M. A. Ali, S. M. Seraj and S. Ahmad (eds): ISBN 984-823-002-5

Performance Evaluation of FCD/FCDI Projects During the 1998 Flood

A.F.M. Saleh, S.M.U. Ahmed, M.R. Rahman, M. Salehin, and M.S. Mondal
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
and
M. Mirjahan
Department of Water Resources Engineering
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

Abstract

The performances of six flood control and drainage projects in mitigating the damage from the flood of 1998 have been evaluated. The magnitude of the 1998 flood exceeded the respective design flood levels of Dhaka-Narayanganj-Demra (D-N-D) project, Meghna Dhonagoda Irrigation Project (MDIP) and Narayanganj-Narsingdi (N-N) Project. But the projects were able to withstand the flood because of the freeboard and preventive measures taken by BWDB. In Compartmentalization Pilot Project (CPP), the 1998 flood was also higher than the design flood but the embankment was breached at three locations and cut at one location by outsiders. In Nagor River and Sakunia Beel projects the flood levels were below the design flood levels. But, because of cuts by outsiders, most of the Nagor River project was inundated. Except MDIP and Sakunia Beel projects, all the other projects could not achieve their desired targets of protecting the Aman crop. In D-N-D and N-N projects, the Aman crop was partially damaged due to drainage congestion. Because of flooding in Nagor River project, the Aman crop was totally damaged. In CPP, the compartmentalization concept has not worked and inadequate drainage together with failure by the sub-compartments to store floodwater have resulted in reduction in Aman area by about 50%. But, in spite of the damages inflicted, preliminary analyses on costs of flood fighting and returns from the Aman harvest in MDIP, CPP, D-N-D and N-N projects show that the benefits overwhelmingly outweigh the costs incurred, even without considering the intangible benefits.

INTRODUCTION

The flood of 1998 has been a catastrophic flood in terms of recurrence interval, flooded area and duration, especially in the Ganges and lower Brahmaputra basins. Because of the resulting colossal damage and destruction, it has raised a number of issues regarding the planning, design and performance of infrastructure, especially the Flood Control and Drainage (FCD)/Flood Control, Drainage and Irrigation (FCDI) projects. Bangladesh Water Development Board (BWDB), to protect the Aman crop from flooding and to enhance the agricultural productivity, implemented these projects. Over the years, BWDB has constructed more than 400 FCD/FCDI projects covering about 3.7 million hectare, which is about 60% of the total flood vulnerable area and about 40% of the net cultivable area of the country (Chowdhury et al., 1996). It has been estimated that because of the damages to Aman crop due to 1998 flood, the harvest has been reduced by about 2 million tons.

The FCD/FCDI projects are normally designed to withstand the 20-year flood with a freeboard of 0.9 m (BWDB, 1996). For most of the major and medium rivers of Bangladesh, the differences in peak water level between the average flood and the 100-year flood are in the order of 1-1.5 m. The difference between 20-year and 100-year flood is less than 1 m (Kruger and BCEOM, 1992; Chowdhury et al., 1996). Thus, even though the FCD/FCDI projects are designed for 20-year flood, with the additional freeboard of about 1 m, these projects should theoretically be able to withstand the 100-year flood without being overtopped. Whether the embankments of these projects are actually capable of withstanding the 100-year flood depends a lot upon how well have they been maintained. The specific objective of this study was to evaluate the magnitude of the 1998 flood in the context of the FCD/FCDI projects and to assess the performances of these projects in mitigating the flood damage, especially to Aman crop. The details of the findings of the study are given in Saleh et al., (1998).

METHODOLOGY

There are lots of variations in the more than 400 FCD/FCDI projects implemented by BWDB, in terms of the hydrologic setting, type, planning and design criteria, size and age of the projects. It is therefore difficult, if not impossible, to select a few projects that would represent the diversity. But, because of limited time and financial resources to complete the study, only six projects were selected for performance evaluation. The two criteria that dominated the selection process were that the projects must be located in the

severely flooded zone in 1998 and should have available past reports. Representation of all the major hydrologic zones, planning and design criteria, size, age and funding agency were also considered. The six selected projects were: (1) Compartmentalization Pilot Project (CPP), Tangail; (2) Dhaka-Narayanganj-Demra (D-N-D) Project, Dhaka; (3) Meghna-Dhonagoda Irrigation Project (MDIP), Chandpur; (4) Nagor River Project, Bogra; (5) Narayanganj-Narsingdi (N-N) Project, Narayanganj; (6) Sakunia Beel Project, Faridpur. The salient features are given in Table 1.

The methodology followed for the performance evaluation comprised of two phases. In the first phase, all existing secondary information (reports and data) of the relevant projects were collected. The information were then analysed and interpreted for developing a framework of parameters (both qualitative and quantitative) to be used in the evaluation. The developed framework was used during the field visits for assessing the physical condition, design appropriateness and effectiveness of the infrastructure. In addition, the design criteria of the infrastructure were also reviewed to check their adequacy in mitigating losses from a flood of the magnitude of 1998 flood. For analysing the magnitude of 1998 flood, all relevant hydrologic data for the selected projects were also collected from BWDB.

Table 1: Salient features of the selected projects

Name of Project	Hydrologic Zone	Type	Area (ha)	Funding Agency	Year of Completion
CPP	Central	FCD	13,200	FAP-20	1995
D-N-D	Central	FCDI	8,340	World Bank	1968
Meghna-Dhonagoda	SE	FCDI	17,580	ADB	1987
Nagor River	NW	FCD	15,400	EIP	1986
N-N	Central	FCDI	3,000	JICA	1993
Sakunia Beel	SW	FCD	5,700	GoB	1985

The field visits to each of the selected projects were undertaken in the second phase and the existing condition of the infrastructure (flood control and drainage) was assessed using the developed framework of parameters. Qualitative assessment of the performance of the project and flood damage (if any), was made by interviewing a wide range of informants, visiting the affected/damaged areas and reaching informed judgements in the field. The information collected from the field were cross checked with the data available with the BWDB project officials and in case of any contradiction the information collected by the team prevailed.

ANALYSIS OF THE 1998 FLOOD

From the analyses of flood magnitude it was evident that the 1998 flood was of moderate magnitude in the middle Brahmaputra-Jamuna basin. For Nagor River project and CPP, the 1998 flood magnitude was lower than the previous highest flood (1988 flood) with flood return periods of 10-year and 27-year, respectively. In the lower Brahmaputra and lower Meghna basins, the 1998 flood was catastrophic and exceeded all previous records, both in terms of water level height and in duration. For N-N and D-N-D projects of lower Brahmaputra basin, and MDIP of lower Meghna basin, the 1998 flood could well be classified as the 100-year flood. Even though the 1998 flood was also catastrophic in the Ganges basin, the Sakunia Beel project was not seriously affected as this has now become a compartment of the greater Faridpur-Barisal project and is protected by the Ganges Right Embankment. Because of the regulated flow of the Kumar River, the 1998 flood was like a normal flood for the Sakunia Beel project. The 1998 flood return period and the durations above the danger/design levels for the studied projects are given in Table 2.

Table 2: Return period and duration of 1998 flood

Name of Project	Design Return Period (Yrs)	1998 Flood Return Period (Yrs)	Duration Above Danger/Design Level (days)
CPP	Not Available	100	44
D-N-D	20	27	62
Meghna-Dhonagoda	100	> 100	64
Nagor River	20	10	N/A
N-N	25	100	33
Sakunia Beel	20	Not Applicable	Not Applicable

PROJECT PERFORMANCE

Compartmentalization Pilot Project

Flood Control

Contrary to the concept of the traditional FCD projects, where river flooding is both unacceptable and undesirable, the Compartmentalization Pilot Project (CPP), Tangail, was designed to serve the purposes of flood control, controlled or beneficial flooding and flood storage in pre-defined sub-compartments to reduce flood damages elsewhere. Controlled flooding within the compartment would be achieved mainly through the Main Regulator on Lohajang River, and that within

the sub-compartments by the sub-compartment water management committees through other peripheral inlets and water control structures. By lowering the water level of the Lohajang river using the Main Regulator, the river would be allowed to act as an outlet in which the sub-compartments would drain through their numerous internal regulators.

Unlike normal flood years when the Main Regulator along with other inlets are kept open in the pre-monsoon season, the unusual rainfall in May 1998 (103% higher than average) at Tangail forced the Main Regulator to be closed with the outlets open to facilitate drainage. As the water level started rising, the Main Regulator along with other inlets were opened on 1 June to 'control flooding' so as to allow the entry of fingerlings into the compartment and siltation on the field. The Main Regulator was partially closed on 9 July in 1998 to effect 'flood control' by restraining the inside water level from surpassing the allowable level of 11 m PWD. The water level upstream of the inlet exceeded the danger level of 12.04 m on 15 July and remained over the danger level for 62 days. The level was as high as 13.39 m PWD on 8 September that corresponded to a 27-year flood, only 4 cm lower than the previous highest flood level of 1988. The main regulator was totally closed on 26 August following a breach in the peripheral embankment at Rasulpur on 25 August, in order to lower the water level of Lohajang river and to facilitate 'drainage' of flood water.

The water level difference inside and outside CPP during the flood was more than 2 m threatening a major failure of CPP embankment. Although as per the original concept, the embankment was to be overtopped in case of a more than 20-year flood with all the inlet structures open, this was not allowed to happen by the project people. The freeboard of 0.3 m beyond the 1988 flood level did not allow overtopping of the embankment, but at some locations (approximately a total of length of 9 km) overtopping was prevented by raising the crest level with sand bags.

Much effort was given to prevent the CPP area from flooding by taking protective measures along its peripheral embankment, and by operating its inlet structures carefully. But, despite all efforts made by the sub-compartment water management committees, individuals and project officials, some of the areas of the CPP suffered from flooding due to breaching at three locations (Rasulpur, Passbetur and Indrabelta) and public cut at one location (Pauli) along the peripheral embankment. The public cut and the breaches except the one at Rasulpur were closed in two days, while the breach at Rasulpur that occurred on 25 August could not be closed due to high head difference. About 200 m of the embankment was badly damaged by erosion of Pungli River at Birnahali during the flood. Thus, although designed against a 20-year flood, the project was partially successful in mitigating damages from 27-year flood of 1998.

Drainage

The unusual rain in May and July (103% and 68% above average, respectively) caused severe inundation and restrained seedbed preparation, destroyed seedlings and delayed transplantation of T. Aman. Because of the breaches and the public cuts, there was flooding and crop damage in sub-compartments 6, 7 and 8. There was backwater effect starting from 9 September at the southern part of the project that could not be controlled because of the absence of any such provisions, and hence it caused considerable flooding and crop damage in sub-compartments 13, 14 and 15. Thus, 'compartmentalization concept' did not work during the 1998 flood.

The sub-compartmental embankments being porous also resulted in drainage congestion during the heavy rainfall of May and July that caused crop damage. With adequate control on water in watertight sub-compartments, damages due to rainfall, breaching and backwater flooding could have been averted.

Dhaka-Narayanganj-Demra (D-N-D) Project

Flood Control

The elevation of the top of the flood wall (where it exists) of the D-N-D project varied from 7.47 m to 7.62 m PWD and the highest water level during the 1998 flood at the project's pumping station was 6.49 m. So the flood wall was not overtopped at any place of the project and was always at least about one meter above the highest flood level at all points. The railway embankment top between I.T. School and Chashara Railway Station where there is no flood wall was set at about 6.8 m to 7.4 m PWD after the 1988 flood. The highest water level recorded at Narayanganj was 6.92 m PWD. Though the maximum difference between the highest water level at Narayanganj and the embankment top was 12 cm, the embankment was overtopped at a number of points by water depths of up to 65 cm. This might have happened due to inadequate maintenance or settlement during the last 10 years. Several slope failures due to seepage, piping, leakage, sliding and overtopping were observed during the field visit.

It can therefore be concluded that the embankment of the project having floodwall has been successful and effective in protecting the area from the 1998 flood. The problems encountered in this part of the embankment were mainly due to 18 drainage pipes of WASA and one old culvert at Ranimahal. These buried pipes and old culvert should immediately be removed or be adequately sealed up for the safety of the embankment. The embankment between I.T. School and Chashara is a very weak railway-cum-flood protection embankment and its performance during the flood was very poor. The crest level, crest width and side slopes should be corrected and revised for the safety of the project.

Drainage

The D-N-D project has provisions for pump drainage but the four pumps of the project were out of operation from 4 September to 14 September, 1998, for a total of 11 days because of rise in river side water level beyond the pump operation limit (6.2 m). The drainage situation was further deteriorated due to increase in drainage volume through rainfall, leakage, seepage, piping, overtopping, industrial and domestic wastes etc.. It was assessed that in about half of the gross project area the crop loss due to drainage congestion was at least 40%. In fact, in about 1915 ha (40% of the gross land), which are located below the elevation 2.64 m PWD, and where the submergence was more than 15 days, the damage to Aman crop was total. Farmers also corroborated these findings during the field visit in October 1998.

Meghna-Dhonagoda-Irrigation Project

Flood Control

The MDIP was successful in withstanding the 1998 flood, which was unprecedented in the history of the project, both in terms of magnitude and duration. The highest1998 flood water level of 5.64 m at Chandpur on Meghna corresponded to a more than 100-year flood. The previous highest level of 5.08 m in 1988 corresponded to around 30-year flood. The water level was above the danger level for 88 days and above the 100-year flood level for 6 days. So it was the freeboard that prevented the embankment from being overtopped.

The project started experiencing multifarious problems since the second week of July when flood water first exceeded the danger level. There were four flood peaks, on 29 July, 10 August, 25 August and 9 September. Each one came before the river level could recede, and so there was continuous flow of large volume of water for over two months, causing huge damages to the embankment. About 250 seepage holes, 320 boiling points, 83 piping points, 3610 m of sliding of country side (c/s) and 2525 m sliding of river side (r/s) slopes of the embankment were reported by BWDB.

The main reason for such damage may well be attributed to persistently long high water level beyond the design level, head difference between the inside and outside water levels, weak sub-soil properties of the embankment, and inadequate embankment design (less than design crest width). Field visit revealed that most parts of the embankment were constructed with sandy soils that were vulnerable to piping and seepage problems. The portion resectioned (12 km) with proper width and r/s slope suffered little, while the old portion suffered most, especially in areas adjacent to launch terminal and where there were borrow pits on the c/s. Besides, the embankment was endangered by thousands of trees along the embankment. Wave action and wind caused the trees to get dislodged leading to piping and seepage at many places.

The protective measures undertaken by BWDB during the flood were: (i) piling and filling of slopes by sand bags to prevent sliding (3380 m); (ii) share key to prevent sliding (at 151 locations); (iii) ring filter for protection against boiling (at 99 locations); (iv) control of erosion due to wave action by packing water hyacinth (13 km); and (v) feeding of water to the irrigation canal to minimize the head difference.

As the Meghna near MDIP carries the combined flow of both the Meghna and the Padma (the Ganges and the Brahmaputra), riverbank erosion is a major problem. The setback distance designed considering 100 years of river erosion has proved to be inadequate as the present erosion rate is much higher than the rate estimated at the feasibility stage. In the western part of the Project (Mohanpur and Dashani), river bank erosion assumed a serious turn because of 1998 flood. Around 3 km of such embankment along Meghna was under threat, so was around 1.5-2 km of the Dhonagoda side in the south-eastern part (Gazipur, Shibpur, Amirabad and Torki).

Drainage

The MDIP has provisions for pump drainage and there was very little drainage congestion problem inside the project area during the flood, as reported by BWDB. The water level inside the project was kept slightly higher than the design level by pumping water from the rivers to the irrigation canals with the purpose of minimizing the head difference between the inside and outside of the project.

Nagor River Project

The return period of 1998 flood in Nagor River was about 10 years and it was not an exceptionally high flood both in terms of magnitude and duration. The average flood water level remained about 1 meter below the embankment top and embankment was not overtopped at any place during the 1998 flood. Overtopping had rarely been observed since the implementation of the project in 1986. However, since its completion, Nagor River Project has regularly experienced flooding due to public cuts on its embankment made by the inhabitants of adjacent Nagor Valley Project. During the flood, the neighbouring Nagor Valley Project (on the right bank of Nagor river and just opposite to the Nagor River Project) was submerged due to heavy rainfall and overflow of floodwater from the Raktadoha-Lohachura Project. Consequently, the Nagor Valley Project inhabitants cut the embankments on both sides of the Nagor river so that water finds a direct route to south-eastern lower floodplain through the Nagor River Project. This phenomenon of public cut has become a routine event. Public cuts were made during 1987 and 1988 floods and after reviewing the

prevalent situation, FPCO (1991) considered the project as a total failure. The project has been rehabilitated in 1997/98 as per "Redesign Project" undertaken in 1993/94. Nagor Valley project has also been rehabilitated in the mean time. But the situation remains unchanged. Public cuts were made in 1996 and 1997. The 1998 flood year was no exception. Public cuts were made very early in the flood season inundating the entire project area. During the field visit in November 1998, six public cuts were seen.

Field level discussion with Nagor Valley Project inhabitants revealed that they made the public cuts to save their homesteads from flood damage. They said that given the hydrological situations of the area they have no other alternatives and they will continue to do so in future under similar circumstances. Inhabitants of Nagor River Project patrolled their embankment regularly to deter the public cuts but of no avail.

According to the Nagor River Project inhabitants, the damage to their Aman crop would have been much lower in absence of any embankment at all. Before the project, water level used to rise slowly and B.Aman could grow gradually with the floodwater. Because of the public cuts, the damage to the Aman crops is total as the water level increases suddenly in the project area and the water velocity remains very high.

In Atrai basin, series of projects have been implemented since late seventies without basin-wide planning. As a result, problems like waterlogging, confinement, back flow and backwater effects, siltation, public cutting etc. have become commonplace. Among the projects, Nagor River Project being situated in the downstream end is the worst affected. Given the hydrological situation in the region, modification of the entire project into a submersible one with adequate post-monsoon drainage facilities so that the area remains under free flow condition during monsoon, appears to be the only viable option. BWDB project officials and local people also supported this option during the field visit. Under this option, damage to Aman crop will reduce and the gain in Boro production will be retained.

Narayanganj-Narsingdi Irrigation Project

Flood Control

The crest level of the embankment was set at 7.5 m PWD and the highest water level during the 1998 flood was at 7.12 m. Thus, the embankment was not overtopped at any place of the project and was always at least 30 cm below the crest level at all points. But, the persistently long high flood level beyond the designed level of 6.6 m for more than a month had its toll on the stability of the embankment. BWDB officials reported more than 300 major and minor leakage points along the embankment. But during field visit on 11-12 October 1998,

seven severe slope failures due to seepage, piping and leakage problems were observed.

Random sampling of cross section measurements at a number of points of the embankment showed that the side slopes of both the r/s and c/s have been adequate and maintained as per design. The crest width was never found to be 6 m (the designed value) and varied from 4.5 to 5.2 m. The embankment was heavily encroached, especially on the c/s slope by shops, homestead, trees etc.. The turf on the r/s has been damaged by flood but where they existed in the c/s, they were in good condition.

It can therefore be concluded that the embankment of the project has been successful and effective in protecting the area from 1998 flood even though the flood level was 0.5 m higher than the designed flood level. The problems encountered during the 1998 flood, which threatened the embankment and the project, were not because of inadequate design but because of improper construction. The borrow pits/ponds/depressions on the c/s adjacent to the toe of the embankment should be immediately filled up and the buried pipes/culverts (not belonging to the project) should be immediately removed or adequately sealed up for the safety of the embankment.

Drainage

The designed pumping capacity of the project was adequate to meet the internal drainage demand of the 1998 flood. But, even then, there were significant damages to Aman crop during the 1998 flood due to severe drainage congestion. Because of interruption in power supply the pumps could not operate at the desired time and rate. The average daily power interruption during the flood season (from 1 July, 1998 to end of September) was 2.17 hours with a maximum of 8.9 hours. Even when there was power, the pumps could not be operated because of low voltage (the pumps require 400V for their operation). Moreover, higher than designed flood level at the r/s resulted in a total shut down of the pumping station for 24 days (from 25 August to 17 September) with disastrous effect on the standing Aman crop. As per the operation manual, the pumps are not to be operated if the water level in the r/s exceeds 6.8 m PWD.

From the analyses of water levels in the c/s and r/s at the pumping station during the 1998 flood and area-elevation curve of the project, it was evident that in more than one third of the total arable land of the project area the crop loss due to drainage congestion was at least 40% or more. In fact, 25% of the agricultural land, where the submergence was for more than 15 days, the damage to Aman crop was total. The farmers also corroborated these findings during the field visits.

Sakunia Beel Project

Flood Control

The Sakunia Beel Project, consisting of a number of small beels including Sakunia as the main one, is now considered as one of the several sub-projects of the large scale Faridpur-Barisal Project. The Ganges right embankment of the project now protects the Sakunia Beel Project along with other sub-projects; and the Madankhali regulator at the mouth of Kumar at Faridpur regulates the flow of water in the Kumar inside the project area.

Contrary to the unprecedented magnitude and duration of the 1998 flood elsewhere in the country, the project was almost completely free from flooding of Kumar River. The highest water level of the Ganges at Goalundo upstream of the Madankhali regulator was 10.19 m corresponding to a flood with well over 100-year return period and the water level remained above the danger level for 68 days. However, efficient operation of the Madankhali regulator ensured that the water level of Kumar at Faridpur was always maintained far below the danger level of 7.5 m. So there was no question of the Kumar river embankment being overtopped.

The flood control embankment along the Kumar performed well against the regulated flooding in the Kumar. However, the embankment suffered some damages to the r/s slopes at several locations due to the non-existence of proper setback distance. The FAP 12 study (FPCO, 1991) as well as field inspection revealed that almost no setback distance was provided for about 85% of embankment reach.

The BWDB did not take any emergency protective measures in the project as the extent of damage was not as threatening as that of other severely affected flood control projects. Their flood fighting activities were mainly concentrated along the large scale Ganges embankment as prevention of any breaches would automatically reduce the risk of any significant damage to the sub-projects of the Faridpur-Barisal Project.

Drainage

The project experienced severe backwater flow in the Gabra khal on the southern part of the project, which overtopped the adjacent dwarf embankment (from Joyjhap to Gotti bridge, poorly constructed with earth spoil with no defined crest level) over most of its parts causing breaches at two locations. Consequently, about 20% area in this extreme southern part of the project was inundated, and drainage congestion prevailed over one month as reported by the local people. The backwater flow seems to have resulted from the unusual high water in the lower reaches of Kumar river due to serious bank erosion by flood water that washed away a 5 km reach of the Ganges embankment near Char Harirampur and Char Bhadrashan Unions.

Drainage in the greater upper part of the area was reasonably effective, if not very efficient. Defective lifting device of one gate of the Mridhadangi regulator, siltation of the drainage canal and cracked wing wall were observed during the field visit. Although the operation was not affected much, the damages need to be repaired soon as it may pose the risk of getting worse with time.

COSTS AND BENEFITS OF FLOOD FIGHTING

Except MDIP and Sakunia Beel project, all the other projects could not achieve their desired targets of protecting the Aman crop. In D-N-D and N-N projects, the Aman crop was partially damaged due to drainage congestion resulting from persistently high river water level above the design level. Because of flooding in Nagor River project, the damage to Aman crop was total. In CPP, the compartmentalization concept has not worked and inadequate drainage together with failure by the sub-compartments to store floodwater has resulted in reduction in Aman area by about 50%.

But, in spite of the damages inflicted on Aman crop, preliminary analyses on costs of flood fighting and returns from the Aman harvest in MDIP, CPP, D-N-D and N-N projects show that the benefits overwhelmingly outweigh the costs incurred, even without considering the intangible benefits. The costs of flood fighting and the gross return from Aman harvests for the studied projects are given in Table 3.

Table 3: Costs of flood fighting and returns from Aman harvests

Name of Project	Cost of Flood Fighting* (Million Taka)	Return from Aman Harvest (Million Taka)
CPP	4.78	5.64
D-N-D	7.00	38.20
Meghna-Dhonagoda	7.40	234.40
Nagor River	1.07	0
N-N	4.00	19.20
Sakunia Beel	N/A	N/A

*Source: BWDB (1998)

CONCLUSIONS

For N-N and D-N-D projects of lower Brahmaputra basin and MDIP of lower Meghna basin, the 1998 flood was catastrophic with 100-year return period,

which exceeded all previous records, both in terms of water level height and duration. Even though the 1998 flood was catastrophic in the Ganges basin, Sakunia Beel project was not seriously affected, as this has now become a compartment of the Greater Faridpur-Barisal project. For both Nagor River project and CPP, the 1998 flood magnitude was lower than the previous highest flood (1988), with return periods of 10-year and 27-year, respectively.

Even though the 1998 flood magnitude exceeded their respective design flood levels, D-N-D, MDIP and N-N projects were able to withstand the flood because of the freeboard and preventive measures taken by BWDB. In CPP also, the 1998 flood was higher than the design flood but the embankment was breached at three locations and cut at one location by outsiders, thus, partly depriving the people of the benefits of the embankment. In Nagor River and Sakunia Beel projects the flood levels were below the design flood levels. But, because of public cuts by outsiders, most of the project was inundated.

Except MDIP and Sakunia Beel project, all the other projects could not achieve their desired targets of protecting the Aman crop. In D-N-D and N-N projects, the Aman crop was partially damaged due to drainage congestion resulting from persistently high water level above the design level. Because of flooding in Nagor River project, the damage to Aman crop was total. In CPP, the compartmentalization concept has not worked and inadequate drainage together with failure by the sub-compartments to store flood water has resulted in reduction in Aman area by about 50%.

In spite of the damages inflicted on Aman crop, preliminary analyses on costs of flood fighting and returns from the Aman harvest in MDIP, CPP, D-N-D and N-N projects show that the benefits overwhelmingly outweigh the costs incurred, even without considering the intangible benefits.

From the review of the design criteria of the studied projects, analysis of the 1998 flood data and performance evaluation of the projects during the 1998 flood, it has become evident that the present embankment design criteria is adequate to withstand even the 100-year flood and there is no need to revise or upgrade the design flood level. In none of the studied projects the embankment was overtopped and breaches that occurred were not because of faulty design but because of public cuts, poor construction and/or inadequate maintenance.

The repercussions of FCD/FCDI projects on the flood level in the unprotected areas deserve a holistic analysis. Unless this is done the disgruntled outsiders will continue to cut the embankment and curtail the benefits of the FCD/FCDI projects. Piecemeal implementation of FCD/FCDI projects should be discontinued and projects should be implemented only after rigorous regional analysis.

REFERENCES

BWDB (1996).Standard Design Manual, Vol. 1, Design Section, Bangladesh Water Development Board, Dhaka.

BWDB (1998). Report on damage to infrastructure during 1998 flood and the probable cost rehabilitation. Monitoring and Evaluation Office, Bangladesh Water Development Board, Dhaka.

Chowdhury, J.U., M.R. Rahman and M. Salehin (1996). Flood control in a flood plain country: Experiences of Bangladesh. Institute of Flood Control and Drainage Research, BUET and Islamic Educational Scientific and Cultural Organization, Rabat, Morocco, p.135.

FPCO (1991). FAP 12 FCD/I Agricultural Study: Rapid Rural Appraisal of Nagor River Project, Flood Plan Coordination Organization, Dhaka.

Kruger Consult and BCEOM (1992). Flood Modeling and Management, Flood Hydrology Study, Main Report, FAP 25, Flood Plan Coordination Organization, Dhaka.

Saleh, A.F.M., S.M.U. Ahmed, M.M. Miah, M.R. Rahman, M. Salehin and M.S. Mondal (1998). Performance Evaluation of FCD/FCDI Projects During 1998 Flood. Institute of Flood Control and Drainage Research, Bangladesh University of Engineering and Technology, Dhaka.