputra.	Construction of embankment for CFD area, overflow weir and dwarf embankment for Green River, and drainage path
14	Lower Bangali	Breach of BRE due to bank erosion, breach in the embankment of Hurasagar, Bangali, and public cut of SIRDP west embankment.	Strengthening of BRE and construction of embankment for CFD area and provision of flow area for Green River in southern areas of Hurasagar and SIRDP project areas.
15	Pabna		Pabna Phase II Project proposal

5.2 Planning Condition

For the purpose of formulating the comprehensive FCD plan in the north west region(NWR), the following are taken into consideration as the planning condition:

a) National border: The NWR is bordered on the north and west by India and bounded on the east by the Brahmaputra and on the south by the Ganges. But the perennial rivers in the NWR come from India and accordingly the drainage basins of the rivers extend to India. In other words, the hydrological boundary is not coincident with the national border. Therefore the flooding situation in the NWR is partially much affected by that in India.

In general, the comprehensive flood control plan is formulated for the whole drainage basin and river system. Since any information and data are not available concerning the FCD works on-going and planned in their upstream reaches in India, those FCD plans outside Bangladesh are not incorporated in making the regional plan for NWR.

b) The Brahmaputra river: There are many breaches in the existing Brahmaputra right embankment (BRE). But sealing of the BRE is taken as a given condition in formulation of the regional plan of NWR since the rehabilitation of the breaches as well as the construction of setback embankment is being implemented even though the quality of the embankment is still insufficient from the engineering point of view.

On the other hand, there is no flood embankment on the left bank of the Brahmaputra (BLE). Even though provision of BLE is determined in near future, it is estimated that it will take quite long time until sealing of the Brahmaputra left bank is completed. Therefore the formulation of regional plan is made on the present without BLE condition.

The Jamuna Bridge over the Brahmaputra is now at the stage of completion of prequalification of the tenderers for construction. Flood water levels of the Brahmaputra would rise to some extent if the bridge is completed. But in consideration of the time span that takes until its completion due to its huge amount of construction cost, and necessity of development of the hydrodynamic model of the river in the course of the time, the bridge construction is not considered in the present regional planning.

c) Impact to other area: Scenarios proposed for other units or areas in the regional planning are taken as given conditions in considering the impact or influence to the area under consideration. On the other hand, there is a possibility that the improvement of the flooding situation in certain area has negative impact on adjacent or downstream areas. Basic policy for formulating the regional planning is that such an improvement of certain area never incurs adverse effect to other or adjacent areas concerning the flooding situation. If it is clear that some development scenario of certain area may incur adverse effect to other area, the countermesure is necessarily included in the scenario.

5.3 Planning Units No. 1 and 2: Thankurgaon and Upper Atrai

5.3.1 Flooding Situation

These Planning Units are located in the most northwestern part of the NW region, comprising the entire area of Greater Dinajpur and the western part of the Rangpur district. The railway line which passes from Joypurhat to Nilphamari and across the national border constitutes the eastern boundary. The location of these Planning Units is shown in Figure 5.2. The Dinajpur, Panchagarh and Thakurgaon area covered by these Planning Units is one of the highest land areas in this country. The gross area is 610,865 ha. The topography of the area is relatively steep with ground elevation varying from 31m to 91m above mean sea level. The land generally sloped to the southeast at a rate of about 1 metre per kilometre.

The Atrai river is the main river whilst the Karatoya-Atrai is a tributary of the Atrai river. The river Atrai and Karatoya-Atrai are perennial rivers in their upper reaches. The river Dhepa is a distributary of the Atrai which joins the Punarbhaba river at Phulhat. The Atrai bifurcates at Bhushirbandar into the Atrai and Kakra rivers, which join again at Shamjiaghat. The river Tangon originates in India and flows through Thakurgaon ultimately meeting the Mahananda river.

The area is climatically somewhat different from the other parts of the NW region having relatively cold winter season although the monsoon season is characterised by very intensive rainfall. The main climatological factor which influences flooding in the area is rainfall. The average annual rainfall varies between 1,700mm and 2,800mm. A low annual rainfall of 862mm occurred in 1972, whilst in 1987 the annual total amounted to about 3,000mm. The peak monthly rainfall reaches 1,000mm which is one of the causes of flooding resulting in crop and infrastructural damages. Such unusual monthly rainfall took place in Dinajpur in 1974, 1979 and 1987.

The main sources of flooding in the area are torrential rainfall and flash flood flow from the upper reaches in India. In this area, flooding generally takes place in a form of flash flood with a relatively short duration. These flash flood tends to cause the spillage flow which leads to the damage both to crops and infrastructures. Since the duration of inundation is short, however, the agricultural damage due to crop submergence is generally seen in the lower land.

According to the Thana flood phase statistics, there is very little F2 land within the area. Most of the F2 land is located in the most southeastern part of the area, which include the Thanas of Fulbaria, Hakimpur, and Birampur to a lesser extent. The infrastructure damage data on the area indicate that the major flooding problems in this area which result from flash flooding lie along the Dhepa and Punarbhaba rivers. The worst flooded zone lies between the Bushirbandar-Shamjiaghat and Thakurgaon-Dinajpur roads in the west. The flooding tends to be more severe in the southern part of the area. It is caused mainly by the flood flows in the Atrai and Kakra rivers.

The comparatively moderate flooding also occurs in Dinajpur town area extending along the river Punarbhaba. The flooding of short duration was also reported to occur in area from Panchagarh to Ghoramaraghat, which exists along the upper Atrai just downstream of the international boarder with India. Further west, the damage along the Tangon is relatively minor, indicating that this river is not susceptible to flash flood.

There are problems of river bank erosion at Dinajpur and Panchagarh towns. Dinajpur town is under the active threat from the river Punarbhaba whilst Panchagarh town is being threatened by the bank erosion of the river Karatoya. A part of the Dinajpur town area has already been washed away by the river bank erosion and the existing road bridge is under threat. Panchagarh town is also under threat due to bank erosion of the Karatoya and a part of the town has been already lost.

These erosion problems are to be dealt with by the Town Protection Project by FAP 9. FAP 9A has proposed an integrated plan for flood control, drainage and river training. The proposed scheme involves construction of flood embankment along the Karatoya, drainage improvement and construction of river training works. At Dinajpur, embankment construction started in 1968. There was a major breach in 1974 which was followed by subsequent embankment construction in 1975 by BWDB. Embankment construction at Panchagarh has been less extensive.

The major issue in planning the flood control works for this area is cross-border flow, both from India through the upstream Atrai as well as spills from the upstream Teesta, and to India through the downstream reach of the Punarbhaba and Atrai. It is therefore considered that in general major structural works are not appropriate at present, taking into account the unknown flood control plans in the upstream reaches in India as well as the infavourable increase of cross-border flow in the downstream reach in India and the further downstream one of the Atrai where it reenters Bangladesh.

5.3.2 Tangon River

(1) Hydrological and hydraulic situation

On the Tangon river, there are gauging stations at Thakurgaon and Kodalkatigaon, and three river cross-sections are available in the reach between the two stations. Discharge data at Thakurgaon are available between 1964 and 1988 with some interruption. The rainfall-runoff of basin-15 by NAM Model gives discharge hygrograph at Thakurgaon. Since the relation between peak discharges by these two discharge hygrographs for the period shows a good correlation, probable flood peak discharges at Thakurgaon are calculated based on the peak flows by NAM Model because NAM Model gives the continuous discharge hygrograph from 1965 to 1989. As a result of the frequency analysis for the annual maximum peack discharges, the probable 20-year flood peak at Thakurgaon is derived to be around 370 m³/sec as follows:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	210	279	325	369

Discharge data at Kodalkatigaon are available for the period from 1973 to 1989 with some lack of data. The rainfall-runoff of basin-15 and basin-23 by NAM Model also gives discharge hygrograph at Kodalkatigaon. These two discharge data show a good correlation. The probable 20-year flood peak at Kodalkatigaon is calculated to be about 900 m³/sec based on generated discharge hygrograph by NAM Model as follows:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	414	594	734	893

(2) Development scenario

The relations between flood peaks for 1 in 20 year return period and the present conveyance capacities of the Tangon are shown in Figure 5.2. It shows that the Tangon has, as a whole, enough conveyance capacity except in some short reaches near Thakurgaon town. This corresponds to the field information obtained by the study team that some flooding in Thakurgaon take place in 1987. It also implies that the local flood protection for Thakurgaon town, which is now being studied by FAP 9, would not cause substantial adverse effect to the downstream reaches including those in India.

5.3.3 Upper Atrai

(1) Hydrological and hydraulic situation

On the Dehpa river there are two gauging stations, namely; at Kantanagar and Phulhat just upstream of a border with India along the Punarbhaba. On the Atrai river there is a gauging station at Bushirbandar about 10 km downstream of diversion point of the Dehpa.

a) Kantanagar

Discharge data at Kantanagar are available for the period from 1964 to 1979 with the interruption of one year. On the other hand, it is judged through cross-checking of the discharge data that NAM Model do not give good simulated hygrograph at Kantanagar, presumably because the discharge at Kantanagar mainly consists of diversion flow from the Atrai. Accordingly, the probable peak

discharges at Kantanagar are calculated based on the observed data thereat. Through the frequency analysis, the probable 20-year flood peak discharge at Kantanagar on the Depha river is estimated to be around 1,530 m^3/sec as shown below:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	750	1,088	1,312	1,527

b) Phulhat

The Phulhat gauging station is located just downstream of Dinajpur town, far downstream of the Kantanagar station and upstream of the international border with India. Since no discharge data are available thereat, discharge hygrographs at Phulhat are generated by adding the runoff of the basin-16 by NAM Model as the residual runoff to the discharge hygrograph at Kantanagar. Analysis of probable peak discharges at Phulhat is made based on the discharge hygrographs thus generated. Consequently, the probable 20 year flood peak at Depha on the Punarbhaba river is estimated at about 1,800 m3/s as shown below:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	972	1,330	1,567	1,795

c) Bushirbandar

The Bushirbandar gauging station is located on the Atrai, downstream of diversion point of the Depha. Discharge data at Bushirbandar are available for the period from 1964 to 1989 with much interruption. Though the discharge at Bushirbandar is much influenced by the flooding situation in India and diversion flow of the Depha, the relation between discharge at Bushirbandar and rainfall-runoff of basin-2 by NAM Model shows a good correlation. Accordingly, the probable peak discharges at Phulhat are calculated based on the NAM Model results since the model gives the longer discharge data covering a period of 1965 to 1989. Consequently, the probable 20-year peak discharge at Bushirbandar on the Atrai is estimated at about 2,160 m3/sec as shown below:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	1,161	1,529	1,820	2,154

d) Sjamjaghat

The Sjamjaghat gauging station is located on the Atrai just upstream of the border with India. Since no discharge data are available thereat, the discharge data at Sjamjaghat are generated by adding the rainfall-runoff of basin-17 of NAM Model as the residual runoff to those at Bushirbandar, derived above. Consequently, the probable 20-year flood at Sjamjaghat on the Atrai is estimated at about 2,430 m3/sec as follows:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	1,285	1,701	2,033	2,430

The present river conveyance capacities of the Atrai, Dehpa and Punarbhaba in the planning units 1 and 2 are calculated as shown in Figure 5.3. The relationship between the probable 20-year floods and present conveyance capacities of the rivers is shown in Figure 5.3, which reveals that the present river conveyance capacities are far less than the 20-year probable flood discharges.

(2) Development proposal

Flooding in the area along the uppermost reaches of the Karatoya is influenced by the situation in the upstream reaches in India as aforesaid. However, the information on the flooding situation of the reaches and the future flood control plans in those reaches in India are not available at present. As such being, the accurate estimate of the design discharge (20-year return period) in these reaches which takes into account the future development in the upper reaches is practically difficult. It is considered that it will take time in order to settle the issues of TRE sealing and flood control in upper reaches in India. Accordingly in consideration of past history on flood damage around these reaches and the effect of improvement of these reaches to downstream reaches in the Dinajpur area where people have been suffering comparatively more serious damage, it would be practical to leave these reaches as they are.

Figure 5.3 implies that full confinement of river in the southern part of this unit to cope with the probable 20-year flood would cause significant impacts to the downstream reaches in the Indian area. Besides there is no beel suitable for flood retention in this area. Therefore, provision of flood retention area is also difficult. In the reaches of the Punarbhaba inside India downstream of this area, there is a wide beel area where the river forms the international border. These beels act as a natural storage basin. Increasing flow in the Punarbhaba would therefore not cause detrimental effects from the region-wide point of view, although in principle increase of flood flows in the downstream reaches is undesirable. Consideration could therefore be given to diverting some Atrai flows down the Punarbhaba.

Although the probable 20-year flood exceeds the present river conveyance capacity as aforesaid, however, the duration of the exceedance is only a few days, resulting in rather small crop damage. In view thereof as well as the adverse affect due to increase of the cross-border flow, it is suggested that no measures be urgently implemented. Moreover it is recommended that any substantial flood protection project in this basin should not be implemented without joint work of flood control with India. Figure 5.3 also shows that the present conveyance capacities almost cover the 5-year probable flood peak and that Town Protection Project under FAP-9A would not cause any substantial adverse effect to the downstream reaches including those in India.

5.3.4 Ichamati Jamuna and Kharkharia

(1) Hydrological and hydraulic situation

The confluence of the Little Jamuna and the Kharkharia is called Phulbari but discharge data are not available at this site. Rainfall-runoff of basin-3 by NAM Model gives discharge data at Phulbari. Accordingly probable peak flows of at Phulbari are calculated based on the generated discharges by the Model. Consequently, the probable 20-year flood peak at Kharkharia is estimated at about 230 m3/sec as follows:

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	108	155	188	229

(2) Development proposal

The present river conveyance capacity is estimated to be around 260 m3/sec through the hydraulic calculation, which exceeds the probable 20-year flood peak at this point. Accordingly, any flood control works are not proposed for this basin.

5.4 Planning Unit No.3 : Teesta Right Bank

5.4.1 Flooding situation

The planning unit covering a gross area of 131,732 ha consists of parts of Nilphamari and Rangpur districts and Kaliganj and Lalmonirhat Thanas of Lalmonirhat district. The eastern boundary of this area is the Teesta river and the Kaliganj-Pirgacha railway. The west boundary is the Ghaghot river, the Mohadevpur-Jaldhaka road and the Buri Teesta river. The area lies within the physiographic unit - the Teesta Flood Plain. The Teesta and Buri Teesta are the major rivers in the area. The location of the planning unit is shown in Figure 5.4.

The Teesta right embankment project is a completed CFD scheme for protecting the right bank area from flooding. The flood embankment of 26.4 km in length and a regulator have been constructed. However, the problems of flooding and drainage in this area are mainly due to spillage of the Teesta flood water. Spillage of the Teesta is mainly due to embankment failure caused by the severe bank erosion along TRE. In recent years, erosion on the right bank of the Teesta is very prominent. Most of the Thanas along the right bank of the Teesta are affected by the flood water through the breaches which occurred mainly due to bank erosion.

A devastating flood occurred in the project area in 1987 and 1988 which lasted for about a fortnight and did widespread damage to crops, human lives, livestock, home, household properties, roads, bridges and other public and private properties. At present, the river is still eroding its bank and threatening the embankment along right bank at a number of locations. Massive river training works were executed with groynes in the reaches upstream of the existing Teesta barrage. But in the reaches downstream of the barrage, erosion is seriously taking place. Although some protection measures were taken under BWDB Second Flood Rehabilitation Programme (1988-1990), it appears that the measures are in a limited scale.

The embankment was also washed away during the 1990 flood in a section from Noahali to Paikan under Gangachara Thana. At present, BWDB provides a village road with low crest level as embankments for immediate measure. However, those embankments have less crest width and steeper side slope than the standard design criteria on the flood embankment. The length of breach in this location is about 4 km. During the 1991 flood, farmers are much affected by the overflow from the Teesta river through the breached portion .

5.4.2 Hydrological and hydraulic situation

The hydrological and hydraulic situation of the planning unit has been made clear through the same procedure with that presented in the following Section 5.5 on Teesta Left Embankment. The longitudinal profile is shown in Figure 5.5. The situation is also almost the same as the Teesta Left Embankment but the insufficiency in the height of flood embankment is much less than the left embankment.

5.4.3 Options and development proposal

As presented in the above, required for the Teesta right bank is to stop the spillage of the flood water of the Teesta. The spillage occurs through breaches of the Teesta right embankment. The breaches occur due to bank erosion and insufficiency of the embankment in height and quality. The quality includes the structural dimensions as to side slope, crest width and berm, as well as the construction quality such as the embankment material used, compaction and others.

Strengthening of the Teesta right embankment (TRE) in this planning unit area will not cause any adverse effect to other areas, since the existing breaches in TRE downstream of the unit is also going to be sealed under the Gaibandha Improvement Project (GIP) as explained in the succeeding Section 5.8. Accordingly, the conceivable options in this unit for flood control and drainage are strengthening of the flood embankment and river training works against bank erosion. The river training works are planned applying the same criterial with those designed for GIP. The proposed major works are summarized below and the general layout is shown Figure 5.4.

- Strengthening of embankment from Kaunia to Teesta Barrage (44.00 to 103.25 km)
- Provision of 500m long groyne at an internal of 1 km (for the location of severe bank erosion)
- at Haragacha to Mohipur (59.00 to 63.00 km) : 5 nos
- at Godownerhat (70.00 to 72.00 km) : 3 nos

5.5 Planning Unit No.4 : Teesta Left Bank

5.5.1 Flooding situation

Teesta left bank is located in the most northern part of NWR. The area is bounded on the south and west by the Teesta, on the east by the Kurigram South project area (the existing railway), and on the north by the national border with India. Its location is shown in Figure 5.6. The gross area of this planning unit is 94,036 ha. This area basically consists of the drainage basins of the Sati and the Teesta rivers. But the area also includes the drainage basins of the Bateswari river and the Dorasalu drainage channel. The area is under Lalmonirhat district consisting of three Thanas such as Kaligonj, Aditmari and Lalmonirhat Sadar. This area had been suffering flooding from the Teesta and overland flow from India. The Teesta river is a braided river and transports huge quantities of sediment. Accordingly the area was also suffering sediment deposit in the area.

The Sati Nadi Scheme was planned for flood control and drainage purpose of this area under BWDB, covering an area of 141.64 km2. Then the Teesta left embankment was constructed in 1975 in the reach from Kaligonj to Kaunia without providing any structure at the outfall of the Sati river. But the flood water of the Teesta intrudes into the area in the upstream reaches of Hatibandha to Kaligonj through the openings along the railway line and road that connects Hatibandha and Kaligonj and also through the Sati river by the backwater flow. The area is also suffering from severe erosion by the Teesta. Due to the erosion in the left bank of the Teesta, the Teesta Left Embankment (TLE) in the lower reach from Kalmati to the Sati Nadi outfall has been washed away except only two small pieces of embankment in between, leaving the inland area open against flooding from the Teesta. Thousands of people have become homeless as a result of the severe erosion of the Teesta over this reach.

About seven cross-bars were constructed on the left bank of the Teesta. The cross-bars were either small and inadequate or too weak to withstand the erosive power of the Teesta flow and do not exist any more. Six cross bars located in the downstream part along the TLE were already washed away due to the severe bank erosion of the Teesta river in 1989-90 & 1990-91 flood. At the same time one vent sluice at Kalmati Harinchura was washed away along with the 9 km long embankment. The gate of Chandamari regulator has been lost and the backwater from the Teesta comes into the inland area.

Many water control structures have been constructed along the internal rivers for irrigation purpose and in front of those much sediment deposition is observed. Consequently, the drainage capacities of those internal rivers have been much reduced. The main drainage channels of the Sati and the Dora

are silted up and need desilting or re-excavation. The silt deposition in the channels has created such problems as shortage of surface water for irrigation as well as decreases of flow capacity of the internal rivers.

The damage to the existing CFD structures in the unit is summarized below;

No.	Name/Location	Volume/Length	Present Condition
1	Madhuram Cross Bar (at 47.50 km)	305 m	Washed away
2	Parulia Cross Bar (at 48.50 km)	285 m	Washed away
3	Harinchura Cross Bar (at 50.50 km)	366 m	Washed away
4	Khaniagash Cross Bar (at 52.50 km)	244 m	75% Washed away
5	Kalahati Cross Bar (at 55.500 km)	549 m	Washed away
6	Ghobardhan Cross Bar (at 57.50 km)	415 m	Washed away
7	Harinchura Regulator (at 51.00 km)	1 - 1.52 x 1.83 m	Washed away
8	Candimari Regulator (at 62.25 km)	2 - 1.52 x 1.83 m	Gate leaf was lost
9	Embankment (44.00 - 72.00 km)	27.00 km	7 km Washed away

5.5.2 Hydrological and hydraulic situation

The design flood for the Teesta is adopted to be a flood peak one in 20 year return period. The probable 20-year flood peak of the Teesta at the Kaunia bridge is estimated at 8,710 m3/sec.

Accordingly, the design discharge of the Teesta in the reaches upstream of the Kaunia bridge is determined to be 8,750 m3/sec. The design high water level at the Kaunia bridge site is 30.60 m PWD. Based on these, water level in the upstream reaches of the Kaunia bridge for the discharge of 8,750 m3/sec is been calculated by using non-uniform formula to determine the design high water levels. The design crest levels of the flood embankments are calculated by adding a freeboard of 1.52 m to the calculated design high water levels. These design crest levels of the flood embankment are shown in Figure 5.7 together with the present crest and bank levels in the reaches. The Figure shows that the present crest levels of the flood embankment are not high enough for the design ones in the whole reaches.

5.5.3 Options

The existing flood embankment along the TRE needs to be constructed, heightened. Likewise, river training works against the bank erosion are also needed. The two options are conceived concerning the treatment of the outfall of the Sati stream to the Teesta. One is to keep it open and construct backwater embankment along the Sati stream. The other is to close the outfall of the Sati to the Teesta through provision of new drainage regulator thereat. The features of those options are presented below:

Option 1 : Full confinement with the backwater embankment along the Sati

Main feature of this option is to provide strengthening of Teesta left embankment and backwater embankment along the Sati against the Teesta flood water. Drainage regulators are also proposed for each sub-basin for the inland drainage purpose. The major works of this option are summarized below;

- Heightening/resectioning of Teesta left embankment from Kaunia to Hatibandha (53.50 km)

- Construction of backwater embankment (25.67 km) along the Sati river
- Construction of drainage regulators near the Sati outfall (5 vent regulator for sub-basin 1 and 15 vents regulator for sub-basin 2)
- Construction of groynes at the location where bank erosion is severe
- Reconstruction of Harinchura regulator (1 vent)
- Repair of Candimari regulator (2 vents)

Option 2 : Full confinement by means of providing the Sati outfall regulator

Main feature of this option is to strengthen the Teesta left embankment as well as the Option-1 above and to provide the Sati outfall regulator to cope with the Teesta high stage and intrusion of sediment. The major works of this option are summarized below;

- Heightening/Re-sectioning of Teesta Left Embankment from Kaunia to Hatibandha (53.50 km)
- Construction of drainage regulators at the Sati outfall (25 vents)
- Construction of groynes at the location where bank erosion is severe
- Reconstruction of Harinchura regulator (1 vent)
- Repair of Candimari regulator (2 vents)

Option 3: Full confinement with the backwater embankment of the Sati without the river training works along the Teesta.

Main feature of this option is the same with the above option 1, but river training works are not included in this option in consideration of the cost constraint.

Out of the aforesaid three options, the Option-3 gives the lowest implementation cost since it excludes the river training works being the most costly among the work items involved in those options. Taking into consideration that the Teesta river tends to shift to the south as a whole, the Option 3 might be satisfactory to cope with the present bank erosion along the left bank. On the other hand, the Option 1 would ensure maintaining the present bank line and it is the most recommendable from the engineering point view. In reality, as long as the spot imageries show, the upstream reach of the Teesta in India is successfully protected with groynes on the both river banks. Although the further studies are needed to select the best option from among the three Options, the Option-1 is preliminarily proposed for the planning unit in consideration of the uncertainty in the Option-3

5.5.4 Development Proposal

The option 1 is adopted as the development proposal of this planning unit. General layout of proposed works is shown in Figure 5.6. The work components are as listed above.

5.6 Planning Unit No. 5 - Kurigram

5.6.1 Flooding Situation

This area consists of the Kurigram district and Lalmonirhat Thana of the Lalmonirhat district. The area is bounded on the north by the international border with India, on the south by the Teesta, on the east by the Brahmaputra and on the west by the Kaunia-Lalmonirhat railway. The Dharla and Dudhkumar are major rivers which drain the area. The upstream catchment area of these rivers however extend into the Indian territory. Its location is shown in Figure 5.8.

The Planning Unit covering an area of 166,612 ha is divided into two sub-units; namely: the north unit (North Kurigram) and the south unit (South Kurigram). The annual rainfall in the north unit falls between around 1,600 and 4,000 mm in these 30 years, while that in the south unit between around 900 and 4,900 mm.

Since most land is of highland or medium-highland, the internal flooding is not a major problem in the normal years. However, since the area is bounded by the major rivers such as the Brahmaputra, Teesta and Dudkumar, the flooding becomes serious when the stages of such major river rise as experienced in the 1987 and 1988 floods. In 1987 there took place serious damage to flood control and drainage facilities. Those were significantly in the Brahmaputra right embankment, particularly between the outfalls of the Dharla and Dudkumar to the Brahmaputra. The damage also occurred in the flood embankment along the Dharla.

In 1988, the extensive damage caused in the flood embankments along the major rivers, particularly along the Dharla near Kurigram town. The damage to minor structures in 1988 spread throughout the area. In addition, the existing infrastructure such as roads and bridges were also very seriously damaged by the 1988 flood. The Ratnai regulator in the northern part of the area along the Dharla river was damaged due to the 1988 flood. Since then flood flow of the Dharla river has intruded into the area causing damage.

It is reported that inland water accumulating in the southern part of the area overtopped the flood embankment from the inland side due to deterioration of Harichai regulator. It is reported that, this is partly because the insufficient flow capacity of the inland drainage channel outfalling to the Brahmaputra through the Chilmari regulator decreased due to sedimentation in the channel. In addition, the Planning unit suffers serious erosion on the right bank of the Dharla and Brahmaputra as well as on the left bank of the Teesta. Erosion is the main cause of breaches of the flood embankment.

The area also suffers drainage congestion due to long-lasting high river stages during the monsoon season as well as the insufficient carrying capacities of drainage channel, especially in the southern part. The drainage capacities of the present regulators in the area are assessed to be insufficient. The river bank erosion, breaches in the flood embankment provided along the major rivers and spills from the major rivers are the major problems in the planning unit. These problems are recognized particularly round Kurigram town.

5.6.2 Options

The north and south units are delineated by the Dharla river, which flows from east to west. Due to the geographical conditions, the full confinement of this planning unit will not cause any adverse effect to other areas in terms of flood discharge or river stage.

Concerning the issues related to the cross-border flow from India, the basic policy for comprehensive flood control of the whole river system is recommended to be established through the joint works between Bangladesh and India, since construction of the flood wall or diversion channel along the national border as the tentative measure to solve the flooding problem due to overland flow would result in the waste of the national resources or will create a political issue.

Regarding the drainage congestion, rehabilitation and/or new construction of drainage regulators and reexcavation of main drainage channel are the conceivable options. To cope with the breaches and deterioration of flood embankment as well as the severe bank erosion being the main cause of the

breaches, the following alternatives measures are conceivable:

- setback embankment
- river training works
- rehabilitation of existing embankment

5.6.3 Development Proposal

Flood control and drainage schemes for this unit have been so far implemented but there are still a lot of flooding problems to be solved. Since the both sub-units have been or being studied at the feasibility study level, the further study on the Planning unit is not carried out in the present regional planning. The both studies are to be finalised taking into account the aforesaid flooding problems and measure, even though the FCD components are not included in those projects.

5.6.4 Features of the Past and On-going Schemes

A feasibility study for the whole Planning unit area was completed in 1969 and implementation of the flood embankment as well as other related works were commenced in 1973. At present, those works have been mostly completed.

After then, a feasibility study for the North Kurigram Unit was commissioned by JICA and the report was completed in October 1990. This project is awaiting implementation. The proposed development covers a gross area of 42,800 ha and a cultivable area of 35,100 ha. The project aims to increase productivity by improving drainage, but in particular increasing irrigation. It also includes road network improvement and agricultural storage and support services strengthening. Approximately 80 % of the main river embankment in the Kurigram North unit area is already completed. The 1990 report proposed completion of the remainder, together with necessary repairs to the existing embankment, and drainage pumping at the tail section. Irrigation water is to be supplied mainly from the Dudhkumar (the Dharla being committed for Kurigram South Unit). Two pump stations are proposed of capacity of 42 and 5 m3/s, the downstream one being reversible.

In 1991, a feasibility study for the South Kurigram unit was started by JICA independently and is scheduled to be completed in 1993. In March 1992, the progress report No.1 on the study was issued by the study team. According to the report, most of the CFD facilities were completed during 1973-1984 based on the F/S carried out in 1969/71, and the existing flood embankment is functioning, though some rehabilitation works are required. The report proposes some alternatives on flood control component, drainage improvement component and irrigation development component. Alternatives on flood control component are, 1) rehabilitation of existing embankment and 2) river protection works. Alternatives on drainage improvement are, 1) improvement of major drainage system, 2) improvement of minor drainage systems, 3) construction of a new Ratnai drainage canal and 4) rehabilitation of existing regulators. Alternatives on irrigation development are, 1) construction of headworks and irrigation canal system, 2) small scale groundwater development for irrigation and 3) command area development. The basic concepts on CFD are, 1) only rehabilitation works of the existing CFD facilities are mainly considered, because the large scale river protection works are not economically feasible, 2) drainage congestion should be improved as much as possible to the extent that the investment can be justifiable.

In October 1992, the progress report No.2 was issued. According to the report, the basic strategy on flood control and drainage is that flood control component be concentrated on upgrading and

rehabilitation works of the existing flood protection facilities, including the bank protection works at the intake site. The drainage improvement is planned to be made by gravity drainage system in principle, while drainage networks by provision of desilting works of the existing channels and beels. The work components proposed in the report are 1)rehabilitation of flood embankment for about 1 km, 2)bank protection works for about 1 km in reaches upstream and downstream of proposed structures, 3)construction of diversion channel of the Ratnai river for about 3.5 km, 4)rehabilitation of drainage regulators of 2 nos, 5)desilting works of the existing drainage channels for 19 km, 6)erosion protection works at 3 sites where serious erosion is expected to occur.

Kurigram town is located on the right bank of the Dharla. Town Protection Project of Kurigram was under construction by local authorities in 1991. The right bank of the Dharla in the reaches near the Kurigram town was going to be protected by constructing groyne, revetment works consisting of brick gabions and cut-off channel of low water channel to shift it to the central side in order to avoid the scouring at the foot of bank protection works.

Other than the above, Kurigram town is covered by the Secondary Towns Integrated Flood Protection by FAP 9A. Draft Final Report of FAP 9A has been issued in February 1992. According to the report, the following works are proposed as the CFD components:

- construction of some 1,000 m of bank revetment works
- construction of two new groynes
- extension and rehabilitation of the existing groyne
- partial repairs to the flood embankment
- rehabilitation, enlargement and extension of the surface water drainage system

5.7 Planning Unit No.6 : Upper Karatoya

5.7.1 Hydrological and Hydraulic Situation

The major rivers in this planning unit are the Karatoya, Jamuneswari and Chikli. The Jamuneswari and Chikli are a tributary of the Karatoya. The flooding and drainage problems in the unit are spillage of flood water from the Karatoya. The flooding in the unit is quite extensive in terms of crop damage and human discomfort. Infrastructure damage in 1987 and 1988 appears to be widely distributed throughout the whole planning unit area. Serious flooding occurred during September 1991 when a cut was made on the right bank of the Upper Karatoya at its downstream end to relieve problems upstream. In general, infrastructure and crop damages have been relatively severe in the downstream reaches of the Upper Karatoya.

There is a gauging station at Nijbari on the Chikli. Discharge data at this site are available for the period from 1965 to 1979 with some lack of data. Since NAM Model does not give rainfall-runoff at this site, the probable flood peaks at Nijbari are preliminarely estimated based on the observed discharge data. Through the frequency analysis, the probable 20-year flood peak thereat estemated at about 250 m3/sec as shown below;

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	139	184	214	242

With the same procedure, the probable 20-year flood peak at Baratia on the Jamuneswari is estimated to be about 500 m3/sec based on the discharge data available between 1964 and 1987 with some interruption as follows;

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	263	365	432	497

At the Badarganj gauging station located just downstream of the confluence of the Chikli and Jamuneswari, discharge data are available only for a few years from 1985 to 1989. Rainfall-runoff of basin-1 of NAM Model gives discharge hydrograph at Badarganj but due to the constrains on the data availability, runoff by the model and the discharge data at Baratia and Nijbari are compared with each other in terms of the area ratio. As a result, some modification of the model result for the discharges at Badarganj is made to generate the discharge hydrograph. By using the hydrographs, the probable 20-year flood peak discharge at Badarganj is estimated to be about 1,020 m3/sec as shown below;

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	584	774	899	1,020

Siraj is located in the middle reach of the Upper Karatoya. Discharge data are not available at this site. NAM Model gives rainfall-runoff at this site as the combined one of the runoff of basin-1 and basin-4. By modifying the runoff of basin-1 as mentioned above, discharge hydrograph at Siraj is generated. The frequency analysis is made based on annual maximum peak discharges obtained from the generated hydrograph. Consequently, the probable 20-year flood peak thereat is estimated to be about 1,260 m3/sec as shown below;

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	688	912	1,061	1,254

The Kathakali river is a downstream reach of the Upper Karatoya before joining the Alai river which comes from the GIP area. The discharge hydrographs at the confluence are generated by adding the rainfall runoff of basin-10 by NAM Model multiplied by the area ratio to the generated hydrograph at Siraj. Through the frequency analysis for the annual maximum peak discharges generated, the probable 20-year flood peak thereat is estimated to be around 1,470 m3/sec as shown below;

Return Period (Year)	2	5	10	20
Probable Flood Peak (m3/sec)	789	1,044	1,213	1,465

The probable peak discharges 1 in 20 year return period calculated above and present conveyance capacities of those rivers are shown in Figure 5.10. The Figure reveals that the Jamuneswari and Chikli have enough conveyance capacities against the 20-year probable discharges that are 500 m3/s at Baratia and 250 m3/s at Nijbari. But the Karatoya has much less conveyance capacities in the reaches between Siraj and the confluence with the Alai against the 20-year probable discharges that are 1,260 m3/s at Siraj and 1,470 m3/s at the confluence with the Alai. The conveyance capacities therein are approximated between 790 m3/s and 1,000 m3/s respectively as shown in Figure 5.10.

5.7.2 Options

It is clarified through the preliminary hydrological and hydraulic analyses that the reaches downstream of Siraj has insufficient conveyance capacity against the probable 20-year flood. Accordingly, the

flood control works need to be provided for this reach of the Karatoya. The conceivable options for this reach are summarized below;

- partial protection
- full confinement
- Bangali floodway

(1) Partial protection

This option is to provide the flood retention reservoir in the basin in order to reduce the flood peak up to the present conveyance capacities. For this purpose, generated discharge hydrograph at the confluence with the Alai is examined for estimate of the reservoir scale. The conveyance capacity at the downstream end of the objective reaches is estimated approximately at 790 m3/sec. Accordingly, the flood water in excess of the conveyance capacity needs be retained in the flood retention reservoir. Based on the discharge hydrograph shown in Table 5.1, the volume of the excessive flood water is estimated at 833 million m3. Figure 5.11 shows the longitudinal profile of the Upper Karatoya. Based on the profile, it is estimated that maximum water depth of the flood retention reservoir could be about 2 m. It is assumed that lower part of flood retention reservoir below the ground level is already filled with the antecedent precipitation. Accordingly, the required area of the flood retention is estimated to be about 416.5 km2 (833 million m3 divided by 2 m). The residual area between Siraj and Kathakali is 1,103 km2. Accordingly, the ratio of the required flood retention area is about 38% of the whole residual area. It would be practically inconceivable to provide such a large scale flood retention reservoir surrounded by embankment, which is to be inundated in such a depth for the period of about one month during the monsoon season. If the total volume of excess flood water is to be retained in the whole basin, on the other hand, the average depth of inundation comes to 0.76 m (833 million m3 devided by 1,103 km2).

If the compartmentalisation could be well implemented, the flooding situation may not be so serious. The well distributed road network is expected to function for compartmentalisation to cope with the rainfall runoff in the basin. However, flood water coming from upstream of Siraj has already been too excessive, while in addition thereto the flood water from the basin downstream of Siraj enters therein. Therefore, the partial protection option in this unit is practically ineffective.

(2) Full confinement

In case of the full confinement of the rivers in the basin, impact to the downstream reach needs to be taken into consideration. To cope with this, the following options are conceiable;

- full confinement in the reaches of the Middle and Lower Bangali
- construction of the Bangali floodway

In the former case, the flood embankment along the Middle and Lower Bangali needs to be constructed on the both banks. The length of the flood embankment required will be approximately 200 km on both sides of the Bangali river. In addition thereto, many related structures such as drainage regulators and backwater embankment will also be needed. On the other hand, the new channel of the Bangali floodway is only 10 km in length in case of the proposed Route 1. From the view point of the least cost, it is obvious that the full confinement in the downstream reaches is not a viable option in comparison with the Bangali floodway.

Accordingly, the conceivable option is to construct the Bangali floodway. The two alternatives routes have been examined as discussed in the succeeding Section 5.17.

5.7.3 Development proposal

As presented above, provision of the Bangali floodway is the sole conceivable measure for this planning unit. A general layout plan of the components in case of the Bangali floodway is shown in Figure 5.9. The work quantities of the components are included in those of the Bangali floodway as explained in the succeeding Section 5.17.

5.8 Planning Unit No.7 : Gaibandha

The planning unit "Gaibandha" is bounded by the Teesta on the north, the Brahmaputra on the east and Ghagot/Alai on the west. Its location is shown in Figure 5.12. The major floding problems are summarized below;

a) spills from Teesta through the downstream breach between Kaunia and Sundarganj
b) spills from Teesta through the upstream breach which has been sealed by BWDB but the embankment height is still low as compared with the designed water level of the Teesta and connection of the Ghagot and Teesta through the breach.
c) bank erosion along the Teesta and Brahmaputra
d) spills from the Ghagot upstream of Bamondanga to the GIP area
e) remarkable erosion due to meandering of the Ghagot river along Gaibandha town area and habitual inundation in Gaibandha town
f) drainage congestion due to insufficient drainage capacity of regulators and closure of drainage route by rural road system especially in sub-drainage system flowing into the major drainage canal.
g) severe river bank erosion on the Brahmaputra right bank, in particular the upstream reach of the Manas regulator which is predicted to be washed away within a few years

To improve the above flooding situation, the following measures are proposed:

a) Strengthening of Teesta Right Embankment

1)	Provision of new flood embankment	: 13.2 km
2)	Resectioning & heightening of the existing flood embankment	: 33.4 km
3)	Provision of new groyne with a length of 50 m to 220 m	: 24 nos.
4)	Rehabilitation of the existing groyne	: 3 nos.
5)	Provision of new regulators	: 3 nos.
6)	Rehabilitation of the existing regulators	: 5 nos.
7)	Additional regulator at Mirganj	: 1 nos.
8)	Provision of sluice	: 5 nos.

b) Ghagot

1)	Provision of back-water levee	
	- right bank	: 25.0 km
	- left bank	: 32.7 km
2)	Resectioning and heightening of the existing flood embankment on the left bank	: 180 km

3) Extension of the existing left embankment : 32.9 km
4) Provision of new regulator : 9 nos.
5) Additional regulators for the existing regulators : 4 nos.
6) Provision of sluices : 24 nos.
7) Channel excavation at the outfall : 1.2 km
8) Short-cut channel at Gaibandha : 0.5 km

c) Compartmentalisation
1) New road embankment as a compartment boundary : 6.3 km
2) Closure of openings by earth filling or provision of sluice : 12 places
3) Provision of new regulator along the BRE : 1 no. with 4 vents
4) Provision of drain pipe : 450 nos.

Details of the above proposed CFD works are described in Vol. 5 "Gaibandha Improvement Project, Engineering".

5.9 Planning Unit No.8 : Middle Bangali Basin

5.9.1 Flooding Situation

The planning unit with a gross area of 225,431 ha km2 area is bounded on the north by the Katakhali-Alai, on the west by the Rangpur-Bogra-Nagarbari highway from Gobindhagonj to Kumajpur via Shibgonj on the east by the BRE from Gaibandha to Serajganj, and on the south by Serajganj-Bogra road as well as the downstream reach of the Katakhali. Its location is shown in Figure 5.13. The area consists of the Teesta and Karatoya/Bangali floodplains.

The Karatoya-Bangali river is the principal one in the planning unit area, which was linked with the lower Bangali by the two old river channels called the Old Karatoya and Old Bangali rivers. The Katakhali is a man-made channel, which was excavated to connect the Karatoya river and Alai near Mahimaganj. Downstream of Mahimaganj, the river is known as the Bangali river which flows down up to Chaksodhi. The original Karatoya (old) starting from Gobindaganj flows down near the Bogra town and finally joins the Bangali river at Chaksodhi. The Old Bangali river, at present called the Ichamati river, starts downstream of Mathurapara and finally outfalls to the Bangali river near Chandgati.

During the monsoon season, the habitual flooding occurs in the southern part of the Bogra-Sariakandi road due to accomulation of water spilled from the Old Karatoya-Bangali, the internal rainfall runoff and overland flow through breaches of BRE. The flooding in the southern part usually starts in July and the high water level therein lasts for approximately three months. The flooding situation is similar in the Thanas of Kazipur, Sherpur, Raiganj and Serajganj.

The normal inundation depth over the paddy field is about 2 to 2.5 m between July and August. These areas were affected by flood before construction of BRE and even after completion of BRE, particularly at Sariakandi. The surrounding area of Sariakandi along the Phulbari and Bangali rivers are affected by the Brahmaputra river through breaches at Sariakandi and Mathurapara.

The area under jurisdiction of Sherpur and Dhunot Thana covering partial catchment area of the Karatoya, Bangali and Ichamati rivers is affected mainly by the Brahmaputra river due to its breaches

during the monsoon period. Most of the village roads in the area are submerged to a water depth of about 0.6 m. Average water depth over the paddy field is about 2.5 m in July and remained submerged with almost the same depth for a period of next three month.

According to opinion of the farmers, the flood water entered into this area through the breaches of Brahmaputra river at Sariakandi and Mathurapara which damaged the growing t. aman crops after 1987 until now. The area is less affected by flood due to spillage from the Karatoya and Ichamati, and also by local drainage congestion. On the other hand, these internal river systems are functioning as drainage channels to drain out the spillage water from the Brahmaputra into the Karatoya-Bangali, although the carrying capacities of those river channels are not enough for the drainage purpose. Before breaching of BRE in the upstream, there was no significant damage to t. aman at these locations and there was no serious drainage problem even in the low-lying areas. The northern area of Serajganj town along the Brahmaputra is also under significant river bank erosion. The nearby paddy field along BRE was seriously damaged due to deposit of sediment by about 0.3 m in thickness as a result of the intrusion of flood water from the Brahmaputra through breaches about at Kazipur.

Accordingly, the causes of flooding in the planning unit are (1) spillage of the Old Karatoya and Bangali that affects the downstream Nuruller Beel Scheme, (2) breaches of BRE that affects the eastern area of railway line connecting Mahimagonj and Bogra, and its downstream portion, (3) public cuts along the Alai river that affects flooding in the area of Sonail Embankment Scheme. Among them, the major cause of flooding in the planning unit is considered to be the bank erosion and breaching of BRE along the Brahmaputra downstream of Sariakandi.

5.9.2 Issues on existing CFD infrastructure

The major CFD infrastructure in the planning unit is the BRE. Two other existing CFD schemes in the unit are the Sonail Embankment Scheme and the Nuruller Beel Scheme.

The Sonail Embankment Scheme area is situated southeast of Gaibandha town. The scheme constructed embankment of 19.4 km long which consists of 3.1 km of new construction and 16.3 km of resectioning of existing road and embankment, including provision of sluices and other related structures.

During the 1991 flood, the Sonail embankment was cut by people living outside the project area for quick drainage of accumulated runoff water coming from the upstream reaches of the Alai/Ghagot and also spillage of flood water from the Alai river. Hence, the embankment is now completely ineffective in the southern part of the project area.

The Nuruller Beel Scheme is located south of Gaibandha town and north of Bogra town. The project constructed the 30.7 km long embankment on the right bank of the Katakhali river for a section from Sahebgonj to Mahimagonj, which consists of 3.7 km of new embankment and 27 km of resectioning of the existing road/embankment system. To provide adequate drainage facilities, four regulators, flushing sluice and five outlets were proposed and scheduled to be completed by 1992-93.

The nearby villagers claim that in severe flood years flood water spills over the Nuruller Beel embankment so that large volume of water rush into the Karatoya creating flooding problems.

5.9.3 Options

- The northern part

There are basically two flooding problems in the northern part of the planning unit. One of these is related with the flooding in the upstream reaches of the Alai and Karatoya. Control of flood water coming into the area via the Alai and the Karatoya is recommended to be achieved. This planning is influenced by the development of GIP and the upper Karatoya basin.

The major option for the Middle Bangali is concerned with the provision of the Bangali Floodway at Sariakandi for drainage of the Karatoya basins. Such interceptor will require a backwater levee, together with the necessary control structures. The purpose of the Bangali floodway is to discharge flood flow in the Bangali-Karatoya system directly to the Brahmaputra, rather than allowing these discharges to augment the flooding in the Lower Bangali basin. Construction of the Bangali floodway would enable some development of the Upper Karatoya to take place, as well as reducing the flooding problems in the downstream reaches.

Spillage from the Alai is being considered under the potential EIP projects, and will be affected by proposals to be made under NWRS for the Gaibandha Improvement Project and the Bangali floodway.

Provision of better drainage in this area is another requirement. Desilting of the old Karatoya and Bangali and also the reexcavation of the drainage system between them would improve the present drainage problem in the area and reduce over-spillage onto the surrounding land. This is being considered as part of the SRP project at a feasibility study level, which is also looking at dry season supplies of irrigation water through provision of regulator on the Karatoya upstream of Katakhali bridge.

- The southern part

The most important measure to improve the flooding situation in the southern part of the region is the sealing of the BRE as described above. Consideration has also been given to providing a second line of defence against breaches in the BRE. An appropriate measure would be an embankment along the right bank of the Ichamati, which would accommodate any flows from the Brahmaputra, allowing them to drain through the Ichamati. However it is unlikely that such relatively major works could be justified if investment is made in sealing the BRE itself. A "second line of defence" has therefore not been considered further in the present regional planning study.

Rehabilitation and strengthening of the BRE is being studied under FAP 1. Regional planning for FAP 2 assumes that the BRE will be effectively sealed before implementation of any options proposed in the FAP 2 study.

5.9.4 Development proposal

According to the hydraulic modelling analysis results, flooding phases of the unit will be that 97% of the whole area will be F0-F1 land on the condition of sealing of BRE even though the upstream conditions are the same. Besides, the Bangali floodway is to reduce the flood water coming from the Upper Karatoya and Alai. In addition, SRP is going to improve the drainage situation in the area as mentioned above.

In conclusion, the proposal on flood control and drainage of this planning unit is the construction of the Bangali floodway and the GIP. The detail of the Bangali floodway is presented in the Section 5.17.

5.10 Planning Unit No.9 : Joypurhat

5.10.1 Hydrological and hydraulic situation

The Joypurhat area consists of four areas ;

- the Tulsi Ganga river basin,
- the Little Jamuna basin,
- the area bounded by the basin boundary of the Little Jamuna, the basin boundary of the Atrai and the Naogoan-Mohadevpur road,
- the area bounded by the basin boundary of the Nagor, the basin boundary of the Tulsi Ganga, and Naogoan-Bogra road.

Its location is shown in Figure 5.14. In this area three flood control and drainage projects have been implemented, namely ; Tulsi Ganga Project, Tulsi Ganga Left Embankment Project and Badalgachi Project.

- Tulsi Ganga River

In the reaches along the Tulsi Ganga river, there is a gauging station named Sonamukhi where discharge data are available between 1976 and 1989 with some interruption. Rainfall runoff of basin-27 by NAM Model gives the discharge hydrograph at a point near this site. Since the discharges data by the model are rather less than those observed, accordingly, discharge hydrograph by the model has been modified to adjust to the discharge data at Sonamukhi. The frequency analysis is made based on discharge hydrographs thus generated at Sonamukhi for the period of 25 years of 1965 to 1989. As a result of the frequency analysis, the probale 20-year flood peak is estimated at about 270 m^3/sec.

Return Period, (year)	2	5	10	20
Probable Flood Peak (m^3/sec)	144	198	234	268

The probable discharge at Sonamukhi and present conveyance capacities of the river are shown in Figure 5.15. The Figure shows that flood control works are not needed along the all reaches of the river, though insignificant spillage may occur near the Sonamukhi site.

- Little Jamuna River

In the reach along the Little Jamuna river, there is one gauging station at Naogoan and discharge data at this site are available.

Discharge data at Naogoan are available for the period from 1973 to 1989. The combined rainfall-runoff of basin-3,basin-26 and basin-27 of NAM Model gives discharge hydrograph at this site. The model result and discharge data show a good correlation. Accordingly, the discharge hydrograph generated by the model is used for the estimate of the probable floods at the site since the model gives a long series of discharge for the period of 25 years. For the analysis the presently constructed flood

embankment on the right bank of the river is taken into consideration. As a result, the probable 20-year flood peak is estimated at about 780 m^3/sec.

Return Period, (year)	2	5	10	20
Probable Flood Peak (m^3/sec)	381	532	638	772

The Badalgachi Project has constructed the flood embankment on the right bank of the Little Jamuna from the confluence with the Tulsi Ganga up to the Badalgachi site under EIP. Accordingly though the discharge data at this site are not available, the probable 20-year flood at this site is analyzed using discharge hydrographs is generated by NAM Model in consideration of the basin ratio of basin-26 to basin-3. The probable 20-year flood peak thereat is estimated to be about 510 m^3/sec.

Return Period, (year)	2	5	10	20
Probable Flood Peak (m^3/sec.)	237	334	404	504

The present river conveyance capacities of the Little Jamuna are shown in Figure 5.15. The Figure shows that flood control works are not needed in upstream reaches of Naogoan up to Badalgachi and in further upstream reaches of the Little Jamuna.

- Northern area of the Naogaon - Mahadebpur road

The present situation is that partly the flood water in the area is retained in beel area of Naogaon Polder in downstream basin and that partly flood water is retained in beel area on the northern area of Naogaon-Mahadebpur road.

- Northern area of the Naogaon - Bogra road

The present situation is that partly the flood water in the area is retained in Bogra Polder-2 area in downstream basin and partly flood water is retained in retained in north side of Naogaon-Bogra road.

5.10.2 Development proposal

In view of the hydrological and hydraulic condition as well as the flooding situation in the area the flood control and drainage options are worked out as presented below:

- The drainage basin of the Little Jamuna and the Tulsi Ganga

Since the present conveyance capacities are nearly same or more than the 20 year probable flood peak, no flood control and drainage works are proposed.

- Northern area of the Naogoan - Mahadebpur road

According to the information from EIP, some area near Badalgachi in the basin of the Little Jamuna of this area suffers from flooding. The extension of the right embankment of the Little Jamuna upstream to the confluence with the Ghamya river may improve the flooding situation of the area and may even improve the situation of the Naogoan Polder to some extent since some part of this area forms a drainage basin thereof. Layout of the plan is shown in Figure 5.14.

The major work components are listed below:

- Provision of new embankment(strengthening of road embankment) : 9.5 km
- Provision of regulator : 2 vents (1.52 m x 1.83 m)
- Northern area of the Naogoan - Bogra road

The northern area of the road connecting Naogaon to Dupchanchia is under the same flooding situation as the northern area of the Naogoan Polder. The difference is that the downstream area is the Bogra Polder 2 area. Thus the same idea, but taking account of the condition of Bogra Polder 2, will be adopted for this area. Other than, this for relieving the Bogra Polder 2 from much rainfall runoff, a diversion drainage channels connecting the Iramati river to the Nagor river is conceivable. This will be discussed in the planning unit of the Atrai Left Bank.

5.11 Planning Unit No.10 : Barind Tract

5.11.1 Flooding situation

The Barind Tract with a gross area of 268,532 ha is bounded on the west by the railway line forming the east boundary of the Mohananda basin, on the south by the Ganges, on the north by the national border with India, and on the east by the Atrai and the Shib rivers. Its location is shown in Figure 5.16.

Barind Tract is basically of a high land and generally does not suffer serious flooding problem but locally there still exist some flooding and drainage congestion.

The western strip area along the Shib river suffers the serious flooding and drainage congestion. This is due to the construction of flood embankment of Chalan Beel Polder D. Before the provision thereof, the natural drainage direction of the area was from west to east. But this natural drainage flow was interrupted by the embankment. The conveyance capacity of the Shib river is not enough for this increased drainage basin. Localized drainage congestion also exists in the area located north of the Chalan Beel Polder D. There existed some drainage channels flowing from north to south. Due to the construction of the flood embankment of the Chalan Beel Polder D, these channels were closed without construction of any diversion channel.

The area bounded by the flood embankment of Polder D on the east and by the road embankment connecting Choubariaghat to Silimpur on the south also suffers the localized drainage congestion due to the constriction of the Shib river by the road bridge thereat.

5.11.2 Options

Flooding in the strip area along the Shib river has often caused public cut of the flood embankment of Chalan Beel Polder D and serious damage to the crop in the Polder D. Countermeasure against this has been strongly needed and the study other than FAP-2 study on this issue including rehabilitation of other Chalan Beel Polders has been recently finished. Discussion on this issue is presented in the Section on the Lower Atrai of this report.

Regarding the drainage congestion in the area on the north of Chalan Beel Polder D, the following are the conceivable options;

- construction of drainage diversion channel to the Atrai river
- construction of drainage regulators at those sites where the drainage channels were closed off,
- construction of drainage diversion channel to the Shib river

In consideration of the high flood embankment on the right bank of the Atrai near the site and high flow of the Atrai, the first option is not a practical solution. Construction of drainage regulator at the closed off sites may cause conflicts between people outside and inside Polder D. Hence, also the second option is not deemed to be a better solution. Accordingly construction of drainage diversion to the Shib is considered to be the best.

5.11.3 Development proposal

The drainage congestion discussed above is rather localized issue for the regional planning. It should be treated by the local government level. Accordingly the issue is not adopted as a part of regional plan.

Development scenario on the flooding along the Shib is presented in the Section of the Lower Atrai. Other than that, rather large scale schemes in this planning unit are going on as flood control and drainage and/or irrigation schemes as follows:

For the southern part of the area adjacent to the Ganges, a feasibility study for the North Rajshahi Irrigation Project funded by JICA, was completed in August 1988. The proposed development of the project covers irrigation, drainage, rural road network, inland fisheries on a gross area of 61,630 ha. Of the net irrigable area 51,200 ha, area of 42,200 ha lies in the Barind area and the reminder in the Paba flood plain. The project also includes establishment and improvement of systematic drainage network in the area. The drainage plan proposes to connect the Joakhali river at Kasba to the Ganges with regulator, near the proposed pumping station with possibility of utilising pumps reversibly. In the Barind Tract area, only farm drainage improvement is planned together with the Shib river improvements in reaches where the cross section is considered insufficient. Other than this, as presented in the foregoing Chapter on present situation, the FCD/I schemes such as Barnai River System, Karnahar Bara Bila and Adjoining Beel System, Rajshahi Town Protection Scheme, Ganges Left Flood Embankment are ongoing.

5.12 Planning Unit No.11 : Mohananda Basin

5.12.1 Flooding Situation

This basin receives flows from the catchments of the Mohananda, Punarbahba and Pagla rivers. Flooding situation is mainly due to rainfall runoff from high land and high stage at the outfall to the Ganges. The area is subject to severe flooding, with F2 - F4 land occupying between 10 and 30 % of the NCA. Its location is shown in Figure 5.17.

The main flooding problems appear to lie on the right bank area of the river, and to the north of the Pagla. The left bank area of the Mohananda is comparatively of land, and is well protected by the existing Capai Nawabganj-Rohanpur road and sufficient drainage regulators. Aside from the flooding problem, the problems in this part of the basin appear to be associated with shortage of dry season supplies of irrigation water, rather than the monsoon flooding, since ground water resources are not abundant in this basin.

5.12.2 Hydraulic Situation

The Mohananda river is a tributary of the Ganges. The Pagla and the Punarbhaba rivers are a tributary of the Mohananda. At present the Capai Nawabganj-Rohanpur road is functioning as the flood embankment of the Mohananda river on the left side. Besides the left bank of the Mohananda is a part of Barind Tract consisting of rather highly elevated land. On the other hand, there is no flood embankment on the right side of the Mohananda except a small section of embankment constructed by the Marichar Danra scheme. The other asphalt-paved road runs from Capai Nawabganj to Kansat regulator site, partly forming a flood embankment of the Pagla river on its left side.

Hydrological observation in this unit are being carried out of the following gauging stations:

- Rohanpur the Punarbhaba river : water level and discharge
- Capai Nawabganj (the Mohananda river) : water level
- Godagari (the Mohananda river) : water level and discharge

Rohanpur is located just upstream of the confluence of the Mohananda and Punarbhaba river. Godagari is located downstream of the confluence of the Mohananda and the Pagla. Accordingly discharge data in the reaches between the both confluences are not available. Therefore water levels are analyzed to estimate the water level 1 in 20 year return period.

The observed water levels at Capai Nawabganj and Rohanpur, indicate a good correlation of water level between the both stations as shown in Figure 5.18. The regression equation is derived as follows:

H(Capai Nawabganj) = H(Rohanpur)-1.0 m

Compared with the water levels at Capai Nawabganj, water levels at Rohanpur has a long record ranging from year 1964 to date. The probability analysis for annual maximum water levels at Rohanpur, accordingly, is carried out by the Gumbel method. The results are shown in Figure 5.19 and below:

Return Period (year)	2	5	10	20
Probable Flood Water Level (m)	21.69	22.64	23.27	23.87

By using the above regression equation and the probable water levels at Rohanpur, longitudinal profile of the probable water levels along the Mohananda river is derived as shown in Figure 5.20 together with the other river features. Since Rohanpur is located just upstream of the confluence of the Mohananda and Punarbhaba rivers, it is assumed that the water level at the confluence is the same with that at Rohanpur. With the same procedure, the probable water levels for the period until the 10th of June in consideration of boro crop harvest are also calculated as shown in Figure 5.10. Consequently, the probable water levels at Rohanpur are estimated as follows;

Return Period (year)	2	5	10	20
Probable Flood Water Level (m)	14.71	15.24	15.58	15.92

The Figure shows that the riverine right bank is high enough compared with those water levels except the portion with opening.

5.12.3 Options

In view of the above hydraulic situation as well as the present flooding situation in the Mohananda basin, the conceivable options for flood control and drainage are as follows:

- Left bank : no additional development
- Right bank : no additional development in upstream reaches and full confinement in downstream reaches for the probable 20 year flood or

In the above, full confinement in downstream reaches for the probable 20 year flood includes construction of flood embankment along the right side of the Mohananda and the left side of the Pagla and some flushing regulators at present opening sites. No drainage regulators is proposed to be provided additionally since the present drainage regulators have sufficient capacities to drain out the internal rainstorm water.

Flooding also occurs between the Pagla river and the Ganges due to the high stages of the Ganges. But the area is so small with a strip shape that no protective CFD works are proposed therein.

The upstream area of the confluence of the Mohananda and the Punarbhaba is also composed of a very wide beel area along the international border, forming a natural retarding basin. Even in the dry season a large quantity of water remains in the beel area. Existing beel extends into the Indian territory across the interractional border. No CFD works are proposed for this area, since existing beel covers not only the area of Bangladesh but also the area of India and some countermeasure only in Bangladesh causes another flooding problem in India.

The general layout plan of the proposed CFD structures is shown in Figure 5.20 together with existing ones.

5.12.4 Development proposal

General layout of proposed work is shown in Figure 5.17 and the major work components are listed below;

- Construction of embankment : 56.2 km
- Provision of regulators : 10 vents (1.52 m x 1.83 m)

5.13 Planning Unit No.12 : Atrai Left Bank

The planning unit consists of Naogaon Polder-1, Bogra Polder 2, 3 and 4. It is bounded by the Bhadai on the east, the Atrai on the south and the west, and the Naogoan-Bogra road on the north. Its location is shown in Figure 5.21. The Atrai river is the main river in the planning unit area as well as the Little Jamuna and Nagor rivers. The Lower Atrai which forms the southern boundary of the area flows from northwest to southeast. The Little Jamuna and Nagor rivers flow from north to south through the area to join the Lower Atrai at Rasulpur and Khorsuti, respectively. At the time of peak monsoon, backwater effect of the Atrai extends up to Naogaon on the Little Jamuna and up to Talora on the Nagor.

5.13.1 Flooding situation

In the northern highland of the area, flooding problem is relatively insignificant. While, the southern low land of the area, including a large part of the Bogra Polder 4 area is flooded every year and acts as offstream storage. The low-lying areas are therefore the main flooding ones in the planning unit. At present, the main flooding problems seem to be caused by failure of the flood protection infrastructure. In addition, it is affected by the confinement effect of all the CFD works provided on both banks of the Lower Atrai, since most of the unprotected lowland is at the downstream end of the area.

The flooding problems in the highland areas appear to be not so significant, although in the transitional zone between the high land and low-lying areas there is a possibility of flooding causing damage to t. aman. The flash floods in the early monsoon season have damaged boro crop from time to time to date. The existing schemes do not appear to provide effective protection against this type of damage. Two types of crop damage are identified, namely damage to boro crop at around the harvest time due to the early monsoon flash floods, and damage to b. aman and t. aman during the monsoon season. More recently, crop damage resulting from breaches in the embankment has become the serious problem. In the Nagor river project area, for example, it is now impossible for farmers to secure b. aman crop due to breaches therein, whereas one of the main justifications of the project was to reduce crop damage to b. aman. In addition, the defective operation of CFD structures and public cuts have augmented the crop damage.

On the other hand, the planning unit area is covered by the dynamic hydraulic model for the NW region. The hydrological and hydraulic studies for the planning unit is extensively made by using the hydraulic model. The study results are presented in Volume 9, Hydraulic studies.

5.13.2 Approach to planning

Planning for the Lower Atrai is based on the premise that the full confinement cannot work in the basin: even if it does, that is at the expense of other areas and only for a short time. The basic reason why full confinement cannot work is the huge volume of flow that comes into the area which cannot be drained because of the backwater influence of the Brahmaputra. This flow, once confined, builds up large head differences between "protected" and "unprotected" areas. In addition, construction has gone ahead without proper consideration for people outside the polders who would be adversely affected. These people also contribute to the failure of the system by cutting the embankment, but even if they were compensated or resettled, the basic hydrological condition of the basin would still be likely to frustrate full confinement.

It should be noted that, at this stage, many farmers would be satisfied if they could get a b. aman crop in most years. Instead of ambitious plans to replace b. aman by t. aman, in some areas neither crop can now be obtained because of the impact of breaches and cuts. It is worth emphasising that there has been remarkable growth in paddy output in the Chalan Beel area, but this has mostly been a result of introducing irrigated HYV boro, which is not dependent on flood control (except for occasional flash floods). Farmers are mostly dependent on HYV boro to give them food security and a surplus, while the aman crop is now seen as an important supplementary crop. If it is secured in the monsoon season, probably most farmers would be satisfied.

In addition, when the needs of capture fisheries and navigation are taken into account, a strong case emerges for a system which allows more scope for the gradual flooding, which was used to occur before polderisation. The proposed options for development are based on these considerations.

The implications of all the options considered are that the level of nominal protection and size of protected area will be less, but the benefits on a basin-wide measurement should nonetheless be greater. The principle to be aimed at is to reduce the confinement effect while at the same time allowing productive activity (probably b. aman and fisheries). In some more upland areas where t. aman could be grown, there might be a case for providing more effective flood control. The concept of compartmentalisation (meaning the prevention of flood flows across drainage basin boundaries where possible) has been an integral part of basin planning.

The flood retention function of the Chalan Beel polders have been taken into account in the option planning. Where areas are being considered as offstream storage areas, the flood proofing measures to deal with severe floods are important.

5.13.3 Options

(1) General

The options considered here are based on the identification of current problems as being closely associated with:

- the confinement effect on the Lower Atrai, and
- the non-functioning of parts of the schemes already constructed. In general, therefore, full confinement which was studied in the first part of NWRS, was rejected as a inviable development scenario for the Lower Atrai, even with the possible intervention of the major drains (The Intercepter and Diversion). An exception is Naogoan Polder, but that is partly to do with the large amount of money already invested in that scheme: its operation should be closely monitored for the first few years to see if it can function effectively and achieve the benefits predicted.

A general approach of allowing flow into some polders, providing CFD protection in more upland areas, and sub-dividing polders to facilitate drainage, is therefore adopted for these planning units. In addition, Polder 4 (and, in early stages of planning, Naogoan Polder), is considered as flood storage zones.

In areas where CFD is not considered practical, an option is to provide partial protection and improved drainage. This might have two objectives:

- protection of the boro harvest from flash floods (as in NE region in Bangladesh)
- control of the rate of rise of monsoon water levels so that TDW aman can be grown.

The need for pre-monsoon protection of boro is not so critical in the NW region because of the different climatological conditions. These influence the onset of flooding and the planting/harvesting timings for crops.

For the CFD areas a form of compartmentalisation is envisaged whose primary function is to prevent transfer of flood flow across drainage basin boundaries within protected areas. As far as possible, such flow will be routed to the main or internal rivers bordering the compartments. Maximum use will be made of existing infrastructure such as local roads to provide compartment boundaries and control structures. The flood proofing is an important component in unprotected areas or flow areas.

(2) Options and scenarios

Based on the consideration presented above, a number of options have been considered.

Options and scenarios in the lower Atrai are dealt with in more detail in the part of the hydraulic modelling study. Here the promising scenarios are set up by combining the options in the respective planning sub-units in the Lower Atrai area as summarized below:

1) Scenario A : The Green River as summarized below;

Left Bank

Sub-Unit		Option
Naogaon Polder	:	CFD assuming completion of the present project
Polder 2	:	A part of the polder adjacent to the Atrai is used for flood flows. Upper part of the polder is CFD.
Polder 3	:	Same as Polder 2.
Polder 4	:	No development.
SIRDP	:	Flow through the lower area. Upper area is CFD. Closure of drainage channels from the right bank of the Karatoya.

Right Bank :

Sub-Unit		Option
Polder D	:	Provision of a drainage path from the Shib to the Fakirni in Polder D area.
Polder C	:	Flow through the polder with higher areas sub-poldered for CFD.
Polder B	:	CFD in higher areas with flow area in lower areas adjacent to the Atrai.
Polder A	:	Same as Polder B.
Barnai Project	:	Completed.
Baral Basin Project	:	Completed.

2) Scenario B : Development of Polder 4; Partial protection of Polder 4 is considered. Other features are the same with the Scenario A.

3) Scenario C : Partial Protection of Polder D; Partial protection of the middle band of Polder D with side overflow weirs on the drain is considered. The other features are the same with the Scenario A.

4) Scenario D : Modification of Naogaon Polder Concept; This scenario modifies the Naogaon polder concept to allow flood flows in the lower areas of the polder. The other features are the same with the Scenario A.

5) Scenario E : CFD in Polder C; Polder C is fully protected. The other features are the same with the Scenario A.

6) Scenario F : Partial Protection in Polder 4; Some areas in Polder 4 are CFD. The other features are the same with the Scenario A.

The option on each polder in the planning unit are discussed hereunder;

- Naogoan Polder

Naogoan Polder is situated in the upstream end of the Lower Atrai. Basically this polder is not affected by the backwater of the Brahmaputra. But the area badly suffers from flooding from the Atrai and overland drainage flow. The project area receives much drainage flow from the north. Its location is shown in Figure 5.22.

Flood embankments are constructed along the Atrai from Mohadebpur to Rasulpur and along the Little Jamuna from Rasulpur to Naogoan town. However, flood embankment situated north of Mohadebpur of Patnitola scheme protects the Naogoan polder area from spillage of the Atrai.

The following two options on this polder have been studied.

a) Option 1 : CFD

As Naogoan Polder is nearing completion, this option covers its full completion to CFD facilities. Two sub-polders for improving the agriculture and distributing the rainfall runoff, through effective flood management, are also studied. The boundary of the sub-polders follows the Manda-Naogoan road.

The spillage from the L.Jamuna is being checked by the Badalgachi project which is located north of Naogoan town. However it is reported that overbank spillage occurs in upstream reaches of Badalgachi which flows ultimately to the Naogoan polder-1 and Naogoan town area.

Based on the available river cross-sections, it is clarified that the upstream reaches of the Little Jamuna have enough conveyance capacities against the 20 year probable discharge. However flood stage analysis by hydrodynamic model shows that spillage occurs in the reaches.

And it is also reported that spillage from the upstream reaches of the Little Jamuna threatens the effectiveness of the Naogoan Polder Project. Some extension of the flood embankment of the right bank of the Little Jamuna in reaches upstream of Badalgachi may be accepted in consideration that the extension will not cause substantial adverse effect to downstream areas. The extension of the right embankment of the Little Jamuna to the upstream reaches is discussed in the foregoing section, Planning Unit No. 9 : Joypurhat.

b) Option 2 : Partial protection

Option 2 studies the possibility of reducing peak water levels in the Atrai by allowing storage through partial protection only in the downstream part of the polder. In this option CFD facilities would be provided in the area located at higher elevation as for Option 1.

- Bogra Polder 2

The Bogra polder - 2 area is bounded by the Little Jamuna in the west, the Atrai in the south and Nagor river in the east. In this area about 128.0 km of flood embankment and 15 sluices are installed at present for the drainage purpose. However, the northern side of the polder is kept open to allow intrusion of drainage flow from the northern areas.

The general land slope is from north to south. Major drainage channels are the Irabati and Raktadah streams which are connected with Roktodah beel and the Kashiabari sluice, respectively. During the monsoon season, drainage flows from the upstream basin reaches the low-lying area. Since the river stage is high at Kashiabari sluice, gravity drainage to the river is not possible. The flood water flows towards the southeast to Khorsuti. Due to increase of inundation water, publiccuts are made to the polder-2 embankment along the Atrai. Since flood water accumulates in the Khorsuti area, publiccuts are also made at Khorsuti.

It has been assessed that the existing regulators are inadequate, the present drainage plans are also not proper.

At present, a total of 128 km long flood embankments are provided in the Bogra polder - 2 scheme along the Little Jamuna river, Atrai and Nagor river. The flood embankments are constructed manually without proper compaction and as a whole the quality of construction is poor. The existing embankment height is not sufficient at lower reaches along the Little Jamuna and Atrai which requires further heightening. Frequent breaches along the Atrai is very common. As for the drainage facilities, the existing flood embankment along the Little Jamuna, Atrai and Nagor has three, four and eight sluices, respectively.

Since the Bogra Polder 2 area is not fully empoldered along the surrounding rivers in the upstream reaches, heavy inundation occurs in low-lying area along the lower Atrai due to overland flows from northern area and spillage from the surrounding rivers in the north during large scale floods.

Full confinement of the Little Jamuna and Nagor along the polder would effectively protect the polder from flooding without causing serious adverse effect to the downstream reaches. But full confinement of the Lower Atrai has proved to be impractical because it makes the river stages very high along the whole reaches of the Lower Atrai. This results in public cuts in the lower reaches.

Taking into account the aforesaid situation, the lower unit of the polder needs to be of an area of partial protection to avoid the high stages of the Lower Atrai, while the upper area can be fully protected without occurrance of the adverse effect. Therefore, the lower area is planned to be of flow area and CFD facilities are planned to be provided in the upper area. CFD embankment behind the lower area is needed because otherwise the backwater would extend well inside the upper area. This embankment would have facilities for controlled flooding into the upper area.

The flood embankment is planned for a section from the Atrai railway bridge to Hingolkandi following a village road. Since the embankment passes through the valley, a drain to collect the drainage flow is planned as well as a strong embankment. Sub-poldering through Raninagar to Parghate following a village road is also planned. In total, seven compartments are planned to reduce drainage load on the lower reaches, by diverting upland flow to the internal rivers. Polder 2 is scheduled for redesign in this year under EIP.

- Bogra Polder 3

Bogra Polder 3 is bounded by the Nagor on the west, the Atrai on the south and the Nator - Singra road on the east. Along the Nagor and the Atrai, 63.5 km long flood embankment is completed with 18 structures. The area is subject to overland flow from the polder-2 area. The north edge of the polder is open and then drainage flow from upstream basin reaches the downstream area. In the upper reaches, embankments have not been breached or cut, implying that they are relatively effective in keeping out floods. However, this land is higher and less susceptible to flooding in any case. At present, existing 63.5 km long flood embankment provided along the Nagor and the Atrai river but the polder suffers from flooding due to the overland drainage flows and augmented flows from the upstream basin. While, the area along the lowermost reach suffers from flooding due to public-cut of flood embankment at Khorsuti to allow the drainage flows from polder-2 area and Nagor river.

Concerning drainage, there are 15 sluices along the Nagor and 3 sluices along the Atrai. These sluices are inadequate as the area is subject to spillage from upstream river Nagor. As well, there is outfall constrains due to backwater influence of the Hurasagar/ Brahmaputra rivers.

Since the flooding is due to upstream and overland drainage flow through Khorsuti which causes breach/cut at the lower end of the polder, the lowermost part of the polder will remain open to realize the Green River flow.

As for polder 2 it may be noted that public cuts are made in the lower reaches of the polder, but not in the upstream reaches. Therefore flooding through partial protection is proposed for the lower area and CFD facilities are proposed in the upper areas. Flood embankments are planned from Hingolkandi to Pakuria following a village road. Since the embankment passes through the valley, a drain is planned collect the drainage flow in addition to the embankment. Sub-poldering is proposed to reduce drainage load to downstream reaches.

- Bogra Polder 4

There is no CFD development in this area. The area is bounded by the Atrai on the south, by the Singra - Bogra road on the west and the SIRDP project and the Bogra-Baghabari road on the east. The Bhadai river is an internal river passing through the middle part of the polder-4 area. The area is under the active influence zone of backwater of the Brahmaputra. After the construction of SIRDP, the polder 4 area badly suffers flooding. Since the SIRDP embankment is located within the drainage path of the area, the area suffers serious flooding. The area suffers from flooding due to floods of the Atrai, flood flows from Bogra Polder 3 and flood water from the Karatoya when BRE is breached at Kazipur or Sirajganj. The polder 4 area is situated at the tail end of the Barind Tract so that all the drainage flows are accumulated here and ultimately flow down to the Hurasagar.

Option 1 : Historically this area is a flood storage and flow area, and any flood control development will not reduce the storage capacity of the basin. As such, no embanking is planned under this option. Flood proofing facilities would need to be provided to reduce suffering and to minimise damage to existing infrastructures.

Option 2 : In this option the lower part of the area would remain unembanked as it is. In the upper reaches CFD facilities will be provided. Possible alignments for these embankments include the Pakuria-Hatiandighi road and Taras-Baruhas road. Embanking of the upper reaches of the Badai may also be required.

5.13.4 Development scenario

Based on the alternative study on the Lower Atrai, as discussed in the part of the hydraulic modelling study, the Green River concept is proposed for the area from viewpoint of the comprehensive flood control in the Lower Atrai. The brief features of this scenario is presented below;

Polder 2 and 3 areas should provide some flow area in their lower portion for the Green River. Polder 4 should remain as it is without any development in terms of CFD. The whole area is provided for flow area of the Green River. The design discharge distribution for the Lower Atrai and Lower Bangali is shown in Figure 5.36. SIRDP area should provide some flow area for the Green River in its downstream portion. The longitudinal profiles of the Lower Atrai, Shib-Barnai, Little Jamuna and Nagor are shown in Figures 5.24, 5.25, 5.26 and 5.27, respectively. The details of the development scenario of each polder in this unit are proposed hereunder in consideration of the characteristics of each polder in case of the Green River scenario.

- Naogoan Polder

As discussed in the hydraulic modelling study, full confinement of this polder would not give substantial impact to the water levels along the Lower Atrai. In consideration that this project has been recently completed, besides, this polder is proposed to be completed as per the original plan.

- Bogra Polder 2

The Bogra polder - 2 area is proposed to be empoldered for flood protection and seven compartments are proposed in polder 2 as shown in Figure 5.23. The existing road from Atrau railway bridge to Hingolkandi needs further strengthening and breaches need to be closed. The flood embankment provided up to Talora requires to be extended to Dhupchanchia. The lower portion which is about 2,700 ha will be within the Green River. The general layout plan for the Bogra Polder 2 is shown in Figure 5.23. The major items of the flood control and drainage works are listed below;

Major Work Item	Quantity
-Provision of new embankment	8.0 km
-Resectioning and heightening of existing embankment	105 km
-Strengthening of road embankment for compartment	12.5 km
-Provision of channels	25 km
-Provision of regulators	24 vents (1.52 x 1.83 m)
-Provision of navigation lock	1 no.

- Bogra Polder 3

Since the flooding is due to upstream drainage and overland drainage flow through Khorsuti which has led to cuts at the lowermost part of the polder, it will remain open to allow the flood flow to enter inside the area in case of the Green River scenario. Further extenstion of flood embankment from Talora to Dhupchanchia is recommended for CFD measure.

On the other hand, 3 compartments are planned to withhold the upstream runoff and control drainage with water control structures to alleviate the drainage problem of the area. Figure 5.21 shows a general layout plan for the Bogra Polder 3 in case of the Green River scenario. The major items of the flood control and drainage works are listed below;

Main Work Item	Quantity
- Provision of new embankment	5 km
- Resectioning / heightening of existing embankment	56.0 km
- Strengthening of road embankment for compartment	13.5 km
- Provision of channel	8 km
- Provision of regulators	8 vents (1.52 m x 1.83 m)
- Provision of navigation lock	1 no.

- Bogra Polder 4

In the Green River scenario, this area will be left as it is, since the hydraulic modelling analysis clarified that provision of the flood embankment along the river bank will cause serious confinement effect. While, the flood proofing and fisheries development works are recommended in the Polder 4 area. In the Green River scenario, overland drainage flow is considered in the regional plan.

5.14 Planning Unit No.13 : Atrai Right Bank

5.14.1 Flooding situation

The area is bounded by the Atrai river on the north and east, the Ganges and Boral on the south, and the Shib river on the west. Its location is shown in Figure 5.28. It comprises the Chalan Beel polders and the Baral and Barnai project areas. At present, the Chalan beel area occupying a big part of the area is subject to regular deep flooding by the accumulation of water from the rivers. As the land elevations of these portions are relatively low in comparison with the monsoon water level, this area has been acting as natural reservoir. Backwater effect of the Brahmaputra extends up to around the Atrai railway bridge.

After 1982 to date, over 100 public cuts have taken place in the Chalan Beel polders: most of these have been in Polders C and D. These polders have therefore not functioned as originally designed. Most public cuts have been made by people living outside the polders, but it has to be recognised that a high proportion of people owing land inside the polders actually live on the river bank outside: this is particularly the case in Polder C. It is therefore not simply a case of gainers inside and losers outside: if water enters into the polders through a breach or cut, it is often necessary for people inside the polder to make a further cut to drain out the water. It is clear that, at least in Polder C, the exiting drainage structures are not adequate to drain out the water that collects inside the polder.

The case of Polder D is rather more straightforward: the main public cuts are made on the western embankment by outsiders whose lands and houses are severely flooded almost every year by the flooding in the Shib river. The cuts allow a huge volume of water to rush into the polder, causing extensive crop damage. Although in Polders C and D there has taken place a switch from b. aman to t. aman in a limited scale, this switch is not secure, and both b. aman and t. aman are now being extensively damaged. Farmers express a common desire that they would like to harvest securely b. aman crop. First of all, it is considered more important than taking the risk of trying to plant t. aman

crop. Polder A has also not been very effective as compared with the other polders. This is partly because it has never been fully completed, and the main regulator has to be rebuilt. In addition, the Polder A area is subject to overtopping of flood flow by rising water trapped between the Polder and the SIRDP embankment at Taras.

Polder B has been more effective but has been cut to the lesser extent, and the drainage system is not fully effective at present.

In addition to the aforesaid problems within each polder, these are compounded by the interaction between polders, and between these polders and other CFD works in the basin. The construction of the Bogra Polders, for example, has combined with the Chalan Beel Polders to give a significant rise in the Atrai water levels. Further downstream, the SIRDP embankment keeps on the confinement effect. The cuts in Polder D cause an onrush of water that ultimately drains into the Fakirni and results in cuts and breaches in Polder C.

In conclusion, the present system as a whole is not working properly and needs redesign. An overall assessment of the area, taking into account external and downstream impacts, would almost certainly conclude that the existing developments as a whole have not been effective in meeting their original aims and in addition have created further negative impacts in terms of loss of fisheries, increased social conflicts, etc.

5.14.2 Approach to planning

The approach to planning is the same as that presented in the foregoing Section 5.14, Planning Unit 12: Atrai Left Bank.

5.14.3 Options

Polder A

Polder A covering an area of 30,686 ha is situated in the downsteam end of the planning unit area. The southern land of the polder is rather high, but the northern one is relatively low. The elevation difference is about 3.0 m. The most northern part is of low-lying area severely affected by flooding.

Option 1 : The area has been divided into three compartments based on the topographic features. The compartment adjacent to the Atrai is planned to be flow area. Crops in this area are frequently damaged due to the onrush of flood water. In the remaining areas, controlled flooding and drainage facilities are planned to be provided. Provision of the controlled flooding area will also reduce the confinement effect. Drainage improvements are also proposed.

Option 2 : Controlled flooding and drainage measures are considered for the whole area of Chalan Beel Polder A. Since the area provided with partial protection under Option 1 is quite small, Option 2 would have little effect on raising levels. However the area which would be enclosed under Option 2 is an area of deep flooding and an important area for fisheries.

Polder B

The Chalan Beel Polder B covering an area of 32,105 ha is comparatively high land formed by the alluvial deposit of the Ganges. In general the land slopes from south to north. Owing to the topographical condition the polder is less vulnerable to flooding. The village road along the Atrai and Shib - Barnai forms the existing flood embankment of Polder B. In Polder B, there is a small sub-polder scheme called the Barnai River sub-project as shown in Figure 5.28. To further mitigate the flooding in the Polder B area other than the Barnai River sub-project, compartmentalisation is required for the drainage control purpose.

Option 1 : The Polder B area is divided into four compartments based on its topographic features. The partial protection is proposed in the low-lying area adjacent to the Atrai and Barnai rivers. More comprehensive controlled flooding and drainage measures are planned for the remaining area.

Option 2 : If sufficient flow width and flood storage are made available on the left bank of the Atrai, opposite to Polder B, this may enable the more comprehensive flood control and drainage measures to be considered for the whole of Polder B including the low-lying area adjacent to the Atrai and Barnai rivers.

Polder C

The Polder C with an area of 45,970 ha is easterly sloped land, having complex hydrological phenomena. After the completion of the embankment and the sluices, the Atrai river experienced substantial rise in flood peaks due to confinement effect. The river stage has raised by almost two meter due to the full confinement. This has resulted in public cuts practically by people living along the river subject to serious flooding to reduce the flood peaks. While the majority of the people whose land is susceptible to such flooding live on the river bank. Every year, public cuts take place in the northern area along the Lower Atrai, subsequently leading to cuts in the downstream reaches for the drainage purpose. Due to cut in the flood embankment and sudden rush of flooding, the area is refrained from growing B.Aman. On the other hand, it is possible to grow some DWT Aman in the comparatively high land of the Polder C area. At present, there is a small CFD area initiated by the local people near Singra.

In consideration of the above situation a large part of the Polder C area is planned to allow flood flow to enter inside the polder at the peak monsoon.

A control structure is proposed at Bandiakhari to allow flood flow in the Polder C and natural flood flows to the beel Halti. The crest of the weir is fixed in such a manner that it is possible to protect DWT Aman until the 20th of June and that the flow in the polder area will keep steady rise of water to allow the cultivation of DWT Aman. Since the driving head along the Atrai is more than the Barnai there will be an outfall structure on the Atrai upstream of Singra.

Two small areas of Polder C which are on higher ground may be divided into two sub-polders for controlled flooding and drainage purposes. The flood embankment is required to be strengthened with a berm. In this polder brick mattressing work in the flood embankment to prevent wave attacks is considered.

The flood proofing facilities are proposed for the unprotected areas inside the polder and affected areas outside the polder. Due to the importance of boat transport in the Lower Atrai, the navigation facilities are planned.

Polder D

The Polder D area is situated northwest of the Chalan beel polder project area and on the eastern flank of west Barind Tract. The polder D with an area of 57,460 ha was completed in 1988, but the flood embankment along the Shib is cut by people living outside the polder in the western Barind. Due to the cut of the embankment along the Shib, the Polder D area suffers from flooding as before. During the monsoon season large part of the Polder D area is refrained from harvesting T.Aman crops. The flood embankment of Polder D virtually lies on the past drainage path of the western Barind Tract. Accordingly the main requirement in Polder D is to make provision of drainage from the Shib river on the western boundary across the polder to the Fakirni in the east.

For improvement of the agricultural production, the area is divided into three compartments, namely; the upper area (Compartment D/1) the middle area (Compartment D/2) and the lower area (compartment D/3) as shown in Figure 5.28. The compartments D/1 and D/3 will be provided by CFD facilities. However, the compartment D/2, which allows drainage of Barind Tract located west of Polder D, will be provided with dwarf embankment for protection of DWT Aman. The crest level of the dwarf embankment is fixed at water level of 5 year return period on 3rd decade of June, aiming at the protection of DWT Aman. This adjustment in the plan will solve the drainage problem in the western part of the Polder D area and improve the low area of the Polder D by protecting DWT Aman. To mitigate flooding damage in the Polder D area, compartmentalisation is required for flood controlled and drainage.

Barnai Project

This project is nearing completion. As its effect on confinement levels in the Atrai is small, no alternative plans have been prepared. However, it has significant impact on levels in the Shib river, and therefore has implications for planning in Polder D. Thus, its impacts should be monitored.

Baral Basin Project

This project is under study. Proposals being made include strengthening of the Ganges left embankment. As the effect of the proposed project on confinement levels and other scheme areas in the Atrai is small, no alternative plans have been prepared.

5.14.4 Development scenario

Polder A

It is proposed that Polder A should be divided into two portions. The lower area should be a flow area for the Green River. The higher area should be provided with CFD facilities. The general layout plan for the Polder A is shown in Figure 5.28 and the major work items of the proposed are shown below:

- Provision of new embankment : 18.0 km
- Resectioning / heightening of existing embankment : 48.0 km
- Strengthening of road embankment for compartment : 18.5 km

- Provision of channel : 15 km
- Provision of regulators : 20 vents (1.52 m x 1.83 m)

Polder B

It is proposed that Polder B should be divided into two portions. Lower area should be a flow area for the Green River but with protection of DWT Aman. The higher area should be provided with CFD facilities. To further mitigate the flooding in the Polder B area other than the area outside the Barnai River Sub-project, compartments are required for flood control and drainage control as shown in Figure 5.28. The major work components are listed below:

- Provision of new embankment : 18.5 km
- Resectioning / heightening of exist. embankment : 40.5 km
- Provision of new embankment for compartment : 2.5 km
- Provision of channel : 18 km
- Provision of regulators : 23 vents (1.52 m x 1.83 m)

Polder C

A general layout of proposed works is shown in Figure 5.28. The major work components are listed below.

- Resectioning/heightening of existing embankment : 138.0 km
- Strengthening of road embankment for compartment : 10 km
- Provision of new embankment for compartment : 15 km
- Provision of regulators : 14 vents (1.52 m x 1.83 m)

Polder D

A general layout of proposed works are shown in Figure 5.28. The major work components are listed below:

- Resectioning/heightening of existing embankment : 134.0 km
- Provision of new embankment for compartment : 60 km
- Provision of road embankment for compartment : 45 km
- Provision of channel : 10.0 km
- Provision of regulators : 10 vents (1.52 m x 1.83 m)

5.15 Planning Unit No.14 : Lower Bangali

The Planning unit area consists of the Karatoya flood plain, Hurasagar flood plain, Baral-Atrai flood plain and Brahmaputra flood plain. Its location is shown in Figure 5.29. The Lower Bangali basin, which includes the area behind BRE, is subject to prolonged inundation due to back water effect of the Brahmaputra and also suffers flooding due to breaches of BRE. At the lowermost part of the basin, there are two existing CFD schemes, the Serajganj Integrated Rural Development Project (SIRDP) and Hurasagar Project. Except for these schemes, no large areas are at present under consideration by others for the possible flood control and drainage development.

5.15.1 Flooding situation

a) Hurasagar Project

The Hurasagar scheme is a completed CFD project under fund of IFAD. The area is bounded by the BRE on the east, the Karatoya river on the west, and the Baral and Hurasagar rivers on the south. The northern side is closed off with a road embankment and a diversion channel. The Hurasagar project area has been affected by the peripheral rivers such as the Brahmaputra-Jamuna, Karatoya-Bangali and Hurasagar. The Brahmaputra Right Embankment (BRE) which constitutes the eastern boundary of the project is an important facility to safeguard the project area.

In 1987, 1988 and 1989, there occurred many breaches along the Hurasagar which led to significant crop damage in the project area. Also in 1991, breaches occurred on BRE at Kazipur and the western embankment provided along the Karatoya. The southern embankment along the Hurasagar was also breached dur to the insufficient set-back distance and poor construction quality.

In the southern part of the project area, the accumulated rainfall runoff causes the severe inundation during the monsoon season, since it can not be drained out because of the high stage of the Hurasagar.

Beside the unmetalled road in the northern boundary, there is a diversion channel which outfalls to the Karatoya at the western side. The rainfall runoff coming from the upstream basins beyond the project area outfalls into the diversion channel without intrusion to the project area. In 1991 the crop in the upper area of the Hurasagar scheme was damaged significantly due to breaches of BRE.

b) SIRD Project

SIRDP which covers an area of 62,730 ha is a completed project but still subject to severe flooding, particularly in the southern part. As a result of the site reconnaissance, people living outside the SIRDP area particularly in the Bogra polders, are convinced that the SIRDP embankment has created the drainage constraints. Hence, they cut the western embankment. People living north of the SIRDP area, particularly at Taras, have also expressed drainage and flooding problem in the area. People living in the Taras area is hoping drainage through the SIRDP area.

The Bogra - Baghabari road was functioning as flood embankment with closed culverts, but after the 1988 flood the culvert and bridge gaps were made open to allow the passage of flow for security of the road from the structural point of view. Now the east embankment that is the trunk road from Nagarbari to Bogra has, along the SIRDP area, 67 bridge or culvert openings. During the normal monsoon season, water spilled from the Karatoya intrudes into the project area through these bridge/culvert openings of the Bogra-Baghabari road which is the eastern boundary. Besides, flood water from the northern catchment also enter into the project area through bridge and culvert opening of the Bhuiyagati-Taras road.

A study carried out in 1990 recommended that the southern part should be reserved for controlled flooding by introduction of a escape structure at Baghabari to allow flooding in the lowermost part of the SIRDP area, so that a side overflow weir was completed in 1991 as the escape structure. The escape structure was completely washed away due to the 1991 flood. The area located north of the railway line was recommended to be of CFD.

The topographic condition of the SIRDP area does not permit gravity drainage of the monsoon runoff so that the vast area therein becomes below the outfall river stage. Therefore, the accumulated runoff cannot be drained out because of the high stage at outfall of the Hurasagar to the Brahmaputra.

5.15.2 Options

a) Hurasagar Project

Through the examining of the present inundation and drainage conditions as well as the present cropping pattern in the project area, it is recommended to extend the present Hurasagar scheme area to further north and to divide it into two compartments. As a result, the proposed Hurasagar project covers a gross area of about 36,500 ha, which consists of 29,000 ha in the north and 7,500 ha in the south.

These two compartments are delineated by the existing Hat Panchil-Shahzadpur road. The new project area proposed in the present study extends up to the Nalkasengati-Sirajganj road. For adopting full flood control of the northern compartment, it is proposed to construct a new embankment along the left bank of the Karatoya for a section from Shahzadpur to Nalkasengati. The bridge opening along the proposed northern boundary (existing Hat Panchil-Shahzadpur road) is required to be closed. Consequently, no intrusion of water into the project area will occur. To divert the rainfall runoff in the upstream area of the road to Sirajganj, existing drainage channel is recommended to be exlarged. The north compartment is to be protected by BRE on the east, proposed CFD road embankment on the north, CFD embankment along the Karatoya on the west and the existing road which is to be used as southern CFD embankment.

The south compartment is planned to remain subject to flooding during monsoon period after harvesting boro crops.

Hurasagar North Unit

The area suffers from flooding due to back water effect of the Karatoya and breaches of BRE. The FCD option theron is worked out on the condition that BRE is sealed. At present there is no flood embankment along the Bangali river. As long as BRE is to be maintained in a good condition, therefore, flooding in the north unit comes from the Bangali. To mitigate the flooding problem in the area, it is proposed to extend the existing flood embankment along the Hurasagar from Baghabari to Nalkasengati.

Hurasagar South Unit

The area is empoldered with flood embankment provided along the Banglai and Hurasagar on the west and the south respectively, as well as BRE forming the eastern boundary.

Option 1: The present Hurasager FCD scheme becomes ineffective due to breaches in the existing flood embankments. The area could be developed as an important conservation area for fish recruitment and wild life, etc. This option is to be applied only to the south unit from the topographic condition so that it would allow the flooding during the monsoon period after harvesting boro crops. Flood proofing is planned to be provided to mitigate the suffering of the area where appropriate.

Option 2 : The landsat imagery clarified that, even at the peak of the 1987 flood, the Hurasagar southern unit was not seriously flooded since the Hurasagar has the wide and deep sections at this point. Consideration could therefore be given to comprehensive controlled flooding and drainage measures to the Hurasagar area, provided that appropriate designs and methods of construction were applied. Since the area is at the lower end of the Atrai basin, major embankment protection measures would not contribute significantly to adjacent or downstream impacts.

b) SIRD Project

Option

In line with the planning concept for the Lower Atrai as well as in consideration of the present situation of the area, options for development were worked out. The SIRDP area is divided into 3 compartments for the effective flood control and flood management. The controlled flooding and drainage (CFD) are proposed for the compartment 1 and offstream flood storage and partial protection for the compartment 3.

The closed gaps in existing six bridges on the Taras-Nimaichara embankment are proposed to be opened again to allow flows across the lower sub-unit adjacent to the Atrai. The CFD embankment would follow the Taras-Ullapara road. This area will also be suitable for capture fisheries. The flood proofing facilities should be provided.

For adopting CFD in the northern areas, it is suggested to construct a new embankment along the right bank of the Karatoya from Ullahpara to Chandaikona without disturbing the roads and highway boundary to protect the area from the flood flow in the Karatoya. The right embankment of the Karatoya will protect the area from flooding and close off distributaries(such as the Durgadah) which currently drain through the project area. The northern portion is divided into two compartments in view of the requirement of the drainage facilities as well the topographical condition as follows:

Compartment 1: Located west of the Durgadah river, bounded by the Taras-Ullapara road forming the western compartment boundary. Its gross area is 11,210 ha.

Compartment 2: Located east of the Durgadah river, bounded by the Dharail-Ullapara road and the Karatoya on the east. Its gross area is 15,358 ha.

5.15.3 Development scenario

a) Hurasagar North Unit

A general layout of the proposed works is shown in Figure 5.29. The major work components of the Hurasagar north unit are listed below:

- Provision of channel : 11 km
- Provision of regulators : 20 vents (1.52 m x 1.83 m)
- Closing of road culverts : 6 nos.

b) Hurasagar South Unit

To mitigate the flood damage and improve the agriculture partial protection in the Hurasagar south unit is proposed. A general layout of proposed works is shown in Figure 5.29. The work components are listed below:

- Provision of new embankment : 1 km
- Resectioning/heightening of existing embankment : 13.75 km
- Strengthening of road for embankment : 10.0 km
- Provision of regulators : 8 vents (1.52 m x 1.83 m)

c) SIRD Project

A general layout of the proposed works is shown in Figure 5.29 and the major work components are listed below:

- Strengthening of road for embankment : 65.0 km
- Strengthening of road for compartment : 8.0 km
- Provision of channel : 5 km
- Provision of regulators : 20 vents (1.52 m x 1.83 m)
- Closing of road culverts : 15 nos.

5.16 Planning Unit No.15 : Pabna

5.16.1 Flooding situation

The area is situated in the district of Pabna and Natore. The area is bounded by the Brahmaputra on the east, the Ganges on the south, Ishwardi-Rajshahi railway line on the west and the Boral-Hurasagar on the north as shown in Figure 5.31. The area with a gross area of 215,000 ha consists of the Ganges flood plain. About 50% of the land area is highland or medium-highland, and 50% medium or lowland. Annual rainfall in the area falls between 800 mm and 2400 mm in the last 30 years.

Presently the drainage network basically takes place from west to east, comprising the Chiknai, Baral, Ichamati, Atrai and Bhadai rivers as well as other internal drainage channels. Before completion of the Pabna Project Phase I, the area was subject to inundation by overbank flows from these rivers and by rainfall runoff during the monsoon season. About 52% of the project area was inundated every year due to overflow from the Jamuna, Ganges and Baral.

Over a period of the late 70's and early 80's the main flood protection embankment was built, which basically prevents spillage of water from the Jamuna and Ganges into the Project area. These major flood embankment was designed against a 1:100 year flood event,

Flooding in the scheme area has reportedly reduced very significantly since the construction of the main embankment (160 km in length) around the area. Previously a large part of the area had been flooded by spills into the area from the major rivers, as well as through backflow of the natural drainage channels of the Atrai and Baral rivers, the Kageswari Channel, the Ichamati and Sutikhali Channels. These inflows led to significant flooding in the Gandahesti, Ghughudaha and Pindurihati Beels.

People in many parts of the area say that at present flooding is by no means as severe as was experienced in the past, although flooding persists in certain areas, where the local draiange congestion occurs due to rainfall runoff within the scheme boundary. On the other hand, the flooding is currently experienced through the spillage of water from the Ganges which passes through the cross drainage culverts on the Paksey to Abdulpur railway line and hence into the scheme area.

Another source of overland flooding results from spillage from the Nandakuja channel in the north; these flows pass through Chalan Beel Polder A into the Moraa Baral Channel and then flows into the scheme area. It's occurrence is not infrequent, significant flows having only reportedly taken place in the severe monsoon flood of 1988.

Crop damage in this area appears to have been lower than that in other areas with significant proportions of medium lowland. This may be at least partly due to the effectiveness of the flood embankments. In the 1987 flood about 21% of the planted area of aman crops was estimated to be fully damaged, while in 1991 the corresponding figure was only about 5%.

However, no serious damage to infrastructure was reported concerning the 1987 flood. But in 1988, infrastructure under the local government was damaged to the tune of Tk. 13.5 million in the vicinity of Chatmohar, Atgharia, Madhapura and Bera and the amount of damage to road and bridges was estimated at Tk. 8.3 million.

Deeply flooded area in this planning unit is located mainly in the riverin area along the Hurasagar and Jamuna. The main constraint for flood control of this area is breach of flood embankment due to bank erosion along the Jamuna. Certain sections of the flood embankment located southeast of Bera are under aggressive attack of flood flow of the Jamuna.

5.16.2 Development scenario

Main constraint for flood control of this area is breach of embankments due to bank erosion along the Jamuna. But this should be covered by FAP 1 study.

The area has fairly effectively been provided with major flood protection facilities. The drainage facilities have also been provided with the both gravity and pumped types. Major impacts have already been effected both to fisheries and navigation.

Further development options are focused on securing the existing facilities and to provide further works to address shortcomings in the existing system by on-going schemes.

This planning unit area is located at the downstream end of the NW region and flood protection facilities do not have any adverse effect to any other area. Accordingly CFD suggested in on-going schemes may be supported by this regional planning.

In consideration of the present situation on development schemes of the planning unit presented below, no other proposal will be made in the present regional planning study.

5.17 Bangali Floodway

The Bangali floodway, which is contemplated as one of the promising CFD options for Planning Unit No.6 (Upper Karatoya) and/or Planning Unit No. 8 (Middle Bangali) where flood peak discharge is expected to increase due to provision of flood embankment in the upstream reaches. The floodway is planned to divert the flood flow of the Bangali coming from the upper Karatoya into the Brahmaputra. In addition to the mitigation of flooding in these basins, there will be advantages not only enabling to supply irrigation and domestic water from the Brahmaputra to the middle/lower Bangali reaches during the dry season but also to navigate from the Brahmaputra toward the upper Karatoya when the Brahmaputra is at high stage.

5.17.1 Alternative route

Two alternative routes, Route-1 and -2, which take different courses at the outfall point are examined, but these routes upstream of the confluence with the Bangali are the same. The alternative routes are shown in Figure 5.32.

The new channel at the downstream reach of Route-1 is aligned to connect the Bangali and the Brahmaputra near Sariakandi, where a length of the new channel is as short as about 5 km. The upstream end of the floodway is identified to be near Siraj through the hydraulic analysis, which clarifies that the upper Karatoya has sufficient conveying capacity in the upstream reach of Siraj and that the downstream reach thereof needs to be embanked. The Route-1 is about 120 km in river length, which comprises that in the Karatoya where the river improvement works by means of provision of flood embankments or excavation of existing channel are required.

The new channel of Route-2 diverts to the Brahmaputra about 20 km north of Sariakandi on the Bangali. The Route-2 is about 110 km in river length which likewise comprises that in the Karatoya.

5.17.2 Alternative channel section

For channel type of the floodway in the reach upstream of the confluence with the Bangali, three different channel types are conceived in terms of the typical cross section. One is single section and the others are compound section. Regarding the latter, two channel types are conceived, out of which one is to use the existing channel as it is and the other is enlargement of existing one. These channel sections are shown in Table 5.2. By combining the alternative routes and the alternative channel cross sections, the following six options are examined;

Option 1	:	Route-1, compound cross section with excavation of the existing river in the upper reach
Option 2	:	Route-2, compound cross section with excavation of the existing river in the upper reach
Option 3	:	Route-1, compound cross section without excavation of the existing river in the upper reach
Option 4	:	Route-2, compound cross section without excavation of the existing river in the upper reach
Option 5	:	Route-1, single cross section with excavation of the existing river in the upper reach
Option 6	:	Route-2, single cross section with excavation of the existing river in the upper reach

5.17.3 Planning principles

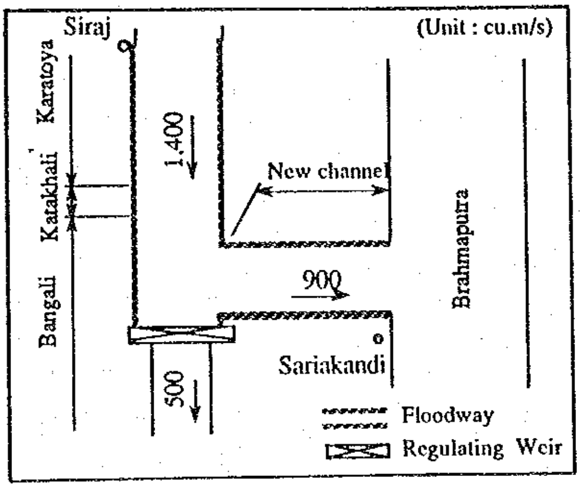
The preliminary design for the Bangali Floodway has been made at the pre-feasibility study level based on the design criteria described in Chapter 3 and in accordance with the following principles;

a) Design flood discharge

The present carrying capacity of the middle Bangali is estimated to be around 500 m^3/s through the uniform flow calculation. The Bangali floodway is planned to have the protection level of 20-year probability. Design flood discharge distribution for the floodway is determined on the conditions that;

- the Brahmaputra Right Embankment (BRE) is completely sealed.
- the Teesta Right Embankment (TRE) is completely sealed.
- the Ghagot Left Embankment(GLE) is embanked all along the reach as proposed.
- the regulator on the Alai which is proposed in GIP is kept closed during the monsoon season.

The design flood discharge distribution for the Bangali floodway, which is applied to both routes is established through the following examination;



b) Longitudinal profile

The river-bed slope of the new channel is determined to be almost the same as the average river-bed slope (1/10,000) of the present river stretch. The present features of the Karatoya / Bangali are shown in Figure 2.9.

c) Channel section

Flood water levels in the floodway in case of the single section type are set almost at the present left river bank levels along the alignment except for the lowermost stretch. The flood embankments for

the lowermost stretch are designed to have a crest level same as that of BRE at the outfall. Thus, the height of the embankments is determined taking account of the 100-year probable water level of the Brahmaputra at the outfall. The probable 20-year and 100-year water levels of the Brahmaputra at the outfall are as follows.

Alternative route	20-year probable water level	100-year probable water level
Route-1	17.95 m	19.17 m
Route-2	18.76 m	19.78 m

In case of the compound section with resectioning of the existing river channel, flood embankments are setback to the extent that the flood water levels become higher than the present left river bank levels by around 2 m so as not to make the present inundation conditions therein worse.

In case of the compound section without resectioning of the existing river, both flood embankments are setback at the same distance as that in the above case. Both types of the embankments in the compound section are required to be setback since it is favourable that the average velocity of the flood water is limited to less than around 3 m/sec in the high water channel from the viewpoint of safety of the embankments.

The new channel section is of a single section, since it doesn't require a long hauling distance to spoil excavated materials, and the embankments are able to be constructed with the excavated materials. Besides, it is possible to utilize the earth material in excess of the use for embankment for elevating the ground level of the nearby homesteads to reduce the spoil bank area. And the problem of local communication divided by the channel excavation is settled by means of constructing the regulating weir with bridge across the channel.

d) Backwater levee

Five tributaries such as the Mohila, Maccha, Akhira, Nalya, and Alai meet the floodway between Siraj and the outfall to the Brahmaputra. Usually, backwater levees become required to be constructed along the tributaries to avoid prolonged flooding caused by the backwater effect. On the other hand, regulators are planned to be provided at each confluence with the Alai and the Akhira. Therefor backwater levees are not required to be constructed at confluences with these rivers, taking into account that the catchment areas of the tributaries are not so large. The Alai is planned to be closed at the upstream end under GIP. As to the Akhira, the flood water of the Akhira is diverted into the Maccha with the backwater levees about 20 km upstream of the confluence with the floodway. Regarding single cross section type of the floodway, it is not necessary to provide the back-water levees along the tributaries since the flood water levels are set to be lower than the river bank levels.

e) Regulating weir

The regulating weirs are contemplated to be provided on the Bangali river and on the new channel both being located just downstream of the dividing point. The former is to function to divert the flood water from the Bangali into the new channel during the monsoon season, while the latter to take the irrigation and domestic water in the middle and lower Bangali basins during the dry season. The offtake and diversion discharges through the floodway are regulated by means of the proper operation of the gates to be installed on both the Bangali and the new channel.

f) **Regulator and sluiceway**

Regulators need to be provided along the left embankment of the floodway and along the tributaries on the northern side of the floodway to drain the inland water of the left bank side to the floodway. Regarding single cross section type of the floodway, regulators and sluiceways are also required to be provided in both the lower reaches and the upper reaches.

5.17.4 Comparison of alternative plan

The above alternatives of the floodway are designed and costed at the pre-feasibility level in accordance with the criteria and the planning principles so as to select the most favourable one. The total construction cost and land acquisition cost for each of the alternative plans are shown in Table 5.3 and summarized below.

Cost Item	Compound cross section without excavation low channel		Compound cross section with excavation low channel		Single cross section	
	Route-1	Route-2	Route-1	Route-2	Route-1	Route-2
	OPTION-1	OPTION-2	OPTION-3	OPTION-4	OPTION-5	OPTION-6
Construction (mil.TK)	2,076	1,854	1,540	1,358	4,051	3,527
Land acquisition (mil.TK)	235	200	219	189	810	684
Total (mil.TK)	2,311	2,054	1,759	1,547	4,861	4,211

The above table shows that construction cost of the Route-2 is about 10% less than that of the Route-1 in every case of the channel section. Moreover, the type of the compound cross section without excavation of the existing channel gives the lowest construction cost among three channel cross section types.

As for the route, Route-2 is preferable to Route-1, since the embankment volume and inundation area along the floodway for the former are less than those for the latter, although the excavation volume of the new channel in the Route-2 is more than that in the Route-1. Especially, in case of the compound section with excavation of the existing river, there is a great difference in work quantity and construction cost between the two routes.

As for the channel cross section, the compound cross section is preferable to the single section from viewpoint of the lower construction cost and the morphological change of the floodway.

Compared the two types of the compound cross section with/without excavation of the existing river, the type of 'without excavation' is preferable from the required construction cost, since in case of 'with excavation' a huge quantity of excavated materials needs to be hauled beyond the flood embankments located far from the river channel. Consequently, it will require the considerable spoil bank area and hauling cost. However, the inundation area in case of 'without excavation' is found to be larger than that of 'with excavation'.