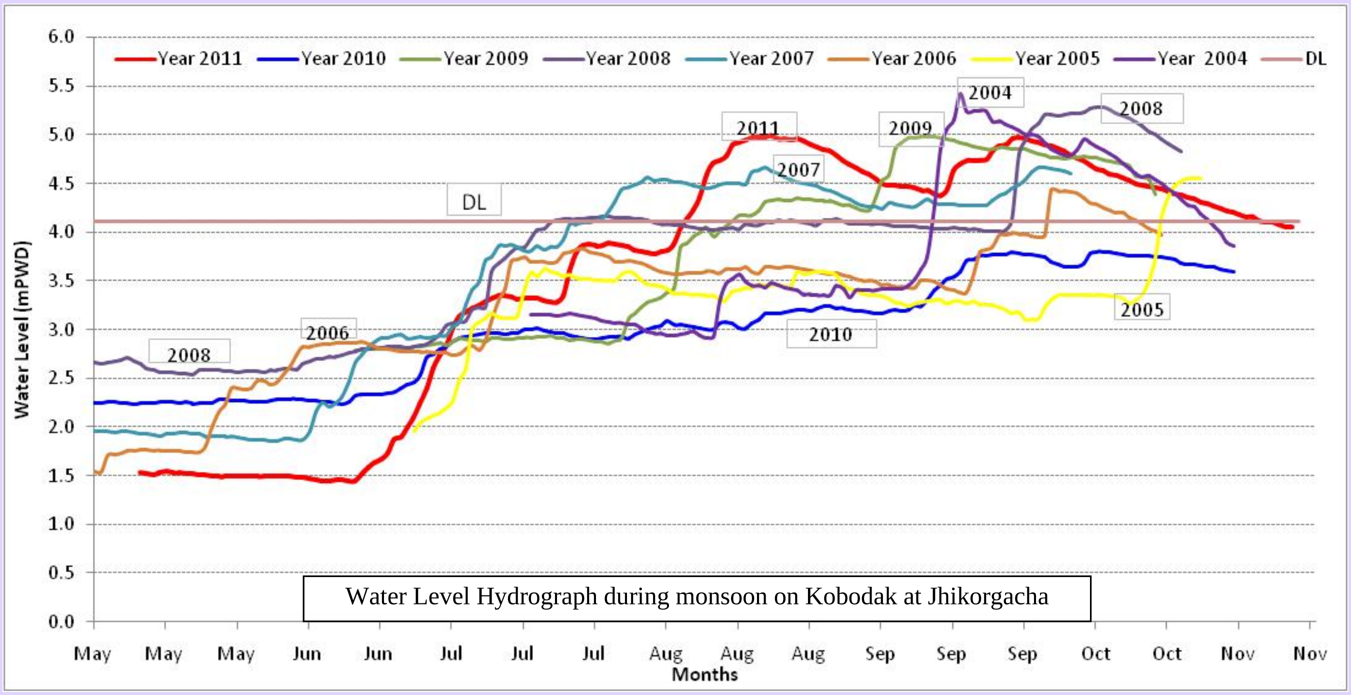
ANNUAL FLOOD REPORT 2011



FLOOD FORECASTING & WARNING CENTRE
PROCESSING & FLOOD FORECASTING CIRCLE
BANGLADESH WATER DEVELOPMENT BOARD

Annual Flood Report 2011

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Published by the FFWC, BWDB, Ministry of Water Resources, Dhaka with financial assistance from the CDMP-II, Ministry of Food & Disaster Management

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PREFACE

Bangladesh is the part of world's most dynamic hydrological and the biggest active delta system. The topography, location and outfall of the three great rivers shapes the annual hydrological cycle of the land. Too much and too little water in a hydrological cycle is the annual phenomenon. Regular monsoon event is the flood, the depth and duration of inundation are the deciding factors whether it affecting beneficially or adversely. Monsoon inflow along with rainfall historically shapes the civilization, development, environment, ecology and the economy of the country. Extreme events of flood adversely affect the development, economy, poverty and almost every sector. In flood management, Bangladesh has been taken structural and non-structural measures. One of the main non-structural measures is the flood forecasting and warning.

As stated in the BWDB Act-2000, Flood Forecasting in Bangladesh is the mandate and responsibility of Bangladesh Water Development Board (BWDB) and Flood Forecasting and Warning Center (FFWC) is being carried out this. The FFWC was established in 1972 and is fully operative in the flood season, from April to October every year, as directed by the Standing Orders for Disaster (SOD) of the Government of Bangladesh. The FFWC is acting as the focal point in co-ordination with other ministries and agencies like BMD, DMB, DAE etc during the monsoon for flood disaster mitigation and management.

The objectives of flood forecasting and warning are to enable and persuade people and organizations to be prepared for the flood and take action to increase safety and reduce damage. Its goal is to alert the agencies/departments to enhance their preparedness and to motivate vulnerable communities to undertake protective measures.

The professionals of FFWC gratefully acknowledge the valuable advice and leadership of Director General, BWDB for his interest, continuous drive and suggestion. The valuable suggestions and encouragement provided by the ADG (Planning), BWDB to improve the quality of works of the center. The direct contribution, directives and sharing of Mr. Md. Salim Bhuiyan, Superintending Engineer, Processing & Flood Forecasting Circle, BWDB are respectfully remembered in carrying out the activities of the FFWC.

The services of Gauge Reader's, Wireless operators and other support service providers are gratefully acknowledged. The FFWC is also grateful to the print and electronic news media and those who helped in disseminating the flood information during flood 2011. A number of NGOs have been working in different areas for dissemination of the FFWC flood warning message at grass root level (Union and Village), this enables flood preparedness at local level.

With support from the Bangladesh Disaster Management Bureau (BMD), Cell Broadcasting (CB) has been started from July-2011 for flood warning message dissemination. Instant Voice Response (IVR) method is used; anyone can call 10941 from Teletalk mobile and hear a recorded Bangla Voice Message regarding days flood situation. As normal call charge applicable, the voice message is given within one minute duration. This method of innovative type disaster message dissemination is awarded in the Digital Innovation Fair 2011.

It is great pleasure that the regular observer of the FFWC web-site, noted by distinguished personalities at home and abroad is source of inspiration for improving the quality of services. Suggestion, feed-back and appreciation from policy level, ministries, different levels of GOs and NGOs is great encouragement of the professionals working in the FFWC. This is indeed a struggle and commitment to continue the services from April to October continuously, without week-ends and holidays. The FFWC with its very limited resources and manpower is working very hard to carry out the responsibility during the monsoon. The FFWC is trying to develop further the process and system to cope-up with the technological and computational development. One of the main struggle and demand is to increase flood forecasting and warning lead time.

The FFWC hopes that this report might be a point of interest to the planners, designers, administrators, working in the water sector, disaster managers/fighters and various activities of formulating measures for flood mitigation/management in Bangladesh. The FFWC warmly welcomes comments and suggestions; these would certainly improve the services, activities and output of the FFWC in the coming days.

Finally, I sincerely thank and acknowledge my colleagues of the FFWC whose earnest and sincere co-operation made it possible to publish this Annual Flood Report-2011.

(Md. Amirul Hossain)
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Executive Summary

The characteristics of flood of 2011, is a representative one in respect of flood timing, duration and magnitude. During the monsoon 2011, the flood was not severe one, duration was short in the north (along the Brahmaputra-Jamuna River) and short to moderate in the part of north east. Duration of flooding in the central part(along the Padma river) was moderate. Duration of flooding in the south west, in the part of Satkhira and Khulna districts was prolong, due to slow drainage or very low carrying capacity of rivers, specially Kobodak, Haribhanga & Shibsa river system. Water Level of Kobodak River at Jhikorgacha flowed above danger level for 89 days. As a whole, the monsoon 2011 was a normal flood year. The evaluation indicated that the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2011 is around 93%, 88% and 78% accurate for 24hrs, 48hrs and 72hrs lead time respectively.

The country as a whole received 5.9% less rainfall than normal during the monsoon-2011 (May to September). The Brahmaputra, Meghna, South Eastern Hill and basins received 10.8%, 13.3% and 0.7% less rainfall than the normal value respectively and only the Ganges basin (in the north-west, west and south-west region of the country) received 5% more rainfall. During the monsoon-2011 all the basins of the country recorded rainfall value higher than the normal in August and considered as wet month. All the basins of the country recorded less rainfall than the normal in July. Basin wise monthly percent less(-) or more(+) rainfall than the normal is presented in the following table.

The monthly rainfall recorded during August at Serajgonj, Bogra, Rajshahi, Satkhira and Panchpukuria exceeded the previous monthly maximum value of those stations.

Month	Brahmaputra basin	Ganges basin	Meghna basin	SE Hill basin
May	-19.9%	-33.6%	-16.0%	+7.0%
June	-39.7%	+18.1%	-23.8%	-23.7%
July	-25.0%	-12.2%	-16.8%	-29.2%
August	+61.2%	+59.3%	+13.2%	+30.6%
September	-16.0%	-14.3%	-22.5%	+47.8%

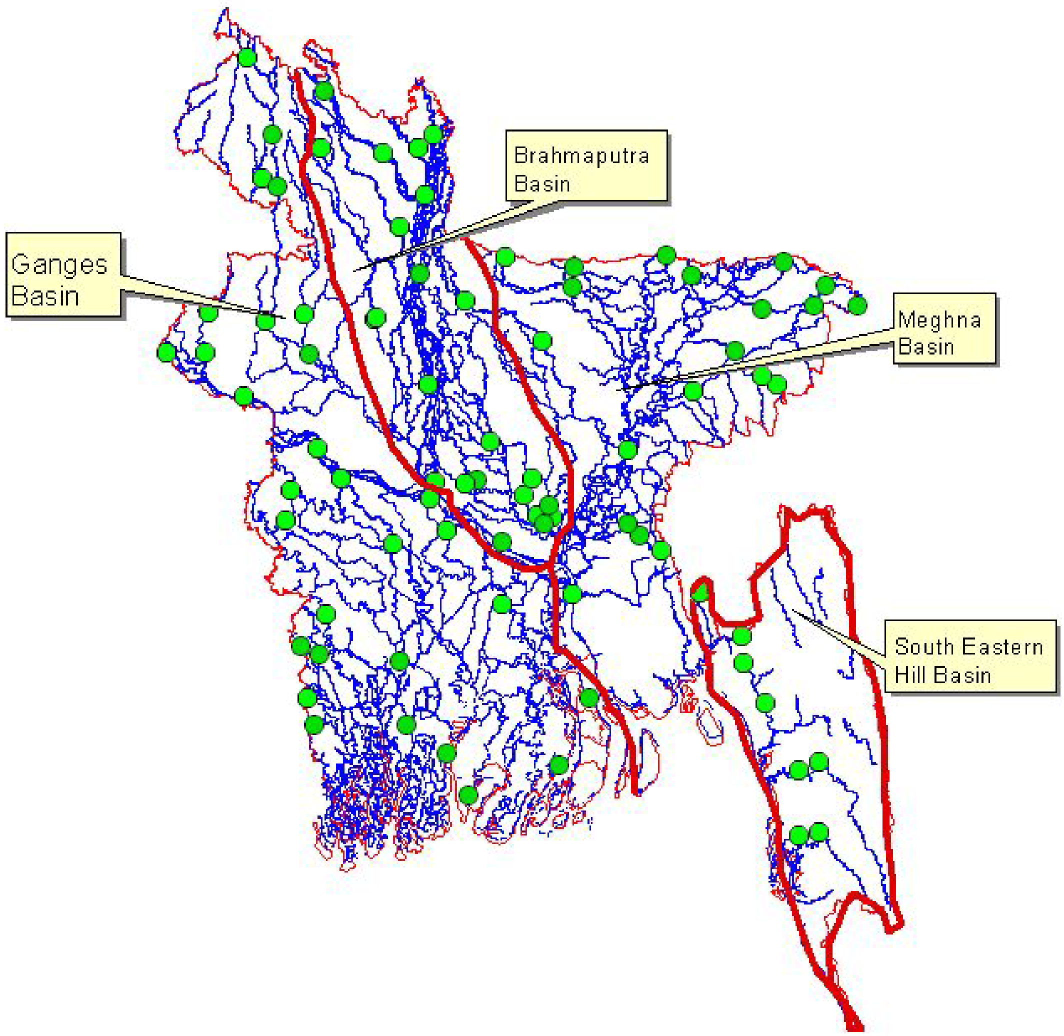
BWDB Data 2011

Professionals of the FFWC has been fully dedicated and committed to generate and disseminate flood forecasting and warning services despite of limited resources, technology, logistics and man-power.

During the monsoon-2011, maximum flooded area was 20% of the whole country (29,800 sq-km approximately). Some of the regions experienced river bank errosion and flash flood. The part of south west area flooded for prolong period.

List of Abbreviations

ADG	Additional Director General
ADPC	Asian Disaster Preparedness Centre
BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CB	Cell Broadcast
CDMP	Comprehensive Disaster Management Programme
CEGIS	Centre for Environmental Geographical Information Services
CFAB	Climate Forecast Application Bangladesh
CARE	Cooperative for American Relief Everywhere
CFAN	Climate Forecast Application Network
DG	Director General
DL	Danger Level
DMB	Disaster Management Bureau
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
DEM	Digital Elevation Model
DAE	Department of Agriculture Extension
FFWC	Flood Forecasting and Warning Centre
GM	General Model
GBM	Ganges Brahmaputra Meghna
IWM	Institute of Water Modelling
IVR	Instant Voice Response
MAE	Mean Absolute Error
MoFDM	Ministry of Food and Disaster Management
MoWR	Ministry of Food Water Resources
NGO	Non-Government Organization
MSL	Mean Sea Level
RIMES	Regional Integrated Multi-hazard Early Warning System
SOD	Standing Order on Disaster
SSB	Single Site Band
SPARRSO	Space Research and Remote Sensing Organization
USAID	United States Agency for International Development
WL	Water Level



Basin Map of Bangladesh with Water Level Monitoring Stations

CHAPTER 1: INTRODUCTION

1.1. THE PHYSICAL SETTING

Bangladesh lies approximately between $20^{o}30'$ and $26^{o}40'$ north latitude and $88^{o}03'$ and $92^{o}40'$ east longitude. It is one of the biggest active deltas in the world with an area of about 1,47,570 sq-km. The country is under sub-tropical monsoon climate, annual average precipitation is 2,300 mm, varying from 1,200 mm in the north-west to over 5,000 mm in the north-east. India borders the country in west, north and most part of east. The Bay of Bengal is in the south, Myanmar borders part of the south-eastern area. It has 230 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna. Three rivers originated from Myanmar. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment, inundation of more than that causing direct and indirect damages and considerable inconveniences to the population.

The country is mostly flat with only few hills in the southeast and the northeast part. Generally ground slopes of the country extend from the north to the south and the elevation ranging from 60 meters to one meter above Mean Sea Level (MSL) at the boundary at Tentulia (north) and at the coastal areas in the south. The land in the west of the Brahmaputra is higher than the eastern part. Several large depressions have been formed, particularly in greater Mymensingh, Sylhet and part of Pabna-Rajshahi districts. The country consists of the flood plains of the Ganges, the Brahmaputra and the Meghna rivers and their numerous tributaries and distributaries. The Ganges and the Brahmaputra join together at Aricha-Goalundo and is known as the Padma River. The river Meghna joining the Padma near Chandpur flows to the Bay of Bengal as the Meghna River.

1.2. THE RIVER SYSTEM

The Ganges, Brahmaputra and Meghna river systems together, drain the huge runoff generated from large area with the highest rainfall areas in the world. Their total catchment area is approximately 1.6 million sq-km of which only about 7.5% lies in Bangladesh and the rest, 92.5% lies outside the territory. It is assumed that an average flow of 1,009,000 Million cubic meters passes through these river systems during the monsoon season. Most of the rivers are characterized by having sandy bottoms, flat slopes, substantial meandering, banks susceptible to erosion and channel shifting. The river system of Bangladesh is one of the most extensive in the world, and the Ganges and the Brahmaputra are amongst the largest rivers on earth in terms of catchment size, river length and discharge.

The Brahmaputra (Jamuna) river above Bahadurabad has a length of approximately 2,900 km and a catchment area about 5,83,000 sq-km. Started from the glaciers in the northernmost range of the Himalayas and flows east far above half its length across the Tibetan plateau. In the complex mountain terrain bordering north-east India and China it bends through a series of gorges and is joined by a number of major tributaries, e.g., the Dihang and the Luhit before entering its broad valley section in Assam. This stretch is about 720 km long to the border of Bangladesh and throughout most of this, the course is braided. This braided channel is continued to the confluence with the Ganges.

Within Bangladesh, the Brahmaputra receives four major Right Bank tributaries - the Dudkumar, the Dharla, the Teesta and the Hurasagar. The first three are flashy rivers, rising in steep catchments on the southern side of the Himalayan between Darjeeling and Bhutan. The Hurasagar River is the outlet to the Karatoya-Atrai river system, which comprises much of the internal drainage of northwest of Bangladesh.

The Old Brahmaputra is the main left-bank distributaries of the Brahmaputra river presently known as the Jamuna. The shift of river course appears to have been taken place after a major earthquake and catastrophic flood in 1787. It is now a high flow spill river contributing largely to flood, as in the Dhaleswari, and their behavior is highly dependent on the variations of siltation at their entries.

Total length of the Ganges River is about 2,600 km to its confluence with the Brahmaputra -Jamuna at Aricha-Goalondo and a catchment area of approximately 9,07,000 sq-km. Started from the high western Himalayans glaciers, the Ganges has a short mountain course of about 160 km. From there it flows south easterly in a vast plain with major tributaries from the southern Himalayans in Nepal and smaller rivers from the central Indian Plateau to the south. With deep-water channel with numerous bar formations (chars), the Ganges is not braided. After its confluence with the Jamuna at Goalondo, the river, known as the Padma, flows in a wide and straight. At Chandpur, the Padma is joined to the Meghna from where it flows to the sea with tidal influence.

The Meghna system originates in the hills of Shillong and Meghalaya of India. The main source is the Barak River, which has a considerable catchment in the ridge and valley terrain of eastern Assam bordering Myanmar. On reaching the border with Bangladesh at Amalshid in Sylhet district, it bifurcates into Surma and the Kushiyara rivers. The Surma, flowing on the north of the Sylhet basin receives Right Bank tributaries from Khasia and Jaintia Hills of Shillong. These are steep, highly flashy rivers, originating in one of the wettest area of the world, the average annual rainfall at Cherrapunji at Assam being about 10,000 mm. The Kushiyara receives left bank tributaries from the Tripura Hills, the principal ones being the Manu. Also flashy in nature with less elevations and rainfall of Tripura makes these rivers less violent than the northern streams.

Between the Surma and Kushiyara, there are many internal draining depressions (haors), meandering flood channels and abandoned river courses, which are widely flooded every monsoon season. The two rivers rejoined at Markuli and flow via Bhairab as the Meghna to join the Padma at Chandpur. The major tributaries of any size outside the Sylhet basin are the Gumti and the Khowai River, which rises in Tripura and other hilly streams from Meghalaya and Assam of India to join the Meghna.

The streams of the southeast region are all short and of a flashy nature, rising in the Chittagong Hill Tracts or adjacent parts of eastern India. The main streams are the Muhuri, Halda, Sangu, Matamuhuri, etc.

1.3. ACTIVITIES OF FFWC

The importance of the flood forecasting and warning is widely recognized as a vital non-structural measures to aid the mitigating the loss of lives, crops and properties caused by the annual flood occurrence. The Flood Forecasting and Warning Centre, under the Directorate of Processing and Flood Forecasting Circle, Hydrology, BWDB carries out monitoring of 86 representative water level stations and 56 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, forecast for 24, 48 & 72 hours about 52 monitoring points, production of Upazilla/Thana Status Map, Satellite Imageries, special flood report along with different graphical and statistical presentation during the monsoon season. The Centre is also involved in preparation of flood status report on National level, a weekly bulletin during dry season and monthly and annual flood reports. The Centre is responsible to act as a focal point in respect of flood from the month of April to November as per Government order for formulating the flood forecasts that are issued with the river situation bulletin and also provide support services to DMB, BMD and SPARRSO during cyclonic disaster.

Before 1990, forecast for six locations viz. Bahadurabad, Serajgonj, Aricha, Goalondo, Bhagyakul and Hardinge Bridge on the Padma – Brahmaputra –Jamuna system were issued by Co-axial correlation, Gauge to Gauge relation and Muskingum-Cunge Routing Model. After the devastating flood of 1987 and catastrophic flood of 1988, it was deeply realized that the forecast formulation should be introduced in the process of river modelling. In view of the above, the simulation model MIKE11 developed by Danish Hydraulic Institute (DHI) was installed at FFWC and a special version of MIKE11 FF conceptual Hydrodynamic model is in operation for forecast formulation.

The General Model (GM) developed under MIKE11 was adapted to real time operation in which boundary extended near to the Indian border on all main rivers. A supermodel now is in operational at FFWC covering entire flood affected area of Bangladesh, except coastal zone, the southern part.

The Supermodel covers about 82,000 km^2 of entire country, except the coastal zone of the country. The areas are sub-divided into 107 sub-catchments. It includes 195 river branches, 207 link channels, 40 Broad Crested Weirs. The total river length modeled is about 7300 km. Model operation and data base management, a well-managed server based (Widows 2000) LAN–Operating System has been installed with PCs at the FFWC.

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (73 WL stations and 56 rainfall stations) is collected by SSB wireless, fixed & mobile telephone from the BWDB hydrological network. WL for non-tidal stations are collected five times daily at 3 hourly intervals during day time from 6:00 AM to 6:00 PM, and for tidal stations collected hourly. Rainfall is collected daily period beginning at 9 AM. The data collections at FFWC are usually completed by 10:30 A.M. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through internet, e-mail, and from BMD.

Essential Information's: Estimation of WL at the model boundaries and rainfall for the catchments are required input to the model upto the time of Forecast (24h, 48h & 72h). For the rainfall estimation, satellite images from NOAA and IMD is used. In addition a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

Forecast Calculation: Collected/observed WL and rainfall data are given input to the computer database and checked. The WL and rainfall estimation has to be prepared. The basis for WL estimation is considering trend Hydrograph extrapolated upto the period of forecast from previous few days data, response characteristics of rivers, effect of rainfall on WL and Indian available WL & forecasts data. Rainfall estimation based on previous 2-day's rainfall and analysis of information collected. After input required data and boundary-estimated data to the model, model run started. It takes 30 to 40 minutes time to complete the calculations.

Daily forecast bulletin is prepared upto 72 hours for important locations and region-wise flood warning messages. The bulletins are disseminated to more than 600 recipients including different ministries, offices(central & district level), individuals, print & electronic news media, development partners, research oraganisations, NGO's etc. including President's & Prime Minister's Secretariat. Whenever, the forecast river stage cross the DL, the concern field offices and limited key officials are informed through mobile SMS. Cell Broadcast has been initiated since July 2011 through Teletalk mobile.

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 3-days ahead of its occurrence. An accurate forecast would be one where the forecast level and corresponding observed level at the stipulated time are within a small range of variation.

1.5. NATURE AND CAUSES OF FLOODING

1.5.1. CAUSATIVE FACTORS

There are two distinct seasons, a dry season from November to April (or May) and the wet (flood) season from June to September (or October). Over 80% of the rainfall occurs during the monsoon or rainy season also known as flood season. The normal annual rainfall of the country varies approximately from 1,200 mm in the west to over 5,000 mm in the east. Long periods of steady rainfall persisting over several days are common during the monsoon, but sometimes local high intensity rainfall of short duration also occurs.

Floods in Bangladesh occur for number of reasons. The main causes are excessive precipitation, low topography and flat slope of the country; but others include:

- *The geographic location and climatic pattern:* Bangladesh is located at the foot of the highest mountain range in the world, the Himalayas, which is also the highest precipitation zone in the world. This rainfall is caused by the influence of the south-west monsoon. Cherapunji, highest rainfall in the world, is located a few kilometers north east of the Bangladesh border
- *The confluence of three major rivers, the Ganges, the Brahmaputra and the Meghna:* the runoff from their vast catchment (about 1.72 million km²) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are about 310 major and minor rivers in the country. The total annual runoff of surface water flowing through the rivers of Bangladesh is about 12,000 billion cubic meters.
- *Man-made environment:* the construction of embankments in the upstream catchments reduces the capacity of the flood plains to store water. The unplanned and unregulated construction of roads and highways in the flood plain without adequate opening creates obstructions to flow.
- *The influence of tides and cyclones*: the frequent development of low pressure areas and storm surges in the Bay of Bengal can impede drainage. The severity of flooding is greatest when the peak floods of the major rivers coincide with these effects.
- *Long term environmental changes:* climate changes could influence the frequency and magnitude of flooding. A higher sea level will inhibit the drainage from the rivers to the sea and increase the impact of tidal surges. Deforestation in hilly catchments causes more rapid and higher runoff, and hence more intense flooding.

The springtides of the Bay of Bengal retard the drainage of floodwater into the sea and locally increase monsoon flooding. A rise of MSL at times during the monsoon period due to effect of monsoon winds also adversely affect the drainage and raise the flood level along the coastal belt.

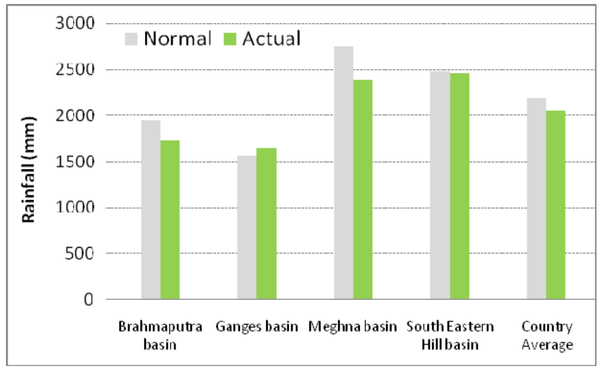
1.5.2. STATISTICS OF FLOODING

Many parts of the Asia during monsoon frequently suffer from severe floods. Some parts of India and Bangladesh experience floods almost every year with considerable damage. The floods of 1954, 1955, 1974, 1987, 1988, 1998, 2004 and 2007 all caused enormous damages to properties and considerable loss of life. The floods of 1987, 1988 1998, 2004 and 2007 flood caused heavy damage. During the monsoon 2011, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin. In the South Western part of the country experienced prolong flooding in few stations, longer then the previous flood years, specially part of Khulna, Jessore and Satkhira districts. During the monsoon-2011 other flood affected districts (part of full, on the low-lying areas) are Gaibandha, Serajgonj, Tangail, Jamalpur, Rajbari, Kushtia, Faridpur, Manikgonj, Munshigonj, Madaripur, Gopalgonj, Sariatpur, Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, Kishoregonj, Brahmmanbaria, Habigonj, Chandpur, Chittagong, Bandarban and Cox's Bazar. Percent of total area of Bangladesh affected by the flood are available since 1954 is presented in Table 3.1.

Table 1. 1 :Year-wise Flood Affected Area in Bangladesh

Year	Flood Affected area		Year	Flood affected area		Year	Flood affected area	
	Sq-Km	%		Sq-Km	%		Sq-Km	%
1954	36,800	25	1975	16,600	11	1995	32,000	22
1955	50,500	34	1976	28,300	19	1996	35,800	24
1956	35,400	24	1977	12,500	8	**1998**	**1,00,250**	**68**
1960	28,400	19	1978	10,800	7	1999	32,000	22
1961	28,800	20	1980	33,000	22	2000	35,700	24
1962	37,200	25	1982	3,140	2	2001	4,000	2.8
1963	43,100	29	1983	11,100	7.5	2002	15,000	10
1964	31,000	21	1984	28,200	19	2003	21,500	14
1965	28,400	19	1985	11,400	8	2004	55,000	38
1966	33,400	23	1986	6,600	4	2005	17,850	12
1967	25,700	17	1987	57,300	39	2006	16,175	11
1968	37,200	25	**1988**	**89,970**	**61**	**2007**	**62,300**	**42**
1969	41,400	28	1989	6,100	4	2008	33,655	23
1970	42,400	29	1990	3,500	2.4	2009	28,593	19
1971	36,300	25	1991	28,600	19	2010	26,530	18
1972	20,800	14	1992	2,000	1.4	2011	29,800	20
1973	29,800	20	1993	28,742	20			
1974	52.600	36	1994	419	0.2			

CHAPTER 2 : RAINFALL SITUATION



During the monsoon-2011 (May to September), the country experienced as a whole 5.9% less rainfall than normal. The Brahmaputra, Meghna & South Eastern Hill & basins received 10.8%, 13.3% and 0.7% less rainfall than the normal value respectively and only the Ganges basin (in the north-west, west and south-west region of the country) recorded 5% more rainfall than the normal value. Comparison of the basin and country average of normal and actual rainfall for the monsoon-2011 (May to September) is presented in the bar chart. Considering monthly value, all the basins experienced more rainfall than their respective normal in the month of August and recorded less rainfall in the month of July. For the Ganges basin the monsoon 2011 may be considered as a wet year as it exceeds the monsoon normal rainfall. Monthly total normal and actual rainfall of all the basins and the country average of normal and actual monsoon rainfall is shown in Table 2.1.

Table 2.1: Rainfall statistics for the monsoon 2011 over the four Basins

Month	Brahmaputra Basin(mm)		Ganges Basin(mm)		Meghna Basin(mm)		South Eastern Hill Basin(mm)		Monsoon average (mm)	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
May	316.8	253.8	204.8	136.05	491.0	412.4	290.4	310.7		
June	441.0	265.9	340.3	401.9	621.0	473.1	599.8	457.6		
July	496.1	372.2	377.3	331.3	650.5	541.4	728.5	515.7	2183.7	2054.6
August	339.7	547.5	320.8	511.0	537.9	608.7	536.9	701.3		
September	353.4	296.5	285.4	244.6	449.2	348.2	317.9	470.0		
Total	1947.0	1753.9	1564.8	1643.3	2473.6	2455.3	2183.7	2054.6		
% More/Less	10.8% less		5.0% more		13.3% less		0.7% less		5.9% less	

Rainfall situation of the country for the monsoon-2011(May to September) is described in the following sections.

2.1 MAY

Important Rainfall Information for May 2011

Monthly Maximum at Sheola 559.0 mm

1-day maximum at Parsuram: 130.0 mm
10-day maximum at Ramgarh: 296.0 mm

The country, as a whole, experienced rainfall less than normal during the month of May 2011. The Brahmaputra, the Ganges, the Meghna recorded 19.9%, 33.60%, 16% less rainfall and the South Eastern Hill basin received 7% more rainfall than their respective monthly normal value. The summery of rainfall situation of the country during May 2011 is shown in the Table 2.2.

Table 2. 2 : Summary of the rainfall situation during the month of May 2011

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	12	11	11
Average Rainfall (mm) of the basin:	253.76	136.05	412.35	310.65
%More(+)/Less(-) than the Normal:	-19.9%	-33.60%	-16%	+7%
Number of Stations above Normal Rainfall:	5	3	3	8
Highest 1-day Maximum Rainfall with Stations:	Kurigram 99.5 mm	Panchagarh 124.0mm	Kanaighat 126.0mm	Parshuram 130.0mm
Number of Rain Fed Flood* Stations:	0	0	0	0

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In Brahmaputra basin, out of 12 rainfall monitoring stations, 6 stations recorded more rainfall than the normal and the other 6 stations received less rainfall than their normal of the month of May. The Basin received 19.9% less rainfall than their normal during the month May 2011.

In Ganges basin, out of 12 rainfall monitoring stations, 3 stations Panchagarh and Dinajpur recorded more rainfall than the normal value and all the other 9 stations received less rainfall than their normal value of the month. The basin as a whole received 33.60% less rainfall than the normal during the month of May-2011.

In the Meghna basin, out of 11 rainfall monitoring stations, 3 stations namely Monu Railway Bridge (Moulvi Bazar District), Durgapur (Netrokona district) and Comilla recorded more rainfall than the normal value of the month and all the other 8 stations recorded less rainfall than their normal value of the month. The Basin received 16% less rainfall than their monthly normal during the month of May 2011.

In the South Eastern Hill basin, all the rainfall monitoring stations received more rainfall than their normal rainfall, except Noakhali, Swandip and Cox’s Bazar. The basin as a whole recorded 7% more rainfall than the normal rainfall during the month of May 2011 with maximum 1-day value of 130mm at Parshuram and 10-day consecutive maximum of 296.0mm at Ramgarah.

The Isohyets of the actual rainfall of the month of May-2011 is shown in the Figures 1.

2.2 JUNE

Important Rainfall Information for June, 2011
Maximum, at Durgapu : 749.5 mm
1-day maximum, at Dinajpur : 190.0 mm
10-day maximum, at Cox's Bazar : 453.0 mm

The country, as a whole, recorded less rainfall than normal during the month of June-2011. The Brahmaputra, the Meghna and South Eastern Hill basins recorded 39.7%, 23.8%, 23.7% less and the Ganges basin recorded 18.1% more rainfall than their respective monthly normal rainfall during the month of June-2011. The summery of the rainfall situation during the month of June 2011 is shown in the Table 2.3.

Table 2. 3: Summary of the rainfall situation during the month of June 2011

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	12	11	11
Average Rainfall (mm) of the basin:	265.92	401.90	473.15	457.65
%More(+)/Less(-) than the Normal:	-39.7%	+ 18.1%	-23.8%	-23.7%
Number of Stations above Normal Rainfall:	0	9	2	2
Highest 1-day Maximum Rainfall with Stations:	Kurigram 103.0 mm	Dinajpur 190.0mm	Durgapur 189.0mm	Narayanhat 145.5mm
Number of Rain Fed Flood* Stations:	0	2	1	3

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In the Brahmaputra basin, all the 13 rainfall monitoring stations recorded less rainfall than the normal. The Basin received 39.7% less rainfall than the normal value during the month of June 2011.

In the Ganges basin, out of 12 rainfall monitoring stations, only 3 stations namely Naogaon, Panchagarh, and Rajshahi recorded less rainfall than the normal value and all the other 9 stations recorded more rainfall than their normal value of the month. The Basin received 18.1% more rainfall than their monthly normal during the month of June 2011 with 1-day maximum rainfall of 190mm at Dinajpur and 10-day consecutive maximum rainfall of 453.0mm recorded at Cox's Bazar.

In the Meghna basin, out of 11 rainfall monitoring stations, 2 stations Habigonj and Durgapur recorded more rainfall than the normal value and all the other 9 stations received less rainfall than their normal value of the month. The basin as a whole received 23.8% less rainfall than the normal during the month of June-2011.

In the South Eastern Hill basin, all the rainfall monitoring stations received less rainfall than their normal rainfall, except Narayanhat and Rangamati. The basin as a whole recorded 23.70% less rainfall than the normal rainfall during the month of June 2011 with maximum 1 day value of 145.5mm at Narayanhat.

The Isohyets of the actual rainfall of the month of June-2011 are shown in the Figure 2.

2.3 JULY

Important Rainfall Information for July 2011
Maximum at Cox's Bazar: 908.10 mm
1-day maximum at Sunamgonj: 243.00 mm
10-day maximum at Cox's Bazar: 724.00 mm

The country, as a whole, experienced rainfall less than normal during the month of July 2011. The Brahmaputra, the Ganges, the Meghna and South Eastern Hill basins received 25.0%, 12.2%, 16.77% and 29.21% less rainfall than their respective monthly normal value. The summery of the rainfall situation during the month of July 2011 is shown in the Table 2.4.

Table 2. 4: Summary of the rainfall situation during the month of July 2011

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	12	11	11
%More(+)/Less(-) than the Normal:	-25.0%	-12.2%	-16.77%	-29.21%
Number of Stations above Normal Rainfall:	0	5	2	0
Highest 1-day Maximum Rainfall with Stations:	Gaibandha 160.0 mm	Satkhira 157.7mm	Sunamgonj 243.0mm	Cox's Bazar 231.0mm
Number of Rain Fed Flood* Stations:	1	1	4	3
Name of Rain Fed Flood* Stations:	-	Satkhira	Kanaighat Sylhet Sunamgonj Sheola	Lama Sawndip Cox's Bazar

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In the Brahmaputra basin, all the stations received less rainfall than their normal. The Basin received 25.0% less rainfall than their normal during the month July 2011.

In the Ganges basin, 5 stations recorded more and other stations recorded less rainfall than their normal value of the month. The basin as a whole received 12.2% less rainfall than its normal during the month of July-2011.

In the Meghna basin, all the stations recorded less rainfall than their normal value of the month, except Sunamgonj and Habigonj. The Basin recorded 16.77% less rainfall than their normal during the month of July 2011.

In the South Eastern Hill basin, all the rainfall monitoring stations received less rainfall than their normal rainfall. The basin as a whole received 29.2% less rainfall than its normal rainfall during the month of July 2011

Total 8 stations recorded more than 300 mm rainfall for consecutive 10-day period during July-2011. In the month of July-2011 maximum consecutive 10-day rainfall of 724.00mm was recorded at Cox's Bazar and 1-day maximum rainfall of 243.0mm was recorded at Sunamgonj. Rain fed flood situation developed in Satkhira and part of Khulna, Jessore, Cox's Bazar and Bandarban districts. The isohyets of the actual rainfall of July-2011 is shown in the Figure 3.

2.4 AUGUST

<u>Important Rainfall Information for August 2011</u>
Maximum at Teknaf : 1382.6 mm
1-day maximum at Sunamgonj & Bogra : 240.0 mm
10-day maximum at Cox's Bazar : 973.0 mm

The intensity of rainfall in the Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin was moderately heavy to very heavy at most of the places during the month of August. All four hydrological basins of the country received more rain fall than their respective monthly normal during August, 2011. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin received 61.2%, 59.3%, 13.2% and 30.6% more monthly rainfall than their respective normal rainfall. The monthly rainfall recorded during August at Serajgonj(679.2mm), Bogra(1148.9mm), Rajshahi(607.0mm), Satkhira (822.5mm) and Panchpukuria(940.0mm) exceeded the previous monthly maximum rainfall value of those stations. Considering the rainfall in the country, the August was the wet month of the monsoon-2011. Table 2.5 represents the summary of rainfall situation all through the country during August-2011.

Table 2. 5: Summary of the rainfall situation during the month of August 2011

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	12	11	11
Basin average rainfall at August,2011(mm):	548	513	609	701
%More(+)/Less(-) than Normal:	+61.2%	+59.3%	+13.2%	+30.6%
No. of Stations above Normal Rainfall:	9	11	7	9
Highest 1-day Maximum Rainfall Stations:	Bogra (240mm)	Satkhira (145.7 mm)	Sunamgonj (240 mm)	Cox's Bazar (218 mm)
No of Rain Fed Flood* Stations:	9	10	8	9

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

The above table shows that 9 out of 13 stations in the Brahmaputra basin, 11 out of 12 stations in the Ganges basin, 7 out of 11 stations in the Meghna basin and 9 out 11 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, 1-day maximum rainfall was recorded at Bogra and Sunamgonj and 10-day consecutive maximum rainfall of 973.0mm was recorded at Cox's Bazar during August-2011. Maximum monthly rainfall of 1382.6mm was recorded at Teknaf and next to it, 1193.0mm rainfall was recorded at Cox's bazaar.

The table also shows that all the 9 stations in the Brahmaputra basin, 10 stations in the Ganges basin, 8 station in the Meghna Basin and 9 station in the South Eastern Hill basin received more than 300 mm rainfall in consecutive 10-day period.

The Isohyets of the actual rainfall of the month of August-2011 is shown in the Figure 4.

2.5 SEPTEMBER

Important Rainfall Information for September 2011
Maximum at Chittagong : 743.0 mm
1-day maximum at Sandwip: 222.0mm
10-day maximum at Sandwip: 586.0mm

The country, as a whole, experienced rainfall less than the normal value except the South Eastern Hill basin during the month, September 2011. Among the four hydrological basins of the country, the Brahmaputra, the Ganges and the Meghna basins received 16%, 14%, and 22 % less rainfall and the South Eastern Hill basin received 48% more rainfall than their respective monthly normal rainfall during the September. At Chittagong the monthly maximum rainfall was recorded 743.0mm, which exceeded the previous monthly maximum value of Chittagong for September. Table 2.6 represents the summary of rainfall situation all through the country.

Table 2. 6: Summary of the rainfall situation during the month of September 2011

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	12	11	11
Basin average rainfall at September,2011(mm):	296.54	274.8	348.2	470.0
%More(+)/Less(-) than Normal:	-16%	-14%	-23%	+48%
No. of Stations above Normal Rainfall:	4	5	2	9
Highest 1-day Maximum Rainfall Stations:	Dalia (188 mm)	Panchagarh (175 mm)	Durgapur (180 mm)	Sawndip (226 mm)
No of Rain Fed Flood* Stations:	3	1	2	4
Name of Rain Fed Flood* Stations:	Dalia, Bogra, Serajgonj	Panchagarh	Sylhet, Durgapur	Lama, Chittagong, Cox's Bazar, Sawndip

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

The above table shows that 4 out of 13 stations in the Brahmaputra basin, 5 out of 12 stations in the Ganges basin, 2 out of 11 stations in the Meghna basin and 9 out 11 stations in the South Eastern Hill basin received more rainfall than their monthly normal rainfall of September. Among all monitoring stations, 1-day maximum and 10-day consecutive maximum rainfall of 226.0mm and 586.0mm respectively was recorded at Sawndip in the South Eastern Hill basin. The monthly maximum rainfall of 743.0mm was recorded at Chittagong during September-2011, this maximum value exceeded the previous historical maximum rainfall (previous maximum value was 638.8mm) at Chittagong.

The table also shows that all the 3 stations in Brahmaputra basin, 1 station in the Ganges basin, 2 stations in the Meghna Basin and 4 stations in the South Eastern Hill basin recorded more than 300 mm rainfall in consecutive 10-day period. As a result, Nilphamari, Bogra, Serajgonj, Panchagrah, Sylhet, Jamalpur, Chittagong, Cox's Bazar and Sawndip were affected by rain feed flood during September 2011. It may be mentioned here that 300 mm or more rainfall in 10-Day period may cause rain fed flood.

The Isohyets of actual rainfall for the month of August-2011 is shown in the Figure 2.5.

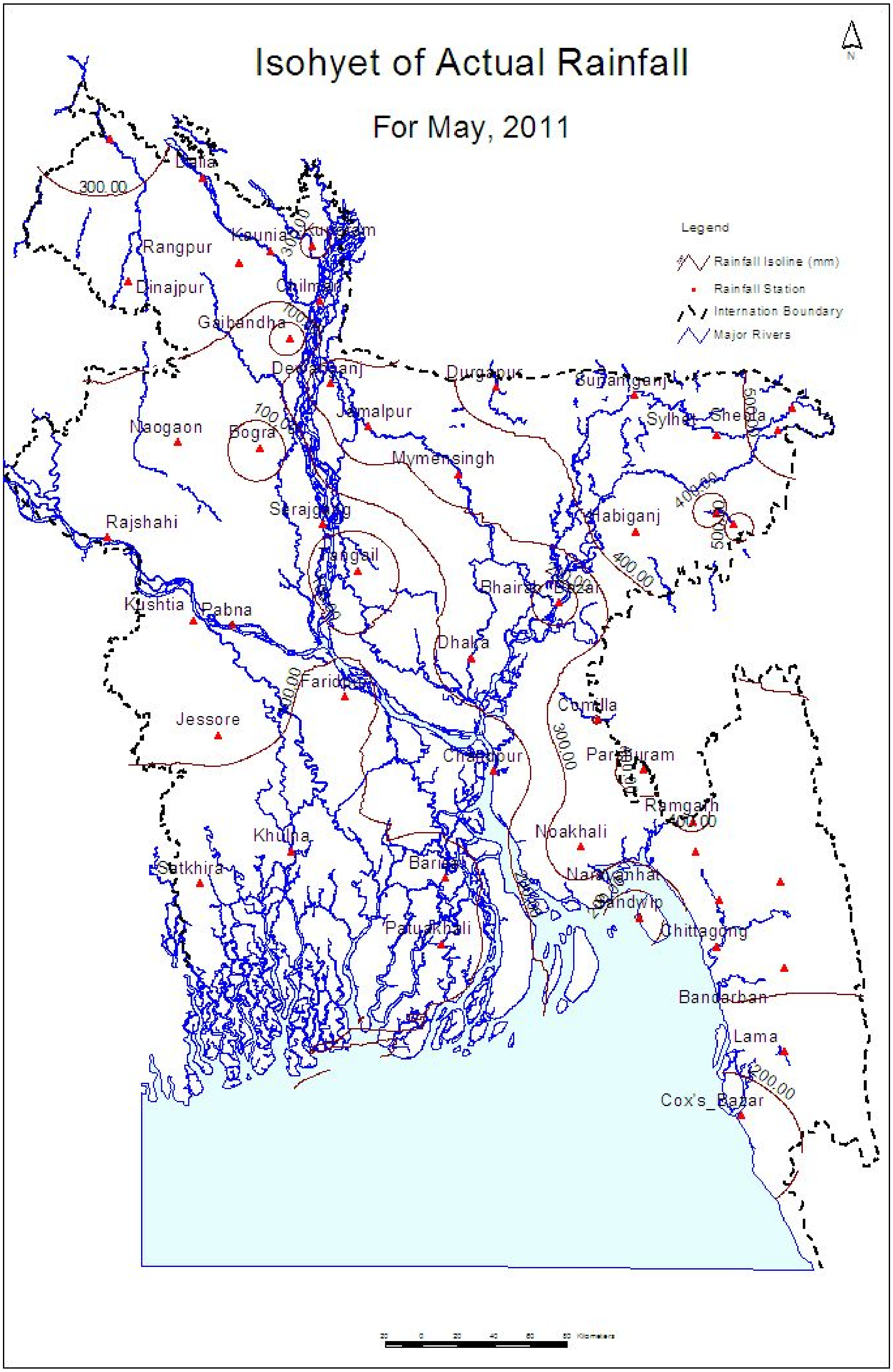


Figure 2.1 : Isohyets of Actual Rainfall (May 2011)

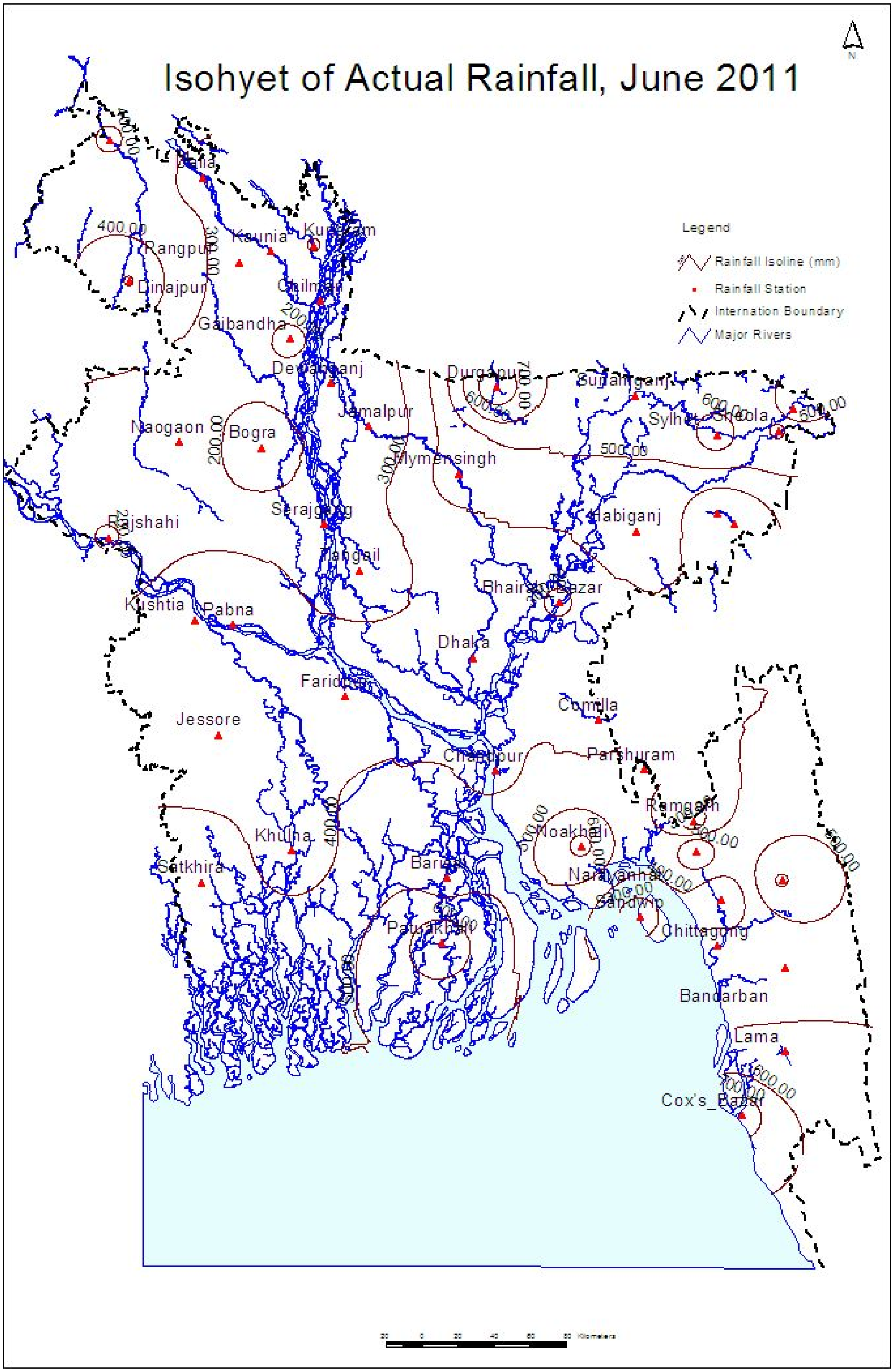


Figure 2.2 : Isohyets of Actual Rainfall (June 2011)

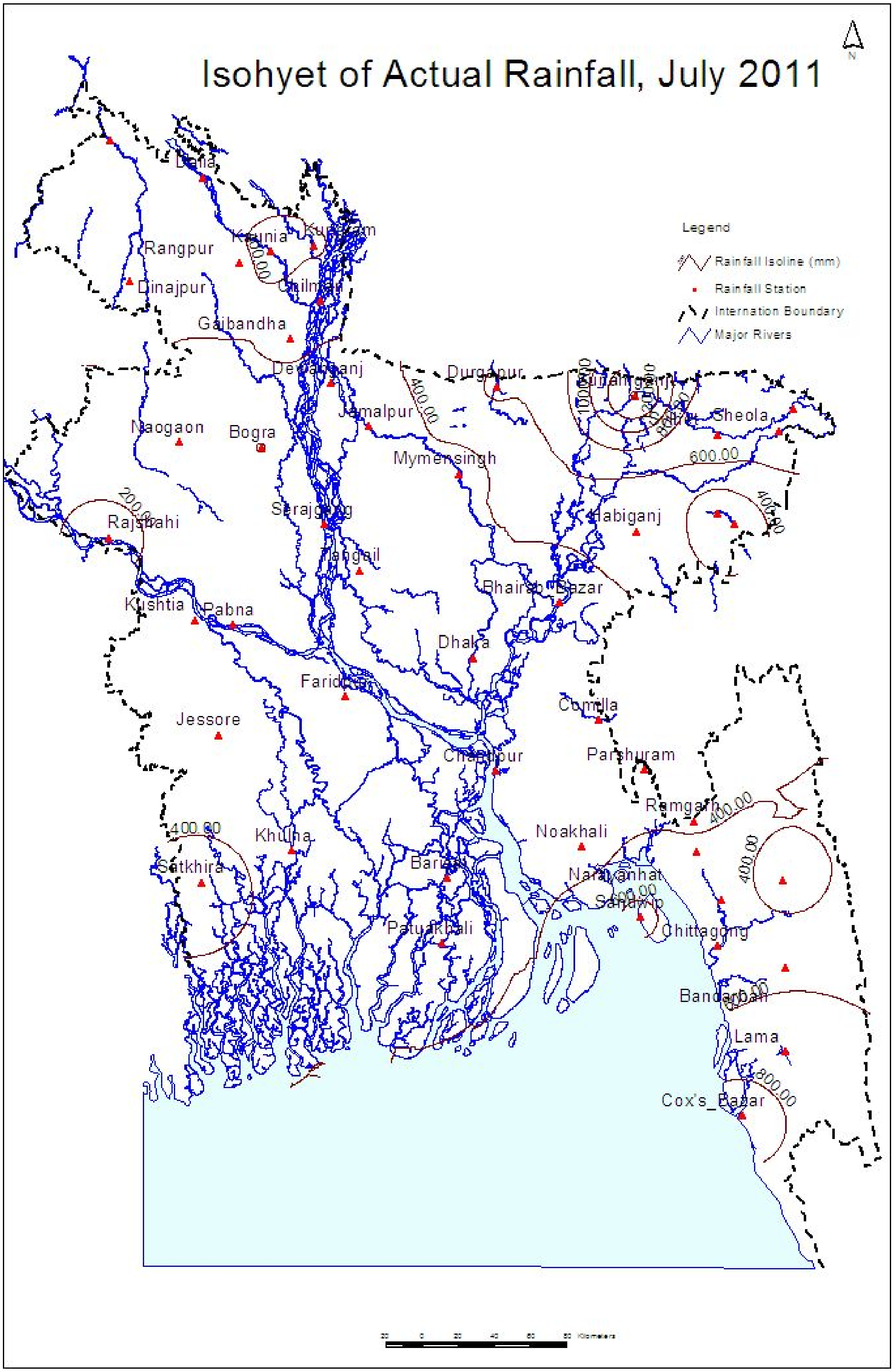


Figure 2.3 : Isohyets of Actual Rainfall (July 2011)

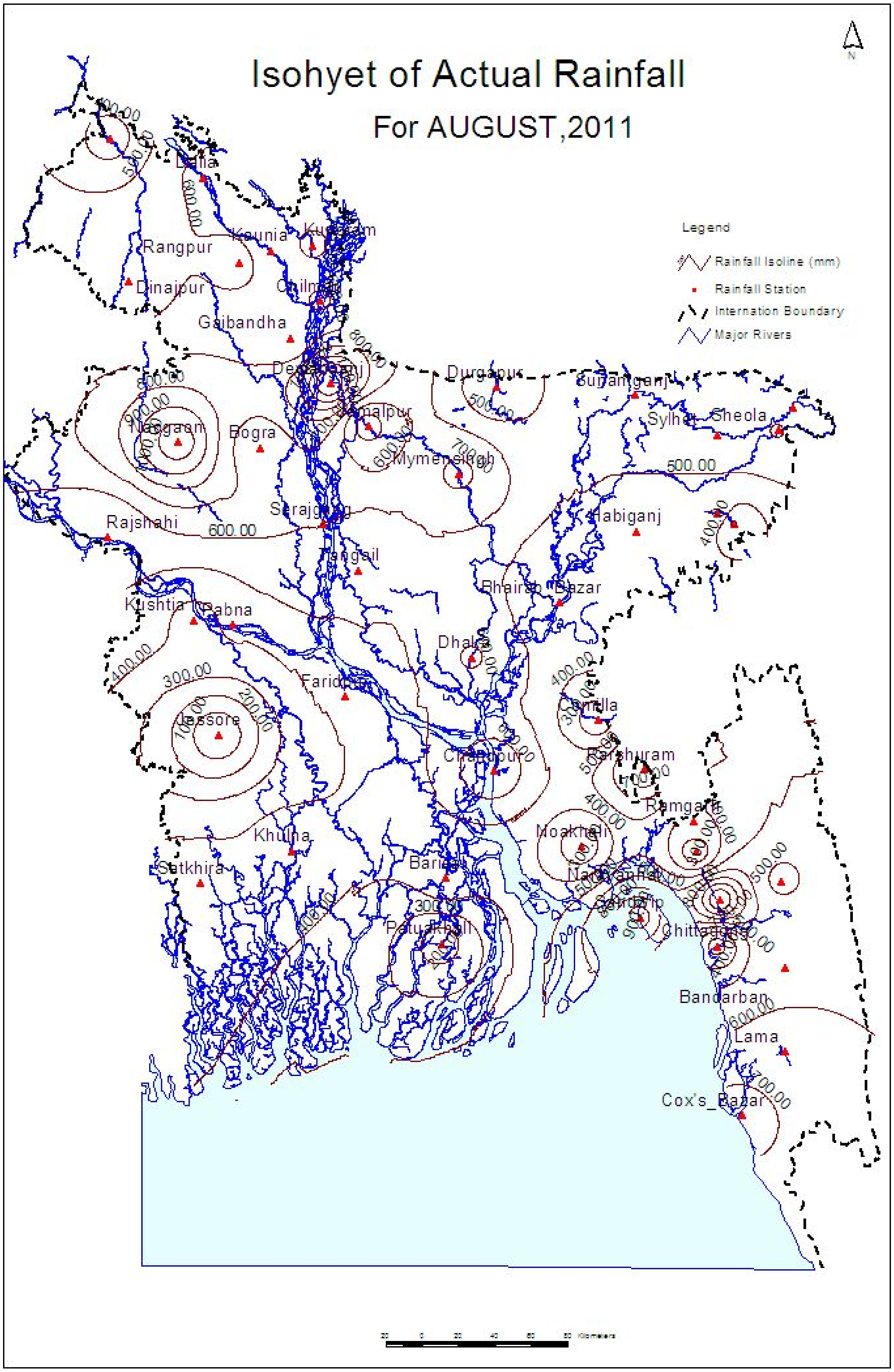


Figure 2.4 : Isohyets of Actual Rainfall (August 2011)

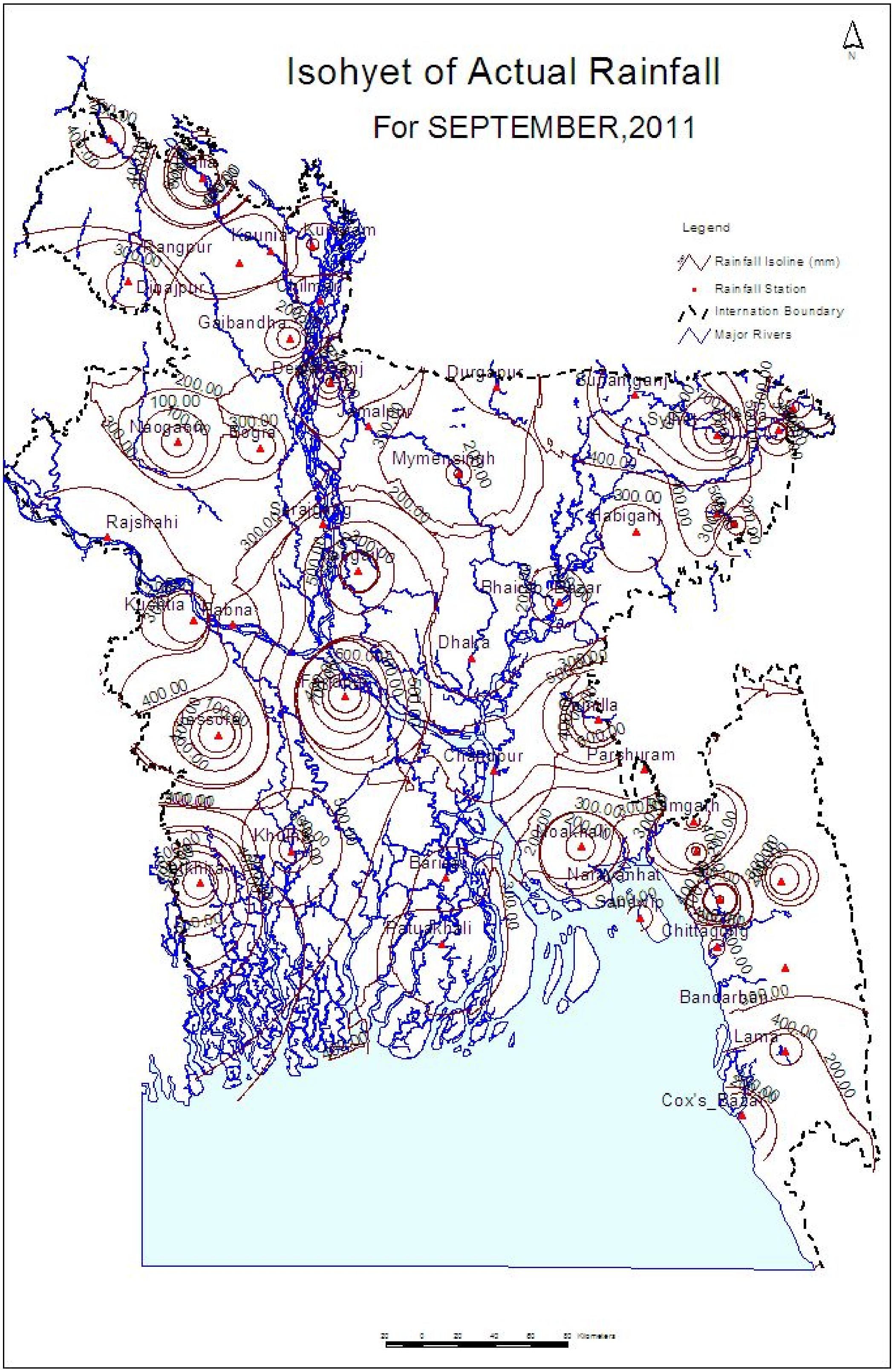


Figure 2.5 : Isohyets of Actual Rainfall (September 2011)

CHAPTER 3: RIVER SITUATION

During the monsoon 2011, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except few stations of the south west part of the country. The South Western part of the country experienced prolong flooding in few stations, longer then the previous flood years, specially part of Khulna, Jessore and Satkhira districts. Water Level at Jhikorgacha on Kobodak was flowed above the danger level for continuous 89 days. During the monsoon-2011 there were flash floods affecting the Jariajanjail (in the North east, in Netrokona district) and Bandarban-Coxs Bazar(South east). Basin wise WL situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 15 Water Level (WL) monitoring stations in this basin, at 3 stations river WL was crossed their respective Danger Levels (DL), these are Jamuna at Bahadurabad for 7 days and Serajgonj for 5 days and Tongi Khal at Tongi for 29 days during July, August and September. As a result, low-lying areas of Gaibandha, Serajgonj, Tangail, and Jamalpur districts were flooded for short period. A comparative statement of WL for current year 2011 and historical events of 1988 and 1998 for the Brahmaputra Basin is shown in the Table 3.1. The details of the river situation in this basin are described in the following sections:

The Dharla at Kurigram

The WL of Dharla river at Kurigram registered three distinct peaks during the monsoon 2011, in July, August and September. It did not cross the DL during the monsoon. WL at Kurigram attained highest peak of 26.10 on 30th July at 18:00 hours, which was 40cm below the DL (26.50 m), then fall of WL was recorded and again rise upto 26.0m (50cm below the DL) in the 3rd week of September.

The Teesta at Dalia and Kaunia

The Teesta river is flashy in nature. The WL of river Teesta showed several peaks during the monsoon both at Dalia and Kaunia. At Dalia WL crossed its DL mark on 20th September for one day only with peak of 52.50m, which was 10cm above its DL (52.40m). At Kaunia WL of the river Teesta did not cross the danger mark, attained the peak of 29.20m on 18th which is 80cm below the DL(30.0m) at this point.

The Brahmaputra at Noonkhawa and Chilmari

The river Brahmaputra at Noonkhawa and Chilmari observed sharp rise and fall at several times throughout the monsoon. At both the stations the river WL did not cross the DL during the monsoon-2011. At Noonkhawa WL of the Brhamaputra river attained the peak of 26.20m in 24 July during 06:00 and 09:00 hours, which was 105cm below the DL (27.25mPWD) at this point. At Chilmari the peak WL of the Brahmaputra river was recorded 23.61m, which was 39cm below its DL(24.00m).

The Jamuna at Bahadurabad, Serajgonj and Aricha

The WL of river Jamuna at Bahadurabad, Serajgonj & Aricha demonstrated similar trends as Brahmaputra at Noonkhawa and Chilmari. At Bahadurabad the Jamuna flowed above DL for 7 days from 20th July to 27 July with the peak of 19.65m, which is 15cm above the DL(19.50m) at this point. At Serajgonj the Jamuna flowed above DL from 22 to 26 July for 5 days with peak of 13.42m, which is 7cm above the DL(13.35m). At Serajgonj it maintained almost steady WL around the DL from the 3rd week of July to 3rd week of August. At Aricha the WL of Jamuna flowed below the DL with peak WL of 9.24m, which was 16cm below the DL(9.40m).

The Old Brahmaputra at Jamalpur and Mymensingh

The WL of Old Brahmaputra river at Jamalpur showed rise and fall during the monsoon, one peak of 15.30m, one of 15.25 at the 2nd week of August and the last and the highest one at 3rd week of August was recorded 15.41m, which was 159cm below the DL(17.00m) at this point. At Mymensingh the WL of the river followed the similar trend, the recorded peak was 10.72m at 19th August, which was178cm below the DL (12.5m).

The Rivers around Dhaka

Stations near or around Dhaka city like Buriganga at Dhaka, the Lakhya at Narayangonj, and the Turag at Mirpur attained the peak of the monsoon during the August, mostly from the middle to end. WL at all these stations did not cross their respective DLs. The WL of the Tongi Khal at Tongi followed the similar trend, flowed above the DL for 29 days. The Buriganga at Dhaka, the Balu at Demra and the Turag at Mirpur recoded their highest peak of 5.20 m (DL 6.0m) on 22nd August, 5.75m just at DL (DL 5.75m) on 21st August, 5.70 m(DL 5.94m) on 19th August respectively. The WL of Tongi Khal at Tongi flowed above DL for 29 days from 8th August to 6 September with peak of 6.38m DL(6.08m), 30cm above the DL at this point.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha showed a similar trend to that of the Jamuna at Serajgonj and Brahmaputra at Bahadurabad, flowed near to the DL during 3rd week of July to 3rd week of August. It flowed above the DL for 4 days from 21st July to 24th July with peak of 21.81m on 22nd of July, which was 11cm above its DL(21.70m) at this point.

The Lakhya at Narayangonj

The WL of Lakhya river at Narayangonj showed a similar trend to that of the Buriganga. The river at this station remained below the respective danger line throughout the season.

The peak WL recorded at Narayangonj on Lakhya river was 5.40 m on 1st September, which was 10 cm below its danger mark (5.50 m).

The Kaliganga at Taraghat

The WL of Kaliganga river at Taraghat showed a trend similar to that of the Buriganga at Dhaka. The river at this station remained below the DL throughout the season with peak of 7.82 m on 25th September, which was 58 cm below its DL(8.40 m) at Taraghat.

Comparative hydrographs for the year of 2011, 2007, 1998 & 1988 of few stations of the Brahmaputra basin are shown in Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 and 3.7.

Table 3. 1 : Comparison of Water Level of 2011 and Historical Events of 1988 & 1998 of Some Important Stations in the Brahmaputra Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2011	98	88	11	98	88
1	Dharla	Kurigram	27.66	26.50	26.10	27.22	27.25	-	30	16
2	Teesta	Dalia	52.97	52.25	52.37	52.20	52.89	-	-	8
3	Teesta	Kaunia	30.52	30.00	29.20	29.91	30.43	-	-	38
4	Brahmaputra	Noonkhawa	28.10	27.25	26.2	27.35	NA	-	-	NA
5	Brahmaputra	Chilmari	25.06	24.00	23.61	24.77	25.04	-	22	15
6	Ghagot	Gaibandha	22.81	21.70	21.81	22.30	22.20	4	51	17
7	Jamuna	Bahadurabad	20.62	19.50	19.65	20.37	20.62	7	66	27
8	Jamuna	Serajgonj	15.12	13.75	13.42	14.76	15.12	5	48	44
9	Jamuna	Aricha	10.76	9.14	9.6	10.76	10.58	-	68	31
10	Old Br.putra	Jamalpur	18.00	17.00	15.41	17.47	17.83	-	31	8
11	Old Br.putra	Mymensingh	14.02	12.50	10.72	13.04	13.69	-	33	10
12	Buriganga	Dhaka	7.58	6.00	5.16	7.24	7.58	-	57	23
13	Lakhya	Narayangonj	6.71	5.50	5.39	6.93	6.71	-	71	36
14	Turag	Mirpur	8.35	5.94	5.7	7.97	NA	-	70	NA
15	Tongi Khal	Tongi	7.84	6.08	6.38	7.54	NA	29	66	NA
16	Kaliganga	Taraghat	10.39	8.38	7.82	10.21	10.39	-	66	65

3.2 THE GANGES BASIN

In this basin the WL monitoring stations exceeded the respective DLs are Ganges/ Padma at Goalondo, Bhagyakul, Punarbhaba at Dinajpur, Upper Atrai at Bhusirbondor (Upazila-Chirirbandar, district Dinajpur), the Gorai at Kamarkhali, Kobodak at Jhikorgacha and Arialkhan at Madaripur during the monsoon 2011. The WL of river Padma at Bhagyakul was flowed for 36 days above DL. The low lying areas of Rajbari, Kushtia, Faridpur, Manikgonj, Tangail, Munshigonj, Madaripur, Sariatpur, Gopalgonj, Jessore and Khulna districts was affected by normal flooding during the month of August. WL of Arialkhan river at Madaripur flowed above the DL for 30 days. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul and Madaripur WL gauge stations. Prolong flooding situation was prevailing in Satkhira district due to very poor drainage condition along with very high rainfall during August. The WL of Kobodak river at Jhikorgacha flowed above the DL for continuous 89 days from the 1st week of August to the 1st week of November 2011, which is unprecedented. Flood duration covered two Eid festivals and caused immense suffering of the people of the locality. All other rivers, including the Ganges flowed below their respective DLs. A comparative statement of WL for 2011 (current year) and historical events of 1998 & 1988 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below:

The Punarbhaba at Dinajpur

The WL of river Punarbhaba at Dinajpur showed sharp rise and fall during the monsoon, total 8 peaks were recorded during July to September. The WL of it crossed the DL for one day with peak value of 33.55m on 19th August during 09:00 and 12:00 hours, which was 5cm above its DL (33.50m).

The Upper Atrai at Bhusirbandar

The WL of river Upper Atrai at Bhusirbandar (Upazila – Chirirbandar, District –Dinajpur) also showed similar trend of Punarbhaba, crossed the DL for one day with peak of 39.92m on 18th August at 06:00hour, which was 30cm above the DL(39.62m).

The Ganges/Padma at Pankha

The river at Pankha showed comparatively sharp rise from the end of June to 1st week of July. Then gradual rise and fall upto the end of September. From the begging of October to mid there was sharp fall. All through the monsoon, it flowed below the DL at Pankha with the peak of 22.21m during the day of 21st of August, which is 29cm below the DL (22.50m) at this point.

The Ganges/Padma at Rajshahi and at Hardinge Bridge

The Ganges at Rajshahi and at Hardinge Bridge showed nearly similar trend as at Pankha and flowed below their respective DL throughout the monsoon-2011. It attained its peak of 18.17m on 21st August at 6:00 hours, which was 33cm below its DL (DL18.50m) and again it went upto 18.0m at the 2nd of October at Rajshahi. At Hardinge Bridge; it attained its peak of 13.75m on 22nd August and 13.78 on 3rd of October, which was 47 cm below its DL (14.25m) at this point.

The Padma at Goalundo

At Goalondo river WL started to rise from the 3rd week of June, during August it flowed around the DL, 4 times above the DL. The river at this point as a whole remained above its DL for 18 days. The WL of the river Padma at Goalondo attained its yearly peak of 8.86m on 21st August, which was 21 cm above its DL (8.65m) at this point.

The Padma at Bhagyakul

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma showed the similar trend as that of Goalundo, it touched the DL on 26th of July, then slight fall, again crossed the DL on 1st of August and flowed above throughout the month till 5th of September, for 36 days. The WL of the river attained its highest yearly peak of 6.62 m on 23rd of August, which was 32cm above the DL (6.30m) at Bhagyakul.

The Gorai at Gorai Railway Bridge and Kamarkhali

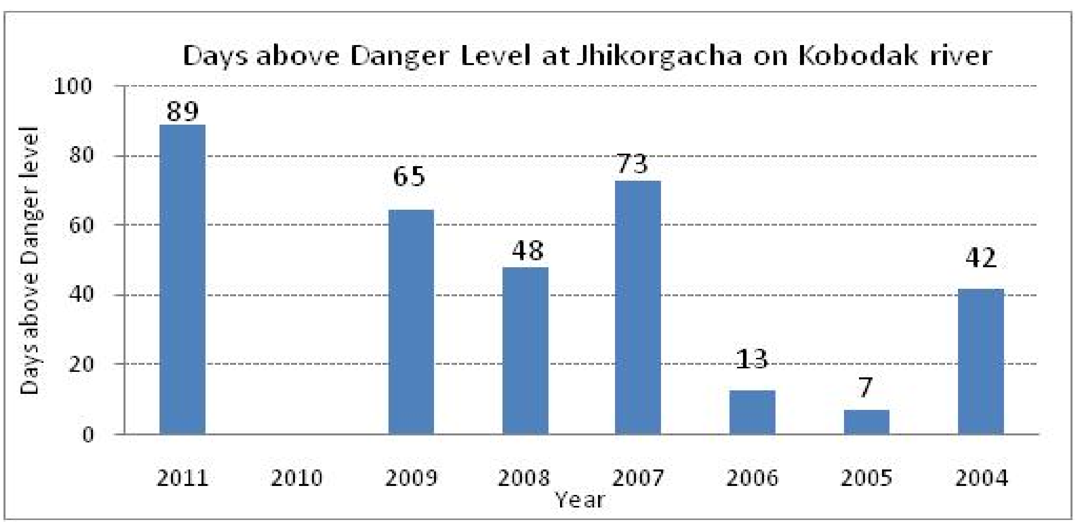
The WL of river Gorai at Gorai Railway Bridge and Kamarkhali showed steady rise and fall during July to October. The WL of river Gorai did not cross the DL at Gorai railway Bridge, but flowed above its DL at Kamarkhali for 15 days, from 14th August to 29th August with peak of 8.44m on 22nd August at 06:00 hrs, which is 24cm above the DL (8.20m). WL attained its highest peak of 12.42m on 22nd August at 09:00 hours, which was 33cm below its DL (12.75m) at Gorai Railway Bridge.

The Arialkhan at Madaripur

At Madaripur the WL of the river Arialkhan showed similar trend of rise and fall of the river Padma. The WL of Arialkhan at Madaripur flowed above the DL from 05th August to 04th September for 30 days. The WL attained its highest peak of 4.37 m on the 15th of August, which was 20cm above the DL (4.17m) at Madaripur.

Kobodak at Jhikorgacha

A prolong flooding situation was prevailed along the Kobodak river. At Jhikorgacha, the WL flowed above the DL for continuous 89 days with a peak of 4.99m on 21st August, which was 88cm above the DL(4.11m) at this point. As a result, part of Satkhira, Khulna and Jessore districts were flooded for prolong period. This is due to the poor drainage condition and more rainfall in the region. At Jhikorgacha, the WL of river Kobodak crossed the DL on 8th August & remained above the DL till 5th of November. From the figure, it may be seen that, except 2010, the Kobodak flowed above its DL at Jhikorgacha in every year since 2004 and the trend is increasing.



Comparative hydrographs for few important stations for the year of 2011, 1998 & 1988 of the Ganges basin are shown in figures 3.8 to 3.16.

Table 3 2 : Comparison of Water Level of 2011 and Historical Events of 1988 & 1998 of Some Important Stations in Ganges Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger Level		
					2011	98	88	2011	98	88
1	Punarbhaba	Dinajpur	34.40	33.50	33.55	34.09	34.25	1	3	4
2	Ganges	Pankha	22.97	25.50	22.21	24.14	NA	-	66	NA
3	Ganges	Rajshahi	20.00	18.50	18.17	19.68	19.00	-	28	24
4	Ganges	Hardinge Bridge	15.04	14.25	13.78	15.19	14.87	-	27	23
5	Padma	Goalundo	10.01	8.50	8.86	10.21	9.83	18	68	41
6	Padma	Bhagyakul	7.58	6.00	6.62	7.50	7.43	36	72	47
7	Gorai	Gorai Railway Bridge	13.65	12.75	12.42	13.45	13.65	-	25	25
8	Gorai	Kamarkhali	9.48	8.20	8.44	NA	NA	15	NA	NA
9	Arialkhan	Madaripur	5.80	4.17	4.37	NA	NA	30	NA	NA
10	Kobodak	Jhikorgacha	5.59	4.11	4.99	NA	NA	89	NA	NA

3.3 THE MEGHNA BASIN

Most of the rivers in this basin are flashy in nature. Out of 20 WL monitoring stations in the Meghna basin only 6 stations flowed below their respective DL during the monsoon 2011. Total 14 stations flowed above their respective DLs for 2 days (Manu at Manu Railway Bridge) to 42 days (Kangsha at Jariajanjail). As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, Kishoregonj, Brahmmanbaria, Habigonj and Chandpur during the monsoon 2011. The WL of all the major rivers in the Meghna basin (north eastern part of the country) exceeded the DL, except the Upper Meghna and Gumti rivers during the monsoon 2011. A comparative statement of WL and days flowed above the DL for 2011 and historical events of 1998 and 1988 for this basin are shown in Table 3.3.

The Surma at Kanaighat

As a flashy river, WL of the river Surma at Kanaighat (under Sylhet district) showed several peaks during the monsoon-2011. WL of it flowed above its DL at Kanaighat during 1st week of July and twice during the last week of August. The WL of Surma at Kanaighat crossed its DL on 1st July and flowed for 12 days above the DL, on 18th August for 2-days and again it crossed its DL on 26th August for 4 days (total 18 days). It attained its highest peak of 13.94 m on the 3rd July at 6:00 hours, which was 74cm above the DL(13.20 m) at Kanaighat.

Surma at Sylhet

The WL of river Surma at Sylhet flowed below DL during the monsoon of 2011. It attained its highest yearly peak WL of 10.66m during 2nd and 3rd July, which was 59cm below its DL (11.25m).

The Surma at Sunamgonj

The WL of the river Surma at Sunamgonj flowed above the DL for 5 days at the beginning of July and again for 5 days during 16th and 20th August (total 10 days). The WL of Surma at Sunamgonj recorded its highest peak of 8.56m on 17th August at 15:00 hrs, which was 31cm above its DL (8.25m).

The Kushiyara at Amalshid

The river at this point observed several peaks during the monsoon 2011. It flowed above DL for 9 days at the begging of July, again for one day at 18th August and for 6 days during 24th to 29th of August (total 16 days). It attained its yearly highest peak of 16.75m on 26th August at 18:00 hrs, which was 90cm above the DL (15.85m) at Amalshid.

The Kushiyara at Sheola and Sherpur

The Kushiyara at Sheola and Sherpur observed similar rise and fall as of that Amalshid. At Sheola it flowed above the DL for 9 days from 2nd to 10th July, for 2 days during 15th and 16th August and for 7 days during 24th to 30th August (total 18 days). It attained its monsoon highest peak of 14.18 m on 26th August at 15:00hrs, which was 58 cm above its DL (13.50 m). At Sherpur it flowed above the DL on 19th August for one day, from 23rd August to 27th August for 5 days (total 6 days). It attained its yearly highest peak of 9.12 m on 24th August, which was 122cm above its DL (9.00 m).

The Manu at Manu Railway Bridge and Moulvi Bazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvi Bazar observed several peaks during the monsoon-2011. The WL of Manu river crossed the DL at Manu Railway Bridge for one day in June(peak 18.25, which is 25 cm above the DL) and one day in August (18th August, peak 18.04m, DL 18.0m). At Manu Railway Bridge the WL of Manu flowed 2-days at two different times, only one day each time. At Moulvi Bazar the WL of Manu flowed below DL attained the peak of 11.41m on June, which was 34cm below its DL(11.75m) at this point.

The Someswari at Durgapur

As the flashy river in it showed several peaks during the monsoon 2011, remained above its DL for on 29th June for one day, touched the DL and flowed above the DL from 16th to 18th August 3 days. It attained monsoon highest peak of 14.71m on 16th August at 15:00hours, which was 171cm above its DL (9.75m). During the monsoon it flowed on or above the DL for 5 days.

The Jadukata at Lorergarh

The WL of the flashy river Jadukata at Lorergarh (under Sunamgonj District) flowed above its DL for 2 days during 29th and 30th June, and again during 16th and 17th August (total 4 days), with monsoon peak of 9.54m on 17th August at 15:00hours, which was 101cm above its DL.

The Kangsha at Jariajanjail

As the flashy river it showed several peaks during the monsoon 2011, remained above its DL for 10 days in July from 3rd to 12th July, for 32 days from 5th August to 6th September (total 42 days on or above the DL). It attained its yearly highest peak of 11.80m on 18th August at 09:00hours, which was 195cm above its DL (9.75m).

The Khowai at Habigonj and Bullah

As the flashiest river in Bangladesh, the Khowai at Habigonj showed several peaks during the monsoon 2011, the WL at Habigonj remained above its DL for 3 days in three different times, for one day at the middle of May, for one day at the end of July and again for one day at the middle of August. The WL recorded its yearly highest peak of 11.50 m on middle of May, which was 200 cm above its DL (9.50m). At Bullah the WL of Khowai flowed above the DL from 17th to 20th August for 4 days, with peak of 22.83m on 18th August at 15:00 hours, which is 119cm above the DL (21.64m).

The Dhalai at Kamalgonj

The WL of the flashy river Dhalai at Kamalgonj flowed above its DL for 4 days during 17th and 20th August, with monsoon peak of 20.15m on 19th August at 18:00hours, which was 33cm above its DL.

The Bhugay at Nakuagaon

The WL of the flashy river Bhugai at Nakuagaon flowed above its DL for one day on 25th May (peak 23.6m at 06:00hrs), for 2-days during 29th and 30th June (peak 23.0m), for 3 days during 1st to 3rd July (peak 23.55m), for 2 days during 5th to 6th August, for 1 day 10th August, for 3 days during 16th to 18th August and again for 4 days during 16th and 19th September (total 16 days). The WL of Bhugai at Nakuagaon flowed above the DL for total 16 days during the monsoon-2011, with peak WL of 25.50m on 16th August at 15:00hours, which was 310cm above its DL(22.40m).

The Meghna at Bhairab Bazar

The WL of the Upper Meghna river at Bhairab Bazar flowed below its DL during the monsoon 2011. The WL recorded the peak of 6.08m on 24th August at 12:00 hours, which was 17cm below of its DL at this point.

Comparative hydrographs for few stations the year of 2011, 2004, 1998 & 1988 of rivers of the Meghna basin are shown in figures 3.17 to 3.30.

Table 3. 3: Comparison of Water Level of 2011 and Historical Events of 1988 & 1998 of Some Important Stations in Meghna Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					11	98	88	11	98	88
1	Surma	Kanaighat	15.26	13.20	13.94	15.00	15.10	18	73	75
2	Surma	Sylhet	11.95	11.25	10.66	11.72	11.95	-	14	21
3	Surma	Sunamgonj	9.46	8.25	8.56	8.90	9.03	10	56	62
4	Kushiyara	Amalshid	18.28	15.85	16.75	17.60	17.50	16	54	65
5	Kushiyara	Sheola	14.60	13.50	14.18	14.14	14.09	18	37	80
6	Kushiyara	Sherpur	9.68	9.00	9.12	NA	NA	6	NA	NA
7	Jariajanjail	Kangsha	13.37	9.75	11.80	NA	NA	42	NA	NA
8	Manu	Manu Railway Bridge	20.42	17.07	18.25	18.63	18.95	2	6	66
10	Manu	Moulvi Bazar	15.50	11.75	11.01	11.68	13.01	-	-	25
11	Khowai	Habigonj	12.00	9.50	11.76	11.44	11.06	3	8	14
12	Upper Meghna	Bhairab Bazar	7.66	6.25	6.08	7.33	7.66	-	68	68
13	Gumti	Comilla	13.56	10.38	-	12.79	11.80	-	17	17

3.4 THE SOUTH EASTERN HILL BASIN

The South Eastern Hill basin is constituted with the basin areas of the hilly rivers like the Muhuri, the Halda, the Sangu, the Matamuhuri and the Feni in the South Eastern Part of the country. The WL of the rivers Halda, Matamuhuri and Snagu crossed their respective DLs for 1 to 11 days during this monsoon-2011. As a result, a short duration flood occurred at Narayanhat (Halda river), Bandarban(Sangu river), Dohazari (Sangu river) Chiringa (Matamuhuri river) and Lama (Matamuhuri river) during the monsoon 2011. As a result, low lying areas of Chittagong, Bandarban and Cox's Bazar were affected by the flood for short duration. All other rivers of this basin flowed below their respective DLs. The details of WL of different river are described in following sections. A comparative statement of water level and days flowed above the DLs for the monsoon-2011 and historical events of 1998 and 1988 for this basin are shown in the Table 3.4.

The Muhuri at Parshuram

The Muhuri river is a flashy one flowed below the DL during the monsoon-2011. It attained its highest peak 12.84m on 1st July during 15:00 and 18:00 hours, which was 16cm below its DL (13.00 m).

The Halda at Narayanhat

The WL of the river Halda (a flashy river) at Narayanhat also showed several peaks during this monsoon. It crossed danger mark four times during the monsoon-2011, on 1st July for one day with peak of 15.95 at 15:00 hours-70cm above the DL, and again three times during the month of August, each time for one day. The WL attained its highest peak of 15.80m on 10th August at 15:00 hours, which was 55 cm above the DL(15.25 m) at Narayanhat. The WL of the river Halda at Narayanhat flowed above the DL for 4 days in the monsoon-2011.

The Halda at Panchpukuria

The river here observed several peaks like Narayanhat, but flowed below its DL during the monsoon 2011. At Panchpukuria it attained its highest peak of 7.95m on 1st July at 15:00 hours, which was 155cm below its DL (9.50 m).

The Sangu at Bandarban

The river at this point showed several medium and high peaks during this monsoon. It flowed above the danger mark from 9th August at 15:00 hours till 10th August 18:00 hours. The highest peak recorded was 15.65 m on 10th August at 06:00 and 09:00 hours, 125 cm above its DL (15.25m).

The Sangu at Dohazari

The water level of river Sangu at this point also showed several peaks as of Bandarban flowed above the DL for one day only. The highest peak of the WL recorded at Dohazari of the river was 7.73m on 11th August at 06:00 hours, which was 73cm above its danger mark (7.00 m) at this point.

The Matamuhuri at Lama

The river Matamuhuri at Lama observed several peaks and crossed the DL in the middle of July for 1-day, 21st and 22nd of July for 2-days and 9th and 10th August for 2-days. The highest peak recorded 14.06m on 9th August at 18:00 hours, which was 181cm above its DL(12.25m).

The Matamuhuri at Chiringa

The Muhuri at Chiringa recorded several peaks during the monsoon and crossed DL 6 times for flowed above the DL for 11 days, end of June 1-day, begging of July 1-day, 3rd week of July for 4-days, twice in August for 3-days and middle of September for 2-days. It attained its yearly highest peak 7.03 m on 9th August at 15:00 hours, which was 128 cm above the DL (5.75 m).

The Feni at Ramgarh

The WL of river Feni at this point observed several peaks and flowed below its DL during the monsoon-2011. The highest peak WL attained by the river was 15.38 m on 14th June, which was 199cm below its DL (17.37m) at this point.

Table 3. 4 : Comparison of Water Level of 2011 and Historical Events of 1988 and 1998 of Some Important Station in South Eastern Hill Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					11	98	88	11	98	88
1	Muhuri	Parshuram	15.03	13.00	12.84	14.60	12.42	-	9	48
2	Halda	Narayanhat	18.05	15.25	15.95	16.57	NA	4	21	NA
3	Halda	Panchpukuria	11.55	7.00	7.95	10.44	10.05	-	4	6
4	Sangu	Bandarban	20.38	15.25	16.5	15.25	16.80	2	1	3
5	Sangu	Dohazari	9.05	5.75	7.73	7.42	NA	1	2	NA
6	Matamuhuri	Lama	15.45	12.25	14.06	13.05	12.18	5	2	-
7	Matamuhuri	Chiringa	6.83	5.75	7.03	6.85	NA	11	5	NA
8	Feni	Ramgarh	21.41	17.37	15.38	17.50	NA	-	1	NA

Comparative hydrographs for the year of 2011, 2004 and 1998 of few stations of the South Eastern Hill Basin are shown in Figures 3.31 to 3.36.

3.5 RECORDED HIGHEST WATER LEVEL

Table 3. 5: Recorded Peak Water Level with Date during the monsoon 2011

SL No	River name	Station	Peak WL-2011 (m)	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	26.04	31/07/11
2	TEESTA	DALIA	52.50	19/09/11
3	TEESTA	KAUNIA	29.20	17/08/11
4	JAMUNESWARI	BADARGANJ	31.83	19/08/11
5	GHAGOT	GAIBANDHA	21.81	22/07/11
6	KARATOA	CHAK RAHIMPUR	20.07	22/08/11
7	KARATOA	BOGRA	15.50	11/08/11
8	BRAHMAPUTRA	NOONKHAWA	26.20	24/07/11
9	BRAHMAPUTRA	CHILMARI	23.61	24/07/11
10	JAMUNA	BAHADURABAD	19.65	25/07/11
11	JAMUNA	SERAJGONJ	13.42	25/07/11
12	JAMUNA	ARICHA	9.60	21/08/11
13	OLD BRAHMAPUTRA	JAMALPUR	15.41	20/08/11
14	OLD BRAHMAPUTRA	MYMENSINGH	10.72	19/08/11
15	BURIGANGA	DHAKA	5.16	21/08/11
16	BALU	DEMRA	5.74	20/08/11
17	LAKHYA	NARAYANGONJ	5.39	01/09/11
18	TURAG	MIRPUR	5.70	19/08/11
19	TONGI KHAL	TONGI	6.38	18/08/11
20	KALIGANGA	TARAGHAT	7.86	24/08/11
21	DHALESWARI	JAGIR	7.15	24/08/11
22	DHALESWARI	REKABI BAZAR	5.08	31/08/11
23	BANSHI	NAYARHAT	5.91	04/09/11
	GANGES BASIN			
24	KARATOA	PANCHAGARH	69.90	17/08/11
25	PUNARBHABA	DINAJPUR	33.55	19/08/11
26	ICH-JAMUNA	PHULBARI	29.43	19/08/11

SL No	River name	Station	Peak WL-2011 (m)	Date
27	TANGON	THAKURGAON	50.33	18/08/11
28	UPPER ATRAI	BHUSIRBANDAR	39.92	18/08/11
29	MOHANANDA	ROHANPUR	21.65	25/08/11
30	MOHANANDA	CHAPAI-NAWABGANJ	21.43	28/09/11
31	LITTLE JAMUNA	NAOGAON	15.13	21/08/11
32	ATRAI	MOHADEBPUR	18.75	20/08/11
33	GANGES	PANKHA	22.21	21/08/11
34	GANGES	RAJSHAHI	18.17	22/08/11
35	GANGES	HARDINGE BRIDGE	13.78	10/02/11
36	PADMA	GOALONDO	8.86	20/08/11
37	PADMA	BHAGYAKUL	6.62	22/08/11
38	GORAI	GORAI RAIL BRIDGE	12.42	22/08/11
39	GORAI	KAMARKHALI	8.44	21/08/11
40	ICHAMATI	SAKRA	3.70	01/09/11
41	MATHABHANGA	CHUADANGA	10.17	20/08/11
42	MATHABHANGA	HATBOALIA	12.23	22/08/11
43	KOBADAK	JHIKORGACHA	4.99	21/08/11
44	KUMAR	FARIDPUR	5.45	18/08/11
45	ARIALKHAN	MADARIPUR	4.37	14/08/11
	MEGHNA BASIN			
46	SURMA	KANAIGHAT	13.94	31/07/11
47	SURMA	SYLHET	10.90	10/07/11
48	SURMA	SUNAMGONJ	8.56	17/08/11
49	KUSHIYARA	AMALSHID	16.75	26/08/11
50	KUSHIYARA	SHEOLA	14.18	26/08/11
51	KUSHIYARA	SHERPUR	9.12	24/08/11
52	SARIGOWAIN	SARIGHAT	12.78	02/07/11
53	MANU	MANU RAILY BRIDGE	18.25	08/06/11
54	MANU	MOULVI BAZAR	11.41	08/06/11
55	KHOWAI	BALLAH	21.93	20/08/11
56	KHOWAI	HABIGONJ	11.50	22/05/11
57	DHALAI	KAMALGONJ	20.22	11/06/11
58	BHUGAI	NAKUAGAON	25.50	16/08/11
59	JADUKATA	LORERGARH	9.54	16/08/11
60	SOMESWARI	DURGAPUR	14.71	16/08/11
61	KANGSHA	JARIAJANJAIL	11.80	18/08/11
62	MEGHNA	BHAIRAB BAZAR	6.08	24/08/11
63	GUMTI	COMILLA	10.81	02/07/11
64	GUMTI	DEBIDDAR	6.88	22/08/11
65	MEGHNA	CHANDPUR	4.55	04/08/11
	SOUTH EASTERN HILL BASIN			
66	MUHURI	PARSHURAM	88.67	18/11/11
67	HALDA	NARAYAN HAT	15.95	01/07/11
68	HALDA	PANCHPUKURIA	7.95	01/07/11
69	SANGU	BANDARBAN	16.50	08/10/11
70	SANGU	DOHAZARI	7.73	11/08/11
71	MATAMUHURI	LAMA	14.06	09/08/11
72	MATAMUHURI	CHIRINGA	7.03	09/08/11
73	FENI	RAMGARH	15.38	26/05/11

Table 3. 6: Recorded Historical Highest Water Level with Date

Sl. No.	River	Station	Danger Level (m)	Recorded highest WL (m) before 2011 flood (date)	WL (Date) Exceeding previous Highest WL (m)
1	Dharla	Kurigram	26.50	27.66 (14.07.96)	-
2	Teesta	Dalia	52.40	52.97 (29.07.72)	-
3	Teesta	Kaunia	30.00	30.52 (06.01.68)	-
4	Brahmaputra	Noonkhawa	27.25	28.10	-
5	Brahmaputra	Chilmari	24.00	25.07 (23.08.62)	-
6	Jamuna	Bahadurabad	19.50	20.62 (30.08.88)	-
7	Jamuna	Serajgonj	13.35	15.12 (30.08.88)	-
8	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
9	Old Brhamaputra	Jamalpur	17.00	18.00 (31.07.54)	-
10	Old Brhamaputra	Mymensingh	12.50	13.71(1.09.88)	-
11	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
12	Lakhya	Narayangonj	5.50	6.93 (10.09.98)	-
13	Turag	Mirpur	5.94	8.35 (10.09.88)	-
14	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-
15	Kaliganga	Taraghat	8.38	10.37(2.09.88)	-
16	Punarbhaba	Dinajpur	33.50	34.40	-
17	Padma	Pankha	21.50	24.14 (07.09.97)	-
18	Padma	Rajshahi	18.50	20.00 (13.09.1910)	-
19	Padma	H- Bridge	14.25	15.19 (10.09.98)	-
20	Padma	Goalundo	8.50	10.21 (03.08.08)	-
21	Padma	Bhagyakul	6.00	7.58	-
22	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
23	Surma	Kanaighat	13.20	15.26	-
24	Surma	Sylhet	11.25	12.44 (19.07.04)	-
25	Surma	Sunamgonj	8.25	9.75 (20.07.04)	-
26	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
27	Kushiyara	Sheola	13.50	14.60 (09.09.08)	-
28	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
29	Manu	Moulvi Bazar	11.75	13.25(8.06.93)	-
30	Khowai	Habigonj	9.50	12.00 (18.06.07)	-
31	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
32	Gumti	Comilla	11.75	13.56 (23.07.93)	-
33	Muhuri	Parshuram	13.00	16.33(13.09.04)	-
34	Halda	Narayanhat	15.25	19.30(13.08.99)	-
35	Halda	Panchpukuria	7.00	12.54(27.06.03)	-
36	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
37	Sangu	Dohazari	5.75	9.05	-
38	Matamuhuri	Lama	12.25	15.46(12.08.99)	-
39	Matamuhuri	Chiringa	5.75	7.03 (10.07.97)	-
40	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

WL - Water Level

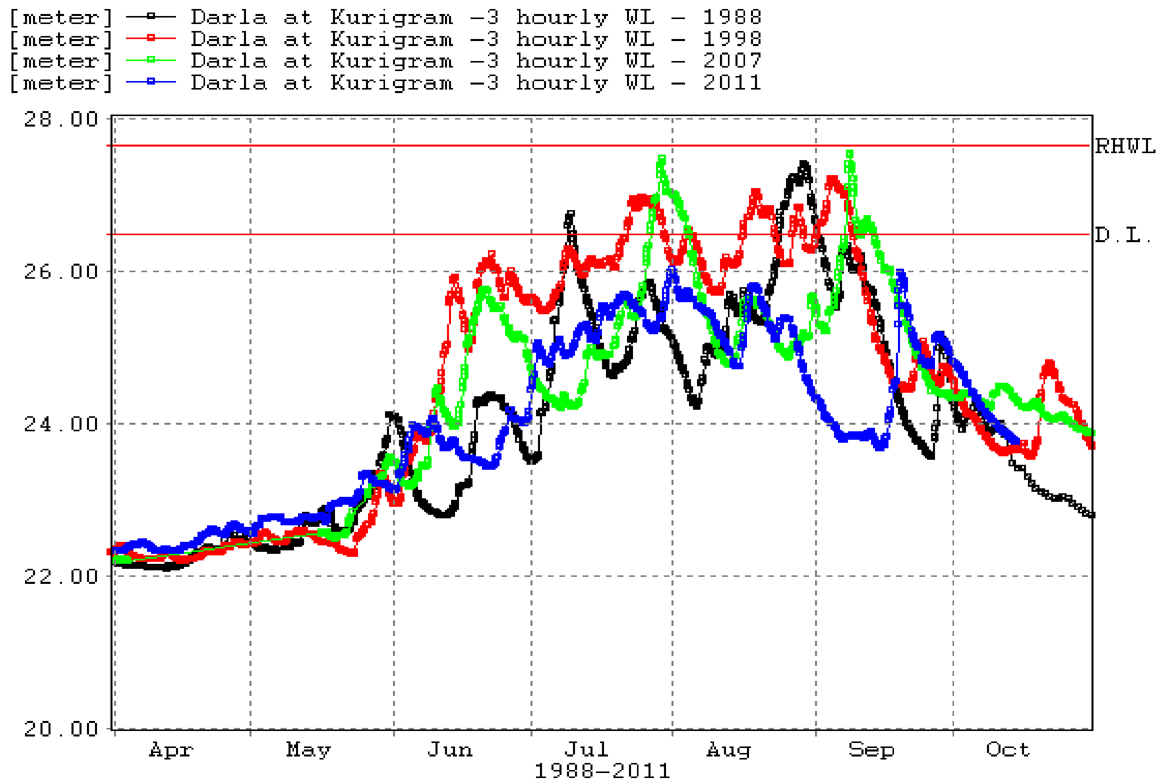


Figure 3. 1 : Comparison of Hydrograph on Dharla at Kurigram

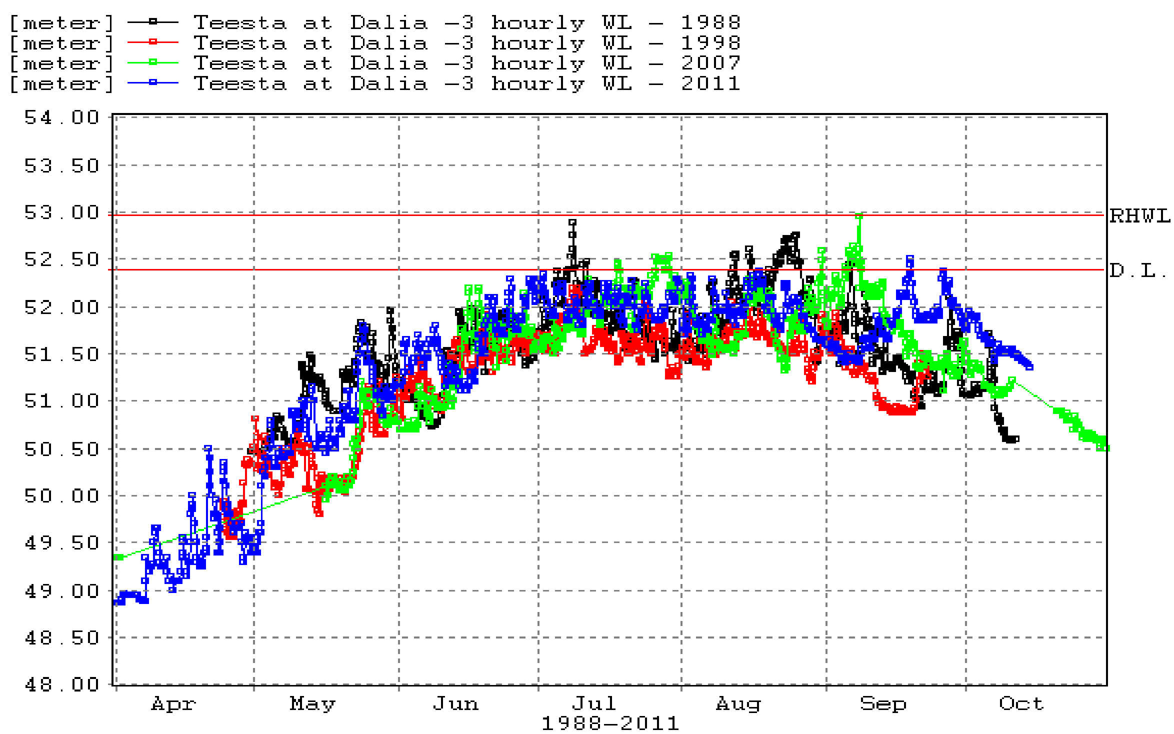


Figure 3. 2 : Comparison of Hydrograph on Teesta at Dalia

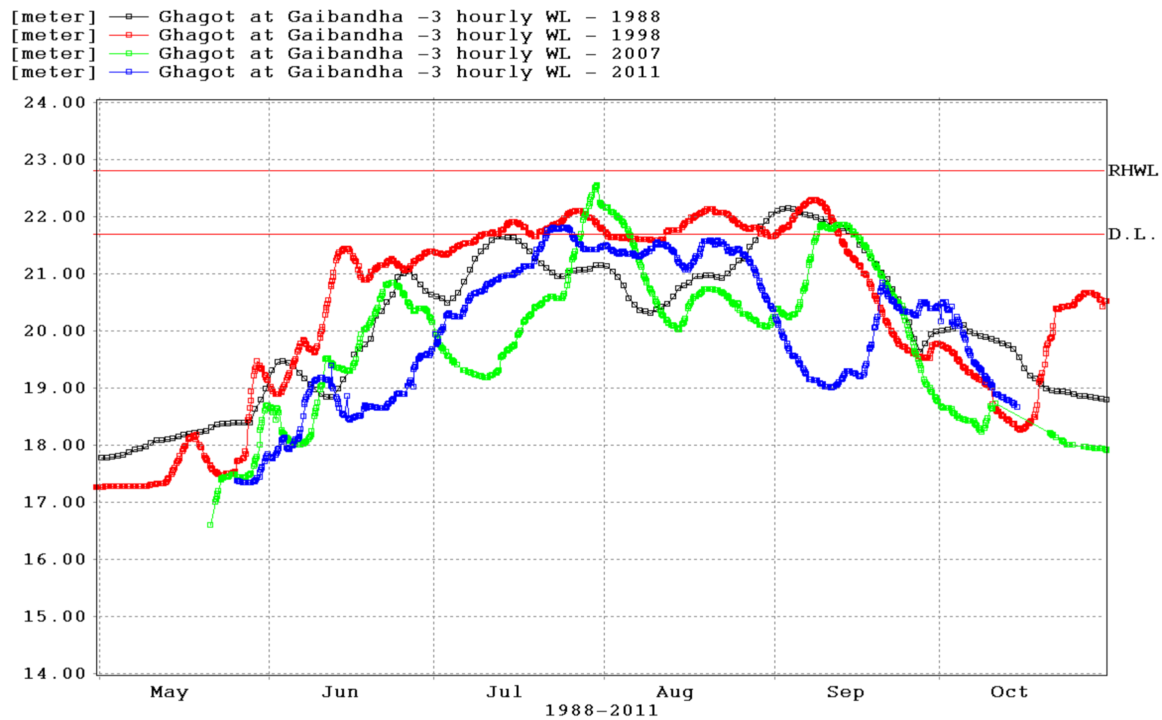


Figure 3. 3 : Comparison of Hydrograph on Ghagot at Gaibandha

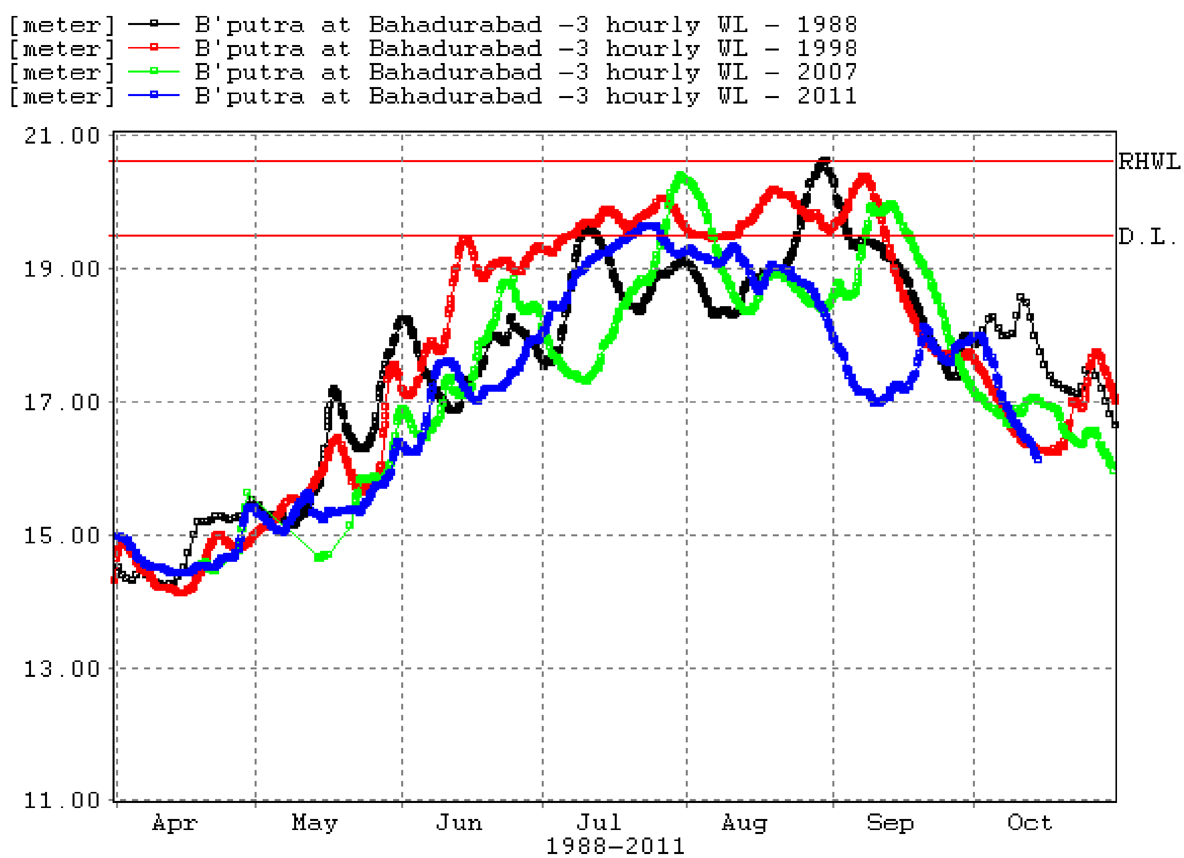


Figure 3. 4 : Comparison of Hydrograph on Brahmaputra at Bahadurabad

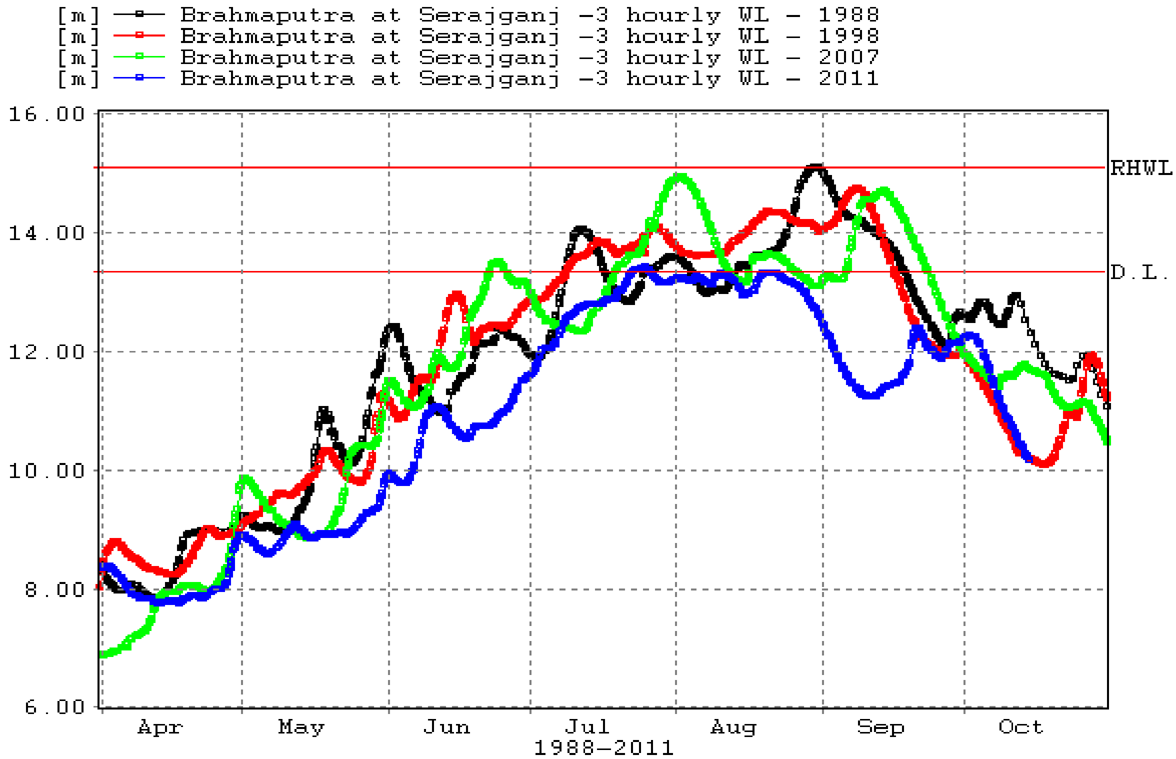


Figure 3. 5 : Comparison of Hydrograph on Jamuna at Serajgonj

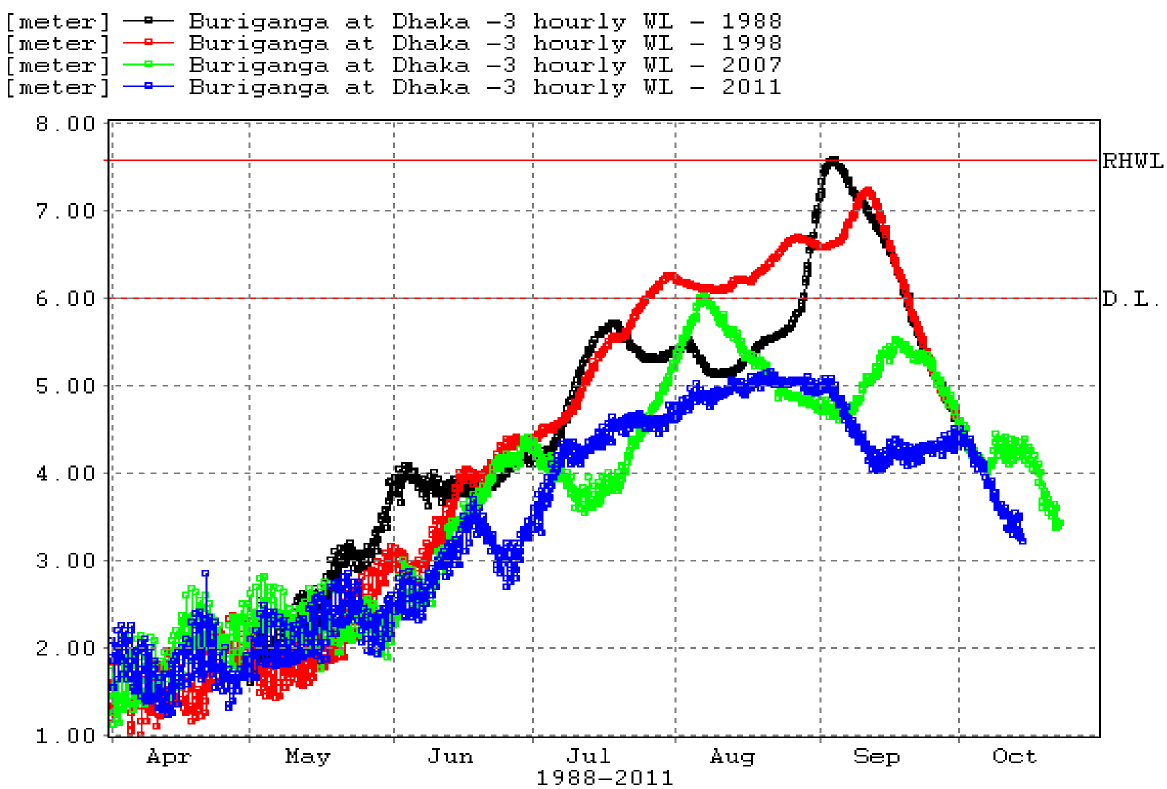


Figure 3. 6 : Comparison of Hydrograph on Buriganga at Dhaka(Milbarak)

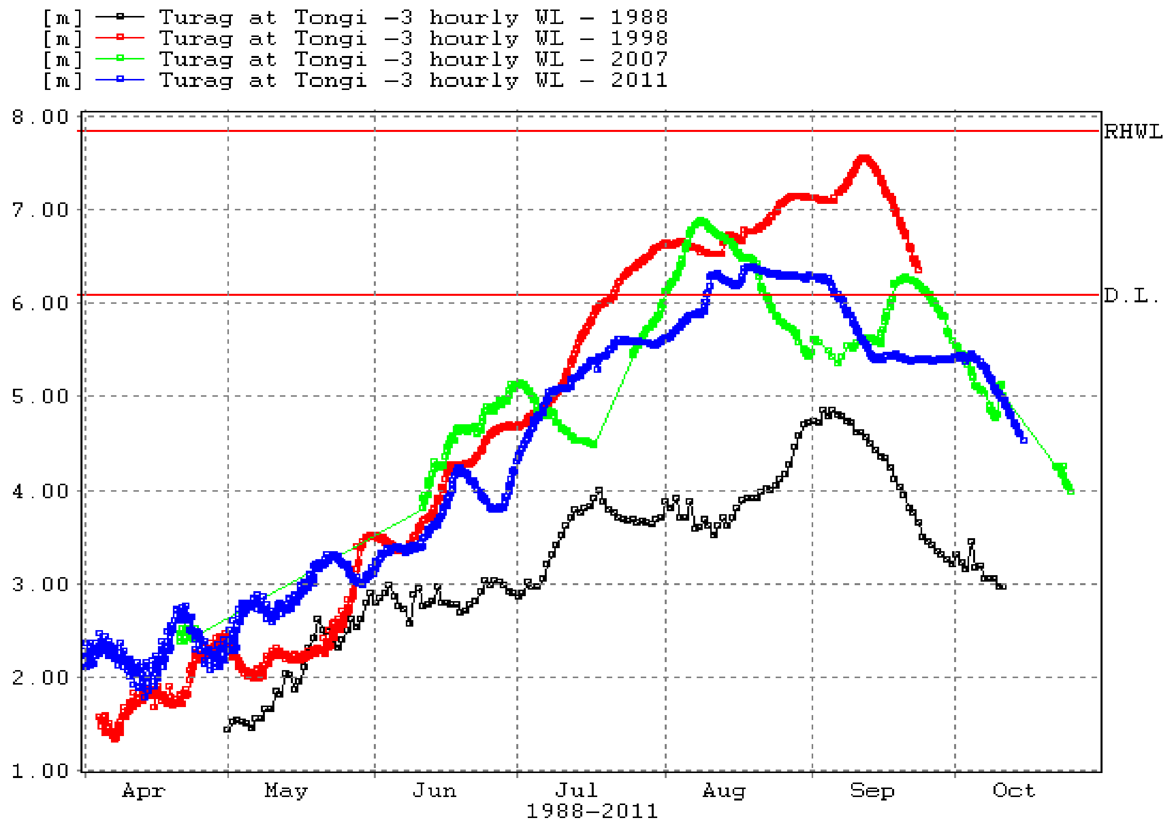


Figure 3. 7 : Comparison of Hydrograph on Tongi Khal at Tongi

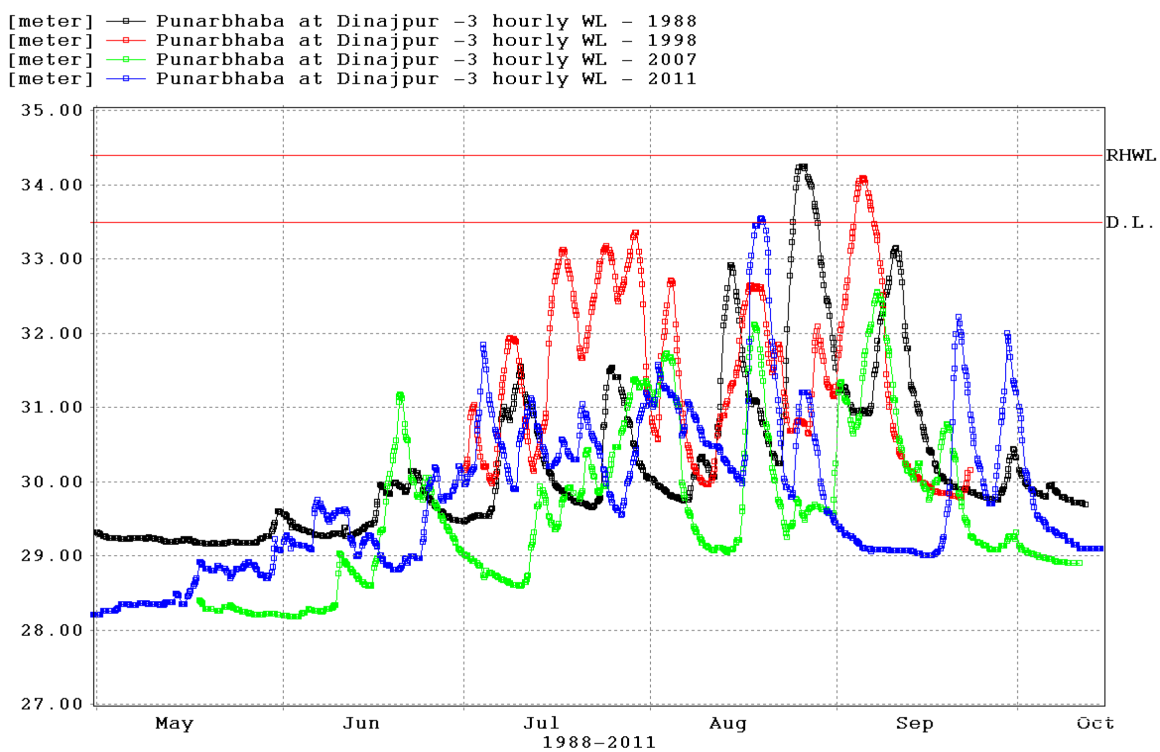


Figure 3. 8 : Comparison of Hydrograph on Punarbhaba at Dinajpur

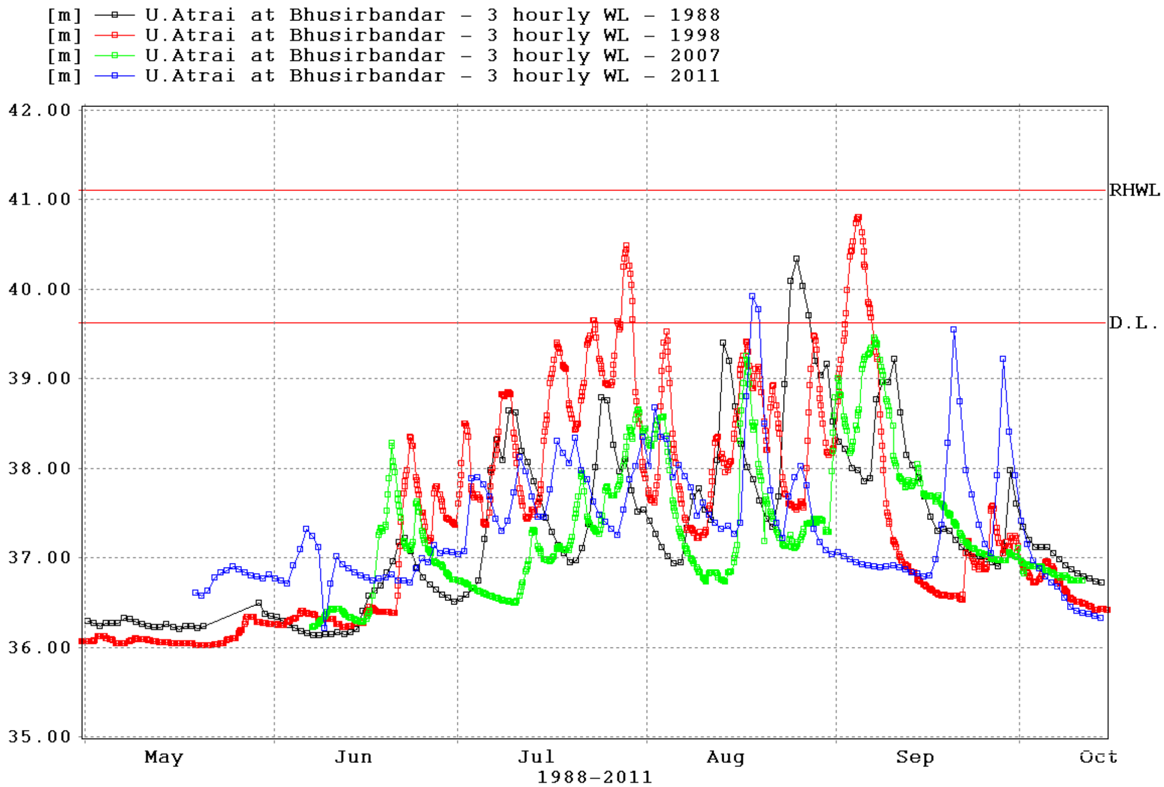


Figure 3. 9 : Comparison of Hydrograph on Upper Atrai at Bhusirbandar

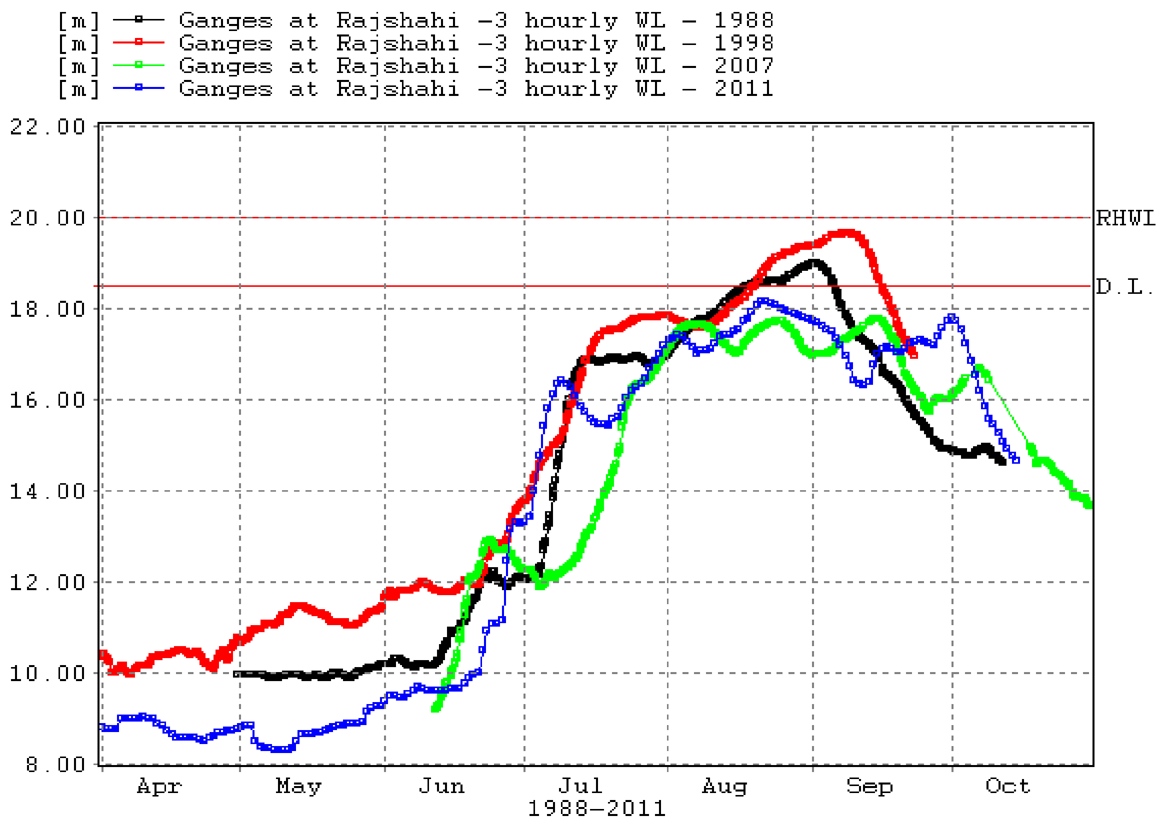


Figure 3. 10 : Comparison of Hydrograph on Ganges at Rajshahi

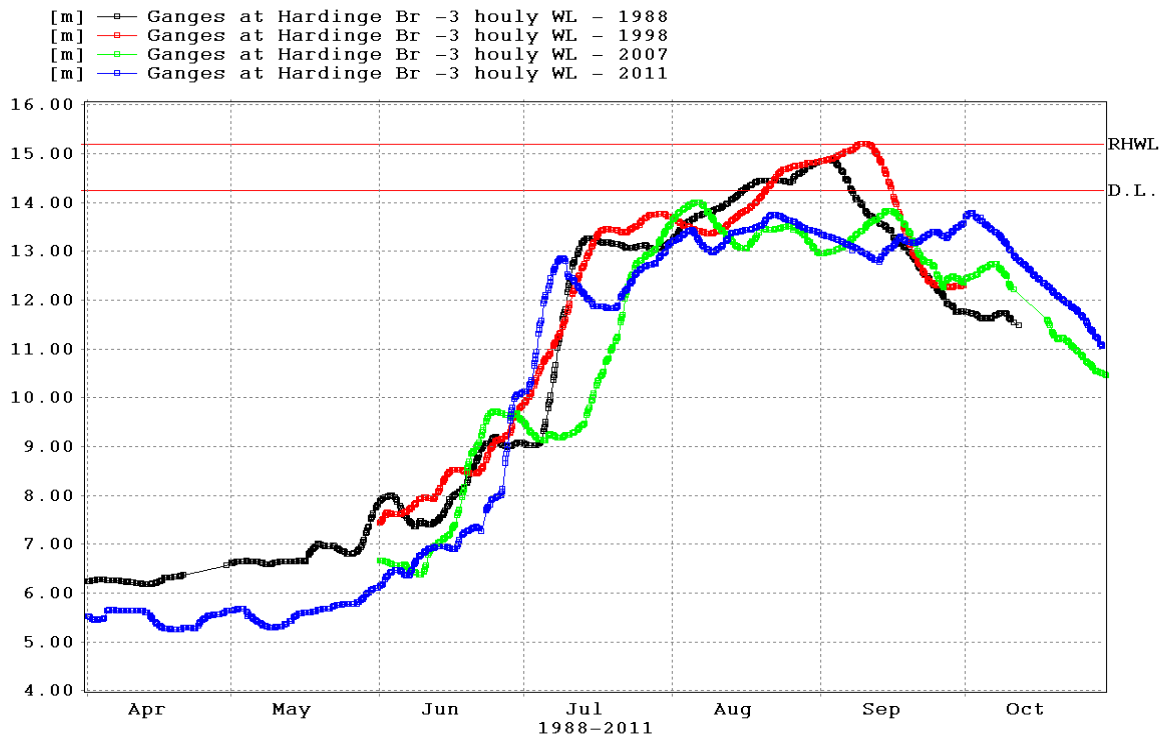


Figure 3. 11 : Comparison of Hydrograph on Ganges at Hardinge Bridge

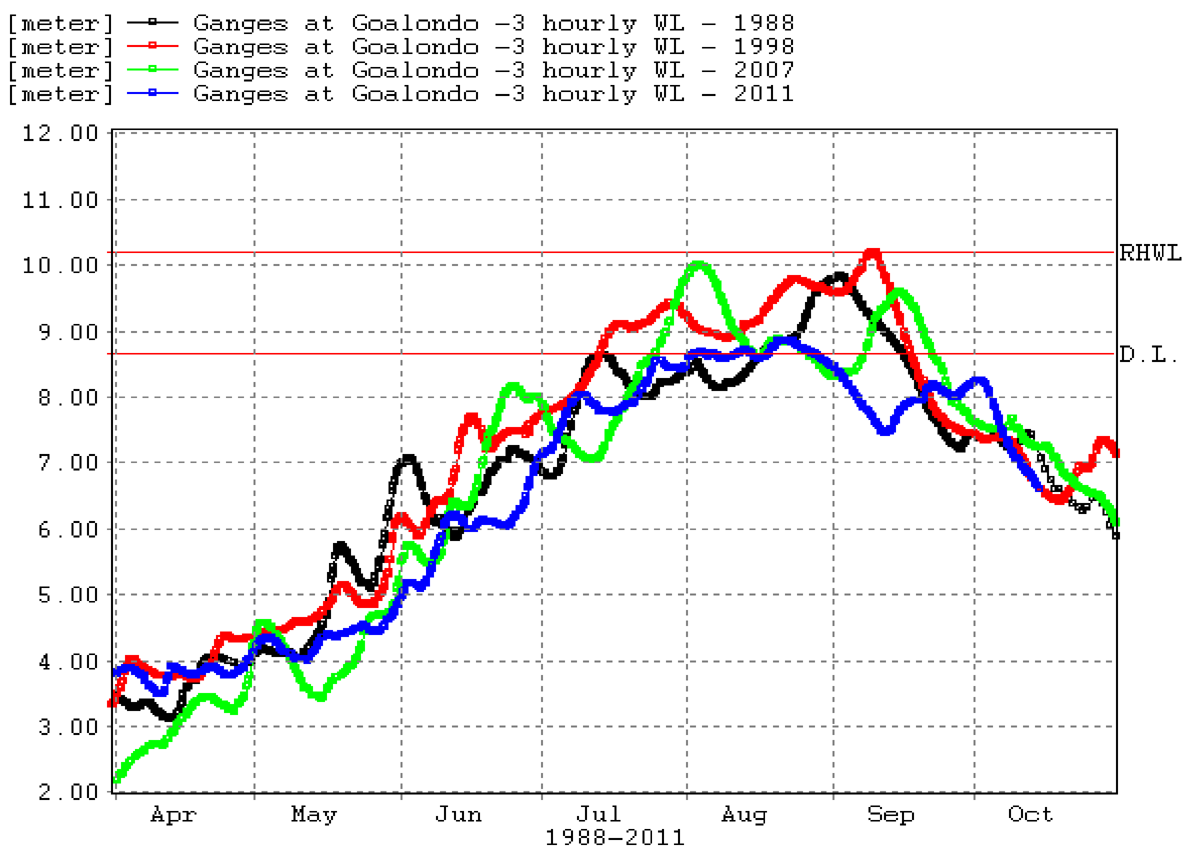


Figure 3. 12 : Comparison of Hydrograph on Padma at Goalondo

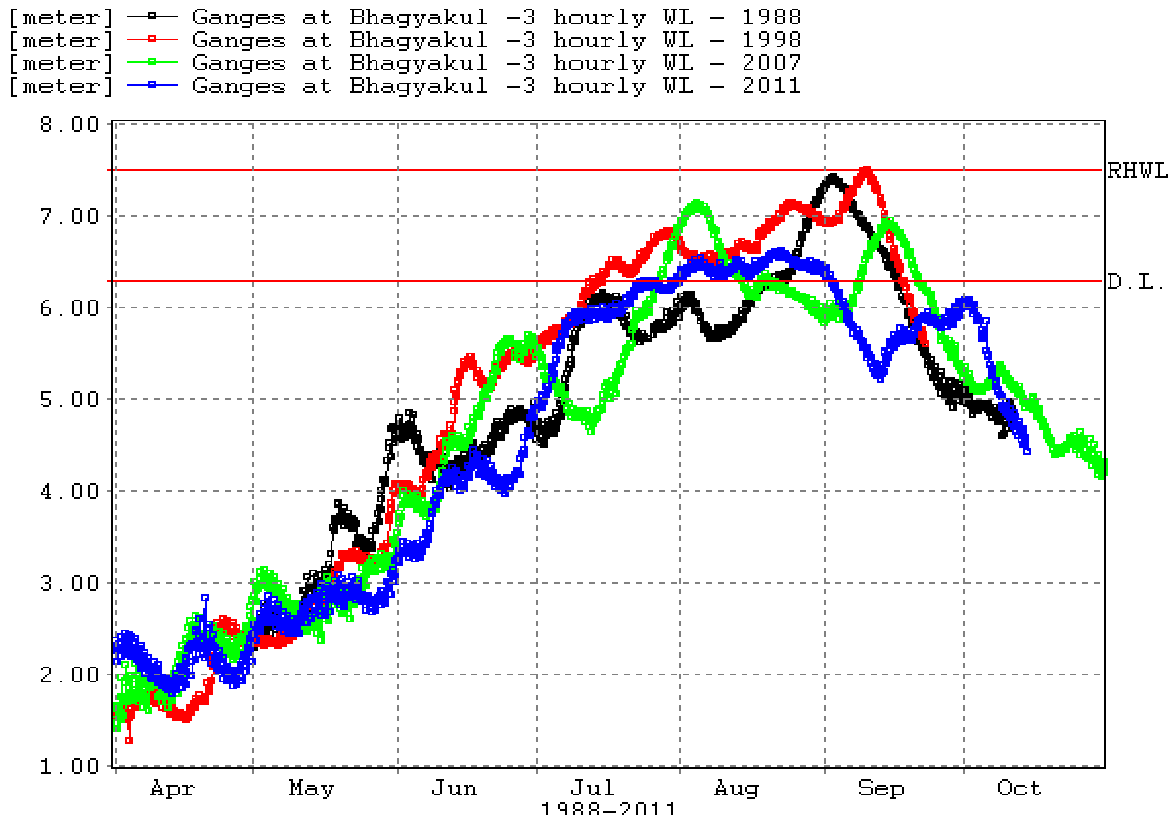


Figure 3. 13 : Comparison of Hydrograph on Padma at Bhagyakul

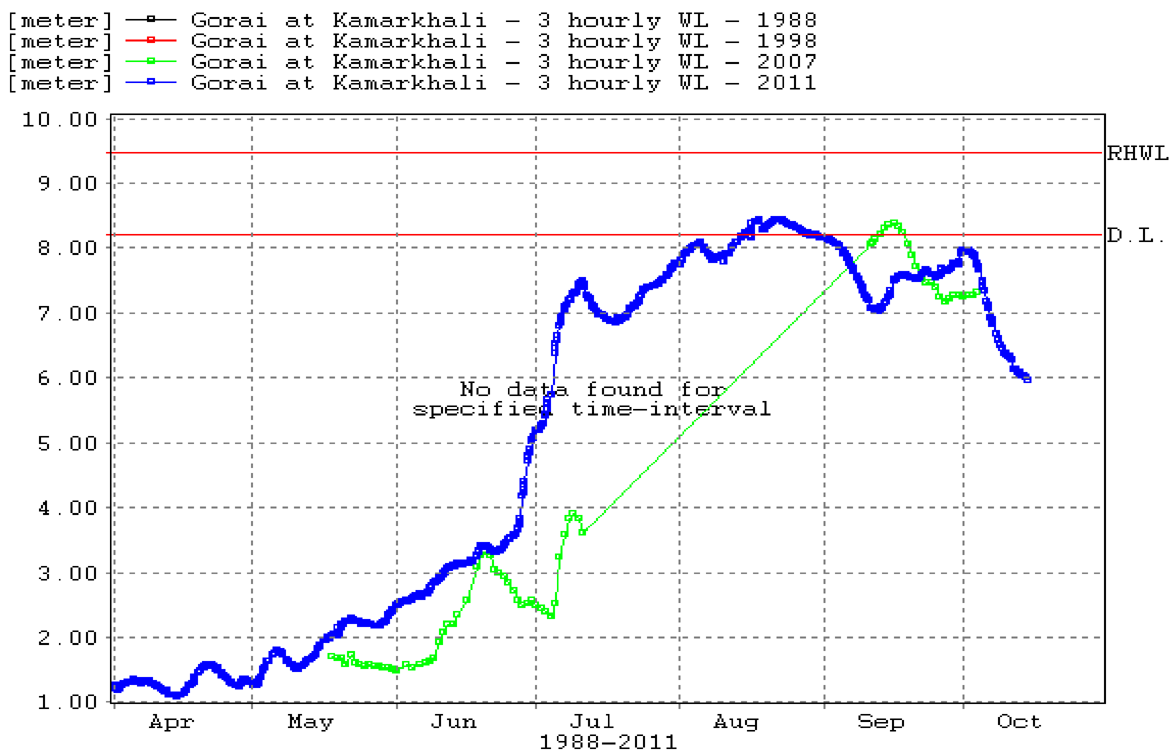


Figure 3. 14 : Comparison of Hydrograph on Gorai at Kamarkhali

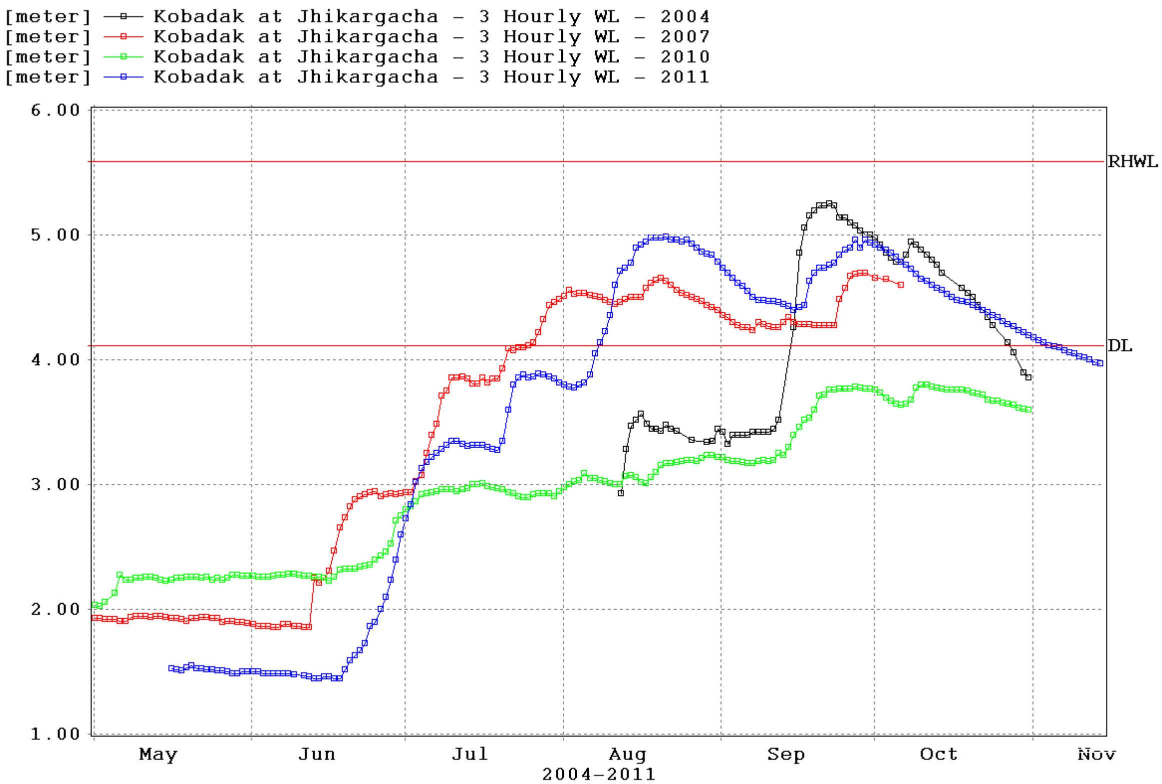


Figure 3. 15 : Comparison of Hydrograph on Kobodak at Jhikorgacha

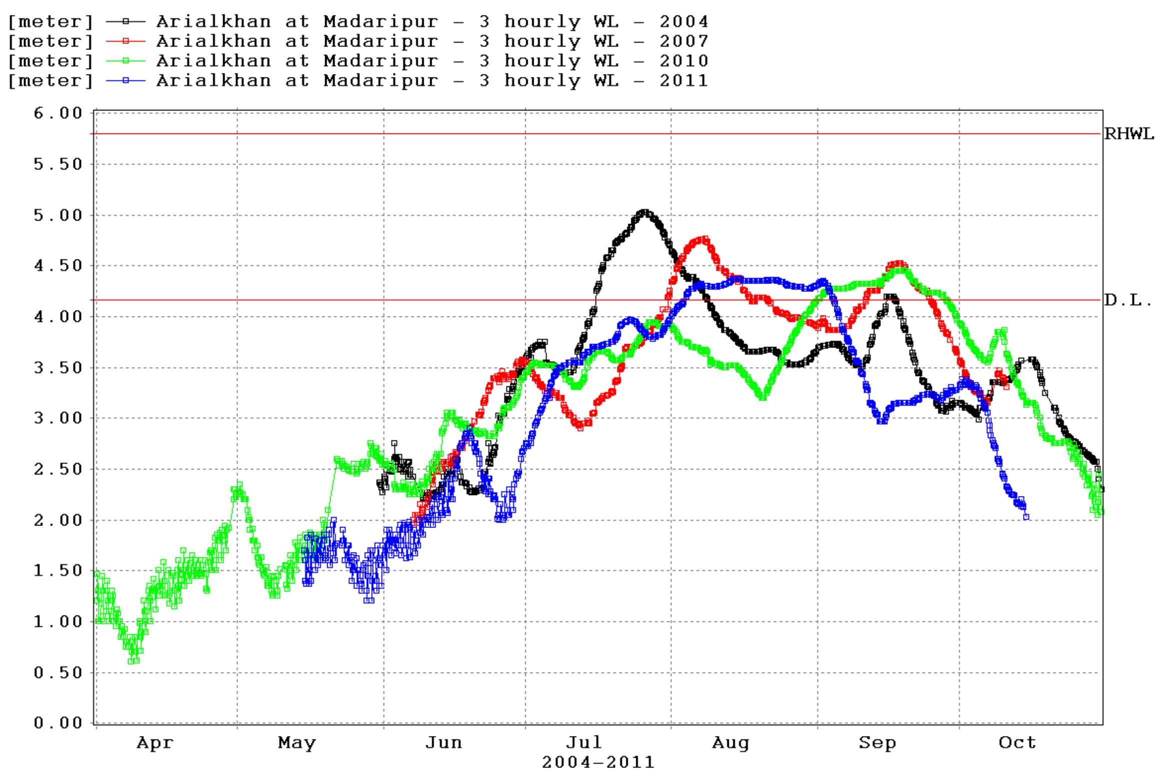


Figure 3. 16 : Comparison of Hydrograph on Arialkhan at Madaripur

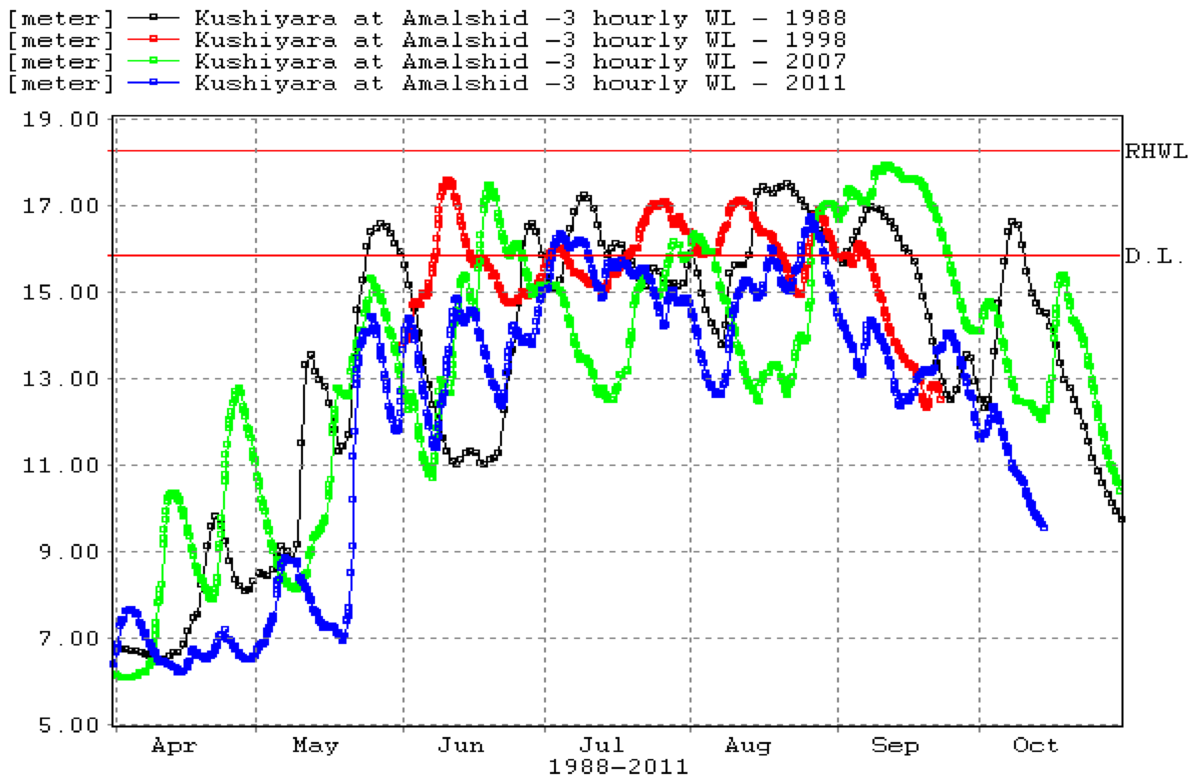


Figure 3. 17 : Comparison of Hydrograph on Kushiyara at Amalshid

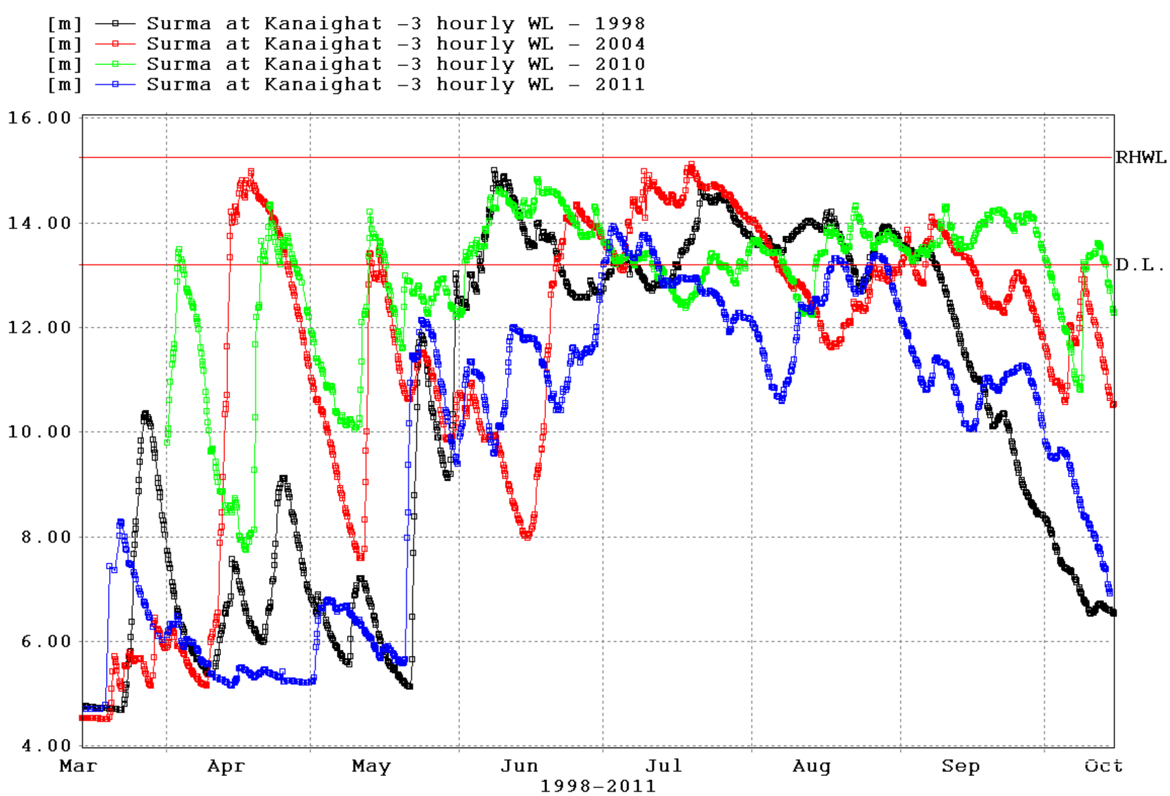


Figure 3. 18 : Comparison of Hydrograph on Surma at Kanaighat

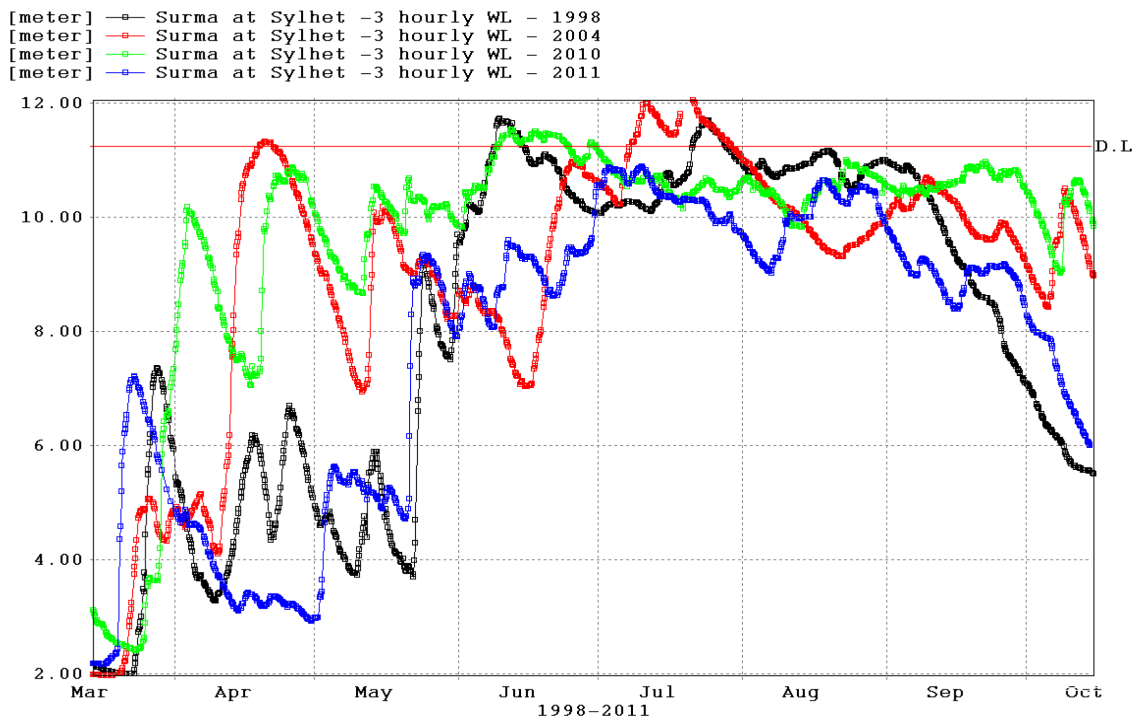


Figure 3. 19 : Comparison of Hydrograph on Surma at Sylhet

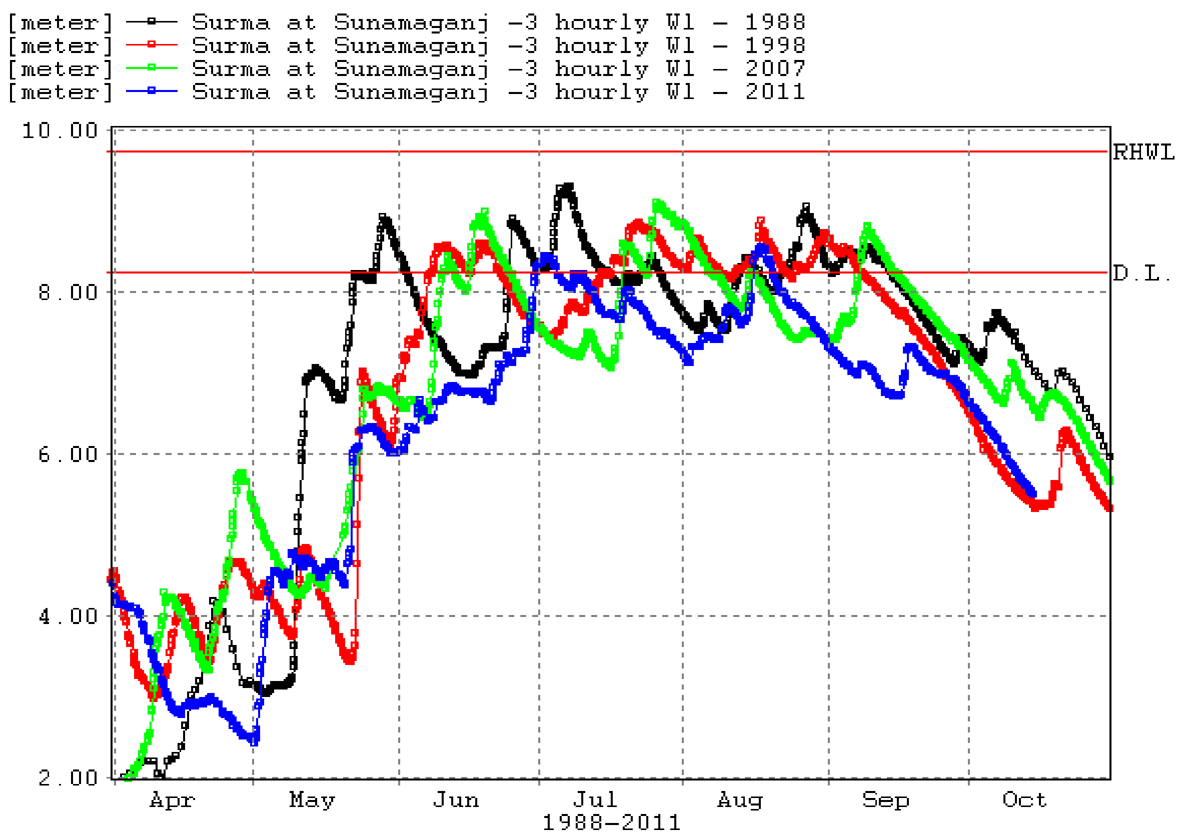


Figure 3. 20 : Comparison of Hydrograph on Surma at Sunamgonj

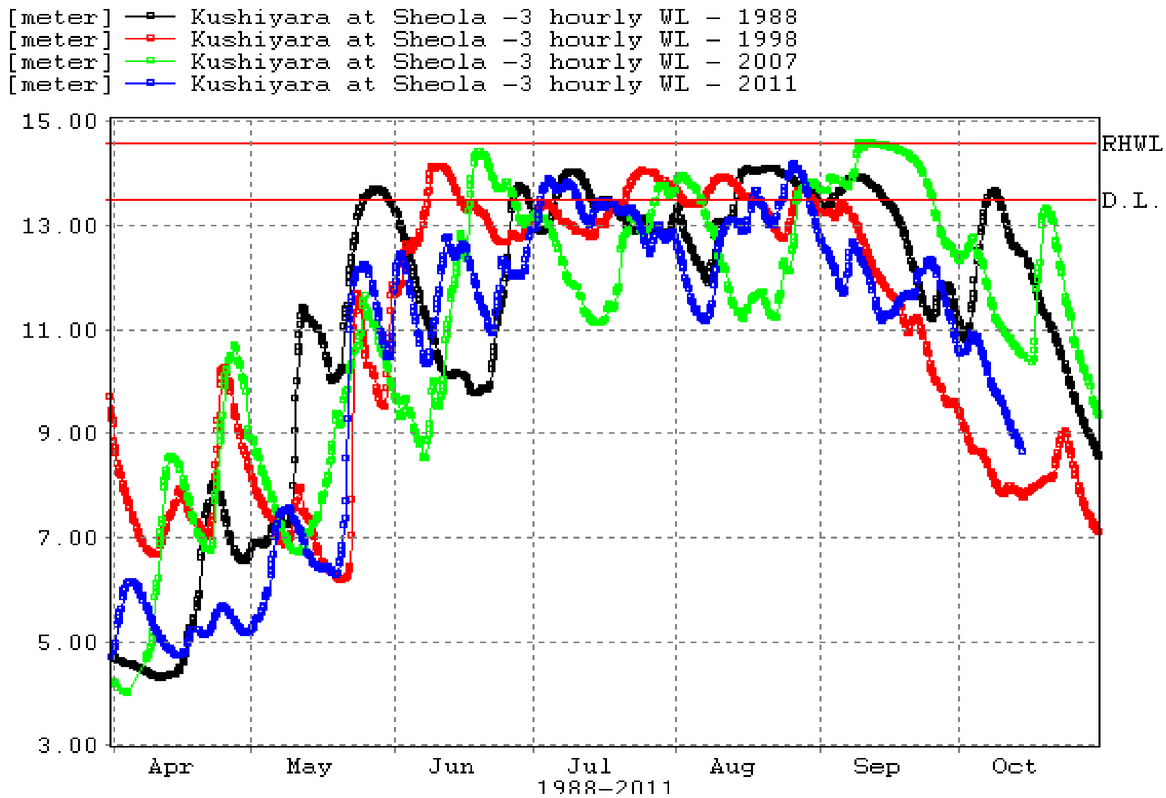


Figure 3. 21 : Comparison of Hydrograph on Kushiyara at Sheola

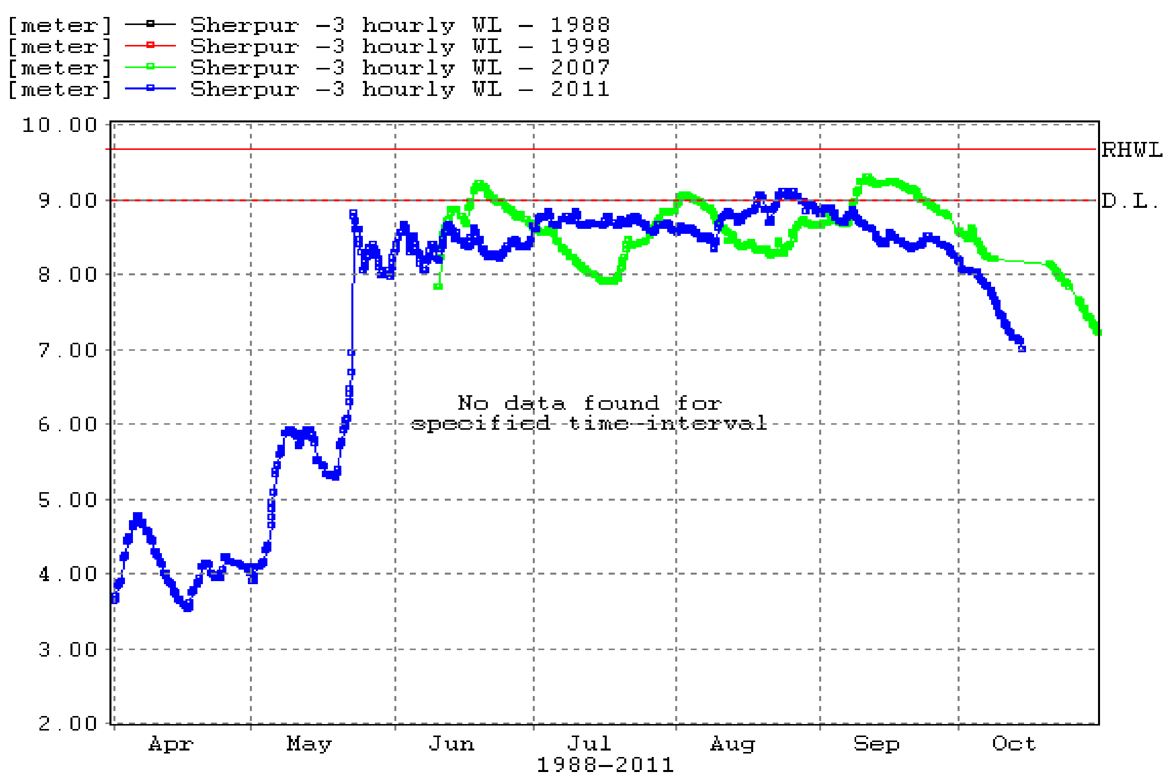


Figure 3. 22 : Comparison of Hydrograph on Kushiyara at Sherpur

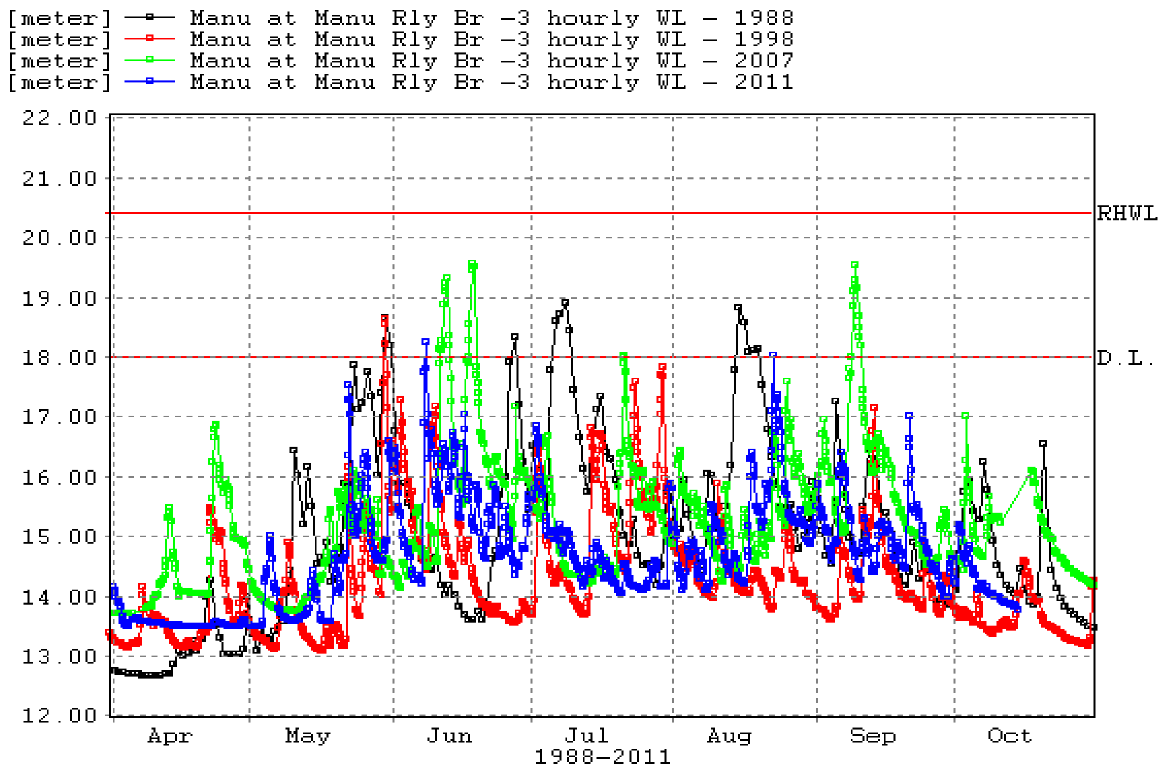


Figure 3. 23 : Comparison of Hydrograph on Manu at Manu Railway Bridge

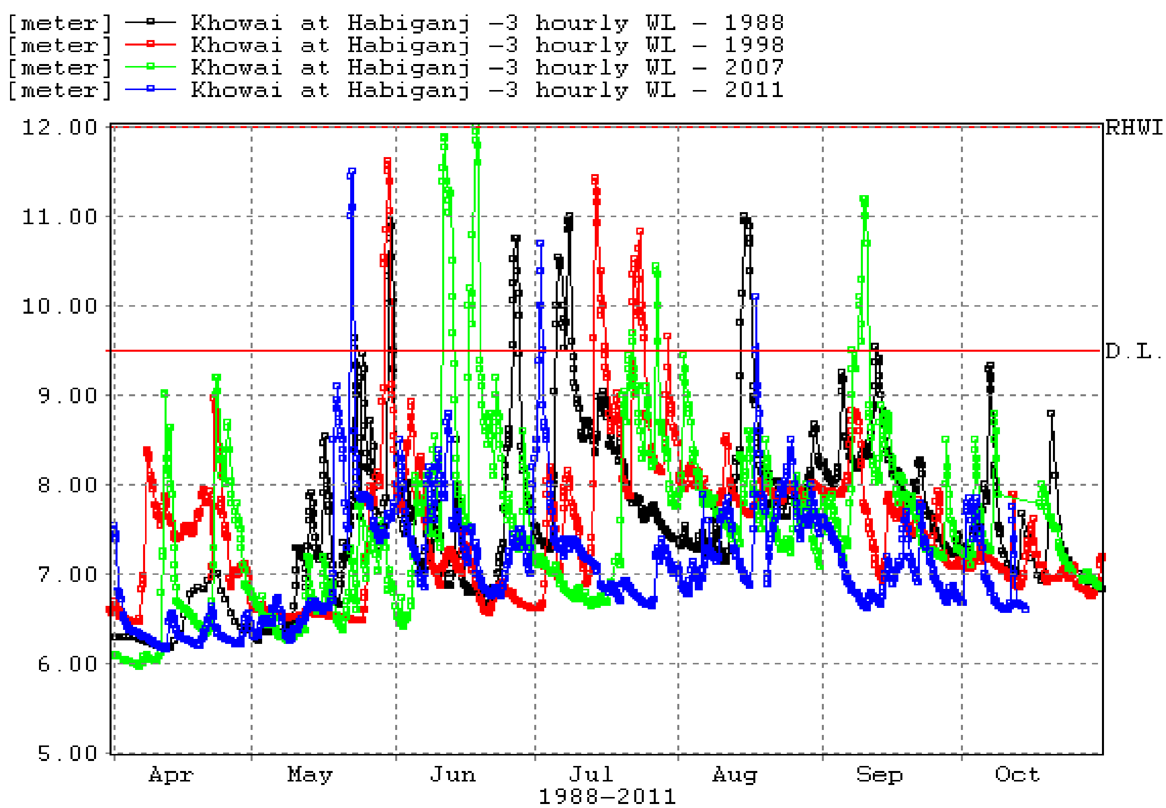


Figure 3. 24 : Comparison of Hydrograph on Khowai at Habigonj

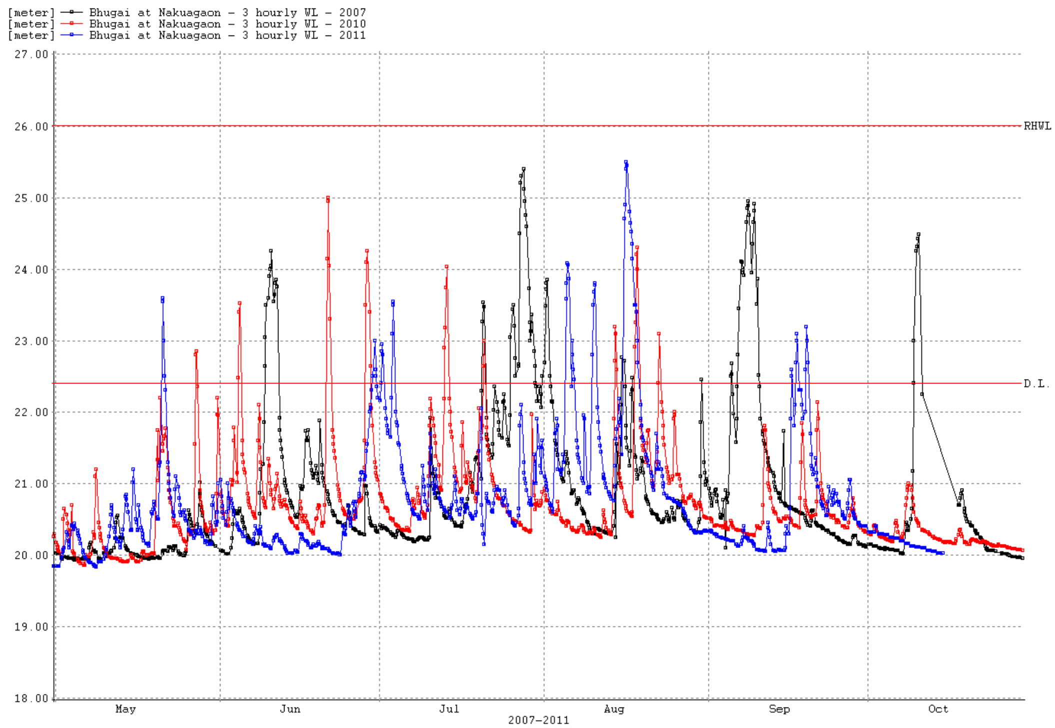


Figure 3. 25 : Comparison of Hydrograph on Bhugai at Nokuagaon

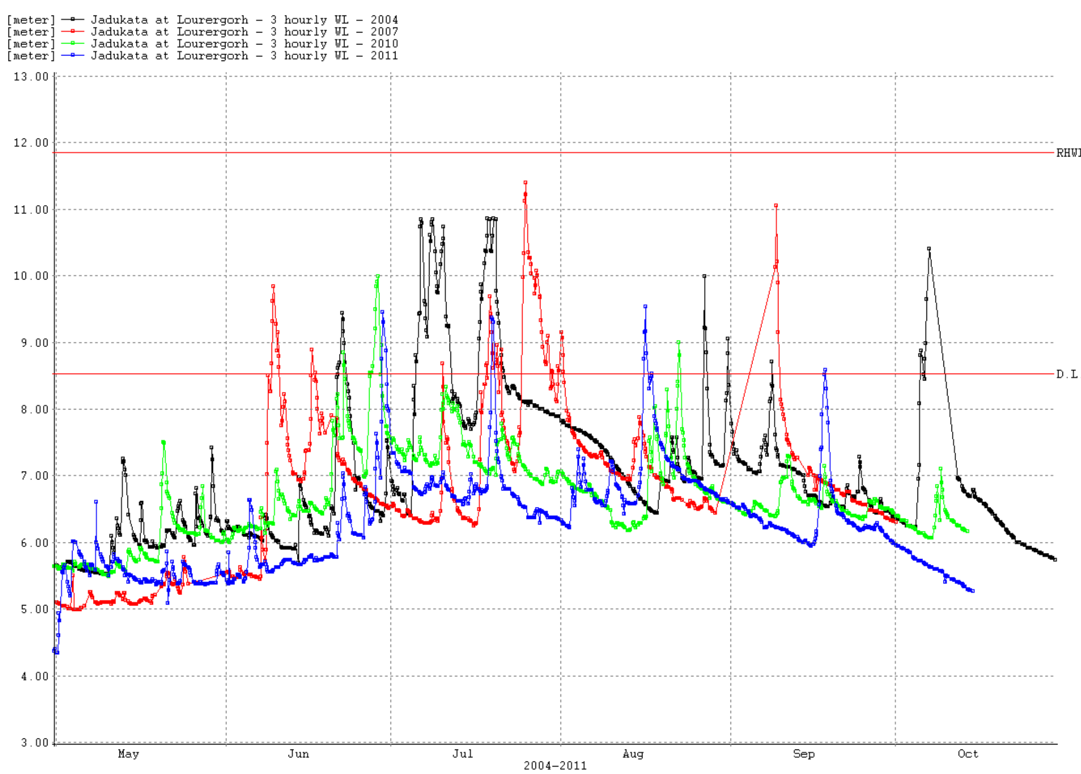


Figure 3. 26 : Comparison of Hydrograph on Jadukata at Lorerghor

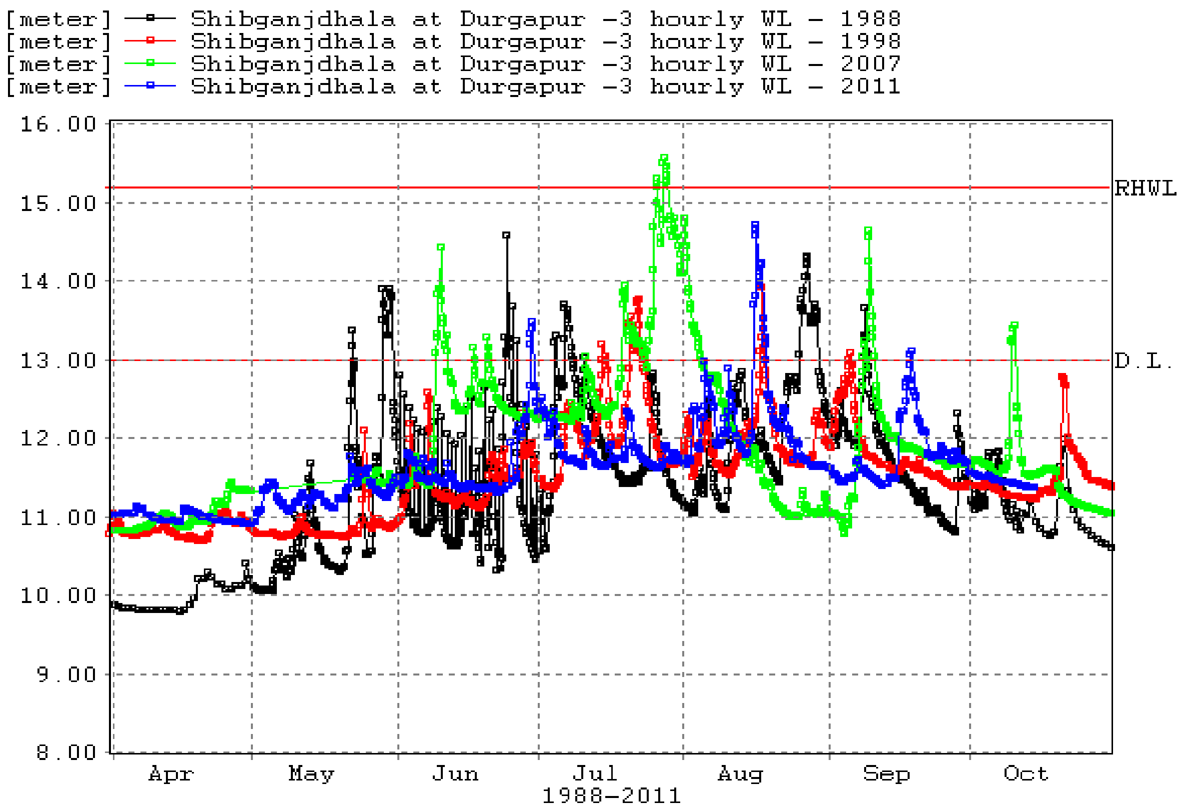


Figure 3. 27 : Comparison of Hydrograph on Someswari at Durgapur

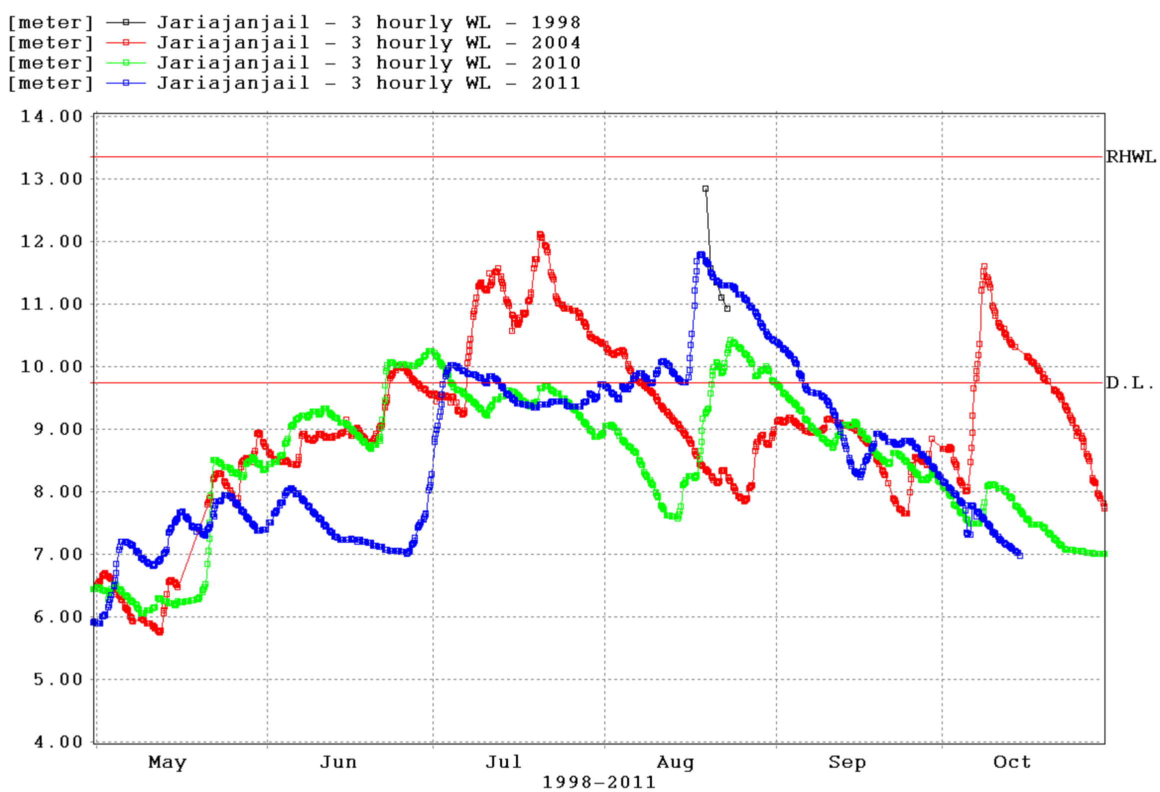


Figure 3. 28 : Comparison of Hydrograph on Kangsha at Jariajanjail

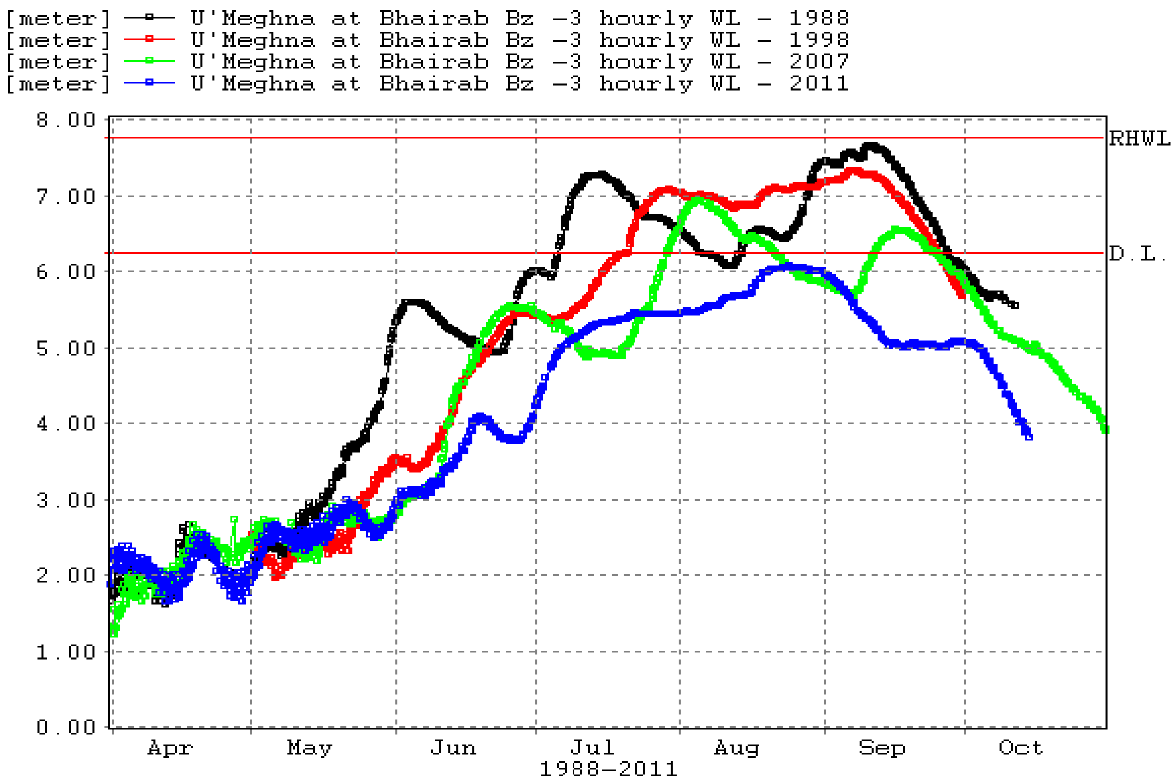


Figure 3. 29 : Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

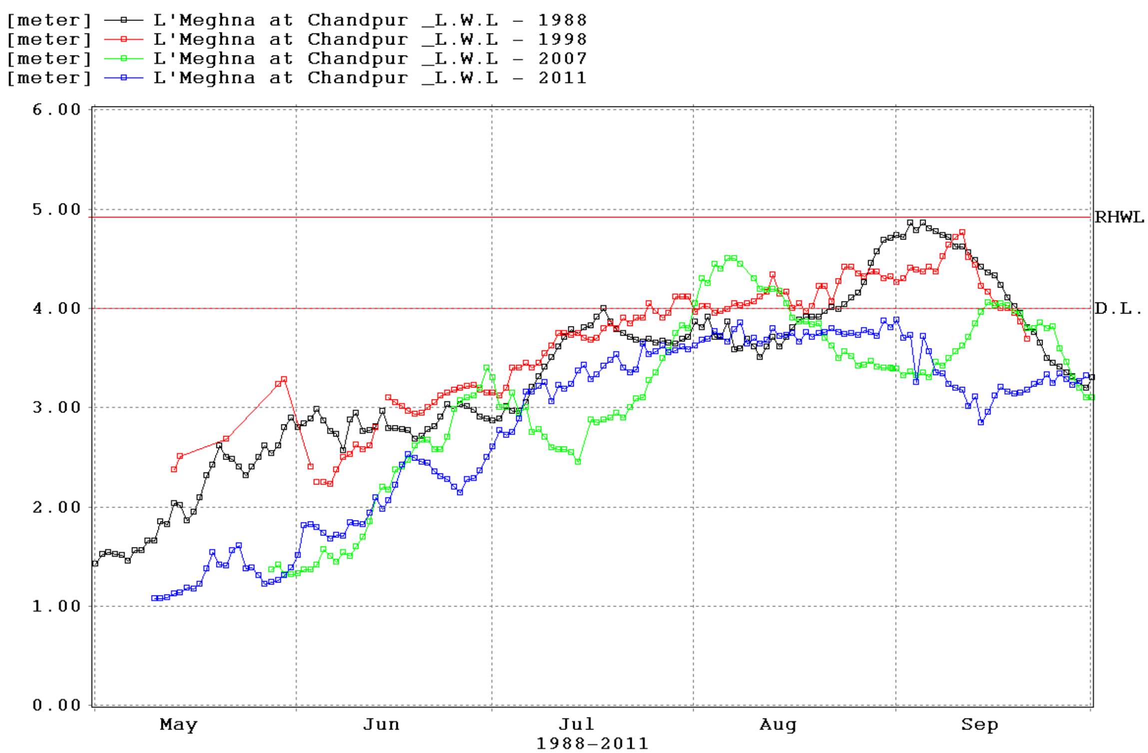


Figure 3. 30 : Comparison of Hydrograph on Lower Meghna at Chandpur

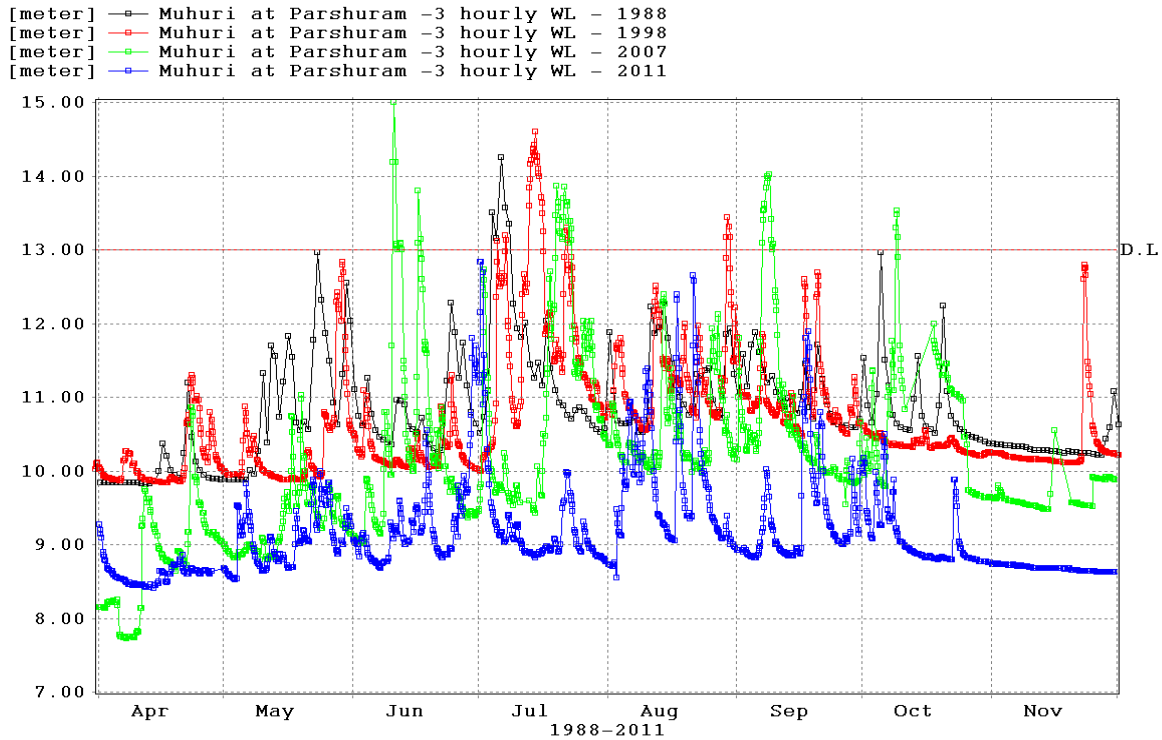


Figure 3. 31 : Comparison of Hydrograph on Muhuri at Parshuram

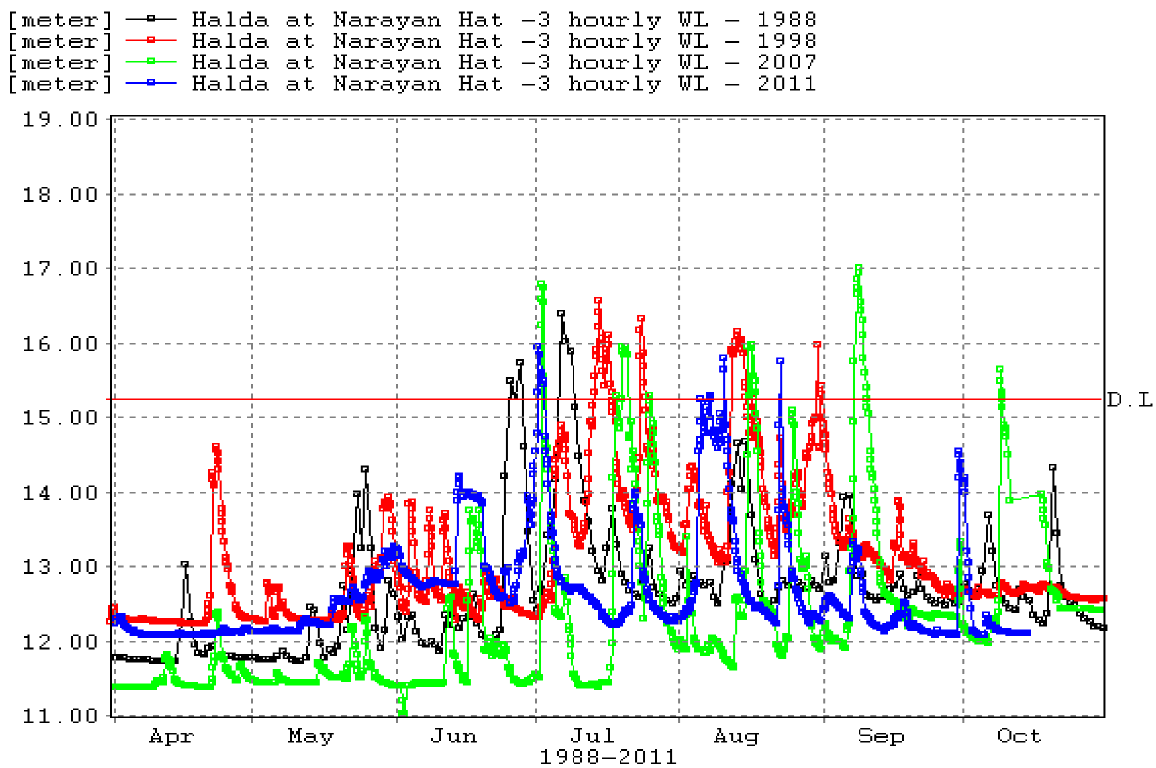


Figure 3. 32 : Comparison of Hydrograph on Halda at Narayanhat

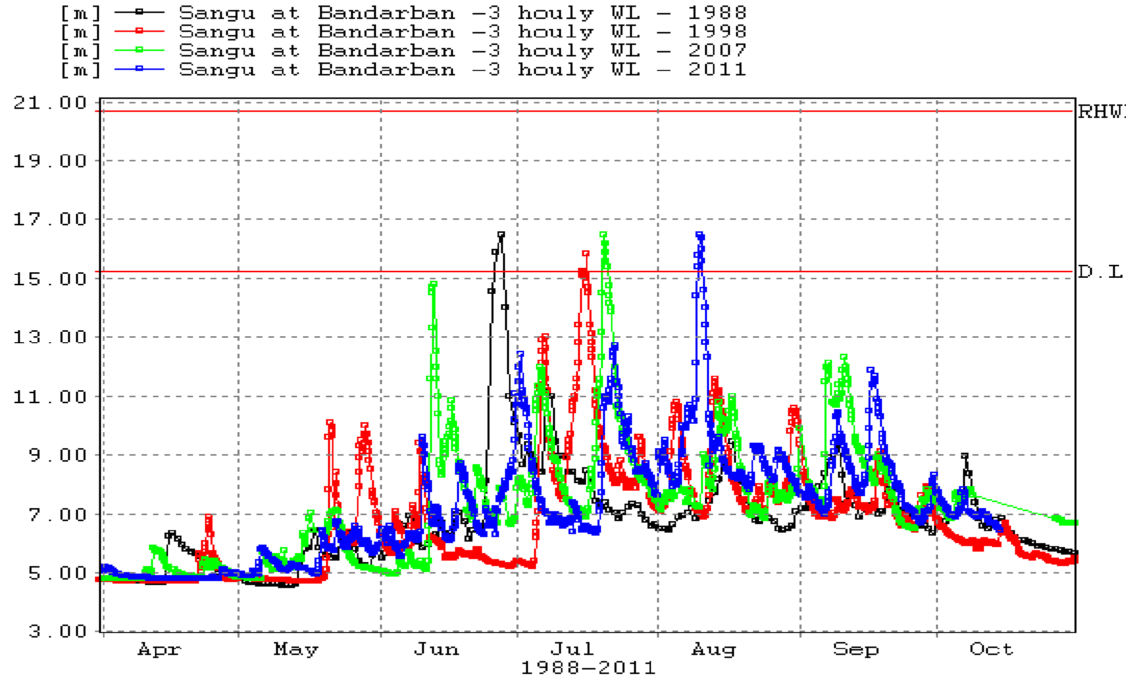


Figure 3. 33 : Comparison of Hydrograph on Sangu at Bandarban

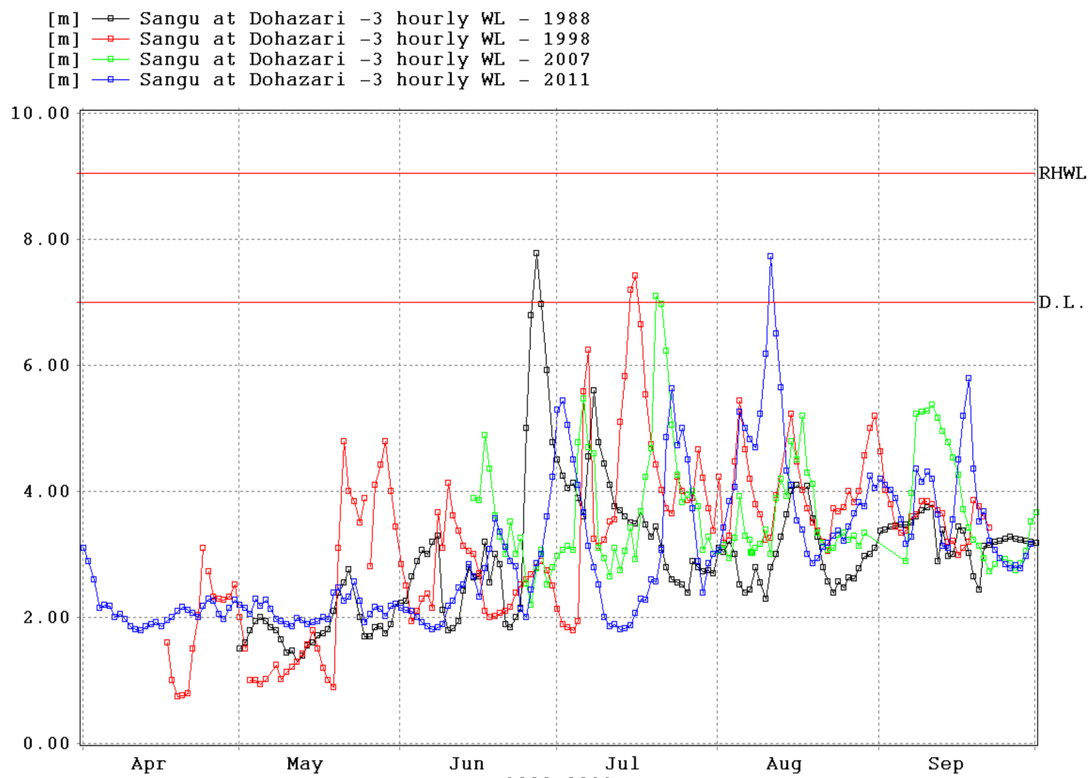


Figure 3. 34 : Comparison of Hydrograph on Sangu at Dohazari

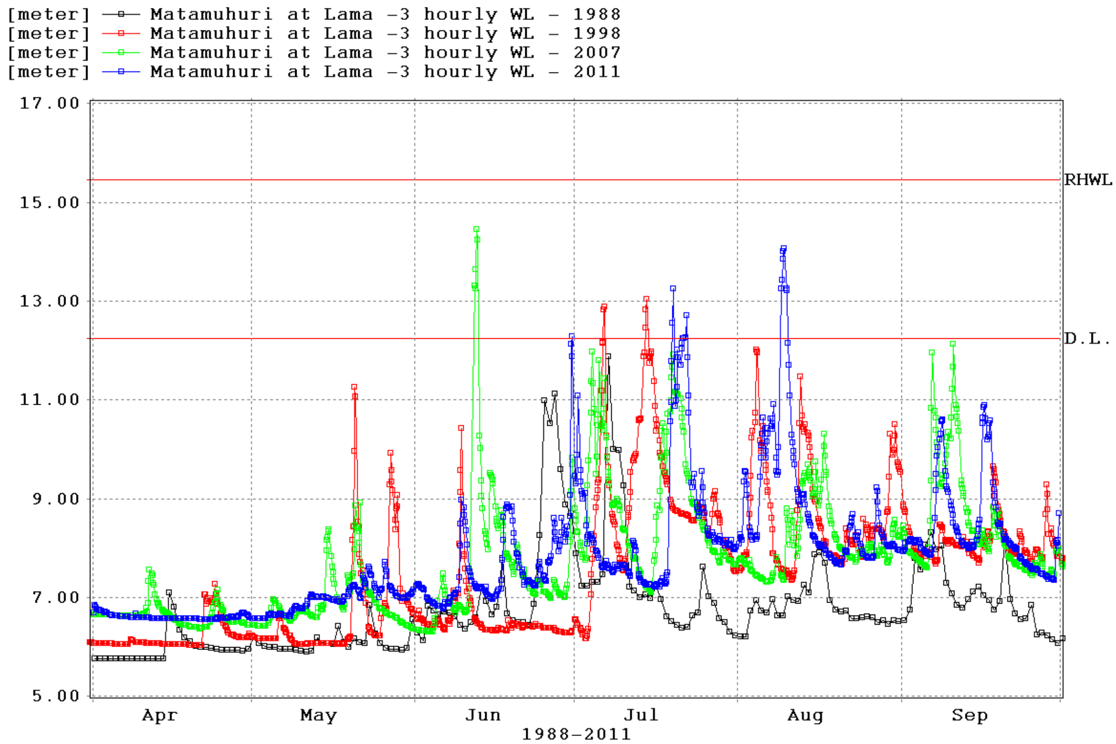


Figure 3. 35 : Comparison of Hydrograph on Matamuhuri at Lama

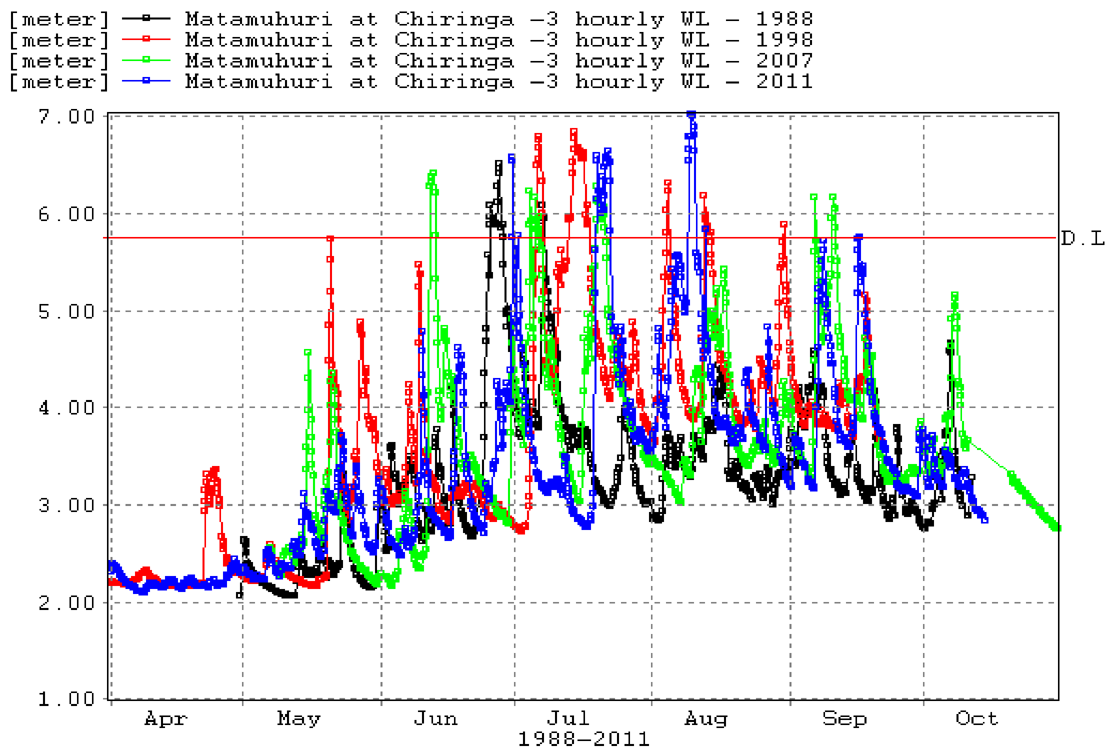


Figure 3. 36 : Comparison of Hydrograph on Matamuhuri at Chiringa

CHAPTER 4: FORECAST EVALUATION, 2011

4.1 GENERAL

Flood Forecasting and Warning Centre (FFWC) of BWDB is mandated for preparation of flood forecasting, early warning and its dissemination in Bangladesh (BWDB Act-2000). Flood forecasting models of FFWC are developed on MIKE 11, one-dimensional modeling software used for the simulation of WLs and discharges in the river network and flood plains. Presently early warning on floods provides a lead time of 24, 48 and 72 hours. There are needs and expectations for increasing lead time forecast for cropping decisions, such as early harvesting, or to implement a contingency crop plan or protect infrastructure and preserve livelihoods. A research initiative has been started from July 2011 to increase lead time for deterministic flood forecast upto 5 days from present 3-days and to extend the Flood Forecast to few selected BWDB projects with support from CDMP-II under Ministry of Food and Disaster Management (MoFDM).

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tier overlapping forecast system with improved lead time during monsoon season 2003 and 2004, which showed a success in forecasting the discharges at Hardinge Bridge station of Ganges and Bahadurabad station of Brahmaputra rivers of Bangladesh. From March 2006 – June 2009, CARE-Bangladesh and United States Agency for International Development (USAID), Dhaka supported the program with an objective to technology transfer and capacity building for sustainable end-to-end generation and application through pilot projects at selected sites.

The project implemented with the active participation of key stakeholders in Bangladesh through a Steering Committee process. Membership in the CFAB Steering Committee includes the Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Department of Agriculture Extension (DAE), Disaster Management Bureau (DMB), Center for Environmental and Geographic Information Services (CEGIS), Institute of Water Modeling (IWM), and CARE Bangladesh. The Steering Committee meets periodically to review, monitor and guide the implementation of CFAB in Bangladesh.

4.2 EVALUATION CRITERIA OF FORECAST PERFORMANCE

Two statistical criteria considered for the performance evaluation of the model are as follows:

- Mean Absolute Error, MAE
- Co-efficient of Determination, r^2

4.2.1 MEAN ABSOLUTE ERROR (MAE)

MAE is the mean of the absolute difference between *Observed* and *Forecast* levels as shown in the following equation:

$$MAE = \frac{\sum_{i=1}^{n} |x_i - y_i|}{n}$$

Where,

$x_1, x_2 \ldots\ldots x_n$ are *Observed* water levels
$y_1, y_2 \ldots\ldots y_n$ are *Forecast* water levels
n is the number of *Observed/Forecast* levels

4.2.2 CO-EFFICIENT OF DETERMINATION, R2

r^2 is the *Co-efficient of Determination* for the correlation of *Observed* and *Forecast* water levels and is given by the relation as show in the equation below:

$$r^2 = \frac{\left[\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})\right]^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}$$

Where,

$x_1, x_2 \ldots\ldots x_n$ are *Observed* water levels

$\bar{x}$ is the average of *Observed* water levels

$y_1, y_2 \ldots\ldots y_n$ are *Forecast* water levels

$\bar{y}$ is the average of *Forecast* water levels

n is the number of *Observed/Forecast* levels

4.3 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2011 have been evaluated from the statistical components r^2 (*Co-efficient of Determination*) and *MAE* (*Mean Absolute Error*). Values of the above two components in their ideal case are generally assumed to be in the order of $MAE = 0$
$r^2 = 1$

Utilizing above two indicators, 5 category scales have been used to describe forecast performances. Stations having a minimum value of 0.9 for r^2 and a maximum value of 15 centimeter for *MAE* have been considered as "*Good*" performance. Table 4.1 presents the definition of scales used in the evaluation:

Table 4. 1 : Scales used for performance evaluation

Sl. No.	Scale	Value
1	*Good*	*MAE* <= 0.15 meter & r^2 >= 0.9
2	*Average*	*MAE* <= 0.2 meter & >0.15 meter and r^2 >= 0.7 & <0.9
3	*Not satisfactory*	*MAE* <= 0.3 meter & >0.2 meter and r^2 >= 0.4 & <0.7
4	*Poor*	*MAE* <= 0.4 meter& >0.3 meter and r^2 >= 0.3 & <0.4
5	*Very Poor*	*MAE* > 0.4 meter or r^2 < 0.3

Simulations were made for maximum 72 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour and 72-hour intervals. Usually, the forecast quality gradually deteriorated with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases. This means that forecasts are the best at 24-hour interval followed by 48-hour interval and then 72-hour interval. Figures from 4.1 to 4.3 are shown the comparison of observed and forecasted WL for 24, 48 and 72 hours. Result of the statistical analysis and performance on the basis of the aforesaid scale are presented in Table 4.2, Table 4.3 and Table 4.4.

4.4 FORECAST STATISTICS AND MODEL PERFORMANCE, 2011

4.4.1 DETERMINISTIC FORECAST PERFORMANCE

For deterministic forecast, simulations were made for maximum 72 hrs. The forecast quality gradually deteriorated where forecast intervals were moved further away from the time of forecast. Usually as lead time increases the accuracy (variation of forecast & observe value) decreases. This means that forecasts were the best at 24-hour interval (i.e. 24 hrs/1-day lead time) followed by 48-hrs interval and then 72-hrs(3-days). Total 31 stations located within the model area (including some boundary stations) are evaluated. The forecast statistics along with their performance are provided in Tables 4.2 to 4.4 and in Figures 4.1 to 4.3. From the tables it may be seen that the forecast performance was 93% (Mean Absolute Error 7%), 88% (MAE 12%) and 78% (MEA 22%) accurate for 24hrs, 48hrs and 72 hrs respectively.

Table 4. 2 : Statistics for 24- hour forecast performance

Sl. No.	Station	MAE (m)	r2	Performance
1	Aricha	0.04	0.98	Good
2	Bahadurabad	0.05	0.97	Good
3	Bhagyakul	0.04	0.97	Good
4	Bhairabbazar	0.03	0.96	Good
5	Bhusirbandar	0.42	0.61	Not satisfactory
6	Bogra	0.14	0.96	Good
7	Chakrahimpur	0.15	0.96	Average

Sl. No.	Station	MAE (m)	r2	Performance
8	Chilmari	0.07	0.96	Good
9	Demra	0.07	0.93	Good
10	Dhaka	0.06	0.96	Good
11	Goalundo	0.04	0.98	Good
12	Gorai-RB	0.06	0.99	Good
13	Hardinge-BR	0.07	0.99	Good
14	Jagir	0.04	0.34	Average
15	Jamalpur	0.06	0.98	Good
16	Kamarkhali	0.06	0.98	Good
17	Kaunia	0.11	0.87	Average
18	Mirpur	0.05	0.96	Good
19	Moulvibazar	0.27	0.57	Not satisfactory
20	Mymensingh	0.09	0.98	Good
21	Mohadevpur	0.36	0.82	Poor
22	Naogaon	0.21	0.96	Poor
23	Narayangonj	0.06	0.95	Good
24	Nayarhat	0.04	0.97	Good
25	Rajshahi	0.09	0.98	Good
26	Serajgonj	0.04	0.97	Good
27	Sheola	0.19	0.87	Average
28	Sunamgonj	0.08	0.92	Good
29	Sylhet	0.11	0.90	Good
30	Taraghat	0.06	0.97	Good
31	Tongi	0.04	0.97	Good

Table 4. 3: Statistics for 48- hour forecast performance

Sl. No.	Station	MAE (m)	r2	Performance
1	Aricha	0.07	0.99	Good
2	Bahadurabad	0.10	0.98	Good
3	Bhagyakul	0.06	0.98	Good
4	Bhairabbazar	0.06	0.97	Good
5	Bhusirbandar	0.78	0.40	Very Poor
6	Bogra	0.29	0.89	Average
7	Chakrahimpur	0.28	0.91	Average
8	Chilmari	0.14	0.97	Good
9	Demra	0.11	0.90	Good
10	Dhaka	0.08	0.96	Good
11	Goalondo	0.07	0.98	Good
12	Gorai-RB	0.11	0.98	Good
13	Hardinge-BR	0.14	0.98	Good
14	Jagir	0.06	0.35	Average
15	Jamalpur	0.11	0.98	Good
16	Kamarkhali	0.10	0.98	Good
17	Kaunia	0.18	0.74	Average
18	Mirpur	0.08	0.96	Good
19	Moulvibazar	0.41	0.38	Poor
20	Mymensingh	0.16	0.97	Average

Sl. No.	Station	MAE (m)	r2	Performance
21	Mohadevpur	0.65	0.61	Poor
22	Naogaon	0.39	0.91	Average
23	Narayangonj	0.10	0.95	Good
24	Nayarhat	0.08	0.96	Good
25	Rajshahi	0.19	0.98	Average
26	Serajgonj	0.08	0.99	Good
27	Sheola	0.39	0.80	Average
28	Sunamgonj	0.15	0.91	Average
29	Sylhet	0.21	0.93	Poor
30	Taraghat	0.10	0.97	Good
31	Tongi	0.07	0.97	Good

Table 4. 4: Statistics for 72- hour forecast performance

Sl. No.	Station	MAE (m)	r2	Performance
1	Aricha	0.11	0.98	Good
2	Bahadurabad	0.16	0.95	Good
3	Bhagyakul	0.10	0.97	Good
4	Bhairabbazar	0.09	0.96	Good
5	Bhusirbandar	1.13	0.21	Very Poor
6	Bogra	0.47	0.77	Not satisfactory
7	Chakrahimpur	0.41	0.83	Not satisfactory
8	Chilmari	0.20	0.93	Average
9	Demra	0.14	0.86	Average
10	Dhaka	0.11	0.95	Good
11	Goalondo	0.11	0.98	Good
12	Gorai-RB	0.18	0.98	Average
13	Hardinge-BR	0.22	0.97	Average
14	Jagir	0.08	0.34	Average
15	Jamalpur	0.15	0.96	Good
16	Kaunia	0.16	0.97	Average
17	Kamarkhali	0.24	0.66	Not satisfactory
18	Mirpur	0.11	0.95	Good
19	Moulvibazar	0.50	0.23	Very Poor
20	Mymensingh	0.21	0.95	Not satisfactory
21	Mohadevpur	0.88	0.44	Not satisfactory
22	Naogaon	0.57	0.84	Not satisfactory
23	Narayangonj	0.13	0.93	Good
24	Nayarhat	0.11	0.95	Good
25	Rajshahi	0.31	0.96	Average
26	Serajgonj	0.14	0.97	Good
27	Sheola	0.55	0.69	Not satisfactory
28	Sunamgonj	0.21	0.84	Not satisfactory
29	Sylhet	0.30	0.86	Average
30	Taraghat	0.14	0.97	Good
31	Tongi	0.11	0.96	Good

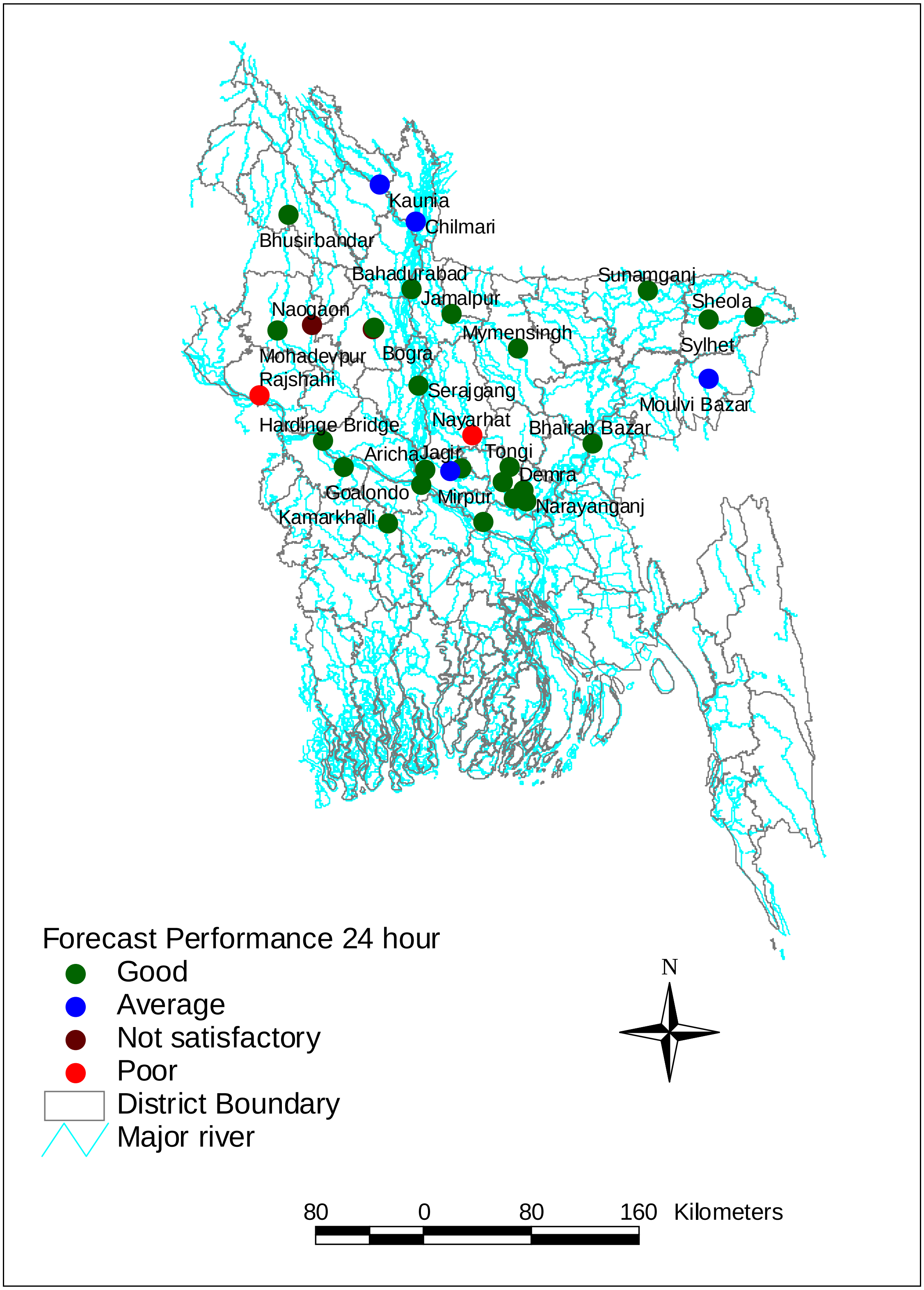


Figure 4. 1: 24 hr Forecast Evaluation (Year, 2011)

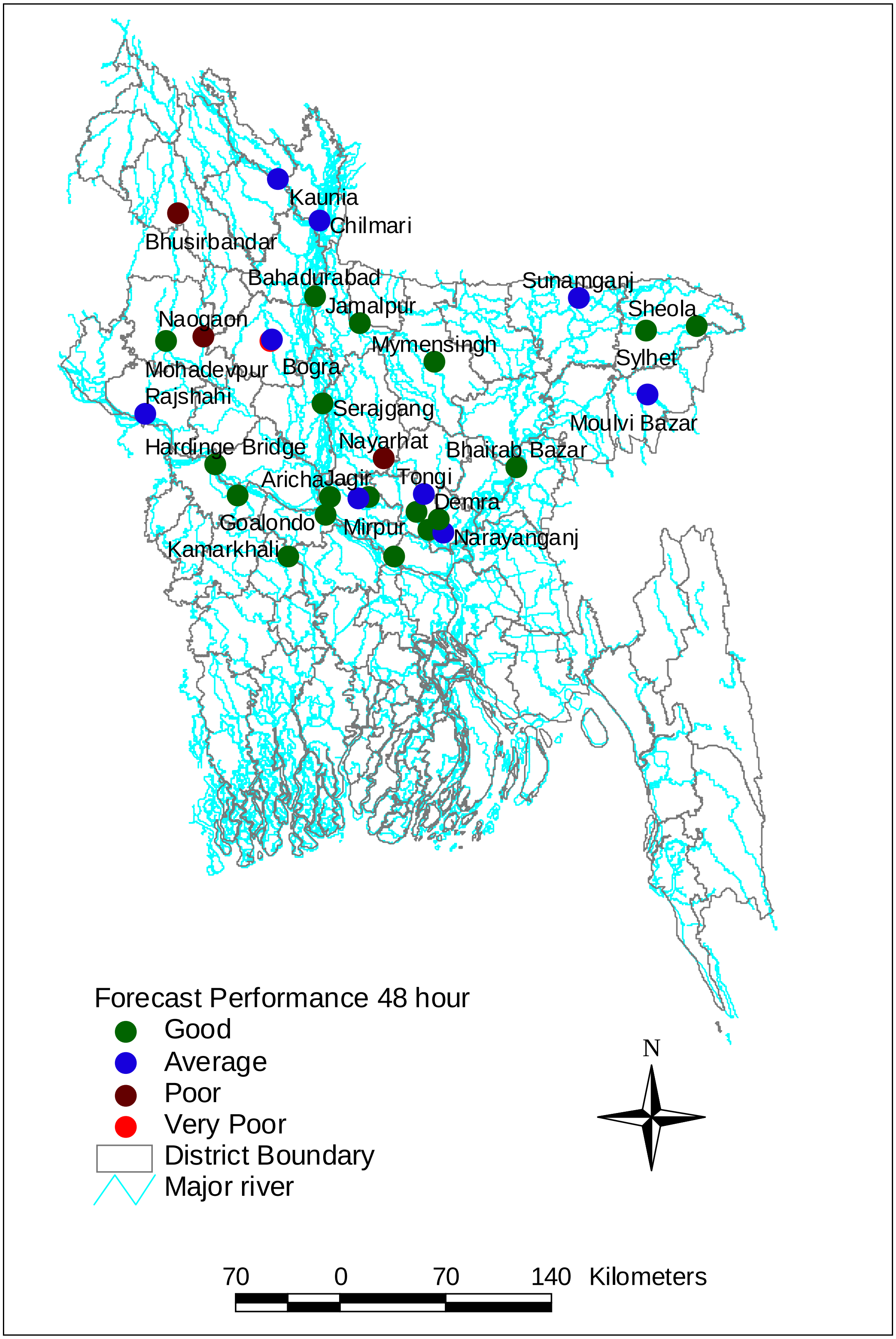


Figure 4. 2: 48 hr Forecast Evaluation (Year, 2011)

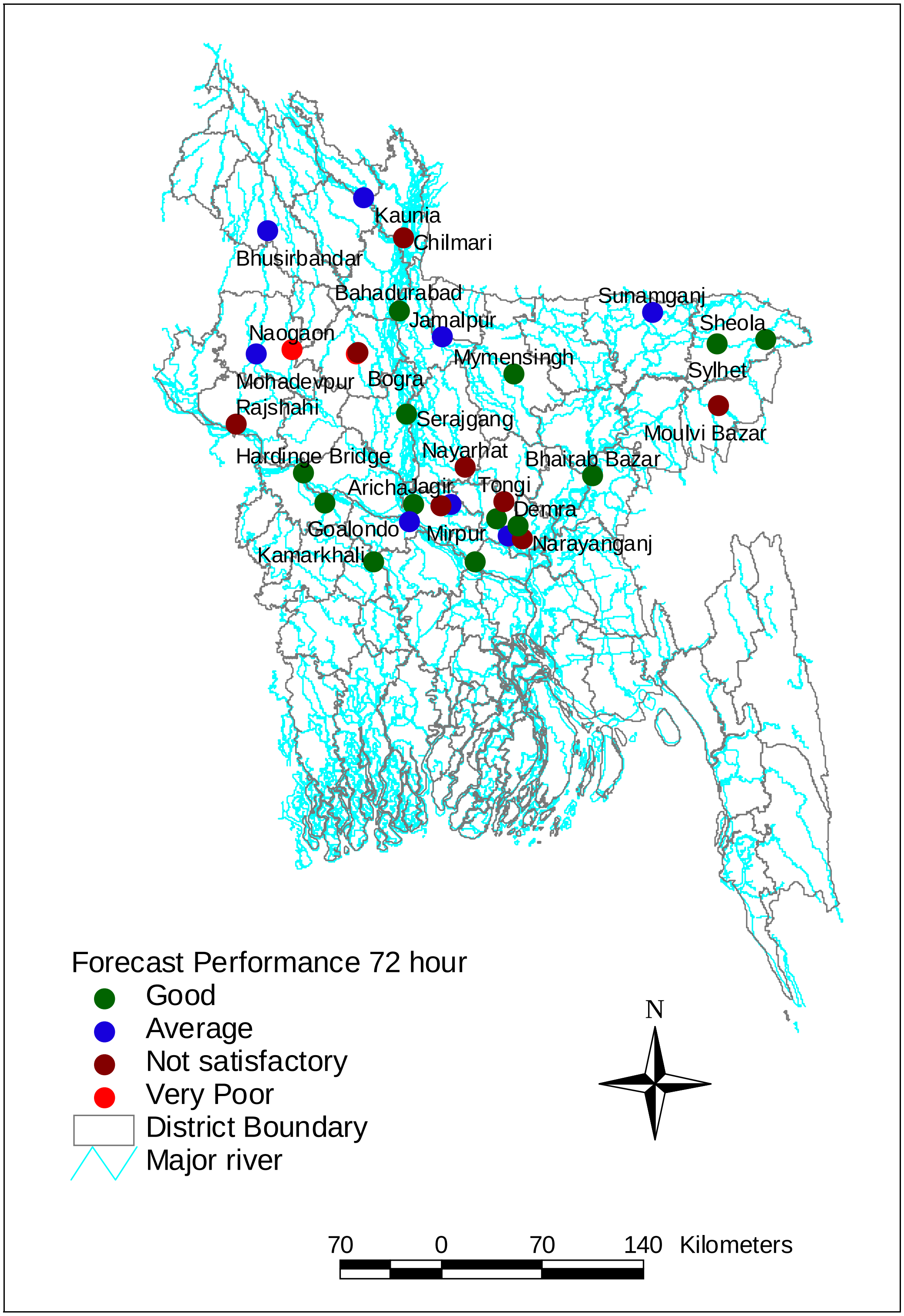


Figure 4. 3 : 72 hr Forecast Evaluation (Year, 2011)

4.4.2 Probabilistic (CFAN) Forecast Performance

CFAN (Climate Forecast Application Network) utilizes ECMWF (European Centre for Medium-Range Weather Forecasts) weather prediction data in their model to generate 51 sets of ensemble discharge forecasts data on the Brahmaputra at Bahadurabad and on the Ganges at Hardinge-Bridge. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions. The customized FFWC model used for the flood forecasting of extended lead-time (upto 10-days) using climate forecast application data has been named CFAB-FFS (CFAB Flood Forecasting Study) model.

In addition to existing 24, 48 & 72 hrs deterministic forecast, CFAN model generates 10 days lead-time probabilistic forecasts for mean, upper bound and lower bound WL at 18 locations listed below. The Mean Water Level forecast made from the mean discharge and the mean rainfall forecast of all 51 ensemble series. The Upper bound and Lower bound water corresponds to +1 standard deviation from the mean and -1 standard deviation from the mean respectively.

The statistics of forecast performance for the stations inside Bangladesh have been presented through Table 4.5 to Table 4.8. These tables and indicate the performance forecasts at individual stations for upto 10-days period.

Table 4. 5 : Performance of 3-day Probabilistic Forecast

	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE(m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2
Aricha	0.51	0.18	0.85	0.45	0.17	0.82	0.46	0.15	0.77
Bhagyakul	0.41	0.14	0.88	0.36	0.13	0.86	0.35	0.11	0.82
Bhairabbazar	0.22	0.08	0.50	0.22	0.08	0.50	0.22	0.08	0.50
Demra	0.21	0.08	0.16	0.21	0.08	0.16	0.21	0.08	0.17
Dhaka	0.20	0.07	0.31	0.20	0.07	0.30	0.20	0.07	0.28
Goalondo	0.46	0.16	0.76	0.42	0.14	0.68	0.44	0.13	0.63
Gorai-RB	0.52	0.15	0.26	0.49	0.14	0.15	0.51	0.14	0.12
Kamarkhali	0.50	0.14	0.40	0.48	0.14	0.36	0.52	0.14	0.36
Mirpur	0.18	0.07	0.54	0.18	0.07	0.57	0.18	0.07	0.59
Mohadevpur				1.08	0.37	0.91			
Moulvibazar				2.24	1.18	1.00			
Naogaon				0.53	0.19	0.21			
Serajgonj	0.94	0.36	0.98	0.78	0.32	0.98	0.70	0.26	0.97
Sheola				1.65	0.48	0.96			
Sherpur				0.62	0.34	0.99			
Sunamgonj				0.36	0.11	0.87			
Sylhet				0.97	0.26	0.95			
Tongi	0.18	0.06	1.55	0.18	0.06	1.55	0.18	0.06	1.57

Table 4. 6: Performance of 5-day Probabilistic Forecast

	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE(m)	RMSE(m)	R2	MAE(m)	RMSE(m)	R2	MAE(m)	RMSE(m)	R2
Aricha	0.66	0.23	0.91	0.50	0.18	0.86	0.42	0.13	0.73
Bhagyakul	0.53	0.18	0.93	0.40	0.14	0.89	0.34	0.10	0.79
Bhairabbazar	0.27	0.09	0.63	0.26	0.09	0.63	0.26	0.09	0.61
Demra	0.24	0.09	0.26	0.24	0.09	0.25	0.24	0.09	0.24
Dhaka	0.27	0.09	0.55	0.27	0.08	0.52	0.26	0.08	0.47
Goalundo	0.62	0.21	0.86	0.44	0.16	0.74	0.41	0.12	0.54
Gorai-RB	0.57	0.18	0.48	0.51	0.15	0.21	0.55	0.15	0.23
Kamarkhali	0.59	0.17	0.51	0.51	0.14	0.30	0.54	0.14	0.32
Mirpur	0.25	0.08	0.13	0.25	0.08	0.08	0.24	0.08	0.01
Mohadevpur				1.25	0.37	0.91			
Moulvibazar				3.03	1.75	1.00			
Naogaon				0.53	0.16	0.06			
Serajgonj	1.17	0.39	0.99	0.83	0.31	0.98	0.62	0.24	0.97
Sheola				1.85	0.55	0.97			
Sherpur				0.96	0.61	1.00			
Sunamgonj				0.39	0.12	0.63			
Sylhet				1.08	0.29	0.95			
Tongi	0.23	0.08	0.43	0.23	0.08	0.48	0.23	0.07	0.53

Table 4. 7: Performance of 7-day Probabilistic Forecast

	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE(m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2
Aricha	0.66	0.23	0.91	0.50	0.18	0.86	0.42	0.13	0.73
Bhagyakul	0.53	0.18	0.93	0.40	0.14	0.89	0.34	0.10	0.79
Bhairabbazar	0.27	0.09	0.63	0.26	0.09	0.63	0.26	0.09	0.61
Demra	0.24	0.09	0.26	0.24	0.09	0.25	0.24	0.09	0.24
Dhaka	0.27	0.09	0.55	0.27	0.08	0.52	0.26	0.08	0.47
Goalondo	0.62	0.21	0.86	0.44	0.16	0.74	0.41	0.12	0.54
Gorai-RB	0.57	0.18	0.48	0.51	0.15	0.21	0.55	0.15	0.23
Kamarkhali	0.59	0.17	0.51	0.51	0.14	0.30	0.54	0.14	0.32
Mirpur	0.25	0.08	0.13	0.25	0.08	0.08	0.24	0.08	0.01
Mohadevpur				1.25	0.37	0.91			
Moulvibazar				3.03	1.75	1.00			
Naogaon				0.53	0.16	0.06			
Serajgonj	1.17	0.39	0.99	0.83	0.31	0.98	0.62	0.24	0.97
Sheola				1.85	0.55	0.97			
Sherpur				0.96	0.61	1.00			
Sunamgonj				0.39	0.12	0.63			
Sylhet				1.08	0.29	0.95			
Tongi	0.23	0.08	0.43	0.23	0.08	0.48	0.23	0.07	0.53

Table 4. 8: Performance of 10-day Probabilistic Forecast

	Standard Deviation(-1)			Mean			Standard Deviation(+1)		
	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2	MAE (m)	RMSE(m)	R2
Aricha	0.66	0.20	0.89	0.34	0.12	0.67	0.30	0.09	0.51
Bhagyakul	0.52	0.16	0.93	0.23	0.08	0.77	0.25	0.07	0.69
Bhairabbazar	0.44	0.17	0.88	0.42	0.17	0.88	0.41	0.16	0.87
Demra	0.70	0.34	0.19	0.70	0.34	0.17	0.71	0.34	0.14
Dhaka	0.44	0.14	0.90	0.40	0.13	0.88	0.40	0.13	0.86
Goalondo	0.60	0.18	0.85	0.28	0.09	0.45	0.26	0.08	0.34
Gorai-RB	0.43	0.14	0.14	0.38	0.12	0.14	0.60	0.17	0.40
Kamarkhali	0.45	0.14	0.28	0.42	0.12	0.09	0.56	0.16	0.47
Mirpur	0.44	0.14	0.77	0.41	0.13	0.73	0.40	0.13	0.71
Mohadevpur				0.98	0.26	0.31			
Moulvibazar				4.11	2.55	1.00			
Naogaon				0.50	0.14	1.42			
Serajgonj	1.07	0.28	0.92	0.62	0.19	0.83	0.32	0.12	0.55
Sheola				2.61	0.76	0.95			
Sherpur				1.59	0.98	1.00			
Sunamgonj				0.48	0.14	0.50			
Sylhet				1.33	0.38	0.91			
Tongi	0.40	0.13	0.60	0.39	0.12	0.56	0.27	0.08	0.11

CHAPTER 5 : INUNDATION STATUS

The country as a whole experienced normal flooding during the monsoon-2011. The flood during 2011 was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except few stations of the south west part of the country. The South Western part of the country experienced prolong flooding in few stations, longer then the previous flood years, specially part of Khulna, Jessore and Satkhira districts. Water Level at Jhikorgacha on Kobodak was flowed above the danger level for continuous 89 days covered two Eid festivals. During the monsoon-2011 there were flash floods affecting the Jariajanjail (in the North east, in Netrokona district) and par to f Bandarban-Coxs Bazar(South east).

Out of 15 Water Level (WL) monitoring stations in the Brahmaputra basin, at 3 stations river WL was crossed the respective DLs, these are Jamuna at Bahadurabad for 7 days and Serajgonj for 5 days and Tongi Khal at Tongi for 29 days during July, August and September. As a result, low-lying areas of Gaibandha, Serajgonj, Tangail and Jamalpur districts were flooded for short period.

In the Ganges basin river and the WL monitoring stations exceeded the respective DLs are Ganges/ Padma at Goalondo, Bhagyakul, Punarbhaba at Dinajpur, Upper Atrai at Bhusirbondor (Upazila- Chirirbandar, district Dinajpur), the Gorai at Kamarkhali, Kobodak at Jhikorgacha and Arialkhan at Madaripur during the monsoon 2011. Total 5 WL monitoring stations of the Ganges basin crossed the DLs during the monsoon 2011. The WL of river Padma at Bhagyakul was flowed for 36 days above DL. The low lying areas of Rajbari, Kushtia, Faridpur, Manikgonj, Munshigonj, Madaripur, Gopalgonj and Sariatpur districts was affected by normal flooding during the month of August. WL of Arialkhan river at Madaripur flowed above the DL for 30 days. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul and Madaripur WL gauge stations. Prolong flooding situation was prevailing in Satkhira district due to very poor drainage condition along with very high rainfall during August. The WL of Kobodak river at Jhikorgacha flowed above the DL for continuous 89 days from the 1st week of August to the 1st week of November 2011, which is unprecedented. Flood duration covered two Eid festivals and caused immense suffering of the people of the locality. Part of Khulna and Jessore districts also were flooded.

Out of 20 WL monitoring stations in the Meghna basin only 6 stations flowed below their respective DL and other 14 stations flowed above their respective DLs for 2 days (Manu at Manu Railway Bridge) to 42 days (Kangsha at Jariajanjail – Netrokona Districts, caused moderate duration of flooding). As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi

Bazar, Kishoregonj, Brahmmanbaria, Habigonj and Chandpur during the monsoon 2011. The WL of all the major rivers in the Meghna basin (north eastern part of the country) exceeded the DL, except the Upper Meghna and Gumti rivers during the monsoon 2011.

In the South Eastern Hill basin WL of the rivers Halda, Matamuhuri and Snagu crossed their respective DLs for 1 to 11 days during this monsoon-2011. As a result, a short duration flood occurred at Narayanhat (Halda river), Bandarban(Sangu river), Dohazari (Sangu river) Chiringa (Matamuhuri river) and Lama (Matamuhuri river) during the monsoon 2011. Total 5 WL monitoring stations in the South Eastern Hill basin crossed DLs during the Monsoon-2011. As a result, a flood of short duration was experienced in the districts of Chittagong, Bandarban and Cox's Bazar.

In flood period, Flood Inundation Map based on the result file/data the Flood Forecasting Model and digital elevation map (DEM) was developed at FFWC as a part of routine output. This was done by using MIKE 11 GIS, where the results were found from MIKE 11 Rainfall-Runoff and Hydrodynamic modelling simulation. In addition, River Situation Map was also developed in the FFWC. Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country. A detail and authentic DEM shall improve significantly showing inundation status map. Sample of Flood Inundation Map and River Situation Maps based on 24 hour and 48 hours forecast respectively are presented in the following pages (Fig 5.1 and Fig 5.2).

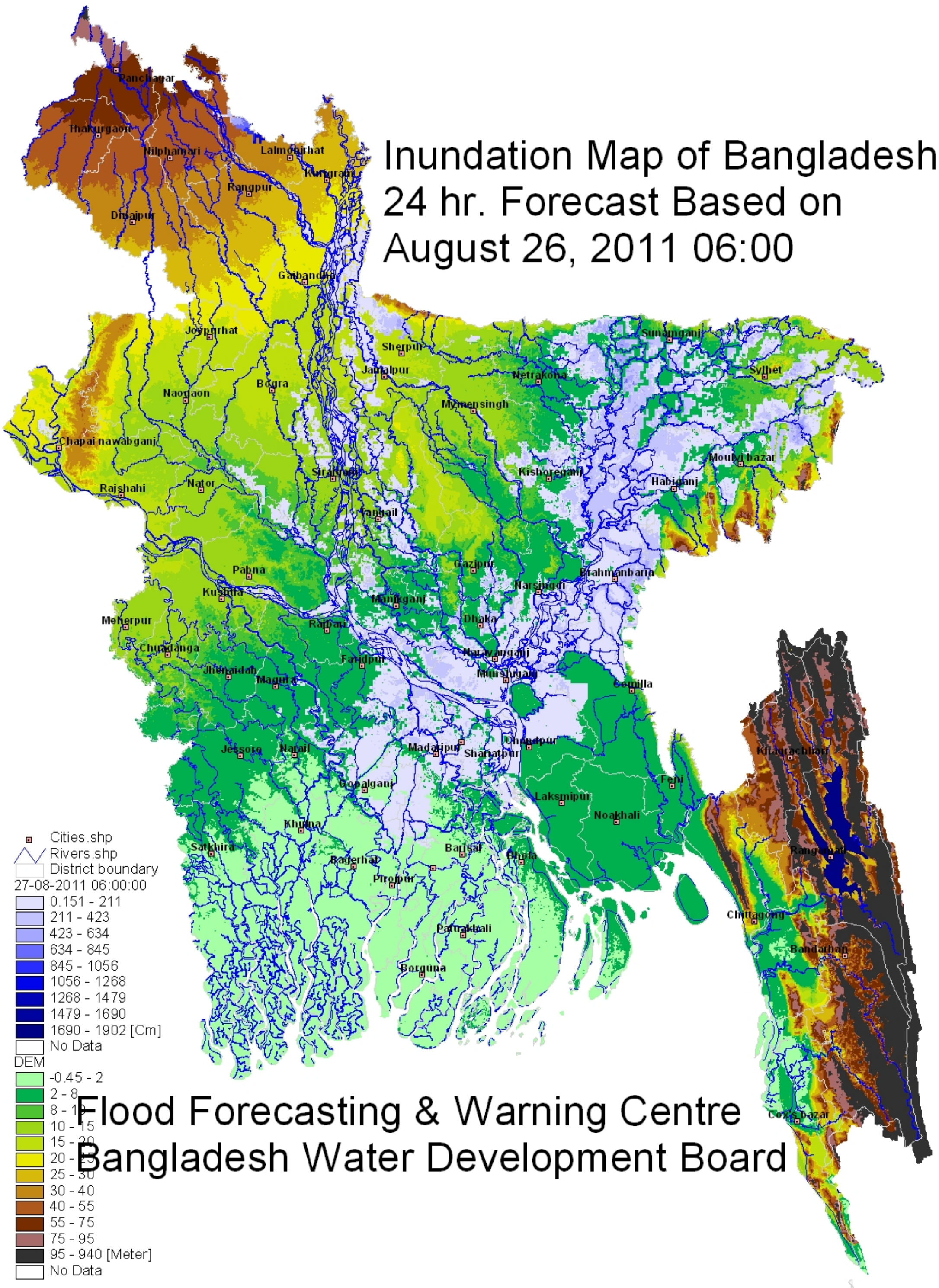


Figure 5. 1: Flood Inundation Map of Bangladesh (24hr Forecast 26 August 2011)

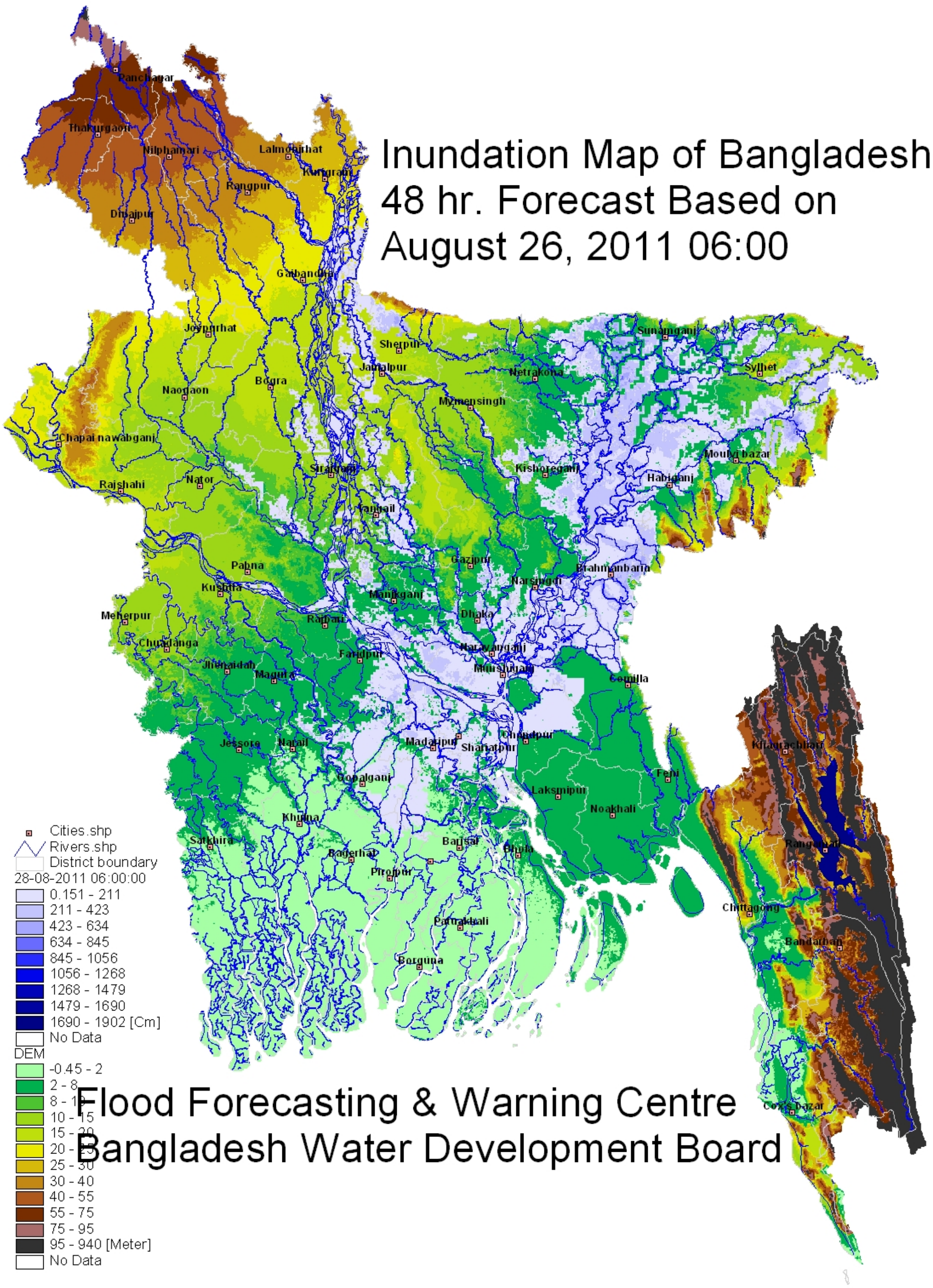


Figure 5. 2 : Flood Inundation Map of Bangladesh (48hr Forecast Based on 26 August 2011)

CHAPTER 6: CONCLUSIONS

The flood problem in Bangladesh is extremely complex. There are a number of reasons: the country is an active delta; it has extensive flood plains which surface water of about 1.7 million sq-km drains; and it has an extensive network of rivers and canals with flood plains. The country has an average annual rainfall of about 2300 mm, the range being 1500 mm in the west to over 5000 mm in the north-east. Flood occurs in Bangladesh almost every year and devastating ones in every 5 to 10 years.

Floods are normal events in the deltaic plains of Bangladesh. Although the lifestyle of the people in Bangladesh is well adapted to normal monsoon flood phenomena, the damages due to inundation, riverbank erosion or breach of embankment, etc. still occur in various regions in almost every monsoon season. They often have disastrous consequences: major damage to infrastructure, great loss of property, crops, cattle, poultry etc, human suffering and impoverishment of the poor. With every major flood in Bangladesh, food security and poverty situation has been worsening.

The runoff from GBM catchments of 1.76 million sq-km passes through the intricate network of river systems of Bangladesh where only 7% area lies within the country. The characteristic of river varies from river to river and differs from region to region. Usually, in the Brahmaputra basin, flood begins in the late June while in the Ganges basin it starts from the second half of July. In the Meghna and South-Eastern Hill basins, flash flood occurs at the beginning of monsoon causing loss of crops and source of hardship for the population in the region.

As mandated, FFWC of BWDB monitored the flood situation from the very beginning of the flood season 2011. The FFWC has issued daily flood bulletin from May to October with a forecast lead-time of 24hrs, 48hrs and 72hrs along with warning messages and flood inundation maps.

In addition to 24hrs, 48hrs & 72 hrs deterministic flood forecasts, FFWC issued 10 days lead-time probabilistic forecasts at 18 locations with the technical assistance of CFAN projects which utilizes ECMWF weather prediction data over the GBM basin to generate 51 sets of ensemble discharge forecasts on the Brahmaputra at Bahadurabad and on the Ganges rivers at Hardinge-Bridge. Technical support from the RIMES-Thailand (Regional Integrated Multi-hazard Early Warning System) is recgnised for preparing and providing the 10-day lead time probabilistic flood forecast on experimental basis. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions.

The FFWC also issued special type of flood bulletin during the critical time and tried to disseminate the whole situation to the people of the country through different mass media, news agencies, e-mail, web site and Cell Broadcast through Teletalk mobile phone. The Cell Broadcast is a new way of dissemination started from July 2011, in cooperation of DMB, anyone can call in 10941 number from Teletalk mobile and hear a short voice message in Bangla. The information has been used by various organizations: national and international disaster management operators, many Government agencies, NGOs and BWDB itself.

However, due to different shortcomings including limited upstream hydro-meteorological information, detail & accurate digital elevation model (DEM) and limited technological development of the center itself, the services were fully not satisfactory to all corners. Area-inundation forecast have been indicative, based on a coarse DEM and old topographic maps. Information on flash flood was limited due to technological limitation and non-availability of the real time data at a much shorter interval than the usual.

The continued achievement of the FFWC is notable. It is trying hard to overcome the limitations and realities. Regional models need to have developed to provide regional flood forecasting and warning. Moreover, flood inundation map needs to develop further.

Activity has been initiated to extend the deterministic flood forecast lead time upto 5-days from present 3-days and expand the deterministic flood forecast to few selected BWDB projects with support from Comprehensive Disaster Management Programme (Phase –II) under Ministry of Food & Disaster Management.

The FFWC of BWDB took the privileged to reflect the flood situation as accurate and reliable as possible. All these combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2011.

As a whole the flood of 2011 was fairly normal compare to devastating flood of 1987, 1988, 1998, 2004 and 2007. The maximum flooded area was 20% of the whole country (29,800 sq-km approximately).

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2011 on Major River flood forecasting is around 93%, 88% and 78% accurate for 24hrs, 48hrs and 72 hrs lead time respectively. Flood forecast model, the "*Super Model*" based on MIKE-11FF showed better performance in Brahmaputra and Ganges basins while in the flash flood areas, the model performance needs to improve further.

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With financial support from Comprehensive Disaster Management Programme (CDMP II)

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Disaster Management and Relief Division
Ministry of Food and Disaster Management