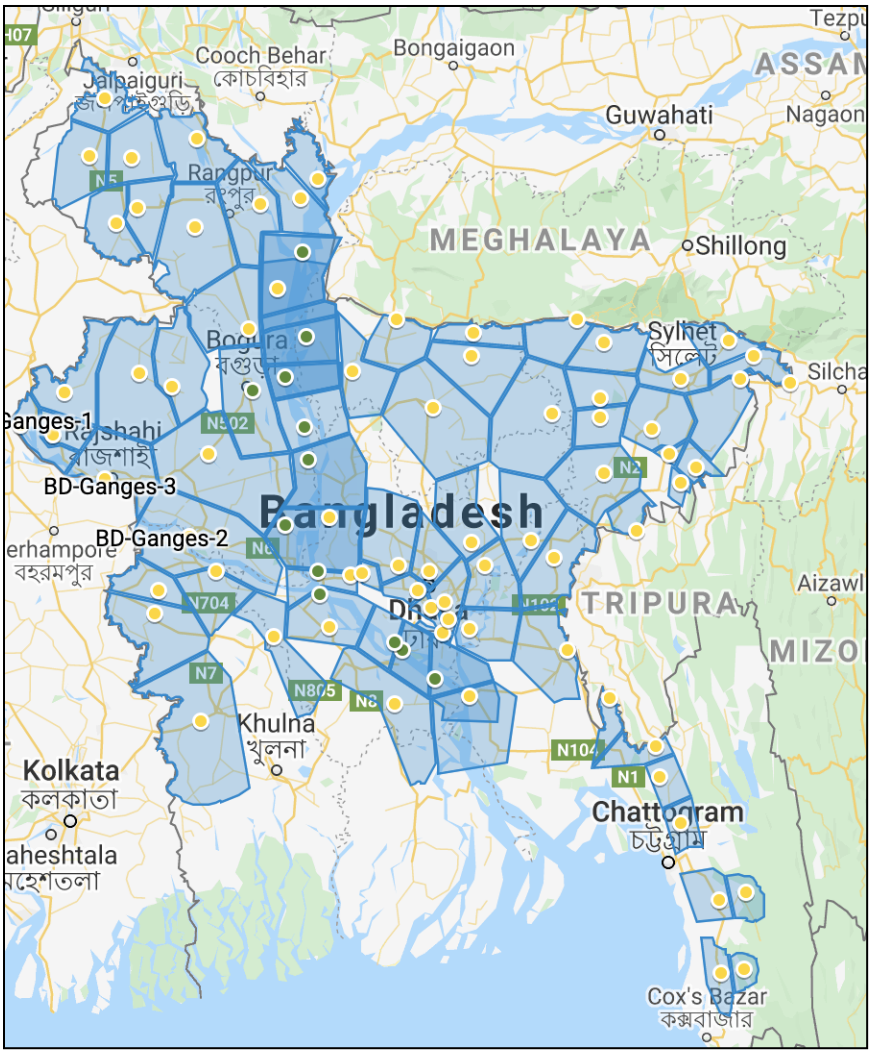
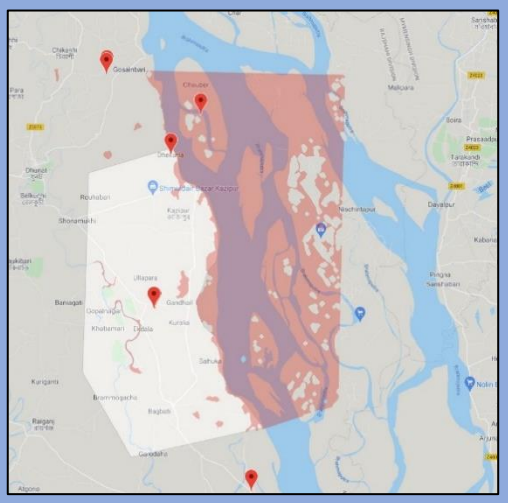
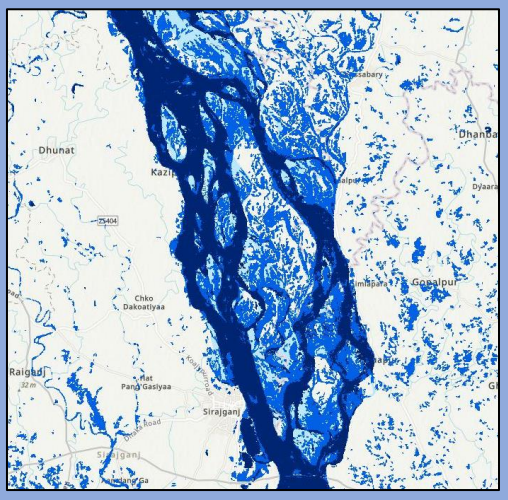
2021

Annual Flood Report







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Bangladesh Water Development Board

Annual Flood Report 2021

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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, food security, 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) under the Ministry of Water Resources (MoWR) and Flood Forecasting and Warning Centre (FFWC) is carrying out this duty. The FFWC was established in 1972 and is fully operative in the flood season, from April to October every year, following the Standing Orders on Disaster (SOD) of the Government of Bangladesh. The FFWC is acting as the focal point on flood forecasting and warning services in co-ordination with other ministries and agencies like Bangladesh Meteorological Department (BMD), Department of Disaster Management (DDM) and Department of Agricultural Extension (DAE) for overall flood disaster management.

The objectives of flood forecasting and warning services are to enable and persuade people, community, agencies and organizations to be prepared for the flood and take necessary actions to increase safety and reduce or protect damages of lives and properties. Its goal is to alert the agencies, departments, communities and people to enhance their preparedness and to motivate vulnerable communities to undertake preparedness and protective measures.

The professionals of FFWC felt greatly inspired receiving encouraging words from Honourable State Minsiter, MoWR and Honourable Deputy Minsiter, MoWR during critical periods of the flood season. We also felt aspired by the valuable advice and guidance of the Senior Secretary, MoWR throughout the season. FFWC gratefully acknowledge the valuable advice and leadership of the Director General, BWDB, which continuously drives FFWC forward. FFWC also gratefully acknowledge the valuable suggestions and encouragement provided by the Additional Director General (Planning, Design & Research), BWDB. The direct involvement and guidance of the Chief Engineer, Hydrology, BWDB and the Superintending Engineer, Processing & Flood Forecasting Circle, BWDB are respectfully acknowledged which greatly improved the quality of works of the centre.

The services of Flood Information Centres (FICs) established at the Division Offices of BWDB, Gauge Readers, Wireless operators, local communities 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 and

warning messages during flood 2021. A number of non-government organizations (NGOs) have been working in different areas for dissemination of the flood warning message generated by the FFWC at community and grass root level (Union and Village), this enables flood preparedness at local level. All the partner supports are more specially acknowledged this year as they relentlessly aided in flood management throughout the difficult situation due to the ongoing Covid-19 pandemic.

FFWC is providing the following services on daily basis during monsoon

- Flood bulletin twice a day
- River and rainfall situation summary report
- 3-days deterministic flash flood forecast
- 5-days deterministic and 10-days probabilistic monsoon flood forecast
- 15-days probabilistic flow forecast
- Special outlook and warning message
- Rainfall Map
- Flood Inundation Map
- Flood warning message dissemination publicly through website (www.ffwc.gov.bd), toll-free Interactive Voice Response (IVR) method (1090) and Android mobile based 'BWDB Flood App'
- Flood warning message dissemination through email and fax to all relevant government organizations and selected medias, NGOs, stakeholders and others

FFWC is primarily disseminating its forecast products through website and feedback from different stakeholders is essential for overall improvement. FFWC is trying to develop further the services and system to cope-up with the technological and computational development. One of the main struggles and demands is to make location specific flood forecast. One step towards improving the local flood warning had been initiated in last two years by entering into parthership with tech giant 'Google'. By utilizing the 5-day flood forecasts and observed water level data of FFWC of BWDB, Google has been able to experimentally produce high-resolution inundation map this year for the Jamuna-Padma river belt which users can access by Android push notification or by searching thorugh Google or Google map. After successful piloting the system was scaled up for the whole country this year and officially launched on 25th October, 2021.

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 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.

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Executive Summary

The characteristics of 2021 flood as a whole is representative of a moderate one with respect to both magnitude and duration. However an unusual and unprecedented late monsoon flooding of catastrophic magnitude in the Teesta basin on 20th October inflicted heavy damages on livelihood and properties, being a marked exception of the seasonal characteristic. Being a less active than normal monsoon with relatively more activity in the later parts, peaking of the major rivers occurred late during the early days of September resulting in a single spell riverine flooding from second half of August till first half of September. This affected mostly the Northern, North-Western, North-Central and Central regions of the country within the Brahmaputra and Ganges basins with moderate intensity and medium duration. However flood stayed longer in parts of the Central, South-Western and South-Central regions of the country due to upstream water rush and tidal influences.The flood however receded mostly within the first half of September and continued so, until the unprecedented late monsoon flood in Teesta basin in third week of October. The South-Eastern and North-Eastern regions of the country within the South Eastern Hill and Meghna basins respectively were only affected by short duration flooding during the monsoon with overall greater intensity in July and August respectively. Moderate to severe flash flooding occurred in parts of South-Eastern region inducing severe landslides in Bandarban and Cox's Bazar districts in last weeks of July.

Notable flood durations of the season included: Dharala at Kurigram for 14 days, Teesta at Dalia for 13 days, Jamuna at Aricha for 17 days, Atrai at Baghabari for 21 days, Padma at Goalundo for 25 days, at Sureswar for 36 days, Kirtonkhola at Barisal for 9 days and Pashure at Khulna for 45 days. In terms of magnitude the flood was less severe than historical major ones except in the Northern region. No pre-monsoon flooding occurred this year. Average accuracy of 5-days deterministic forecasts were around 96%, 91%, 86%, 80% and 75% for 24, 48, 72, 96 and 120 hours respectively.

The monsoon was on average below normal over the GBM basin throughout 2021 except slightly above normal over the Ganges basin. The country as a whole received 12.6% less rainfall than normal during May to October. The Brahmaputra, Meghna and South Eastern Hill basins received respectively 28.2%, 16% and 7% less rainfall than normal, while the Ganges basin received 4% more rainfall than normal. Monthly percentage based basin wise less (-) or more (+) rainfall than the normal is presented in following table.

Month	Brahmaputra basin	Ganges basin	Meghna basin	South East Hill basin
May	-33%	-11%	-35%	-80%
June	-12%	+22%	-16%	+3%
July	-51%	-2%	-21%	+5%
August	+13%	+14%	+34%	+10%
September	-63%	-29%	-58%	-26%
October	-3%	+47%	+4%	+17%

Notable improvements have been made during 2021 as a 15-days experimental probabilistic streamflow forecasting system has been made operational. Also BWDB-Google Flood Forecasting Intiative has been officially launched this year as a location specific forecast service scaled up for the whole country. During the monsoon of 2021, maximum flooded area was 33% of the whole country (48,698 sq-km approximately). Some of the regions experienced severe river bank erosion which continued both during and after the flooding. The Dhaka city remained flood free throughout the season.

List of Abbreviations

BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CDMP	Comprehensive Disaster Management Programme
CFAB	Climate Forecast Application Bangladesh
CARE	Cooperative for American Relief Everywhere
CFAN	Climate Forecast Application Network
DG	Director General
DL	Danger Level
DDM	Department of Disaster Management
DMC	Disaster Management Committee
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
DEM	Digital Elevation Model
FbA	Forecast based Action
FF	Flood Forecast
FFWC	Flood Forecasting and Warning Centre
GM	General Model
GBM	Ganges Brahmaputra Meghna
HILIP	Haor Infrastructure and Livelihood Improvement Project
IWM	Institute of Water Modelling
IVR	Interactive Voice Response
LGED	Local Government Engineering Department
MAE	Mean Absolute Error
MoWR	Ministry of Water Resources
NGO	Non-Government Organization
NWP	Numerical Weather Prediction
PMDL	Pre-monsoon Danger Level
MSL	Mean Sea Level
RHWL	Recorded Highest Water Level
RIMES	Regional Integrated Multi-hazard Early Warning System
SoB	Survey of Bangladesh
SOD	Standing Orders on Disaster
SSB	Single Site Band
SUFAL	Supporting Flood Forecast Based Early Action and Learning
UNDP	United Nations Development Porgramme
USAID	United States Agency for International Development
WL	Water Level

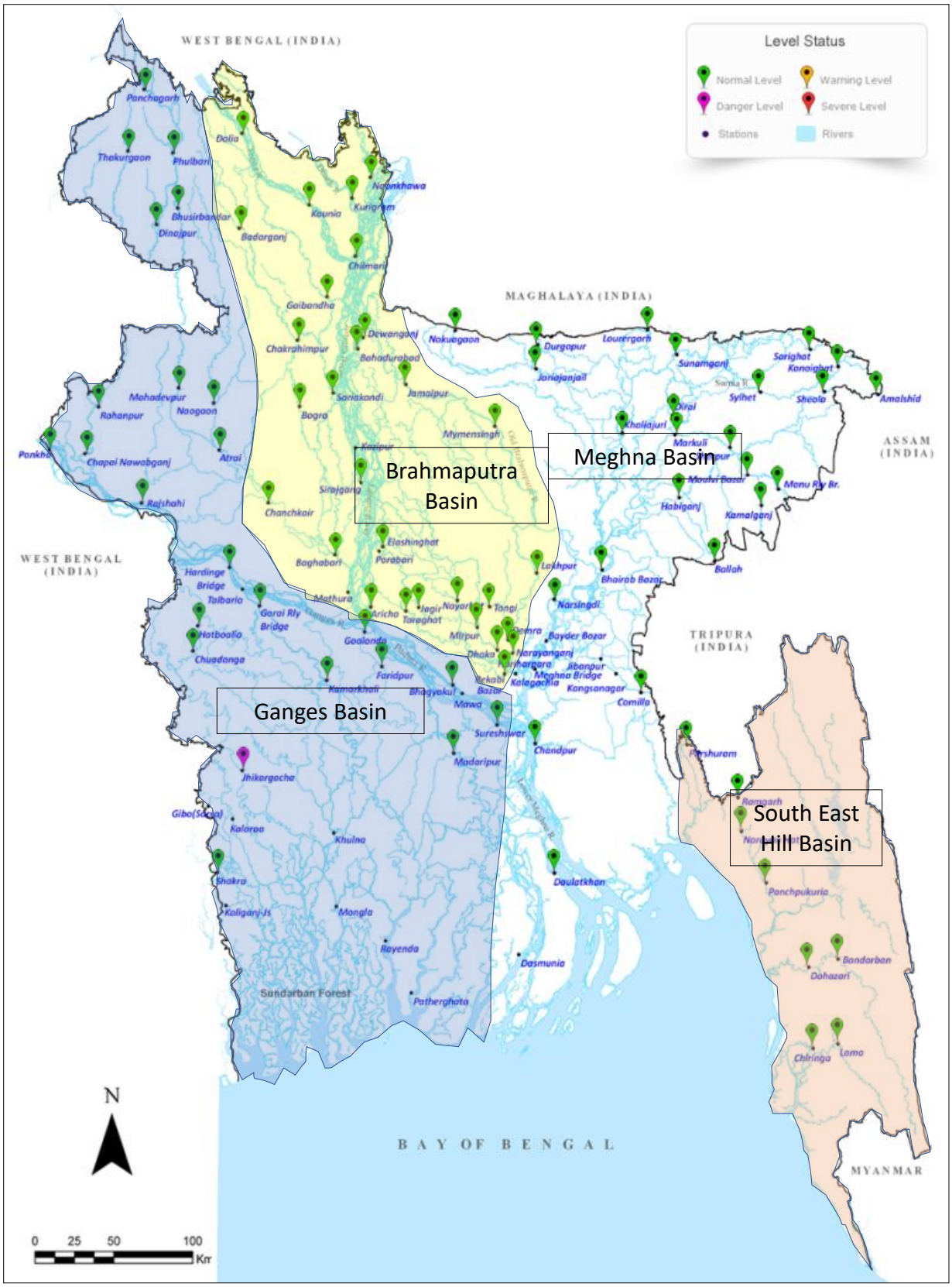

Figure 1: Basin Map of Bangladesh with Water Level Gauge Stations

CHAPTER 1 : INTRODUCTION

1.1. THE PHYSICAL SETTING

Bangladesh lies approximately between 20º30' and 26º40' north latitude and 88º03' and 92º40' 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 405 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna (*Ref. Bangladesher Nod Nodi, BWDB, August 2011*). Three rivers are originated from Myanmar. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment. But flood more than that causing direct and indirect damages and considerable inconveniences to the population.

The country is mostly flat with 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 Northwest boundary of the country 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, Sunamganj 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 Meghalay being about 11,755 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 recognized as a vital non-structural measure 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 Processing and Flood Forecasting Circle, Hydrology, BWDB takes hydrological monitoring data of 109 representative water level stations and 74 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, deterministic forecast for 24, 48, 72, 96 and 120 hours at 54 monitoring points on the major rivers, 10-days probabilistic flood forecast at 37 monitoring points on the major rivers, special flood report along with different graphical and statistical presentation during the monsoon season. During the pre-monsoon season the center is involved in 3-days deterministic flash flood forecasting at 37 monitoring points on the major rivers in the North-Eastern region with a view to saving the standing Boro crops in Haor basins. The Centre is also involved in preparation of flood status report at national level, weekly bulletin during dry season, monthly and annual flood reports. The Centre is responsible as a focal point in respect of flood from the month of April to October as per Government order for generating flood forecast & warning that are issued with the flood bulletin and also provide support services to DDM other relevant organization.

OUTPUTS of the FFWC

- **Daily Flood Bulletin & River situation summary**
- **Forecast bulletin & Hydrograph**
- **Warning message**
- **Special outlook**
- **Rainfall distribution/surface Map.**
- **River situation map**
- **Flood inundation map**
- **Comparison Hydrographs for various years**

Step by step development has been made in the flood forecasting and warning services in Bangladesh, started from 1972. Before 1990, forecast for six locations viz. Bahadurabad, Serajgonj, Aricha, Goalondo, Bhagyakul and Hardinge Bridge on the Padma – Brahmaputra –Jamuna river 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 the coastal zone and South-Eastern hill region. Excluding these regions, the model covers about 82,000 km^2 of entire country. The area covered under the supermodel is divided into 107 numbers of 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 database management is being done with Windows based Operating System installed with desktop PCs at the FFWC.

Flood Forecasting & Warning Services: Brief History

1972 - FFWC Established under BWDB
- Real Time Flood Monitoring at 10 Stations/Points along the Brahmaputra, Ganges and Padma rivers
- Flood Forecast (FF) with few hours lead time at 6 points by Gauge Correlation along Brahmaputra and Padma rivers

1992 - MIKE11-FF Model Introduced
- FF with one day lead time at 16 points/locations

1995-96 - MIKE11 Super Model with GIS
- FF at 30 locations with lead time upto 2-days

2000-04 - Strengthening FFWS
- Expansion of FF areas coverage
- Flood monitoring covers entire country
- Improved accuracy and extended Lead Time upto 3-days
- Improved dissemination

2005-07 - Probabilistic medium range FF with lead time upto 10-days initiated at 18 points/locations of Ganges-Brahmaputra (GB) basin

2007-09 - Further extension of FFWS
- Mike 11 Super Model with GIS introduced with flood ma generation facility
- FF at 38 locations on 21 Rivers upto 3-days Lead Time
- Flood Inundation Mapping
- Improvement of probabilistic medium range FF upto 10-days at 18 points

2012-14 - Strengthening and Improvement of FFWS
- FF at 54 locations on 28 rivers with Extended Lead Time upto 5-days
- Probabilistic 10-days medium range FF expanded to 37 stations of GB basin
- Structure based FF for 4-selected projects upto 5-days lead time (Dhaka-Mawa Highway, Brahmaputra Right Embankment, Pabna Irrigation and Rural Development Project and Meghna-Dhonagoda Irrigation Project)
- Improved and more user friendly web-site with Bangla language
- IVR system for dissemination based on mobile phone introduced
- Improved LAN and display.

2017-19 - Operational 3-days deterministic flash flood forecast at 25 stations for the North-Eastern region
- Establishment of pre-monsoon danger level in North-Eastern region
- Introduction of FFWC mobile app

2020-21 - Operational 15-days probabilistic flow forecast at 3 stations on the major rivers– Brahmaputra, Ganges and Meghna
- Official launching of BWDB-Google Flood Forecasting Intiative as a location specific forecast service scaled up for the whole country
- Deterministic FF coverage increased to 61 locations on 31 rivers

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (109 WL stations and 74 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 within 9.30 A.M. through mobile SMS. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through websites, e-mail and from Bangladesh Meteorological Department (BMD).

Necessary Data & Forecast Calculation: Estimation of WL at the model boundaries and rainfall for the internal catchments are required input to the model upto the time of forecast (24, 48, 72, 96 & 120 hrs).

Collected/observed WL and rainfall data are given input to the computer database and checked. The WL and rainfall estimation up to the time of forecast has to be prepared. During monsoon (June to October) WL of few stations of upper catchments of Ganges, Brahmaputra, Teesta, Dharala and Barak rives has been received since 2010 from Central Water Commission (CWC), India through e-mail. Some WL data are also available publicly in Indian websites. The basis for WL estimation is consideration of 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 are based on previous 3-day's rainfall and analysis of Numerical Weather Prediction (NWP) model rainfall forecasts from BMD. In addition to BMD, NWP model rainfall forecasts from India Meteorological Department (IMD), National Oceanic and Atmospheric Administration (NOAA) and European Centre for Medium Range Weather Forecast (ECMWF) are necessary data for estimating response of rivers due to rainfall in upper catchments. After input required data and boundary-estimated data to the model, model run started. It takes about 30 to 40 minutes time to complete the calculations.

Dissemination: Daily forecast bulletin is prepared upto 5 days 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 organizations, non-government organizations (NGOs) 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. Interactive Voice Response (IVR) through mobile has been initiated since July 2011 through Teletalk. Now, all the mobile operators have started the IVR

Mode of Dissemination

- E-mail
- Website
- Media, print & electronic
- Telephone, Mobile, Fax
- Hard/print copy
- Lobby display
- IVR through mobile no 1090
- Android mobile app ('BWDB Flood App')
- Google push notification/Google search/Google map

since 2015. The FFWC website is openly accessible to all and contains all flood related information. In addition, FFWC has launched a mobile app since 2018 which is publicly available. High-resolution inundation map has been also made operationally available from this year on location specific basis which users can see by searching Google web/map or directly receive through Google push notification.

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 5-days ahead of its occurrence during monsoon. 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 for climatic distinct seasons (i) Winter December to February (ii) Pre-monsoon March to May, (iii) Monsoon June to September (iv) Post-monsoon October to November. 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. During the pre-monsoon season, the country generally receives little rainfall, however the North-Eastern region of the country adjacent to the Meghalaya sometimes receives heavy rainfall which induces flash flood in the Haor basin.

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. Cherrapunji, 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 km^2) 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 405 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, 2007, 2017, 2019 & 2020 all caused heavy damages to properties and considerable loss of life. During monsoon 2021, the flood was a normal one except the Teesta flooding during 20-21 October in the late monsoon. Percentages of total area of Bangladesh affected by flood available since 1954 are presented in Table 1.1.

Table 1.1 :Year-wise Flood Affected Area in Bangladesh

Year	Flood Affected area		Year	Flood affected area	
	Sq-Km	%		Sq-Km	%
1954	**36,800**	**25**	1990	3,500	2.4
1955	**50,500**	**34**	1991	28,600	19
1956	35,400	24	1992	2,000	1.4
1960	28,400	19	1993	28,742	20
1961	28,800	20	1994	419	0.2
1962	37,200	25	1995	32,000	22
1963	43,100	29	1996	35,800	24
1964	31,000	21	**1998**	**1,00,250**	**68**
1965	28,400	19	1999	32,000	22
1966	33,400	23	2000	35,700	24
1967	25,700	17	2001	4,000	2.8
1968	37,200	25	2002	15,000	10
1969	41,400	28	2003	21,500	14
1970	42,400	29	**2004**	**55,000**	**38**
1971	36,300	25	2005	17,850	12
1972	20,800	14	2006	16,175	11
1973	29,800	20	**2007**	**62,300**	**42**
1974	**52,600**	**36**	2008	33,655	23
1975	16,600	11	2009	28,593	19
1976	28,300	19	2010	26,530	18
1977	12,500	8	2011	29,800	20
1978	10,800	7	2012	17,700	12
1980	33,000	22	2013	15,650	10.6
1982	3,140	2	2014	36,895	25
1983	11,100	7.5	2015	47,200	32
1984	28,200	19	2016	48,675	33
1985	11,400	8	**2017**	**61,979**	**42**
1986	6,600	4	2018	33,941	23
1987	**57,300**	**39**	**2019**	**45,747**	**31**
1988	**89,970**	**61**	**2020**	**59,028**	**40**
1989	6,100	4	**2021**	**48,698**	**33**

CHAPTER 2 : RAINFALL SITUATION

During the pre-monsoon months of March and April in 2021, the Meghna basin within the country in the North-Eastern and adjacent region experienced 65.09% and 55.94% less rainfall than normal respectively, while other parts of the country remained mostly dry. During the monsoon-2021 (May to October), the country experienced as a whole 12.64% less rainfall than normal which can be considered as below normal monsoon. The Brahmaputra, Meghna and South Eastern Hill basin basins received 28.2%, 16 % and 7% less rainfall than normal respectively, while the Ganges basin received 4% more rainfall than normal during the season. Comparison of the country basin average of normal and actual rainfall for the monsoon-2021 (May to October) is presented in the bar chart. Considering monthly rainfalls, the country as a whole received less rainfall than normal during the May-October period except in August. The Ganges basin received more rainfall during the monsoon season than the other basin. The monthly normal and actual rainfall of all the basins and the country average are shown in Table 2.1.

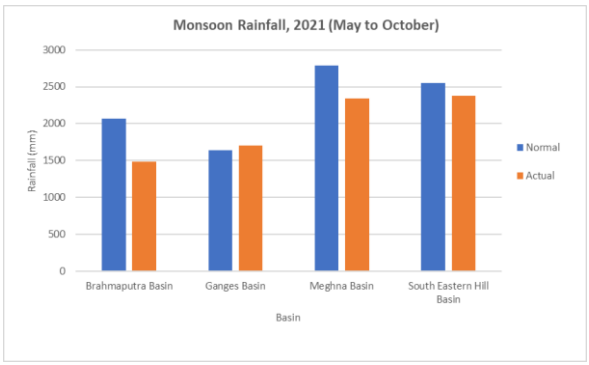

Table 2.1: Rainfall statistics for the Monsoon-2021 over the four Basins

Month	Brahmaputra Basin(mm)		Ganges Basin(mm)		Meghna Basin(mm)		South Eastern Hill Basin(mm)		Monsoon average (mm)	
	Nor	Act	Nor	Act	Nor	Act	Nor	Act	Nor	Act
May	312.1	208.4	189.4	168.0	456.1	295.9	275.2	54.2		
Jun	425.2	374.8	317.9	388.5	593.8	501.0	570.5	590.4		
Jul	484.9	237.2	401.4	393.0	620.1	487.1	677.2	710.8		
Aug	339.6	384.4	318.8	363.9	512.3	685.4	515.6	568.5	**2261.9**	**1976.1**
Sep	353.4	131.6	281.9	201.4	414.2	174.0	348.9	256.9		
Oct	154.6	149.2	129.6	190.0	188.3	195.8	166.6	194.1		
Total	**2069.8**	**1485.6**	**1639.0**	**1704.7**	**2784.7**	**2339.2**	**2554.0**	**2374.8**		
%More/ Less	28.2% Less		4 % More		16% Less		7% Less		12.64% Less	

Month wise rainfall situations of the country during March to October for the pre-monsoon and monsoon seasons of 2021 are described in the following sections.

2.1 MARCH

The Meghna basin of the country experienced rainfall less than normal during the month of March 2021, while the other parts of the country remained mostly dry. The basin received 65.09% less rainfall than monthly normal.

Important Rainfall Information for March-2021
Monthly Maximum at Manu-Rly-Br.: 140 mm
1 day maximum at Sylhet: 68 mm

Table 2.2: Summary of the rainfall situation during the month of March-2021

Basin:	**Meghna**
No of Stations:	28
Average Rainfall (mm) of the basin:	27.60
%More(+)/Less(-) than the Normal:	-65.09
Number of Stations above Normal Rainfall:	07
Highest 1-day Maximum Rainfall with Stations:	Sylhet 68.00 mm
Number of Rain Fed Flood* Stations:	0

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

In the Meghna basin, out of 28 rainfall monitoring stations, 7 stations received more rainfall than their monthly normal. During March, monthly 1-day maximum rainfall of 68 mm and 10-day consecutive maximum rainfall of 82 mm were observed at Sylhet. Summary of the rainfall situation of the basin for the month is presented in Table 2.2. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, no stations crossed the threshold in March.

2.2 APRIL

The Meghna basin of the country experienced rainfall less than normal during the month of April 2021, while the other parts of the country remained mostly dry. The basin received 55.94 % less rainfall than monthly normal.

Important Rainfall Information for April-2021
Monthly Maximum at Sylhet : 371 mm
1 day maximum at Lalakhal : 100 mm

Table 2.3: **Summary of the rainfall situation during the month of April-2021**

Basin:	**Meghna**
No of Stations:	28
Average Rainfall (mm) of the basin:	109.7
%More(+)/Less(-) than the Normal:	-55.94%
Number of Stations above Normal Rainfall:	02
Highest 1-day Maximum Rainfall with Stations:	Lalakhal 100mm
Number of Rain Fed Flood* Stations:	0

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

In the Meghna basin, out of 28 rainfall monitoring stations, 2 stations received more rainfall than their monthly normal. During April, monthly 1-day maximum rainfall of 100mm was observed at Lalakhal, while 10-day consecutive maximum rainfall of 251 mm was observed at Lalakhal. Summary of the rainfall situation of the basin for the month is presented in Table 2.3. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, no stations crossed the threshold value in April.

2.3 MAY

The country as a whole,experienced rainfall less than normal during the month of May 2021.

Important Rainfall Information for May-2021
Monthly Maximum at Lourergorh : 792.5 mm
1 day maximum at Sunamganj : 203 mm

Table 2.4: **Summary of the rainfall situation during the month of May-2021**

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	20	28	11
Average Rainfall (mm) of the basin:	208.42	8	295.92	54.15
%More(+)/Less(-) than the Normal:	-33.21	-1.46	-35.11	-80.33
Number of Stations above Normal Rainfall:	2	8	6	0
Highest 1-day Maximum Rainfall with Stations:	Gaibandha (125mm)	Chapai-Nawabganj (167 mm)	Sunamganj (203 mm)	Ramgarh (52.3 mm)
Number of Rain Fed Flood* Stations:	0	0	7	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 13 rainfall monitoring stations, 2 stations received more rainfall than their normal. One day maximum rainfall of 125 mm was recorded at Gaibandha. The Basin received -33.21% less rainfall than normal during the month May2021.

In Ganges basin, out of 20 rainfall monitoring stations, 8 stations received more rainfall than their normal. One day maximum rainfall of 167 mm was recorded at Chapainawabganj. The Basin received 1.46% less rainfall than normal during the month May2021.

In the Meghna basin, out of 28 rainfall monitoring stations, 6 stations received more rainfall than their normal. One day maximum rainfall of 203 mm was recorded at Manu Rly Br, while 10-day consecutive maximum rainfall of 384 mm was observed at Sunamganj. The Basin received 35.11% less rainfall than normal during the month May 2021.

In the South Eastern Hill basin, out of 11 rainfall monitoring stations, no stations received more rainfall than their normal. One day maximum rainfall of 52.3 mm was recorded at Ramgarh. The Basin received 80.33% less rainfall than normal during the month May2021.

Summary of the rainfall situation of the country is presented in Table 2.4. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, as many as 7 stations crossed the threshold value in this month. The maximum 1-day rainfall of 203 mm was recorded at Sunamganj and 10-day consecutive maximum rainfall of 422.5 mm was recorded at Lourergorh.

The Isohyet of the actual rainfall of the month of May-2021 is shown in the Figure 2.1.

2.4 JUNE

Important Rainfall Information for June, 2021

Monthly Maximum at Lourergorh: 1308 mm

1 day maximum at Lalakhal : 231 mm

The country, as a whole, experienced more rainfall than normal during the month of June 2021.Among the four hydrological basins, the Ganges and South-Eastern Hillbasin received 35.76 & 3.49 more rainfall respectively, while the Brahmaputra and Meghna basin received 11.85 & 15.63 less rainfall respectively in the month of June 2021. Table 2.5 represents the summary of rainfall situation all through the country.

Table 2.5: Summary of the rainfall situation during the month of June -2021

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
Basin average rainfall at June, 2019 (mm):	374.82	388.46	501.04	590.41
%More(+)/Less(-) than Normal:	-11.85	35.76	-15.63	3.49
No. of Stations above Normal Rainfall:	5	16	7	5
Highest 1-day Maximum Rainfall Stations:	Gaibandha 183	Pabna 177	Lalakhal 231	Narayan-Hat 168
No of Rain Fed Flood*Stations:	0	3	8	7

*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 5 out of 13 stations in the Brahmaputra, 16 out of 20 stations in the Ganges, 7 out of 28 stations in the Meghna and 5 out of 11 stations in South Eastern Hill Basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Lalakhal in the Meghna basin is the daily highest (231 mm) rainfall recipient station.

The table also shows that 3 station in the Ganges, 8 stations in the Meghna and 7 stations in the South Eastern Hill basin received more than 300 mm rainfall in 10-day period. It is to be mentioned here that 300 mm or more rainfall in 10-Day period may cause rain fed flood.

The Isohyet of the actual rainfall of the month of June-2021 is shown in the Figure 2.2.

2.5 JULY

The country, as a whole, experienced less rainfall than normal during the month of July 2021.The Brahmaputra and Meghna received 51.09% & 21.45% less rainfall respectively while the Ganges and the South Eastern Hill basin received 8.78% & 4.95% more rainfall than their respective monthly normal values during the month.

Important Rainfall Information for July 2021

Monthly Maximum at Lama: 1211 mm

10 day maximum at Barguna: 729.3 mm

1 day maximum at Teknaf: 328 mm

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Table 2.6: Summary of the rainfall situation during the month of July-2021

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
%More(+)/Less(-) than the Normal:	**-51.09%**	**8.78%**	**-21.45%**	**4.95%**
Number of Stations above Normal Rainfall:	2	7	6	5
Highest 1-day Maximum Rainfall with Stations:	157 mm Dalia	252 mm Patuakhali	275 mm Lourergorh	328 mm Teknaf
Number of Rain Fed Flood* Stations:	1	3	9	6

*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, among the 13 stations, 2 stations received more rainfall than their normal rainfall. The Basin received 51.09**%** less rainfall than their normal during the month July 2021. Monthly 1-day maximum rainfall of 157 mm and 10-day max of 405 mm was recorded at Dalia. Rainfall of Dhaka in July 2021 was recorded 367 mm, above the normal rainfall of Dhaka.

In Ganges basin, 7 of 20 stations received more rainfall than their normal. The basin as a whole received 8.78**%** more rainfall than its normal during the month of July-2021. One day maximum rainfall of 252 mm was recorded at Patuakhali while 10-day consecutive maximum rainfall of 729.3 mm was recorded at Barguna.

In Meghna basin, 6 out of 28 stations were recorded more rainfall than their normal value of the month. The Basin as a whole recorded 21.45**%** less rainfall than normal during the month of July 2021. One day maximum rainfall of 275 mm was recorded at Lorergarh and 10-day consecutive maximum rainfall of 543 mm was recorded at Suanmganj.

In South Eastern Hill basin, 5 stations received more rainfall than their normal rainfall .The basin as a whole received 4.95 %more rainfall than its normal rainfall during the month of July 2021. One day maximum rainfall of 328 mm at Teknaf and 10-day consecutive maximum rainfall of 706.3 mm was recorded at Lama. This rainfall caused water logging and local flood at the area.

Summary of the country's rainfall situation is presented in Table 2.6. Out of 72 stations, total 20 stations received more rainfall than normal and 19 stations recorded more than 300 mm rainfall for 10-day period. Maximum 10-daymaximum rainfall recorded at Barguna of 729.3 mm and 1-day at Teknaf of 328 mm. Rain fed flood situation developed at Dalia, Panchagarh, Patuakhali, Barguna, Sylhet, Chattak, Sunamganj, Sheola, Lalakhal, Jaflong, Itakhola, Lourergorh, Moheshkhola, Durgapur, Noakhali, Bandarban, Lama, Chattogram, Cox's Bazar and Teknaf with some additional surrounding places.

A map withIsohyet of the actual rainfall of July-2021 is shown in the Figure 2.3.

2.6 AUGUST

Important Rainfall Information for August 2021
Monthly Maximum at Lalakhal : 1925 mm
One day maximum at Khulna : 200 mm

The intensity of rainfall in the Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin was moderately higher at most of the places during the month of August 2021. The four hydrological basins Brahmaputra, Ganges, Meghna and southern eastern hill basins received more rainfall than their respective monthly normal rainfall during the month of August, 2021. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin received 13.17%, 26.83%, 33.80% and 10.24% more rainfall than their respective normal rainfall of the month. Table 2.1 represents the summary of rainfall situation all through the country.

Table 2.7: Summary of the rainfall situation during the month of August-2021

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
Basin average rainfall at August, 2017(mm):	384.38	363.88	685.44	568.45
%More(+)/Less(-) than Normal:	13.17%	26.83%	33.80%	10.24%
No. of Stations above Normal Rainfall:	9	9	20	7
Highest 1-day Maximum Rainfall Stations:	Mymensingh	Pabna	Chattak	Cox's Bazar
	(143.5 mm)	(135.2 mm)	(262 mm)	(196 mm)
No of Rain Fed Flood* Stations:	2	2	13	4

*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, 9 out of 20 stations in the Ganges, 20 out of 28 stations in Meghna and 7 out of 11 stations in the South-Eastern Hill basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Chattak in the Meghna Basin has the daily highest rainfall recorded station.

The Table 2.1 shows that 2 stations in Brahmaputra basin, 2 stations in Ganges basin, 13 stations in the Meghna Basin and 7 stations in the South Eastern Hill basin received more than 300 mm rainfall in consecutive 10-day period. It may be mentioned that 300 mm or more rainfall in consecutive 10-day period may cause rain fed flood in the locality.

The Isohyet of the actual rainfall of the month of August-2021 is shown in the Figure 2.4.

2.7 SEPTEMBER

Important Rainfall Information for September 2021
Monthly maximum at Bandarban :580.2 mm
1-day maximum at Jaflong : 180 mm

The country, as a whole, experienced less rainfall than normal during the month of September 2021. The Brahmaputra, the Ganges . the Meghna basin and the South-Eastern basin received 62.78%, 20.59%, 57.99% and 26.38 less rainfall repetitively than their respective normal rainfall of the month. Table 2.8 represents the summary of rainfall situation of the month all through the country.

Table 2.8: Summary of the rainfall situation during the month of September-2021

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	20	28	11
Basin average rainfall at September,2019(mm):	131.55	201.44	173.98	256.88
%More(+)/Less(-) than Normal:	-62.78	-20.59	-57.99	-26.38
No. of Stations above Normal Rainfall:	0	5	2	4
Highest 1-day Maximum Rainfall Stations:	Dalia (92 mm)	Satkhira (145.8 mm)	Jaflong (180 mm)	Bandarban (126.3 mm)
No of Rain Fed Flood*Stations:	0	1	0	1

*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 5 out of 20 stations in the Ganges, 2 out of 28 stations in the Meghna and 4 out of 11 stations in the South Eastern Hill basin received more rainfall than their monthly normal. Among all monitoring stations, Jaflong in the Meghna basin is the daily highest (180 mm) rainfall recipient station.

The table also shows that 1 station in the Ganges and 1 station in the South-Eastern Hill basin received more than 300 mm rainfall in 10-day period.

The Isohyet of actual rainfall for September-2021 is shown in the Figure 2.5.

2.8 OCTOBER

Important Rainfall Information for October 2021
Monthly maximum at Chattogram: 427.6 mm
1 day maximum at Narayan-Hat: 198 mm

The country, as a whole, experienced rainfall more than normal during the month of October 2021 except the Brahmaputra basin. The Ganges, the Meghna basin and the South Eastern Hill basin received more rainfall than monthly normal, while the Brahmaputra received less rainfall.Table 2.9 represents the summary of rainfall situation of the month all through the country.

Table 2.9: Summary of the rainfall situation during the month of October-2021

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
Average Rainfall (mm) of the basin:	149.22	189.97	195.81	194.13
%More(+)/Less(-) than the Normal:	-3.45	62.84	4.01	15.59
Number of Stations above Normal Rainfall:	5	12	14	5
Highest 1-day Maximum Rainfall with Stations:	Rangpur (195 mm)	Barguna (158 mm)	Lourergorh (180 mm)	Narayan-Hat (198 mm)
Number of Rain Fed Flood* Stations:	0	1	1	1

*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 13 rainfall monitoring stations, 5 stations recorded more rainfall than the normal and the basin received 3.45% less rainfall than normal during the month October 2021. 1-day maximum rainfall of 195 mm was recorded at Rangpur.

In Ganges basin, out of 20 rainfall monitoring stations, 12 station recorded more rainfall than the normal rainfall of the month. The basin as a whole received 62.84% more rainfall than the normal during the month.1-day maximum rainfall of 158 mm was recorded at Barguna.

In the Meghna basin, out of 28 rainfall monitoring stations, 14 stations recorded more rainfall than the normal value of the month. The Basin received 4.01% more rainfall than monthly normal during the month.1-day maximum rainfall of 180 mm was recorded at Lourergorh.

In the South Eastern Hill basin, out of 11 rainfall monitoring stations 5 stations were recorded more rainfall than normal. The Basin as a whole recorded 15.59% more rainfall than normal during the month. 1-day maximum rainfall of 198 mm was recorded at Narayan-Hat.

The table also shows that 1 station in the Meghna basin, 1 station in Ganges Basin and 1 station in South Eastern Hill basin received more than 300 mm rainfall in 10-day period.

A map with the Isohyet of actual rainfall for the month of October-2021 is shown in the Figure 2.6.

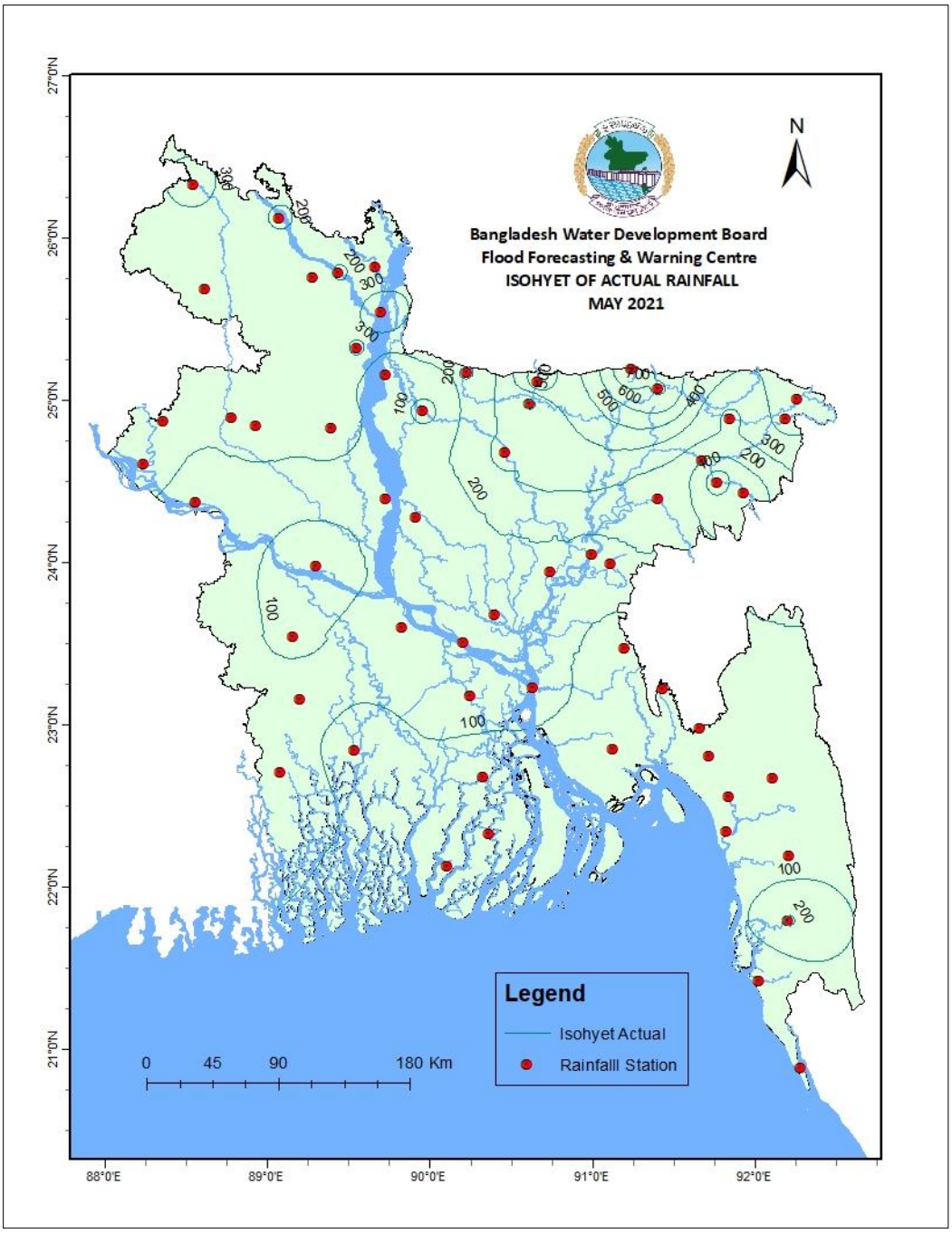


Figure 2.1: Isohyet of Actual Rainfall (May-2021)

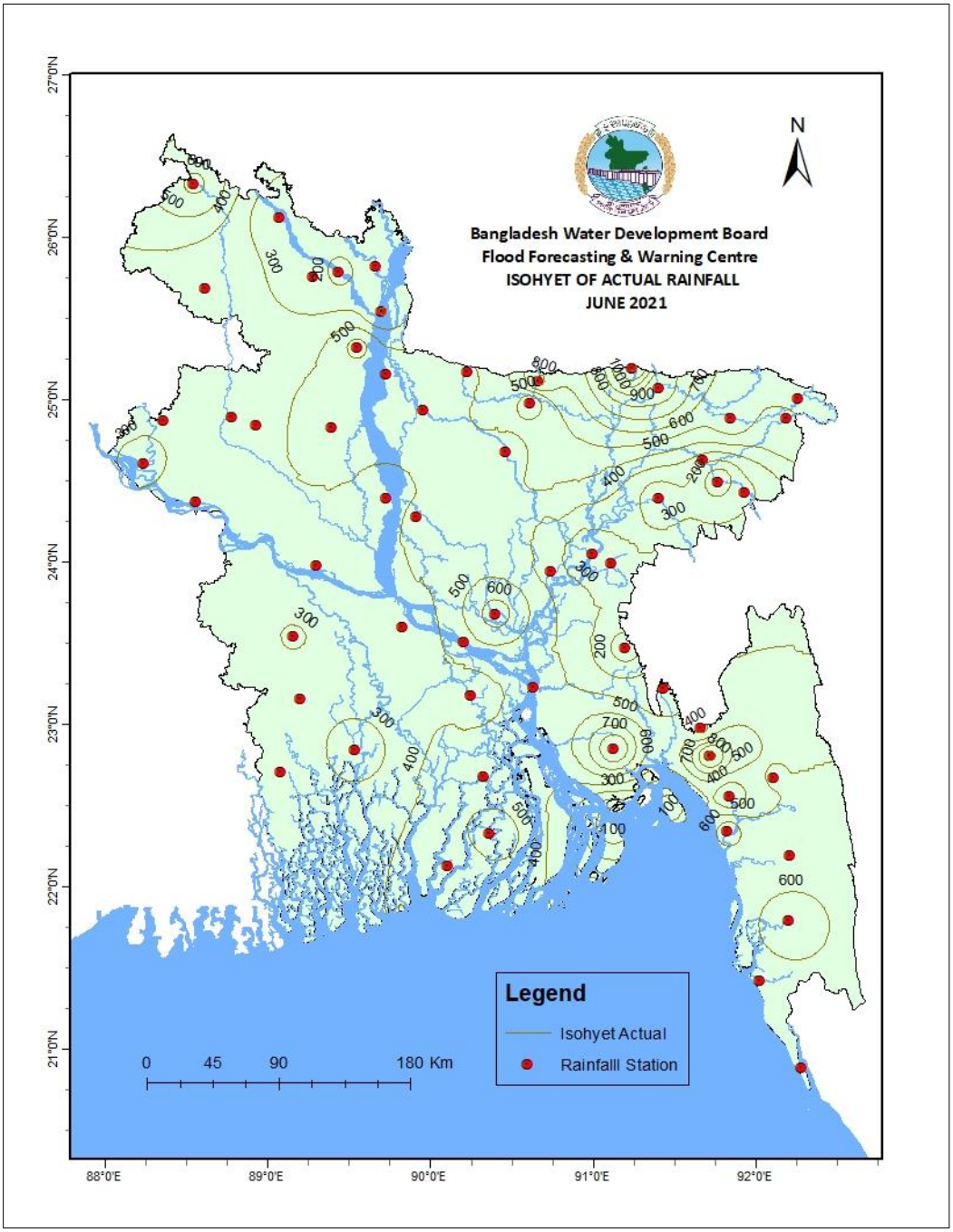


Figure 2.2: Isohyet of Actual Rainfall (June-2021)

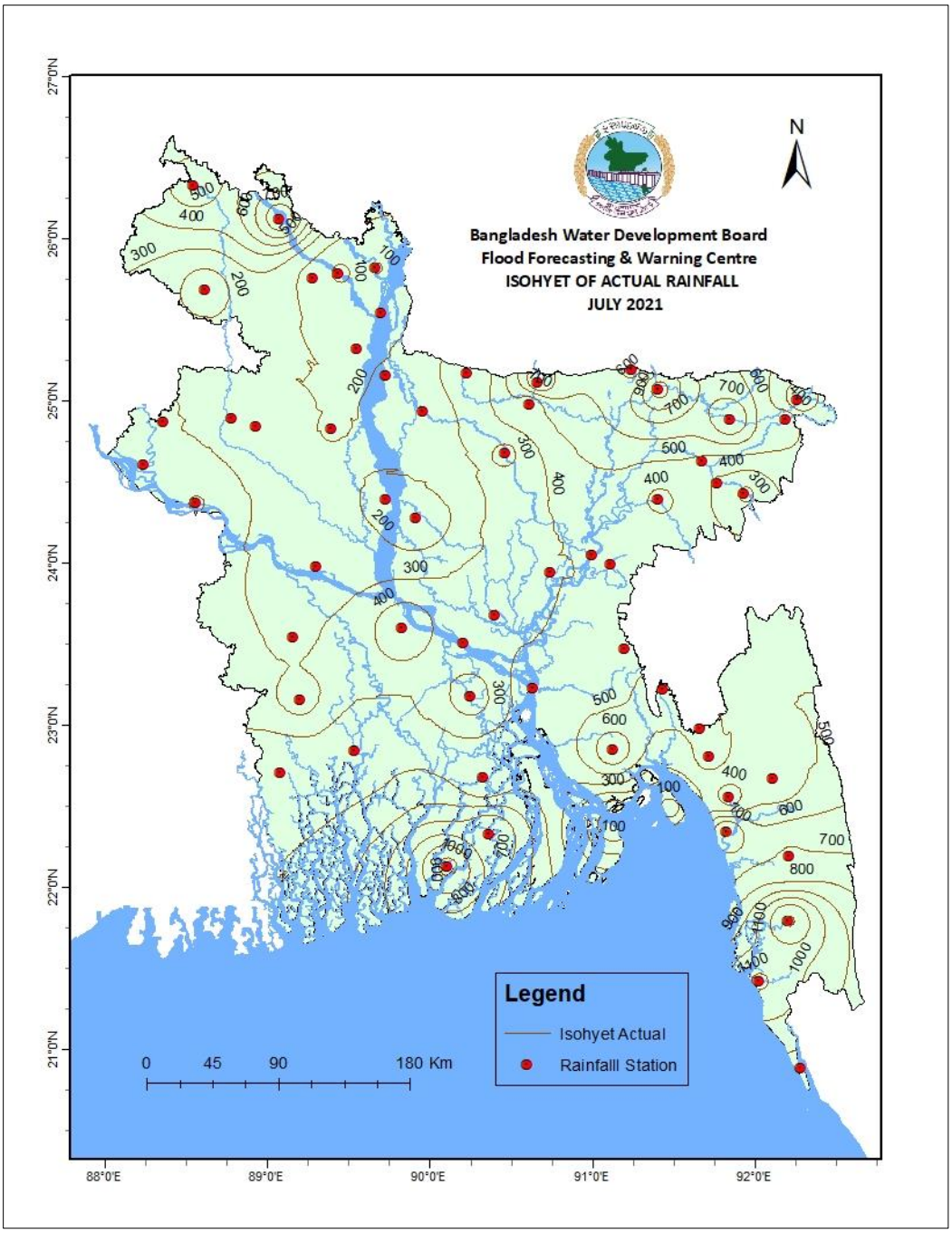


Figure 2.3: Isohyet of Actual Rainfall (July-2021)

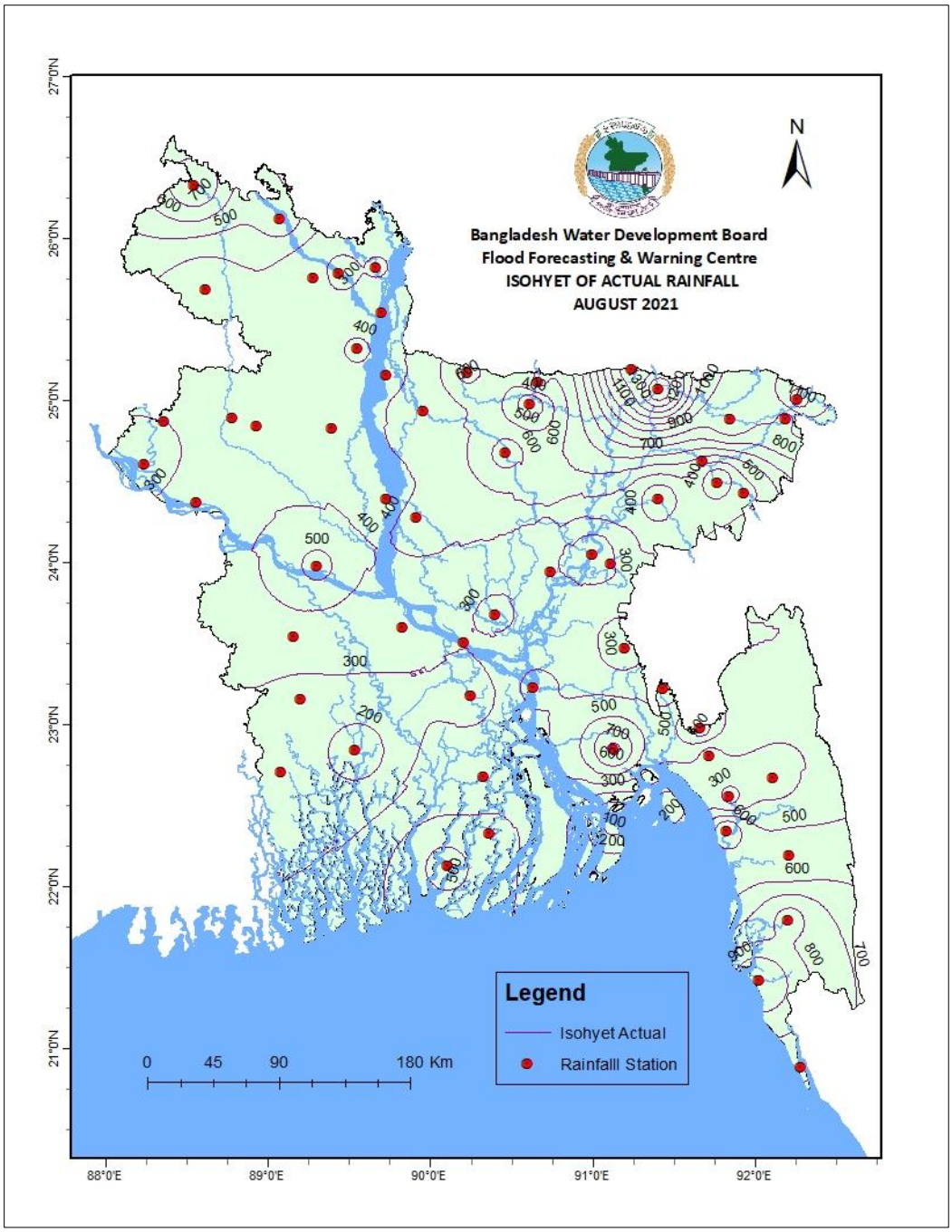


Figure 2.4: Isohyet of Actual Rainfall (August-2021)

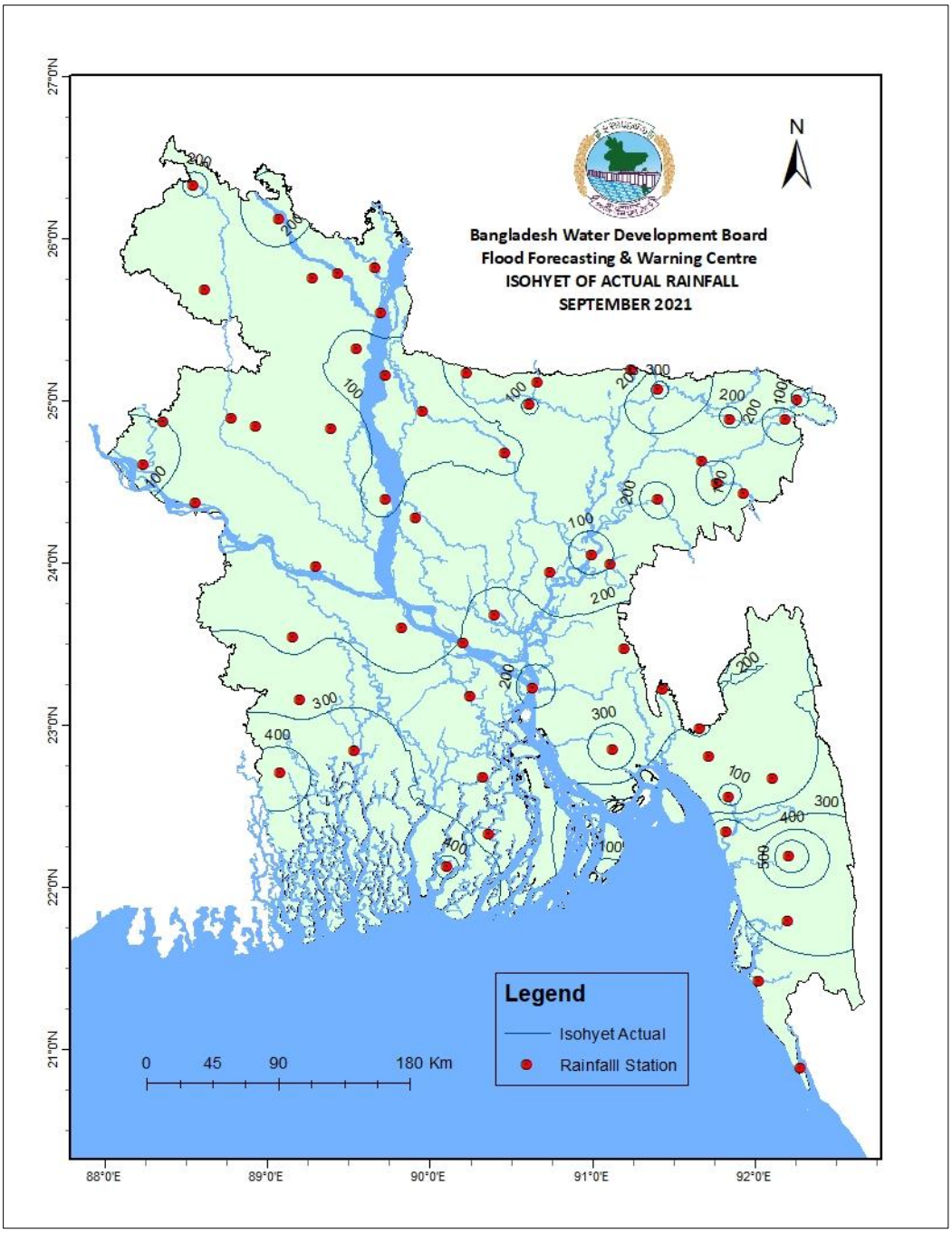


Figure 2.5: Isohyet of Actual Rainfall (September-2021)

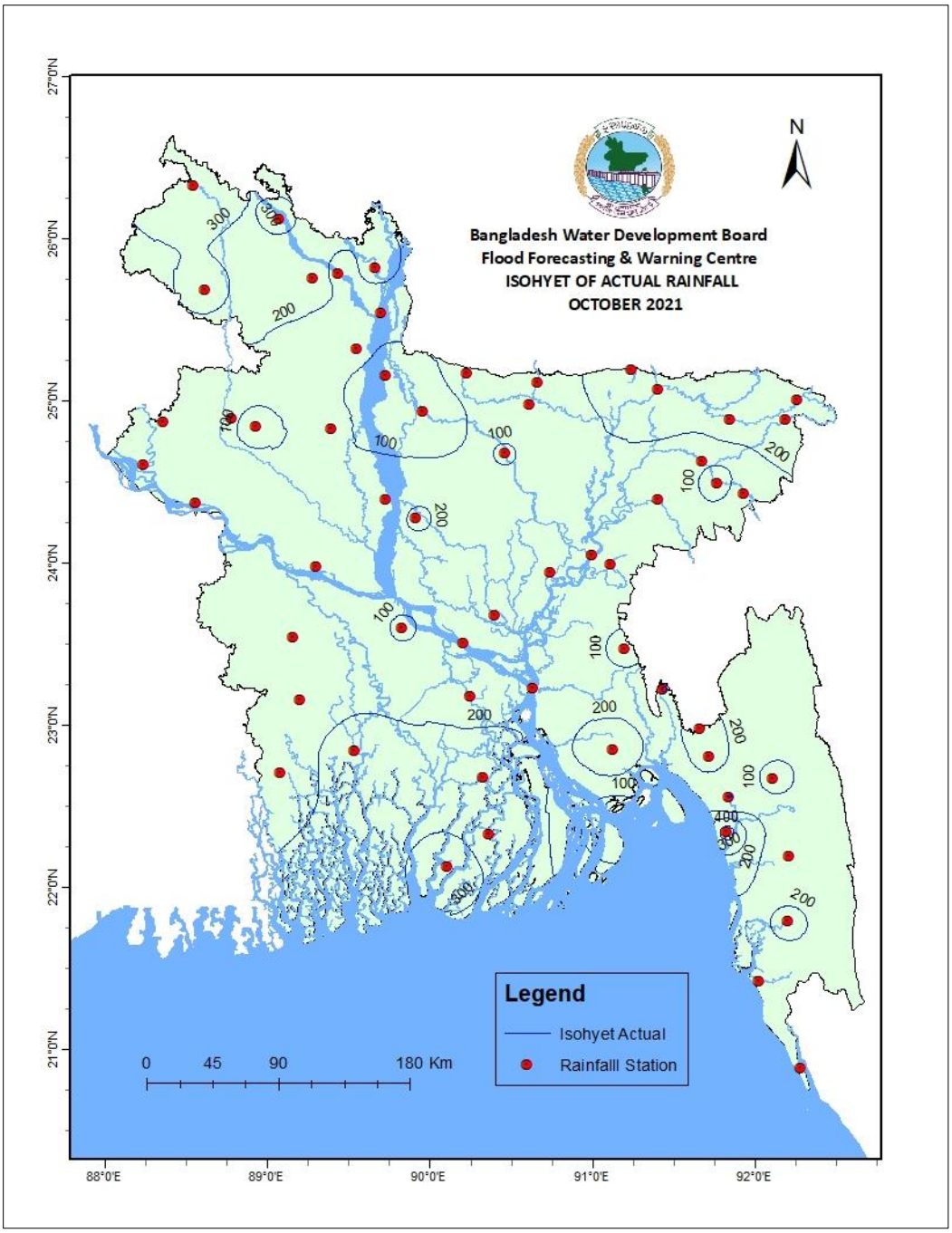


Figure 2.6: Isohyet of Actual Rainfall (October-2021)

CHAPTER 3 : RIVER SITUATION

During the monsoon 2021, the flood was a moderate one which stayed for medium duration across the Brahmaputra and Ganges basins with comparatively greater duration at the confluences and lower parts of Ganges basin. The Meghna and South Eastern Hill basins however faced short duration flooding. The Brahmaputra and Ganges basins experienced flooding throughout second half of August to first half of September. The South Eastern Hill and Meghna basins were only affected by short duration flooding during June-September but with overall greater intensity in July and August respectively. No flooding occurred in the Upper Meghna basin during pre-monsoon period. However, a late monsoon flood affected the Teesta subbasin within Brahmaputra on 20th October with unprecedented intensity. Basin wise water level situation is described in following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 30 Water Level (WL) monitoring stations in this basin, at 16 stations, river WL crossed their respective Danger Levels (DL). Water Level of Brahamaputra Basin started rising from the 1st week of June 2021, for the first time in the monsoon and did not cross its danger level till the 3rd week of August. The river crossed its danger level in the fourth week of August causing a medium flood situation lasted for around 9 to 17 days. During the same period, the Atrai and Dhaleswari river also crossed their respective DL and caused a flood situation around 20 days. At the end of the monsoon period, Teesta River at Dalia on 20th October 2021 unexpectedly reached peaks and crossed the previous recorded highest Water levels. As a result, low-lying areas of Kurigram, Nilphamari, Bogra, Serajgonj, Manikganj, Jamalpur and Tangail districts were mostly flooded for short to medium duration. A comparative statement of WL for current year 2021 and historical events of 2019 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 crossed the DL for two times during the monsoon-2021 at the 4th week of August and flowed above DL for total 14 days. WL at Kurigram attained peak of 27.13 mPWD on 4th September which was 63 cm above the DL (26.50 m).

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 for 11 times during the monsoon, highest peak on 20th October with a WL of 53.3 mPWD, which was 70 cm above its DL (52.40m) and exceeded previous RHWL of 53.15m. At Dalia, it flowed above DL for 13 days throughout the monsoon period. At Kaunia, WL of the river Teesta crossed its DL mark one time during the mosoon-2021, attained the peak of 29.54 mPWD on 21thof October which was 34 cm above the DL(29.2m) at this point.

The Jamuneswari at Badargonj

The WL of Jamuneswari river at Badargonj in monsoon-2021 attained the peak of 31.15 mPWD (DL 32.15m) on 5th October. During the whole monsoon this station flowed below DL.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha during the monsoon-2021 attained peak 21.90 mPWD on 4th September which was 20 cm above DL (21.70m). During the whole monsoon, this station flowed above its DL mark for 4 days.

The Karatoa at Chakrahimpur and Bogra

At Chakrahimpur, the Karatoa reached peak water level 19.98 mPWD on 7th October and flowed below the DL (20.15m) throughout the monsoon. At Bogra point, the Karatoa river did not cross its respective Danger Level with a peak flow of 14.75 mPWD on 3rd July which was 157 cm below the respective DL(16.32mPWD).

The Brahmaputra at Noonkhawa and Chilmari

At Noonkhawa, the WL of the Brahmaputra River attained the peak of 26.50 mPWD on 3rd September, which was same as the respective DL (26.50mPWD) at this point. During the whole monsoon, this station did not cross its DL.

Brahmaputra at Chilmari flowed above its DL(23.70 m) for 10 days in 2021 monsoon. At Chilmari, the Brahmaputra reached peak water level 24.21 mPWD on 2nd September and flowed 51 cm above the DL(23.70m).

The Jamuna at Fulchari, Bahadurabad, Sariakandi, Serajgonj, Kazipur and Aricha

The WL of river Jamuna at Fulchair, Bahadurabad, Sariakandi, Serajgonj & Aricha demonstrated similar trends like Brahmaputra at Noonkhawa and Chilmari. Jamuna reached peak water level 20.13mPWD on 2nd September (63 cm above DL) at Bahadurabad and 20.34 mPWD on 3rd September (52 cm above DL) at Fulchari. Bahadurabad and Fulchari stayed above their respective DL for 10 & 9 days respectively. At Sariakandi, the Jamuna crossed the respective DL (16.70m) in this monsoon like Bahadurabad station. It crossed the DL on 26th August and continued till 6th September for 12 days, with a peak of 17.39 mPWD on 3rd September which was 69 cm above the DL (16.70 m). At Serajgonj, the Jamuna flowed above DL (13.35m) during the monsoon of 2021 for 13 days with a peak of 14.02 mPWD on 3rd September. At Kazipur, the WL of the Jamuna river crossed the Dl(15.24m) with a peak of 15.92 mPWD which is 68 cm above DL and flowed for 14 days during the 2021 monsoon.

At Aricha, the WL of the Jamuna river flowed above the DL (9.40m)during 2021 monsoon for 17 days and the peak WL recorded was 9.80 mPWD on 4th September.

The Atrai at Baghabari

The WL of river Atrai at Baghabari flowed above DL(10.40m) on the month of August-September during 2021 monsoon for 21 days with the peak of 11.11 mPWD on 4th September which is 71 cm above the DL(10.40m) at this point.

The Dhaleswari at Elashin

The WL of river Dhaleswari at Elashin flowed above DL (11.40m) on the month of August-September during 2021 monsoon for 20 days with the peak of 12.19 mPWD on 4th September, which is 79 cm above the DL(11.40m) at this point.

The Old Brahmaputra at Jamalpur and Mymensingh

The WL of the Old Brahmaputra river at Jamalpur and Mymensingh showed rise and fall during the monsoon. At Jamalpur, the water level flowed below the DL(17.00m) with the recorded peak WL of 15.62 mPWD on 5th September all over the monsoon season. At Mymensingh, the WL remained below the DL(12.50m) during the whole monsoon. The peak WL recorded was 9.52 mPWD on 6th September, which was 298 cm below the DL (12.5m) at this point.

The Lakhya Narayanganj

Lakhya River at Narayanganj flowed above DL(5.5 m) during monsoon 2021 for 3 days. It attained its monsoon peak of 5.60 mPWD on 7th September, which was 10 cm above the DL (5.5m).

The Rivers around Dhaka

Stations near or around Dhaka city like Buriganga at Dhaka and the Turag at Mirpur attained the peak of the monsoon during the July in this year. All the river around Dhaka city flowed below their respective DLs. The Buriganga at Dhaka and the Balu at Demra recorded their highest peak of 5.15 mPWD (DL 6.0m) on 8th September, 5.51 m (DL 5.75m) on 7th September respectively. The Turag at Mirpur did not cross its respective DL and flowed with a peak of 5.75 mPWD on 8th September which is 19 cm below the DL (5.94 mPWD). The water level of Tongi Khal at Tongi flowed below DL(6.08m).The peak WL recorded at this station was 5.80 m on 10th September.

The Kaliganga at Taraghat

The Kaliganga river at Taraghat flowed above the DL(8.38mPWD) for 7 days with a peak of 8.72 mPWD on 6th September which is 34 cm above the DL.

Comparative hydrographs for the year of 2021, 2019 &1998 of few stationsof the Brahmaputra basin are shown in Figures 3.1 – 3.16.

Table 3.1 : Comparison of Water Level (in mPWD) of 2021 and Historical Events of 2017&1998 of Some Important Stations in the Brahmaputra Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2021	2019	1998	2021	2019	98
1	Dharla	Kurigram	27.84	26.50	27.13	27.67	27.22	14	15	30
2	Teesta	*Dalia	53.10	52.60	53.30	53.1	52.20	13	11	-
3	Teesta	Kaunia	30.52	29.20	29.54	29.42	29.91	2	3	-
4	Jamuneswari	Badarganj	33.61	32.15	31.15	31.78	33.00	0	0	6

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2021	2019	1998	2021	2019	98
5	Ghagot	Gaibandha	22.81	21.70	21.9	22.64	22.30	4	16	51
6	Karatoa	Chakrahimpur	21.41	20.15	19.98	20.19	20.86	0	3	
7	Karatoa	Bogra	17.45	16.32	14.75	14.97	15.57	0	0	
8	Brahmaputra	Noonkhawa	28.10	26.50	26.50	27.53	27.35	0	10	-
9	Brahmaputra	Chilmari	25.07	23.70	24.21	25.02	24.77	10	17	22
10	Jamuna	Fulchari	21.35	19.82	20.34	21.35	-	9	18	-
11	Jamuna	Bahadurabad	21.16	19.50	20.13	21.16	20.37	10	18	66
12	Jamuna	Sariakandi	19.07	16.70	17.39	17.98	-	12	15	
13	Jamuna	Kazipur	17.47	15.25	15.92	16.51	-	14	14	
14	Jamuna	Serajgonj	15.12	13.35	14.02	14.39	14.76	13	12	48
15	Jamuna	Aricha	10.76	9.40	9.80	9.84	10.76	17	7	68
16	Gur	Singra	13.67	12.65	12.62	12.51	-	0	0	-
17	Atrai	Baghabari	12.45	10.40	11.11	11.23	-	21	15	-
18	Dhaleswari	Elasin	12.52	11.40	12.19	12.36	-	20	17	-
19	Old Br.putra	Jamalpur	18.00	17.00	15.62	17.17	17.47	0	4	31
20	Old Br.putra	Mymensingh	13.71	12.50	9.52	12.31	13.04	0	0	33
21	Lakhya	Lakhpur	8.70	5.80	5.08	5.80	-	0	1	-
22	Buriganga	Dhaka	7.58	6.00	5.15	4.9	7.24	0	0	57
23	Balu	Demra	7.13	5.75	5.51	5.4	-	0	0	-
24	Lakhya	Narayangonj	6.93	5.50	5.60	5.33	6.93	3	0	71
25	Turag	Mirpur	8.35	5.94	5.75	5.27	7.97	0	0	70
26	Tongi Khal	Tongi	7.84	6.08	5.80	5.49	7.54	0	0	66
27	Kaliganga	Taraghat	10.39	8.38	9.20	8.33	-	8	0	-
28	Dhaleswari	Jagir	9.73	8.23	8.30	7.68	-	3	0	-
29	Dhaleswari	Rekabi Bazar	7.66	5.18	4.99	4.67	-	0	0	-
30	Banshi	Nayarhat	8.39	7.32	6.24	5.59	-	0	0	-

*stations exceeding RHWL in 2021

3.2 THE GANGES BASIN

In this basin out of 25 WL monitoring stations, 7 stations flowed above their respective DLs during monsoon 2021. The Padma at Goalundo, Bhagyakul & Sureswar, the Gorai at Kamarkhali, the Ichamati at Sakra, the Kirtonkhola at Barisal and the Pashure river at Khulna station flowed above DL for 2 to 45 days.The details of the river WL situation in this basin are described below:

The Karatoa at Panchagarh

The Karatoa river at Panchgarh showed rise and fall during the monsoon 2021 and flowed below the DL (70.75m) with a peak flow of 68.80 mPWD on 21th August, which was 195 cm below the respective DL (70.75 m)

The Punarbhaba at Dinajpur

The water level of river Punarbhaba at Dinajpur showed rise and fall during the monsoon 2021 and flowed below the DL.The peak WL recorded was 31.10 mPWD on 29th August, which was 240 cm below its DL (33.50m).

The Tangon at Thakurgaon

The Tangon river is flashy in nature and showed various small peaks during the monsoon. It flowed below danger level with highest peak of 48.43 mPWD on 21th October, which was 197 cm below the Danger level (50.40 m).

The Upper Atrai at Bhusirbandar and Atrai at Modevpur

The WL of river Upper Atrai at Bhusirbandar also showed similar trend of Punarbhaba and flowed below the DL. It had a peak value of WL 38.63 mPWD on 30th August. The Atrai at Mohadevpur also flowed below the DL with peak of 16.70 mPWD on 31th August which is 189 cm below the DL(18.59m).

The Mohananda at Chapai-Nawabgonj

This river showed a gradual rise and fall in water level throughout the monsoon. It attained its peak of 20.70 m on 20th August, which was 30 cm below its DL (DL21.00m) at Chapai-Nawabgonj. The Mohananda at Chapai-Nawabgonj flowed below the DL during the whole monsoon 2021.

The Little Jamuna at Naogaon

The Little Jamuna river at Naogaon flowed below its danger level during 2021 monsoon. It attained its peak 14.32 mPWD on 1st September which was 92 cm below the Danger level (15.24 m).

The Ganges/Padma at Pankha, Rajshahi and at Hardinge Bridge

The Ganges River at Pankha showed a gradual rise in August but did not cross the respective DL. At Pankha the peak water level recorded was 22.32 mPWD on 19th August, which was only 18 cm below the DL (22.50m) at this point. At Rajshahi, the Ganges showed nearly similar trend as at Pankha and also flowed below its respective DL. It attained its peak of 17.85 mPWD on 20th August, which was 65 cm below its DL (DL18.50m) at Rajshahi. At Hardinge Bridge, water level flowed below the respective Danger Level and it attained its peak of 14.20 mPWD on 21th August which was 5 cm below its DL (14.25m) at this point.

The Ganges/ Padma at Goalundo

At Goalondo River,WL flowed above the DL during 2021 monsoon for 25 days. The WL of the river Padma at Goalondo attained its yearly peak of 9.43mPWD on the 5th September which was 78 cm above its DL (8.65 m) at this point.

The Padma at Bhagyakul

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma flowed above the DL for 10 days. The WL of the river attained its highest yearly peak water

level of 6.58 mPWD on 6th September which was 28 cm 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-August period during the monsoon in 2018. The WL of river Gorai did not cross the DL at Gorai Railway Bridge. The WL of the river attained its highest yearly peak of 12.52 mPWD on 22nd August, which was 23 cm below the DL (12.75m) at Gorai Rail Bridge. Gorai river at Kamarkhali flowed above the DL for 12 days. The WL of the river attained its highest yearly peak of 8.42 mPWD on 21st August, which was 22 cm above the DL (8.20m) at Kamarkhali station.

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 below the DL throughout the monsoon. The WL attained its highest peak of 4.05 m on 7th September, which was 12 cm below the DL (4.17m) at Madaripur.

Kobodak at Jhikorgacha

Water Level at Jikorgaha flowed below the DL during the whole monsoon with a yearly peak of 4.01 mPWD on 6th August which was 109 cm below the DL (5.10m) at this point.

Comparative hydrographs for few important stations for the year of 2021, 2019 &1998 of the Ganges basin are shown in figures 3.17 to 3.23.

Table 3.2 :Comparison of Water Level (in mPWD) of 2021 and Historical Events of 2019 &1998 of Some Important Stations in Ganges Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2021	2019	1998	2021	2019	98
1	Karatoa	Panchgarh	72.65	70.75	68.80	69.99	-	0	0	-
2	Punarbhaba	Dinajpur	34.40	33.50	31.10	32.58	34.09	0	0	3
3	Ich-Jamuna	Phulbari	30.47	29.95	28.48	28.7	-	0	0	-
4	Tangon	Thakurgaon	51.30	50.40	48.43	49.67	-	0	0	-
5	Upper Atrai	Bhusirbandar	41.10	39.62	38.63	39.45	-	0	0	-
6	Mohananda	Rohanpur	23.83	22.00	21.00	21.47	-	0	0	-
7	Mohananda	Chapai-Nawabganj	23.01	21.00	20.70	20.88	-	0	0	-
8	Little Jamuna	Naogaon	16.20	15.24	14.32	15.06	-	0	0	-
9	Atrai	Mohadebpur	19.89	18.59	16.70	18.57	-	0	0	-
10	Ganges	Pankha	24.14	22.50	22.32	22.23	24.14	0	0	66
11	Ganges	Rajshahi	20.00	18.50	17.85	18.19	19.68	0	0	28

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2021	2019	1998	2021	2019	98
12	Ganges	Hardinge Bridge	15.19	14.25	14.20	14.33	15.19	0	5	27
13	Padma	Goalundo	10.21	8.65	9.43	9.33	10.21	25	17	68
14	Padma	Bhagyakul	7.50	6.30	6.58	6.7	7.50	11	7	72
15	Padma	Sureswar	7.50	4.45	5.25	4.56	-	36	11	-
16	Gorai	Gorai Rail Bridge	13.65	12.75	12.52	12.47	13.45	0	0	25
17	Gorai	Kamarkhali	9.48	8.20	8.42	8.47	NA	12	0	NA
18	Ichamati	Sakra	4.60	3.96	4.33	3.47	-	2	0	-
19	Mathabhanga	Chuadanga	12.67	12.05	9.76	8.88	-	0	0	-
20	Mathabhanga	Hatboalia	15.13	14.50	11.71	11.12	-	0	0	-
21	Kobodak	Jhikorgacha	5.59	5.10	4.01	2.39	NA	0	0	NA
22	Kumar	Faridpur	8.76	7.50	5.04	4.95	-	0	0	-
23	Arialkhan	Madaripur	5.80	4.17	4.05	3.55	NA	0	0	NA
24	Kirtonkhola	Barisal	3.20	2.55	2.70	2.5	-	9	0	-
25	Pashure	Khulna	3.48	3.04	3.36	3.47	-	45	28	-

3.3 THE MEGHNA BASIN

Most of the rivers of this basin entered from the hilly catchment of India (Barak basin, Tripua and Meghalaya) and are flashy in nature. Out of 26 WL monitoring stations in the Meghna basin, 8 stations flowed above their respective DL. Surma River at 2 stations (Kanaighat for 3 days & Sunamganj for 1 day), Sarigowain river at Sarighat for 2 days, Khowai river at Ballah for 1 day, Bhugai river at Nakuagaon for 1 day, Jadukata river at Lorergarh for 2 days, Someswari river at Durgapur for 1day & Kangsha river at Jariajanjail for 1 day flowed above their respective DL.

During 15 March to 15 May 2021, all Water Level (WL) stations of the Meghna basin under FFWC system flowed below their respective Monsoon Danger Levels (DL).

Most of the rivers in this basin are flashy in nature. Out of 36 WL monitoring stations, all stations flowed below their respective Pre-Monsoon Danger Levels (PMDL) upto 15 May. Table 3.3 presents comparative statistics of river situation for some selected stations on major rivers of Meghna basin during 2021 pre-monsoon with that of years 2010 and 2017 (historical pre-monsoon flash flood years).

Table 3.3: Comparative WL of Selected Stations in the Meghna Basin for 15 Mar-15 May, 2021

Sl.No.	River	Station	Monsoon Danger Level (m PWD)	Pre-Monsoon Danger Level (m PWD)	Peak of the Duration (m PWD)			Days above Monsoon Danger Level			Days above Pre-Monsoon Danger Level
					2010	2017	2021	2010	2017	2021	2021
1	Surma	Kanaighat	13.20	11.35	14.35	14.49	10.31	13	06	0	0
2	Surma	Sylhet	11.25	8.75	10.88	11.31	7.56	0	03	0	0
3	Surma	Sunamganj	8.25	6.5	8.05	8.10	5.22	0	0	0	0
4	Kushiyara	Amalshid	15.85	13.50	15.51	16.03	12.23	0	03	0	0
5	Kushiyara	Sheola	13.50	11.15	13.94	13.89	9.57	03	06	0	0
6	Kushiyara	Sherpur	9.0	8.25	8.8	9.03	5.64	0	01	0	0
7	Kushiyara	Markuli	8.50	6.40	7.7	8.27	4.67	0	0	0	0
8	Sarigowain	Sarighat	12.80	11.15	13.38	13.35	9.04	03	03	0	0
9	Manu	Manu Rly Br	18.00	16.90	16.75	17.40	13.25	0	0	0	0
10	Manu	Moulvi Bazar	11.75	10.00	10.49	11.73	6.46	0	0	0	0
11	Khowai	Habiganj	9.50	9.10	7.95	10.60	4.91	0	05	0	0
12	Khowai	Ballah	21.80	21.80	-	22.96	20.60	0	08	0	0
13	Someswari	Durgapur	13.00	11.25	11.78	12.02	11.25	0	0	0	0
14	Kangsha	Jariajanjail	11.00	6.80	6.53	9.71	6.56	0	0	0	0
15	Upper Meghna	Bhairab Bazar	6.25	6.25	3.48	3.57	3.06	0	0	0	0
16	Gumti	Comilla	11.75	11.75	7.37	9.35	5.33	0	0	0	0

The river situations with respect to Monsoon Danger Levels (DL) are described as follows.

The Surma at Kanaighat

Water Level in the Surma river started to rise from the 2nd week of May and it showed rapid rise and fall in several times. FFWC monitors 3 stations on the Surma River.

First it flowed above its DL at Kanaighat from 7th August for 1 day, then 14th to 15th August for 2 days. The Surma at Kanaighat was above DL for 3 days in total during the whole monsoon. It attained its highest peak of 13.49 mPWD on 7th August which was 29 cm above the DL (13.20 m).

Surma at Sylhet

The WL of river Surma at Sylhet showed similar trend like Kanaighat. The Surma at Sylhet flowed below its DL (11.25m). It attained the monsoon peak WL of 10.92 mPWD on 15th August

The Surma at Sunamgonj

The Surma at Sumangnaj showed rapid rise and fall in the same period of the monsoon. The WL of the river Surma at Sunamgonj flowed above its DL (8.25m) for 1 day during

the whole monsoon. The WL of Surma at Sunamgonj recorded its highest peak of 8.41 mPWD on 14th August which was 16 cm above its DL (8.25m).

The Kushiyara at Amalshid, Sheola and Sherpur

The Kushiyara river at Amalshid, Sheola and Sherpur (Sylhet district) observed similar rise and fall trend throughout the monsoon 2021. At Amalshid water level of Kushiyara flowed below the DL during the whole monsoon. At Amalshid, Kushiyara attained the peak flow of 14.92 mPWD on 29th August which was 93 cm below the DL (15.85 mPWD).

At Sheola, it also flowed below the DL during the whole monsoon. It attained its highest peak of 12.49 mPWD on 29th August which was 101 cm below the DL(13.50mPWD).

At Sherpur the river flowed similar trend like Sheola. It flowed below its DL during the whole monsoon. It attained its highest peak of 8.85 mPWD on 2nd September which was 15 cm below its DL (9.00 m)

The Sarigowain at Sarighat

As the flashy river the Sarighat on Saigowain River in Sylhet district showed several peaks during the monsoon 2021 & crossed the respective DL for 2 days. It attained monsoon highest peak of 13.06 mPWD on 29th June which was 26 cm above its DL (12.80 m).

The Manu at Manu Railway Bridge & Moulvibazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvibazar observed several sharp peaks during the monsoon-2021. The WL of Manu river at Manu Railway Bridge and at Moulvibazar flowed below the DL during monsoon 2021. The WL at Manu Railway Bridge had a peak flow of 17.06 mPWD on 1st September which was 94 cm below the DL(18.0 m).

At Moulvibazar the WL of Manu attained its highest peak of 10.76 mPWD on 30th August which was 99 cm below its DL(11.75m) at this point.

The Khowai at Habigonj and Ballah

The Khowai at Habigonj as well as Ballah showed several peaks during the monsoon 2021. The Khowai at Habiganj did not cross the DL throughout the monsoon. The WL recorded as its yearly highest peak was 9.01 mPWD on 1st July which was 49 cm below its DL (9.50 m).

The Khowai at Ballah crossed the DL on 1st July for 1 day during the monsoon. The highest peak was 22.62 mPWD which attained on 1th July which was 101 cm above the DL(21.64 m).

The Bhugai at Nakuagaon

As flashy river the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks in June and July. It flowed above its DL for 1 days during monsoon 2021 .It

attained monsoon highest peak of 23.09 mPWD on 30th June which was 69 cm above its DL (22.40m) at this point.

The Jadukata at Lorergarh

Like other flashy rivers in the North-east region, the Jadukata showed several peaks during the monsoon 2021. It flowed above its DL for 2 days during the whole monsoon. It attained monsoon highest peak of 9.07 mPWD on 29th Jun which was 54 cm above its DL (8.53 m).

The Someswari at Durgapur

As the flashy river the Durgapur in Netrokona district, showed rise and fall during the monsoon 2021 and flowed above its DL(13.0 m) for only 1 day. It attained monsoon highest peak of 13.11 mPWD on 30th June.

The Kangsha at Jariajanjail

As flashy river the Kangsha at Jariajanjail in Netrokona district showed rise and fall during the monsoon-2021 and flowed above the DL (11.00 mPWD) for 1 days in the month of July. It attained its yearly highest peak of 11.03 mPWD on 1st July.

Comparative hydrographs for few stations the year of 2021, 2019 &1998 of rivers of the Meghna basinare shown in figures 3.24 to 3.37.

Table 3.4 : Comparison of Water Level (in mPWD) of 2021 and Historical Events of 2019 & 1998 of Some Important Stations in Meghna Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2021	2019	1998	2021	2019	1998
1	Surma	Kanaighat	15.26	13.20	13.49	13.84	15.00	3	6	73
2	Surma	Sylhet	12.44	11.25	10.92	10.84	11.72	0	0	14
3	Surma	Sunamgonj	9.75	8.25	8.41	8.18	8.90	1	0	56
4	Kushiyara	Amalshid	18.28	15.85	14.92	16.56	17.60	0	5	54
5	Kushiyara	Sheola	14.60	13.50	12.49	13.50	14.14	0	1	37
6	Kushiyara	Sherpur	9.68	9.00	8.85	8.59	NA	0	0	NA
7	Kushiyara	Markuli	8.51	8.50	7.44	7.09	-	0	0	-
8	Sarigowain	Sarighat	14.48	12.80	13.06	12.30	-	2	0	-
9	Manu	Manu RB	20.42	18.00	17.06	17.73	18.63	0	0	6
10	Manu	Moulvi Bazar	13.25	11.75	10.76	11.72	11.68	0	0	0
11	Khowai	Ballah	26.12	21.80	22.62	23.30	-	1	8	-
12	Khowai	Habiganj	12.30	9.50	9.01	9.7	11.44	0	1	8

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2021	2019	1998	2021	2019	1998
13	Dhalai	Kamalganj	21.18	19.82	18.80	20.27	-	0	1	-
14	Old Surma	Derai	7.75	7.00	6.54	6.6	-	0	0	-
15	Baulai	Khaliajuri	9.52	8.50	6.31	6.43	-	0	0	-
16	Bhugai	Nakuagaon	26.01	22.40	23.09	22.33	-	1	0	-
17	Jadukata	Lorergarh	11.85	8.53	9.07	8.78	-	2	3	-
18	Someswari	Durgapur	15.20	13.00	13.11	13.17	-	1	1	-
19	Kangsha	Jariajanjail	13.37	11.00	11.03	10.41	NA	1	0	NA
20	Titas	B.Baria	6.50	5.50	4.82	4.72	-	0	0	-
21	Upper Meghna	Bhairab Bazar	7.78	6.25	4.91	4.63	7.33	0	0	68
22	Meghna	Narsingdi	7.01	5.70	4.75	4.11	-	0	0	-
23	Meghna	Meghna Bridge	6.76	5.03	4.38	3.77	-	0	0	-
24	Gumti	Comilla	13.56	11.75	9.94	9.69	12.79	0	0	17
25	Gumti	Debiddar	9.98	8.50	6.36	6.50	-	0	0	-
26	Meghna	Chandpur	5.35	4.00	4.45	3.68	-	0	0	-

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 and most of the rivers show similar behavior during monsoon flood. The WL of the monitoring rivers crossed their respective DLs several times throughout the monsoon-2021. Due to flashy nature, multiple short duration floods occurred at some places of Chittagong, Feni, Bandarban, Cox's Bazar during the monsoon 2021. 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-2021 and historical events of 2019 and 1998 for this basin are shown in the Table 3.4.

The Muhuri at Parshuram

The Muhuri in Feni, Noakhali district is a flashy river and showed rapid rise-fall during the monsoon 2021. It flowed above the DL for 9 days in total during the whole monsoon. It attained its highest peak 14.34 mPWD on 4th September which was 134 cm above its DL (13.00 m).

The Halda at Narayanhat

As it is a flashy river, the WL of the river Halda at Narayanhat under Hathazari upzilla also showed several rise-fall during the monsoon 2021 but did not cross its DL. It attained its

highest peak 13.85 mPWD on 29th June which was 140 cm below the DL(15.25 m) at Narayanhat.

The Halda at Panchpukuria

The Halda at Panchpukuria flowed below its respective DL during the whole monsoon. It attained its highest peak of 6.13 mPWD on 23th August which was 337 cm below its DL (9.50 m).

The Sangu at Bandarban and Dohazari

The Sangu is also a flashy river which showed several peaks during flood period. The river crossed the DL at Bandarban for one day in this monsoon-2021. It crossed the DL on 27th July. The peak recorded was 15.26 mPWD which was 1 cm above its DL (15.25m). At Dohazari, the Sangu flowed below the DL throughout the season. At Dohazari the highest peak was recorded 6.65 mPWD on 27th July which was 35 cm below its danger mark (7.00 m) at this point.

The Matamuhuri at Lama and Chiringa

The river observed several peaks in the monsoon-2021 like Sangu River. At Lama, the Matamuhuri River crossed the DL only one times on 25th July to 27th July. It was above DL for 3 days in total during the whole monsoon. At Lama the peak recorded was 13.87 mPWD on 26thJuly which was 162 cm above its DL (12.25m). The Matamuhuri at Chiringa crossed the DL 1 time during the monsoon.At Chiringa station the Matamuhuri River was above DL from 26th July to 27th July. It was above DL for 2 days in total during the whole monsoon. At Chiringa the peak recorded was 6.66 mPWD on 27th July which was 41 cm above its DL (6.25m).

The Feni at Ramgarh

The WL of river Feni at this point observed several peaks and flowed below its DL during the monsoon-2021. The highest peak WL attained by the river was 16.31 mPWD on 23th August which was 104 cm below its DL (17.35m) at this point.

Table 3.5 : Comparison of Water Level of 2021(in mPWD)and Historical Events of 2019 and 1998 of Some Important Station in South Eastern Hill Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2021	2019	98	2021	2019	98
1	Muhuri	Parshuram	16.33	13.00	14.34	14.7	14.60	7	2	9
2	Halda	Narayanhat	19.30	15.25	13.85	15.6	16.57	0	3	21
3	Halda	Panchpukuria	12.54	9.50	6.13	9.96	10.44	0	2	4
4	Sangu	Bandarban	20.70	15.25	15.26	18.5	15.25	1	5	1
5	Sangu	Dohazari	9.05	7.00	6.65	8.6	7.42	0	7	2
6	Matamuhuri	Lama	15.46	12.25	13.87	13.84	13.05	3	3	2
7	Matamuhuri	Chiringa	7.32	6.25	6.66	7.17	6.85	2	5	5
8	Feni	Ramgarh	21.42	17.35	16.31	16.6	17.50	0	0	1
9	Karnaphuli	Chittagong	4.98	4.60	3.60	4.85	-	0	1	-

3.5 PEAK AND RECORDED HIGHEST WATER LEVELS

The peak water level with dates of all the water level monitoring stations under FFWC during the monsoon 2021 as well as date of attaining recorded highestlevels of some stations are shown in the following tables. Teesta river at Dalia point crossed RHWL in 2021.

Table 3.6 : Recorded Peak Water Level (in mPWD) with Dates during the Monsoon-2021

SL No	River name	Station	Peak WL-2021	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	27.13	04/09/21
2	TEESTA	DALIA	53.30	20/10/21
3	TEESTA	KAUNIA	29.54	21/10/21
4	JAMUNESWARI	BADARGANJ	31.15	05/10/21
5	GHAGOT	GAIBANDHA	21.90	03/09/21
6	KARATOA	CHAK RAHIMPUR	19.98	07/10/21
7	KARATOA	BOGRA	14.75	03/07/21
8	BRAHMAPUTRA	NOONKHAWA	26.50	03/09/21
9	BRAHMAPUTRA	CHILMARI	24.21	02/09/21
10	JAMUNA	FULCHARI	20.34	03/09/21
11	JAMUNA	BAHADURABAD	20.13	02/09/21
12	JAMUNA	SARIAKANDI	17.39	03/09/21
13	JAMUNA	KAZIPUR	15.92	03/09/21
14	JAMUNA	SERAJGANJ	14.02	03/09/21
15	JAMUNA	ARICHA	9.80	04/09/21
16	GUR	SINGRA	12.62	04/09/21
17	ATRAI	BAGHABARI	11.11	04/09/21
18	DHALESWARI	ELASIN	12.19	04/09/21
19	OLD BRAHMAPUTRA	JAMALPUR	15.62	05/09/21
20	OLD BRAHMAPUTRA	MYMENSINGH	9.52	06/09/21
21	LAKHYA	LAKHPUR	5.08	09/09/21
22	BURIGANGA	DHAKA	5.15	08/09/21
23	BALU	DEMRA	5.51	07/09/21
24	LAKHYA	NARAYANGONJ	5.60	07/09/21
25	TURAG	MIRPUR	5.75	08/09/21
26	TONGI KHAL	TONGI	5.80	10/09/21
27	KALIGANGA	TARAGHAT	8.72	06/09/21
28	DHALESWARI	JAGIR	8.30	08/09/21
29	DHALESWARI	REKABI BAZAR	4.99	07/09/21
30	BANSHI	NAYARHAT	6.24	09/09/21
GANGES BASIN				
31	KARATOA	PANCHAGARH	68.80	21/08/21
32	PUNARBHABA	DINAJPUR	31.10	29/08/21
33	ICH-JAMUNA	PHULBARI	28.48	06/10/21
34	TANGON	THAKURGAON	48.43	21/10/21
35	UPPER ATRAI	BHUSIRBANDAR	38.63	30/08/21
36	MOHANANDA	ROHANPUR	21.00	21/08/21
37	MOHANANDA	CHAPAI-NAWABGANJ	20.70	20/08/21
38	LITTLE JAMUNA	NAOGAON	14.32	01/09/21
39	ATRAI	MOHADEBPUR	16.70	31/08/21
40	GANGES	PANKHA	22.32	19/08/21
41	GANGES	RAJSHAHI	17.85	20/08/21
42	GANGES	HARDINGE BRIDGE	14.20	21/08/21

SL No	River name	Station	Peak WL-2021	Date
43	PADMA	GOALONDO	9.43	05/09/21
44	PADMA	BHAGYAKUL	6.58	06/09/21
45	PADMA	SURESWAR	5.25	06/09/21
46	GORAI	GORAI RAIL BRIDGE	12.52	22/08/21
47	GORAI	KAMARKHALI	8.42	21/08/21
48	ICHAMATI	SAKRA	4.33	19/06/21
49	MATHABHANGA	CHUADANGA	9.76	27/08/21
50	MATHABHANGA	HATBOALIA	20.20	09/11/21
51	KOBADAK	JHIKARGACHA	4.01	06/08/21
52	KUMAR	FARIDPUR	5.04	28/08/21
53	ARIALKHAN	MADARIPUR	4.05	07/09/21
54	KIRTONKHOLA	BARISAL	2.70	08/09/21
55	PASHURE	KHULNA	3.36	26/08/21
MEGHNA BASIN				
56	SURMA	KANAIGHAT	13.49	07/08/21
57	SURMA	SYLHET	10.92	15/08/21
58	SURMA	SUNAMGONJ	8.41	14/08/21
59	KUSHIYARA	AMALSHID	14.92	29/08/21
60	KUSHIYARA	SHEOLA	12.49	29/08/21
61	KUSHIYARA	SHERPUR	8.85	02/09/21
62	KUSHIYARA	MARKULI	7.44	30/08/21
63	SARIGOWAIN	SARIGHAT	13.06	29/06/21
64	MANU	MANU RAILY BRIDGE	17.06	01/09/21
65	MANU	MOULVI BAZAR	10.76	30/08/21
66	KHOWAI	BALLAH	22.62	01/07/21
67	KHOWAI	HABIGANJ	9.01	01/07/21
68	DHALAI	KAMALGONJ	18.80	01/09/21
69	OLD SURMA	DERAI	6.54	08/07/21
70	BAULAI	KHALIAJURI	6.31	27/08/21
71	BHUGAI	NAKUAGAON	23.09	30/06/21
72	JADUKATA	LORERGARH	9.07	29/06/21
73	SOMESWARI	DURGAPUR	13.11	30/06/21
74	KANGSHA	JARIAJANJAIL	11.03	01/07/21
75	TITAS	B. BARIA	4.82	28/08/21
76	MEGHNA	BHAIRAB BAZAR	4.91	07/09/21
77	MEGHNA	NARSINGDI	4.75	07/09/21
78	MEGHNA	MEGHNA BRIDGE	4.38	11/09/21
79	GUMTI	COMILLA	9.94	01/07/21
80	GUMTI	DEBIDDAR	6.36	02/07/21
81	MEGHNA	CHANDPUR	4.45	07/09/21
	SOUTH EASTERN HILL BASIN			
82	MUHURI	PARSHURAM	14.34	06/09/21
83	HALDA	NARAYAN HAT	13.85	01/07/21
84	HALDA	PANCHPUKURIA	6.13	25/08/21
85	SANGU	BANDARBAN	15.26	29/07/21
86	SANGU	DOHAZARI	6.65	29/07/21
87	MATAMUHURI	LAMA	13.87	29/07/21
88	MATAMUHURI	CHIRINGA	6.66	29/07/21
89	FENI	RAMGARH	16.31	25/08/21
90	KARNAPHULI	CHITTAGONG	3.60	27/05/21

Table 3.7 : Recorded Historical Highest Water Levels(in mPWD)with Dates

Sl. No.	River	Station	Danger Level	Recorded highest WL before 2021 flood (date)	WL (Date) Exceeding previous Highest WL
1	Dharla	Kurigram	26.50	27.84 (14.07.96)	-
2	Teesta	Dalia	52.40	53.15 (13.07.2020)	**53.30 (20.10.2021)**
3	Teesta	Kaunia	30.00	30.52 (06.01.68)	-
4	Jamuneswari	Badarganj	32.16	33.61 (15.08.17)	-
5	Brahmaputra	Noonkhawa	27.25	28.10	-
6	Brahmaputra	Chilmari	24.00	25.07 (23.08.62)	-
7	Jamuna	Bahadurabad	19.50	21.16(18.07.2019)	-
8	Jamuna	Fulchori	19.82	21.35(18.07.2019)	-
9	Jamuna	Serajgonj	13.35	15.12 (30.08.88)	-
10	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
11	Dhaleswari	Elasin	11.40	12.80 (31.07.16)	-
12	Old Brhamaputra	Jamalpur	17.00	18.00 (31.07.54)	-
13	Old Brhamaputra	Mymensingh	12.50	13.71(01.09.88)	-
14	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
15	Lakhya	Narayangonj	5.50	6.93 (10.09.98)	-
16	Turag	Mirpur	5.94	8.35 (10.09.88)	-
17	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-
18	Kaliganga	Taraghat	8.38	10.37(02.09.88)	-
19	Punarbhaba	Dinajpur	33.50	34.40	-
20	Tangon	Thakurgaon	50.40	51.30 (12.08.17)	-
21	Gur	Singra	12.65	13.76 (01.10.2020)	-
22	Padma	Pankha	21.50	24.14 (07.09.97)	-
23	Padma	Rajshahi	18.50	20.00(13.09.1910)	-
24	Padma	H. Bridge	14.25	15.19 (10.09.98)	-
25	Padma	Goalundo	8.50	10.21 (03.08.08)	-
26	Padma	Bhagyakul	6.00	7.58	-
27	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
28	Surma	Kanaighat	13.20	15.58 (26.06.12)	-
29	Surma	Sylhet	11.25	12.44 (19.07.04)	-
30	Surma	Sunamgonj	8.25	9.75 (20.07.04)	-
31	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
32	Kushiyara	Sheola	13.50	14.60 (09.09.08)	-
33	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
34	Manu	Moulvi Bazar	11.75	13.25 (08.06.93)	-
35	Khowai	Habiganj	9.50	12.00 (18.06.07)	-
36	Someswari	Durgapur	13.00	15.58 (28.07.07)	-
37	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
38	Gumti	Comilla	11.75	13.56 (23.07.93)	-
39	Muhuri	Parshuram	13.00	16.33 (13.09.04)	-
40	Halda	Narayanhat	15.25	19.30 (13.08.99)	-
41	Halda	Panchpukuria	7.00	12.54(27.06.03)	-
42	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
43	Sangu	Dohazari	5.75	9.05	-
44	Matamuhuri	Lama	12.25	15.46 (12.08.99)	-
45	Matamuhuri	Chiringa	5.75	7.32 (04.07.17)	-
46	Feni	Ramgarh	17.37	21.42 (11.07.68)	-
47	Atrai	Atrai	13.72	14.40 (16.07.2020)	

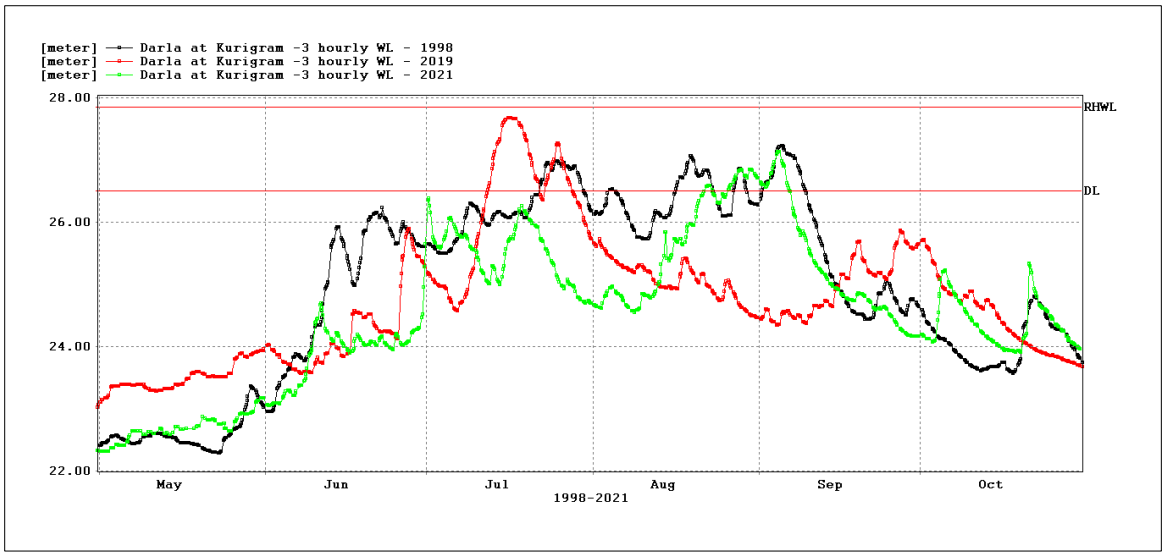


Figure 3.1: Comparison of Hydrograph on Dharla at Kurigram

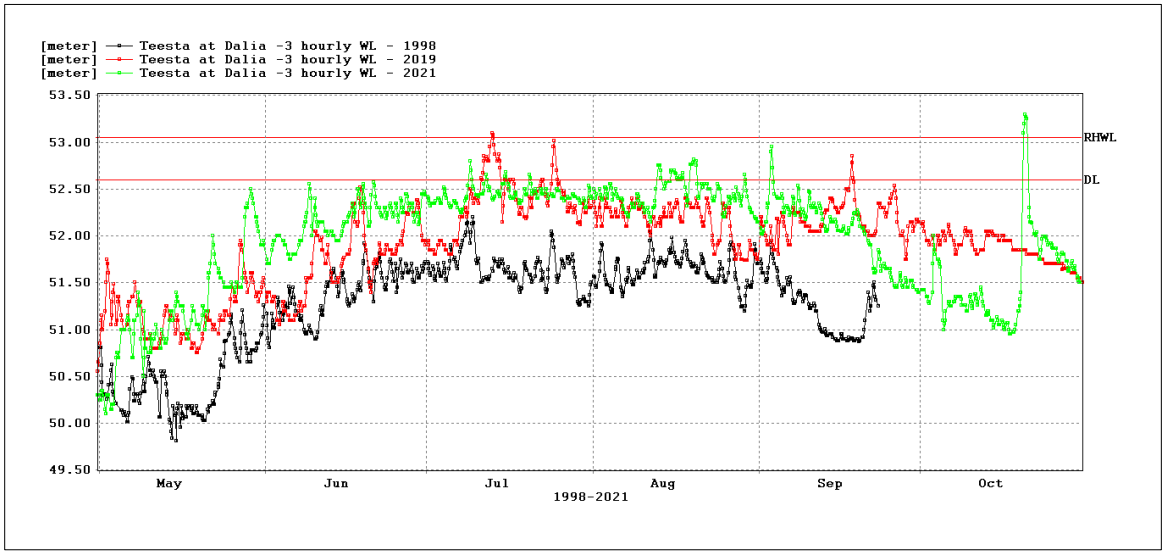


Figure 3.2: Comparison of Hydrograph on Teesta at Dalia

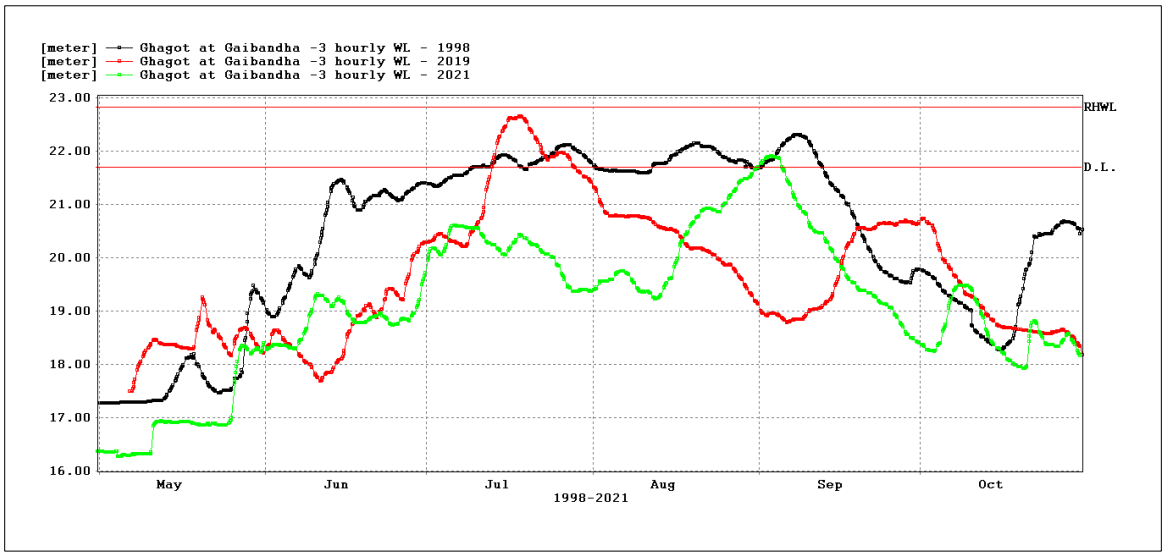


Figure 3.3: Comparison of Hydrograph on Ghagot at Gaibandha

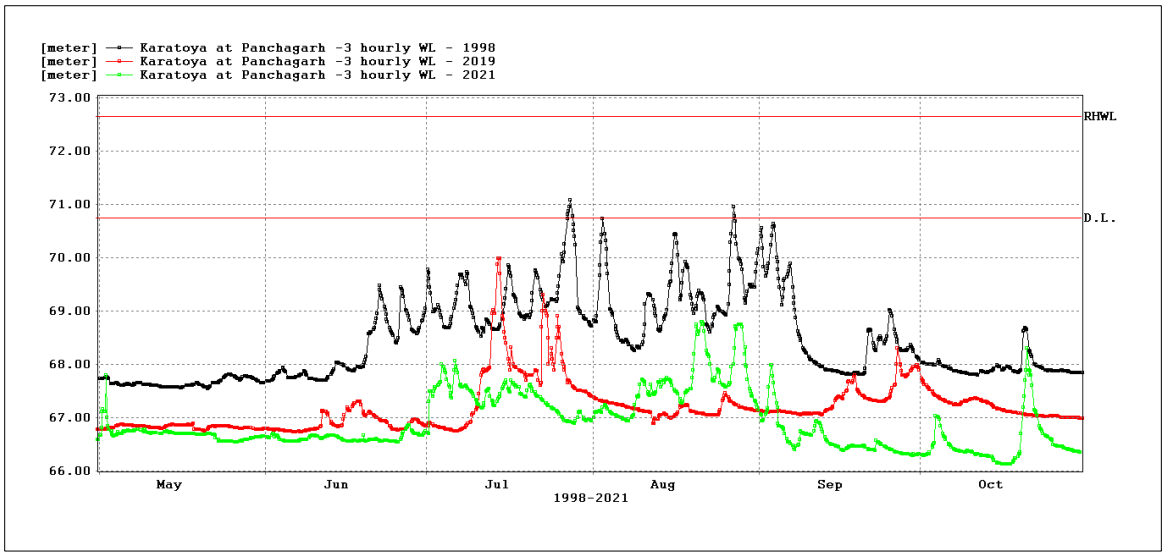


Figure 3.4: Comparison of Hydrograph on Upper Karatoa at Panchagarh

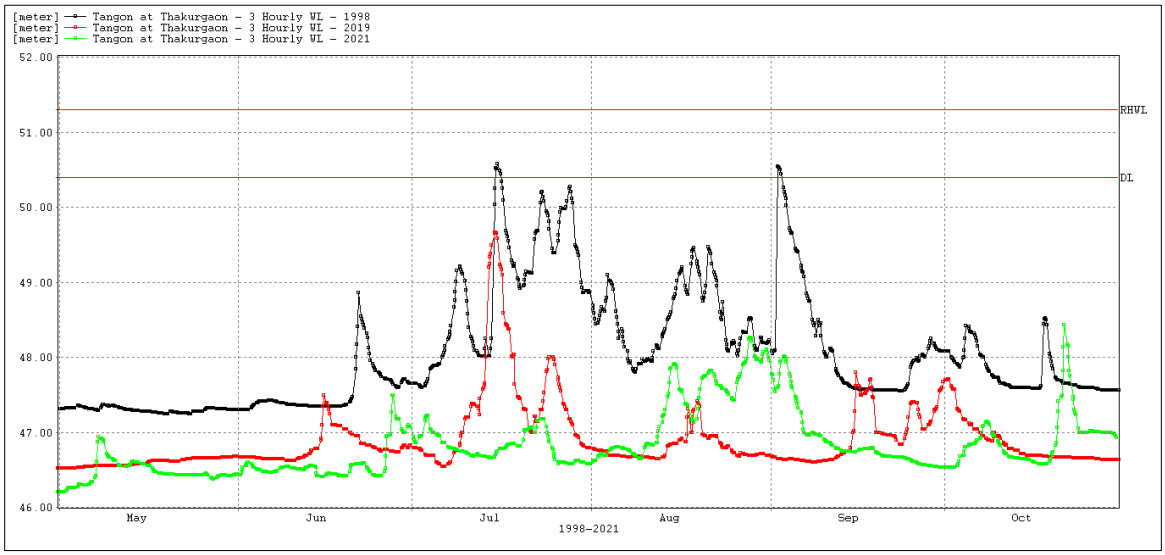


Figure 3.5: Comparison of Hydrograph on Tangon at Thakurgaon

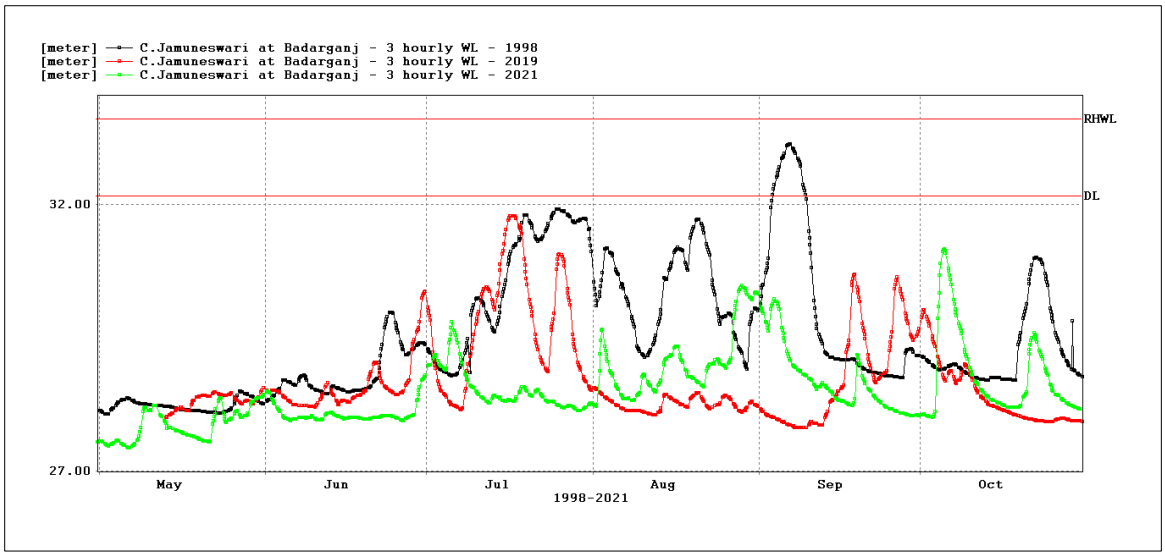


Figure 3.6: Comparison of Hydrograph on C. Jamuneswari at Badarganj

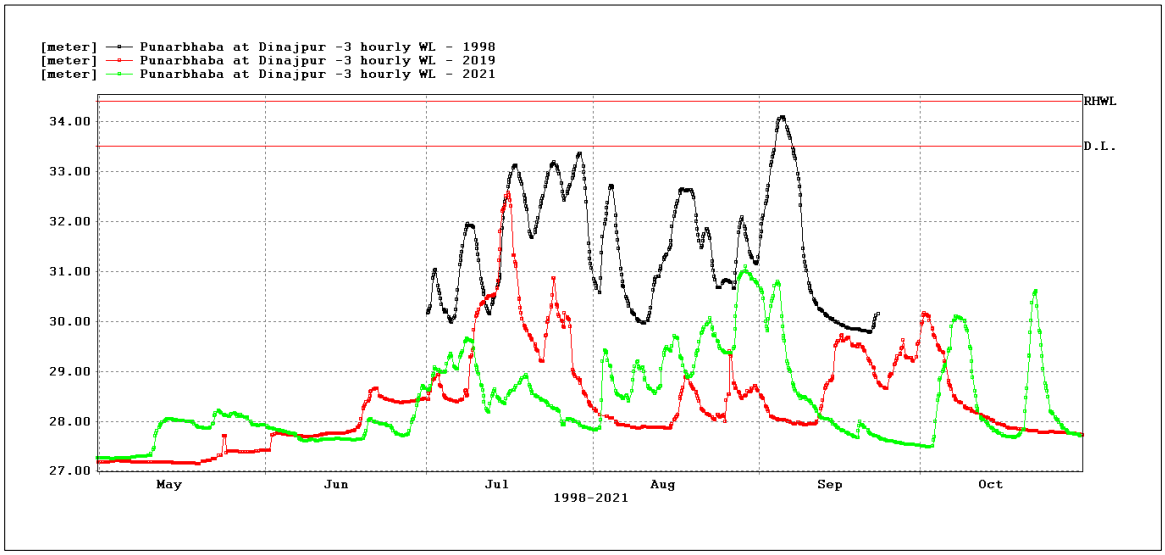


Figure 3.7: Comparison of Hydrograph on Punarbhaba at Dinajpur

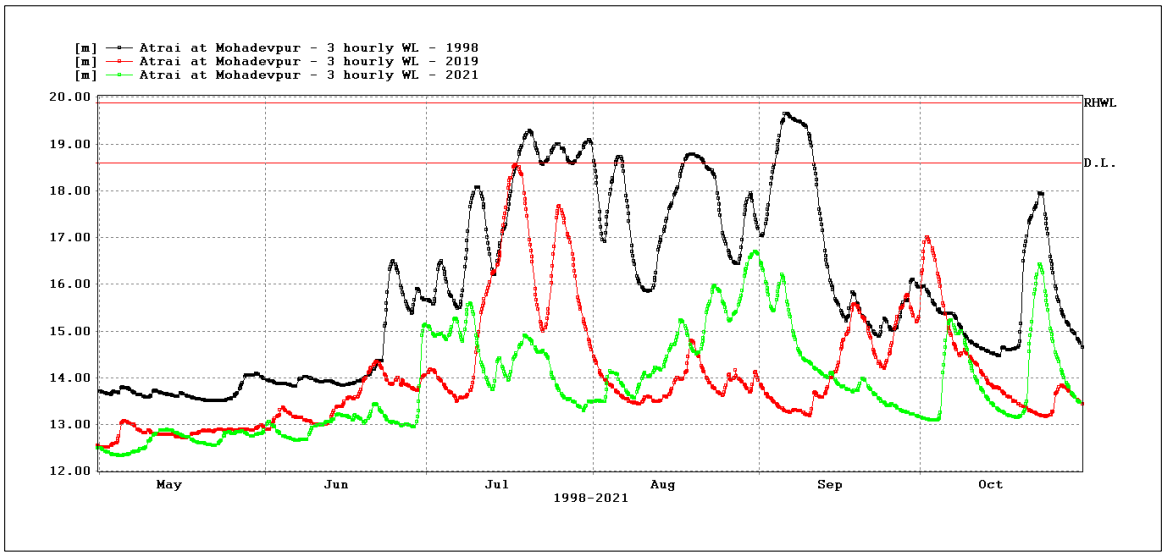


Figure 3.8: Comparison of Hydrograph on Atrai at Mohadevpur

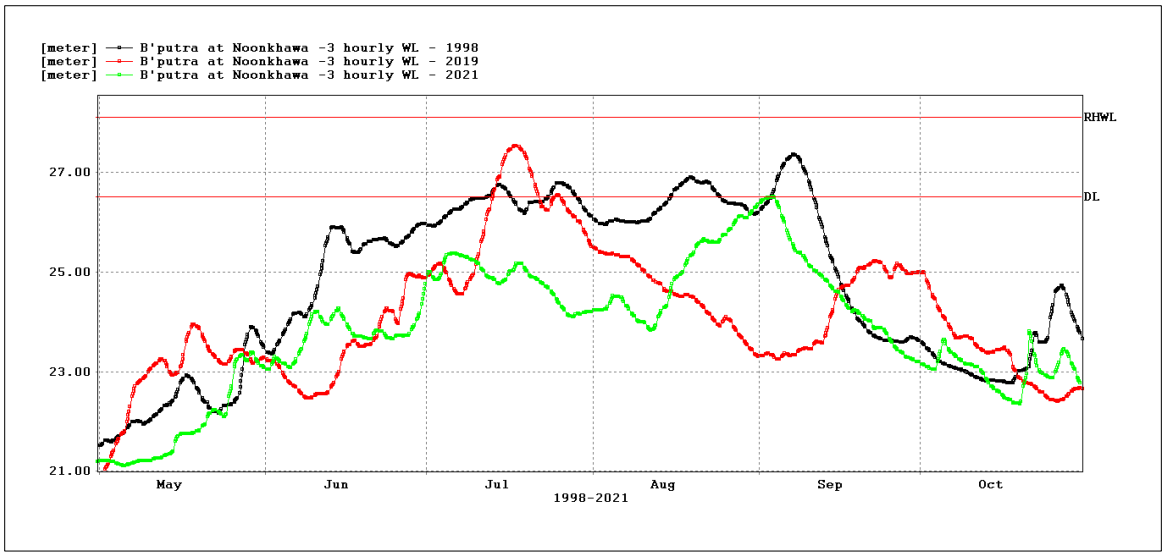


Figure 3.9: Comparison of Hydrograph on Brahmaputra at Noonkhawa

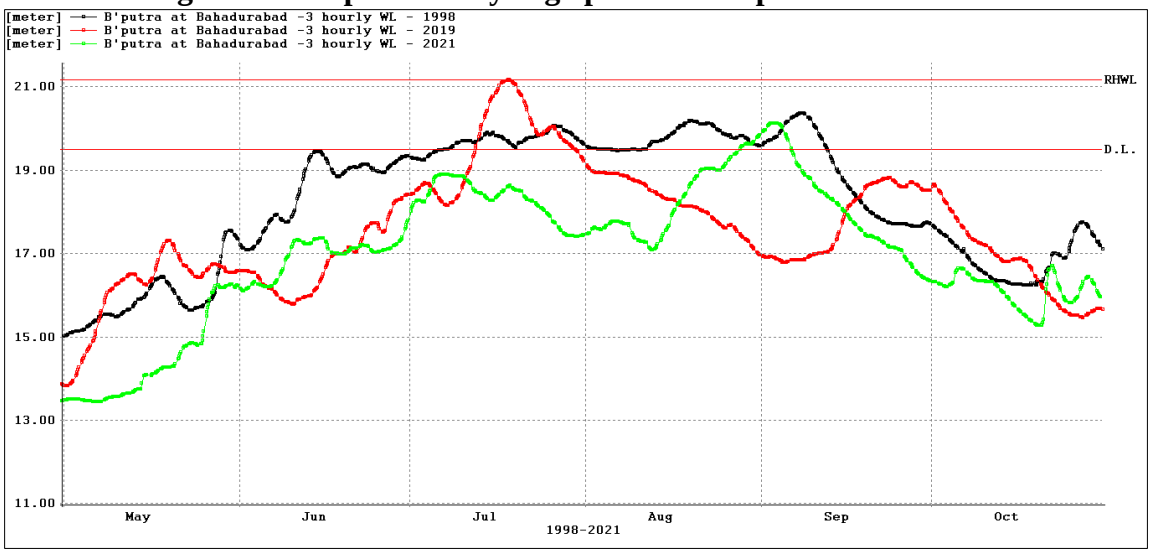


Figure 3.10: Comparison of Hydrograph on Brahmaputra at Bahadurabad

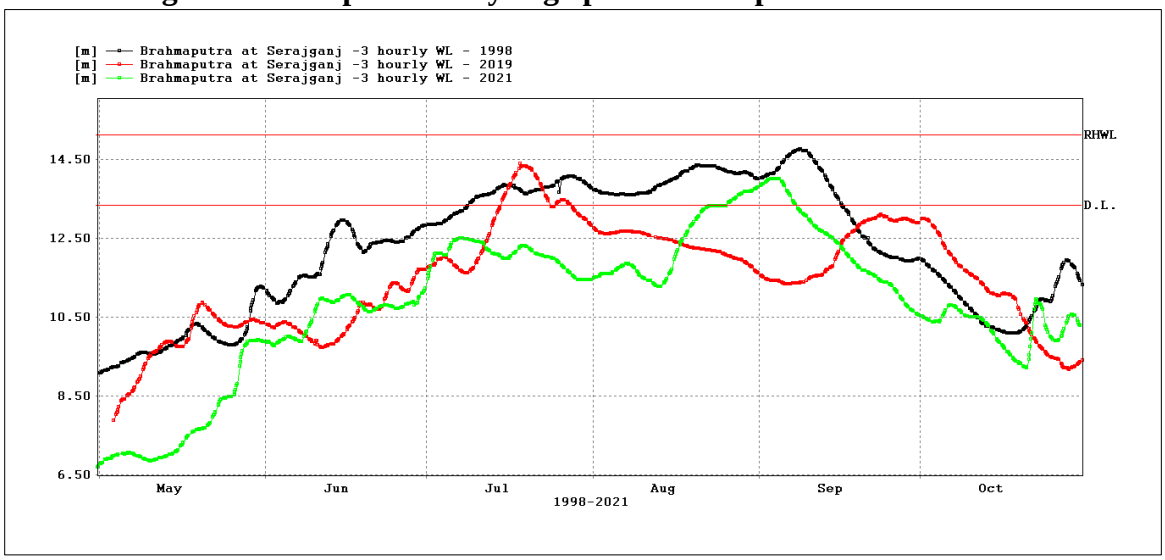


Figure 3.11: Comparison of Hydrograph on Jamuna at Serajgonj

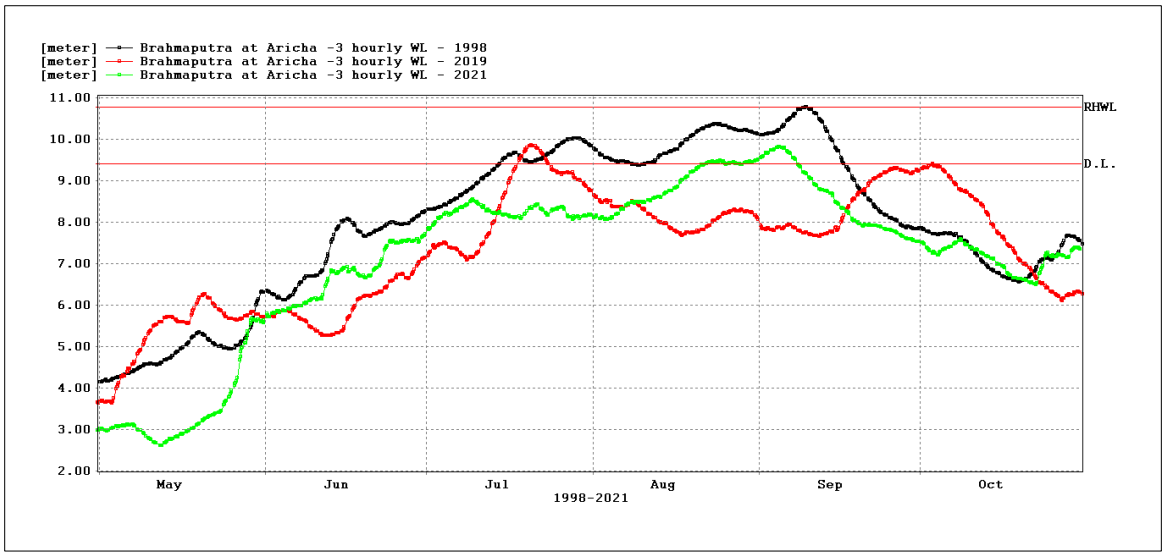


Figure 3.12: Comparison of Hydrograph on Jamuna at Aricha

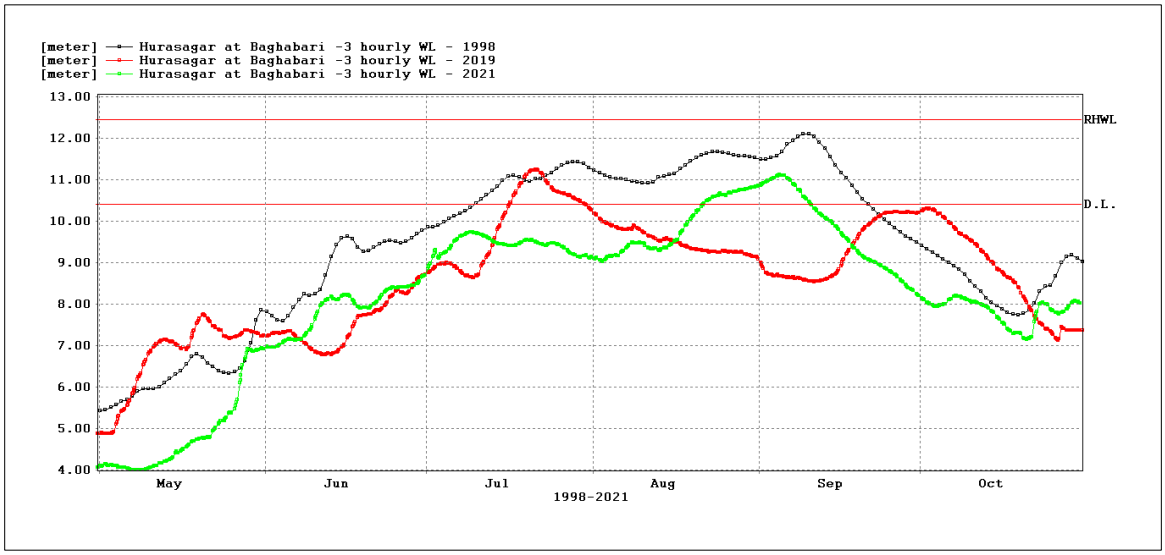


Figure 3.13: Comparison of Hydrograph on Atrai at Baghabari

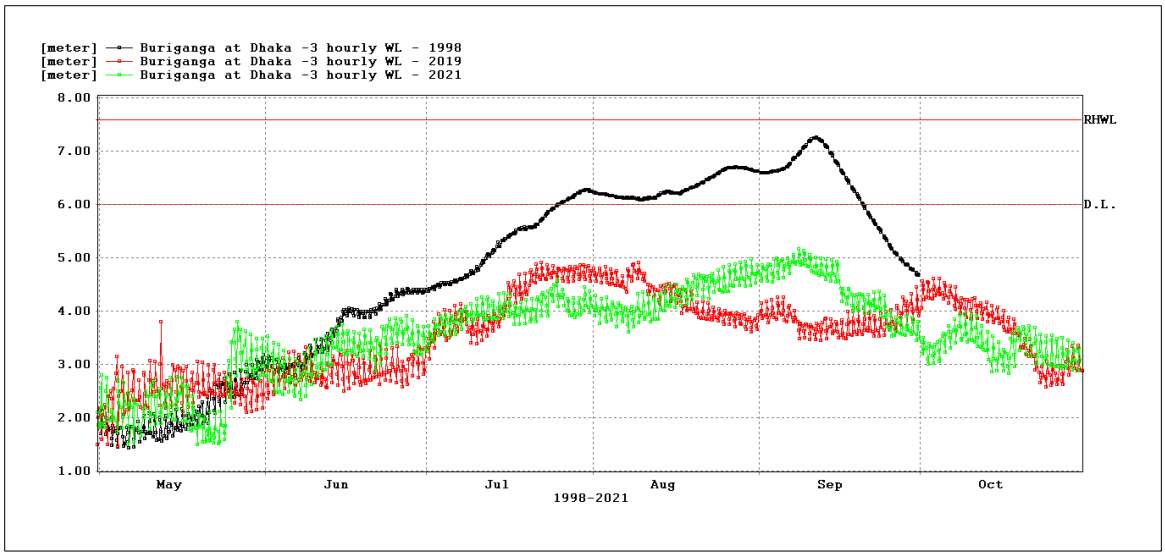


Figure 3.14: Comparison of Hydrograph on Buriganga at Dhaka (Milbarak)

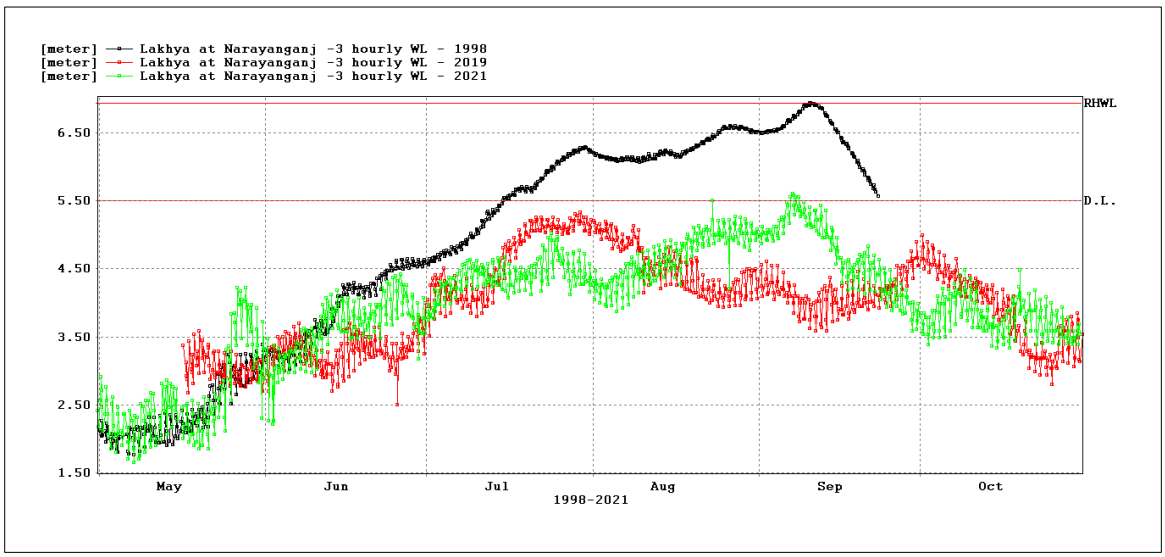


Figure 3.15: Comparison of Hydrograph on Lakhya at Narayangonj

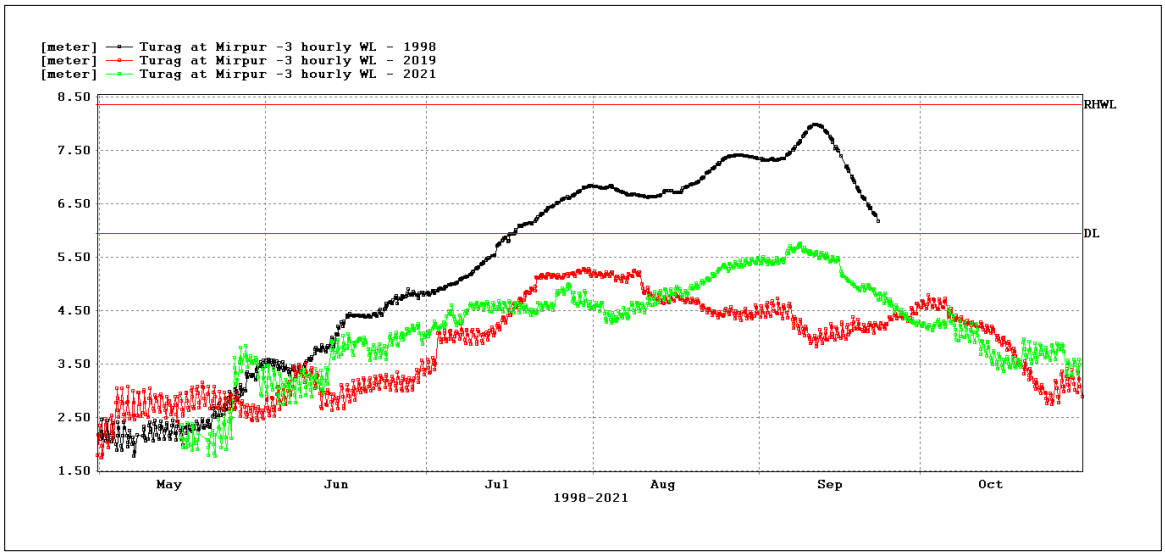


Figure 3.16 : Comparison of Hydrograph on Turag at Mirpur

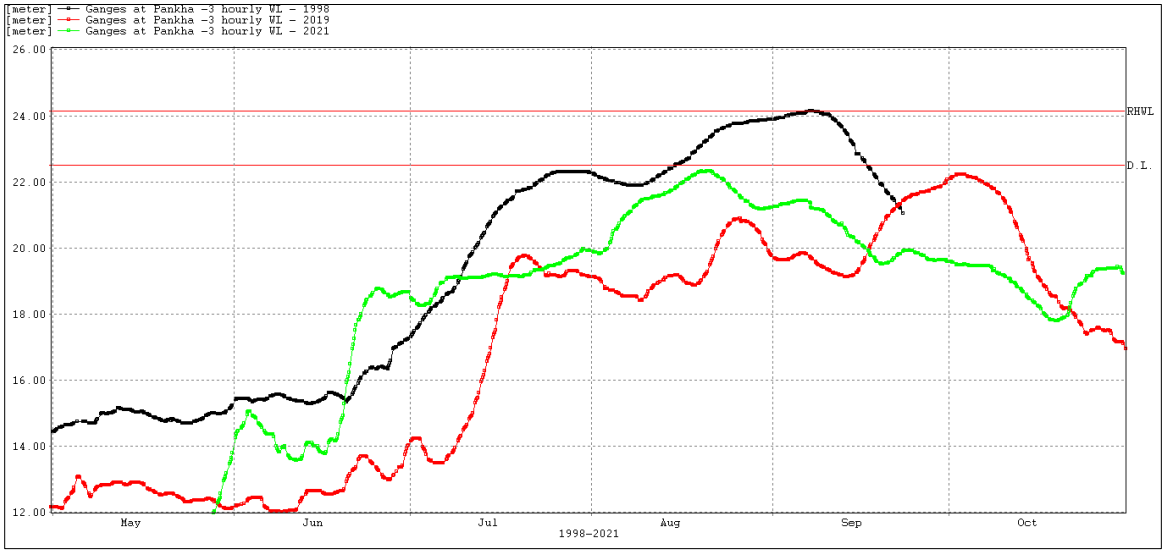


Figure 3.17: Comparison of Hydrograph on Ganges at Pankha

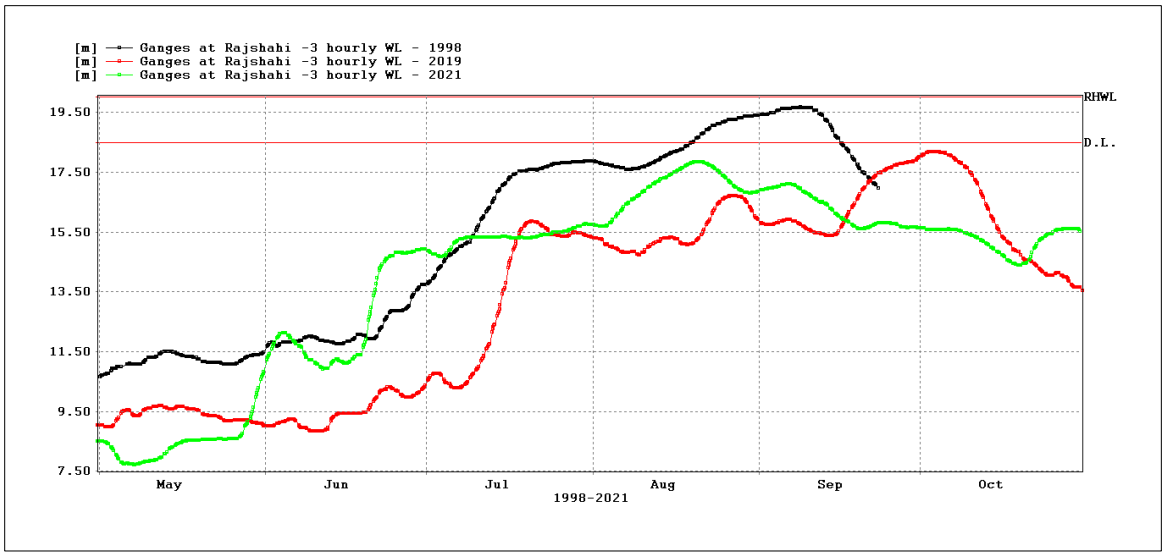


Figure 3.18: Comparison of Hydrograph on Ganges at Rajshahi

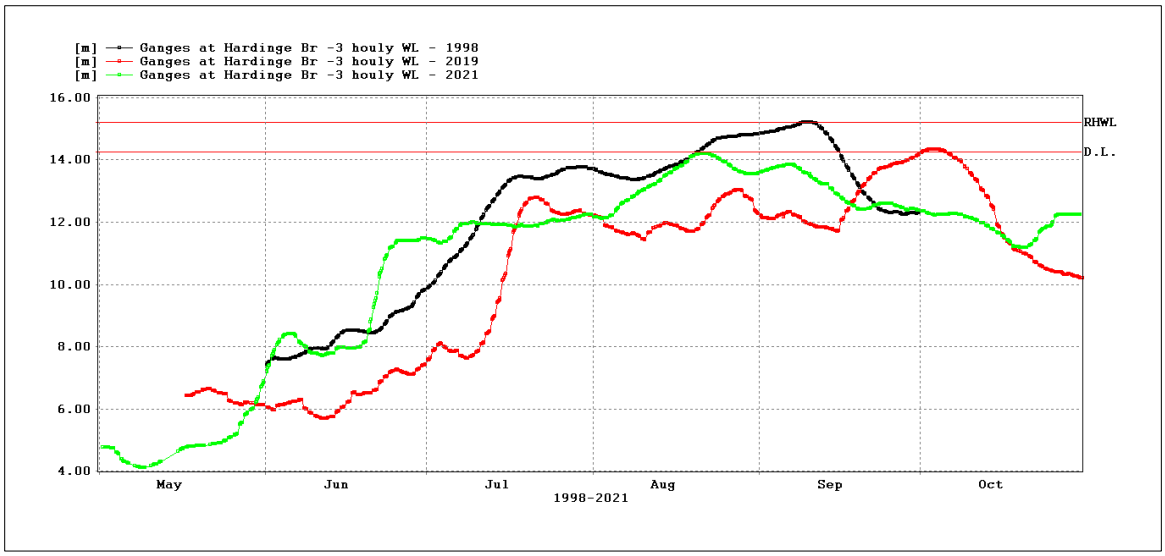


Figure 3.19: Comparison of Hydrograph on Ganges at Hardinge Bridge

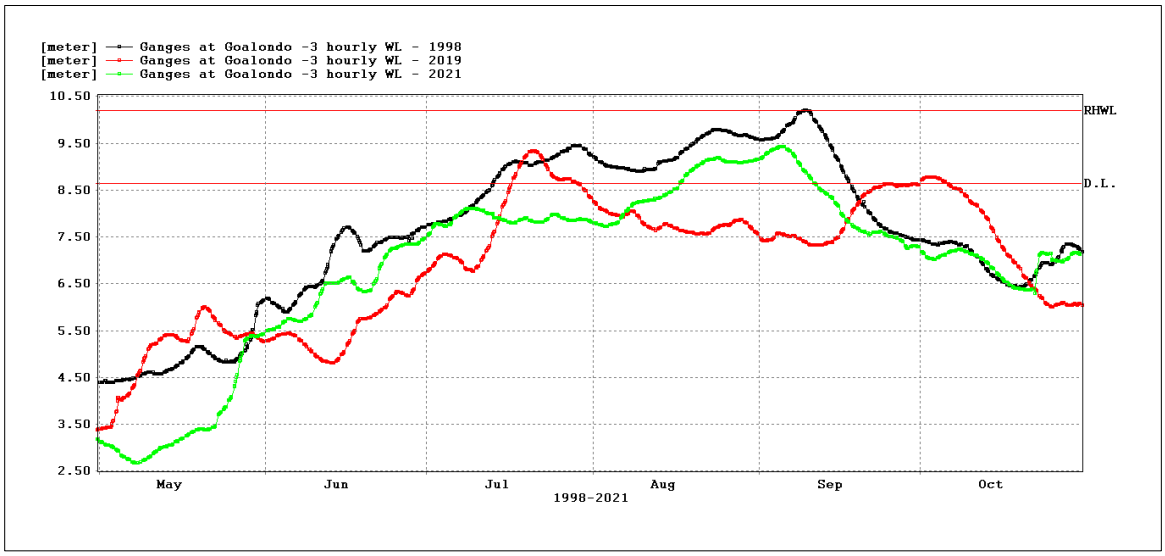


Figure 3.20: Comparison of Hydrograph on Padma at Goalondo

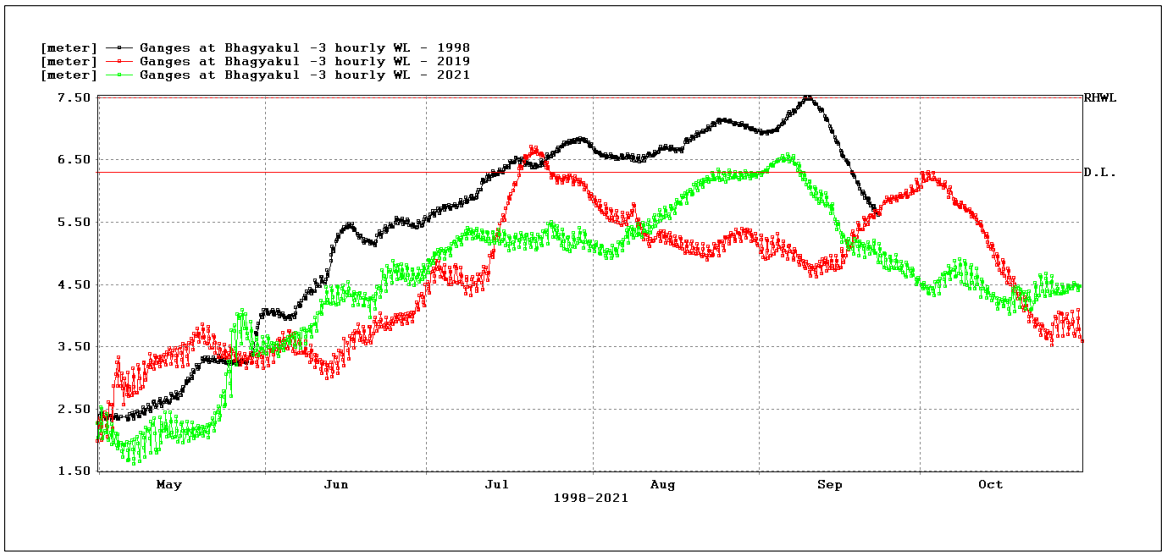


Figure 3.21: Comparison of Hydrograph on Padma at Bhagyakul

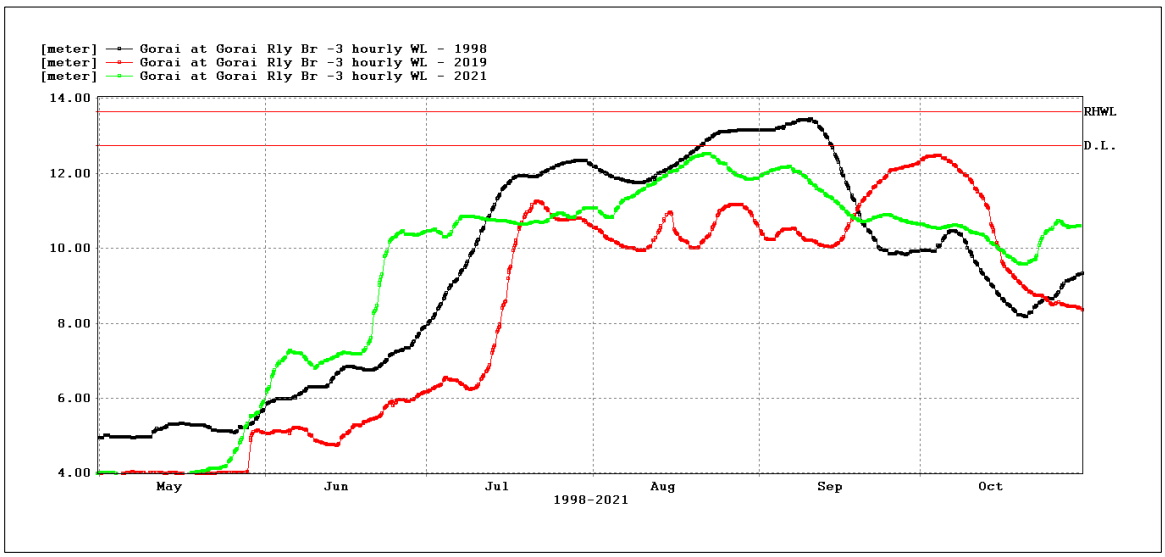


Figure 3.22: Comparison of Hydrograph on Gorai at Gorai Railway Bridge

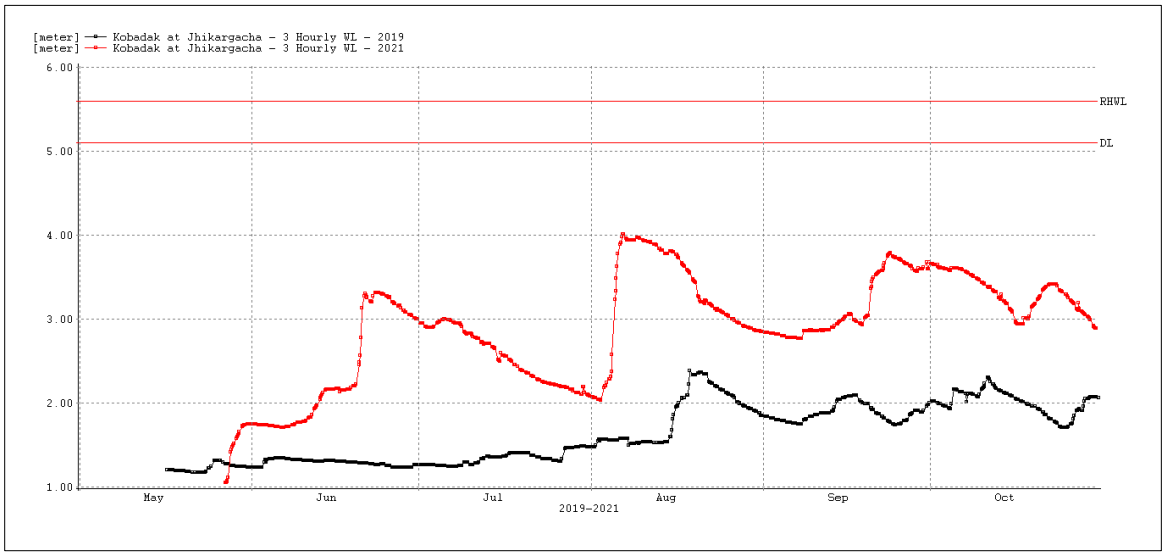


Figure 3.23: Comparison of Hydrograph on Kobodak at Jhikargacha

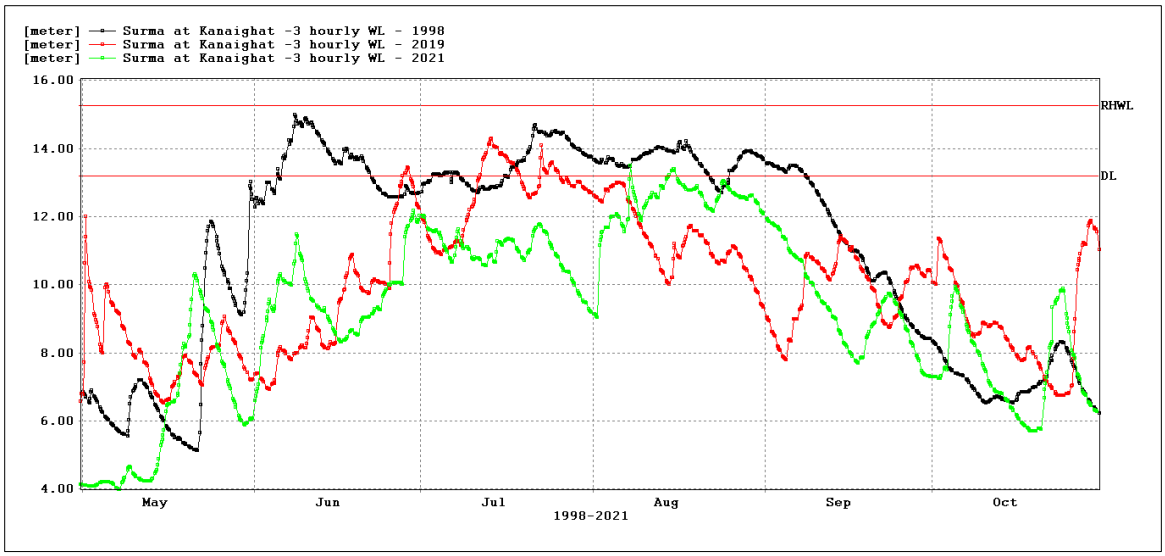


Figure 3.24: Comparison of Hydrograph on Surma at Kanaighat

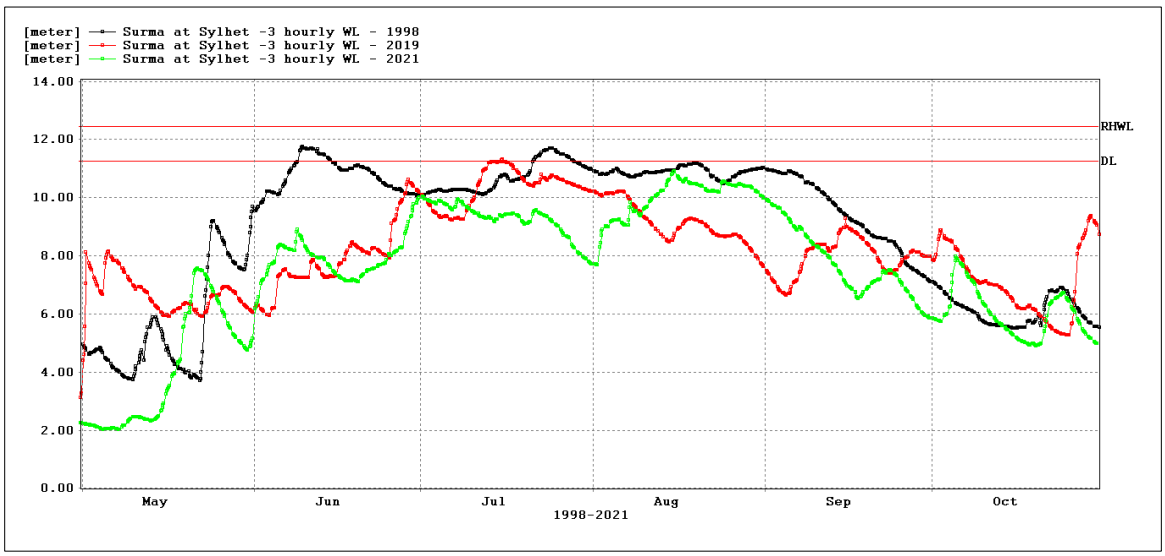


Figure 3.25: Comparison of Hydrograph on Surma at Sylhet

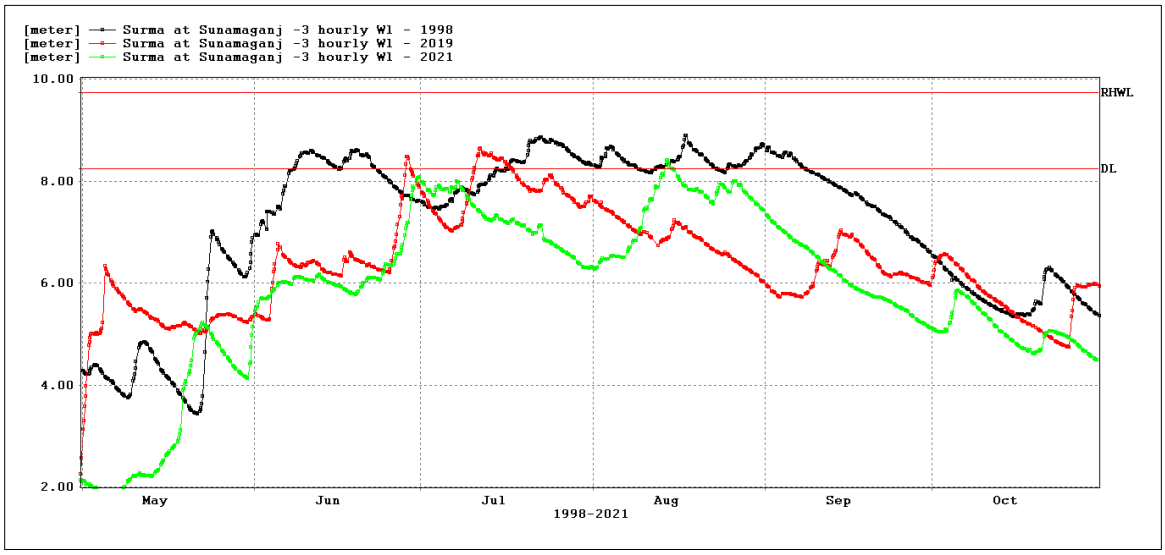


Figure 3.26: Comparison of Hydrograph on Surma at Sunamganj

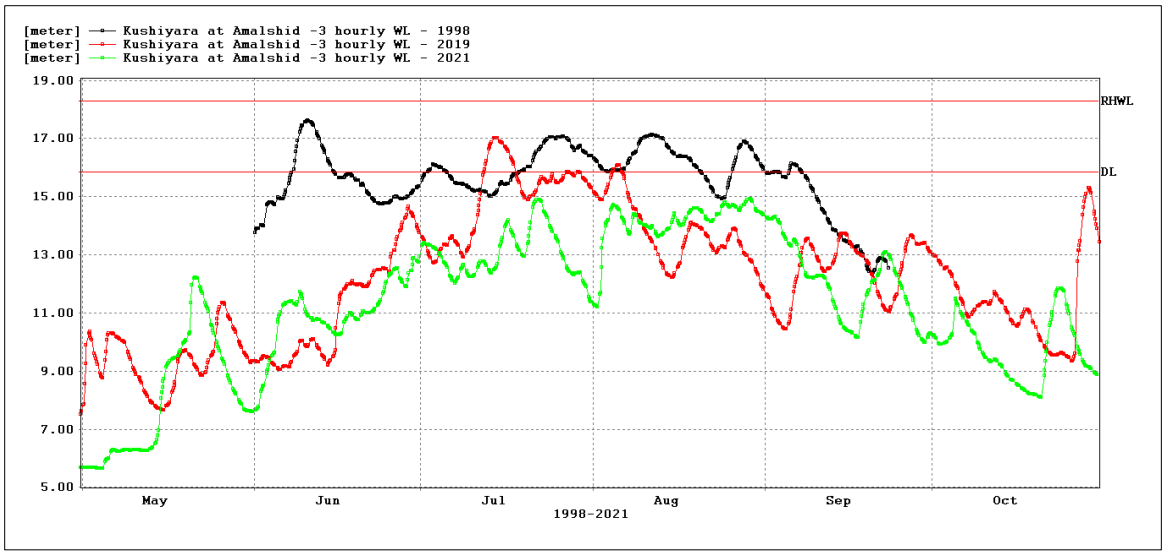


Figure 3.27: Comparison of Hydrograph on Kushiyara at Amalshid

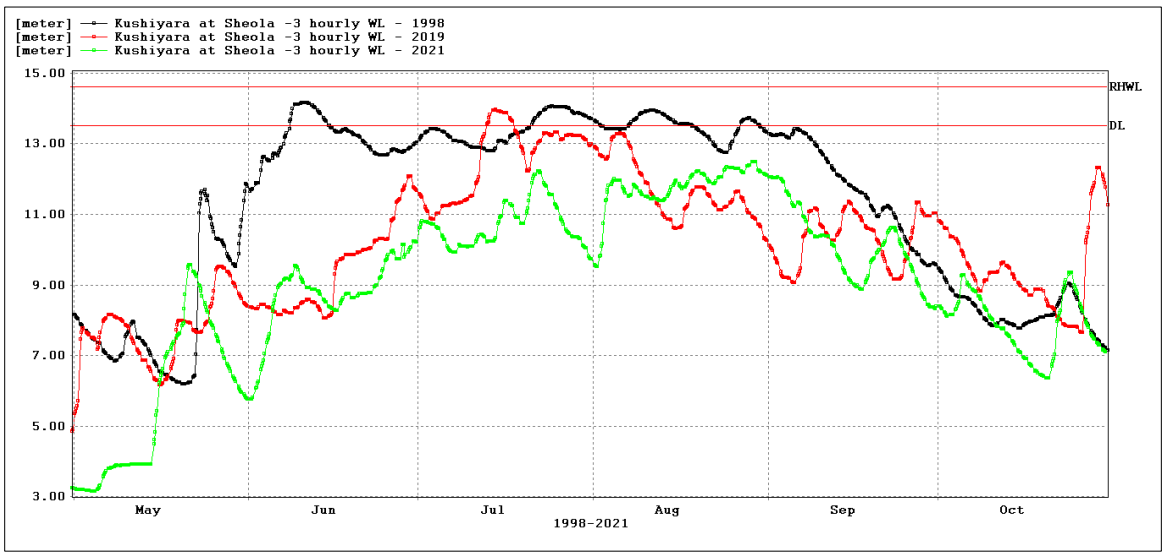


Figure 3.28: Comparison of Hydrograph on Kushiyara at Sheola

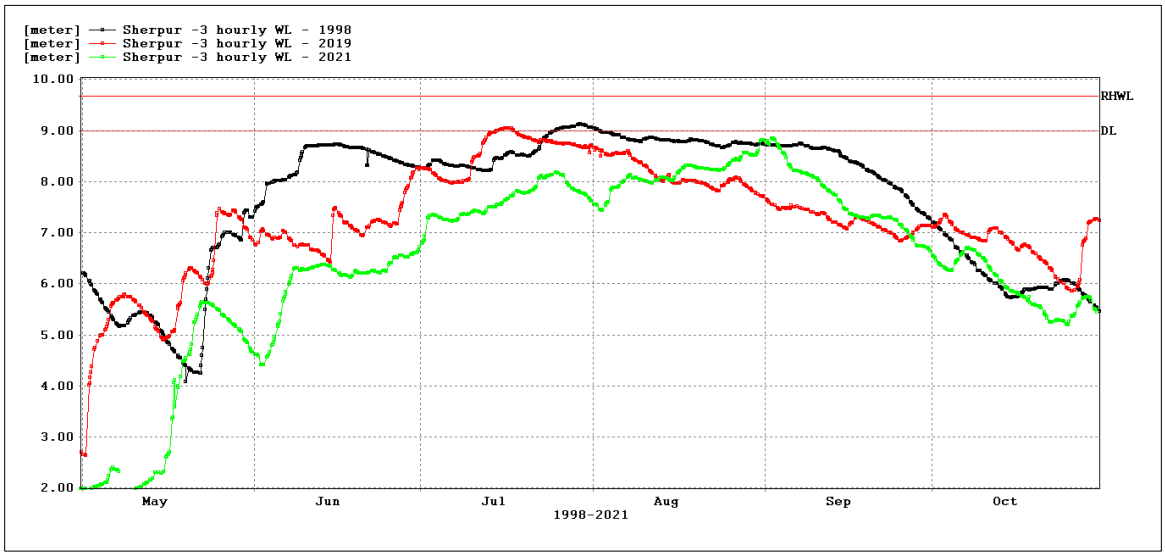


Figure 3.29: Comparison of Hydrograph on Kushiyara at Sherpur

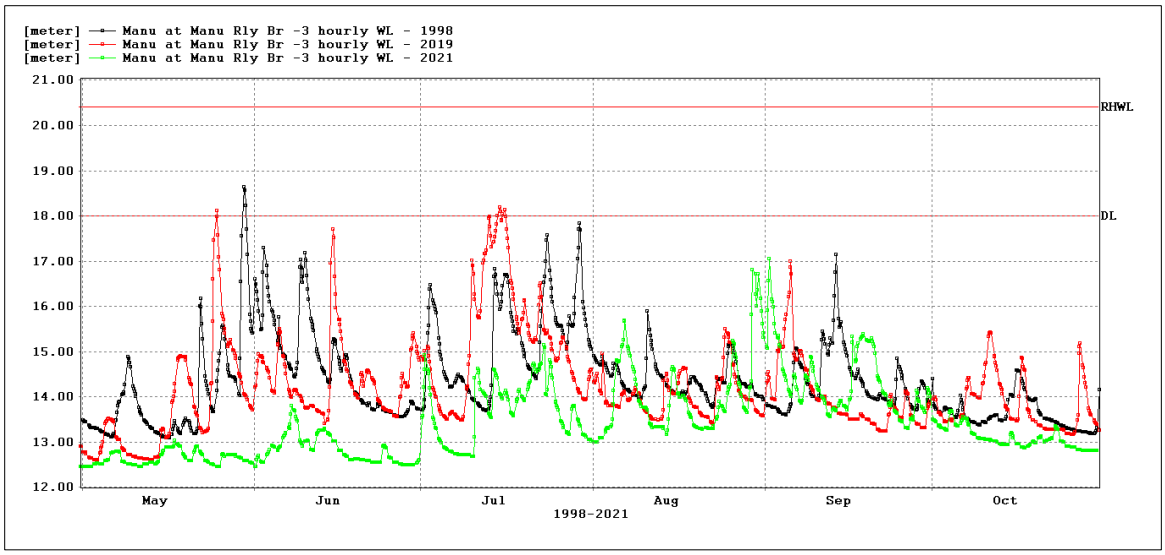


Figure 3.30: Comparison of Hydrograph on Manu at Manu Rail Bridge

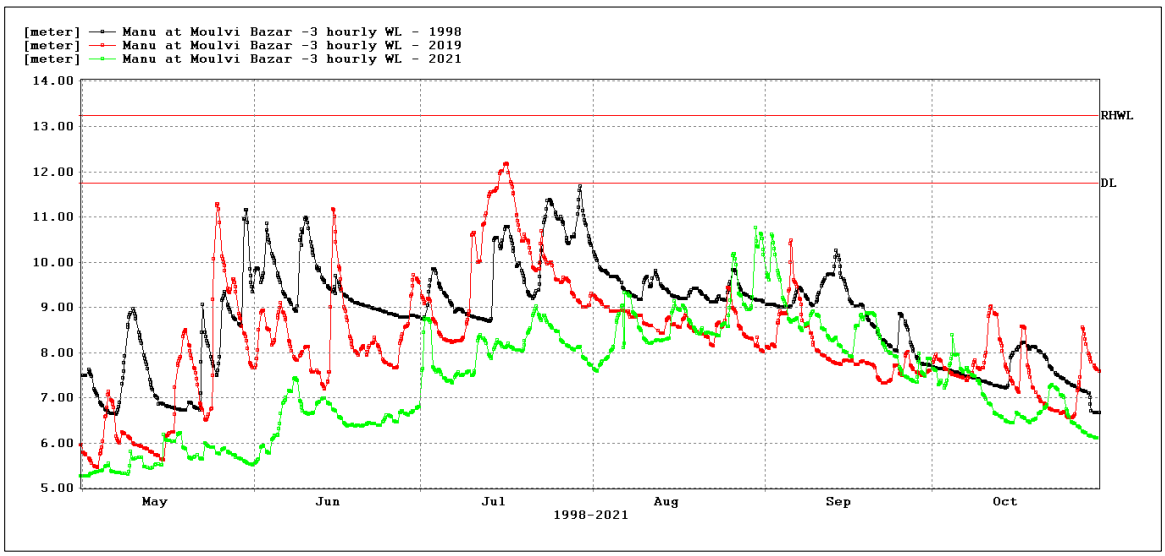


Figure 3.31: Comparison of Hydrograph on Manu at Moulovi Bazar

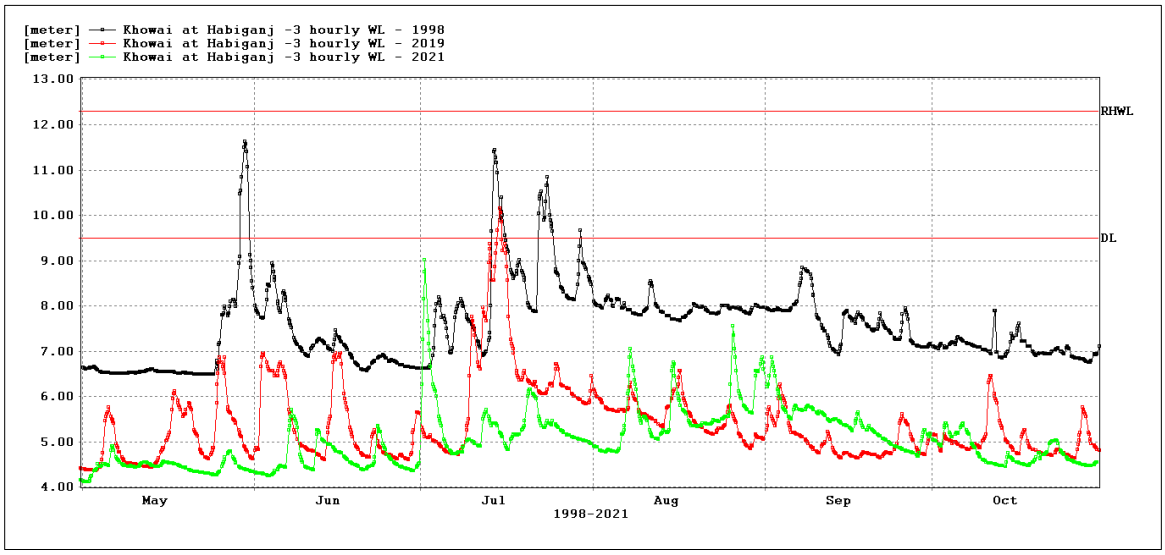


Figure 3.32: Comparison of Hydrograph on Khowai at Habiganj

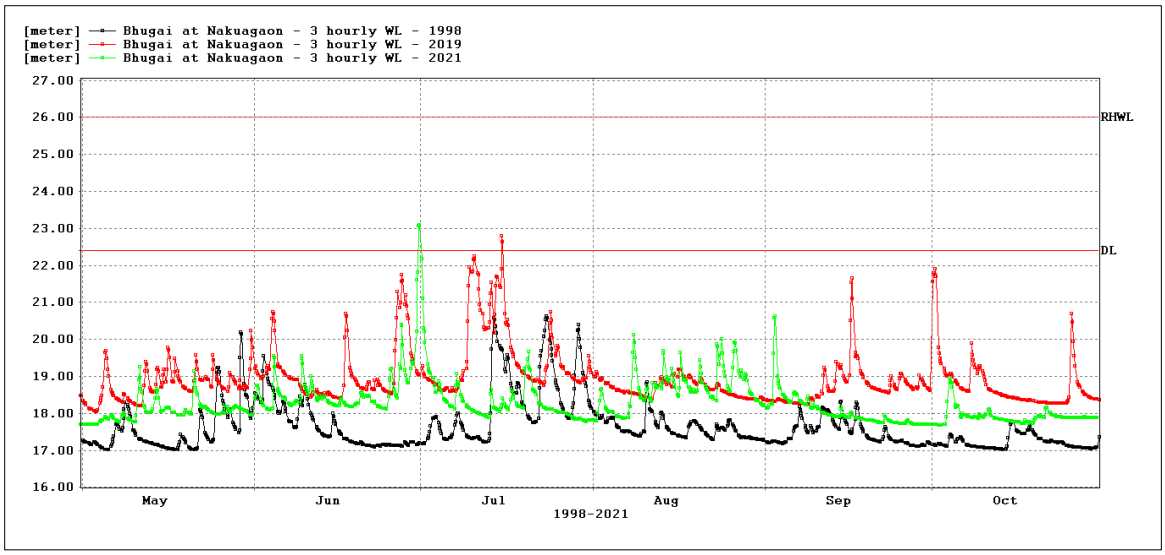


Figure 3.33: Comparison of Hydrograph on Bhugai at Nakuagaon

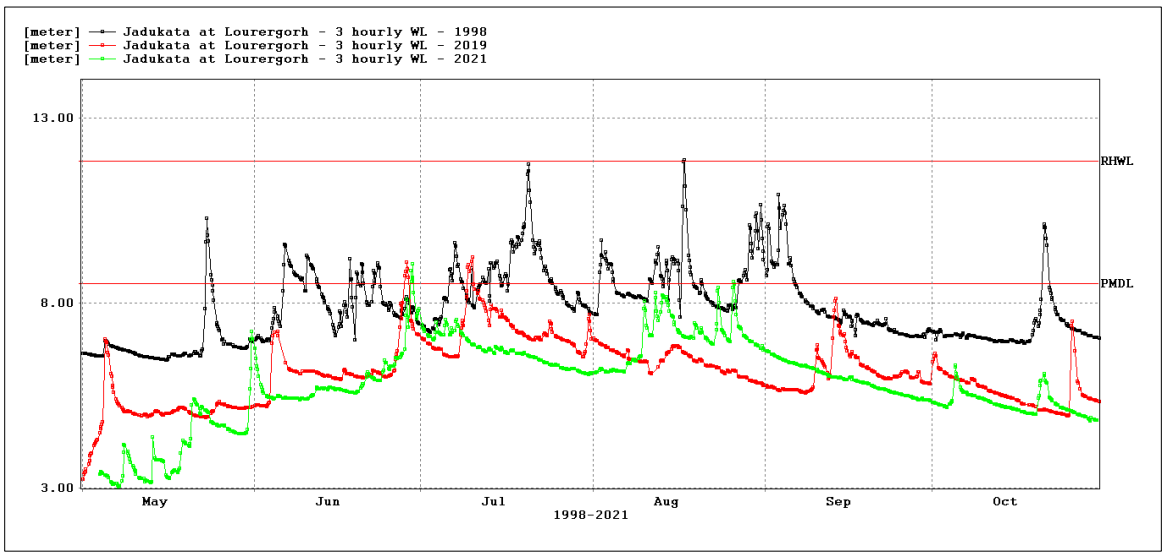


Figure 3.34: Comparison of Hydrograph on Jadukata at Lorergarh

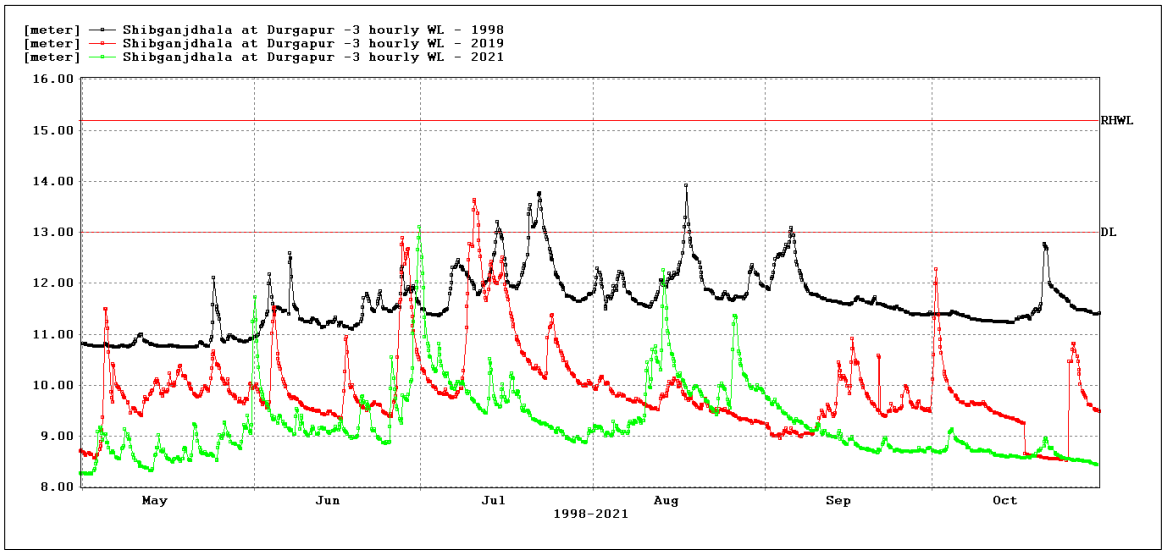


Figure 3.35: Comparison of Hydrograph on Someswari at Durgapur

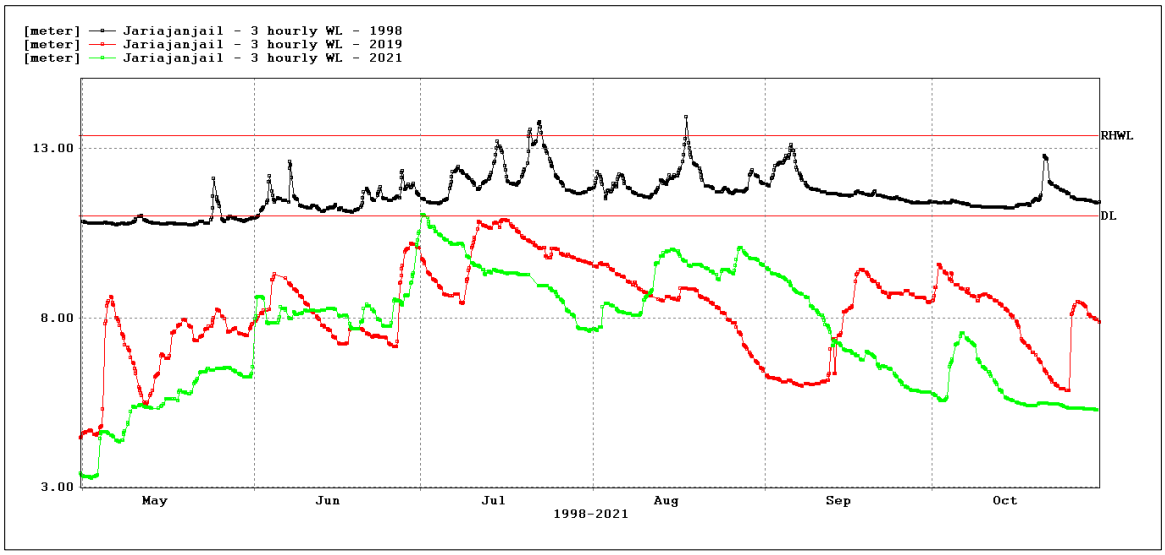


Figure 3.36: Comparison of Hydrograph on Kangsha at Jariajanjail

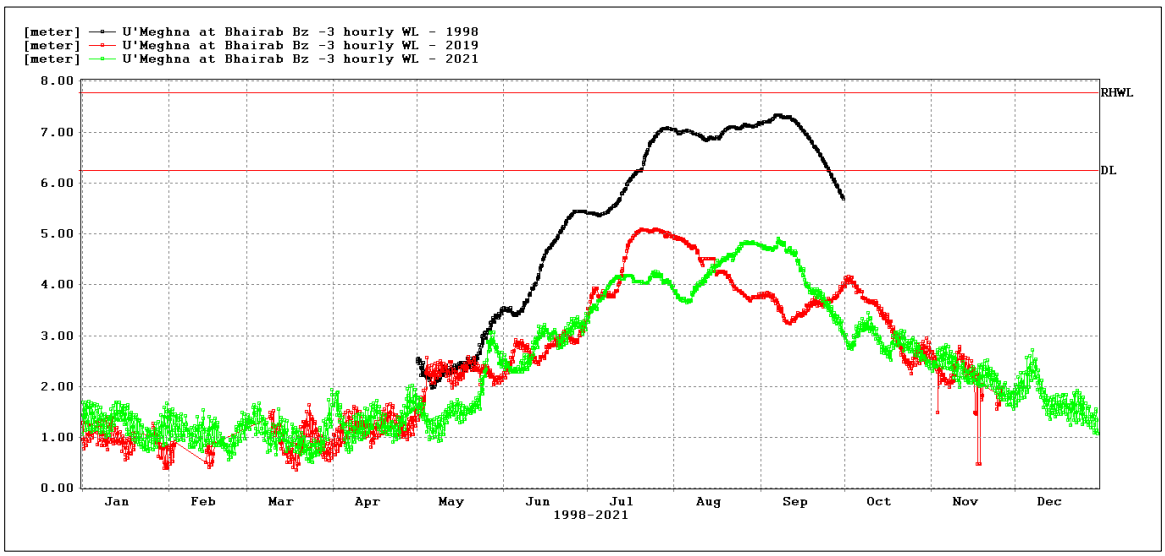


Figure 3.37: Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

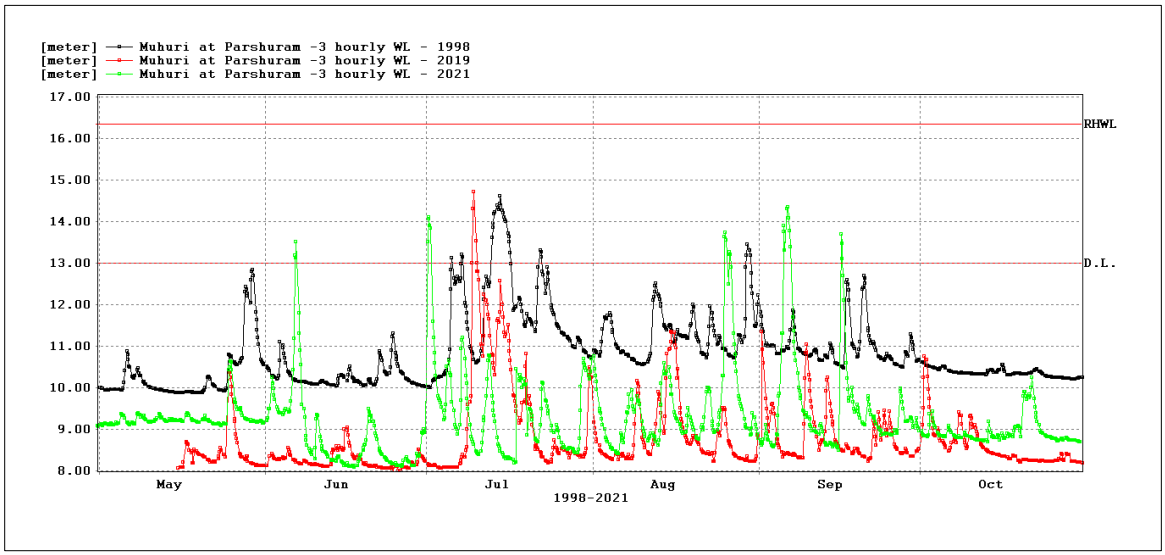


Figure 3.38: Comparison of Hydrograph on Muhuri at Parshuram

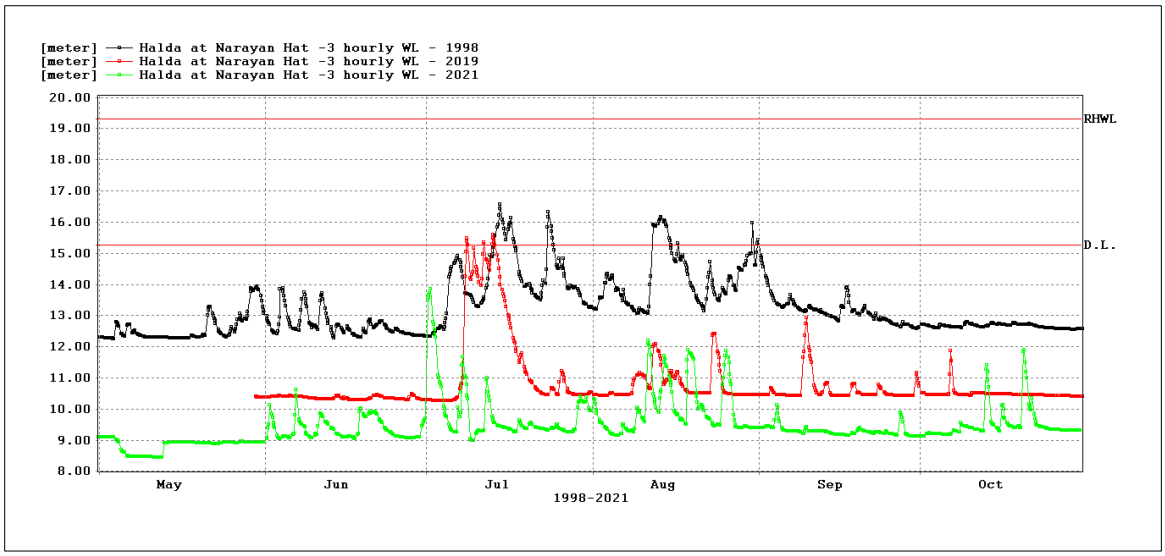


Figure 3.39: Comparison of Hydrograph on Halda at Narayanhat

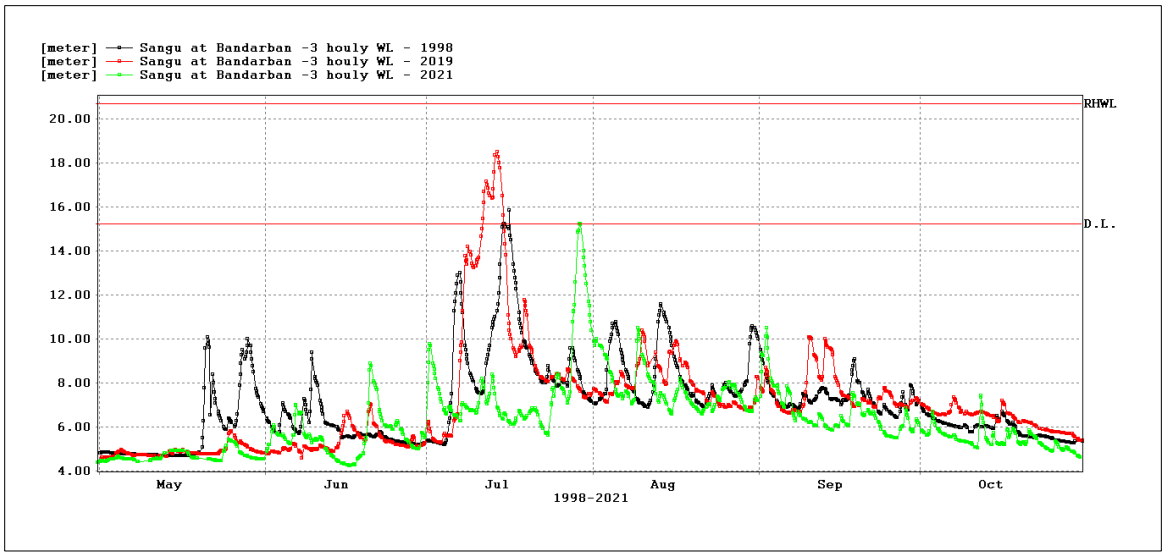


Figure 3.40: Comparison of Hydrograph on Sangu at Bandarban

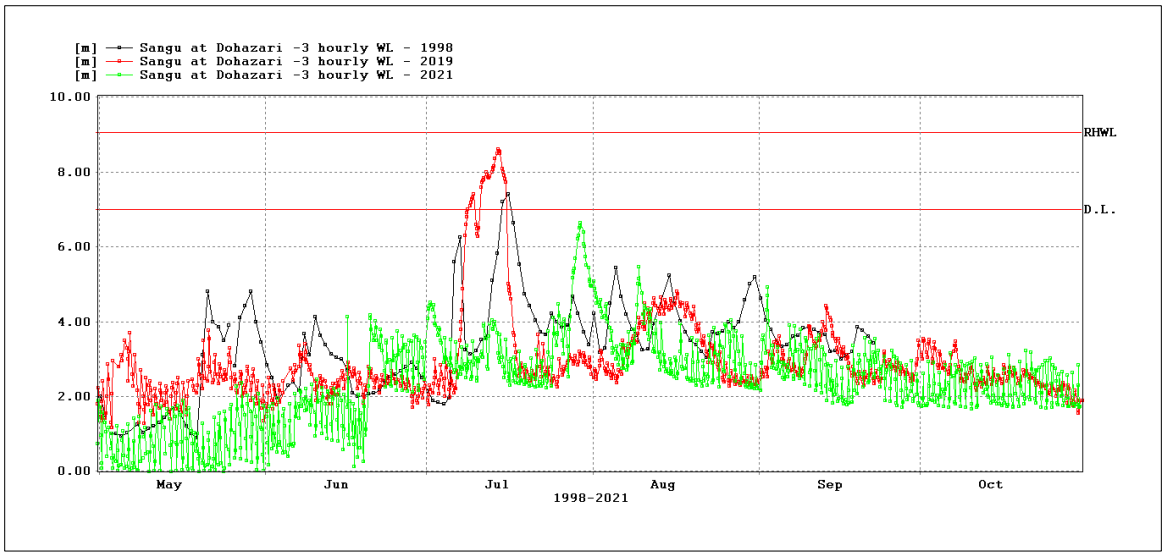


Figure 3.41: Comparison of Hydrograph on Sangu at Dohazari

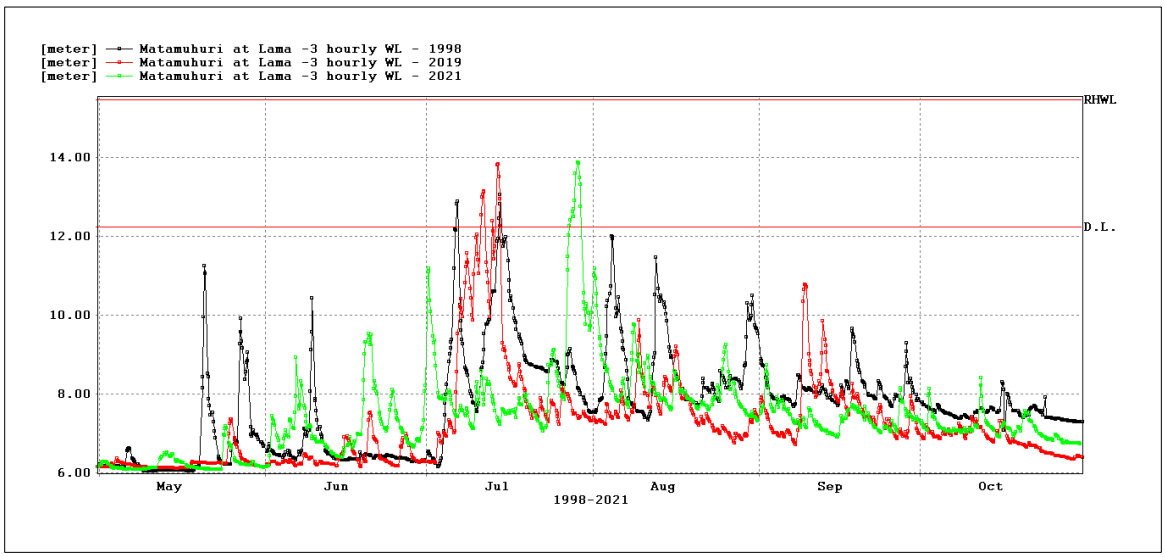


Figure 3.42: Comparison of Hydrograph on Matamuhuri at Lama

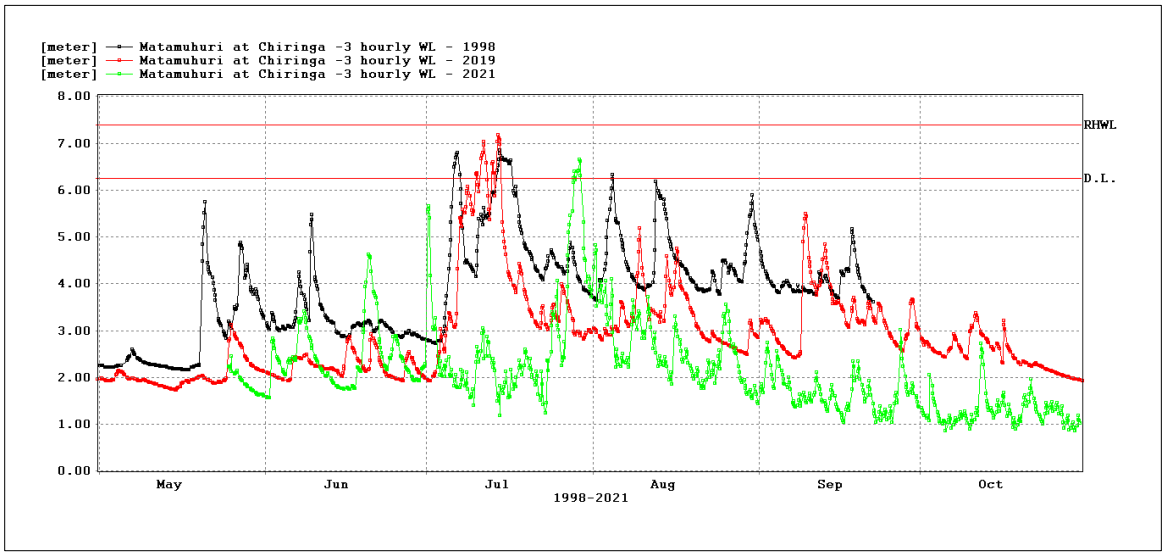


Figure 3.43: Comparison of Hydrograph on Matamuhuri at Chiringa

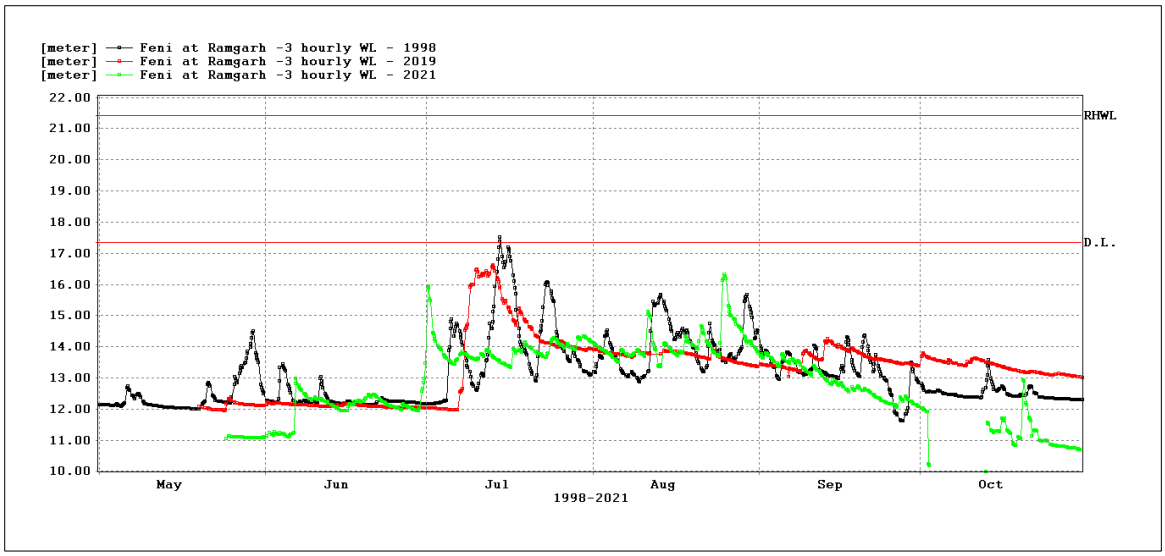


Figure 3.44: Comparison of Hydrograph on Feni at Ramgarh

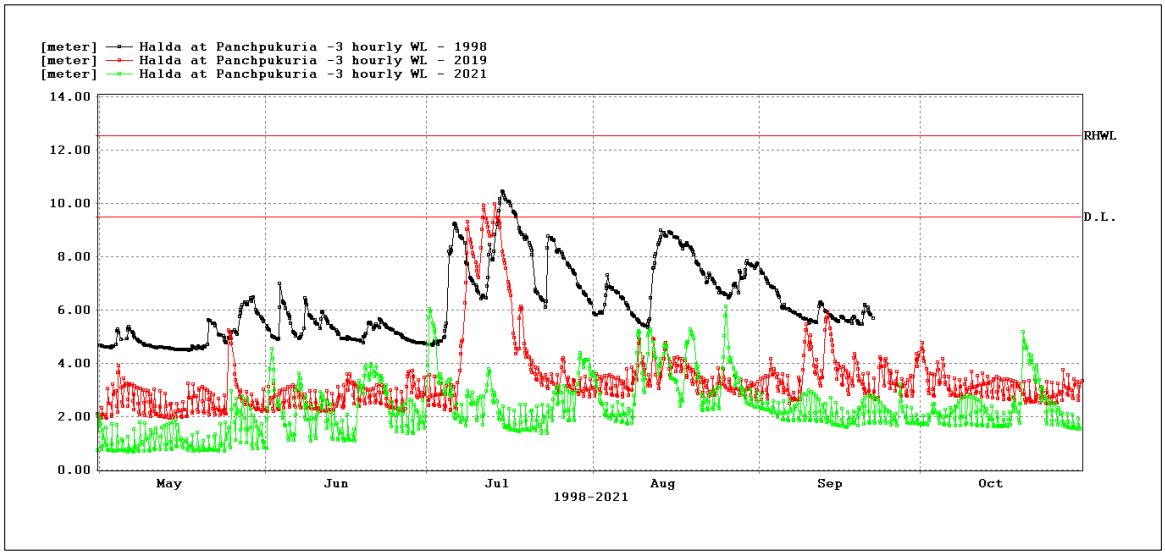


Figure 3.45: Comparison of Hydrograph on Halda at Panchpukuria

CHAPTER 4 : FORECAST EVALUATION, 2021

BWDB is the mandated organization for flood forecasting and warning services in Bangladesh as par the BWDB Act-2000. FFWC under BWDB has been carrying out this task through preparation of flood forecasting and early warning messages and its dissemination. Flood forecasting system of FFWC is developed using MIKE 11, a one-dimensional water modeling software used for the simulation of WLs and discharges in river networks and flood plains. The existing early warning system of floods provides a lead time of 120 hours, previously which was 72 hours. In order to meet the needs and expectations of flood forecast with increased lead times for cropping decisions, such as early harvesting, or to implement a contingency crop plan or protect infrastructure and preserve livelihoods, a research initiative was taken in July 2011 with support from Comprehensive Disaster Management Programme-II (CDMP-II) under Ministry of Food and Disaster Management (MoFDM) (from middle of 2012 renamed as Ministry of Disaster Management and Relief) to increase lead time for deterministic flood forecast up to 5 days (120 hours) from then existing 3-days (72 hours) forecast and also to extend the flood forecast to few selected BWDB projects. Since June 2015, FFWC is generating and disseminating 5-days deterministic flood forecast in 54 stations during monsoon which is currently continuing on operational basis.

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tire overlapping forecast systems with improved lead time during monsoon seasons of 2003 and 2004. It showed a success in forecasting the discharges at Hardinge Bridge station of Ganges and Bahadurabad station of Brahmaputra river of Bangladesh. From March 2006 – June 2009, Cooperative for American Relief Everywhere (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 of flood forecasts through pilot projects at selected sites.

Under the project, the medium range probabilistic flood forecast with 10-days lead time was initiated to a limited number of places (18 stations) on experimental basis. After the termination of the support from the USAID-CARE, this has been continued with technical support from Regional Integrated Multi-hazard Early Warning System (RIMES). Another initiative was started in July 2012 to expand the number of points for medium range 10-days probabilistic flood forecast with a view to increase the areal coverage, along with a long range seasonal flood forecast at 5 places on experimental basis with support from USAID through CARE-Bangladesh under SHOUHARDO-II programme with technical support from RIMES. Currently FFWC is generating medium range 10-days probabilistic flood forecast in 37 stations of Ganges-Brahmaputra basin during monsoon.

4.1 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

4.1.1 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

4.1.2 Co-efficient of Determination, r^2

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:

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

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

4.2 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2021 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 120 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour, 72-hour, 96-hour and 120-hour intervals. Usually, the forecast quality gradually deteriorates with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases.

4.3 DETERMINISTIC FORECAST STATISTICS AND PERFORMANCE, 2021

4.3.1 Deterministic Forecast Performance

For deterministic forecasts, simulations were made up to 120 hours (5-days) in the forecast period. Total 60 stations located within the model area (including some boundary stations) are evaluated. The deterministic forecast statistics along with performance based on the aforementioned scale are provided in Tables 4.2 to 4.6 and in Figures 4.1 to 4.5. From the following tables it can be seen that for 1-day forecast, 97% stations are within the range of Good and Average. For 2-days, 3-days, 4-days and 5-days forecast respectively 82%, 58%, 37% and 22% stations are within the range of Good and Average. A number of stations near boundary showed poor performance for increased lead time, most of which had flow of flashy characteristics or were under upstream regulation outside territory. From the Tables 4.2 to 4.6 it can also be seen that in terms of consistency based on the average statistics of co-efficient of determination, the forecasts are respectively 96%, 91%, 86%, 80% and 75% consistent for 24, 48, 72, 96 and 120 hours of lead time in the monsoon of 2021. Average MAE for 24, 48, 72, 96 and 120 hours of lead time forecasts are 0.09, 0.15, 0.20, 0.26 and 0.31 m respectively.

Table 4.2: Statistics for 24-hours Forecast Performance (Year, 2021)

Sl. No.	Station	MAE (m)	r^2	Performance-24hrs
1	Aricha	0.05	0.99	Good
2	Atrai	0.08	0.97	Good
3	Baghabari	0.03	1	Good
4	Bahadurabad	0.05	1	Good
5	Baidyar Bazar	0.12	0.9	Good
6	Barishal	0.14	0.73	Average
7	Bhagyakul	0.05	0.99	Good
8	Bhairab Bazar	0.1	0.95	Good
9	Bogura	0.13	0.94	Good
10	Chakrahimpur	0.16	0.97	Average
11	Chapai-Nawabganj	0.08	0.99	Good
12	Chilmari	0.06	0.99	Good
13	Demra	0.07	0.98	Good
14	Derai	0.08	0.91	Good
15	Dhaka	0.09	0.95	Good
16	Elasin	0.05	1	Good
17	Fulchari	0.05	1	Good
18	Gaibandha	0.09	0.98	Good
19	Goalondo	0.04	1	Good
20	Gorai-RB	0.05	1	Good
21	Hardinge-RB	0.04	1	Good
22	Haridaspur	0.06	0.91	Good
23	Hariharpara	0.09	0.95	Good
24	Jagir	0.04	1	Good
25	Jamalpur	0.08	0.99	Good
26	Kaliakoir	0.06	0.97	Good
27	Kamarkhali	0.06	1	Good
28	Kaunia	0.15	0.79	Average
29	Kazipur	0.05	0.99	Good
30	Khaliajuri	0.08	0.92	Good
31	Kurigram	0.14	0.94	Good
32	Lakhpur	0.07	0.97	Good
33	Madaripur	0.05	0.99	Good
34	Markuli	0.13	0.93	Good
35	Mathura	0.03	1	Good
36	Mawa	0.05	0.99	Good
37	Meghna Bridge	0.17	0.71	Average
38	Mirpur	0.08	0.96	Good
39	Mohadebpur	0.17	0.93	Average
40	Moulvibazar	0.23	0.86	Not Satisfactory
41	Mymensingh	0.09	0.99	Good
42	Naogaon	0.15	0.94	Good
43	Narayanganj	0.11	0.92	Good
44	Narsingdi	0.1	0.93	Good
45	Nayarhat	0.05	0.99	Good
46	Porabari	0.06	0.98	Good
47	Rajshahi	0.05	1	Good
48	Rekabi-Bazar	0.09	0.95	Good
49	Sariakandi	0.05	1	Good
50	Serajganj	0.04	1	Good
51	Sheola	0.24	0.94	Not Satisfactory
52	Sherpur-Sylhet	0.11	0.95	Good
53	Shimulbari	0.11	0.96	Good
54	Singra	0.05	0.99	Good
55	Sunamganj	0.12	0.96	Good
56	Sureshswar	0.09	0.94	Good
57	Sylhet	0.18	0.96	Average
58	Talbaria	0.04	1	Good
59	Taraghat	0.05	1	Good
60	Tongi	0.05	0.99	Good

Table 4.3: Statistics for 48-hours Forecast Performance (Year, 2021)

Sl. No.	Station	MAE (m)	r^2	Performance-48hrs
1	Aricha	0.08	0.99	Good
2	Atrai	0.16	0.92	Average
3	Baghabari	0.06	0.99	Good
4	Bahadurabad	0.12	0.98	Good
5	Baidyar Bazar	0.15	0.85	Average
6	Barishal	0.26	0.42	Not Satisfactory
7	Bhagyakul	0.08	0.98	Good
8	Bhairab Bazar	0.13	0.93	Good
9	Bogura	0.26	0.81	Not Satisfactory
10	Chakrahimpur	0.29	0.92	Not Satisfactory
11	Chapai-Nawabganj	0.15	0.98	Good
12	Chilmari	0.13	0.97	Good
13	Demra	0.11	0.93	Good
14	Derai	0.10	0.90	Good
15	Dhaka	0.16	0.85	Average
16	Elasin	0.10	0.99	Good
17	Fulchari	0.11	0.98	Good
18	Gaibandha	0.19	0.94	Average
19	Goalondo	0.06	0.99	Good
20	Gorai-RB	0.09	0.99	Good
21	Hardinge-RB	0.09	0.99	Good
22	Haridaspur	0.10	0.78	Average
23	Hariharpara	0.16	0.85	Average
24	Jagir	0.07	1.00	Good
25	Jamalpur	0.15	0.98	Good
26	Kaliakoir	0.11	0.89	Average
27	Kamarkhali	0.09	0.99	Good
28	Kaunia	0.18	0.76	Average
29	Kazipur	0.11	0.97	Good
30	Khaliajuri	0.10	0.91	Good
31	Kurigram	0.23	0.88	Not Satisfactory
32	Lakhpur	0.12	0.91	Good
33	Madaripur	0.08	0.97	Good
34	Markuli	0.19	0.87	Average
35	Mathura	0.06	0.99	Good
36	Mawa	0.08	0.98	Good
37	Meghna Bridge	0.23	0.61	Not Satisfactory
38	Mirpur	0.13	0.91	Good
39	Mohadebpur	0.27	0.86	Not Satisfactory
40	Moulvibazar	0.36	0.73	Poor
41	Mymensingh	0.16	0.96	Average
42	Naogaon	0.30	0.81	Not Satisfactory
43	Narayanganj	0.18	0.82	Average
44	Narsingdi	0.13	0.90	Good
45	Nayarhat	0.09	0.98	Good
46	Porabari	0.10	0.98	Good
47	Rajshahi	0.11	0.99	Good
48	Rekabi-Bazar	0.15	0.86	Average
49	Sariakandi	0.11	0.98	Good
50	Serajganj	0.08	0.99	Good
51	Sheola	0.43	0.85	Very Poor
52	Sherpur-Sylhet	0.16	0.93	Average
53	Shimulbari	0.21	0.90	Not Satisfactory
54	Singra	0.09	0.97	Good
55	Sunamganj	0.18	0.92	Average
56	Sureshswar	0.16	0.80	Average
57	Sylhet	0.30	0.91	Not Satisfactory
58	Talbaria	0.08	0.99	Good
59	Taraghat	0.08	0.99	Good
60	Tongi	0.08	0.97	Good

Table 4.4: Statistics for 72-hours Forecast Performance (Year, 2021)

Sl. No.	Station	MAE (m)	r^2	Performance-72hrs
1	Aricha	0.11	0.98	Good
2	Atrai	0.22	0.86	Not Satisfactory
3	Baghabari	0.10	0.98	Good
4	Bahadurabad	0.19	0.95	Average
5	Baidyar Bazar	0.18	0.78	Average
6	Barishal	0.35	0.17	Very Poor
7	Bhagyakul	0.12	0.96	Good
8	Bhairab Bazar	0.15	0.91	Good
9	Bogura	0.41	0.64	Very Poor
10	Chakrahimpur	0.39	0.86	Poor
11	Chapai-Nawabganj	0.22	0.96	Not Satisfactory
12	Chilmari	0.19	0.93	Average
13	Demra	0.16	0.87	Average
14	Derai	0.12	0.88	Average
15	Dhaka	0.21	0.75	Not Satisfactory
16	Elasin	0.16	0.97	Average
17	Fulchari	0.18	0.96	Average
18	Gaibandha	0.27	0.87	Not Satisfactory
19	Goalondo	0.10	0.98	Good
20	Gorai-RB	0.14	0.98	Good
21	Hardinge-RB	0.15	0.98	Good
22	Haridaspur	0.14	0.62	Not Satisfactory
23	Hariharpara	0.21	0.74	Not Satisfactory
24	Jagir	0.11	0.99	Good
25	Jamalpur	0.21	0.95	Not Satisfactory
26	Kaliakoir	0.16	0.77	Average
27	Kamarkhali	0.13	0.98	Good
28	Kaunia	0.22	0.63	Not Satisfactory
29	Kazipur	0.17	0.95	Average
30	Khaliajuri	0.11	0.91	Good
31	Kurigram	0.30	0.82	Not Satisfactory
32	Lakhpur	0.17	0.84	Average
33	Madaripur	0.11	0.94	Good
34	Markuli	0.21	0.83	Not Satisfactory
35	Mathura	0.09	0.99	Good
36	Mawa	0.11	0.95	Good
37	Meghna Bridge	0.26	0.51	Not Satisfactory
38	Mirpur	0.17	0.86	Average
39	Mohadebpur	0.38	0.79	Poor
40	Moulvibazar	0.44	0.64	Very Poor
41	Mymensingh	0.23	0.93	Not Satisfactory
42	Naogaon	0.42	0.67	Very Poor
43	Narayanganj	0.23	0.71	Not Satisfactory
44	Narsingdi	0.16	0.88	Average
45	Nayarhat	0.13	0.97	Good
46	Porabari	0.16	0.96	Average
47	Rajshahi	0.17	0.97	Average
48	Rekabi-Bazar	0.21	0.73	Not Satisfactory
49	Sariakandi	0.18	0.96	Average
50	Serajganj	0.14	0.97	Good
51	Sheola	0.55	0.75	Very Poor
52	Sherpur-Sylhet	0.20	0.90	Average
53	Shimulbari	0.30	0.84	Not Satisfactory
54	Singra	0.13	0.94	Good
55	Sunamganj	0.25	0.86	Not Satisfactory
56	Sureshswar	0.23	0.62	Not Satisfactory
57	Sylhet	0.42	0.84	Very Poor
58	Talbaria	0.11	0.97	Good
59	Taraghat	0.11	0.99	Good
60	Tongi	0.12	0.94	Good

Table 4.5: Statistics for 96-hours Forecast Performance (Year, 2021)

Sl. No.	Station	MAE (m)	r^2	Performance-96hrs
1	Aricha	0.14	0.97	Good
2	Atrai	0.29	0.79	Not Satisfactory
3	Baghabari	0.14	0.97	Good
4	Bahadurabad	0.25	0.91	Not Satisfactory
5	Baidyar Bazar	0.22	0.73	Not Satisfactory
6	Barishal	0.42	0.03	Very Poor
7	Bhagyakul	0.15	0.94	Good
8	Bhairab Bazar	0.19	0.89	Average
9	Bogura	0.54	0.49	Very Poor
10	Chakrahimpur	0.49	0.79	Very Poor
11	Chapai-Nawabganj	0.28	0.93	Not Satisfactory
12	Chilmari	0.25	0.88	Not Satisfactory
13	Demra	0.20	0.80	Average
14	Derai	0.14	0.86	Average
15	Dhaka	0.26	0.66	Not Satisfactory
16	Elasin	0.22	0.95	Not Satisfactory
17	Fulchari	0.23	0.93	Not Satisfactory
18	Gaibandha	0.33	0.82	Poor
19	Goalondo	0.13	0.97	Good
20	Gorai-RB	0.19	0.96	Average
21	Hardinge-RB	0.20	0.96	Average
22	Haridaspur	0.17	0.48	Not Satisfactory
23	Hariharpara	0.26	0.65	Not Satisfactory
24	Jagir	0.13	0.99	Good
25	Jamalpur	0.29	0.91	Not Satisfactory
26	Kaliakoir	0.21	0.64	Not Satisfactory
27	Kamarkhali	0.17	0.96	Average
28	Kaunia	0.25	0.56	Not Satisfactory
29	Kazipur	0.22	0.93	Not Satisfactory
30	Khaliajuri	0.14	0.88	Average
31	Kurigram	0.35	0.76	Poor
32	Lakhpur	0.22	0.76	Not Satisfactory
33	Madaripur	0.14	0.91	Good
34	Markuli	0.23	0.79	Not Satisfactory
35	Mathura	0.12	0.98	Good
36	Mawa	0.14	0.92	Good
37	Meghna Bridge	0.29	0.41	Not Satisfactory
38	Mirpur	0.20	0.81	Average
39	Mohadebpur	0.50	0.67	Very Poor
40	Moulvibazar	0.56	0.53	Very Poor
41	Mymensingh	0.30	0.89	Not Satisfactory
42	Naogaon	0.57	0.53	Very Poor
43	Narayanganj	0.28	0.59	Not Satisfactory
44	Narsingdi	0.18	0.85	Average
45	Nayarhat	0.17	0.95	Average
46	Porabari	0.21	0.94	Not Satisfactory
47	Rajshahi	0.23	0.95	Not Satisfactory
48	Rekabi-Bazar	0.27	0.62	Not Satisfactory
49	Sariakandi	0.24	0.93	Not Satisfactory
50	Serajganj	0.21	0.94	Not Satisfactory
51	Sheola	0.63	0.68	Very Poor
52	Sherpur-Sylhet	0.24	0.86	Not Satisfactory
53	Shimulbari	0.38	0.77	Poor
54	Singra	0.18	0.90	Average
55	Sunamganj	0.31	0.80	Poor
56	Sureshswar	0.29	0.45	Not Satisfactory
57	Sylhet	0.51	0.79	Very Poor
58	Talbaria	0.15	0.94	Good
59	Taraghat	0.15	0.98	Good
60	Tongi	0.16	0.89	Average

Table 4.6: Statistics for 120-hours Forecast Performance (Year, 2021)

Sl. No.	Station	MAE (m)	r^2	Performance-120hrs
1	Aricha	0.17	0.95	Average
2	Atrai	0.36	0.72	Poor
3	Baghabari	0.18	0.94	Average
4	Bahadurabad	0.31	0.86	Poor
5	Baidyar Bazar	0.25	0.67	Not Satisfactory
6	Barishal	0.47	0.00	Very Poor
7	Bhagyakul	0.18	0.91	Average
8	Bhairab Bazar	0.21	0.86	Not Satisfactory
9	Bogura	0.67	0.37	Very Poor
10	Chakrahimpur	0.62	0.71	Very Poor
11	Chapai-Nawabganj	0.35	0.90	Poor
12	Chilmari	0.31	0.83	Poor
13	Demra	0.24	0.74	Not Satisfactory
14	Derai	0.15	0.85	Average
15	Dhaka	0.29	0.61	Not Satisfactory
16	Elasin	0.29	0.91	Not Satisfactory
17	Fulchari	0.29	0.90	Not Satisfactory
18	Gaibandha	0.39	0.76	Poor
19	Goalondo	0.17	0.95	Average
20	Gorai-RB	0.24	0.92	Not Satisfactory
21	Hardinge-RB	0.25	0.93	Not Satisfactory
22	Haridaspur	0.19	0.42	Not Satisfactory
23	Hariharpara	0.29	0.59	Not Satisfactory
24	Jagir	0.15	0.98	Good
25	Jamalpur	0.38	0.87	Poor
26	Kaliakoir	0.28	0.51	Not Satisfactory
27	Kamarkhali	0.21	0.94	Not Satisfactory
28	Kaunia	0.23	0.54	Not Satisfactory
29	Kazipur	0.28	0.89	Not Satisfactory
30	Khaliajuri	0.15	0.86	Average
31	Kurigram	0.44	0.67	Very Poor
32	Lakhpur	0.27	0.68	Not Satisfactory
33	Madaripur	0.16	0.89	Average
34	Markuli	0.26	0.75	Not Satisfactory
35	Mathura	0.15	0.97	Good
36	Mawa	0.17	0.89	Average
37	Meghna Bridge	0.31	0.42	Poor
38	Mirpur	0.23	0.76	Not Satisfactory
39	Mohadebpur	0.60	0.57	Very Poor
40	Moulvibazar	0.66	0.38	Very Poor
41	Mymensingh	0.38	0.84	Poor
42	Naogaon	0.68	0.43	Very Poor
43	Narayanganj	0.34	0.49	Poor
44	Narsingdi	0.21	0.83	Not Satisfactory
45	Nayarhat	0.22	0.93	Not Satisfactory
46	Porabari	0.28	0.90	Not Satisfactory
47	Rajshahi	0.30	0.92	Not Satisfactory
48	Rekabi-Bazar	0.32	0.52	Poor
49	Sariakandi	0.31	0.89	Poor
50	Serajganj	0.27	0.90	Not Satisfactory
51	Sheola	0.69	0.61	Very Poor
52	Sherpur-Sylhet	0.28	0.81	Not Satisfactory
53	Shimulbari	0.49	0.68	Very Poor
54	Singra	0.23	0.85	Not Satisfactory
55	Sunamganj	0.37	0.75	Poor
56	Sureshswar	0.35	0.30	Poor
57	Sylhet	0.60	0.73	Very Poor
58	Talbaria	0.17	0.90	Average
59	Taraghat	0.19	0.97	Average
60	Tongi	0.20	0.83	Average

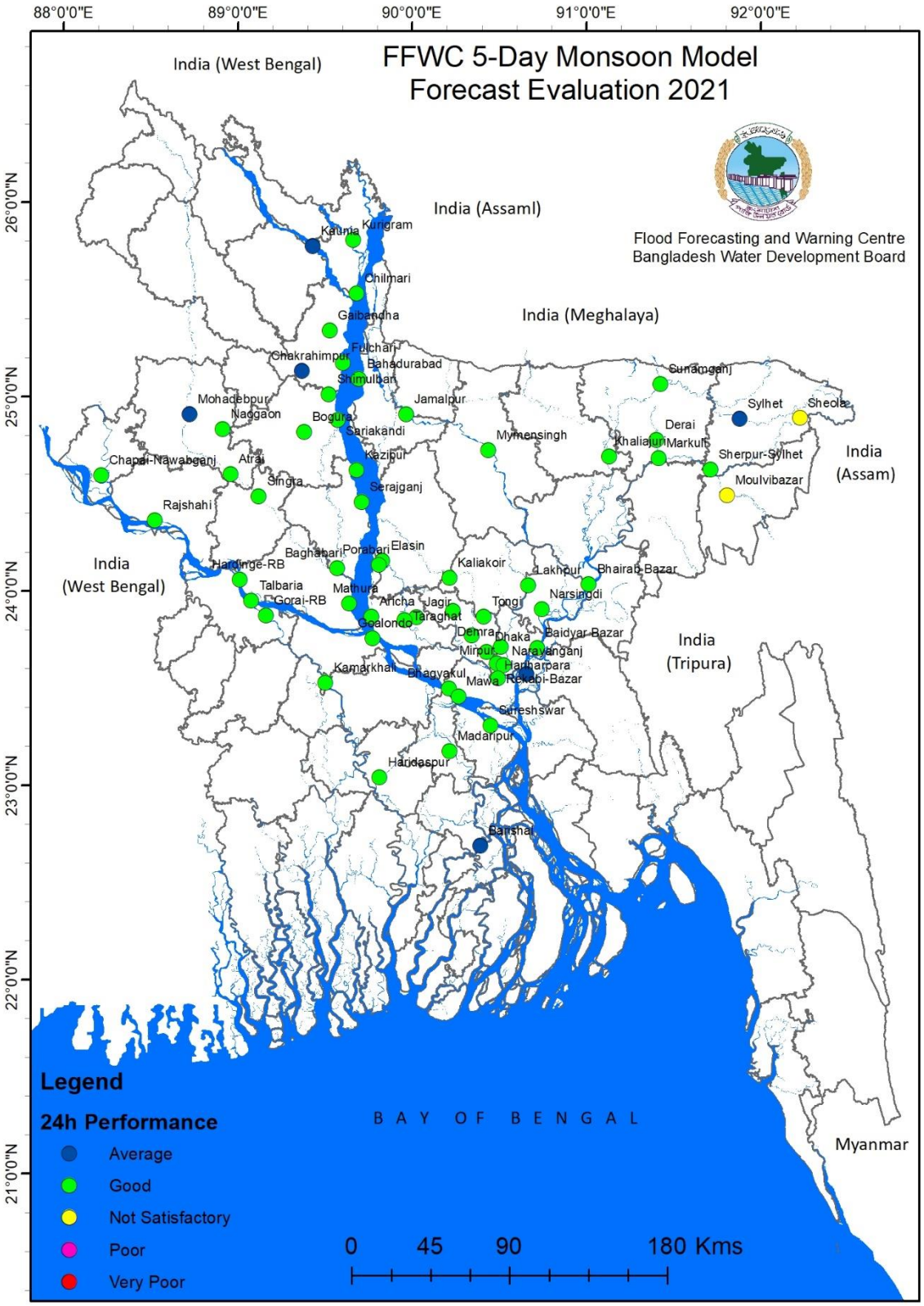


Figure 4.1 : 24-hrs Forecast Evaluation (Year, 2021)

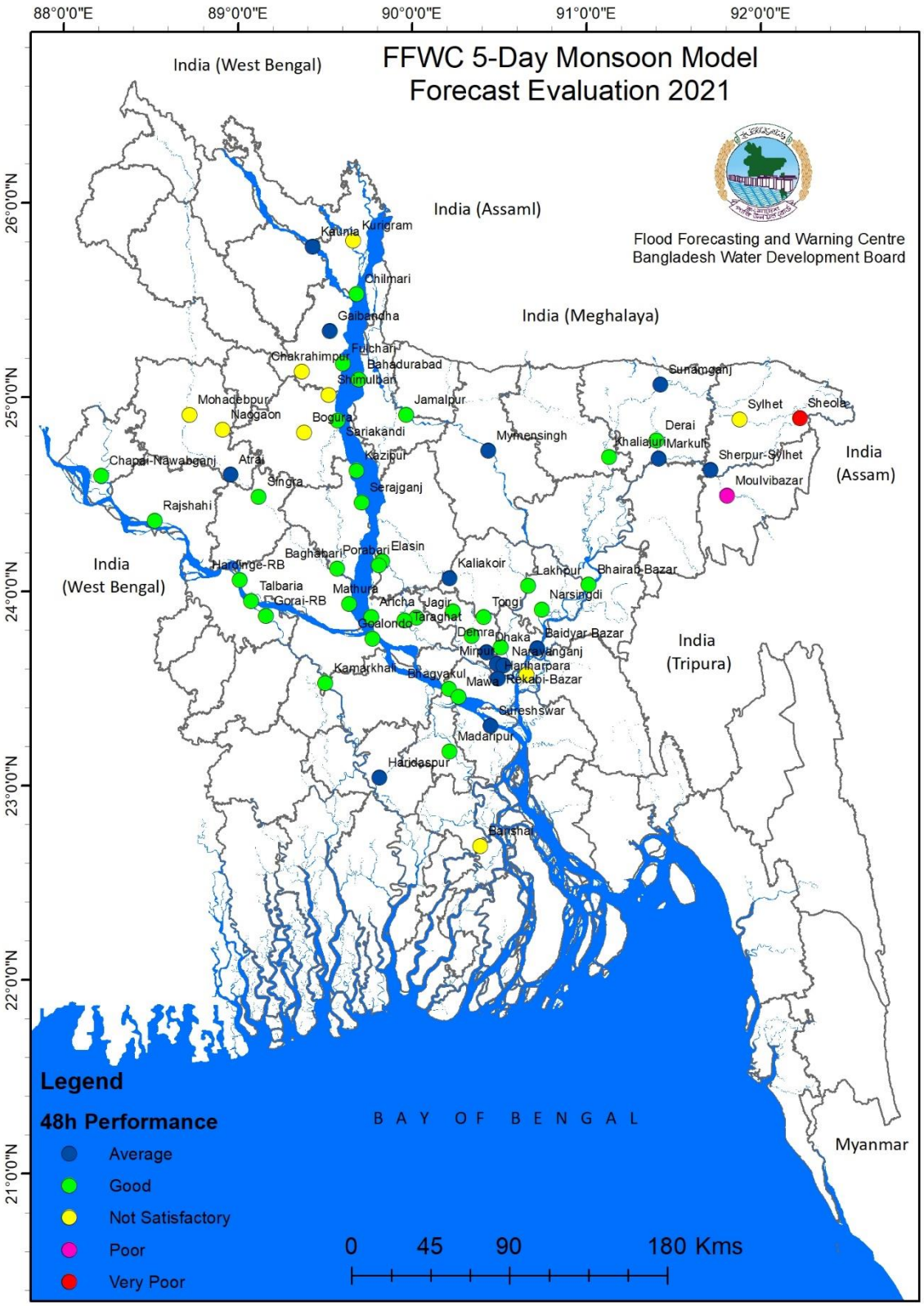


Figure 4.2 : 48-hrs Forecast Evaluation (Year, 2021)

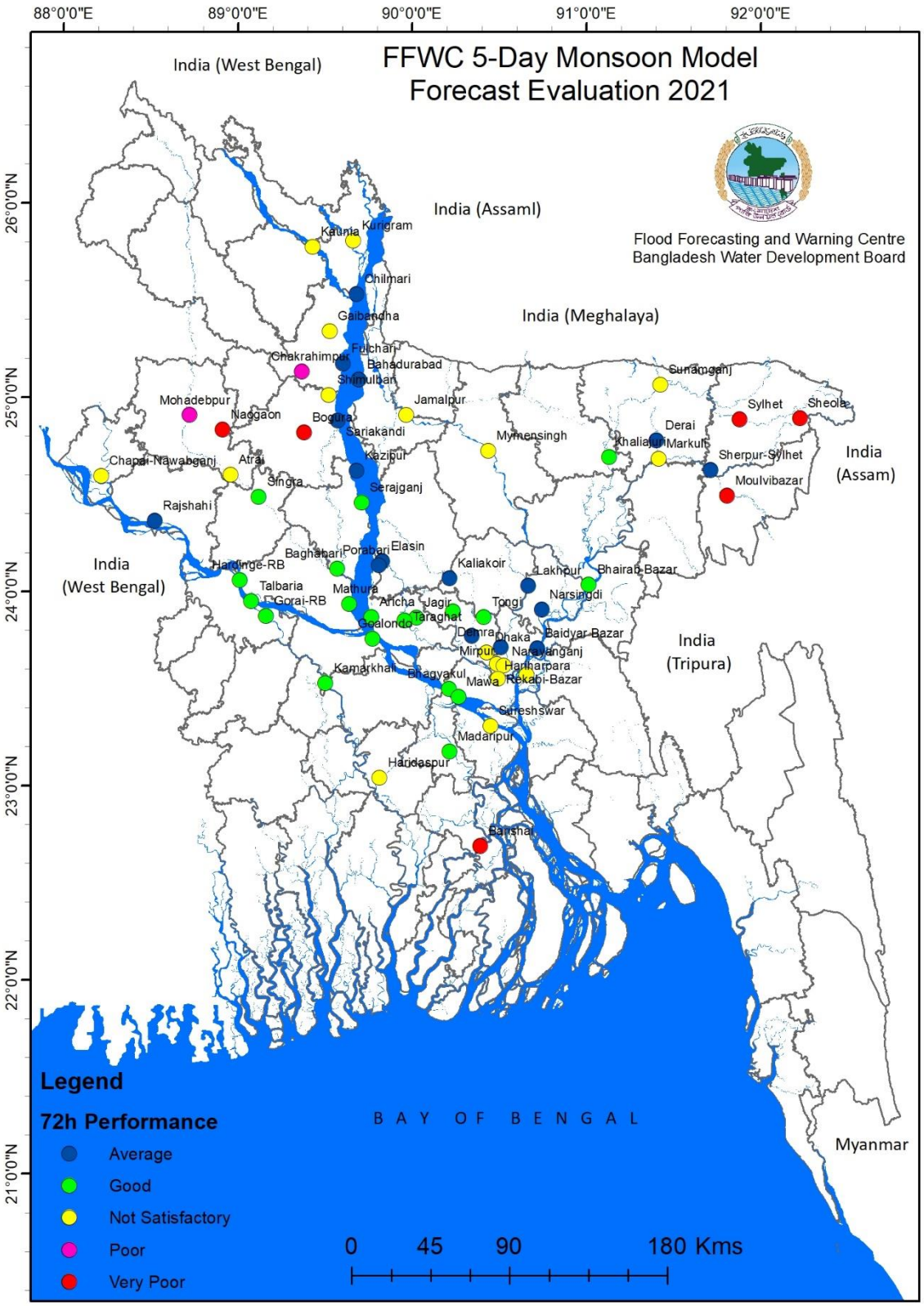


Figure 4.3 : 72-hrs Forecast Evaluation (Year, 2021)

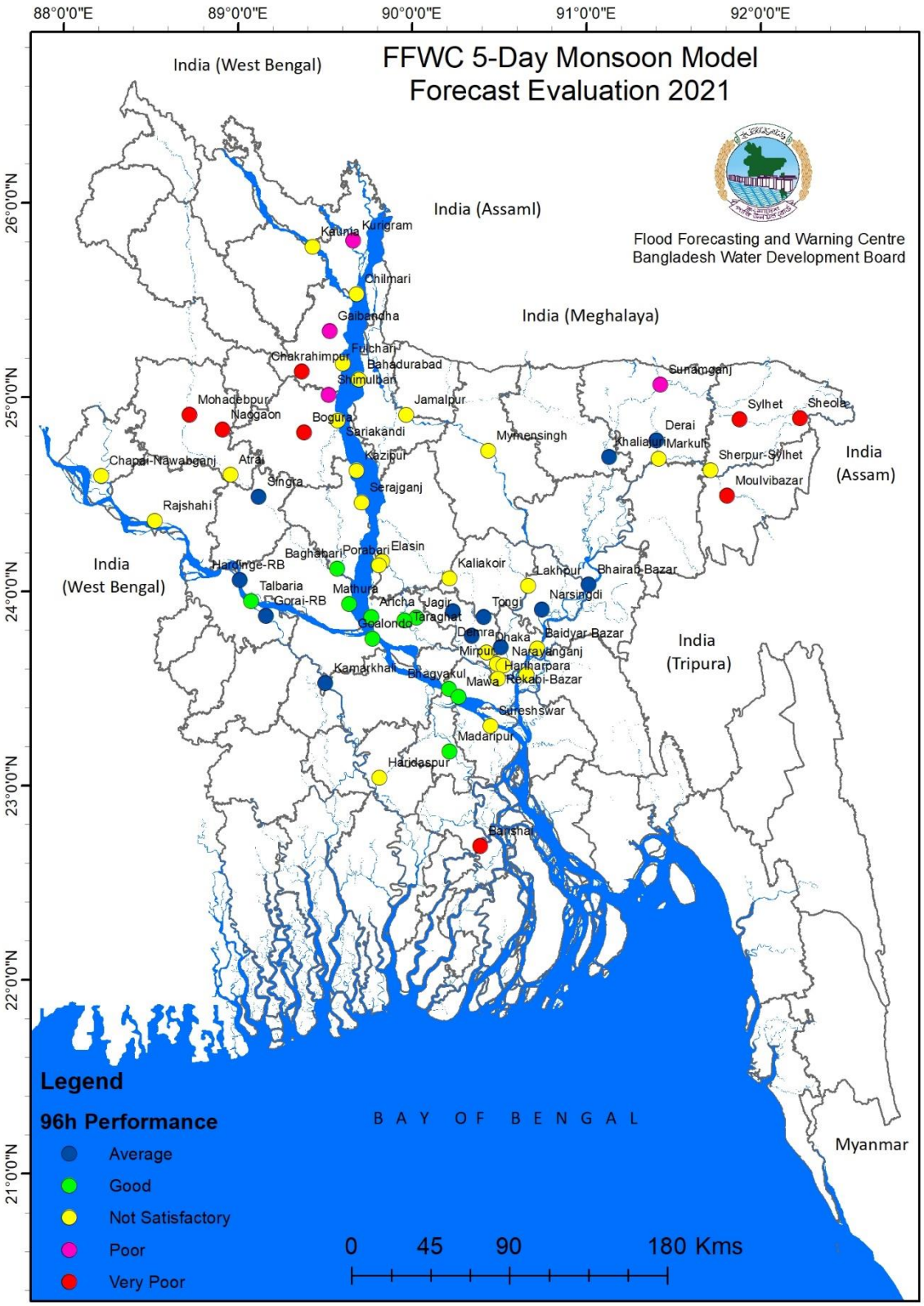


Figure 4.4 : 96-hrs Forecast Evaluation (Year, 2021)

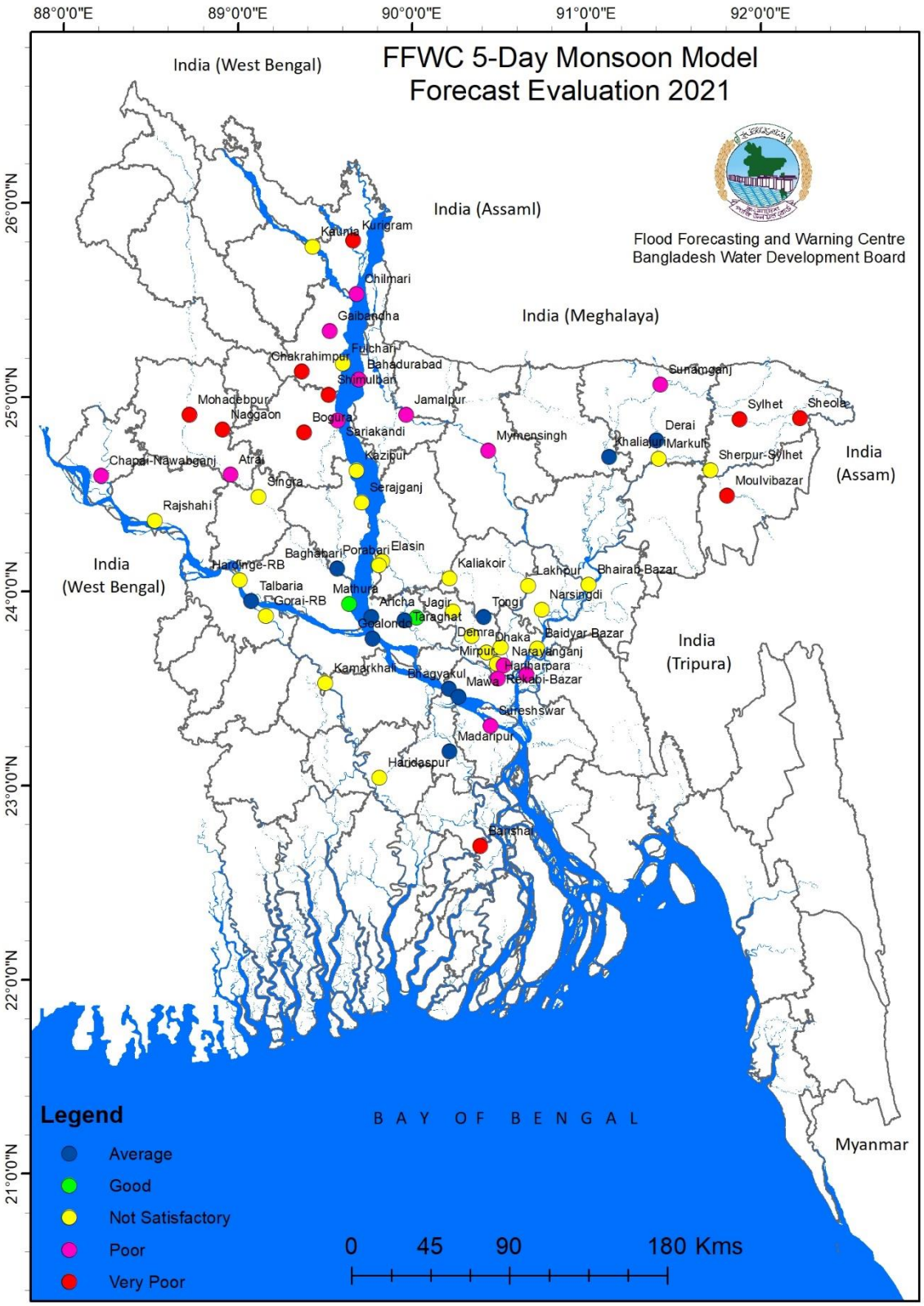


Figure 4.5 : 120-hrs Forecast Evaluation (Year, 2021)

4.3.2 Medium Range (upto 10-days) Probabilistic Forecast Performance

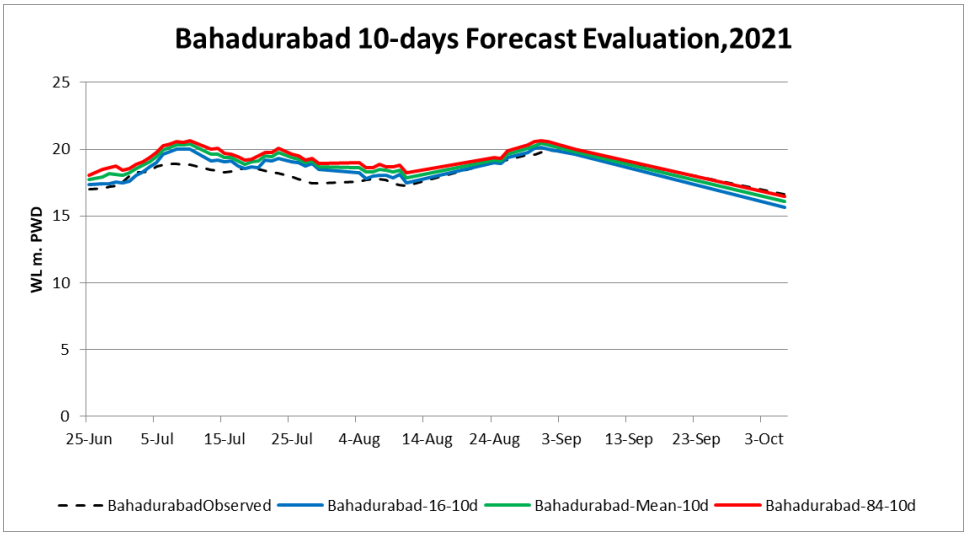
Climate Forecast Application Network (CFAN) utilizes ECMWF weather prediction data in their model to generate 51 sets of ensemble discharge forecasts data on the Brahmaputra at Bahadurabad and on the Ganges at Hardinge-Bridge in Bangladesh. The updated FFWC model was taken for customization for real-time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

In addition to existing 24, 48, 72, 96 & 120 hrs deterministic forecast, CFAN model generates medium range 10 days lead-time probabilistic forecasts for mean, upper bound and lower bound WL at 37 locations. The Mean Water Level forecasts are made from the mean discharge and the mean rainfall forecast of all 51-ensemble series. The Upper bound and Lower bound levels correspond to +1 standard deviation from the mean and -1 standard deviation from the mean respectively.

The statistics of forecast performance based on the MAE, RMSE and r^2 at different time-scale up to 10 days for the 37 number of stations under FFWC system have been presented through below:

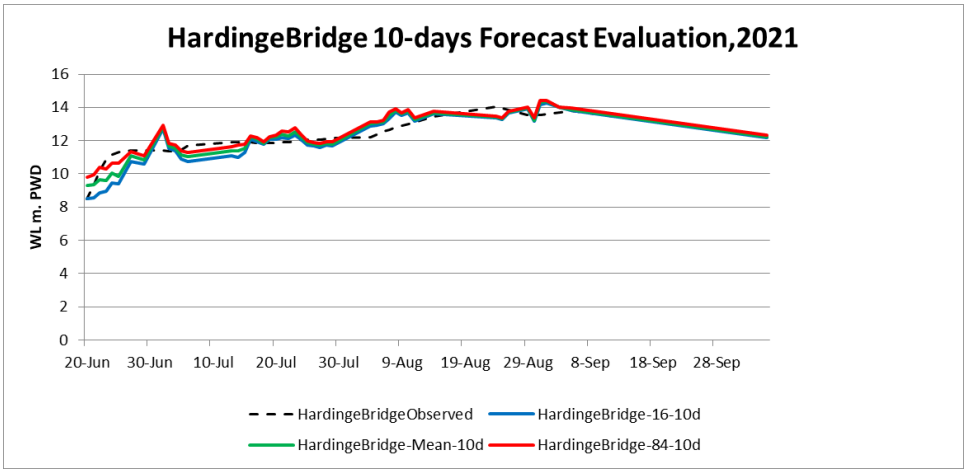
<u>10 Days Evaluation of Bahadurabad:</u>

	MAE	RMSE	r^2
Bahadurabad-16-7d	0.353829787	0.437626577	0.833325377
Bahadurabad-Mean-7d	0.504042553	0.586230294	0.833787182
Bahadurabad-84-7d	0.700851064	0.783521782	0.823946593



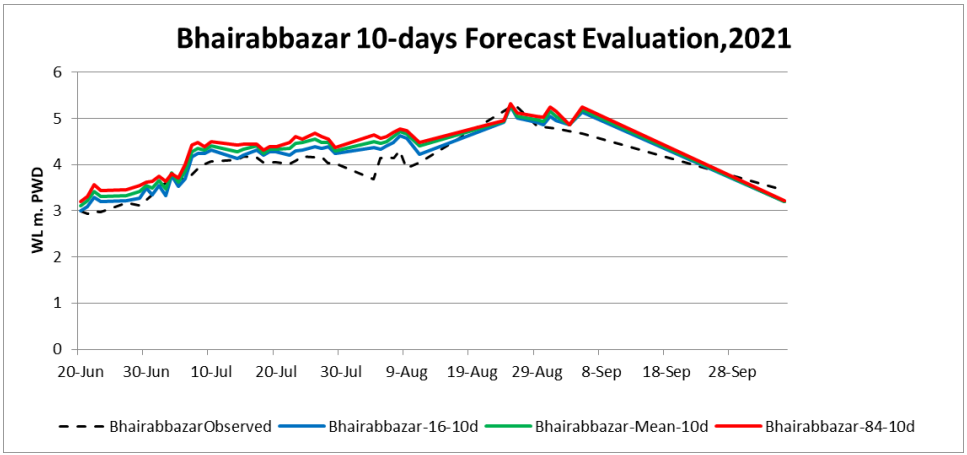
10 Days Evaluation of Hardinge-Bridge:

	MAE	RMSE	r^2
HardingeBridge-16-10d	0.550612245	0.712205542	0.814617331
HardingeBridge-Mean-10d	0.501428571	0.603559171	0.804550641
HardingeBridge-84-10d	0.479183673	0.586501214	0.804771053



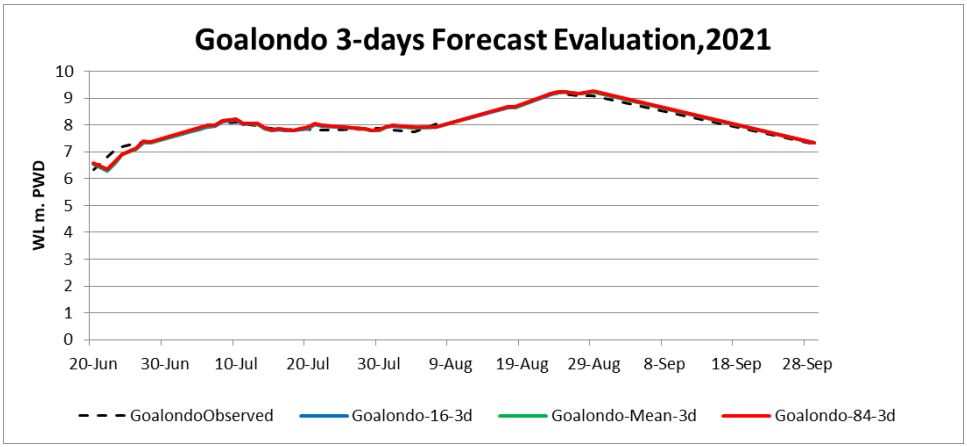
10 Days Evaluation of Bhairb Bazar:

	MAE	RMSE	r^2
Bhairabbazar-16-10d	0.210638298	0.254834114	0.892397099
Bhairabbazar-Mean-10d	0.294042553	0.332258551	0.877455344
Bhairabbazar-84-10d	0.372553191	0.413832631	0.857911118



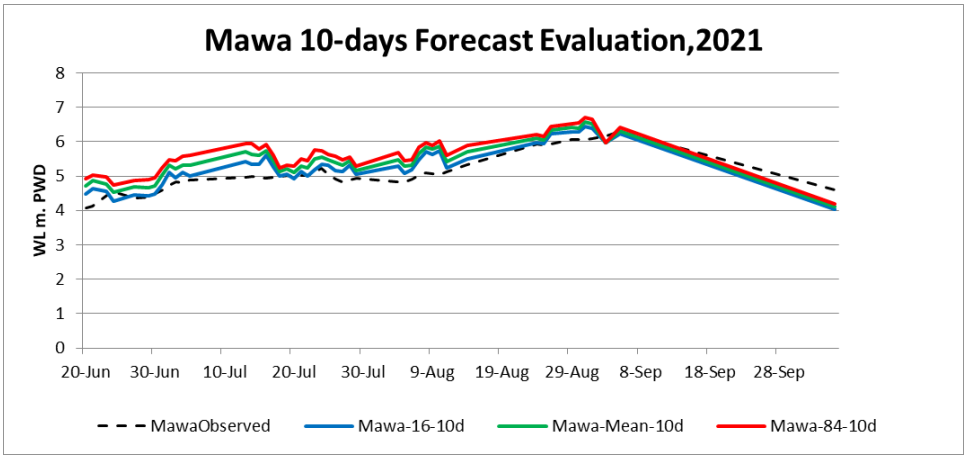
10 Days Evaluation of Goalondo:

	MAE	RMSE	r^2
Goalondo-16-3d	0.104324324	0.157222514	0.954324327
Goalondo-Mean-3d	0.105405405	0.154377565	0.955153291
Goalondo-84-3d	0.107837838	0.152271095	0.955609802



10 Days Evaluation of Mawa:

	MAE	RMSE	r^2
Mawa-16-10d	0.258958333	0.319227583	0.824533466
Mawa-Mean-10d	0.420625	0.468408209	0.788257098
Mawa-84-10d	0.585208333	0.627599594	0.73669659



CHAPTER 5 : INUNDATION STATUS

Flood inundation is a phenomenon that results from overtopping or overflowing of flood water to the river banks. In our country, this situation at a particular place occurs when the river water level exceeds the danger level of that particular place. During normal flooding, it is expected and observed that flood plain along the major rivers becomes inundated and after that flood water progressively enters the adjacent residential and commercial areas depending upon the severity of flood. During the pre-monsoon 2021, no flash flooding occurred in the Upper Meghna basin and also the Haor basin therein. In the monsoon 2021, the country as a whole experienced moderate flooding.

In monsoon 2021, the Brahmaputra basin of the country experienced moderate flooding of short to medium duration at low lying places. The Teesta river at Dalia exceeded its recorded highest water levels this year again after 2020. Along the Padma river in the Ganges basin, the flood was also moderate and of medium to long duration specially at confluences and lower basin parts. However, the Ganges river this year did not cross DL at any monitoring stations. The Meghna basin experienced moderate flooding with multiple flashy peaks, the duration of which was short. Flash flooding also occurred at some places of the South Eastern Hill basin with small durations.

This monsoon the flood events were mostly concentrated starting from the second half of August till first half of September. Simultaneous rise of all the major rivers of the country created flooding of medium duration in Brahmaputra and Ganges river basins during this period, which persisted longer at confluences and lower parts of the Ganges basin. The South-Eastern Hill and Meghna basins were affected for small durations during the monsoon but with overall greater intensity in July and August respectively. As a whole, the flooding occurred in moderate scale the duration of which varied from short to medium at low lying places of Northern, North-Western, North-Central, North-Eastern and South-Eastern regions of the country. Flooding persisted in the Central, South-Western and South-Central coastal parts of the country for longer periods due to upstream water rush and tidal influences. In total, 33% of the country got flood inundated this year.

5.1 BASINWISE INUNDATION STATUS

Brahmaputra Basin:

Out of 31 WL monitoring stations in the Brahmaputra basin, at 16 stations WL crossed and remained over their respective DLs in 2021. Flood in the Brahmaputra-Jamuna river this year came in single spell between 27th August – 9th September.

The stations that crossed and remained over DLs during these periods are: Dharala at Kurigram for 14 days peaking 63 cm above DL; Teesta at Dalia for 13 days peaking 70 cm above DL (15 cm higher than previously recorded highest) and at Kaunia peaking 34 cm above DL; Ghagot at Gaibandha for 4 days peaking 20 cm above DL; Karatoa at

Chakrahimpur remained below DL in 2021; Brahmaputra at Noonkhawa reached upto DL but did not go over it and at Chilmari for it remained over DL for 10 days peaking 51 cm above DL.

Flood wave in Teesta, the major tributary of the Brahmaputra-Jamuna river, consisted of eleven short duration peaks crossing the DL and flowed above DL for 13 days in total. The Teesta at Dalia crossed RHWL again after 2020 on 20th October 2021. This year it went 70cm above DL reaching at WL 53.3 mPWD. At Kaunia, WL croseed DL once on 21st October reaching at 29.54 mPWD, 34cm above DL (29.2 mPWD).

As a result of flood events, low-lying areas of Kurigram, Lalmonirhat, Nilphamari, Rangpur, Gaibandha, Bogra, Sirajganj, Natore, Pabna, Jamalpur, Tangail, Manikganj, Dhaka and Narayanganj districts in the Northern, North-Western and North-Central regions of the country experienced moderate flooding of short to long duration during 2021. The basin as a whole experienced moderate flooding throughout the monsoon.

Ganges Basin:

In the Ganges basin, out of 30 WL monitoring stations, 7 stations flowed above DL during 2021. Flood in the Padma river this year came in single spell between 17th August to 13th September. 3 stations of Padma river crossed the DL in this period, they are Goalondo, Bhagyakul and Mawa. Goalondo remained 25 days above the DL and peaked at 9.43m which is 78cm above the DL. Bhgyakul remained above DL for 7 days, peaking at 6.58m, 28cm above the DL and Sureswar remained above DL for 11 days, peaking at 5.25 which is 80cm above the DL.

As a result of these events, low-lying areas of Dinajpur, Thakurgaon, Ranpur, Naogaon Rajbari, Faridpur, Manikganj, Dhaka, Munshiganj, Madaripur, Shariatpur district of central region of the country experienced moderate flooding of medium to long duration during 2021.

Among the other rivers in Ganges basin, the Sakra and the Kirtonkhola faced short period flood. Ichamoti at Sakra remained above DL for 2 days, peaking at 3.96m, 37cm above the DL and Barisal at Kirtonkhola remained 9 days above the DL, peaking 2.70m which is 15cm above DL. Khulna at Passure crossed the DL several times due to tidal effect. As a result Khulna, Bagerhat, Barisal, Jhalakathi, Patuakhali, Barguna and Pirojpur districts in the South-Western and South-Central regions of the country experienced low flooding of short to long duration during 2021. The basin as a whole experienced normal flooding throughout the monsoon.

Meghna Basin:

During the pre-monsoon (15 March - 15 May), out of 36 WL monitoring stations in the Meghna basin, all stations flowed below respective PMDLs in 2021. No flash flooding occurred in the Upper Meghna basin and also the Haor basin therein.

8 out of 26 water level monitoring stations in the basin crossed danger levels during monsoon 2021. Flood in the basin this year came in a single peak in the Sarigowain, Jadukata, Someswari, Bhugai, Kangsha and Khowai rivers during 29th June-1st July. Flood wave with comparatively greater intensity came in the Surma river during 7th and 14-15th August, while the Kushiyara river flowed below DL.

The stations that crossed and remained over DLs during these periods are: Surma at Kanaighat and Sunamganj for 3 and 1 days peaking 29 and 16 cm above DL respectively, Sarigowai at Sarighat for 2 days peaking 26 cm above DL, Jadukata at Lorergarh for 2 days peaking 54 cm above DL, Someswari at Durgapur for 1 day peaking 11 cm above DL, Bhugai at Nakuagaon for 1 day peaking 69 cm above DL, Kangsha at Jariajanjail for 1 day peaking 3 cm above DL and Khowai at Ballah for 1 day peaking 82 cm above DL.

As a result of these events, low-lying areas of Sylhet, Sunamganj, Netrokona, Habiganj and Sherpur districts in the Nouth-Eastern region of the country experienced moderate flooding but all of short duration in 2021.

South Eastern Hill Basin:

In the South Eastern Hill basin, 4 out of 9 water level monitoring stations crossed danger levels during monsoon 2021. Flood in the basin this year came in a single peak in the Sangu and the Matamuhuri river at the end of July while in 5 small peaks by Muhuri river on 6th June, 1st July, between 25th-26th August, between 5th-6th September and on 16th September.

The stations that crossed and remained over DLs during these periods are: Muhuri at Parshuram for 7 days peaking 134 cm above DL, Sangu at Bandarban for 1 day peaking at 1cm above DL and Matamuhuri at Lama and Chiringa for 3 and 2 days peaking 162 cm and 41 cm above DL respectively.

As a result of these events, low-lying areas of Feni, Bandarban and Cox's Bazar districts in the South-Eastern region of the country experienced moderate to severe flash flooding but all of short duration in 2021. The whole basin experienced flooding during the months of July which induced landslides in Bandarban and Cox's Bazar districts in last weeks of July. The river Muhuri experienced short duration flash flooding during June-September.

5.2 COUNTRYWIDE INUNDATION 2021

Like other previous years, this year also FFWC generated model based nationwide inundation map. Flood map has been generated from Flood Forecasting Model output result files found from MIKE 11 FF Rainfall-Runoff and Hydrodynamic modeling simulation using customized MIKE 11 GIS model as a routine activity during monsoon period. Here, Digital Elevation Model (DEM) having 300 m spatial resolution collected from Survey of Bangladesh (SoB) long ago is used with MIKE 11 GIS tool. This is to mention that flood peaks arrived several times in 2021 which was attenuated during the

second half of October. It was observed from monitoring that the Brahmaputra river attained its monsoon peak on 02nd September, the Jamuna on 3rd September, the Padma on 21st August and the Upper Meghna river on 7th September. From areal coverage perspective, 2nd September 2021, was chosen as the peak time of monsoon on which FFWC observed total number of 19 flood monitoring stations above danger levels.

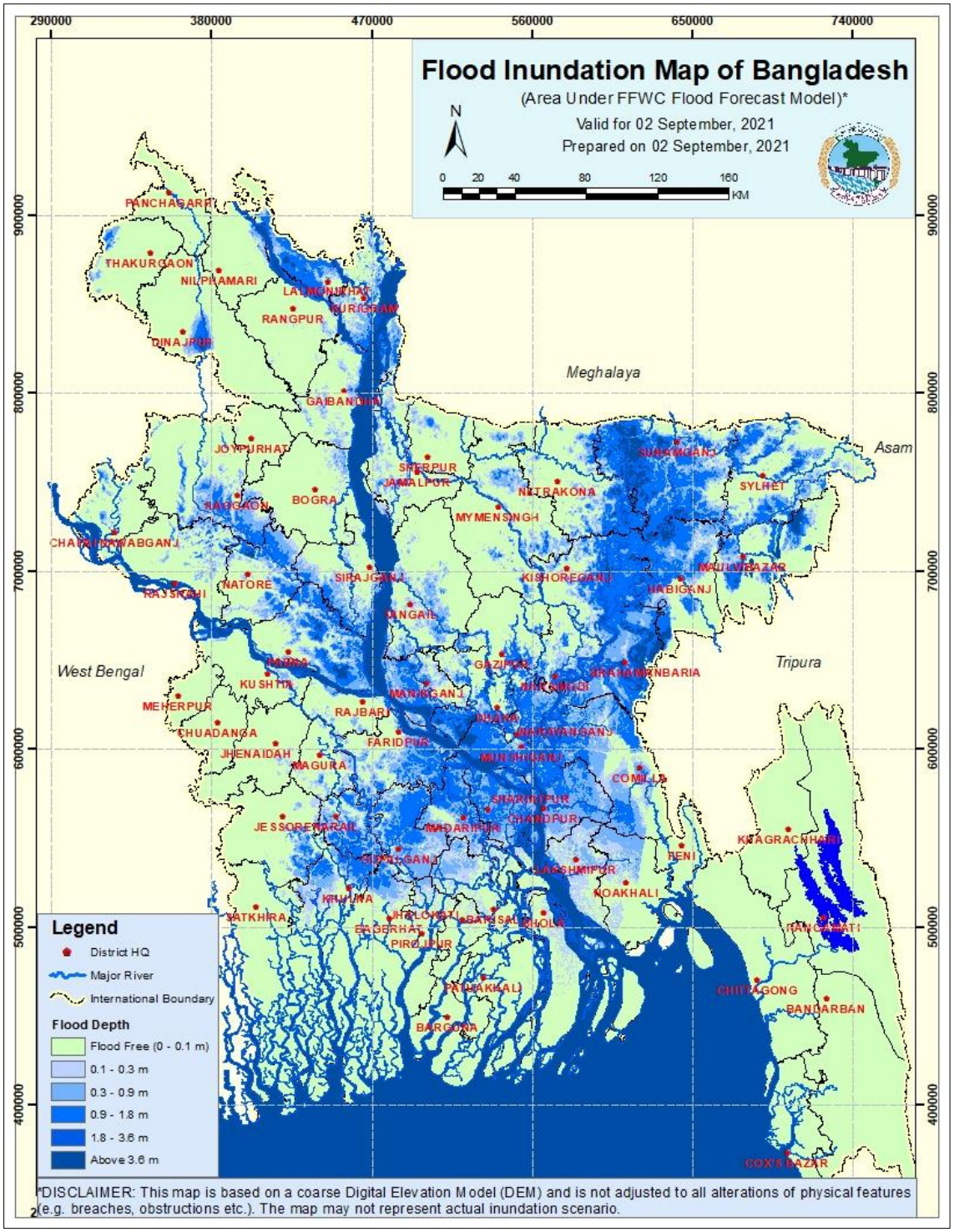


Figure 5.1 : Flood Inundation Map of Bangladesh (on 2nd September, 2021)

Figure 5.1 shows the observed inundation map for 2nd September and then 24, 48, 72, 96 and 120 hours forecasted inundation maps on the day from figures 5.2 to 5.6 respectively.

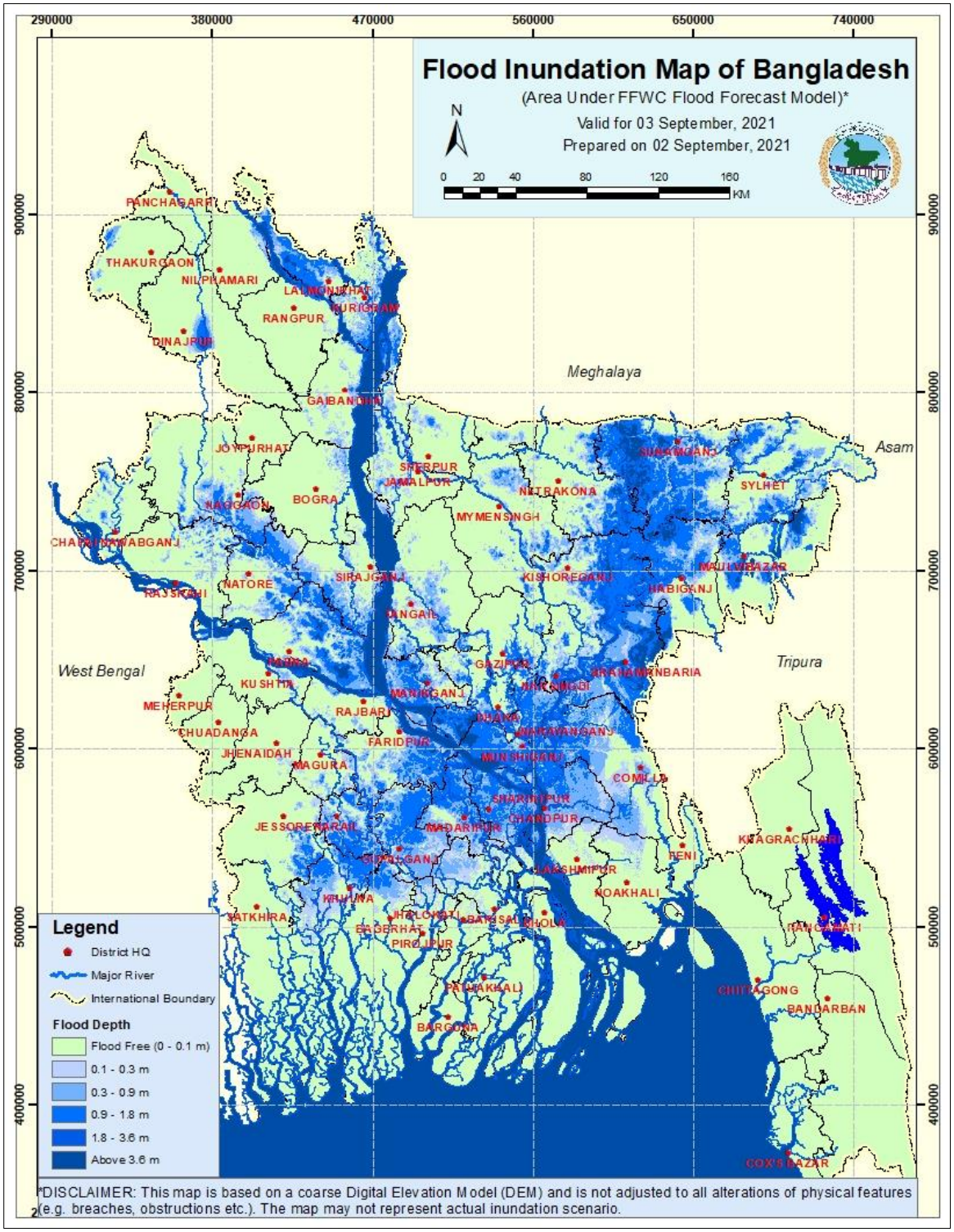


Figure 5.2 : Flood Inundation Map of Bangladesh (24hr Forecast based on 2nd September, 2021)

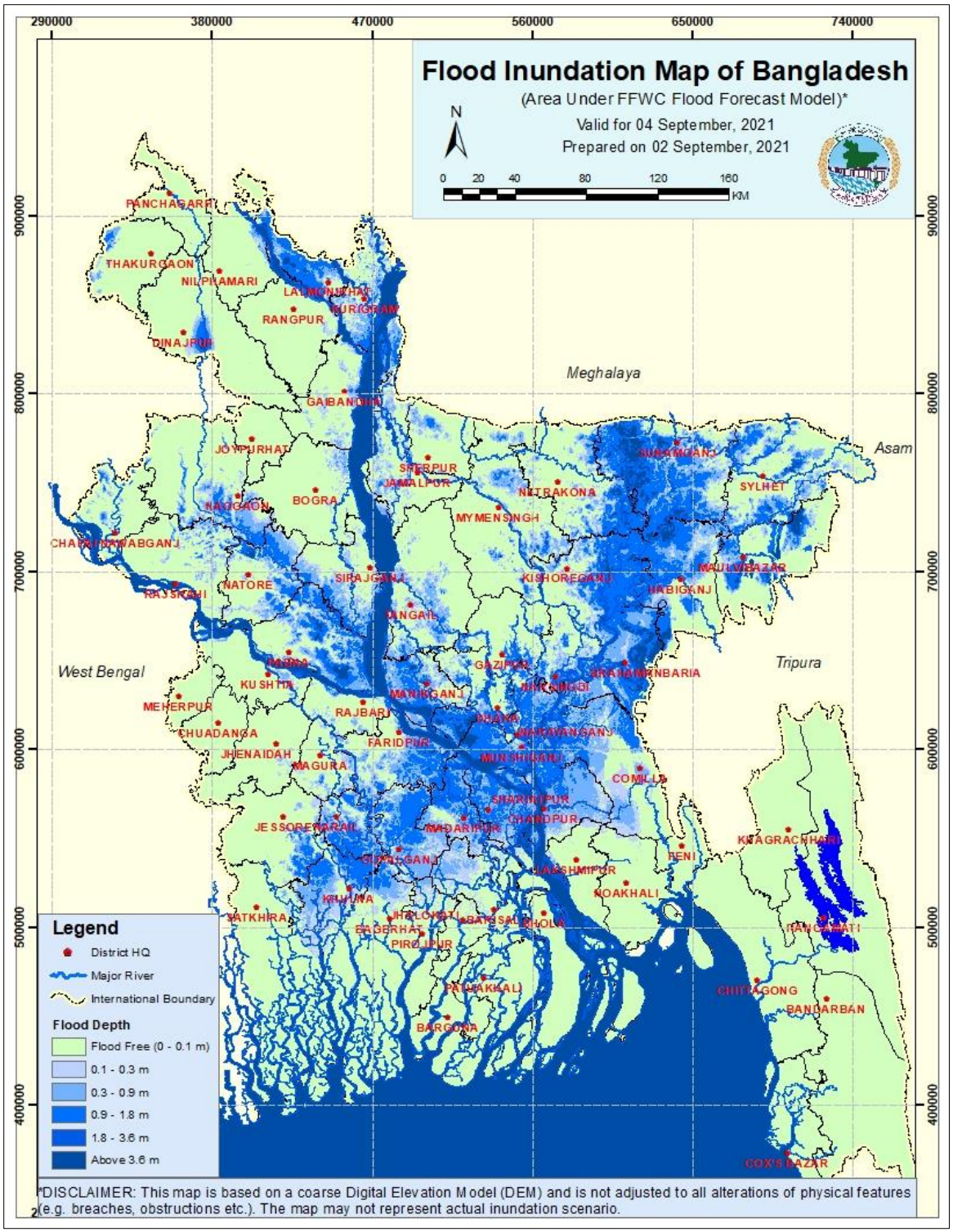


Figure 5.3 : Flood Inundation Map of Bangladesh (48hr Forecast based on 2nd September, 2021)

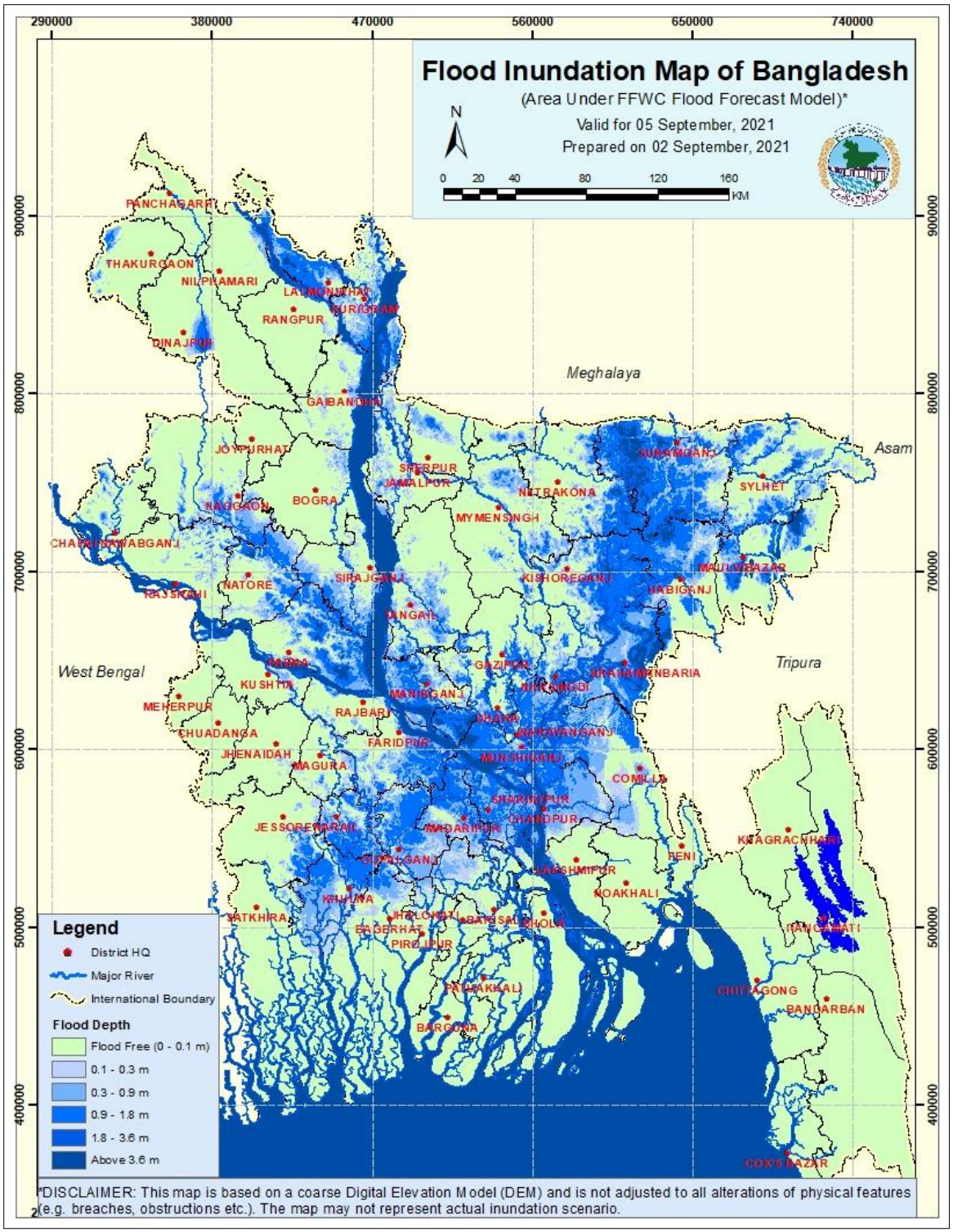


Figure 5.4 : Flood Inundation Map of Bangladesh (72hr Forecast based on 2nd September, 2021)

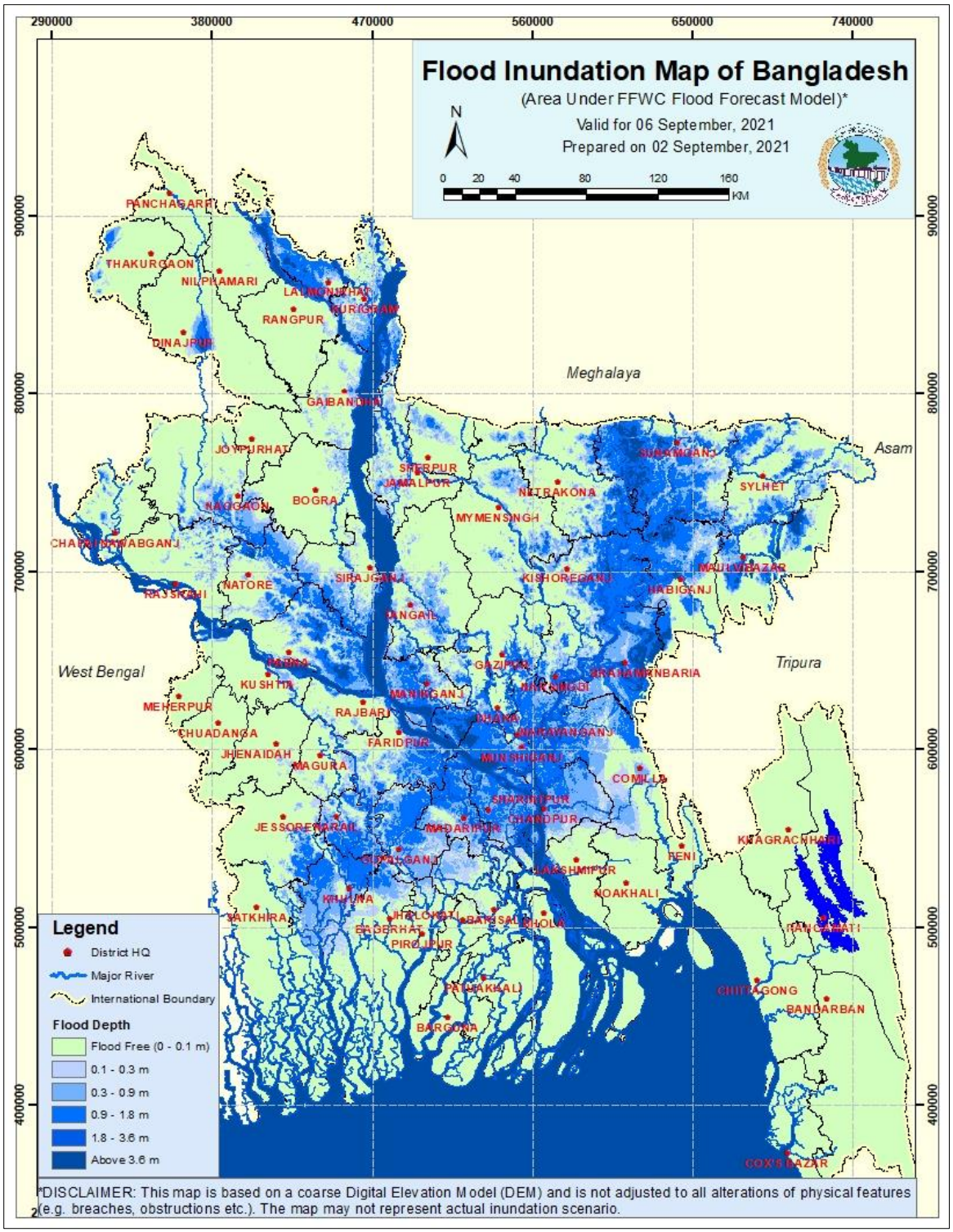


Figure 5.5 : Flood Inundation Map of Bangladesh (96hr Forecast based on 2nd September, 2021)

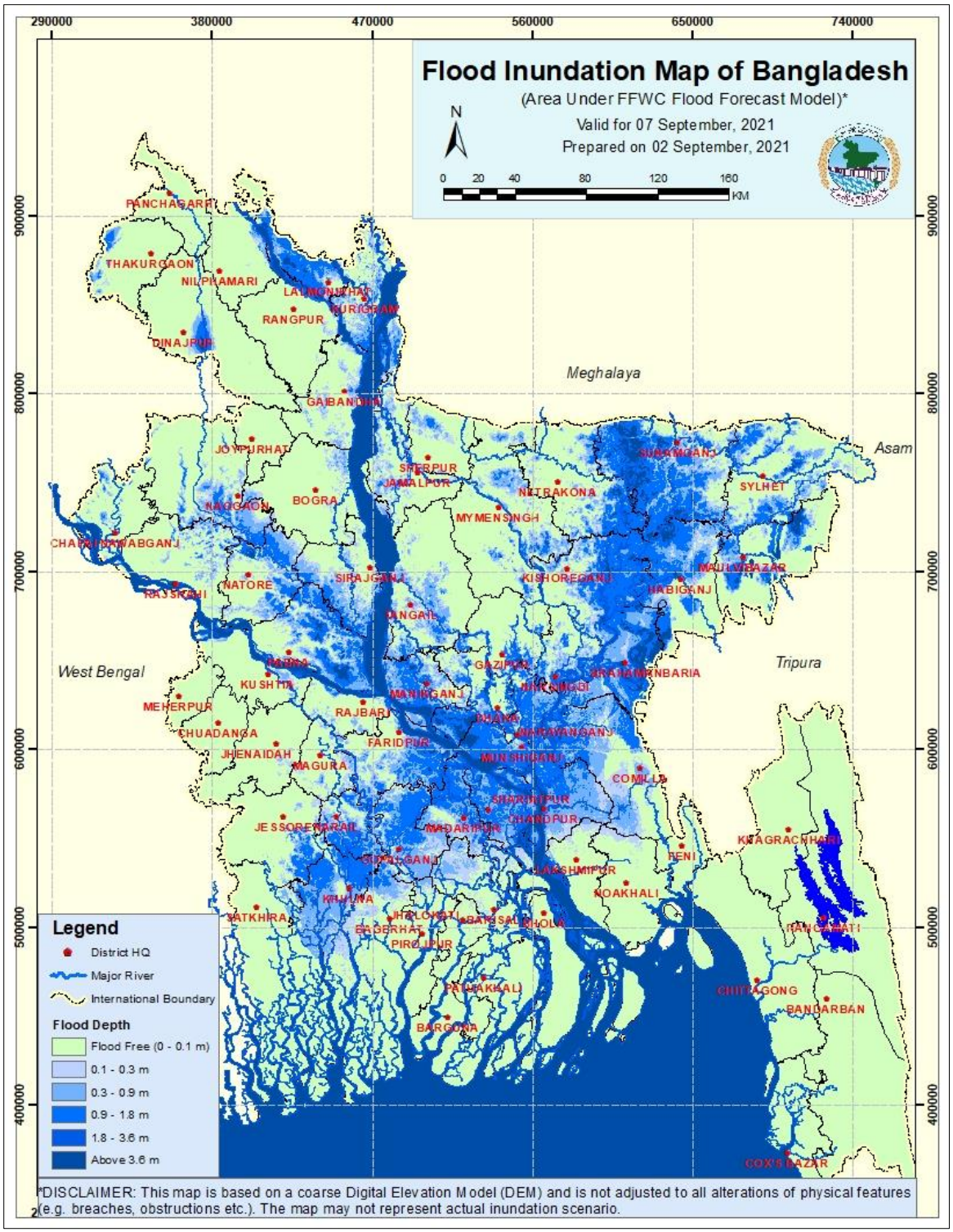


Figure 5.6 : Flood Inundation Map of Bangladesh (120hr Forecast Based on 2nd September, 2021)

The map on 2nd September (Fig 5.1) captures the inundation scenario of the country during monsoon 2021, except relatively small inundations at some places of the North-Eastern, South-Eastern, Northern and North-Western region of the country due to isolated and short-term flood events. Inundated area based on this map is around 48,698 sq-km which is 33% of the country area and is the maximum inundated area found in this flood season. This area excludes the permanent water bodies i.e. perennial streams, lakes, ponds etc. The

calculation of permanent water bodies is also a crucial issue. Some literature reviews and remote sensing-based analysis depict that there are approximately 6-8% of permanent water bodies existing in Bangladesh.

Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country due to coarse resolution DEM. A detail, authentic and finer resolution DEM shall significantly improve generation of inundation map even in the local level.

One of the limitations of this map is that none of the flood map output has been verified and so some obvious errors have been observed. One method currently in practice in operational flood forecasting is the verification of inundation map using satellite imagery. FFWC flood inundation map for peak condition of 2021 was verified with Synthetic Aperture Radar (SAR) based high resolution (10 m) satellite image from Sentinel-1 by European Space Agency (ESA). Radar based imagery are unsusceptible to cloud covers but susceptible to dense forests. So, it would provide nearly accurate flooded area of the country, but only to be underestimated in South-Western mangrove forest (the Sundarban) and South-Eastern hilly forest areas. Because of non-availability of countrywide daily product, Sentinel-1 data from 27th August to 4th September were used to cover the whole country during peak condition and compared with the FFWC flood map of 2nd September, 2021 (Fig 5.7).

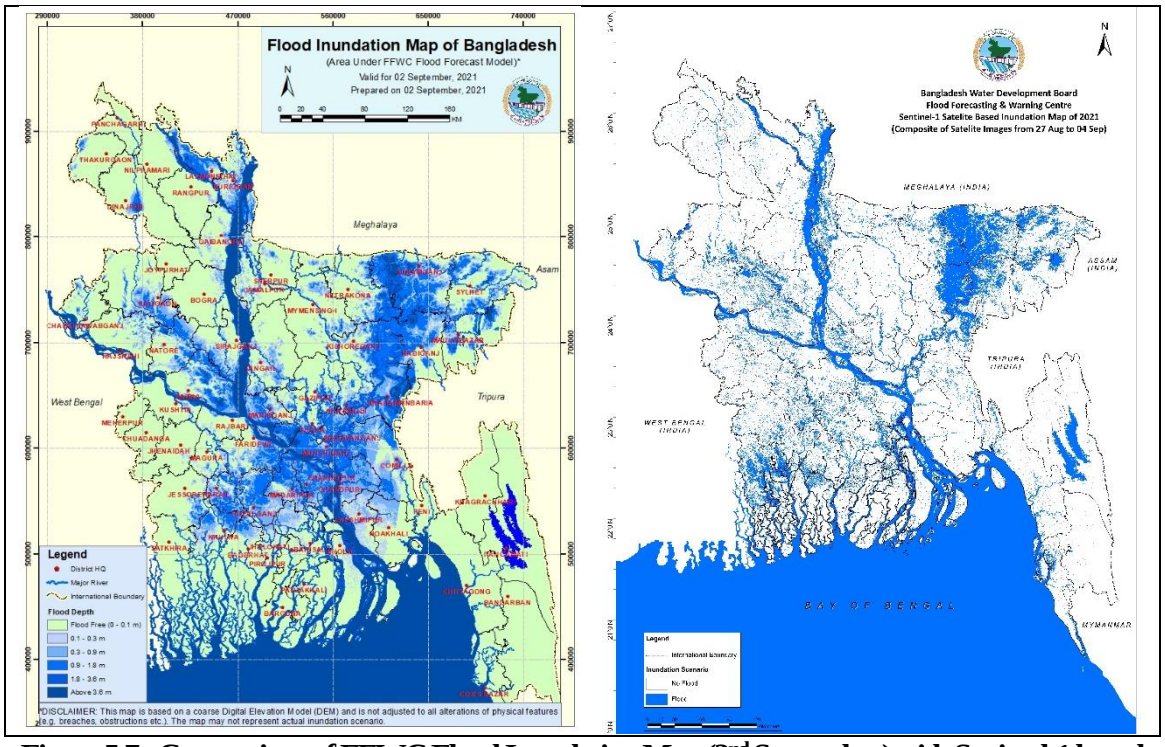


Figure 5.7 : Comparison of FFWC Flood Inundation Map (2nd September) with Senitnel-1 based Inundation Map (between 27th August – 4th September 2021)

Both of the maps are in good agreement in detecting inundated areas in North-Eastern, North-Central and Central-Western parts of the country. However, there are spatial variability in the Northern and Central regions. FFWC's present flood model domain does not cover coastal parts and the South-Eastern region, so model result is not appropriate for inundation analysis or verification of that part. The variability in Northern and Central parts may be an implication of coarse resolution of the DEM along with change in land use.

FFWC MIKE 11 FF Flood super model was developed decade ago. After that, catchment characteristics, river morphology and climatology had changed significantly which were not incorporated in the model. That's why current inundation map explores underestimation as well as overestimation in some places. A total updating of model set up along with latest version of MIKE software are needed to overcome this problem.

CHAPTER 6 : SPECIAL EVENTS OF 2021 FLOOD

6.1 LATE MONSOON FLOOD OF THE TEESTA BASIN

On October 20 2021, a catastrophic flood occurred in the Teesta basin in Northern Bangladesh. The main reason for this flood is the heavy rains that occurred in Gangtok, Jalpaiguri and Darjeeling in the upstream of Bangladesh on 19-20 October. In the monsoon cycle, the country is usually flood-free in the first half of October. As such, the heavy flooding in the Teesta basin in the latter half of October (October 20) is somewhat unusual, an implicit example of climate change.

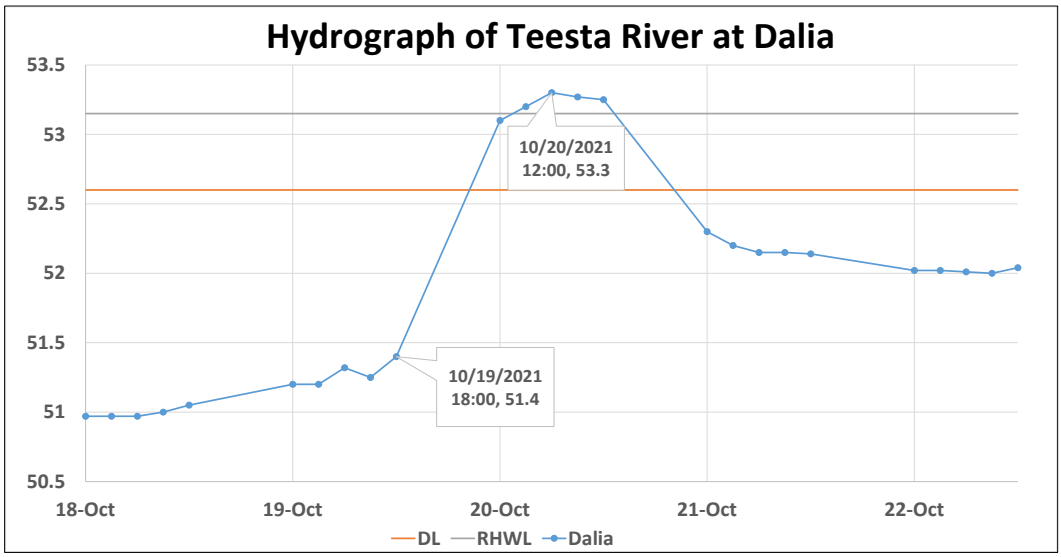


Figure 6.1: Hydrograph of Teesta River at Dalia during 18-22 October 2021

Observing the water level hydrograph of Dalia Point of Teesta River (Fig 6.1), it can be seen that the water level of Teesta River started to rise from evening on October 19 and the water level rose by about 2 meters till noon on 20 October.

Table 6.3 : Rainfall Scenario of the Upper Teesta basin at Gangtok, Darjeeling and Jalpaiguri during 18-22 October 2021

Date	Rainfall (mm)		
	Gangtok	Darjeeling	Jalpaiguri
18-Oct-21	0	0	0
19-Oct-21	101	167	20
20-Oct-21	130	234	151
21-Oct-21	4	1	13
22-Oct-21	12	4	0.4

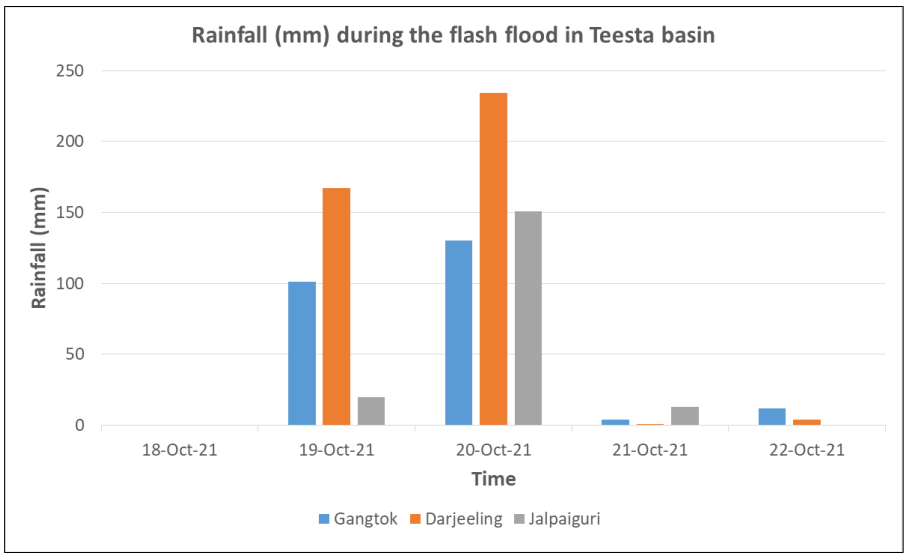


Figure 6.2: Rainfall Scenario of the Upper Teesta basin at Gangtok, Darjeeling and Jalpaiguri during 18-22 October 2021

During the flood, the water level at Dalia was recorded 53.30 mPWD at 12:00 pm which was 70 cm above the danger level (52.60 mPWD) at this point. It was also the recorded highest water level for this point breaking the previous record 53.15 mPWD. The Teesta danger level near the flood bypass is 53.95 mPWD. During the flood, the highest water level recorded near the flood bypass was 54.12 mPWD at 8:00 AM on 20 October, which was 17 cm above the danger level. On site inspection, it can be seen that damages near the flood bypass and its adjacent surrounding areas have increased due to long stay of water level above the danger level of 70 cm.

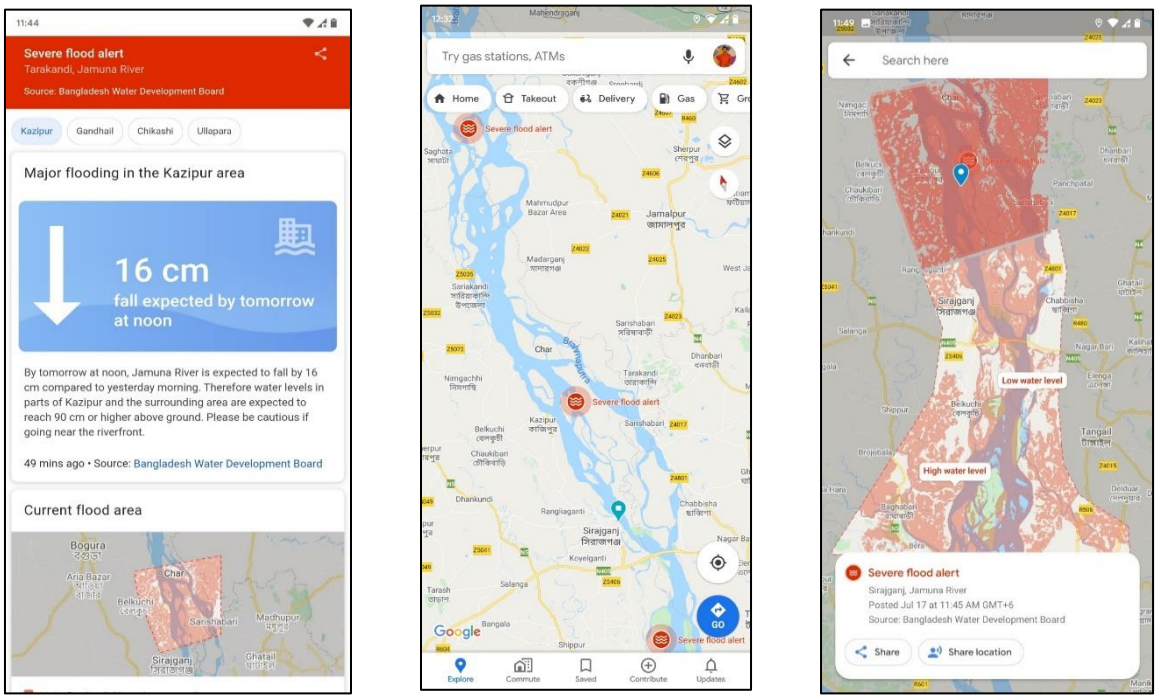
Bangladesh Water Development Board's Flood Forecasting and Warning Center provides necessary forecasts for seasonal and flash floods. Exchange of water level data of trans-boundary rivers between Bangladesh and India is ongoing from 15 May to 15 October. Water level data of Domohani and Gozaldoba points located downstream of Gozaldoba Barrage in India on the upstream side of Teesta River are available twice a day (morning and afternoon) at the specified times. Since the flood is occured after 15 October, it is not possible to provide flood forecast due to lack of upstream water level data. From 9 am to 12 pm on 20 October, a total of 3,000 people from Dimla, Jaldhaka, Kishoreganj, Doani upazilas of Nilphamari and Lalmonirhat districts received Google flood warning notifications on their smartphones in an area of about 2 km from Dalia station. This warning notification continued for 2 more times during the rest of the day until the water levels fell below the danger level.

On the ground inspection of the flood affected area, it can be seen that along with the flood bypass of Dimla and Jaldhaka upazilas of Nilphamari district, embankments, groynes, spars and various types of infrastructure along the right bank of Teesta river have been damaged.

CHAPTER 7 : RESEARCH AND DEVELOPMENT

7.1 Upgradation of Google-BWDB-a2i Flood Forecasting Initiative

Google and BWDB have been officially working together since 2019 with the support from a2i on improving the existing flood forecasting system at local level. The system was proposed to be developed using 5-day deterministic flood forecasts of FFWC, BWDB but additionally with the help of a high-resolution satellite based DEM from Google to develop a more accurate local level flood inundation map. The system would also allow end users to access information on upcoming flood and its magnitude directly from their mobile phone at union level. The process had been set to initiate by synchronizing the 5-day flood forecasts of FFWC, BWDB along with observed water level data to Googles server. After that, Google produces the high-resolution inundation map which users can see by opening Google map or searching in the Google web.



(a) (b) (c)

Figure 7.1: Google-BWDB-a2i Flood Forecasting Initiative: a) forecast and warning information in Google search page, b) flood alert visible in Google map, c) forecast inundation map in Google map

After the completion of piloting in 2019 and initial launch in 2020, BWDB-Google Flood Forecasting Intiative was officially inaugurated as "Digital Flood Forecasting System in Bangladesh" on 25th October, 2021 at Pani Bhaban, Dhaka.

In 2021, the intial system was expanded in the whole country from 14 districts to covering 55 districs and 99 upazillas (Fig 7.2).

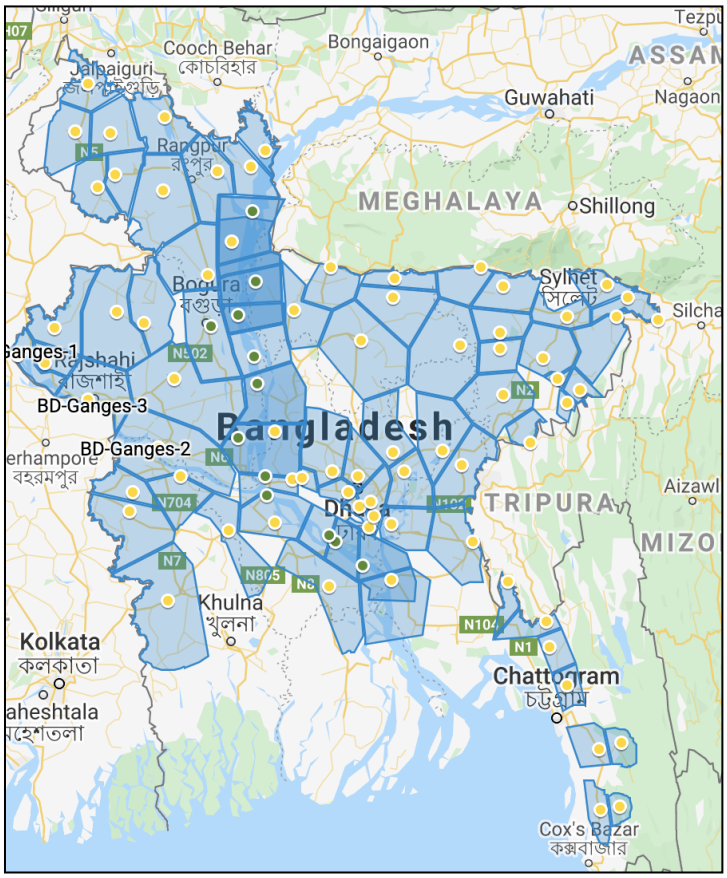
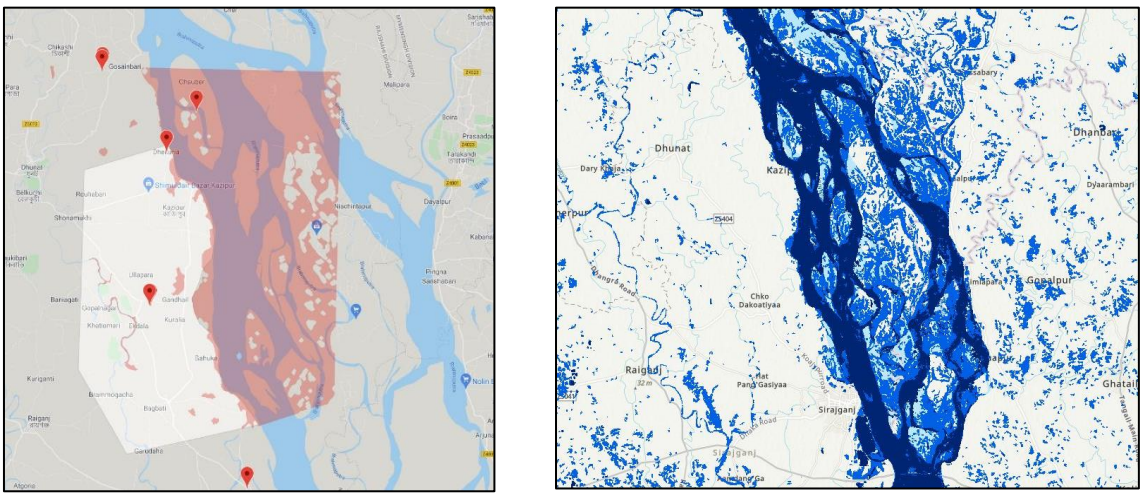


Figure 7.2 : Coverage of Google Floor Forecasting

Over 1M warning messages were sent to local level users through Google alert services using Android push notification in 2020. After the expansion, in 2021, 5M notification alerts were sent. A collaboration of BWDB with Bangladesh Telecommunication Regulatory Commission (BTRC) with support from a2i has been going on. The goal is to directly send SMS text alerts containing warning message and location of nearby flood shelters to people living in the concerned flood areas. This system is currently under process.

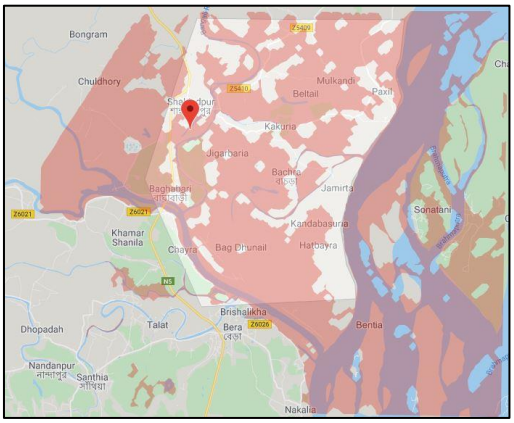


(a) (b)

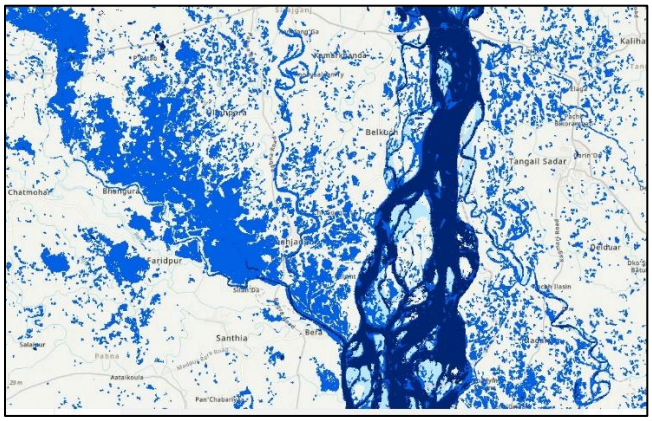
Figure 7.3 : Comaprison of Embankment Based Forecast Inundation Scneario of BRE Serajganj: a) Model Result, b) Satelite based Inundation

In August 2021, the initial development embankment-based forecast system was completed implementing the full BRE starting from Kurigram, ending at Pabna. Two embankment based inundation scenario was taken for validation. The first scenario was of 02 September, 2021 and the area of interest was Serajganj at right bank of Brahmaputra. This scenario was choosen to see the effect of embankment in a large river during flood. From the simulaton, it was seen that even though it was a time of flood in Brahmaputra, the Serajganj area was not flooded as the water level did not cross the crest level of embankment. The scenario was compared to satellite based inuntaion mapping using SAR data from Sentinel-1 satellite, which showed similar inundation scenario (Fig 7.3).

Second scenario was choosen in Pabna-Serajganj region to see the effect of inudndaion in embankment overtopping. The simulaton date was 15 September 2021, when there was a flooding scenario in this region. The scenario was also compared to satellite based inuntaion mapping using SAR data from Sentinel-1 satellite of 18 Spetember 2021, which showed similar inundation scenario. FFWC official also did a field visit to compare the actual inundation status in the region (Fig 7.4).



(a)



(b)

(c)

Figure 7.4: Comaprison of Embankment Based Forecast Inundation Scneario of Pabna-Serajganj: a) Model Result, b) Satelite based Inundation, c) Field Verification

SMS alert system will hopefully launch in next season. BWDB and a2i will keep this system under continuous monitoring and work together for overcoming the existing challenges and bringing new features and updates to this system. The final target is to increase the accuracy of local level flood forecast and disseminate relevant information in the most user-friendly manner for the targeted river belts. Google will also keep supporting the initiative in near future and it is expected that this will help in improved local level flood forecasting as well as capacity building of BWDB professionals.

CHAPTER 8 : CONCLUSION

The flood problem in Bangladesh is extremely complex. The country is an active delta; it has numerous networks of rivers, canals and coast creeks with extensive flood plains through which surface water of about 1.7 million sq-km drains annually. The annual average rainfall is about 2300 mm, the range varies from about 1500 mm in the northwest to over 5000 mm in the north-east.

Floods are normal monsoon phenomena in the deltaic plains of Bangladesh. Although the livelihood of the people in Bangladesh is well adapted to normal monsoon flood, the damages due to inundation, riverbank erosion or breach of embankment, etc. still occur in various regions in almost every monsoon. 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 are adversely affected.

The runoff from GBM catchments of about 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. The parts of Meghna, North and South-Eastern Hill basins are vulnerable to flash flood from the beginning of monsoon or even pre-monsoon, causing loss of standing crops and source of hardship for the population.

As mandated, FFWC of BWDB under MoWR monitored the flood situation during the pre-monsoon, monsoon and also beyond the period when situation demanded. The FFWC has issued daily flood bulletin from May to October with deterministic forecast lead-time of 24hrs, 48hrs, 72hrs, 96 hrs and 120 hrs (upto 5 days) along with warning messages and flood inundation maps. The forecast was based on 5-days WL at 54 stations on 28 major rivers and covered the major floodplains of the country only excluding the coastal and South-Eastern hill regions. There are efforts to make more localized flood forecast increasing the number of forecast stations. Also, there are plans to expand the forecasting domain to coastal and South-East regions in near future. Further improvement is needed for these initiatives.

Recurrent pre-monsoon flash floods in North-Eastern Haor regions are becoming more and more of a concern day by day. Under the CDMP-II programme during 2012-14, FFWC started limited scale 2-days deterministic flash flood forecasting for the region during the season. From 2017, under the HILIP-BWDB component project of Haor Infrastructure & Livelihood Improvement Project (HILIP) by Local Government Engineering Department (LGED), 3-days experimental flash flood forecast was introduced for the region which has been made operational this year by incorporating BMD generated numerical rainfall forecast. Currently flash flood forecast is being generated at 25 stations within the Upper Meghna basin during pre-monsoon with a qualitative outlook focusing on water level trend in coming days based on rainfall forecasts.

Updated/improved more user-friendly website has been in operation since June-2015 with the financial support of CDMP-II. The upgraded website having easy to operate menu and Bangla language option is added with flood warning message in Bangla. Improvement of the website is on-going to make it more user friendly and accessible to a great number of users. A new addition since 2018 is the Android based 'BWDB Flood App' which is a mobile friendly and simple version of the FFWC website. Development of this app has been one major step forward to mass dissemination utilizing the latest ICT technologies. Future versions of the app will be made more user friendly and accessible.

In addition to deterministic flood forecasts up to 5-days lead time, FFWC issued medium range up to 10-days lead-time probabilistic forecasts at 37 locations on operational basis with technical support from RIMES and utilizing ECMWF weather prediction data over the Ganges-Brahmaputra basin to generate 51 sets of ensemble discharge forecasts on the Brahmaputra at Bahadurabad and the Ganges at Hardinge Bridge. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions. Also 15-days probabilistic streamflow forecast for the Brahmaputra-Ganges-Meghna rivers has been launched last year through which the 10-days lead time of medium range forecast can potentially be updated to 15-days in future.

Special type of flood bulletin has been issued during the critical time and disseminated through different mass media, news agencies, fax, e-mail, website and IVR through mobile phone. The IVR system using mobile started from July 2011, in cooperation of DDM, anyone can call 1090 number from any mobile operator and then press 5 to hear a short voice message on flood warning in Bangla free of charge. The information has been used by various communities and organizations: national and international disaster management operators, many Government agencies, NGOs and BWDB itself.

Due to different shortcomings including limited upstream hydro-meteorological information, old & relatively coarse DEM and limited technological development of the centre itself, the services were fully not satisfactory to all corners. Area-inundation forecast based on a coarse DEM and old topographic maps have been indicative. 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 be developed for providing regional flood forecasting and warning. Moreover, flood inundation map needs to develop further. Introduction of flood forecasting in the coastal regions have been a much-talked issue which need to be addressed. Besides demand is growing day by day for urban flood forecasting.

A major step forward towards improving the inundation mapping was the experimental operarion of Google-BWDB-a2i Flood Forecasting Initiative started last year. Google and BWDB have been officially working together since 2019 with the support from a2i on improving the existing flood forecasting system at local level. This system has further

improved and still improving since the piloting. Almost the whole country was added in the system covering 55 district and 99 Upazillas. The present system has been developed using 5-day deterministic flood forecasts of FFWC, BWDB but additionally with the help of a high-resolution satellite based DEM from Google. In addition, in 2021, embankment based forecasting system was also developed which showed a great potential. Over 5M warning messages have been sent to local level users through Google alert services using Android push notification in 2021 which has allowed end users to access information on upcoming flood and its magnitude directly from their mobile phone at union level. The system was officially inaugurated as "Digital Flood Forecasting System in Bangladesh" on 25th October, 2021. SMS alert system in connection to this will hopefully launch in future.

The FFWC of BWDB took the privileges to reflect the flood situation as accurate and reliable as possible. All the combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2021 through the difficult ongoing Covid-19 pandemic situation.

As a whole the flood of 2021 was a moderate one with medium duration which mainly affected some parts of the Northern, North-Western, North-Central and Central regions of the country. Flooding persisted in the Central, South-Western and South-Central coastal parts of the country for longer periods due to upstream water rush and tidal influences, but for shorter durations in the North-Eastern and South-Eastern regions. In terms of magnitude 2021 flood was significantly lower than historical major flood years– except the Teesta river flood at Dalia in mid October, exceeding the RHWL. However moderate to severe flash flooding also occurred in parts of South-Eastern regions which induced severe landslides in Bandarban and Cox's Bazar districts in last weeks of July.

The 2021 flood season as a whole was characteristically a less active than normal monsoon. However due to relatively more activity in the late part of the monsoon, the flood started late peaking during the early days of September. The flood receded mostly within the first half of September and continued so, until the unprecedented late monsoon flood in Teesta basin in third week of October. In general, for the whole country 2021 was a moderate flood year with the exception of Teesta river flood in late monsoon being a catastrophic one.

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2021 on major rivers were around 96%, 91%, 86%, 80% and 75% consistent on average for 24hrs, 48hrs, 72hrs, 96hrs and 120 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. Professionals of the FFWC have been fully dedicated and committed to generate and disseminate flood forecasting and warning services on daily basis during the flood season.

The maximum flooded area was 33% of the whole country this year (48,698 sq-km approximately) corresponding to moderate flooding. Some of the regions experienced severe river bank erosion which continued both during and after the flooding.

Annex-1

5 Days Deterministic Forecast for 24, 48, 72, 96 & 120 Hrs
FFWC, BWDB

SL NO	River	Station	D.L. (meter)	Today 30-08 6:00 AM (meter)	24-hrs forecast 31-08 6:00 AM (meter)	24-hrs +Rise -fall 31-08 6:00 AM (cm)	24-hrs +above -below D.L. 31-08 6:00 AM (cm)	48-hrs forecast 01-09 6:00 AM (meter)	48-hrs +Rise -fall 01-09 6:00 AM (cm)	48-hrs +above -below D.L. 01-09 6:00 AM (cm)	72-hrs forecast 02-09 6:00 AM (meter)	72-hrs +Rise -fall 02-09 6:00 AM (cm)	72-hrs +above -below D.L. 02-09 6:00 AM (cm)	96-hrs forecast 03-09 6:00 AM (meter)	96-hrs +Rise -fall 03-09 6:00 AM (cm)	96-hrs +above -below D.L. 03-09 6:00 AM (cm)	120-hrs forecast 04-09 6:00 AM (meter)	120-hrs +Rise -fall 04-09 6:00 AM (cm)	120-hrs +above -below D.L. 04-09 6:00 AM (cm)
1	Atrai	Mohadevpur	18.59	16.57	16.50	-7	-209	16.04	-46	-255	15.66	-39	-293	15.35	-31	-324	15.09	-26	-350
2	Atrai	Atrai	13.72	13.25	13.30	+5	-42	13.31	+1	-41	13.28	-3	-44	13.23	-5	-49	13.17	-5	-55
3	Atrai	Singra	12.65	12.45	12.50	+5	-15	12.51	+1	-14	12.48	-3	-17	12.45	-3	-20	12.41	-4	-24
4	Karatoa-Atrai-GGH	Baghabari	10.40	10.80	10.82	+2	+42	10.87	+4	+47	10.90	+4	+50	10.96	+5	+56	10.99	+4	+59
5	Little Jamuna	Naogaon	15.25	14.12	14.05	-7	-120	13.98	-7	-127	13.86	-12	-139	13.78	-8	-147	13.77	-1	-148
6	Karatoya	Chakrahimpur	20.15	19.09	19.19	+10	-96	19.15	-4	-100	19.00	-16	-115	18.87	-13	-128	18.82	-5	-133
7	Karatoya	Bogra	16.30	14.60	14.73	+13	-157	14.78	+5	-152	14.71	-8	-159	14.68	-3	-162	14.70	+2	-160
8	Teesta	Kaunia	29.20	29.05	28.73	-32	-47	28.70	-2	-50	28.70	0	-50	28.70	0	-50	28.71	+1	-49
9	Ghagot	Gaibandha	21.70	21.50	21.40	-10	-30	21.30	-10	-40	21.20	-10	-50	21.20	0	-50	21.20	0	-50
10	Dharla	Kurigram	26.50	26.84	26.87	+3	+37	26.86	-1	+36	26.82	-4	+32	26.76	-6	+26	26.76	0	+26
11	Brahmaputra	Chilmari	23.70	23.93	23.98	+5	+28	24.04	+6	+34	24.12	+8	+42	24.13	+1	+43	24.14	0	+44
12	Jamuna	Bahadurabad	19.50	19.62	19.69	+7	+19	19.73	+4	+23	19.79	+7	+29	19.83	+4	+33	19.84	+1	+34
13	Jamuna	Sariakandi	16.70	17.02	17.09	+7	+39	17.12	+3	+42	17.18	+6	+48	17.24	+6	+54	17.24	+1	+54
14	Jamuna	Kazipur	15.25	15.55	15.61	+6	+36	15.64	+4	+39	15.70	+5	+45	15.76	+6	+51	15.78	+2	+53
15	Jamuna	Serajganj	13.35	13.69	13.74	+5	+39	13.79	+5	+44	13.85	+6	+50	13.92	+8	+57	13.95	+2	+60
16	Jamuna	Porabari	12.27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Jamuna	Aricha	9.40	9.47	9.48	+1	+8	9.51	+3	+11	9.54	+3	+14	9.59	+5	+19	9.63	+3	+23
18	Old Brahmaputra	Jamalpur	17.00	14.70	14.78	+8	-222	14.84	+6	-216	14.90	+7	-210	14.98	+8	-202	15.02	+4	-198
19	Old Brahmaputra	Mymensingh	12.50	8.72	8.81	+9	-369	8.89	+8	-361	8.96	+7	-354	9.04	+8	-346	9.11	+7	-339
20	Bangshi	Nayerhat	7.30	5.74	5.78	+3	-153	5.81	+3	-149	5.84	+3	-146	5.87	+3	-143	5.89	+2	-141
21	Old Dhalesari	Jagir	8.25	7.62	7.70	+8	-55	7.78	+8	-47	7.85	+7	-40	7.92	+7	-33	8.00	+7	-25
22	Dhaleswari	Kalagachia	4.88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Kaliganga	Taraghat	8.40	7.99	8.06	+7	-34	8.12	+6	-28	8.18	+6	-22	8.25	+7	-15	8.32	+7	-8
24	Tongi Khal	Tongi	6.10	5.48	5.50	+2	-60	5.52	+2	-58	5.53	+1	-57	5.53	0	-57	5.53	0	-57
25	Turag	Mirpur	5.95	5.35	5.37	+2	-58	5.39	+2	-56	5.41	+1	-54	5.40	0	-55	5.40	0	-55
26	Buriganga	Dhaka (Mill Barrack)	6.00	4.62	4.64	+2	-136	4.66	+3	-134	4.67	0	-133	4.65	-2	-135	4.64	-1	-136
27	Buriganga	Dhaka (Hariharpara)	5.79	4.5	4.52	+2	-127	4.54	+3	-125	4.55	0	-124	4.53	-2	-126	4.52	-1	-127
28	Balu	Demra	5.75	5.00	5.02	+2	-73	5.05	+3	-70	5.06	+1	-69	5.05	0	-70	5.05	0	-70
29	Lakhya	Narayanganj	5.50	4.77	4.79	+2	-71	4.82	+3	-68	4.82	+1	-68	4.81	-1	-69	4.80	-1	-70
30	Dhaleswari	Elashinghat	11.40	11.85	11.88	+3	+48	11.92	+4	+52	11.96	+4	+56	12.02	+6	+62	12.05	+3	+65
31	Lakhya	Lakhpur	5.80	4.96	4.99	+3	-81	5.03	+3	-77	5.06	+3	-74	5.09	+3	-72	5.11	+2	-69
32	Dhaleswari	Rekabi Bazar	5.20	4.36	4.38	+2	-82	4.40	+3	-80	4.41	0	-79	4.39	-2	-81	4.38	-1	-82
33	Mohananda	Chapai Nawabganj	21.00	19.93	19.87	-6	-113	19.81	-6	-119	19.75	-6	-125	19.74	0	-126	19.74	0	-126
34	Ganges	Rajshahi	18.50	16.8	16.79	-1	-171	16.78	-1	-172	16.78	0	-172	16.78	0	-172	16.78	0	-172
35	Ganges	Hardinge Br	14.25	13.53	13.50	-3	-75	13.49	-1	-76	13.49	0	-76	13.49	+1	-76	13.49	0	-76
36	Ganges	Talbaria	12.80	12.54	12.51	-3	-29	12.50	-1	-31	12.49	0	-31	12.50	+1	-30	12.50	0	-30
37	Padma	Goalondo	8.65	9.11	9.11	0	+46	9.14	+3	+49	9.17	+3	+52	9.21	+4	+56	9.24	+3	+59

Note:
1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 31-8-2021 6:00 A.M.
2) 48 hrs. rise/fall indicates changes in water levels from 31-8-2021 6:00 A.M. to 1-9-2021 6:00 A.M.
3) 72 hrs. rise/fall indicates changes in water levels from 1-9-2021 6:00 A.M. to 2-9-2021 6:00 A.M.
4) 96 hrs. rise/fall indicates changes in water levels from 2-9-2021 6:00 A.M. to 3-9-2021 6:00 A.M.
5) 120 hrs. rise/fall indicates changes in water levels from 3-9-2021 6:00 A.M. to 4-9-2021 6:00 A.M.
6) "+ above" means water level flowing above danger level, "-below" means water level flowing below danger level.

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A Sample of 5-days Deterministic Forecast Bulletin

Annex-2

FLOOD FORECASTING AND WARNING CENTER, BWDB
RIVER SITUATION AS ON 28-08-2021 AT 09:00 HOURS

SL	RIVER	STATION NAME	RHWL	D.L.	27-08-2021	28-08-2021	Rise(+) Fall(-)	Above(+) Below(-) D.L.
			m PWD	m PWD	m PWD	m PWD	in cm	in cm
	BRAHMAPUTRA BASIN							
1	DUDHKUMAR	PATESWARI	31.43	30.05	30.1	30.2	+10	+15
2	DHARLA	KURIGRAM	27.84	26.50	26.67	26.82	+15	+32
3	TEESTA	DALIA	53.15	52.60	52.42	52.4	-2	-20
4	TEESTA	KAUNIA	30.52	29.20	28.73	29.12	+39	-8
5	JAMUNESWARI	BADARGANJ	33.61	32.15	29.93	30.4	+47	-175
6	GHAGOT	GAIBANDHA	22.81	21.70	21.23	21.41	+18	-29
7	KARATOA	CHAK RAHIMPUR	21.41	20.15	17.51	18.18	+67	-197
8	KARATOA	BOGURA	17.45	16.30	14.06	14.53	+47	-177
9	BANGALI	SHIMUBARI	19.22	18.23	16.31	16.48	+17	-175
10	BRAHMAPUTRA	NOONKHAWA	28.10	26.50	25.98	26.11	+13	-39
11	BRAHMAPUTRA	HATIA	26.30	24.75	24.26	24.5	+24	-25
12	BRAHMAPUTRA	CHILMARI	25.07	23.70	23.75	23.9	+15	+20
13	JAMUNA	FULCHARI	21.35	19.82	19.66	19.82	+16	0
14	JAMUNA	SAGHATA	21.20	19.20	18.92	19.02	+10	-18
15	JAMUNA	BAHADURABAD	21.16	19.50	19.37	19.52	+15	+2
16	JAMUNA	SARIAKANDI	19.07	16.70	16.77	16.92	+15	+22
17	JAMUNA	KAZIPUR	17.47	15.25	15.31	15.42	+11	+17
18	JAMUNA	SERAJGANJ	15.12	13.35	13.5	13.61	+11	+26
19	JAMUNA	PORABARI	13.30	11.90	11.8	11.89	+9	-1
20	JAMUNA	MATHURA	11.90	10.06	10.06	10.08	+2	+2
21	JAMUNA	ARICHA	10.76	9.40	9.43	9.41	-2	+1
22	GUR	SINGRA	13.76	12.65	12.19	12.25	+6	-40
23	ATRAI	BAGHABARI	12.45	10.40	10.7	10.74	+4	+34
24	DHALESWARI	ELASIN	12.80	11.40	11.68	11.75	+7	+35
25	OLD BRAHMAPUTRA	JAMALPUR	18.00	17.00	14.25	14.41	+16	-259
26	OLD BRAHMAPUTRA	MYMENSINGH	13.71	12.50	8.43	8.5	+7	-400
27	LAKHYA	LAKHPUR	8.70	5.80	4.77	4.92	+15	-88
28	BURIGANGA	DHAKA	7.58	6.00	4.76	4.47	-29	-153
29	BURIGANGA	HARIHARPARA	7.13	5.79	4.72	4.46	-26	-133
30	BALU	DEMRA	7.13	5.75	5.06	5	-6	-75
31	LAKHYA	NARAYANGANJ	6.93	5.50	5.17	5.07	-10	-43
32	TURAG	KALIAKOIR	10.28	8.40	8.19	8.27	+8	-13
33	TURAG	MIRPUR	8.35	5.95	5.33	5.35	+2	-60
34	TONGI KHAL	TONGI	7.84	6.10	5.41	5.49	+8	-61
35	KALIGANGA	TARAGHAT	10.39	8.40	7.75	7.84	+9	-56
36	DHALESWARI	JAGIR	9.96	8.25	7.42	7.5	+8	-75
37	DHALESWARI	REKABI BAZAR	7.66	5.20	4.56	4.49	-7	-71
38	BANSHI	NAYARHAT	8.39	7.30	5.58	5.64	+6	-166
	GANGES BASIN							
39	KARATOA	PANCHAGARH	72.65	70.75	68.3	68.75	+45	-200
40	PUNARBHABA	DINAJPUR	34.40	33.50	29.48	30.88	+140	-262
41	ICH-JAMUNA	PHULBARI	30.47	29.95	27.4	27.43	+3	-252
42	TANGON	THAKURGAON	51.30	50.40	47.92	48.27	+35	-213
43	UPPER ATRAI	BHUSIRBANDAR	41.10	39.62	37.88	38.46	+58	-116
44	MOHANANDA	ROHANPUR	23.83	22.00	20.61	20.56	-5	-144
45	MOHANANDA	CHAPAI-NAWABGANJ	23.01	21.00	20.07	19.97	-10	-103
46	LITTLE JAMUNA	NAOGAON	16.20	15.25	13.38	13.68	+30	-157
47	ATRAI	MOHADEBPUR	19.89	18.59	15.37	15.62	+25	-297
48	ATRAI	ATRAI	14.40	13.72	12.44	12.75	+31	-97
49	GANGES	PANKHA	24.14	22.50	21.4	21.29	-11	-121
50	GANGES	RAJSHAHI	20.00	18.50	17.02	16.9	-12	-160
51	GANGES	HARDINGE BRIDGE	15.19	14.25	13.7	13.62	-8	-63
52	GANGES	TALBARIA	14.53	13.50	12.67	12.59	-8	-91
53	PADMA	GOALUNDO	10.21	8.65	9.1	9.08	-2	+43
54	PADMA	BHAGYAKUL	7.50	6.30	6.23	6.18	-5	-12
55	PADMA	MAWA	7.14	6.10	6.05	5.97	-8	-13
56	PADMA	SURESWAR	5.94	4.45	4.8	4.7	-10	+25
57	GORAI	GORAI RLY BRIDGE	13.65	12.75	12	11.93	-7	-82
58	GORAI	KAMARKHALI	9.48	8.20	8.09	8.01	-8	-19
59	ICHAMATI	SAKRA	4.69	3.95	-0.24	-0.07	+17	-402
60	MATHABHANGA	CHUADANGA	12.67	12.05	9.74	9.58	-16	-247
61	MATHABHANGA	HATBOALIA	15.13	14.50	11.71	11.56	-15	-294
62	KOBADAK	JHIKARGACHA	5.59	5.10	2.96	2.92	-4	-218
63	BETNA	KALAROA	4.89	3.81	3.95	4.06	+11	+25
64	KUMAR	FARIDPUR	8.76	7.50	5.02	5.04	+2	-246
65	ARIALKHAN	MADARIPUR	5.80	4.20	3.81	3.8	-1	-40
66	MADARIPUR BEEL ROUTE	HARIDASPUR	5.05	3.80	3.21	3.21	0	-59
67	KIRTONKHOLA	BARISHAL	3.20	2.55	2.15	2.2	+5	-35
68	PASHURE	KHULNA	3.48	3.05	0.76	1.06	+30	-199
69	PASHURE	MONGLA	3.28	2.07	0	0.42	+42	-165

Flood Bulletin (Page 1 of 4)

A Sample Flood Bulletin

Annex-3

FLOOD INFORMATION CENTRE-1
***FLOOD FORECASTING & WARNING CENTRE* BANGLADESH WATER DEVELOPMENT BOARD PANI BHABAN (LEVEL-2), 72 GREEN ROAD, DHAKA-1205**

E-mail: ffwcbwdb@gmail.com, ffwc05@yahoo.com, Site: http://www.ffwc.gov.bd Tel: 02-2222-30070, 9550755, **Fax:** 9557386

RAINFALL AND RIVER SITUATION SUMMARY AS ON 28 AUGUST, 2021

- ***The Brahmaputra-Jamuna rivers are in rising trend, which may continue in next 48 hours.***
- ***The Ganges river is in falling trend which may continue in next 48 hours, while the Padma river is in steady state, which may rise in next 24 hours.***
- ***Except the Kushiyara, Major rivers in the North-Eastern part of the country are in falling trend, which may continue in the 48 hours.***
- ***In next 24 hours, the flood situation at low lying areas of Kurigram, Gaibandha, Jamalpour, Bogura, Tangail, Sirajganj, Pabna, Manikganj, Rajbari, Faridpur, Shariatpur and Chandpur districts may deteriorate.***
- ***The Jamuna river at Porabari Point may cross danger level in next 24-48 hours.***

A Sample Flood Situation Outlook

Annex-4

Stations above Danger Levels (As on 28 August 2021 09:00 AM):

Station name	River	Today's Water Level (meter)	Rise(+)/Fall(-) (cm) in the last24 hours	Danger Level (meter)	Above Danger Level(cm)
Pateswari	Dudhkumar	30.20	+10	30.05	+15
Kurigram	Dharla	26.82	+15	26.50	+32
Chilmari	Brahmaputra	23.90	+15	23.70	+20
Bahadurabad	Jamuna	19.52	+15	19.50	+02
Sariakandi	Jamuna	16.92	+15	16.70	+22
Kazipur	Jamuna	15.42	+11	15.25	+17
Serajganj	Jamuna	13.61	+11	13.35	+26
Mathura	Jamuna	10.08	+02	10.06	+02
Aricha	Jamuna	9.41	-02	9.40	+01
Baghabari	Atrai	10.74	+04	10.40	+34
Elasin	Dhaleswari	11.75	+07	11.40	+35
Goalundo	Padma	9.08	-02	8.65	+43
Sureswar	Padma	4.70	-10	4.45	+25
Chandpur	Meghna	3.56	-02	3.55	+01

RAINFALL

Significant rainfalls recorded within Bangladesh during last 24 hrs ending at 09:00 AM today:

Station	Rainfall (mm)	Station	Rainfal l (mm)
Dalia	57.0	Panchgarh	47.0
Sheola	45.0	Thakurgaon	40.0

Significant rainfalls recorded during last 24 hrs in India upstream of the country:

Station	Rainfall (mm)	Station	Rainfall (mm)
Passighat	59.0	Aizwal	57.0
Darjeeling	47.0	Silchar	33.0

General River Condition

Monitored Water Level Station	109	Inactive Gauges	0
Rise	53	Gauge Reading Missing	0
Fall	52	Total Not Reported	0
Steady	04	**Above Danger Level**	**14**

For Further Query, Feel Free to Contact:
01318-234963, 01674-356208, 01765-405576

(Md. Arifuzzaman Bhuyan)
Executive Engineer
FFWC, BWDB.
Cell No: 01715040144

A Sample Flood Situation Summary

Annex-5

Flood Forecasting and Warning Center, Bangladesh Water Development Board
Web: www.ffwc.gov.bd, Email: ffwcbwdb@gmail.com
Medium Range 1-10 days Probabilistic Forecast
Forecast As of August 22, 2021

Outlook for Next 10 Days:

- Brahmaputra-Jamuna River system may continue to rise. Water level at Kazipur point of Serajganj and Aricha point of Manikganj may remain steady for the 7 days as a result the ongoing flood situation in these districts may continue for the next 7 days. Water level at Bahadurabad point of Jamalpur and Sariakandi point of Bogra may reach close to danger level by 27th August and water level at Serajganj point of Serajganj and Elashinghat point of Tangail may cross danger level within the next 48 hours.

- Ganges River may remain steady during the next 5 days. Padma River system may continue to rise. Water level at Goalondo point of Munshiganj and Sureshwar point of Shariatpur may remain steady during the next 7 days. As a result, the ongoing flood in the above mentioned districts may continue during the next 7 days. Water level at Bhagyakul point and Mawa point of Munshiganj may reach close to danger level by 25th August.

- Rivers around Dhaka city may rise. No probability of flooding is forecasted in the rivers around Dhaka city.

For viewing interactive hydrographs of the Medium Range forecast please visit:
http://ffwc.gov.bd/index.php/hydrograph/medium-range-1-10-days-forecast

আগামী ১০ দিনের সম্ভাব্য পূর্বাভাস:

- ব্রহ্মপুত্র-যমুনা নদীর পানি সমতল বৃদ্ধি অব্যাহত থাকতে পারে। সিরাজগঞ্জ জেলার কাজীপুর স্টেশন এবং মানিকগঞ্জ জেলার আরিচা স্টেশনে পানি সমতল আগামী ৭ দিন স্থিতিশীল থাকতে পারে, যার ফলে চলমান এ সকল জেলায় বন্যা পরিস্থিতি আগামী ৭ দিন অব্যাহত থাকতে পারে। আগামী ২৭শে আগস্ট নাগাদ জামালপুর জেলার বাহাদুরাবাদ স্টেশন, বগুড়া জেলার সারিয়াকান্দি স্টেশনে পানি সমতল বিপদসীমার কাছাকাছি পৌঁছাতে পারে। সিরাজগঞ্জ জেলার সিরাজগঞ্জ স্টেশন এবং টাঙ্গাইল জেলার এলাসিনঘাট স্টেশনে পানি সমতল আগামী ৪৮ ঘণ্টার মধ্যে বিপদসীমার অতিক্রম করতে পারে।
- গঙ্গা নদীর পানি সমতল আগামী ৫ দিন স্থিতিশীল থাকতে পারে। পদ্মা নদীর পানি সমতল বৃদ্ধি অব্যাহত থাকতে পারে। রাজবাড়ী জেলার গোয়ালন্দ পয়েন্ট ও শরীয়তপুরের সুরেশ্বর পয়েন্টে পানি সমতল আগামী ৭ দিন স্থিতিশীল থাকতে পারে যার ফলে চলমান বন্যা পরিস্থিতি আগামী ৭ দিন অব্যাহত থাকতে পারে। মুন্সীগঞ্জের ভাগ্যকুল এবং মাওয়া পয়েন্টে পানি সমতল ২৫শে আগস্ট নাগাদ বিপদসীমার কাছাকাছি পৌঁছাতে পারে।
- ঢাকার চারপাশের নদীসমূহের পানি সমতল বাড়তে পারে। ঢাকার চারপাশের নদীসমূহের অববাহিকায় বিপদসীমা অতিক্রমের সম্ভাবনা নেই।

১০ দিনের সম্ভাব্যতা ভিত্তিক পূর্বাভাসের ইন্টার‍্যাক্টিভ হাইড্রোগ্রাফ দেখতে ভিজিট করুন:
http://ffwc.gov.bd/index.php/hydrograph/medium-range-1-10-days-forecast

Developed With Technical and Implementation Support from Regional Integrated Multi-Hazard Early Warning System (RIMES)

A Sample Medium Range 1-10 days Probabilistic Forecast Outlook

Annex-6

Forecast made on: 22-08-2021 (Page 1/5)

			today	1-day fore-cast	2-day fore-cast	3-day fore-cast	4-day fore-cast	5-day fore-cast	6-day fore-cast	7-day fore-cast	8-day fore-cast	9-day fore-cast	10-day fore-cast	
Water Level in [m]			22-08	23-08	24-08	25-08	26-08	27-08	28-08	29-08	30-08	31-08	01-09	Forecast type
River	Station	D.L	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	
Jamuna	Bahadurabad	19.50	19.03	19.04	19.12	19.23	19.37	19.59	19.85	20.13	20.41	20.54	20.58	Upper Range
				19.03	19.09	19.17	19.24	19.38	19.55	19.72	19.87	19.96	19.98	Lower Range
				19.03	19.11	19.19	19.31	19.49	19.72	19.93	20.12	20.25	20.30	Mean
Jamuna	Sariakandi	16.70	16.49	16.51	16.56	16.64	16.75	16.91	17.17	17.44	17.69	17.83	17.89	Upper Range
				16.51	16.54	16.59	16.66	16.76	16.89	17.06	17.23	17.34	17.38	Lower Range
				16.51	16.55	16.61	16.70	16.84	17.04	17.27	17.46	17.59	17.65	Mean
Jamuna	Kazipur	14.85	15.24	15.27	15.31	15.39	15.49	15.63	15.88	16.11	16.38	16.58	16.68	Upper Range
				15.27	15.30	15.35	15.41	15.50	15.62	15.78	15.95	16.04	16.09	Lower Range
				15.27	15.31	15.37	15.45	15.57	15.76	15.97	16.14	16.28	16.36	Mean
Jamuna	Serajganj	13.35	13.29	13.35	13.40	13.49	13.62	13.80	14.10	14.40	14.75	15.00	15.12	Upper Range
				13.34	13.38	13.44	13.53	13.64	13.79	13.99	14.19	14.33	14.39	Lower Range
				13.34	13.39	13.47	13.57	13.72	13.95	14.22	14.44	14.63	14.74	Mean
Jamuna	Aricha	9.40	9.41	9.46	9.49	9.54	9.60	9.67	9.80	9.97	10.16	10.33	10.43	Upper Range
				9.46	9.49	9.52	9.56	9.60	9.67	9.76	9.87	9.96	10.01	Lower Range
				9.46	9.49	9.53	9.58	9.64	9.73	9.87	10.01	10.13	10.21	Mean
Ganges-Padma	Hardinge Bridge	14.25	14.19	14.22	14.22	14.21	14.21	14.22	14.24	14.29	14.33	14.37	14.41	Upper Range
				14.21	14.21	14.20	14.19	14.19	14.20	14.22	14.24	14.26	14.26	Lower Range
				14.22	14.21	14.21	14.20	14.20	14.22	14.26	14.30	14.33	14.34	Mean

Developed With Technical and Implementation Support from Regional Integrated Multi-Hazard Early Warning System (RIMES)

A Sample Medium Range 1-10 days Probabilistic Forecast Bulletin

Annex-7

নির্বাহী প্রকৌশলীর দপ্তর
বন্যা পূর্বাভাস ও সতর্কীকরণ কেন্দ্র
বাংলাদেশ পানি উন্নয়ন বোর্ড
পানি ভবন, লেভেল: ২, ব্লক: জি, ৭২ গ্রীন রোড, ঢাকা-১২০৫
ফোন: ৮৮-০২-২২২২-৩০০৭০ ফ্যাক্স: ৮৮-০২-৯৫৫৭৩৮৬
ই-মেইল: ffwcbwdb@gmail.com ; ffwc05@yahoo.com
ওয়েবসাইট: www.ffwc.gov.bd

Office of The Executive Engineer
Flood Forecasting and Warning Centre
Bangladesh Water Development Board
Pani Bhaban (Level: 2, Block: G), 72 Green Road, Dhaka 1205
Phone : 88-02-2222-30070; Fax: 88-02-9557386
E-mail: ffwcbwdb@gmail.com ; ffwc05@yahoo.com
Website: www.ffwc.gov.bd

বন্যা পূর্বাভাস সম্পর্কিত সংক্ষিপ্ত প্রতিবেদন

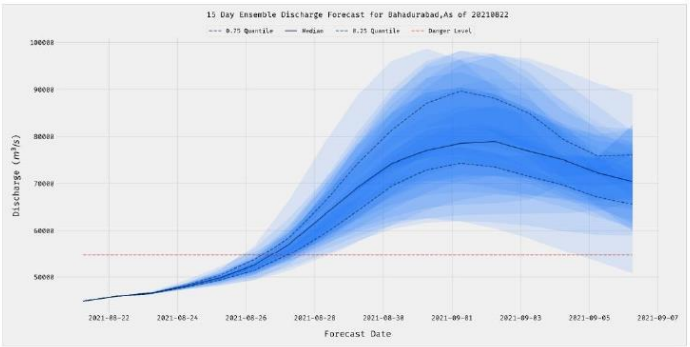
২৪.০৮.২০২১

আগস্ট মাসের তৃতীয় সপ্তাহ হতে বাংলাদেশ ও উজানের অববাহিকাসমূহের স্থানসমূহে সামগ্রিকভাবে মাঝারি থেকে ভারী বৃষ্টিপাত পরিলক্ষিত হয়েছে। এর ফলে দেশের প্রধান নদীসমূহের পানি সমতল বৃদ্ধির উল্লেখযোগ্য প্রবণতা পরিলক্ষিত হয় এবং পদ্মা অববাহিকার কতিপয় জেলা বন্যা কবলিত হয়। আবহাওয়ার সাম্প্রতিক পূর্বাভাস অনুযায়ী আগামী ২ সপ্তাহে উজানের অববাহিকাসমূহের অনেক স্থানে মাঝারি থেকে ভারী বৃষ্টিপাত ঘটার সম্ভাবনা রয়েছে। এর ফলে দেশের প্রধান নদ-নদীসমূহের পানি সমতল সামগ্রিকভাবে বৃদ্ধি পেতে পারে। দেশের প্রধান নদ-নদীসমূহের জন্য অববাহিকাভিত্তিক ধারণাগত পূর্বাভাস নিম্নে প্রদত্ত হলো:

ব্রহ্মপুত্র অববাহিকাঃ

ব্রহ্মপুত্র-যমুনা নদীর পানি সমতল বর্তমানে ধীর গতিতে বৃদ্ধি পাচ্ছে, তবে বিপদসীমার নিচে অবস্থান করছে। বাংলাদেশ ও উজানের অববাহিকায় ভারতের অরুণাচল, আসাম, মেঘালয় ও হিমালয় পাদদেশীয় পশ্চিমবঙ্গের অনেক স্থানে আগামী ৭ দিনে মাঝারি থেকে ভারী বৃষ্টিপাত ঘটার সম্ভাবনা রয়েছে। এর প্রভাবে আগস্ট মাসের শেষ সপ্তাহে ব্রহ্মপুত্র-যমুনা নদীর পানি সমতল বৃদ্ধির উল্লেখযোগ্য প্রবণতা লক্ষণীয় হতে পারে এবং সেপ্টেম্বর মাসের প্রথম সপ্তাহ নাগাদ তা বিপদসীমা অতিক্রম করে কুড়িগ্রাম, গাইবান্ধা, বগুড়া, জামালপুর, টাঙ্গাইল, সিরাজগঞ্জ,পাবনা ও মানিকগঞ্জ জেলায় স্বল্প থেকে মধ্যমেয়াদী বন্যা পরিস্থিতি সৃষ্টি করতে পারে। সেপ্টেম্বর মাসের দ্বিতীয় সপ্তাহ থেকে বন্যা পরিস্থিতির উন্নতি ঘটতে পারে।

আগামী ৭ দিনে হিমালয় পাদদেশীয় পশ্চিমবঙ্গে ভারী বৃষ্টিপাত ঘটার সম্ভাবনার প্রেক্ষিতে দেশের উত্তরাঞ্চলের তিস্তা এবং ধরলা নদীসমূহের পানি সমতল আগস্ট মাসের শেষ সপ্তাহে সময় বিশেষে দ্রুত বৃদ্ধি পেতে পারে। এর ফলে তিস্তা ও ধরলা নদীর পানি সমতল এই সময়ে কতিপয় স্থানে বিপদসীমা অতিক্রম করতে পারে এবং অববাহিকাভুক্ত লালমনিরহাট, নীলফামারী, রংপুর এবং কুড়িগ্রাম জেলার নিম্নাঞ্চলে স্বল্পমেয়াদী বন্যা পরিস্থিতির সৃষ্টি হতে পারে।



চিত্র-১: যমুনা নদী বাহাদুরাবাদে ১৫ দিনের পানি প্রবাহ পূর্বাভাস

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A Sample 2-Weeks Special Flood Outlook

Annex-8

বন্যা তথ্য কেন্দ্র-১
বন্যা পূর্বাভাস ও সতর্কীকরণ কেন্দ্র
বাংলাদেশ পানি উন্নয়ন বোর্ড
পানি ভবন (লেভেল-২), ৭২ গ্রীনরোড, ঢাকা-১২০৫
ই-মেইলঃ ffwcbwdb@gmail.com, ffwc05@yahoo.com; ওয়েবসাইটঃ www.ffwc.gov.bd দূরালাপনিঃ ০২২২২২-৩০০৭০, ৯৫৫০৭৫৫, ফ্যাক্সঃ ৯৫৫৭৩৮৬

বৃষ্টিপাত ও নদ-নদীর অবস্থা
১৩ বৈশাখ, ১৪২৮/২৬ এপ্রিল, ২০২১খৃঃ

এক নজরে হাওড় অঞ্চলের নদ-নদীর পরিস্থিতি ও পূর্বাভাস

- দেশের উত্তর-পূর্বাঞ্চলের সকল প্রধান নদ-নদীসমূহের পানি সমতল হ্রাস পাচ্ছে এবং বিপদসীমার নীচ দিয়ে প্রবাহিত হচ্ছে।
- আগামী ৪৮ ঘণ্টায় দেশের উত্তর-পূর্বাঞ্চলের সকল প্রধান নদ-নদীসমূহের পানি সমতল হ্রাস অব্যাহত থাকতে পারে এবং বিপদসীমার নীচ দিয়ে প্রবাহিত হতে পারে ।

বিপদসীমার উপর দিয়ে প্রবাহিত স্টেশন (১৩ বৈশাখ ১৪২৮ বঙ্গাব্দ/২৬ এপ্রিল ২০২১ খৃঃ সকাল ৯.০০ টার তথ্য অনুযায়ী): নেই

পানি সমতল স্টেশন	নদীর নাম	আজকের পানি সমতল (মিটার)	বিগত ২৪ ঘন্টায় বৃদ্ধি(+)/হ্রাস(-) (সে.মি.)	বিপদসীমা (মিটার)	বিপদসীমার উপরে (সে.মি.)
-	-	-	-	-	-

বারিপাত তথ্য

গত ২৪ ঘন্টায় বাংলাদেশে উল্লেখযোগ্য বৃষ্টিপাত (গত কাল সকাল ০৯:০০ টা থেকে আজ সকাল ০৯:০০ টা পর্যন্ত) : নেই।

স্টেশন	বারিপাত (মি.মি.)	স্টেশন	বারিপাত (মি.মি.)
-	-	-	-

গত ২৪ ঘন্টায় ভারতের উত্তর পূর্বাঞ্চলের সিকিম, আসাম, মেঘালয় ও ত্রিপুরা অঞ্চলে উল্লেখযোগ্য বৃষ্টিপাতের পরিমাণ (বৃষ্টিপাত: মি.মি.): নেই।

স্টেশন	বারিপাত (মি.মি.)
-	-

নদ-নদীর অবস্থা (আজ সকাল ০৯:০০ টা পর্যন্ত)

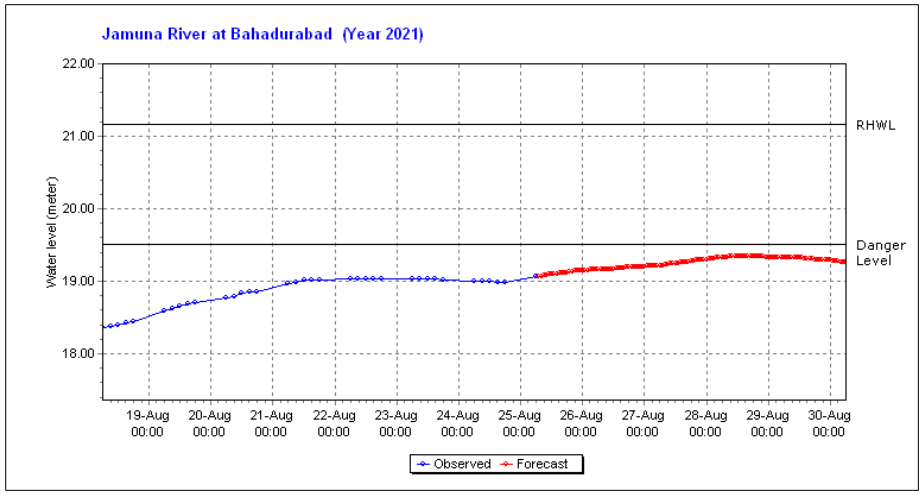
পর্যবেক্ষণাধীন পানি সমতল স্টেশন	৩৯	গেজ স্টেশন বন্ধ আছে	০
বৃদ্ধি	০৭	গেজ পাঠ পাওয়া যায়নি	০
হ্রাস	২৬	মোট তথ্য পাওয়া যায়নি	০
অপরিবর্তিত	০৬	**বিপদসীমার উপরে**	**০**

For Further Query, Feel Free to Contact:
01715040144, 01552353433

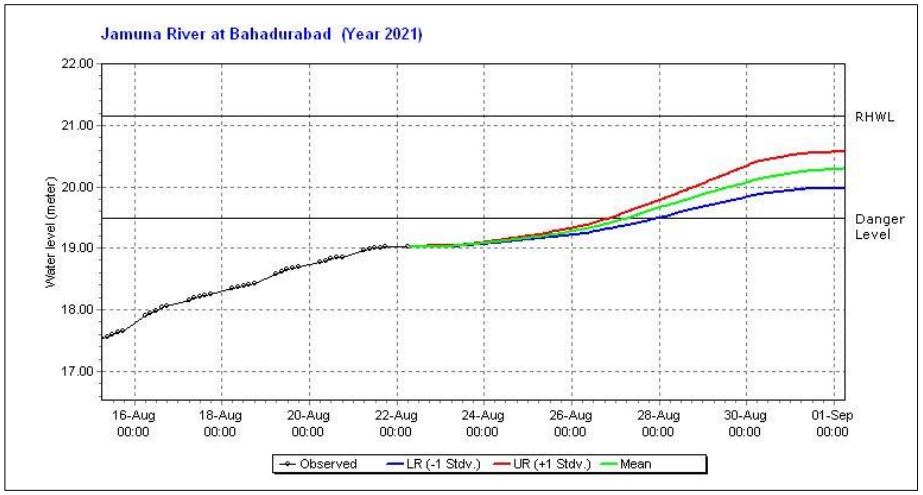
(মোঃ আরিফুজ্জামান ভূঁইয়া)
নির্বাহী প্রকৌশলী
বন্যা পূর্বাভাস ও সতর্কীকরণ কেন্দ্র
বাপাউবো, ঢাকা।
মোবাইল: ০১৭১৫০৪০১৪৪

Sample Flash Flood Outlook for the NE region

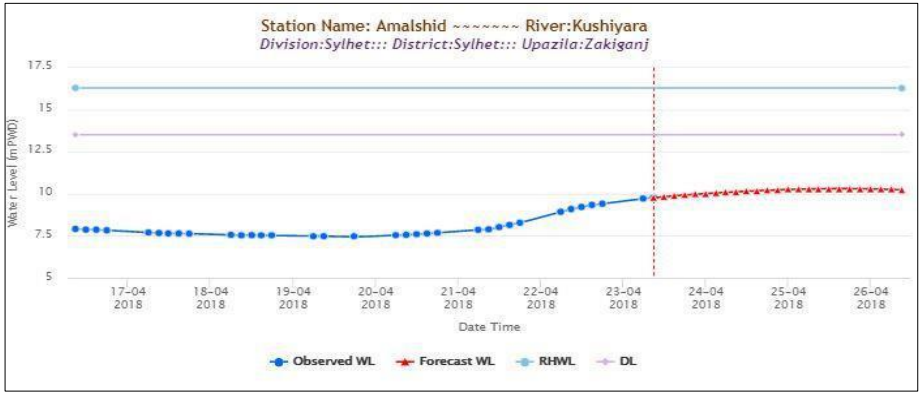
Annex-9



Sample Hydrograph of 5-days Deterministic Forecast



Sample Hydrograph of 10-days Probabilistic Forecast



Sample Hydrograph of 3-days Deterministic Flash Flood Forecast

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