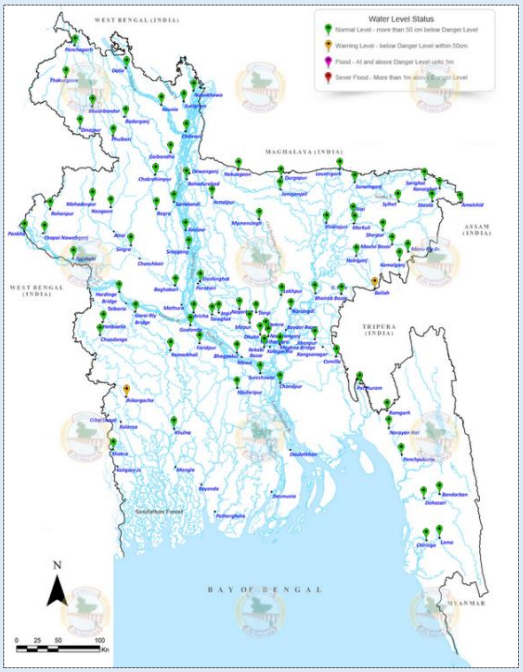
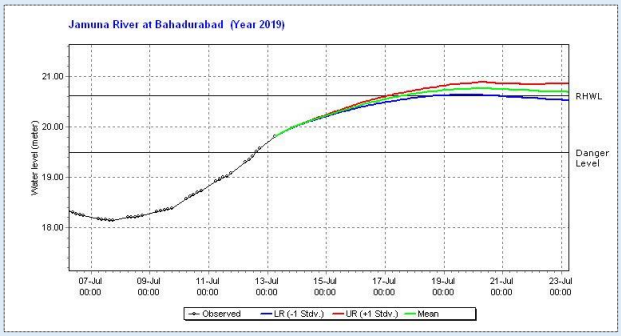
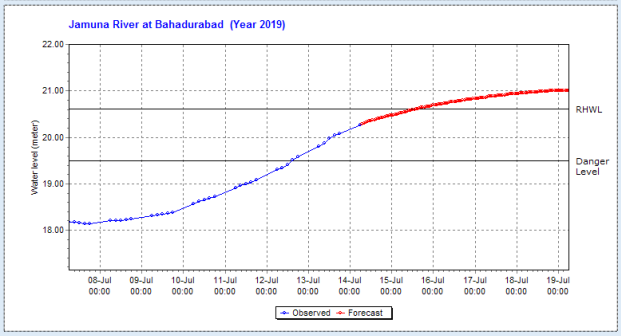
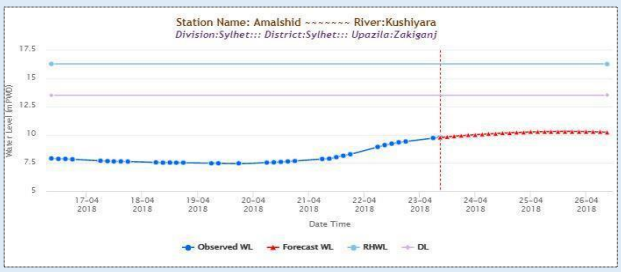
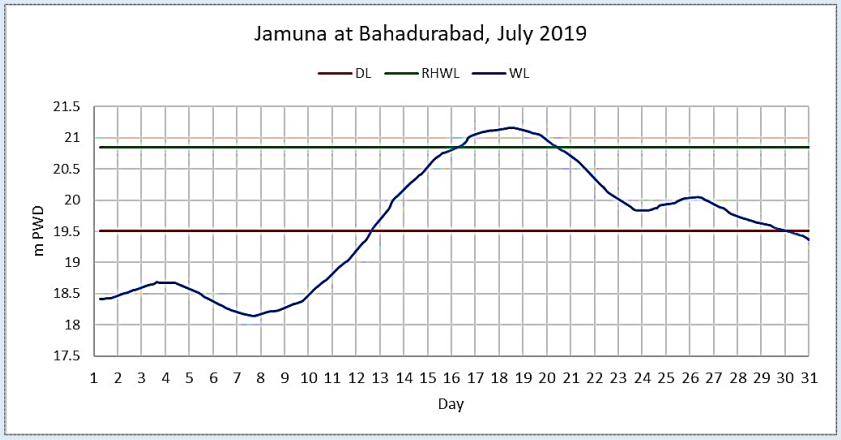
ANNUAL FLOOD REPORT 2019

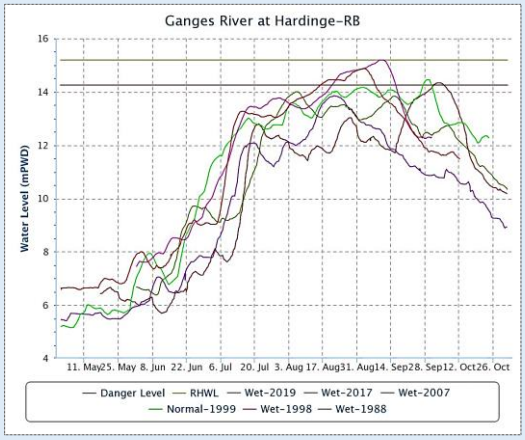












FLOOD FORECASTING & WARNING CENTRE
PROCESSING & FLOOD FORECASTING CIRCLE
BANGLADESH WATER DEVELOPMENT BOARD

Annual Flood Report 2019

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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 BMD, DDM, DAE during the pre-monsoon and monsoon for flood disaster mitigation and 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 aspired by the valuable advice and guidance of the Secretary, MoWR, Govt. of Bangladesh 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), 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 2019. A number of 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.

FFWC is providing the following services on daily basis during monsoon

- Flood bulletin twice a day
- River and rainfall situation summary report
- 5-days deterministic and 10-days probabilistic flood forecast with hydrograph
- Special outlook and warning message
- Structure based forecast at 4 key locations
- Rainfall Map
- Flood Inundation Map
- Flood warning message dissemination publicly through user-friendly website (www.ffwc.gov.bd), toll-free Interactive Voice Response (IVR) method (number 1090) and Android based 'BWDB Flood App'
- Flood warning message dissemination through email and fax to all relevant government organizations and selected medias, NGOs, stakeholders and others

Besides this, during the pre-monsoon season FFWC is providing flash flood forecast and outlook for the North-Eastern region of the country to minimize damage of standing Boro crops in Haor basins. From 2017, FFWC has experimentally started 3-days deterministic flash flood forecasting under the BWDB part of Haor Infrastructure and Livelihood Improvement Project (HILIP) by LGED. The forecast system has been made operational this year at 26 stations over the region incorporating Bangladesh Meteorological Department (BMD) generated quantitative rainfall forecast.

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. Two of the main struggles and demand is to increase flood forecasting and warning lead time and make location specific flood forecast. A step towards improving the local flood warning messages has been initiated this year by entering into parthership with tech giant 'Google' who will provide support for high resolution flood mapping by means of satellite based advanced Digital Elevation Model data and machine learning techniques.

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 flood of 2019 as a whole, is a representative of severe one with respect to magnitude. During the monsoon 2019, all countrywide major flood events occurred during July. The flood stayed up to slightly longer than medium duration in the Northern, North-Western and North-Central regions and was of severe magnitude. The Brahmaputra-Jamuna river primarily caused the flood which exceeded the recorded highest water level at Bahadurabad and Fulchari this year creating locally a much more severe flood at low lying lands of Jamalpur and Gaibandha, causing therein one of the worst floods of recorded history. The Central region of the country along the Padma river experienced flooding of slightly above medium duration in moderate to above moderate magnitude. Moderate to severe flash floods occurred in the North-Eastern and South-Eastern regions during the period but all stayed for short duration. However, during the late monsoon period between 1st to 5th October the Ganges river at Hardinge Bridge flowed above danger level creating a normal flood of short duration in the West-Central portion of the country. This is the first time in last 16 year that the Ganges at Hardinge Bridge flowed above danger level and also the most delayed period of the year for such condition in last 30 years. During pre-monsoon, some low-lying places of the Haor basins were inundated slightly earlier than normal during the 1st week of May due to rainfall event induced by cyclonic storm 'Fani' but no significant damage to crops occurred. Evaluation indicated that average accuracy of 5-days deterministic flood forecasts issued by FFWC were around 95%, 89%, 82%, 76% and 75% for 24, 48, 72, 96 and 120 hours lead time respectively in the monsoon of 2019.

The monsoon was mostly active during July over the GBM basin but remained somewhat dormant during the rest of the period except during September over the Indian parts of Ganges basin. The country as a whole received 18.3% less rainfall than normal during the monsoon of 2019 (May to October). The Brahmaputra, Ganges, Meghna and the South Eastern Hill basins received 27.1%, 8.3%, 12.9% and 23.5% less rainfall than normal respectively. Basin wise monthly percentage based less (-) or more (+) rainfall than the normal is presented in the following table.

Month	Brahmaputra basin	Ganges basin	Meghna basin	South East Hill basin
May	-39.33	-8.56	-10.66	-59.18
June	-43.96	-27.03	-2.44	-71.88
July	+0.14%	-2.96%	+8.67%	+24.48%
August	-59.58%	-9.11%	-48.91%	-39.76%
September	-21.63	-11.32	-36.11	9.62
October	17.11	36.04	14.05	-34.61

Notable improvements have been made during 2019 as the 3-days experimental flash flood forecasting system for the North-East region has been made operational. Also partnership has been signed with tech giant 'Google' for their technical support in improving local level flood mapping. During the monsoon of 2019, maximum flooded area was 31% of the whole country (45,747 sq-km approximately). Some of the regions experienced severe river bank erosion which continued both during and after the flooding.

List of Abbreviations

ADG	Additional Director General
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
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
DEM	Digital Elevation Model
DAE	Department of Agriculture Extension
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
SPARRSO	Space Research and Remote Sensing Organization
UNDP	United Nations Development Porgramme
USAID	United States Agency for International Development
WL	Water Level

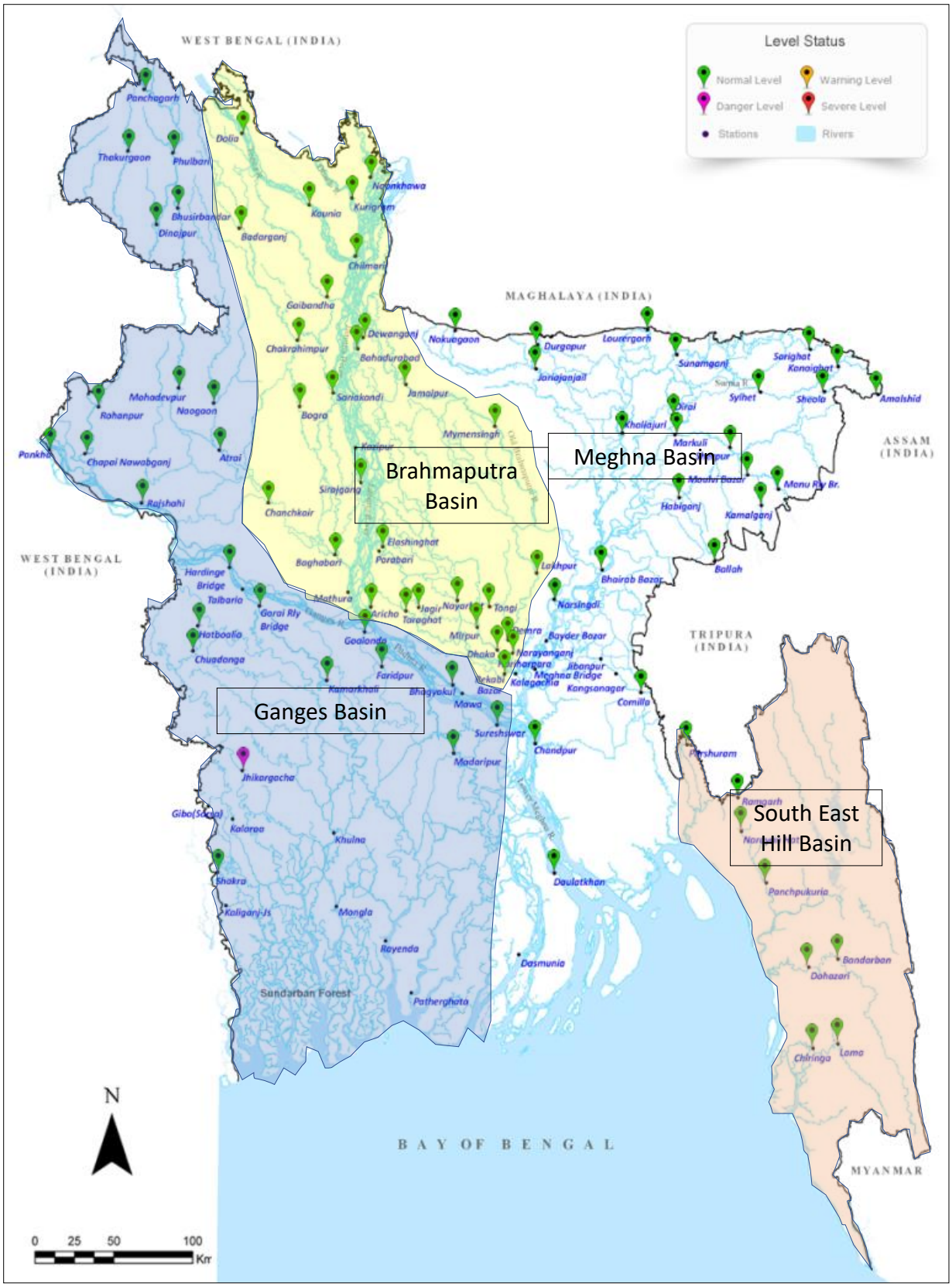


Figure 1 : Basin Map of Bangladesh with Water Level Gauge Stations

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 94 representative water level stations and 70 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, forecast for 24, 48, 72, 96 and 120 hours at 54 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 flash flood forecasting 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**
- **Structure based flood forecast**
- **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 - Experimental 3-days deterministic flash flood forecast for the North-Eastern region during pre-monsoon initiated at 17 stations

2018 - Experimental flash flood forecast expanded to 25 stations and establishment of pre-monsoon danger level in North-Eastern region
- Introduction of FFWC mobile app

2019 - Operational 3-days deterministic flash flood forecast at 26 stations for the North-Eastern region incorporating BMD generated quantitative rainfall forecast

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (94 WL stations and 70 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 internet, e-mail, and from BMD. In addition, a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

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 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 NWP model rainfall forecasts from BMD. In addition to BMD, NWP model rainfall forecasts from IMD, NOAA and 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, NGO's etc. including President's & Prime Minister's Secretariat. Whenever, the forecast river stage cross the DL, the concern field offices and limited key officials are informed through mobile SMS. Interactive Voice Response (IVR) through mobile has been initiated since July 2011 through Teletalk. Now, all the mobile operators have started the IVR 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.

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 (since 2018)

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 5-days ahead of its occurrence. An accurate forecast would be one where the forecast level and corresponding observed level at the stipulated time are within a small range of variation.

1.5. NATURE AND CAUSES OF FLOODING

1.5.1. Causative Factors

There are 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 km²) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are 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.

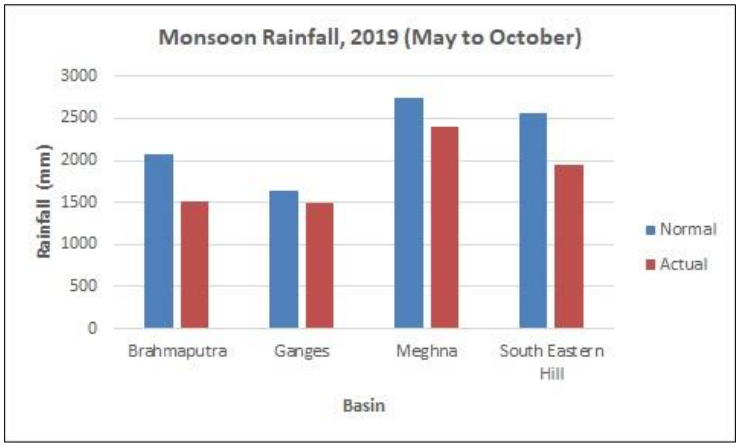
1.5.2. Statistics of Flooding

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 and 2017 all caused heavy damages to properties and considerable loss of life. During monsoon 2019, the flood was also a severe one and stayed for slightly longer than medium duration. The Brahmaputra-Jamuna river caused the severe flood this year affecting low lying lands of Northern and North-Western and North-Central Bangladesh. 31% of the country got flood affected in 2019. 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		Year	Flood affected area	
	Sq-Km	%		Sq-Km	%		Sq-Km	%
1954	**36,800**	**25**	1977	12,500	8	2000	35,700	24
1955	**50,500**	**34**	1978	10,800	7	2001	4,000	2.8
1956	35,400	24	1980	33,000	22	2002	15,000	10
1960	28,400	19	1982	3,140	2	2003	21,500	14
1961	28,800	20	1983	11,100	7.5	**2004**	**55,000**	**38**
1962	37,200	25	1984	28,200	19	2005	17,850	12
1963	43,100	29	1985	11,400	8	2006	16,175	11
1964	31,000	21	1986	6,600	4	**2007**	**62,300**	**42**
1965	28,400	19	**1987**	**57,300**	**39**	2008	33,655	23
1966	33,400	23	**1988**	**89,970**	**61**	2009	28,593	19
1967	25,700	17	1989	6,100	4	2010	26,530	18
1968	37,200	25	1990	3,500	2.4	2011	29,800	20
1969	41,400	28	1991	28,600	19	2012	17,700	12
1970	42,400	29	1992	2,000	1.4	2013	15,650	10.6
1971	36,300	25	1993	28,742	20	2014	36,895	25
1972	20,800	14	1994	419	0.2	2015	47,200	32
1973	29,800	20	1995	32,000	22	2016	48,675	33
1974	**52,600**	**36**	1996	35,800	24	**2017**	**61,979**	**42**
1975	16,600	11	**1998**	**1,00,250**	**68**	2018	33,941	23
1976	28,300	19	1999	32,000	22	**2019**	**45,747**	**31**

CHAPTER 2 : RAINFALL SITUATION



During the Pre-monsoon months of March and April in 2019, the Meghna basin within the country in the North-Eastern and adjacent region experienced 76.8% and 16.3% less rainfall than normal respectively, while other parts of the country remained mostly dry. During the Monsoon-2019 (May to October), the country experienced as a whole 18.3% less rainfall than normal which can be considered as below normal monsoon. The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 27.1%, 8.3%, 12.9% and 23.5% less rainfall than normal respectively during the season. Comparison of the country basin average of normal and actual rainfall for the Monsoon-2019 (May to October) is presented in the bar chart. Considering monthly rainfalls, all the basins have recorded less rainfall than their respective normal during May-June and August-September except for the South-Eastern Hill basin during September. During July and October, all the basins received more rainfall than respective normal except for the Ganges basin during July and the South-Eastern Hill basin during October. 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-2019 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	189.3	189.4	171.0	446.1	398.5	275.2	111.0	**2253**	**1840**
Jun	425.2	238.3	317.9	229.1	585.5	571.2	570.5	160.7		
Jul	484.9	485.6	401.4	383.0	632.3	687.1	677.2	864.3		
Aug	339.6	137.3	318.8	286.1	508.9	260.0	515.6	318.4		
Sep	353.4	277.0	281.9	259.6	402.3	280.0	348.9	386.2		
Oct	154.6	181	129.6	174	173.7	198.1	166.6	112.7		
Total	**2069.8**	**1508.5**	**1639.0**	**1502.8**	**2748.8**	**2394.9**	**2554.1**	**1953.3**		
%More/ Less	27.1% Less		8.3% Less		12.9% Less		23.5% Less		18.3% Less	

Month wise rainfall situations of the country during March to October for the Pre-monsoon and Monsoon seasons of 2019 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 2019, while the other parts of the country remained mostly dry. The basin received 76.76% less rainfall than monthly normal.

Important Rainfall Information for March-2019
Monthly Maximum at Kanaighat : 62 mm
1 day maximum at Kanaighat : 53 mm

Table 2.2: **Summary of the rainfall situation during the month of March-2019**

Basin:	**Meghna**
No of Stations:	17
Average Rainfall (mm) of the basin:	15.17
%More(+)/Less(-) than the Normal:	-76.76%
Number of Stations above Normal Rainfall:	04
Highest 1-day Maximum Rainfall with Stations:	Kanaighat 53.0mm
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 17 rainfall monitoring stations, 4 stations received more rainfall than their monthly normal. During March, monthly 1-day maximum rainfall of 53mm and 10-day consecutive maximum rainfall of 62 mm were observed at Kanaighat. 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 2019, while the other parts of the country remained mostly dry. The basin received 16.34 % less rainfall than monthly normal.

Important Rainfall Information for April-2019
Monthly Maximum at Sylhet : 379 mm
1 day maximum at Comilla : 100 mm

Table 2.3: **Summary of the rainfall situation during the month of April-2019**

Basin:	Meghna
No of Stations:	17
Average Rainfall (mm) of the basin:	190.94
%More(+)/Less(-) than the Normal:	-16.34%
Number of Stations above Normal Rainfall:	07
Highest 1-day Maximum Rainfall with Stations:	Comilla 100 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 17 rainfall monitoring stations, 7 stations received more rainfall than their monthly normal. During April, monthly 1-day maximum rainfall of 100 mm was observed at Comilla, while 10-day consecutive maximum rainfall of 250 mm was observed at B.Baria. 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 2019.

Important Rainfall Information for May-2019
Monthly Maximum at Sunamganj : 673 mm
1 day maximum at Panchagarh : 197 mm

Table 2.4: **Summary of the rainfall situation during the month of May-2019**

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Average Rainfall (mm) of the basin:	189.34	170.98	398.49	111
%More(+)/Less(-) than the Normal:	-39.33	-8.56	-10.66	-59.18
Number of Stations above Normal Rainfall:	3	9	6	0
Highest 1-day Maximum Rainfall with Stations:	Dhaka	Panchagarh	Manu Rly. Br.	Lama
	(104 mm)	(197 mm)	(173 mm)	(81 mm)
Number of Rain Fed Flood* Stations:	0	1	4	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, 3 stations received more rainfall than their normal. One day maximum rainfall of 104 mm was recorded at Dhaka. The Basin received -39.33% less rainfall than normal during the month May 2019.

In Ganges basin, out of 19 rainfall monitoring stations, 9 stations received more rainfall than their normal. One day maximum rainfall of 197 mm was recorded at Panchagarh. The Basin received 8.56% less rainfall than normal during the month May 2019.

In the Meghna basin, out of 17 rainfall monitoring stations, 6 stations received more rainfall than their normal. One day maximum rainfall of 173 mm was recorded at Manu Rly Br, while 10-day consecutive maximum rainfall of 384 mm was observed at Sherpur. The Basin received 10.66% less rainfall than normal during the month May 2019.

In the South Eastern Hill basin, out of 12 rainfall monitoring stations, no stations received more rainfall than their normal. One day maximum rainfall of 81 mm was recorded at Lama. The Basin received 59.18% less rainfall than normal during the month May 2019.

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 5 stations crossed the threshold value in this month. The maximum 1-day rainfall of 197 mm was recorded at Panchagarh and 10-day consecutive maximum rainfall of 388.5 mm was recorded at Panchagarh

The Isohyet of the actual rainfall of the month of May-2019 is shown in the Figure 2.1.

2.4 JUNE

Important Rainfall Information for June-2019

Monthly Maximum at Sunamganj: 1021 mm

1 day maximum at Sunamganj : 415 mm

The country, as a whole, experienced less rainfall than normal during the month of June 2019. The four hydrological basins namely the Brahmaputra, Ganges, Meghna and South-Eastern Hill basins received 43.96%, 27.03%, 2.44% and 71.88% less rainfall respectively in the month of June 2019. 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 -2019

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Basin average rainfall at June, 2019 (mm):	238.31	229.13	571.24	160.73
%More(+)/Less(-) than Normal:	-43.96	-27.03	-2.44	-71.88
No. of Stations above Normal Rainfall:	1	4	7	0
Highest 1-day Maximum Rainfall Stations:	Gaibandha 170	Panchagarh 217	Sunamganj 415	Teknaf 73
No of Rain Fed Flood*Stations:	0	1	9	0

*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 1 out of 13 stations in the Brahmaputra, 4 out of 19 stations in the Ganges and 7 out of 17 stations in the Meghna received more rainfall than their monthly normal rainfall. No stations recorded more than normal rainfall in the South Eastern Hill basin. Among all monitoring stations, Sunamganj in the Meghna basin is the daily highest (415mm) rainfall recipient station.

The table also shows that 1 station in the Ganges and 9 stations in the Meghna basin received more than 300 mm rainfall in 10-day period. As a result, some parts of Sylhet, Sunamganj, Netrokona were affected by rain feed flood during the month of June 2019. 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-2019 is shown in the Figure 2.2.

2.5 JULY

The country, as a whole, experienced more rainfall than normal during the month of July 2019. The Brahmaputra, the Meghna and the South Eastern Hill basins received 0.14%, 8.67% and 24.48% more rainfall respectively while the Ganges basin received 2.96% less rainfall than their respective monthly normal values during the month.

Important Rainfall Information for July-2019

Monthly Maximum at Teknaf : 1543.8 mm

10 day maximum at Lama : 1103 mm

1 day maximum at Lorergarh : 280 mm

Table 2.6: Summary of the rainfall situation during the month of July-2019

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Basin average rainfall in July, 2019 (mm):	485.63	383.01	687.08	864.29
%More(+)/Less(-) than the Normal:	**+0.14%**	**-2.96%**	**+8.67%**	**+24.48%**
Number of Stations above Normal Rainfall:	8	11	13	9
Highest 1-day Maximum Rainfall with Stations:	177 mm Dalia	200 mm Panchagarh	280 mm Lorergarh	230 mm Bandarban
Number of Rain Fed Flood* Stations:	9	4	15	11
Name of Rain Fed Flood* Stations:	Kurigram, Dalia, Rangpur, Dewanganj, Gaibandha, Serajganj, Jamalpur, Dhaka, Tangail.	Panchagarh, Dinajpur, Patuakahli, Barguna	Kanaighat, Sylhet, Sunamganj, Sheola, Moulvi Bazar, Manu Rly Br, Sherpur, Durgapur, Lorergarh, Nakuagaon, Jariajanjail, B.Baria, BhairabBz, Comilla, Narsingdi.	Parshuram, Noakhali, Narayanhat,Panchpukuria, Bandarban, Rangamati, Lama, Chittagong, Ramgarh, Cox's bazaar, Teknaf

*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, 8 stations received more rainfall than their normal rainfall. The Basin received 0.14**%** more rainfall than their normal during the month July 2019. Monthly 1-day maximum rainfall of 177 mm and 10-day max of 603 mm was recorded at Dalia. Rainfall of Dhaka in July 2019 was recorded 473.5 mm, above the normal rainfall of Dhaka.

In Ganges basin, 11 of 19 stations received less rainfall than their normal. The basin as a whole received 2.96**%** less rainfall than its normal during the month of July-2019. Both one day maximum rainfall of 200 mm and 10-day consecutive maximum rainfall of 651 mm was recorded at Panchagarh.

In Meghna basin, 13 out of 17 stations were recorded more rainfall than their normal value of the month. The Basin as a whole recorded 8.67**%** more rainfall than normal during the month of July 2019. One day maximum rainfall of 280 mm was recorded at Lorergarh and 10-day consecutive maximum rainfall of 963 mm was recorded at Suanmganj.

In South Eastern Hill basin, 9 out of 12 stations received more rainfall than their normal. The basin as a whole received 24.48%more rainfall than its normal rainfall during the month of July 2019. One day maximum rainfall of 230mm at Bandarban and 10-day consecutive maximum rainfall of 1103 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 61 stations, total 41 stations received more rainfall than normal and 39 stations recorded more than 300 mm rainfall for 10-day period. Maximum 10-daymaximum rainfall recorded at Lama of 1103 mm and 1-day at Lorergarh of 280 mm. Rain fed flood situation developed at Chittagong, Cox's Bazar, Bandarban, Parshuram, Ramgarh, Noakhali, Barguna, Patuakhali, Kanaighat, Sylhet, Sunamganj, Laurergorh, Moulvibazar, Durgapur, Jariajanjail, Kurigram, Dalia, Panchagarh, Sirajganj, Tangail and Dhaka with some additional surrounding places.

A map with Isohyet of the actual rainfall of July-2019 is shown in the Figure 2.3.

2.6 AUGUST

Important Rainfall Information for August-2019
Maximum at Satkhira : 927.1 mm
One day maximum at Khulna : 200 mm

The intensity of rainfall in the Brahmaputra, Ganges, Meghna and South Eastern Hill basins were moderately low at most of the places during the month of August 2019. All the four hydrological basins received less rainfall than their respective monthly normal rainfalls during the month of August, 2019. The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 59.58%, 9.11%, 48.91% and 39.76% less rainfall than their respective normal rainfall. 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-2019

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	18	16	11
Basin average rainfall at August, 2017(mm):	137.28	286.08	259.97	318.44
%More(+)/Less(-) than Normal:	-59.58%	-9.11%	-48.91%	-39.76%
No. of Stations above Normal Rainfall:	0	5	0	0
Highest 1-day Maximum Rainfall Stations:	Chilmari	Khulna	Sunamganj	Chittagong
	(70 mm)	(200 mm)	(160 mm)	(143 mm)
No of Rain Fed Flood* Stations:	0	1	2	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 5 out of 18 rainfall stations in the Ganges basin received more rainfall than their monthly normal rainfall. In the other basins, lower than normal rainfalls were recorded at all monitoring stations. Among all monitoring stations, Khulna in the Ganges Basin has the daily highest rainfall recorded station.

The Table 2.1 shows that 1 station in Ganges basin, 2 stations in the Meghna Basin and 4 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-2019 is shown in the Figure 2.4.

2.7 SEPTEMBER

Important Rainfall Information for September-2019
Monthly maximum at Teknaf : 1077.4 mm
1-day maximum at Teknaf : 285 mm

The country, as a whole, experienced less rainfall than normal during the month of September 2019. The Brahmaputra, Ganges and Meghna basins received 21.63%, 11.32% and 36.11% less rainfall than their respective normal rainfall of the month. The South Eastern Hill basin received 9.62% more rainfall 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-2019

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	19	17	12
Basin average rainfall at September,2019(mm):	276.98	259.63	280	386.15
%More(+)/Less(-) than Normal:	-21.63	-11.32	-36.11	9.62
No. of Stations above Normal Rainfall:	3	8	2	7
Highest 1-day Maximum Rainfall Stations:	Rangpur (165 mm)	Panchagarh (97.5 mm)	Nakuagaon (155 mm)	Teknaf (285 mm)
No of Rain Fed Flood*Stations:	1	0	3	5

*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 3 out of 13 stations in the Brahmaputra, 8 out of 19 stations in the Ganges and 2 out of 17 stations in the Meghna and 7 out of 12 stations in the South Eastern Hill basin received more rainfall than their monthly normal. Among all monitoring stations, Teknaf in the South-Eastern Hill basin is the daily highest (285 mm) rainfall recipient station.

The table also shows that 1 station in the Brahmaputra, 3 stations in the Meghna and 5 station in the South-Eastern Hill basin received more than 300 mm rainfall in 10-day period. As a result, some parts of Sylhet, Sunamganj, Netrokona and Chittagong hilly districts were affected by rain feed flood during the month of September 2019.

The Isohyet of actual rainfall for September-2019 is shown in the Figure 2.5.

2.8 OCTOBER

Important Rainfall Information for October-2019
Monthly maximum at Lama : 415mm
1 day maximum at Bandarban : 124mm
10 day maximum at Lama : 369mm

The country, as a whole, experienced rainfall more than normal during the month of October 2019. The Brahmaputra, Ganges and Meghna basins received more rainfall than monthly normal, while the South Eastern Hill Basin 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-2019

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Average Rainfall (mm) of the basin:	181	174	198.06	112.65
%More(+)/Less(-) than the Normal:	17.11	36.04	14.05	-34.61
Number of Stations above Normal Rainfall:	9	13	9	4
Highest 1-day Maximum Rainfall with Stations:	Gainbandha (150 mm)	Dinajpur (117.5 mm)	Sunamganj (245 mm)	Lama (94 mm)
Number of Rain Fed Flood* Stations:	0	0	1	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, 9 stations recorded more rainfall than the normal and the basin received 17.11% more rainfall than normal during the month October 2019. 1-day maximum rainfall of 150 mm was recorded at Gaibandha.

In Ganges basin, out of 19 rainfall monitoring stations, 13 station recorded more rainfall than the normal rainfall of the month. The basin as a whole received 36.04% more rainfall than the normal during the month.1-day maximum rainfall of 117.5 mm was recorded at Dinajpur.

In the Meghna basin, out of 17 rainfall monitoring stations, 9 stations recorded more rainfall than the normal value of the month. The Basin received 14.05% more rainfall than monthly normal during the month.1-day maximum rainfall of 245 mm was recorded at Sunamganj.

In the South Eastern Hill basin, out of 12 rainfall monitoring stations, 4 stations were recorded more rainfall than normal. The Basin as a whole recorded less rainfall than normal during the month. 1-day maximum rainfall of 94 mm was recorded at Lama.

The table also shows that 1 station in the Meghna basin received more than 300 mm rainfall in 10-day period.

A map with the Isohyet of actual rainfall for the month of October-2019 is shown in the Figure 2.6.

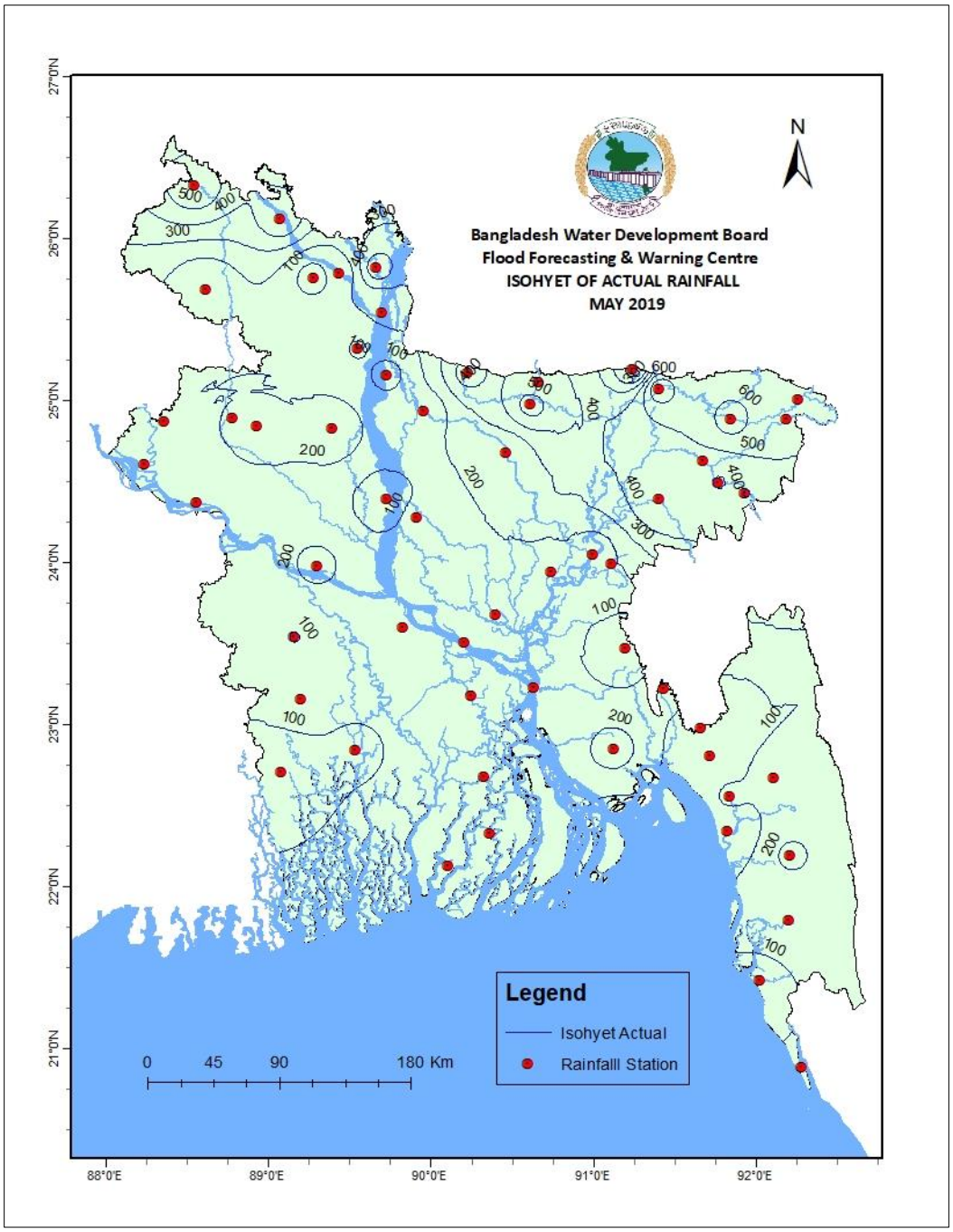


Figure 2.1: Isohyet of Actual Rainfall (May-2019)

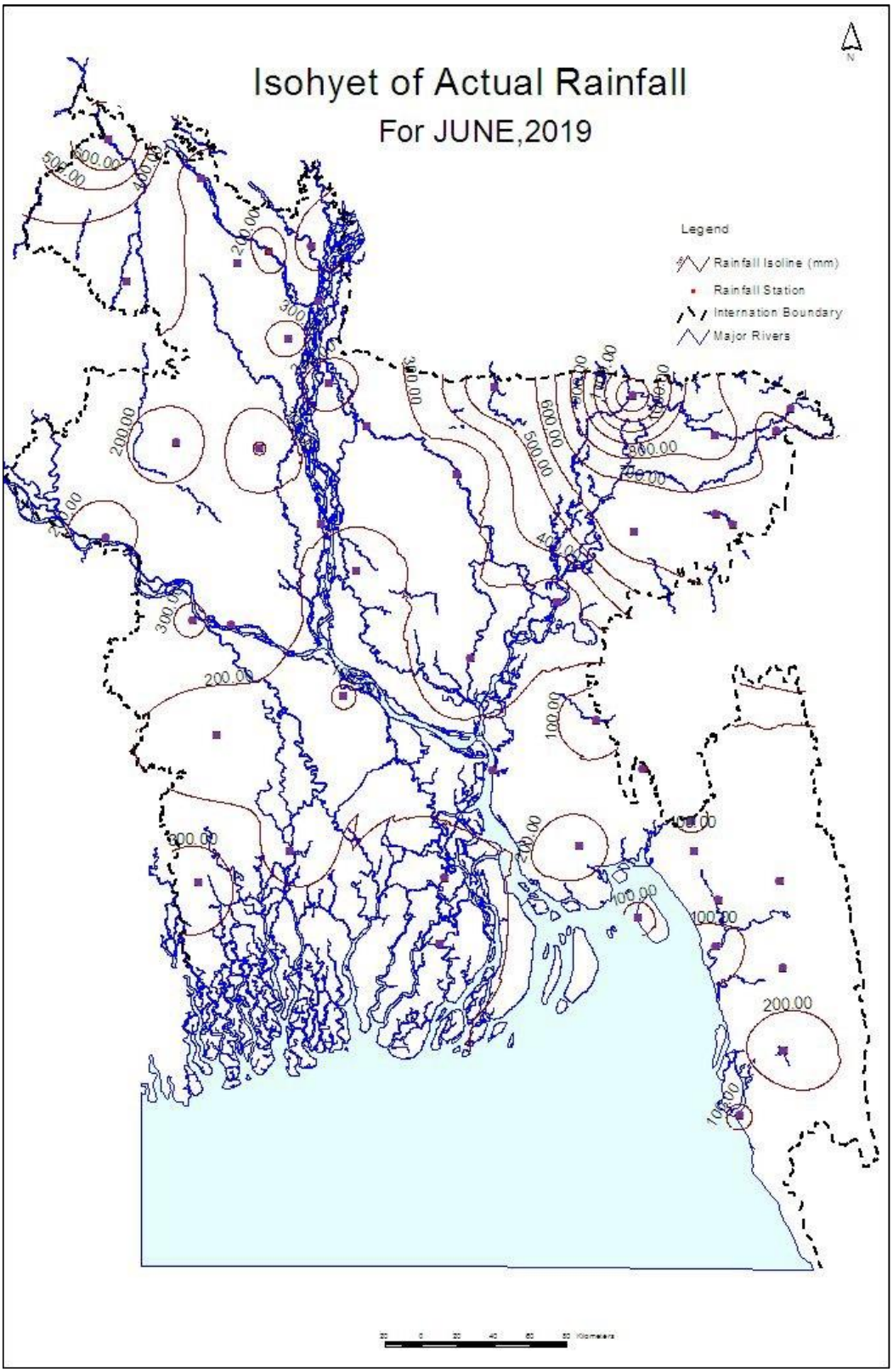


Figure 2.2: Isohyet of Actual Rainfall (June-2019)

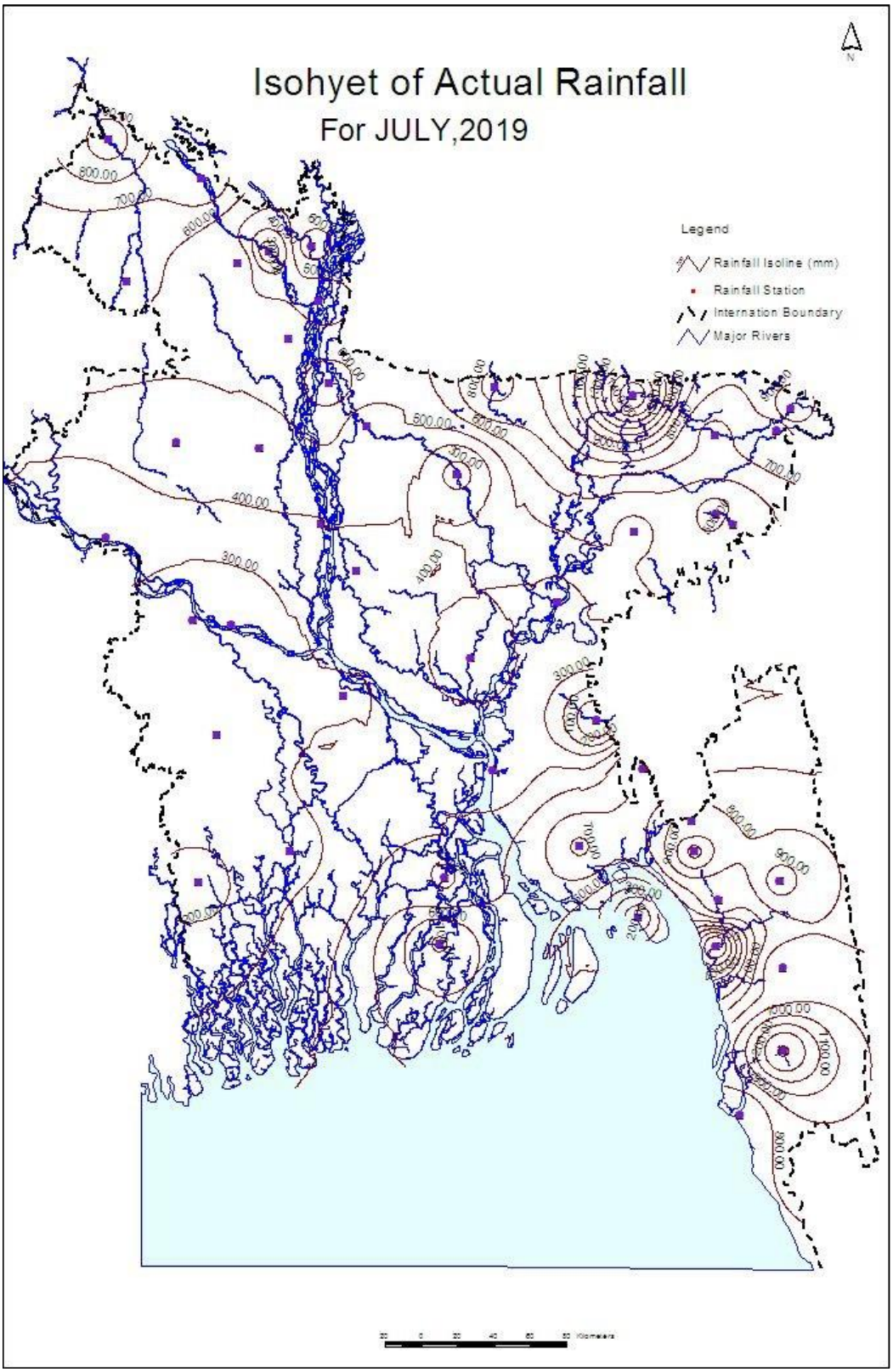


Figure 2.3: Isohyet of Actual Rainfall (July-2019)

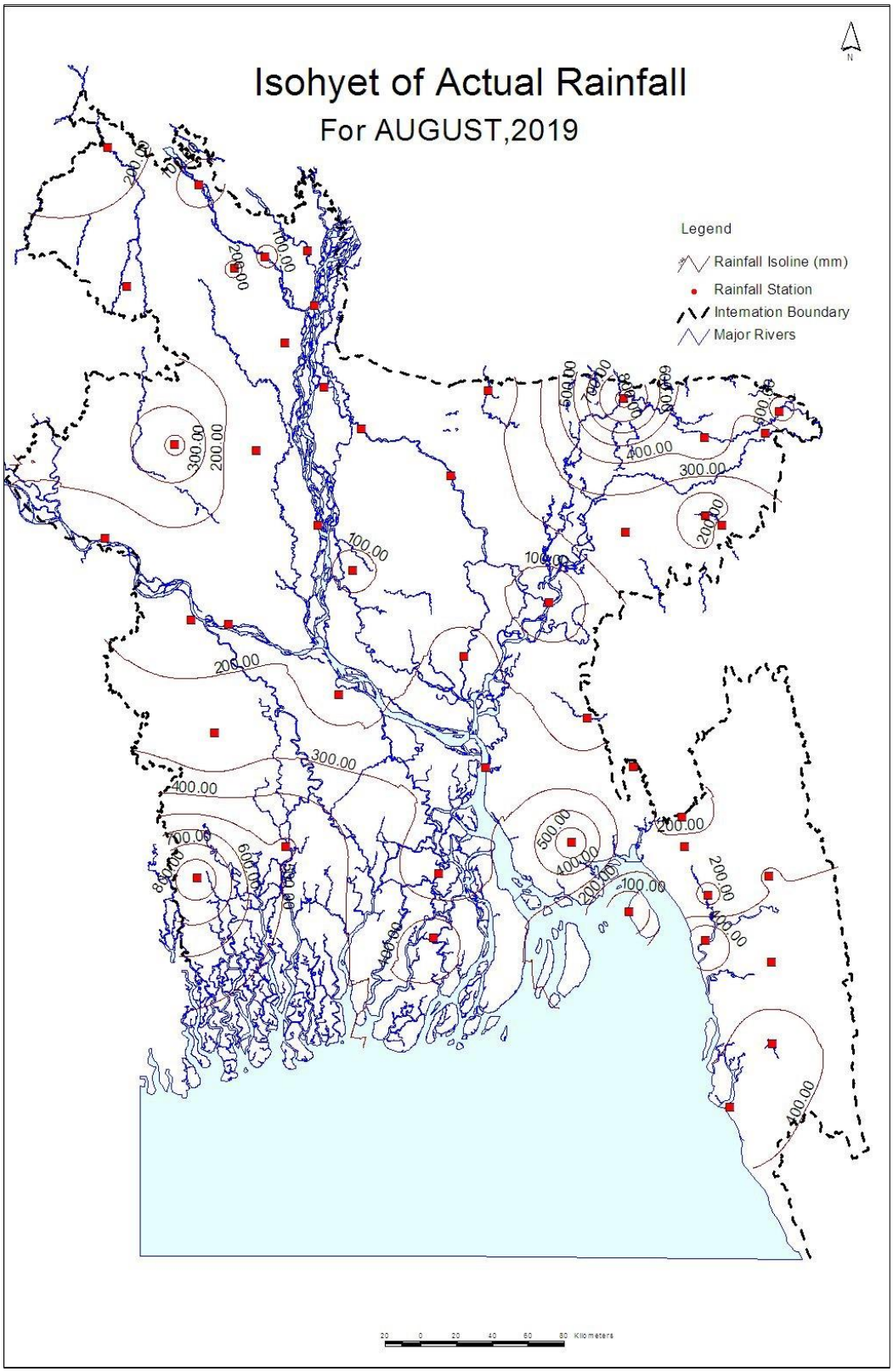


Figure 2.4: Isohyet of Actual Rainfall (August-2019)

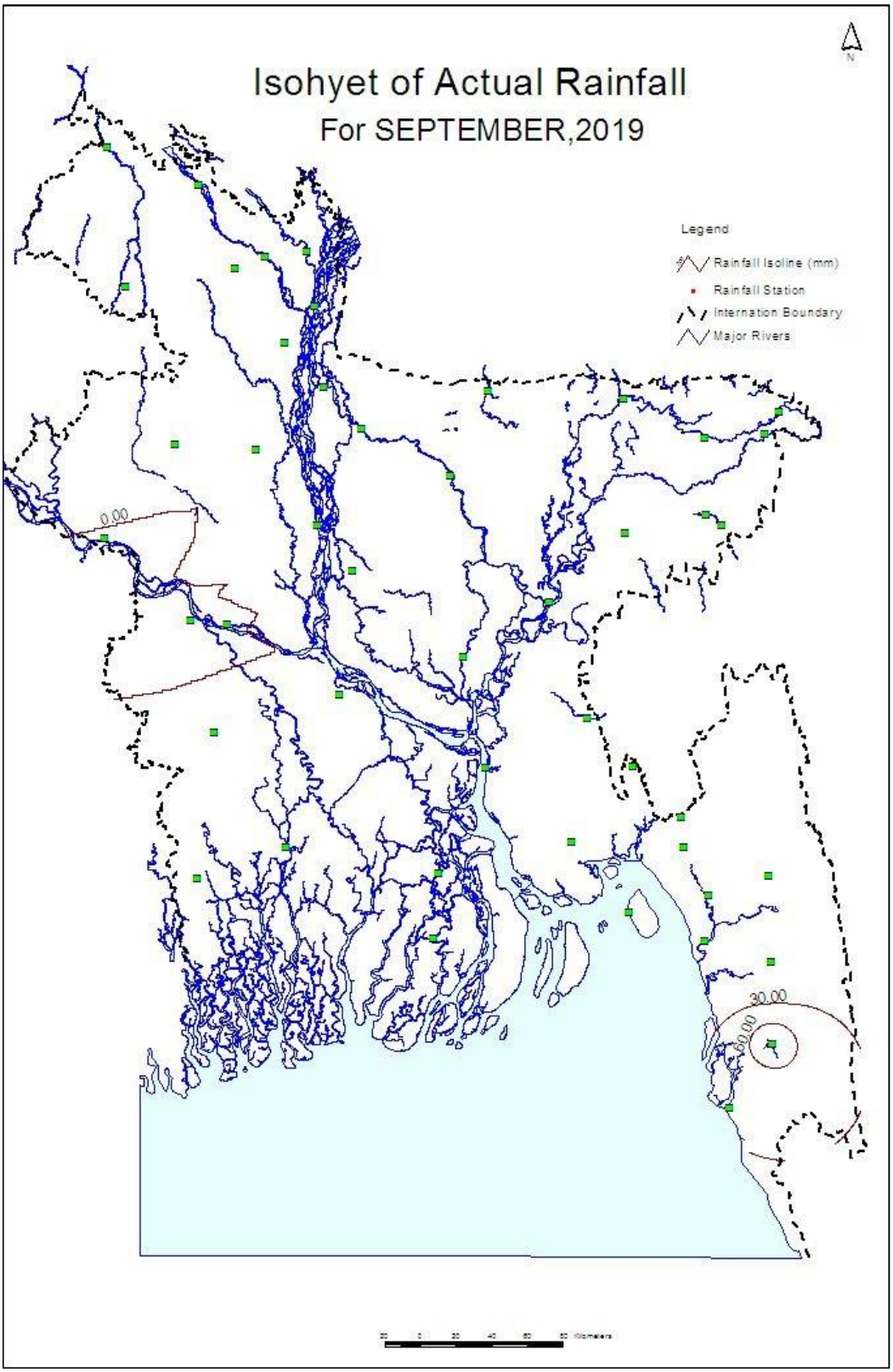


Figure 2.5: Isohyet of Actual Rainfall (September-2019)

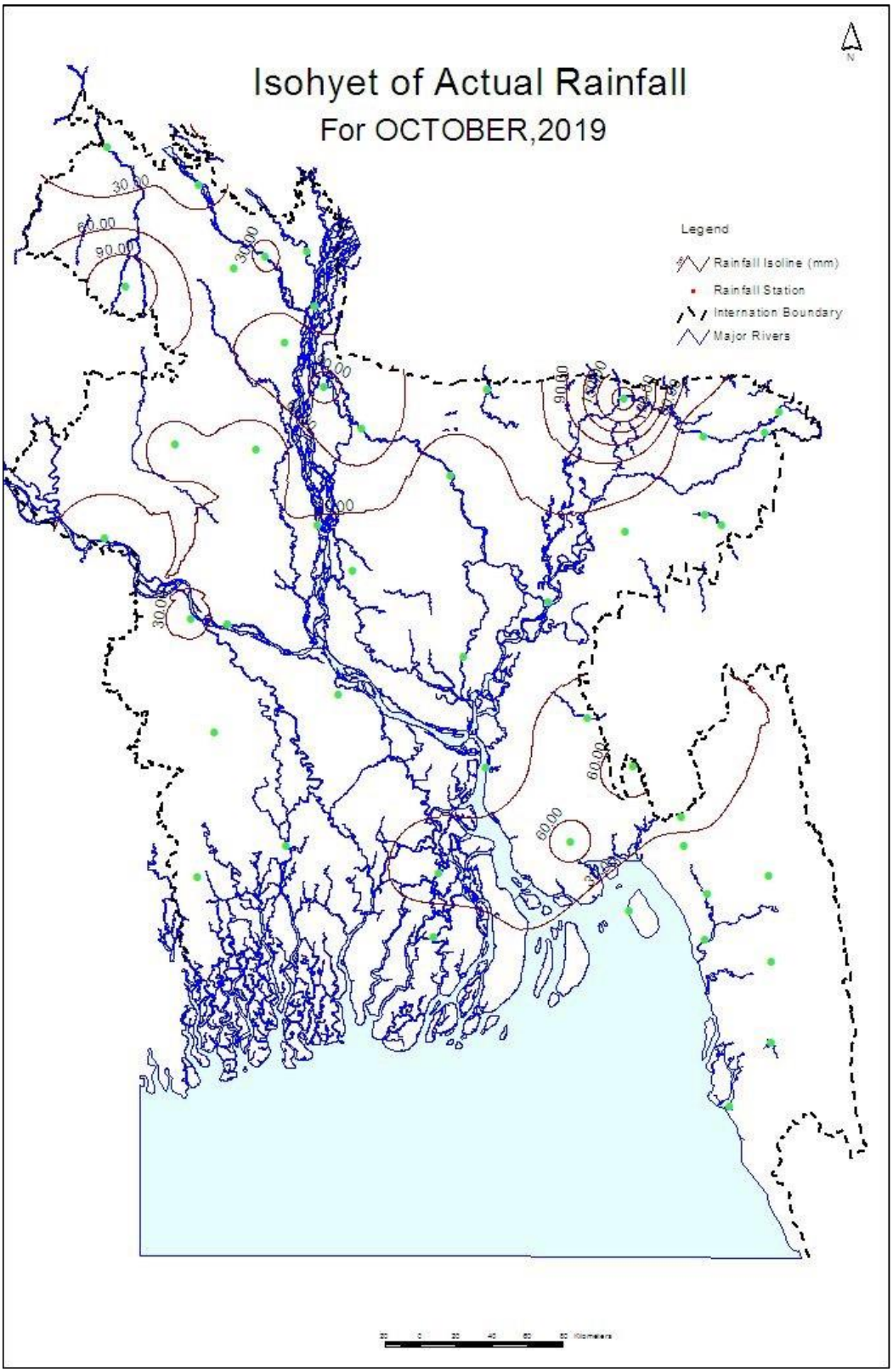


Figure 2.6: Isohyet of Actual Rainfall (October-2019)

CHAPTER 3 : RIVER SITUATION

During the monsoon 2019, the flood was a severe one which stayed for slightly longer than medium duration in the lower parts of Brahmaputra basin, while for medium duration in the lower parts of Ganges basin. The Meghna and the South Eastern Hill basins faced short duration flooding. The Meghna basin faced flooding during June and July, while the Brahmaputra, Ganges and the South Eastern Hill basins during July only. However, a few places along the Ganges river experienced short duration flooding in October this year. Some parts of the Haor region of the Meghna basin were flooded during the late pre-monsoon at first week of May. Basin wise WL situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 30 Water Level (WL) monitoring stations in the Brahmaputra basin, river WL crossed their respective Danger Levels (DL) at 16 stations. Water Level of Brahamaputra Basin started rising from the 2nd week of June 2019, for the first time in the monsoon, and later caused a severe flood situation in July which lasted up to 18 days at low lying places. During this period, the Teesta River at Dalia on 12th July 2019 and the Jamuna River at Bahadurabad and Fulchari on 18th July 2019 reached peaks and crossed the previous recorded highest water levels. As a result, low-lying areas of Kurigram, Lalmonirhat, Nilphamari, Gaibandha, Bogra, Sirajganj, Jamalpur, Tangail and Manikganj districts were mostly flooded for short to slightly longer than medium duration. A comparative statement of WL for current year 2019 and historical events of 2017 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 one time during the monsoon-2019 at the 2nd week of July and flowed above DL for a total of 15 days. WL at Kurigram attained peak of 27.67 mPWD on 16th July which was 117 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 3 times during the monsoon with highest peak on 13th July with a WL of 53.10 mPWD, which was 50 cm above its DL (52.40 m) and exceeded previous RHWL of 53.05 m. At Dalia, it flowed above DL for 7 days throughout the monsoon period. At Kaunia, WL of the river Teesta crossed its DL mark one time during the mosoon-2019, attained the peak of 29.42 mPWD on 14th of July which was 22 cm above the DL (29.20 m) at that point.

The Jamuneswari at Badarganj

The WL of Jamuneswari river at Badarganj in monsoon-2019 attained the peak of 31.78 mPWD (DL 32.15m) on 17th July. During the whole monsoon this station flowed below DL.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha during the monsoon-2019 attained peak of 22.64 mPWD on 18th July which was 94 cm above DL (21.70m). This station flowed above its DL mark for 16 days during the time and flowed below DL during the rest of the monsoon.

The Karatoa at Chakrahimpur and Bogra

At Chakrahimpur, the Karatoa reached peak water level of 20.19 mPWD on 20th July and flowed 4 cm above the DL (20.15m). In the whole monsoon, this station flowed above its DL mark for 3 days only during this time. At Bogra point, the Karatoa river did not cross its respective Danger Level with a peak flow of 14.97 mPWD on 28th July, which was 135 cm below the respective DL (16.32mPWD).

The Brahmaputra at Noonkhawa and Chilmari

The Brahmaputra at Noonkhawa and Chilmari crossed respective DLs once during 2019 monsoon. At Noonkhawa, the WL of the Brahmaputra River attained the peak of 27.53 mPWD on 17th July, which was 103 cm above the DL (26.50 mPWD). During the whole monsoon, this station flowed above its DL mark for 10 days.

Brahmaputra at Chilmari flowed above its DL (23.70 m) for 17 days in 2019 monsoon. At Chilmari, the Brahmaputra reached peak water level 25.02 mPWD on 17th July and flowed 132 cm above the DL (23.70 m).

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

The WL of river Jamuna at Fulchari, Bahadurabad, Sariakandi, Serajgonj, Kazipur & Aricha demonstrated similar trends like Brahmaputra at Noonkhawa and Chilmari and crossed the DL once during the monsoon. Jamuna recorded maximum water level in history at Fulchari (21.35 on 18th July, 153 cm above DL) and Bahadurabad (21.16 on 18th July, 166 cm above DL) and stayed above DL for 18 days in the month of July. At Sariakandi, the Jamuna crossed the respective DL (16.70m) in this monsoon like Bahadurabad station. It crossed the DL on 13th July and continued till 27th July for 15 days, with a peak of 17.98 mPWD on 18th July which was 128 cm above the DL (16.70 m). At Kazipur, the WL of the Jamuna river crossed the DL (15.24m) with a peak of 16.51 mPWD which was 126 cm above DL and flowed for 14 days during the 2019 monsoon. At Serajganj, the Jamuna flowed above DL (13.35m) during the monsoon of 2019 for 12 days with a peak of 14.34 mPWD on 19th July which was 99 cm above DL.

At Aricha, the WL of the Jamuna river flowed above the DL (9.40m) during 2019 monsoon for 7 days and the peak WL recorded was 9.84 mPWD on 18th July which was 44 cm above DL.

The Atrai at Baghabari

The WL of river Atrai at Baghabari flowed above DL (10.40m) in the month of July during 2019 monsoon for 15 days with the peak of 11.23 mPWD on 21st July, which is 83 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) in the month of July during 2019 monsoon for 17 days with the peak of 12.36 mPWD on 20th July, which is 96 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 above the DL (17.00m) for 4 days with the recorded peak WL of 17.17 mPWD on 22nd July. At Mymensingh, the WL remained below the DL (12.50m) during the whole monsoon. The peak WL recorded was 12.31 mPWD on 23nd July, which was 19 cm below the DL (12.50m) at that point.

The Lakhya at Narayanganj

Lakhya River at Narayanganj flowed below DL (5.50 m) during monsoon 2019. It attained its monsoon peak of 5.33 mPWD on 29th July, which was 17 cm below the DL.

The Rivers around Dhaka

Stations near or around Dhaka city attained the peak of the monsoon during July 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 4.90 mPWD (DL 6.0m) on 22nd July and 5.40 m (DL 5.75m) on 29th July respectively. The Turag at Mirpur flowed with a peak of 5.27 mPWD on 30th July which is 67 cm below the DL (5.94 mPWD). The water level of Tongi Khal at Tongi flowed below DL (6.08m) as well and the peak WL recorded at this station was 5.49 m on 27th July.

The Kaliganga at Taraghat

The WL of Kaliganga River at Taraghat showed a trend similar to that of the Buriganga at Dhaka. The river at this station flowed below the DL (8.40 m) with a peak of 8.33 mPWD on 23rd July.

Comparative hydrographs for the years of 2019, 2017 & 1998 at few stations of the Brahmaputra basin are shown in Figures 3.1 to 3.12.

Table 3.1 : Comparison of Water Level (in mPWD) of 2019 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		
					2019	2017	1998	2019	2017	1998
1	Dharla	Kurigram	27.84	26.50	27.67	27.84	27.22	15	12	30
2	Teesta	*Dalia	53.10	52.60	53.10	53.05	52.20	7	6	-

Sl.No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2019	2017	1998	2019	2017	1998
3	Teesta	Kaunia	30.52	29.20	29.42	29.95	29.91	3	NA	-
4	Jamuneswari	Badarganj	33.61	32.15	31.78	33.61	33.00	0	8	6
5	Ghagot	Gaibandha	22.81	21.70	22.64	22.55	22.30	16	15	51
6	Karatoa	Chakrahimpur	21.41	20.15	20.19	20.40	20.86	3	10	-
7	Karatoa	Bogra	17.45	16.32	14.97	15.04	15.57	0	0	-
8	Brahmaputra	Noonkhawa	28.10	26.50	27.53	27.39	27.35	10	3	-
9	Brahmaputra	Chilmari	25.07	23.70	25.02	24.87	24.77	17	14	22
10	Jamuna	*Fulchari	21.35	19.82	21.35	21.03	-	18	NA	-
11	Jamuna	*Bahadurabad	21.16	19.50	21.16	20.84	20.37	18	25	66
12	Jamuna	Sariakandi	19.07	16.70	17.98	17.96	-	15	24	-
13	Jamuna	Kazipur	17.47	15.25	16.51	16.80	-	14	29	-
14	Jamuna	Serajganj	15.12	13.35	14.34	14.87	14.76	12	33	48
15	Jamuna	Aricha	10.76	9.40	9.84	10.16	10.76	7	12	68
16	Gur	Singra	13.67	12.65	12.51	13.67	-	0	24	-
17	Atrai	Baghabari	12.45	10.40	11.23	11.50	-	15	22	-
18	Dhaleswari	Elasin	12.52	11.40	12.36	12.52	-	17	31	-
19	Old Br.putra	Jamalpur	18.00	17.00	17.17	17.01	17.47	4	1	31
20	Old Br.putra	Mymensingh	13.71	12.50	12.31	12.03	13.04	0	0	33
21	Lakhya	Lakhpur	8.70	5.80	5.80	6.77	-	0	22	-
22	Buriganga	Dhaka	7.58	6.00	4.9	5.22	7.24	0	0	57
23	Balu	Demra	7.13	5.75	5.4	5.65	-	0	0	-
24	Lakhya	Narayangonj	6.93	5.50	5.33	5.74	6.93	0	10	71
25	Turag	Mirpur	8.35	5.94	5.27	5.88	7.97	0	0	70
26	Tongi Khal	Tongi	7.84	6.08	5.49	6.10	7.54	0	2	66
27	Kaliganga	Taraghat	10.39	8.38	8.33	9.34	-	0	14	-
28	Dhaleswari	Jagir	9.73	8.23	7.68	9.00	-	0	13	-
29	Dhaleswari	Rekabi Bazar	7.66	5.18	4.67	5.07	-	0	0	-
30	Banshi	Nayarhat	8.39	7.32	5.59	5.93	-	0	0	-

*stations exceeding RHWL in 2019

3.2 THE GANGES BASIN

In the Ganges basin, out of 25 WL monitoring stations, 6 stations flowed above their respective DLs during monsoon 2019. The Padma at Goalundo, Bhagyakul & Sureswar stations flowed above DL for 7 to 17 days. As a result, low-lying areas of Rajbari, Faridpur, Dhaka, Munshiganj, Madaripur and Shariatpur districts were mostly flooded this year in July for medium to slightly longer than medium duration. The Ganges at Hardinge Bridge flowed above DL for 5 days in October. The Pashure at Khulna flowed above DL for 28 days throughout the season mostly due to tidal influences. A comparative statement of WL for current year 2019 and historical events of 2017 and 1998 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below:

The Karatoa at Panchagarh

The Karatoa river at Panchgarh showed rise and fall during the monsoon 2019 and flowed below the DL (70.75m) with a peak flow of 69.99 mPWD on 14th July, which was 76 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 2019 and flowed below the DL. The peak WL recorded was 32.58 mPWD on 16th July, which was 92 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 its highest peak of 49.67 mPWD on 15th July, which was 73 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 39.45 mPWD on 15th July flowing 17 cm below DL (39.62 m). The Atrai at Mohadevpur also flowed below the DL with peak of 18.57 mPWD on 17th July which was 2 cm below the DL (18.59m).

The Mohananda at Chapai-Nawabganj

This river showed a gradual rise and fall in water level throughout the monsoon. It attained its peak of 20.88 m on 3rd October, which was 12 cm below its DL (21.00m) at Chapai-Nawabganj. The Mohananda at Chapai-Nawabganj flowed below the DL during the whole monsoon 2019.

The Little Jamuna at Naogaon

The Little Jamuna river at Naogaon flowed below its danger level during 2019 monsoon. It attained its peak 15.06 mPWD on 18th July which was 18 cm below the Danger level (15.24 m).

The Ganges at Pankha, Rajshahi and Hardinge Bridge

The Ganges River at Pankha showed a gradual rise in July as well as in the end of September but did not cross the respective DL. At Pankha the peak water level recorded was 22.23 mPWD on 2nd October, which was only 27 cm below the DL (22.50m). At Rajshahi, the Ganges showed nearly similar trend as at Pankha and also flowed below its respective DL. It attained its peak of 18.19 mPWD on 3rd October, which was 31 cm below its DL (18.50m) at Rajshahi. However, at Hardinge Bridge, water level flowed above the respective Danger Level for 5 days and attained its peak of 14.33 mPWD on 2nd October which was 8 cm above its DL (14.25m).

The Padma at Goalundo

At Goalundo, the WL of Padma crossed the DL twice during 2019 monsoon and flowed above the DL for 17 days in total. The WL of the river Padma at Goalundo attained its

yearly peak of 9.33 mPWD on the 20th July which was 68 cm above its DL (8.65 m) at that point.

The Padma at Bhagyakul

At Bhagyakul, the WL of river Padma crossed the DL once and flowed above for 7 days. The river Padma has tidal influence at this point. The WL of the river attained its highest yearly peak water level of 6.70 mPWD on 20th July which was 40 cm above the DL (6.30m).

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 12.47 mPWD on 3rd October, which was 28 cm below the DL (12.75m) at Gorai Rail Bridge. Gorai river at Kamarkhali flowed above the DL for 6 days. The WL of the river attained its highest yearly peak of 8.47 mPWD on 3rd October, which was 27 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 as with the river Padma. The WL of Arialkhan at Madaripur flowed below the DL throughout the monsoon. The WL attained its highest peak of 3.55 m on 23rd July, which was 62 cm below the DL (4.17m).

Kobodak at Jhikargacha

Water Level at Jhikargaha flowed below the DL during the whole monsoon with a yearly peak of 2.39 mPWD on 18th August which was 271 cm below the DL (5.10m) at that point.

Comparative hydrographs for few important stations of the basin for the years of 2019, 2017 & 1998 are shown in figures 3.13 to 3.22.

Table 3.2 : Comparison of Water Level (in mPWD) of 2019 and Historical Events of 2017 & 1998 of Some Important Stations in the Ganges Basin

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2019	2017	1998	2019	2017	1998
1	Karatoa	Panchgarh	72.65	70.75	69.99	70.81	-	0	1	-
2	Punarbhaba	Dinajpur	34.40	33.50	32.58	34.30	34.09	0	4	3
3	Ich-Jamuna	Phulbari	30.47	29.95	28.7	30.12	-	0	3	-
4	Tangon	Thakurgaon	51.30	50.40	49.67	51.30	-	0	3	-
5	Upper Atrai	Bhusirbandar	41.10	39.62	39.45	40.35	-	0	3	-
6	Mohananda	Rohanpur	23.83	22.00	21.47	22.70	-	0	14	-
7	Mohananda	Chapai-Nawabganj	23.01	21.00	20.88	21.16	-	0	6	-
8	Little Jamuna	Naogaon	16.20	15.24	15.06	16.06	-	0	13	-
9	Atrai	Mohadebpur	19.89	18.59	18.57	19.38	-	0	7	-
10	Ganges	Pankha	24.14	22.50	22.23	21.48	24.14	0	0	66

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2019	2017	1998	2019	2017	1998
11	Ganges	Rajshahi	20.00	18.50	18.19	17.54	19.68	0	0	28
12	Ganges	Hardinge Bridge	15.19	14.25	14.33	13.85	15.19	5	0	27
13	Padma	Goalundo	10.21	8.65	9.33	9.71	10.21	17	20	68
14	Padma	Bhagyakul	7.50	6.30	6.70	6.81	7.50	7	20	72
15	Padma	Sureswar	7.50	4.45	4.56	5.04	-	11	13	-
16	Gorai	Gorai Rail Bridge	13.65	12.75	12.47	12.21	13.45	0	0	25
17	Gorai	Kamarkhali	9.48	8.20	8.47	8.24	NA	6	3	NA
18	Ichamati	Sakra	4.60	3.96	3.47	3.67	-	0	0	-
19	Mathabhanga	Chuadanga	12.67	12.05	8.88	8.67	-	0	0	-
20	Mathabhanga	Hatboalia	15.13	14.50	11.12	10.62	-	0	0	-
21	Kobadak	Jhikargacha	5.59	5.10	2.39	4.65	NA	0	29	NA
22	Kumar	Faridpur	8.76	7.50	4.95	5.22	-	0	0	-
23	Arialkhan	Madaripur	5.80	4.17	3.55	3.89	NA	0	0	NA
24	Kirtonkhola	Barisal	3.20	2.55	2.5	2.69	-	0	1	-
25	Pashure	Khulna	3.48	3.04	3.47	3.48	-	28	31	-

3.3 THE MEGHNA BASIN

Most of the rivers of the Meghna basin have entered Bangladesh from the hilly catchments of India (Assam, Tripura and Meghalaya) and are flashy in nature. During the pre-monsoon (15 March - 15 May 2019), out of 36 WL monitoring stations in the basin, all stations flowed below their respective Pre-Monsoon Danger Levels (PMDL) upto April. However due to heavy rainfall activity within the basin induced by cyclone ‘Fani’ during the first week of May; 4 stations on Surma, Sarigowain, Someswari and Kangsha rivers crossed PMDL for short period inducing flash floods at local scale. Table 3.3 presents comparative statistics of WL during 2019 pre-monsoon for some selected stations on major rivers of Meghna basin with historical pre-monsoon flash flood years 2010 and 2017. All Water Level (WL) stations of the basin flowed below their respective respective monsoon Danger Levels (DL) during the period.

Table 3.3 : Comparison of Water Level (in mPWD) of 2019 and Historical Events of 2017 & 1998 of Some Important Stations in the Meghna Basin during the Pre-Monsoon (15 Mar-15 May)

Sl. No.	River	Station	Monsoon DL (m PWD)	Pre-Monsoon DL (m PWD)	Peak of the Duration (m PWD)			Days above Monsoon DL			Days above Pre-Monsoon DL
					2019	2017	2010	2019	2017	2010	2019
1	Surma	Kanaighat	13.20	11.35	12.01	14.49	14.35	0	06	13	1
2	Surma	Sylhet	11.25	8.75	8.14	11.31	10.88	0	03	0	0
3	Surma	Sunamganj	8.25	6.5	6.34	8.10	8.05	0	0	0	0
4	Kushiyara	Amalshid	15.85	13.50	10.35	16.03	15.51	0	03	0	0
5	Kushiyara	Sheola	13.50	11.15	8.15	13.89	13.94	0	06	03	0
6	Kushiyara	Sherpur	9.0	8.25	5.79	9.03	8.8	0	01	0	0
7	Kushiyara	Markuli	8.50	6.40	5.02	8.27	7.7	0	0	0	0
8	Sarigowain	Sarighat	12.80	11.15	12.28	13.35	13.38	0	03	03	3
9	Manu	Manu Rly Br	18.00	16.90	13.93	17.40	16.75	0	0	0	0
10	Manu	Moulvi Bazar	11.75	10.00	7.39	11.73	10.49	0	0	0	0
11	Khowai	Habiganj	9.50	9.10	5.76	10.60	7.95	0	05	0	0
12	Khowai	Ballah	21.80	21.80	20.95	22.96	-	0	08	0	0
13	Someswari	Durgapur	13.00	11.25	11.50	12.02	11.78	0	0	0	1
14	Kangsha	Jariajanjail	11.00	6.80	8.61	9.71	6.53	0	0	0	6
15	Upper Meghna	Bhairab Bazar	6.25	6.25	2.56	3.57	3.48	0	0	0	0
16	Gumti	Comilla	11.75	11.75	6.67	9.35	7.37	0	0	0	0

In the monsoon 2019, out of 27 WL monitoring stations in the Meghna basin, 17 stations flowed above their respective DL. The Surma, Kushyara, Sarigowain, Manu, Khowai, Dhalai, Jadukata, Someswari, Bhugai and Old Surma rivers of the Upper Meghna basin crossed and stayed above their respective DL with duration varying from 1 to 19 days in mostly short duration spells during June-July only. However, the flood duration on Someswari at Kalmakanda in Netrokona during July was a medium duration spell. As a result, floods of short duration were experienced at low lying places of Sylhet, Sunamganj, Moulvibazar and Habiganj districts, while some places of Netrokona district experienced medium duration flooding during the monsoon 2019. The Meghna at Chandpur in the Lower Meghna basin flowed discontinuously above DL for 15 days but only for very short duration mostly due to tidal fluctuations.

A comparative statement of WL for current year 2019 and historical events of 2017 and 1998 for the Meghna Basin is shown in the Table 3.4. The details of the river WL situation in this basin are described below:

The Surma at Kanaighat, Sylhet and Sunamganj

Water Level in the Surma river started rising from the last week of April and it showed rapid rise and fall several times. FFWC monitors 3 stations on the Surma River.

At Kanaighat, firstly it flowed above its DL on 28 June for 1 day, then from 11 to 18th July for 8 days, then finally from 22 to 25 July for 4 days. The Surma at Kanaighat was above DL for 13 days in total during the whole monsoon. It attained its highest peak of 14.30 mPWD on 13th July which was 110 cm above the DL (13.20 m).

The WL of river Surma at Sylhet showed similar trend like Kanaighat. The Surma at Sylhet flowed above its DL (11.25m) only for 1 day and attained the monsoon peak WL of 11.30 mPWD on 15th July.

The Surma at Sumanganj showed rapid rise and fall in different periods of the monsoon. The WL of the river Surma at Sunamganj flowed above its DL (8.25 m) for 7 days during the monsoon. The WL of Surma at Sunamganj recorded its highest peak of 8.64 mPWD on 11th July which was 39 cm above its DL.

The Kushiyara at Amalshid, Sheola and Sherpur

The Kushiyara river at Amalshid, Sheola and Sherpur (Sylhet district) exhibited similar rising and falling trend throughout the monsoon 2019. At Amalshid water level of Kushiyara crossed the DL twice, first on 12th July which continued till 17th July and was followed by a short spell during 4th to 5th August. The Kushiyara at Amalshid flowed above the DL for 8 days in total during the whole monsoon. At Amalshid, Kushiyara attained the peak flow of 17.02 mPWD on 14th July which was 117 cm above the DL (15.85 mPWD).

At Sheola, the river crossed the DL one time only. It flowed above DL for 5 days during the whole monsoon and attained its highest peak of 13.96 mPWD on 14th July which was 46 cm above the respective DL (13.50 m).

At Sherpur, the river flowed in a similar trend like Sheola. It flowed above its DL for 3 days during the whole monsoon and attained its highest peak of 9.05 mPWD on 16th July, which was 5 cm above its DL (9.00 m)

The Sarigowain at Sarighat

As a flashy river the Sarighat on Saigowain River in Sylhet district showed several peaks during the monsoon 2019 but did not cross the respective DL. It attained monsoon highest peak of 12.76 mPWD on 28th June which was 4 cm below its DL (12.80 m).

The Manu at Manu Railway Bridge and Moulvibazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvibazar exhibited several sharp peaks during the monsoon-2019. The WL of Manu river at Manu Railway Bridge and at Moulvibazar flowed above the DL for 3 and 2 days respectively during monsoon 2019. The WL at Manu Railway Bridge had a peak flow of 18.19 mPWD on 15th July which was 19 cm above the DL (18.0 m).

At Moulvibazar the WL of Manu attained its highest peak of 12.18 mPWD on 16th July which was 33 cm above DL (11.75m) at that point.

The Khowai at Habigonj and Ballah

The Khowai at Habiganj as well as Ballah showed several peaks during the monsoon 2019. The Khowai at Ballah crossed DL 4 times during the season and flowed above DL for 12 days. The longest spell of the season was during 9th July to 17th July for 9 days. The highest peak of the season was 23.76 mPWD attained on 14th July which was 196 cm above the DL (21.80 m).

The Khowai at Habiganj crossed the DL on 14th July just once in the season with total 2 days above DL throughout the monsoon. The WL recorded as its yearly highest peak was 10.16 mPWD on 15th July which was 66 cm above its DL (9.50 m).

The Dhalai at Kamalganj

The Dhalai at Kamalganj crossed the DL on 14th June and 14th July for only 2 days during the 2019 monsoon. The highest peak was 20.73 mPWD which was 91 cm above the DL (19.82 m).

The Jadukata at Lorergarh

Like other flashy rivers in the North-Eastern region, the Jadukata showed several peaks during the monsoon 2019. It crossed its DL for three times in June and July. First it crossed the DL on 28th June, then on 9th and 10th July with a total of 3 days above the DL in this season. It attained monsoon highest peak of 9.24 mPWD on 10th July which was 71 cm above its DL (8.53 m).

The Someswari at Durgapur and Kalmakanda

As a flashy river the Durgapur in Netrokona district, showed rise and fall during the monsoon 2019 and flowed above its DL (13.0 m) for only 2 days. It attained monsoon highest peak of 13.63 mPWD on 10th July which was 63 cm above its DL.

The Someswari at Kalmakanda in Netrokona on the other hand crossed DL 3 times during the monsoon. First it stayed above the DL during 28th to 30th June, then during 10th to 22nd July and finally during 25th to 27th July with a total of 19 days in the season. Local drainage congestion caused the flood to last longer at the place than usual. It attained monsoon highest peak of 7.73 mPWD on 14th July which was 73 cm above its DL (7.00 m).

The Bhugai at Nakuagaon

As a flashy river, the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks in August and September. It flowed above its DL during monsoon 2019 just for a day on 15th July. It also attained the monsoon highest peak of 22.79 mPWD on the same day which was 39 cm above DL (22.40m) at that point.

The Kangsha at Jariajanjail

As a flashy river the Kangsha at Jariajanjail in Netrokona district also showed rise and fall during the monsoon-2019 but flowed below the DL (11.0 m). It attained its yearly highest peak of 10.87 mPWD on 15th July which was 13 cm below DL.

The Titas at Brahmanbaria

The Titas River at B. Baria point flowed below its DL (5.50 m) during the monsoon 2019. It attained monsoon peak of 5.18 mPWD on 26th July which was 32 cm below DL.

The Meghna at Bhairab Bazar, Narsingdi, Meghna Bridge and Chandpur

The Meghna at Bhairab Bazar point flowed below its DL (6.25 m) during the monsoon 2019. It attained monsoon peak of 5.09 mPWD on 25th July which was 116 cm below DL.

The Meghna at Narsingdi followed similar trend as Bhairab Bazar and flowed below DL in 2019 as well. It attained monsoon peak of 4.57 mPWD on 21st July which was 113 cm below its DL (5.70 m).

The Meghna at Meghna Bridge has significant tidal influence. The Meghna at this point flowed below its DL (5.03 m) during the monsoon 2019. It attained monsoon peak of 4.23 mPWD on 2nd October which was 80 cm below DL at that point.

Being further downstream, the Meghna at Chandpur has more prominent tidal influence than at Meghna Bridge. The Meghna at this point flowed above its DL (4.00 m) for 14 days during the monsoon 2019, but all for very short duration and mostly due to tidal fluctuations. It attained monsoon peak of 4.14 mPWD on 18th July which was 14 cm above DL at that point.

Comparative hydrographs for the years of 2019, 2017 & 1998 at few stations of the Meghna basin are shown in Figures 3.23 to 3.36.

Table 3.4 : Comparison of Water Level (in mPWD) of 2019 and Historical Events of 2017& 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		
					2019	2017	1998	2019	2017	1998
1	Surma	Kanaighat	15.26	13.20	14.30	14.51	15.00	13	92	73
2	Surma	Sylhet	12.44	11.25	11.30	11.70	11.72	1	11	14
3	Surma	Sunamgonj	9.75	8.25	8.64	9.19	8.90	7	15	56
4	Kushiyara	Amalshid	18.28	15.85	17.02	17.34	17.60	8	76	54
5	Kushiyara	Sheola	14.60	13.50	13.96	14.57	14.14	5	88	37
6	Kushiyara	Sherpur	9.68	9.00	9.05	9.45	NA	3	76	NA
7	Kushiyara	Markuli	8.51	8.50	7.55	8.00	-	0	0	-
8	Sarigowain	Sarighat	14.48	12.80	12.76	13.60	-	0	9	-
9	Manu	Manu RB	20.42	18.00	18.19	19.05	18.63	3	6	6
10	Manu	Moulvi Bazar	13.25	11.75	12.18	12.56	11.68	2	11	0
11	Khowai	Ballah	26.12	21.80	23.76	24.02	-	12	34	-
12	Khowai	Habiganj	12.30	9.50	10.16	12.30	11.44	2	18	8
13	Dhalai	Kamalganj	21.18	19.82	20.73	20.45	-	2	9	-
14	Old Surma	Derai	7.75	7.00	7.06	7.48	-	4	37	-
15	Baulai	Khaliajuri	9.52	8.50	6.89	7.39	-	0	0	-
16	Jadukata	Lorergarh	11.85	8.53	9.24	10.57	-	3	5	-
17	Someswari	Durgapur	15.20	13.00	13.63	14.45	-	2	5	-

18	Someswari	Kalmakanda	13.27	7.00	7.73	-	-	19	-	-
19	Bhugai	Nakuagaon	26.01	22.40	22.79	24.86	-	1	3	-
20	Kangsha	Jariajanjail	13.37	11.00	10.87	11.59	NA	0	82	NA
21	Titas	B.Baria	6.50	5.50	5.18	6.01	-	0	30	-
22	Upper Meghna	Bhairab Bazar	7.78	6.25	5.09	6.05	7.33	0	0	68
23	Meghna	Narsingdi	7.01	5.70	4.57	5.32	-	0	0	-
24	Meghna	Meghna Bridge	6.76	5.03	4.23	4.95	-	0	0	-
25	Gumti	Comilla	13.56	11.75	10.15	11.78	12.79	0	1	17
26	Gumti	Debiddar	9.98	8.50	6.96	8.67	-	0	2	-
27	Meghna	Chandpur	5.35	4.00	4.14	4.59	-	15	-	-

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, Halda, Sangu, Matamuhuri and Feni in the South Eastern Part of the country. Most of these rivers show similar behavior during monsoon flood. The WL of the monitoring rivers crossed their respective DLs multiple times in the monsoon-2019, but the duration was small and concentrated only between the second and third week of July. Some parts of the low-lying places of Chittagong, Feni, Bandarban and Cox's Bazar faced short duration flood during this time. A comparative statement of water level and days flowed above the DLs for the monsoon-2018 and historical events of 2017 and 1998 for this basin are shown in the Table 3.5. The details of WL of different rivers of the basin are described in following sections.

The Muhuri at Parshuram

The Muhuri river flowing through Feni and Noakhali districts is a flashy one which flowed above the DL on 9th and 10th July for 2 days in total during the whole monsoon. It attained its highest peak 14.70 mPWD on 9th July which was 170 cm above its DL (13.00 m).

The Halda at Narayanhat and Panchpukuria

As a flashy river, the WL of the river Halda (a flashy river) at Narayanhat in Hathazari upzilla of Chittagong also showed several peaks during this monsoon. It first crossed DL on 8th July, then on 11th July and finally on 13th July for 3 days in total during the monsoon. It attained its peak of 15.60 mPWD on 13th July which was 35 cm above the DL (15.25 m).

The Halda at Panchpukuria crossed the DL on 11th July and on 13th July for only 2 days during the whole monsoon. It attained its highest peak of 9.96 mPWD on 13th July which was 46 cm above 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 one time in this monsoon-2019. It crossed the DL on 11th July and flowed above until 15th July for 5 days. The recorded peak at Bandarban was 18.5 mPWD on 14th July which was 325 cm above its DL (15.25m). At Dohazari also, the Sangu was above DL for 7 days with 1st crossing of danger mark on 8th July to 9th July and then again on 11th July to 15th July. The highest peak recorded at Dohazari was as 8.60 mPWD on 14th July which was 160 cm above danger mark (7.00 m) at that point.

The Matamuhuri at Lama and Chiringa

The Matamuhuri river showed several peaks in the monsoon-2019 like the Sangu River. At Lama, the Matamuhuri River crossed the DL 2 times with 1st crossing on 11 July then again on 13 July to 14th July. It was above DL for 3 days in total during the whole monsoon. The peak recorded it Lama was 13.84 mPWD on 14thJuly which was 159 cm above its DL (12.25m). The Matamuhuri at Chiringa crossed the DL one time during the monsoon. At Chiringa station the Matamuhuri River was above DL from 10th July to 14th July. It was above DL for 5 days in total during the whole monsoon. The peak recorded at Chiringa was 7.17 mPWD on 14th July which was 92 cm above its DL (6.25m).

The Feni at Ramgarh

The WL of river Feni at Ramgarh showed several peaks as well but flowed below its DL during the monsoon-2019. The highest peak WL attained by the river was 16.6 mPWD on 13th July which was 75 cm below its DL (17.35m) at that point.

Comparative hydrographs for the years of 2019, 2017 & 1998 at few stations of the South Eastern Hill basin are shown in Figures 3.37 to 3.44.

Table 3.5 : Comparison of Water Level of 2019 (in mPWD) and Historical Events of 2017 and 1998 of Some Important Stations in South Eastern Hill Basin

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2019	2017	98	2019	2017	98
1	Muhuri	Parshuram	16.33	13.00	14.70	15.20	14.60	2	5	9
2	Halda	Narayanhat	19.30	15.25	15.60	16.85	16.57	3	11	21
3	Halda	Panchpukuria	12.54	9.50	9.96	9.70	10.44	2	2	4
4	Sangu	Bandarban	20.70	15.25	18.50	16.60	15.25	5	3	1
5	Sangu	Dohazari	9.05	7.00	8.60	7.79	7.42	7	3	2
6	Matamuhuri	Lama	15.46	12.25	13.84	13.79	13.05	3	5	2
7	Matamuhuri	Chiringa	7.32	6.25	7.17	7.32	6.85	5	10	5
8	Feni	Ramgarh	21.42	17.35	16.60	16.20	17.50	0	0	1
9	Karnaphuli	Chittagong	4.98	4.60	4.85	-	-	1	-	-

3.5 PEAK AND RECORDED HIGHEST WATER LEVELS

The peak water level with dates during the monsoon 2019 for all the water level monitoring stations under FFWC is presented in Table 3.6. The recorded highest level information along with dates of attainment for some monitoring stations of FFWC, as well as their new recorded highest levels if exceeded in 2019 with dates are provided in Table 3.7. 3 stations in the Brahmaputra basin namely- Dalia on the Teesta river along with Bahadurabad and Fulchari on the Jamuna river exceeded their previously RHWL in 2019.

Table 3.6 : Peak Water Level (in mPWD) with Dates during the Monsoon-2019

SL No	River name	Station	Peak WL-2019	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	27.67	16/07/19
2	TEESTA	DALIA	53.10	13/07/19
3	TEESTA	KAUNIA	29.42	14/07/19
4	JAMUNESWARI	BADARGANJ	31.78	17/07/19
5	GHAGOT	GAIBANDHA	22.64	18/07/19
6	KARATOA	CHAK RAHIMPUR	20.19	20/07/19
7	KARATOA	BOGRA	14.97	28/07/19
8	BRAHMAPUTRA	NOONKHAWA	27.53	17/07/19
9	BRAHMAPUTRA	CHILMARI	25.02	17/07/19
10	JAMUNA	FULCHARI	21.35	18/07/19
11	JAMUNA	BAHADURABAD	21.16	18/07/19
12	JAMUNA	SARIAKANDI	17.98	18/07/19
13	JAMUNA	KAZIPUR	16.51	18/07/19
14	JAMUNA	SERAJGANJ	14.34	19/07/19
15	JAMUNA	ARICHA	9.84	20/07/19
16	GUR	SINGRA	12.51	05/10/19
17	ATRAI	BAGHABARI	11.23	21/07/19
18	DHALESWARI	ELASIN	12.36	20/07/19
19	OLD BRAHMAPUTRA	JAMALPUR	17.17	20/07/19
20	OLD BRAHMAPUTRA	MYMENSINGH	12.31	23/07/19
21	LAKHYA	LAKHPUR	5.80	26/07/19
22	BURIGANGA	DHAKA	4.90	22/07/19
23	BALU	DEMRA	5.40	29/07/19
24	LAKHYA	NARAYANGONJ	5.33	29/07/19
25	TURAG	MIRPUR	5.27	30/07/19
26	TONGI KHAL	TONGI	5.49	27/07/19
27	KALIGANGA	TARAGHAT	8.33	23/07/19
28	DHALESWARI	JAGIR	7.68	25/07/19
29	DHALESWARI	REKABI BAZAR	4.67	22/07/19
30	BANSHI	NAYARHAT	5.59	30/07/19
GANGES BASIN				
31	KARATOA	PANCHAGARH	69.99	14/07/19
32	PUNARBHABA	DINAJPUR	32.58	16/07/19
33	ICH-JAMUNA	PHULBARI	28.70	16/07/19
34	TANGON	THAKURGAON	49.67	15/07/19
35	UPPER ATRAI	BHUSIRBANDAR	39.45	15/07/19
36	MOHANANDA	ROHANPUR	21.47	04/10/19
37	MOHANANDA	CHAPAI-NAWABGANJ	20.88	03/10/19
38	LITTLE JAMUNA	NAOGAON	15.06	18/07/19
39	ATRAI	MOHADEBPUR	18.57	17/07/19
40	GANGES	PANKHA	22.23	02/10/19
41	GANGES	RAJSHAHI	18.19	03/10/19

SL No	River name	Station	Peak WL-2019	Date
42	GANGES	HARDINGE BRIDGE	14.33	02/10/19
43	PADMA	GOALONDO	9.33	20/07/19
44	PADMA	BHAGYAKUL	6.70	20/07/19
45	PADMA	SURESWAR	4.56	02/10/19
46	GORAI	GORAI RAIL BRIDGE	12.47	03/10/19
47	GORAI	KAMARKHALI	8.47	03/10/19
48	ICHAMATI	SAKRA	3.47	31/08/19
49	MATHABHANGA	CHUADANGA	8.88	05/10/19
50	MATHABHANGA	HATBOALIA	11.12	04/10/19
51	KOBADAK	JHIKARGACHA	2.39	18/08/19
52	KUMAR	FARIDPUR	4.95	04/10/19
53	ARIALKHAN	MADARIPUR	3.55	23/07/19
54	KIRTONKHOLA	BARISAL	2.5	03/08/19
55	PASHURE	KHULNA	3.47	01/10/19
MEGHNA BASIN				
56	SURMA	KANAIGHAT	14.30	13/07/19
57	SURMA	SYLHET	11.30	15/07/19
58	SURMA	SUNAMGONJ	8.64	11/07/19
59	KUSHIYARA	AMALSHID	17.02	14/07/19
60	KUSHIYARA	SHEOLA	13.96	14/07/19
61	KUSHIYARA	SHERPUR	9.05	16/07/19
62	KUSHIYARA	MARKULI	7.55	15/07/19
63	SARIGOWAIN	SARIGHAT	12.76	28/06/19
64	MANU	MANU RAILY BRIDGE	18.19	15/07/19
65	MANU	MOULVI BAZAR	12.18	16/07/19
66	KHOWAI	BALLAH	23.76	14/07/19
67	KHOWAI	HABIGANJ	10.16	15/07/19
68	DHALAI	KAMALGONJ	20.73	14/06/19
69	OLD SURMA	DERAI	7.06	16/07/19
70	BAULAI	KHALIAJURI	6.89	16/07/19
71	JADUKATA	LORERGARH	9.24	10/07/19
72	SOMESWARI	DURGAPUR	13.63	10/07/19
73	BHUGAI	NAKUAGAON	22.79	15/07/19
74	KANGSHA	JARIAJANJAIL	10.87	15/07/19
75	TITAS	B. BARIA	5.18	26/07/19
76	MEGHNA	BHAIRAB BAZAR	5.09	25/07/19
77	MEGHNA	NARSINGDI	4.57	21/07/19
78	MEGHNA	MEGHNA BRIDGE	4.23	02/10/19
79	GUMTI	COMILLA	10.15	16/07/19
80	GUMTI	DEBIDDAR	6.96	16/07/19
81	MEGHNA	CHANDPUR	4.14	18/07/19
	SOUTH EASTERN HILL BASIN			
82	MUHURI	PARSHURAM	14.70	09/07/19
83	HALDA	NARAYAN HAT	15.60	13/07/19
84	HALDA	PANCHPUKURIA	9.96	13/07/19
85	SANGU	BANDARBAN	18.50	14/07/19
86	SANGU	DOHAZARI	8.60	14/07/19
87	MATAMUHURI	LAMA	13.84	14/07/19
88	MATAMUHURI	CHIRINGA	7.17	14/07/19
89	FENI	RAMGARH	16.60	13/07/19
90	KARNAPHULI	CHITTAGONG	4.85	07/07/19

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

Sl. No.	River	Station	Danger Level	Recorded Highest WL before 2019 with Date	WL in 2019 Exceeding Previous Level with Date
1	Dharla	Kurigram	26.50	27.84 (14.07.96)	-
2	Teesta	Dalia	52.40	53.05 (13.08.17)	**53.10 (12.07.2019)**
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	20.84 (16.08.17)	**21.16 (18.07.2019)**
8	Jamuna	Fulchari	19.82	21.13	**21.35 (18.07.2019)**
9	Jamuna	Serajganj	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 Brahmaputra	Jamalpur	17.00	18.00 (31.07.54)	-
13	Old Brahmaputra	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	13.67 (22.08.17)	-
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 (09.09.98)	-
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	20.70 (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)	-

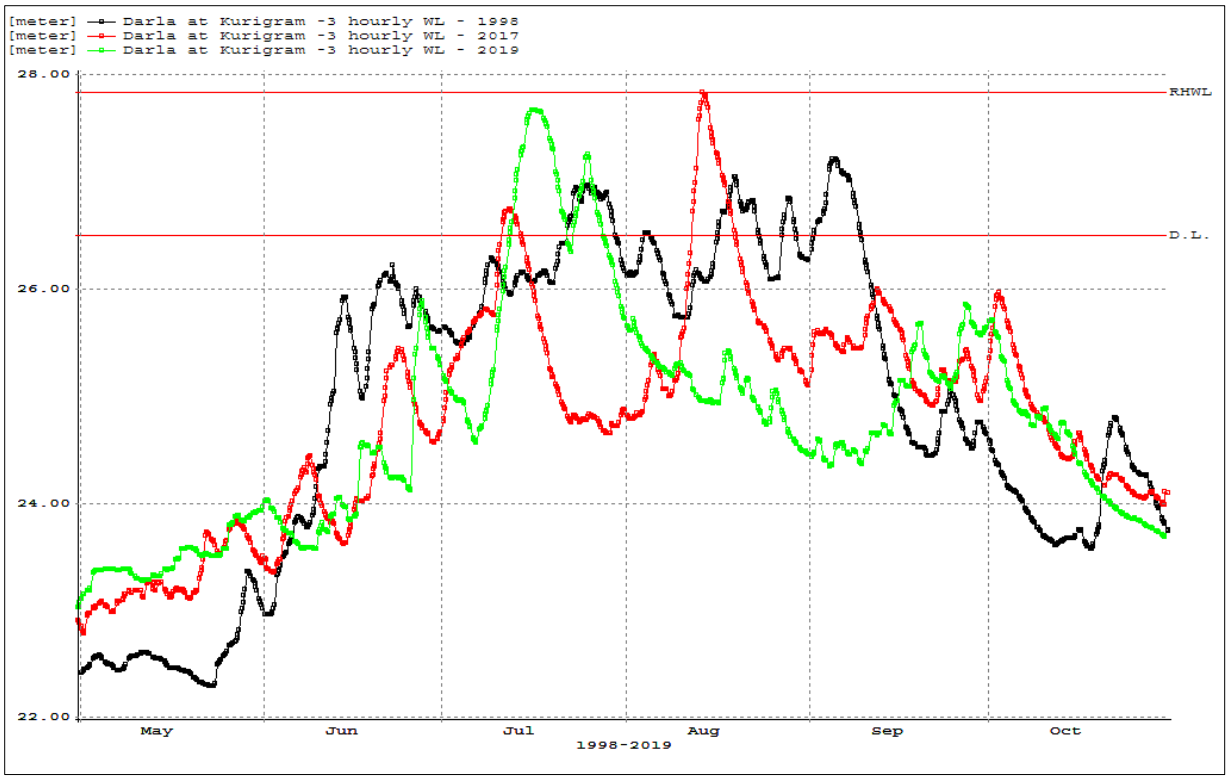


Figure 3.1: Comparison of Hydrograph on Dharla at Kurigram

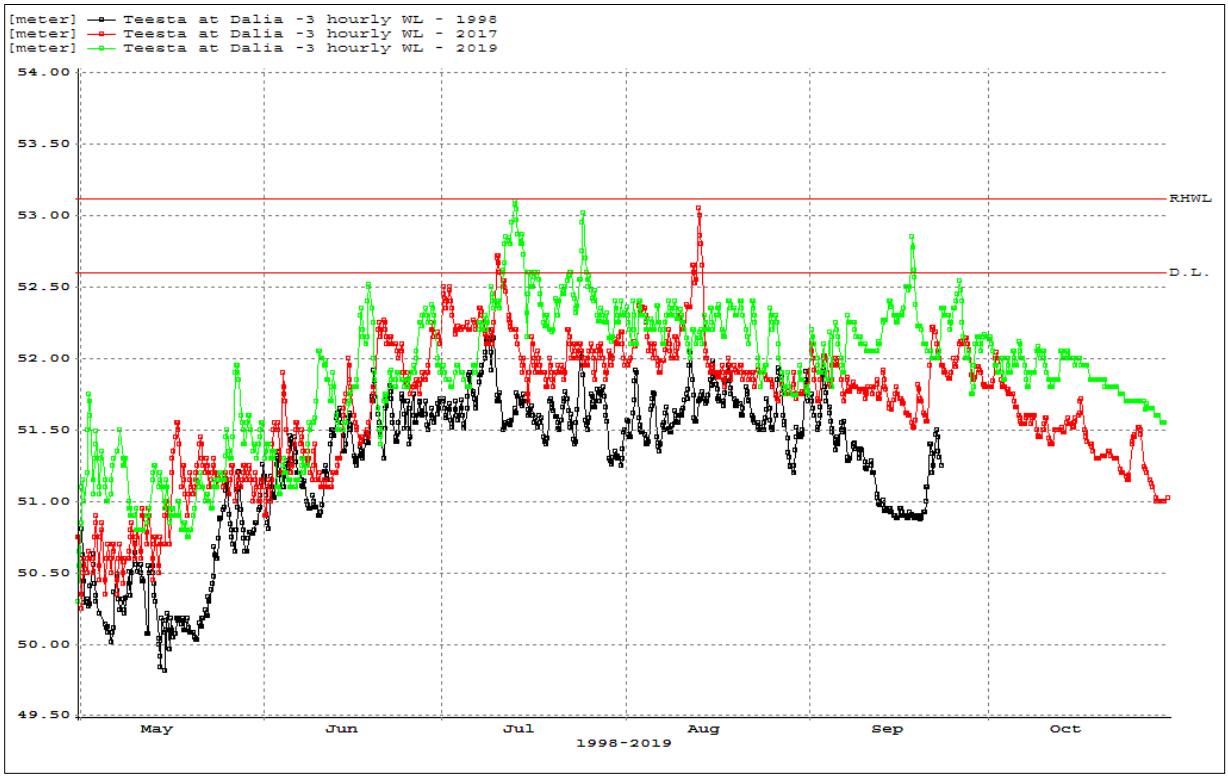


Figure 3.2: Comparison of Hydrograph on Teesta at Dalia

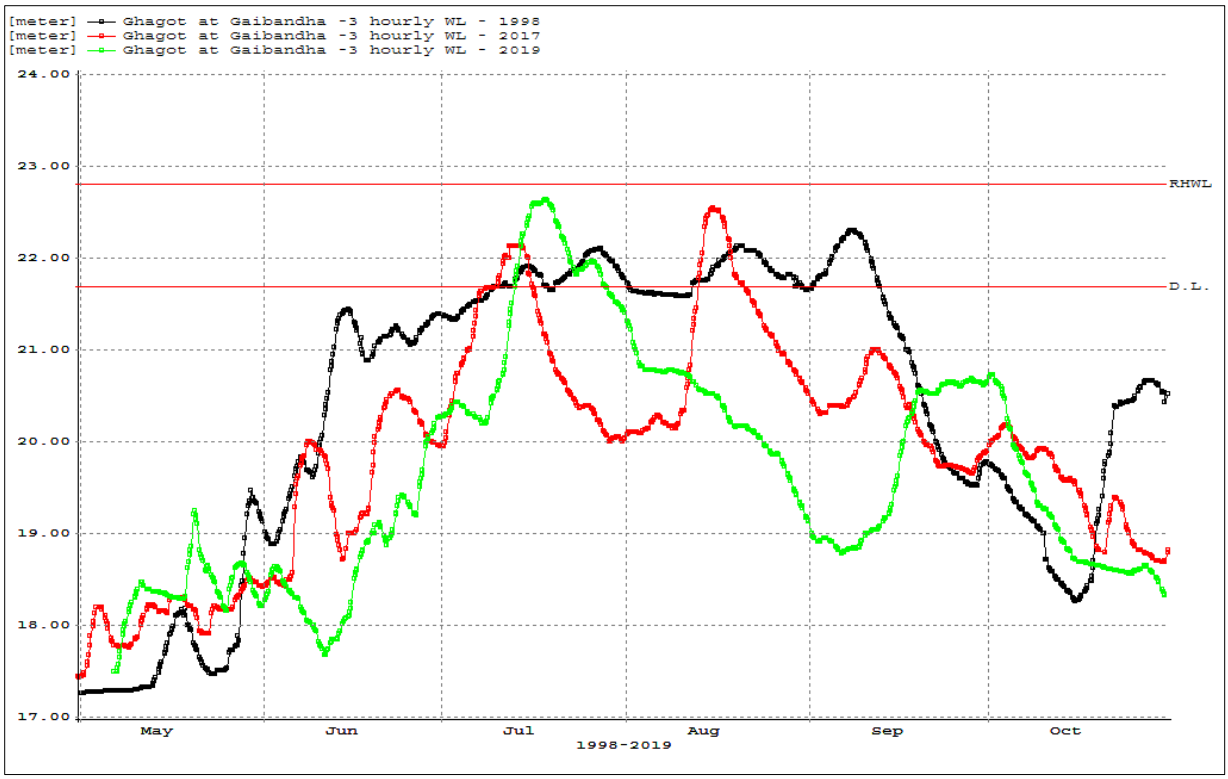


Figure 3.3: Comparison of Hydrograph on Ghagot at Gaibandha

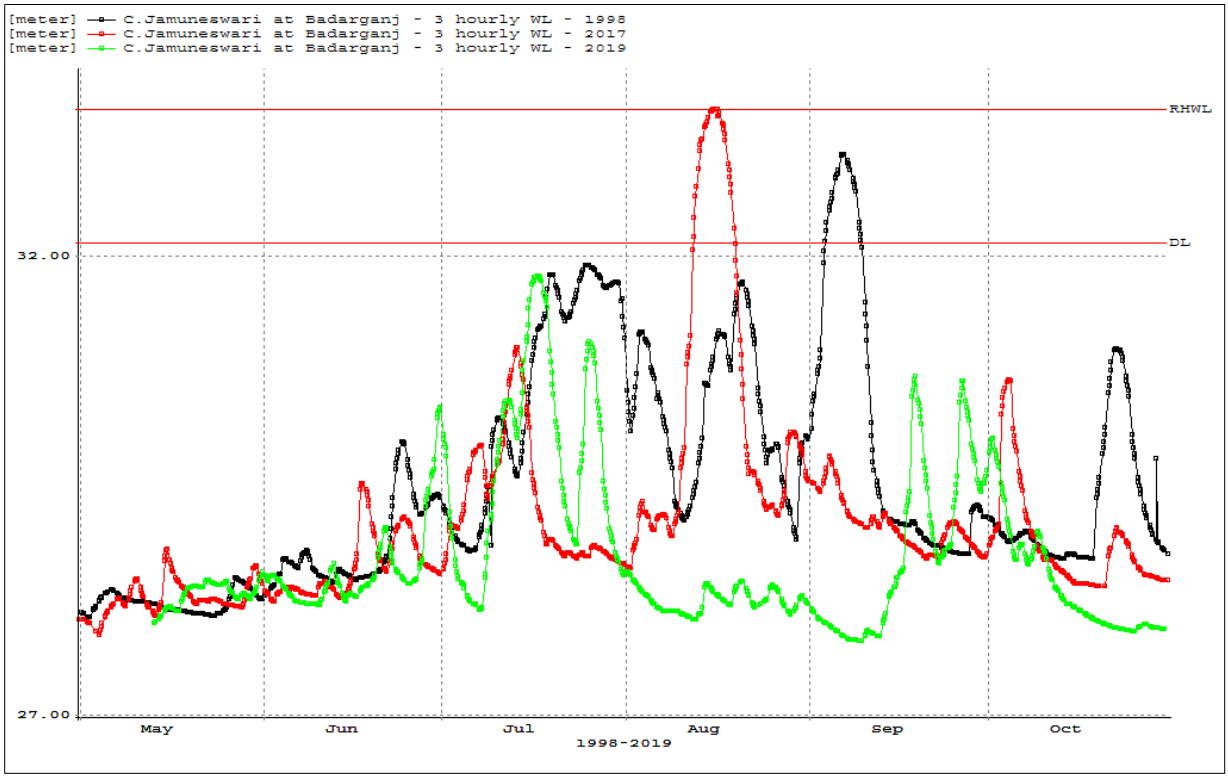


Figure 3.4: Comparison of Hydrograph on C. Jamuneswari at Badarganj

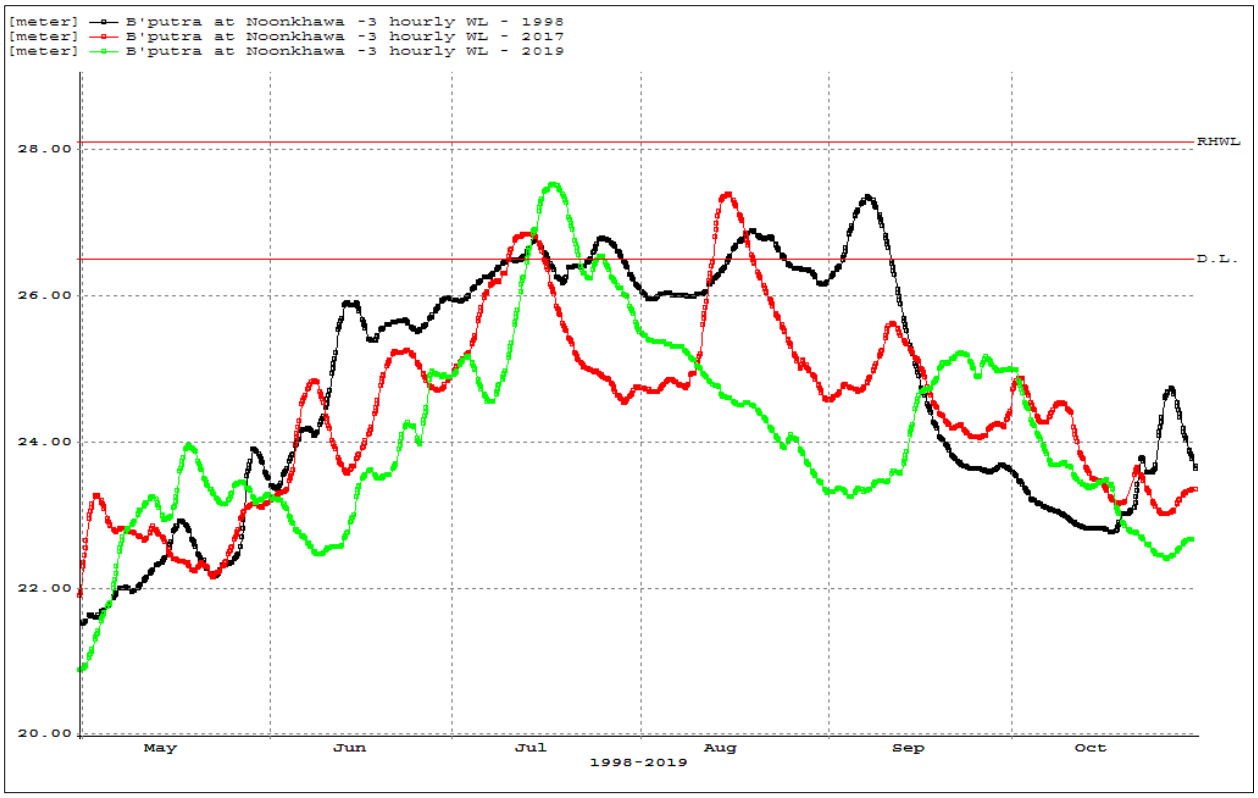


Figure 3.5: Comparison of Hydrograph on Brahmaputra at Noonkhawa

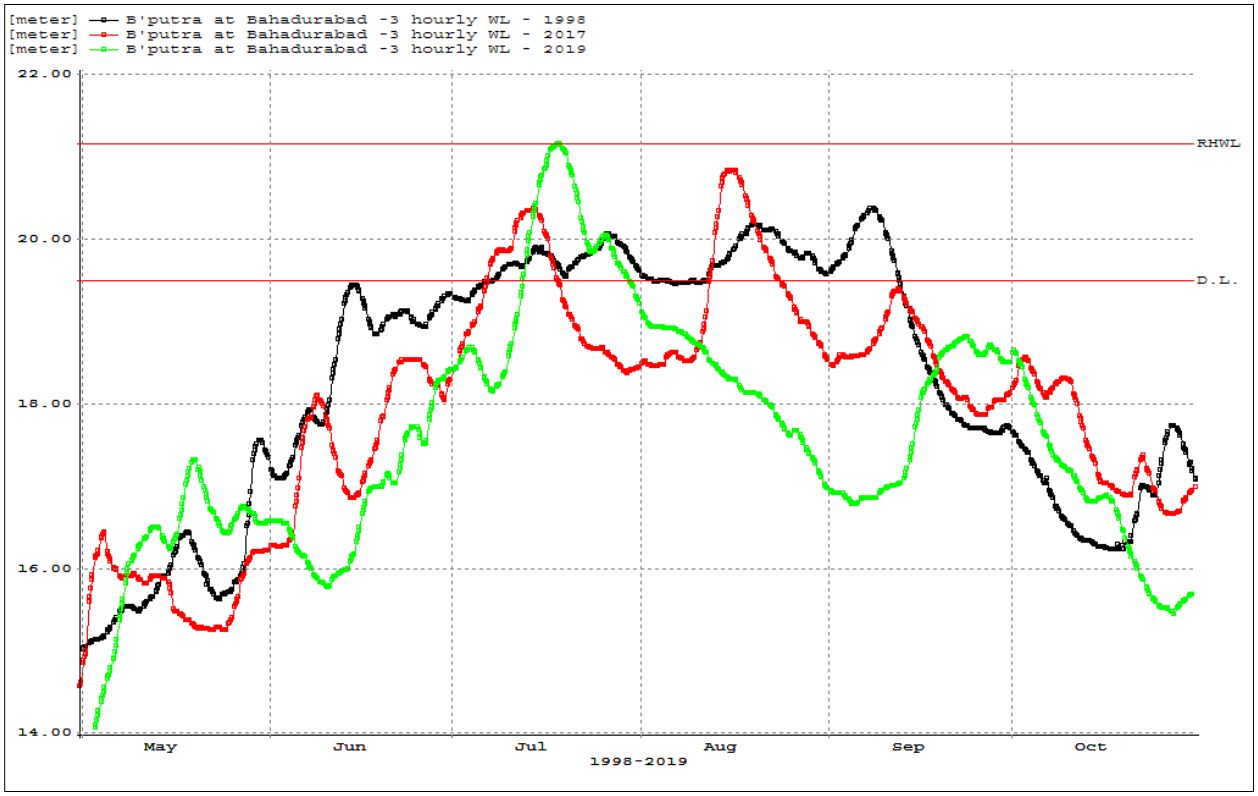


Figure 3.6: Comparison of Hydrograph on Jamuna at Bahadurabad

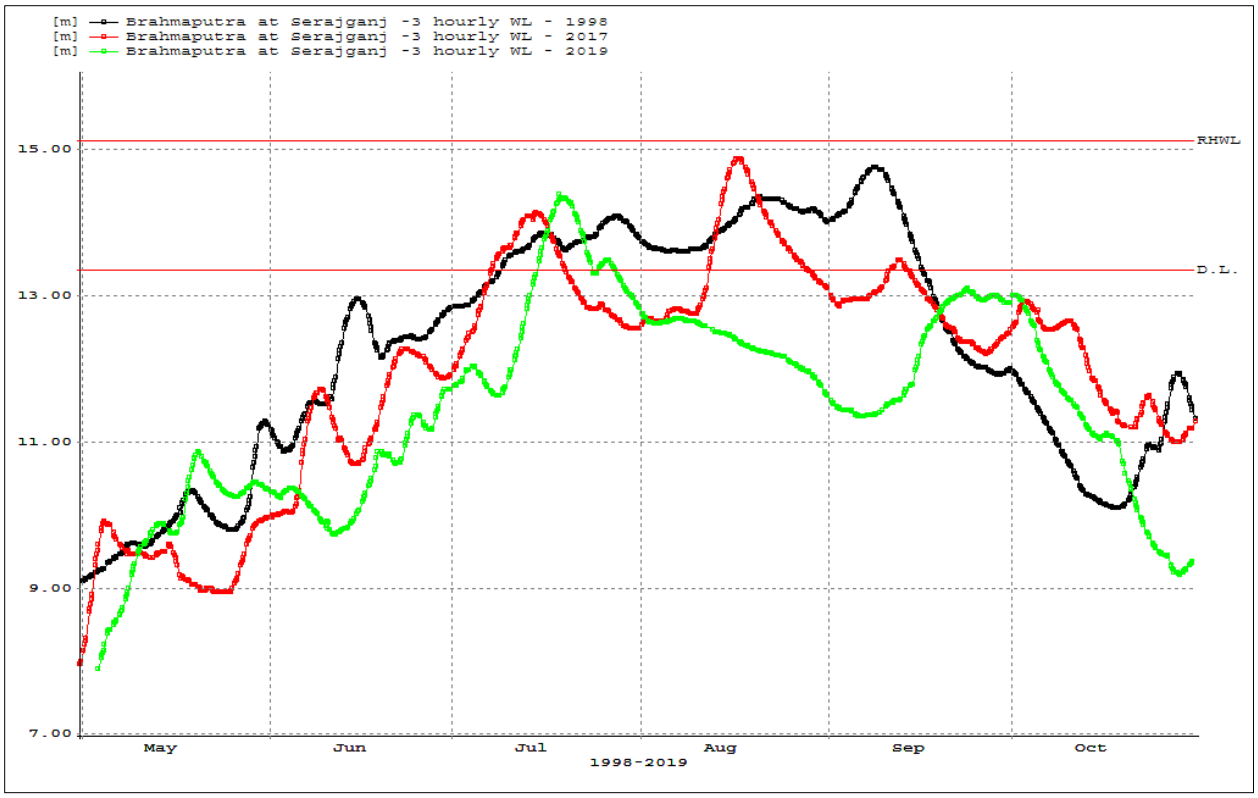


Figure 3.7: Comparison of Hydrograph on Jamuna at Serajganj

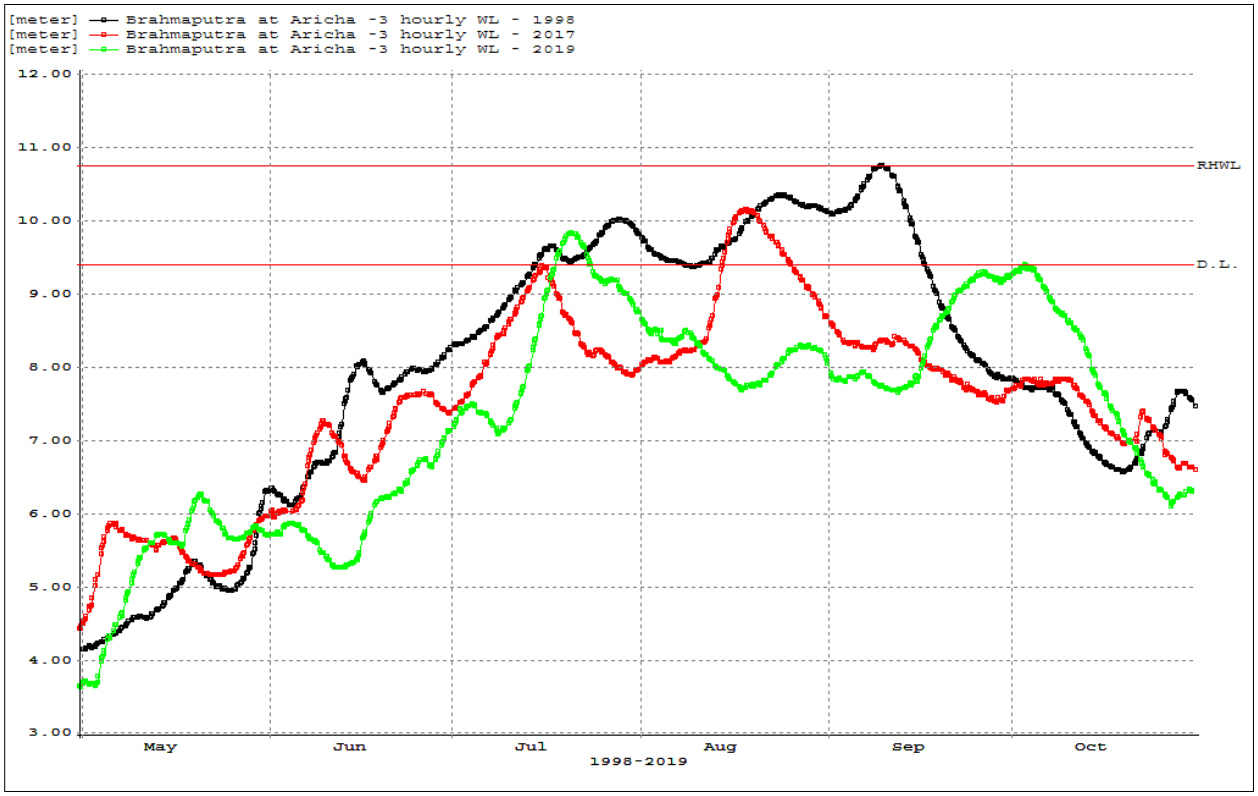


Figure 3.8: Comparison of Hydrograph on Jamuna at Aricha

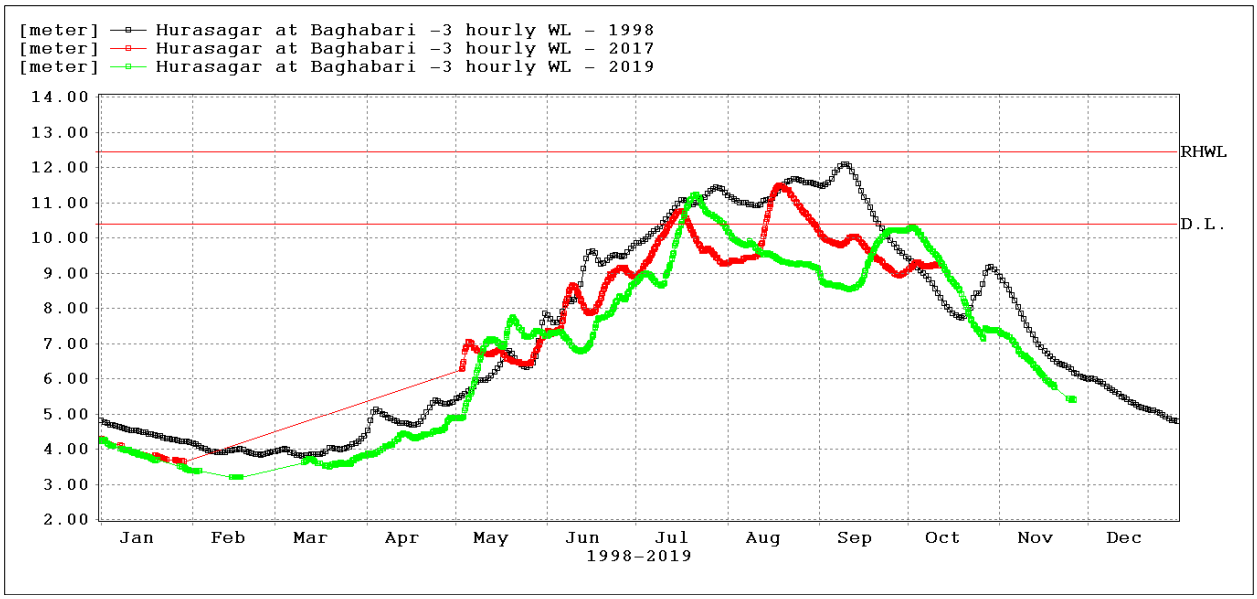


Figure 3.9: Comparison of Hydrograph on Atrai at Baghabari

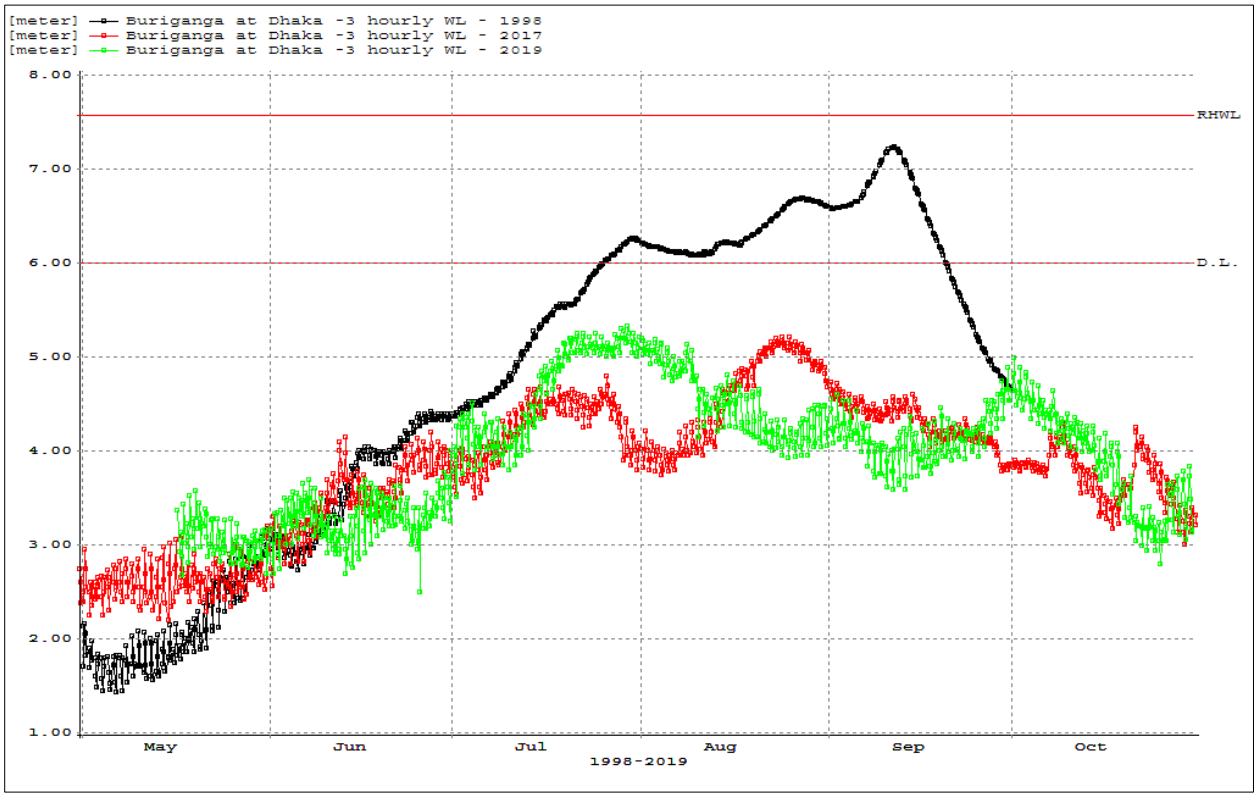


Figure 3.10: Comparison of Hydrograph on Buriganga at Dhaka (Milbarak)

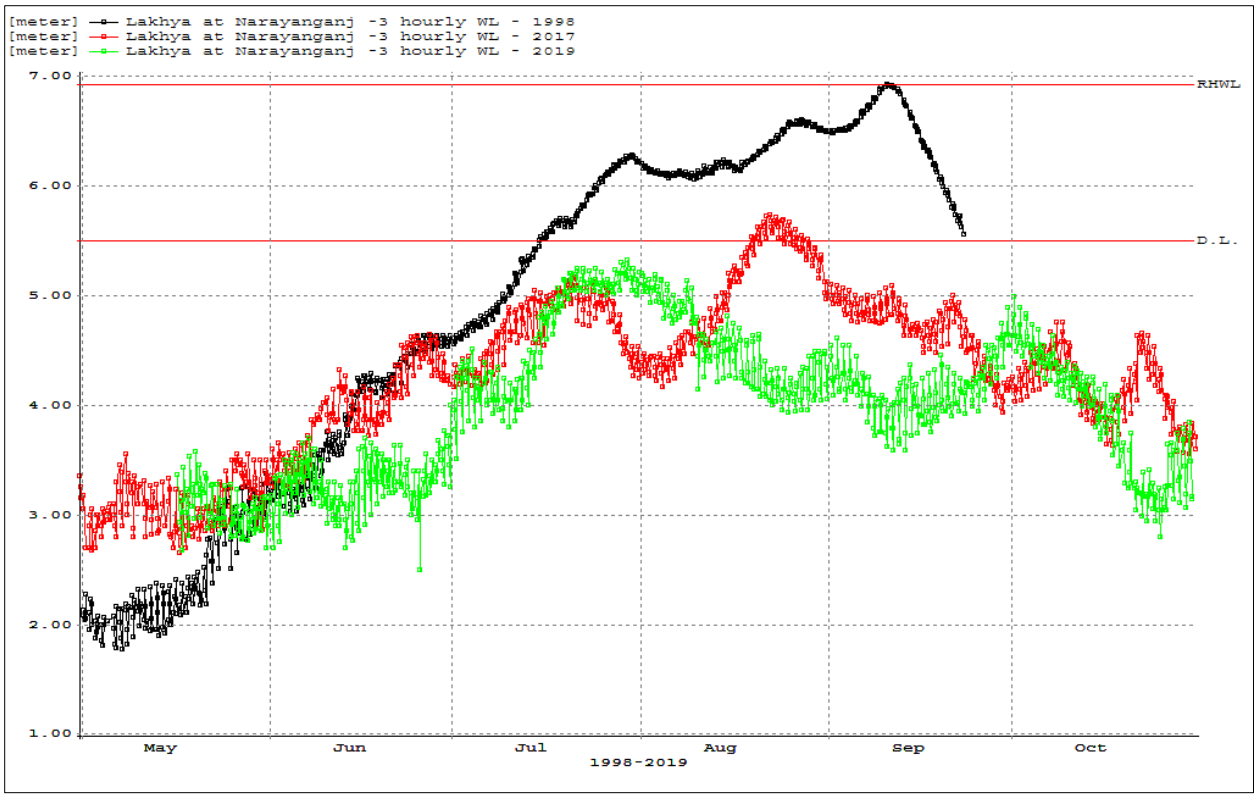


Figure 3.11: Comparison of Hydrograph on Lakhya at Narayanganj

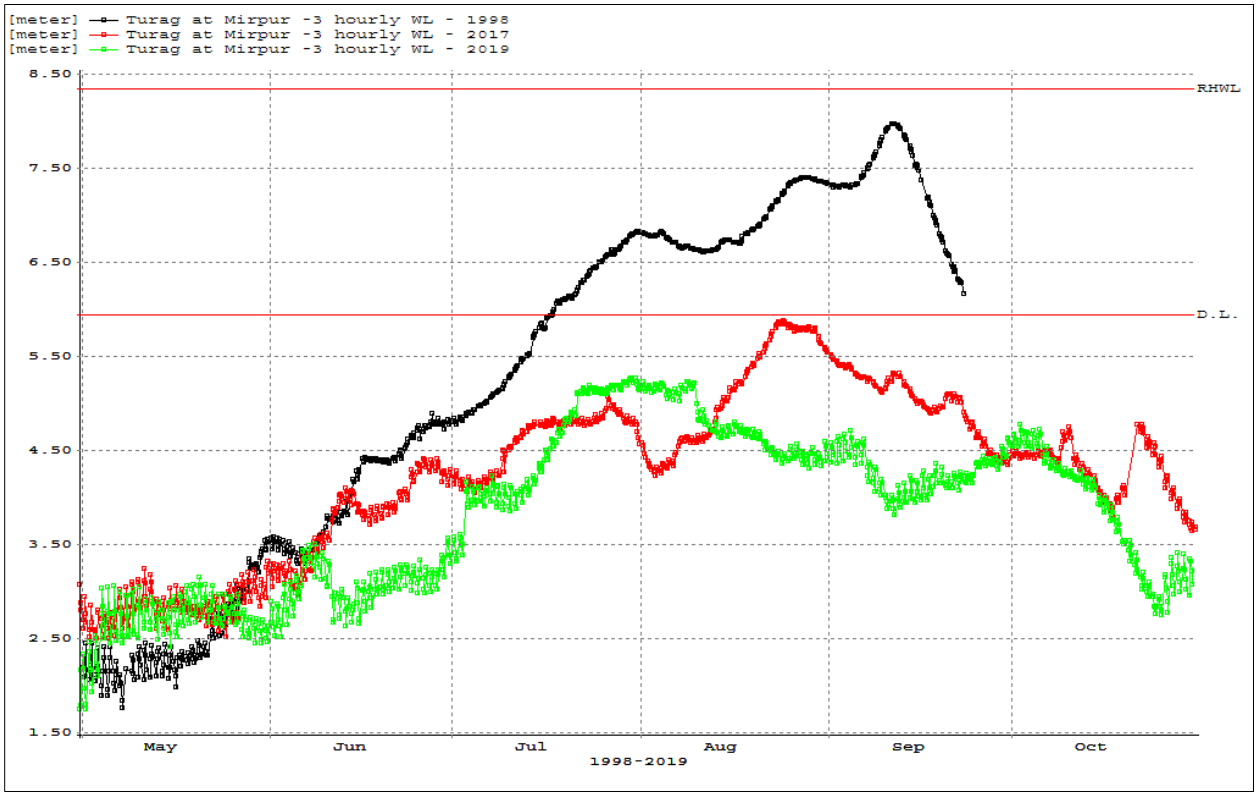


Figure 3.12: Comparison of Hydrograph on Turag at Mirpur

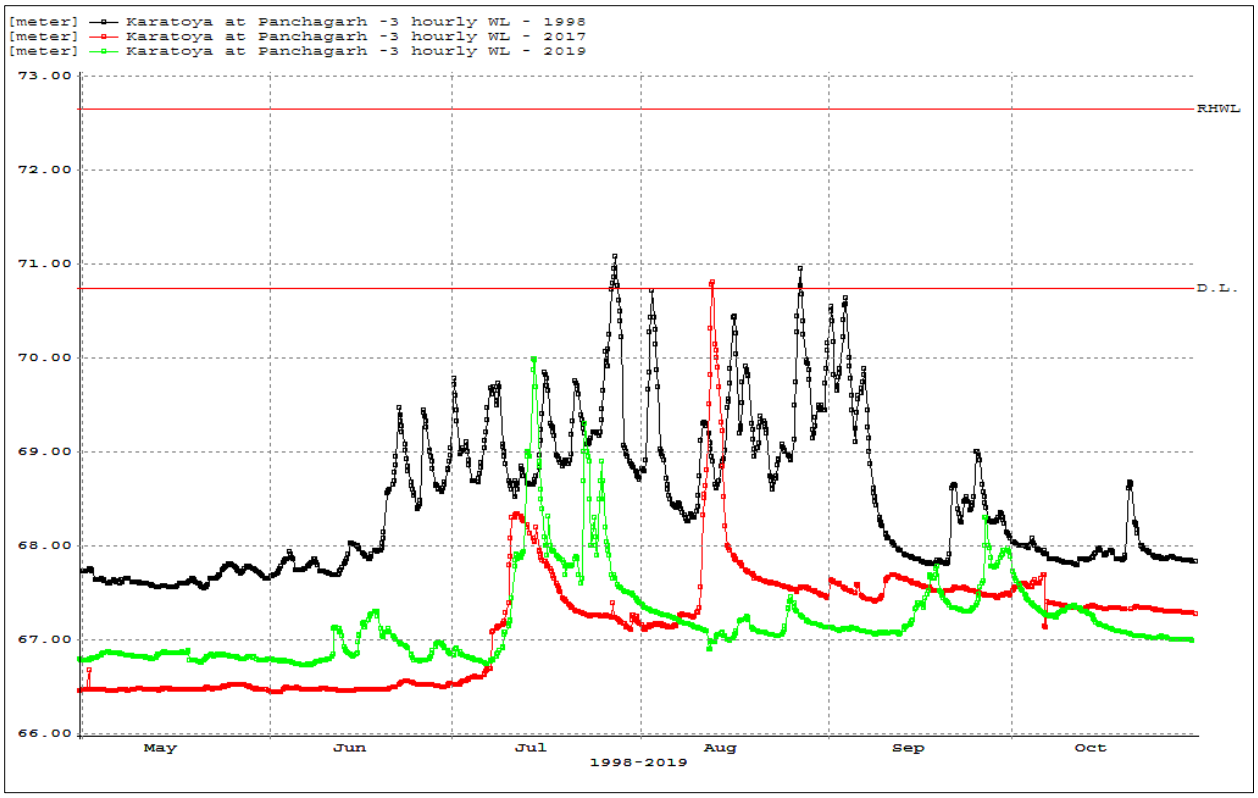


Figure 3.13: Comparison of Hydrograph on Upper Karatoa at Panchagarh

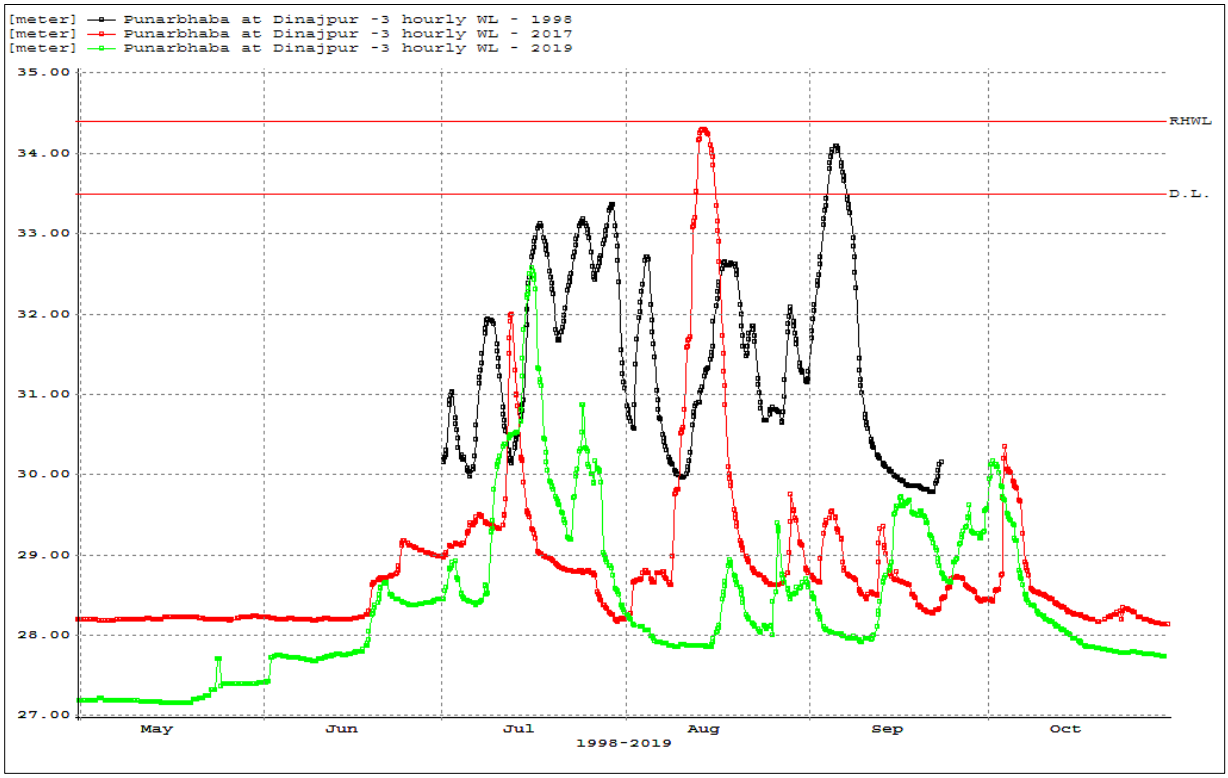


Figure 3.14: Comparison of Hydrograph on Punarbhaba at Dinajpur

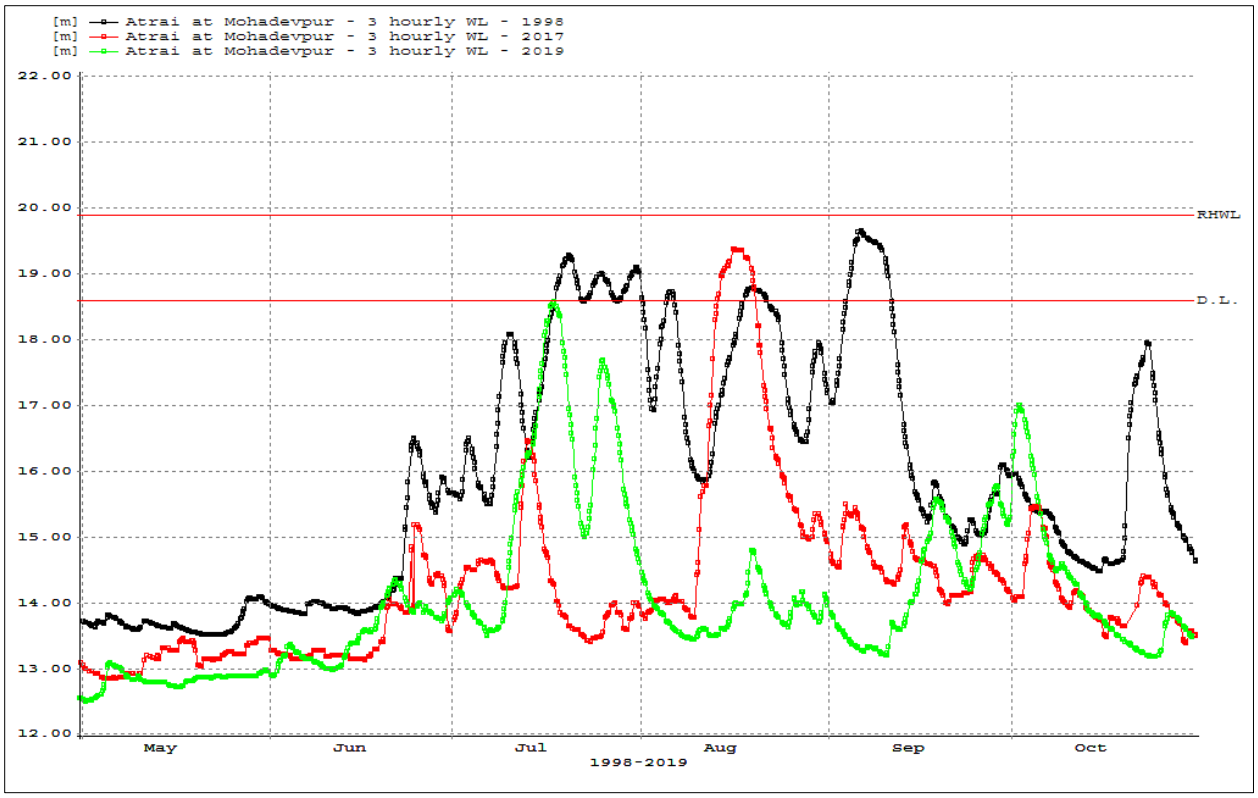


Figure 3.15: Comparison of Hydrograph on Atrai at Mohadevpur

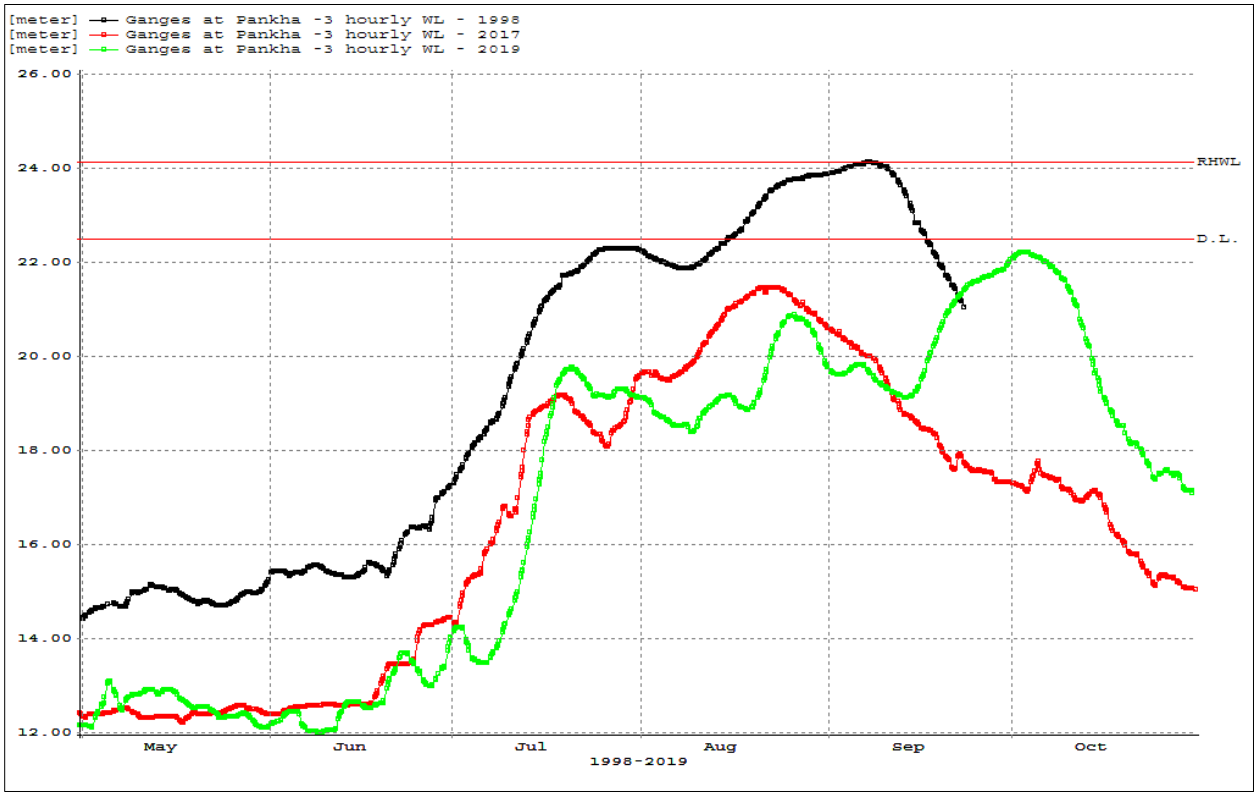


Figure 3.16: Comparison of Hydrograph on Ganges at Pankha

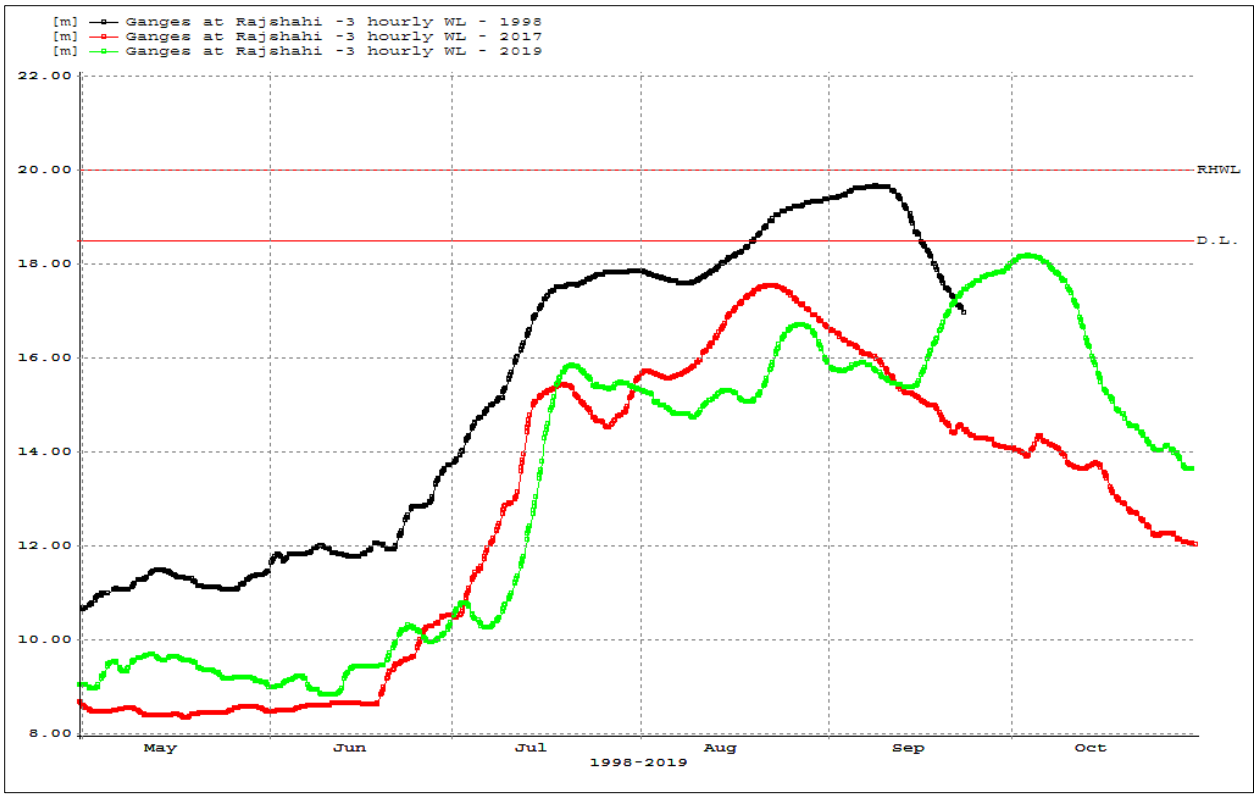


Figure 3.17: Comparison of Hydrograph on Ganges at Rajshahi

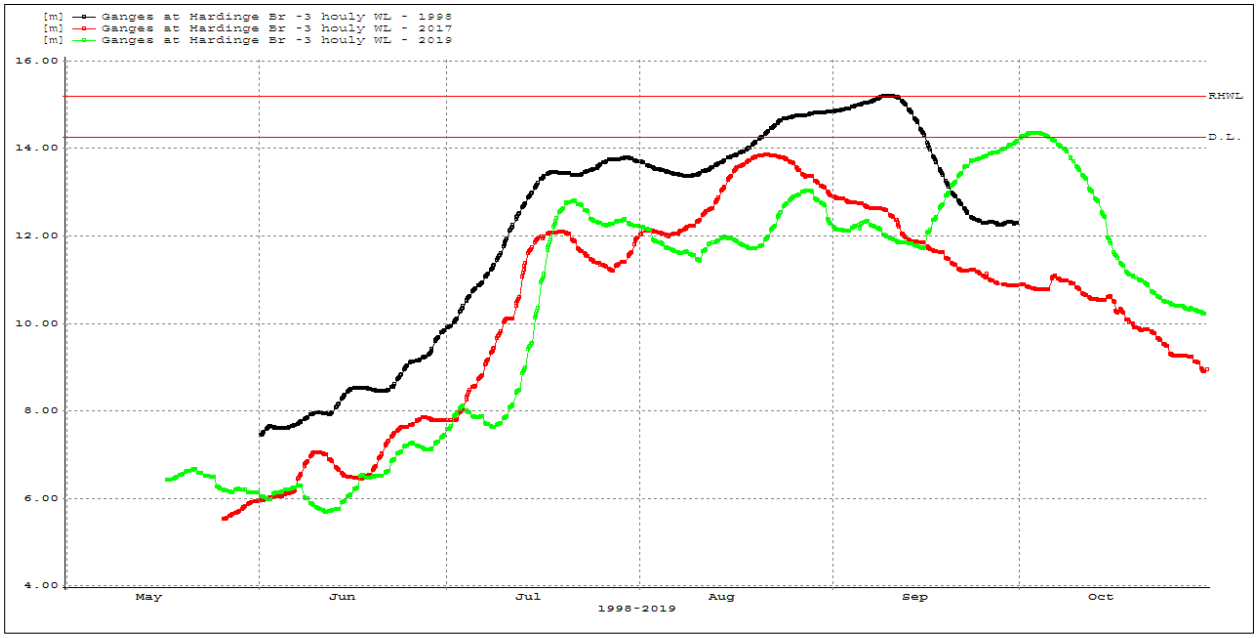


Figure 3.18: Comparison of Hydrograph on Ganges at Hardinge Bridge

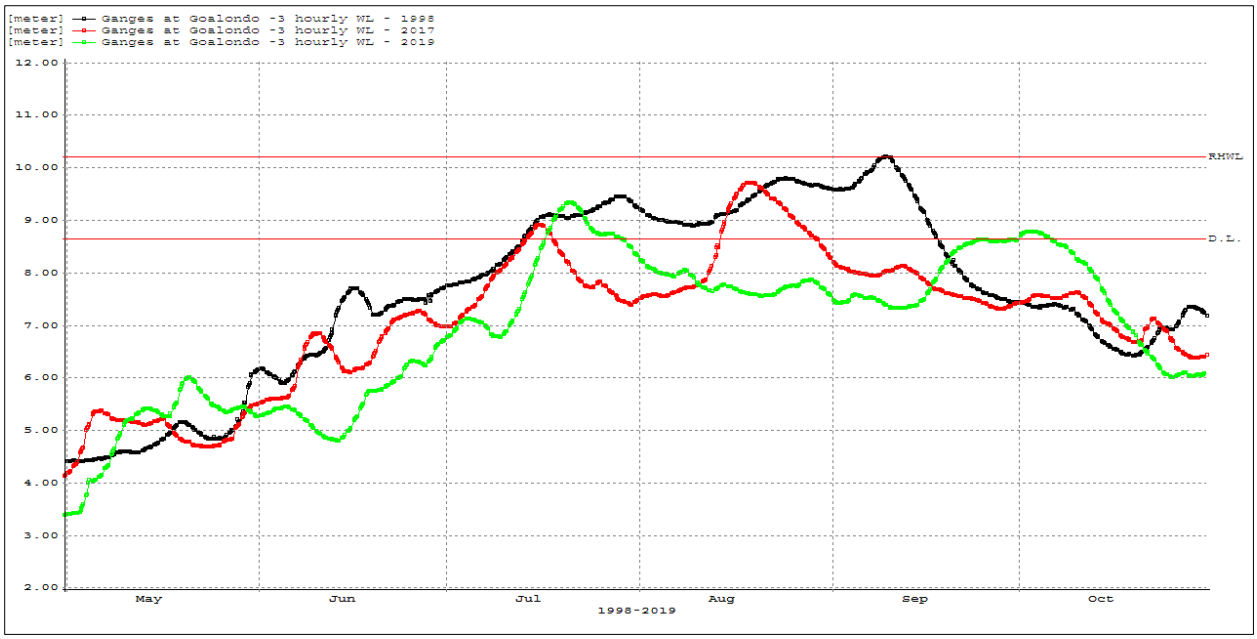


Figure 3.19: Comparison of Hydrograph on Padma at Goalundo

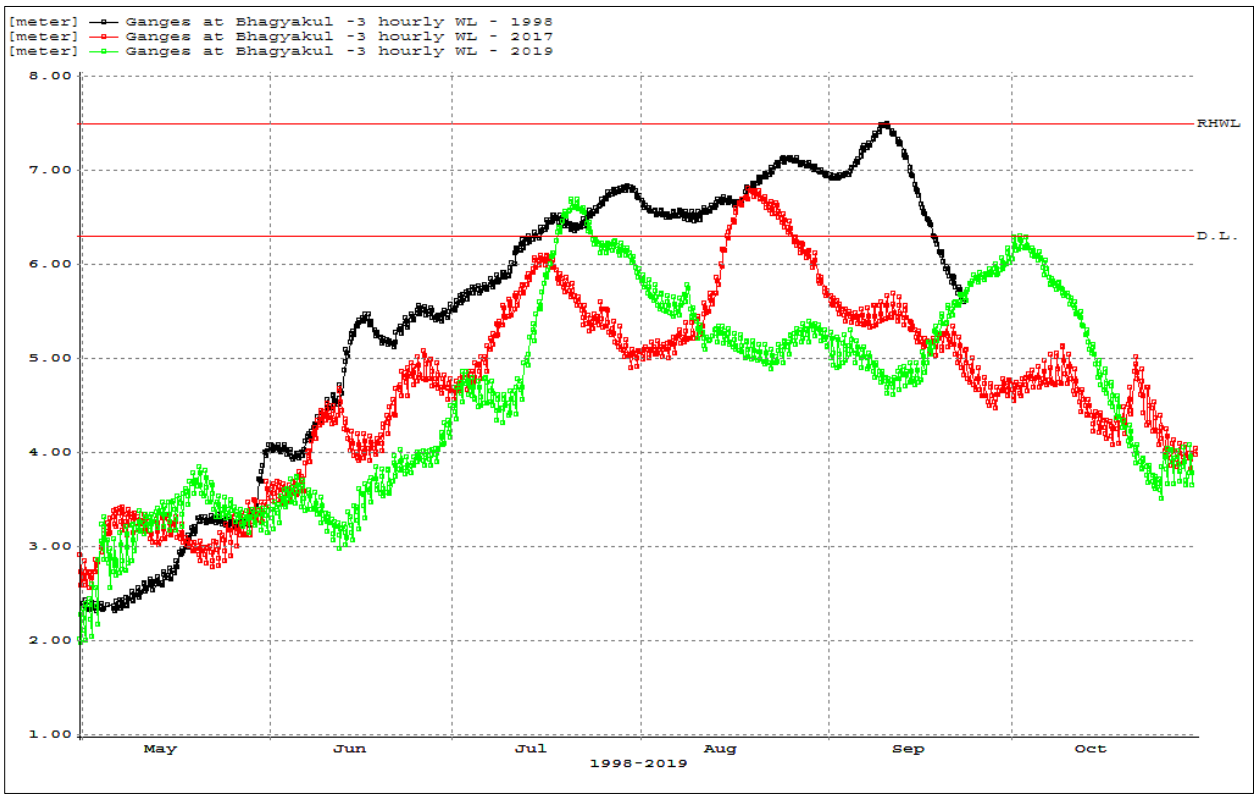


Figure 3.20: Comparison of Hydrograph on Padma at Bhagyakul

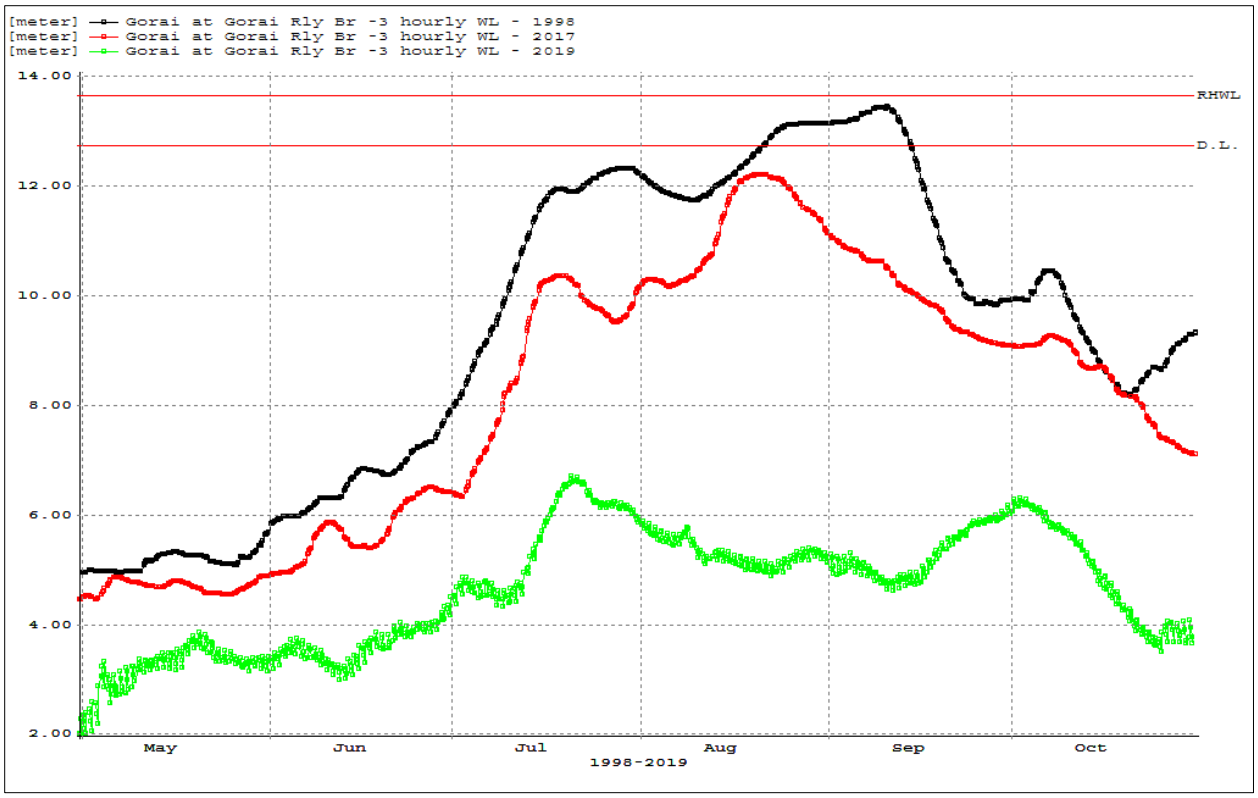


Figure 3.21: Comparison of Hydrograph on Gorai at Gorai Railway Bridge

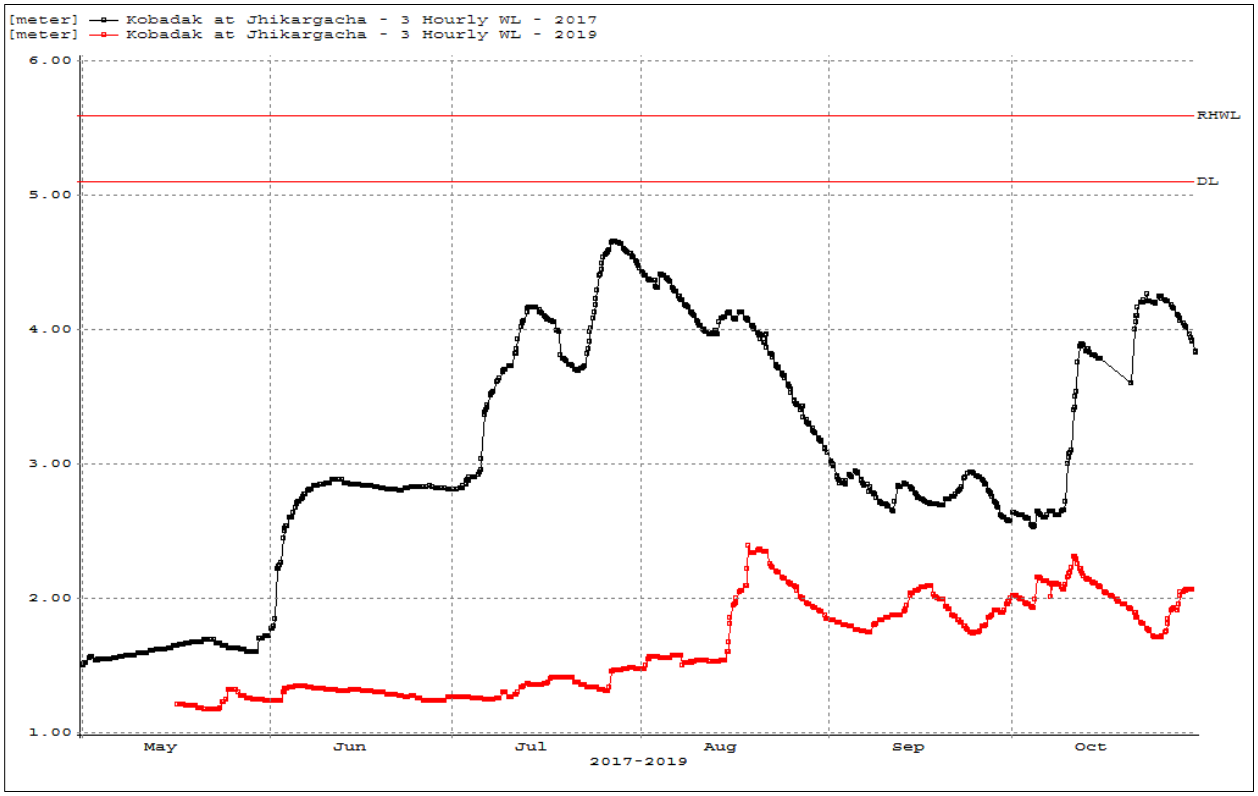


Figure 3.22: Comparison of Hydrograph on Kobodak at Jhikargacha

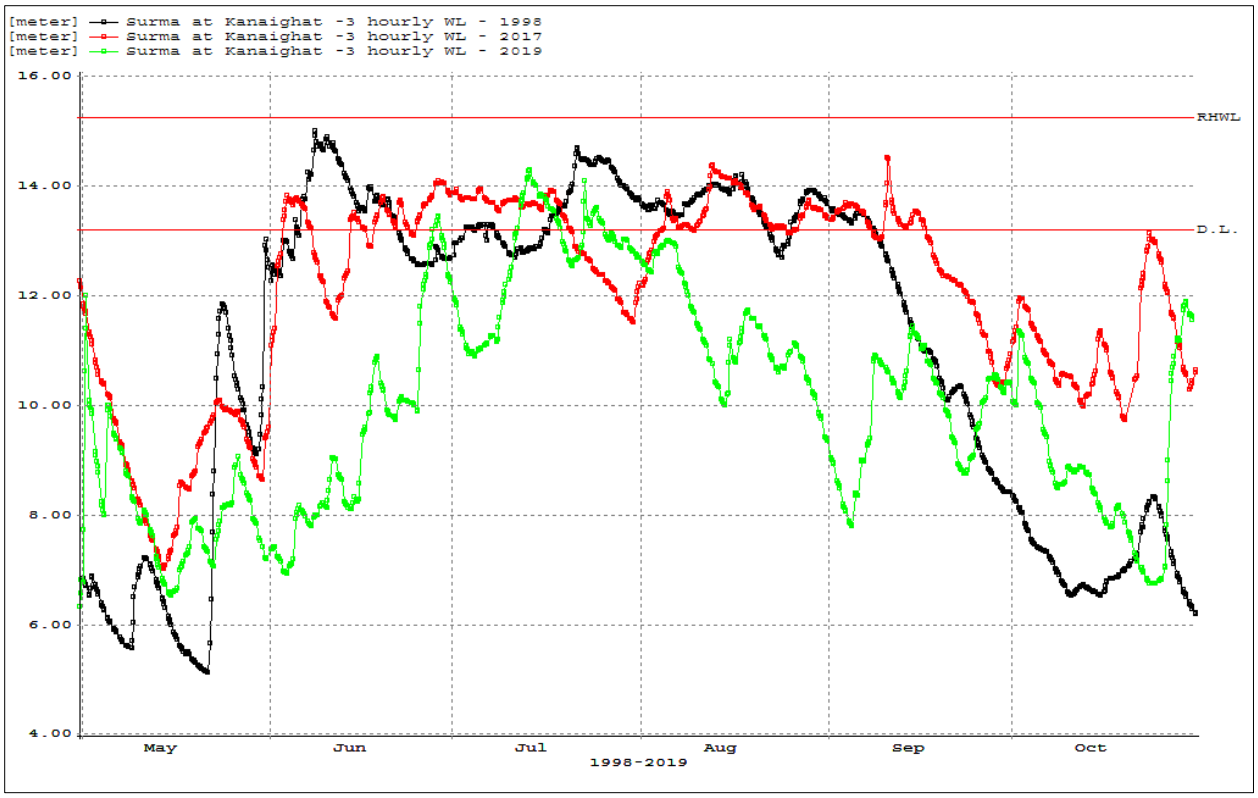


Figure 3.23: Comparison of Hydrograph on Surma at Kanaighat

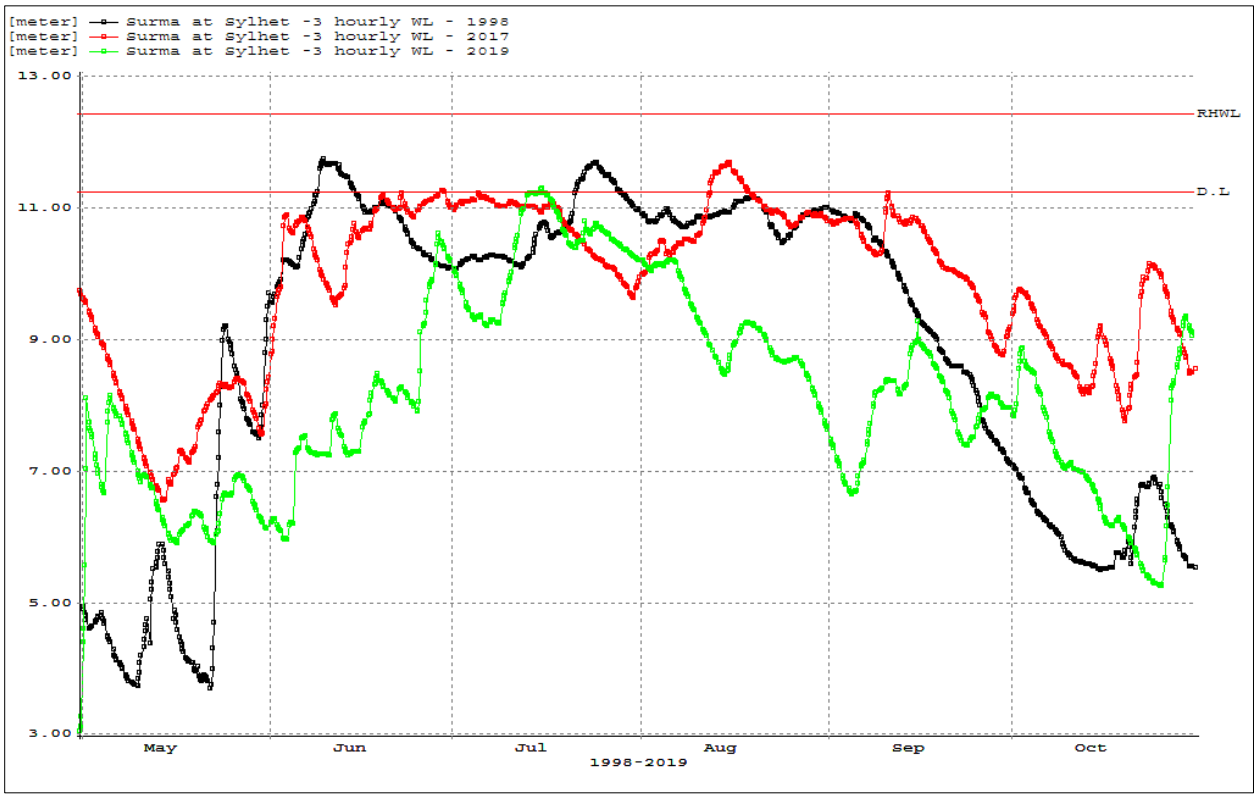


Figure 3.24: Comparison of Hydrograph on Surma at Sylhet

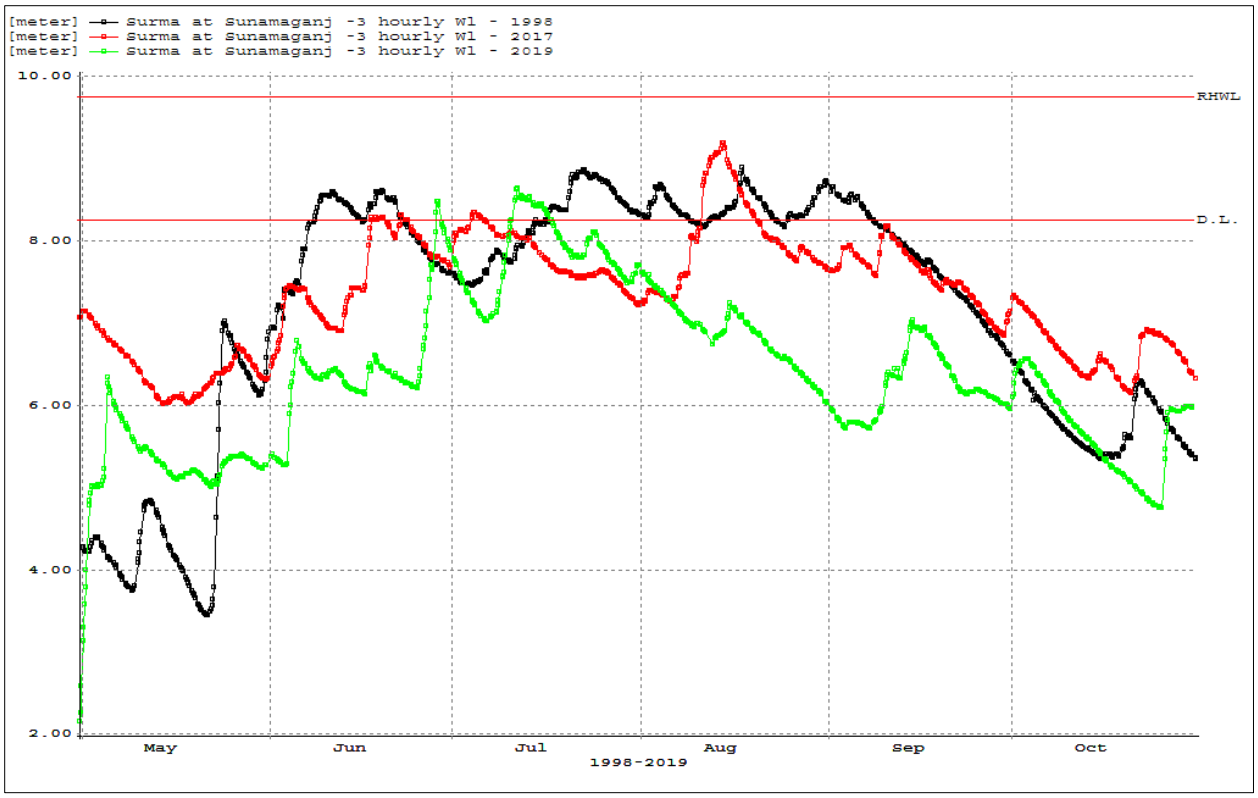


Figure 3.25: Comparison of Hydrograph on Surma at Sunamganj

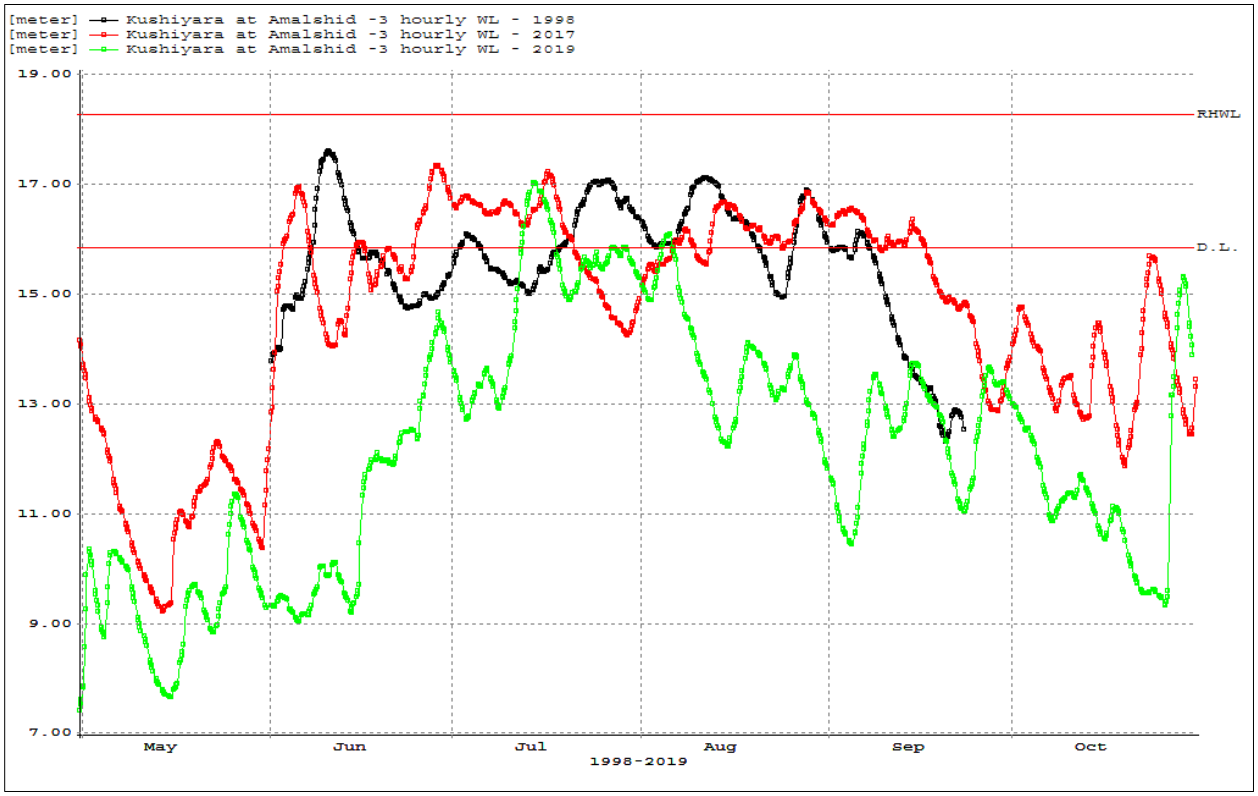


Figure 3.26: Comparison of Hydrograph on Kushiyara at Amalshid

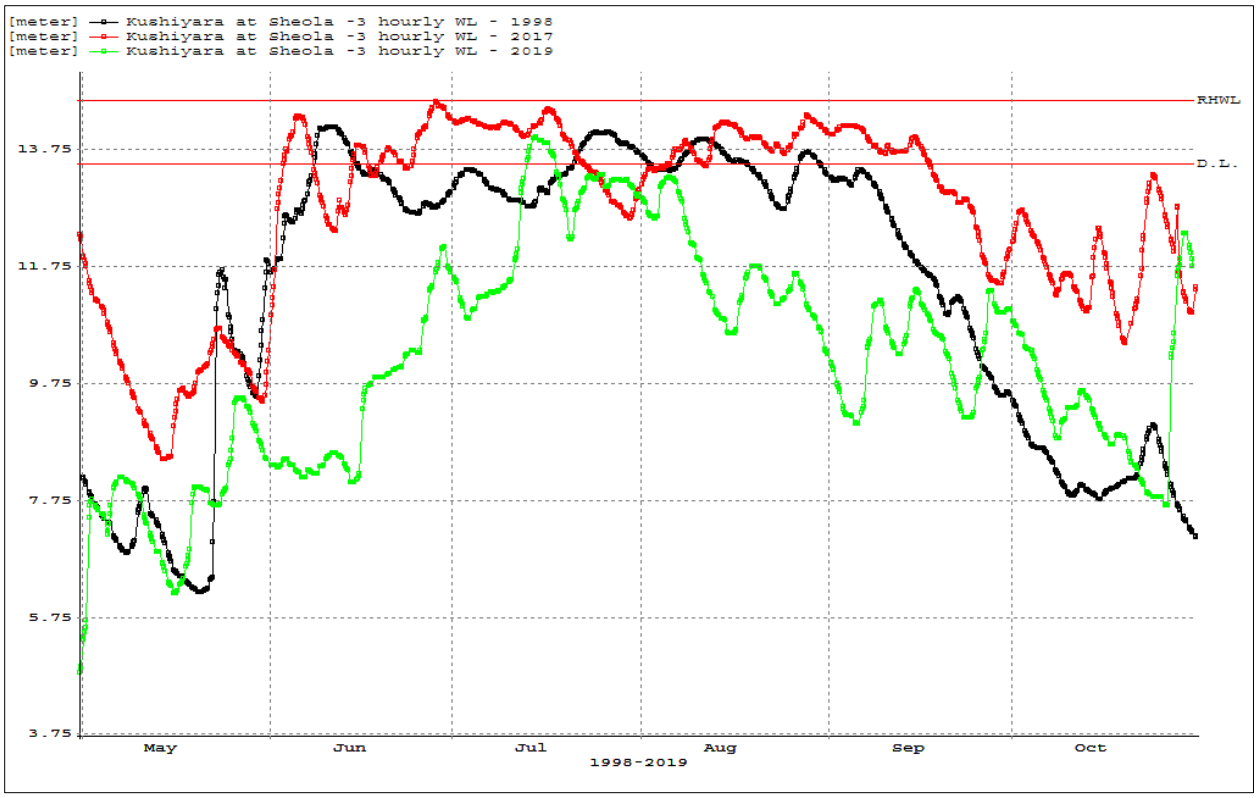


Figure 3.27: Comparison of Hydrograph on Kushiyara at Sheola

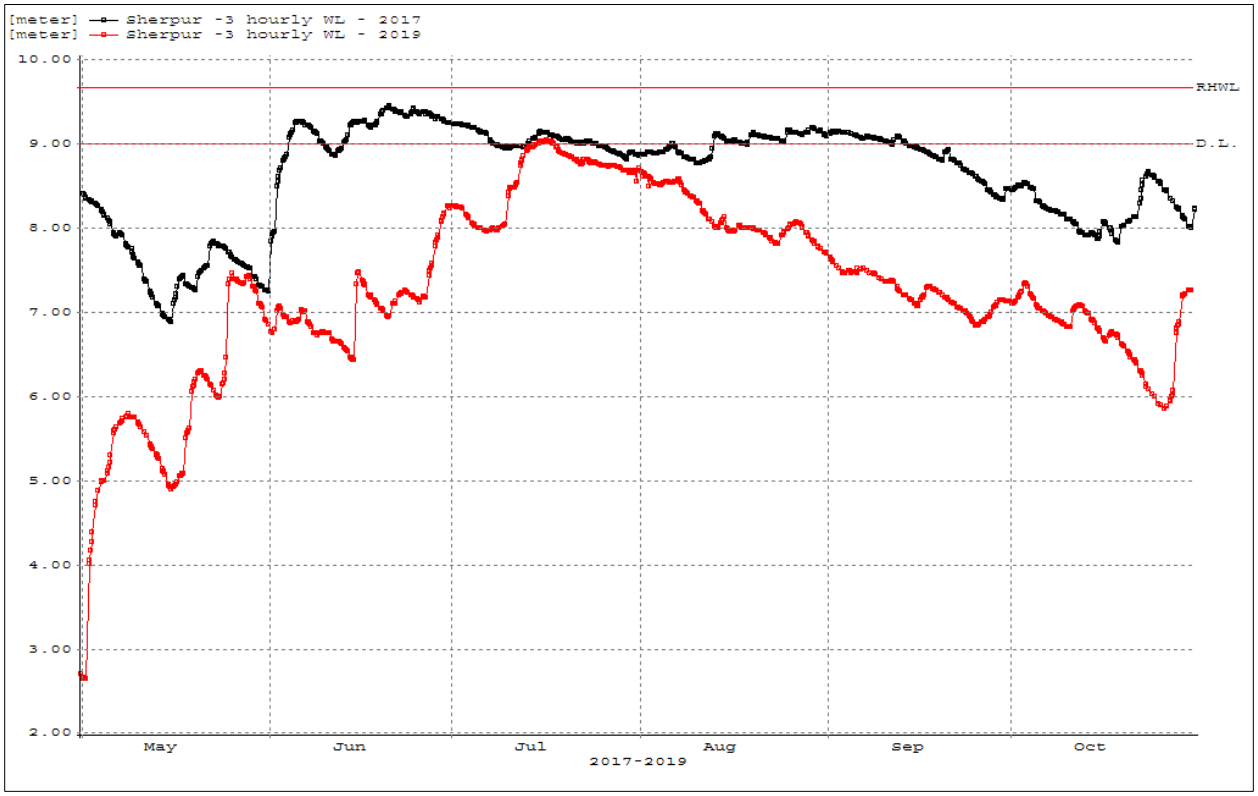


Figure 3.28: Comparison of Hydrograph on Kushiyara at Sherpur

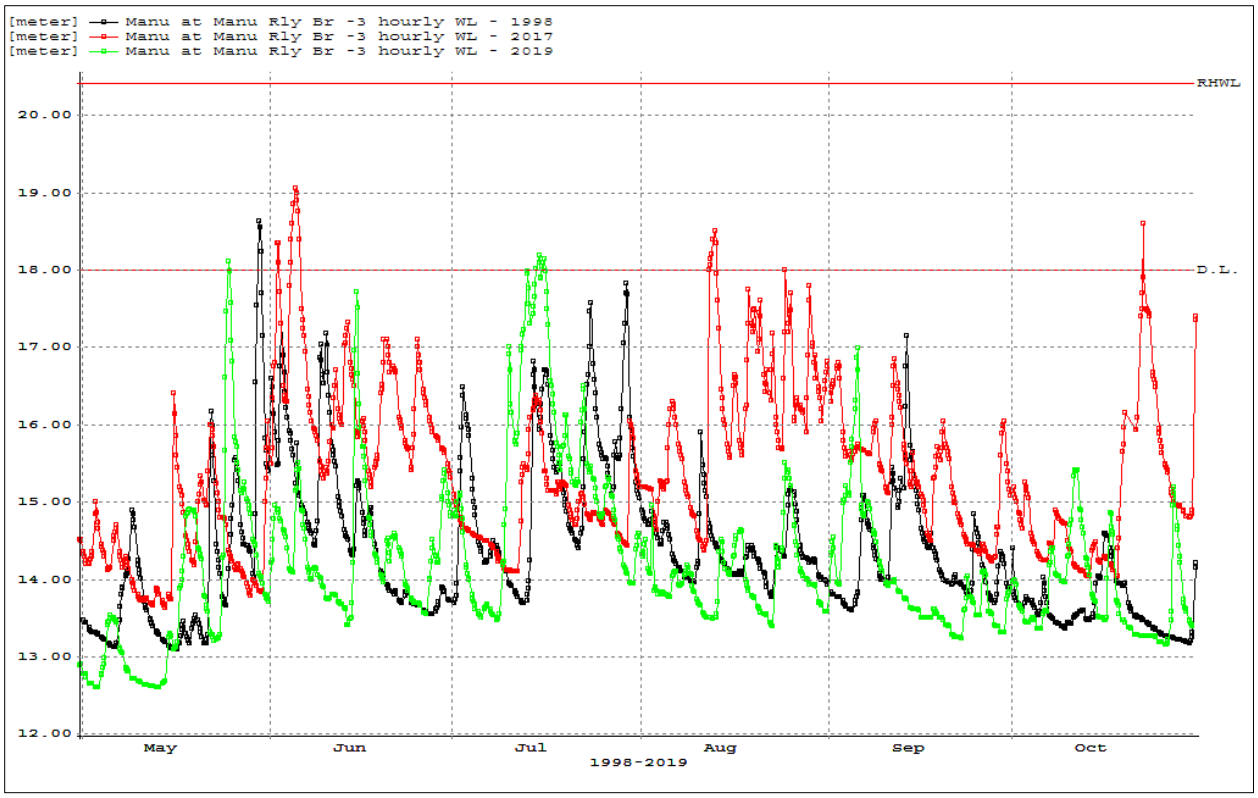


Figure 3.29: Comparison of Hydrograph on Manu at Manu Rail Bridge

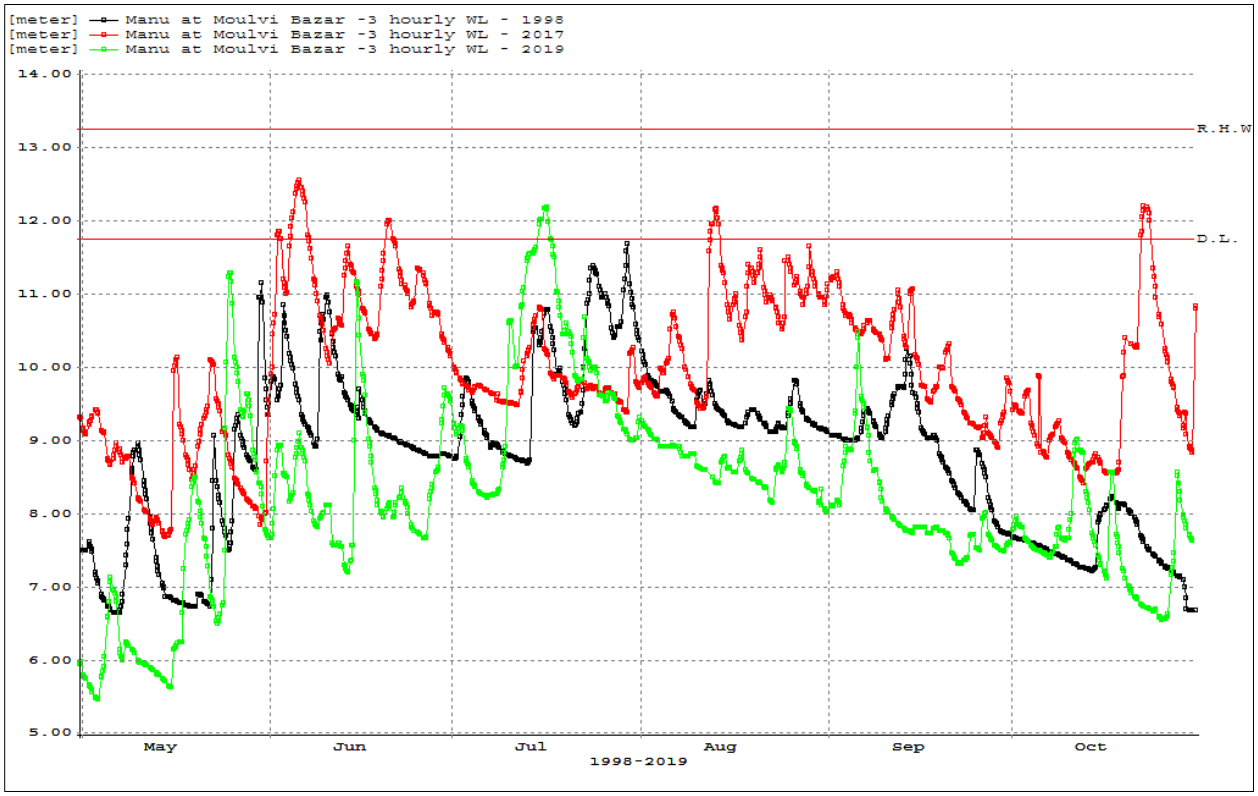


Figure 3.30: Comparison of Hydrograph on Manu at Moulvi Bazar

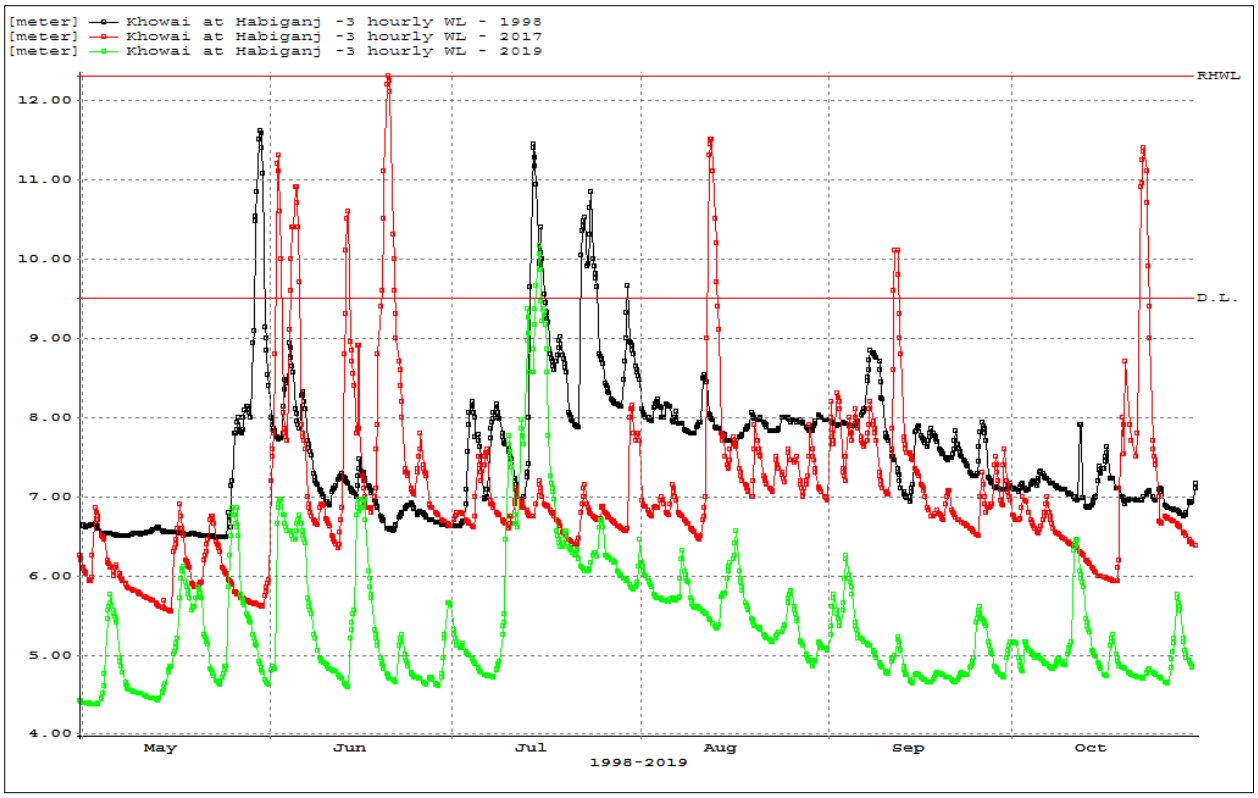


Figure 3.31: Comparison of Hydrograph on Khowai at Habiganj

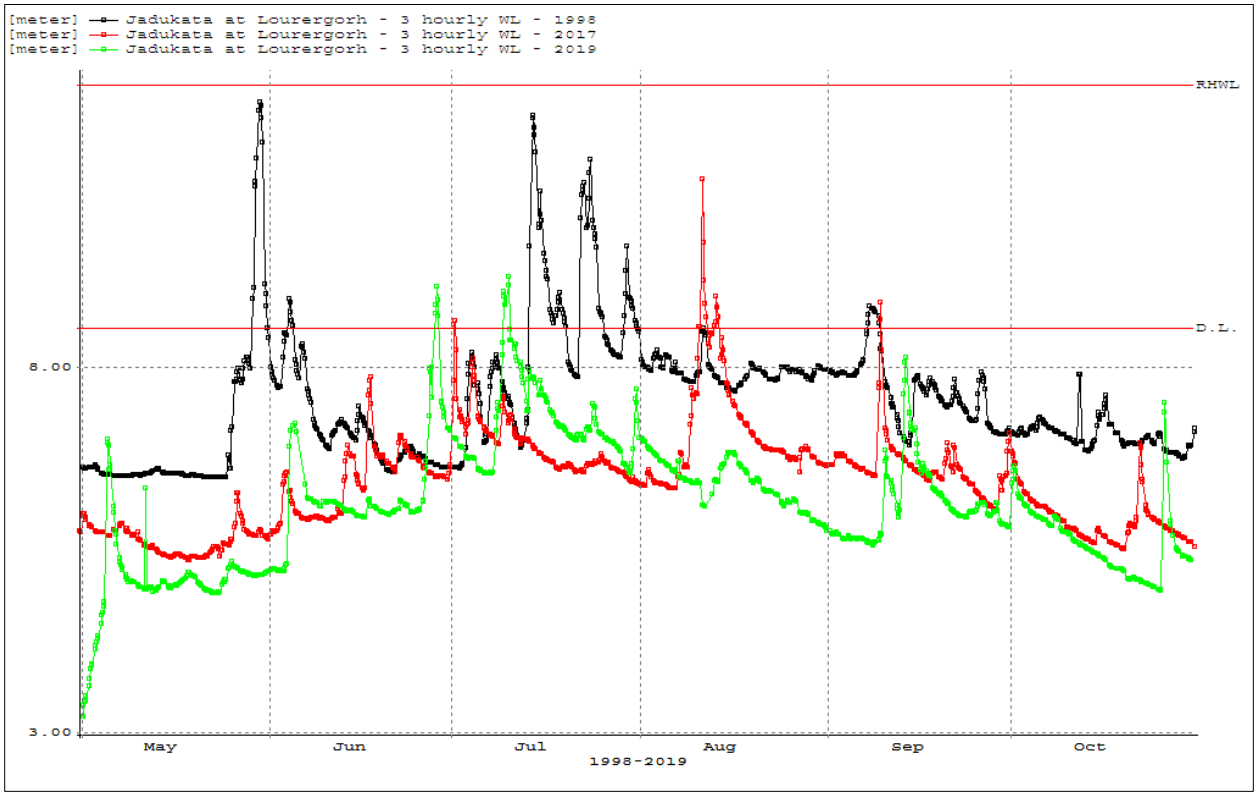


Figure 3.32: Comparison of Hydrograph on Jadukata at Lorergarh

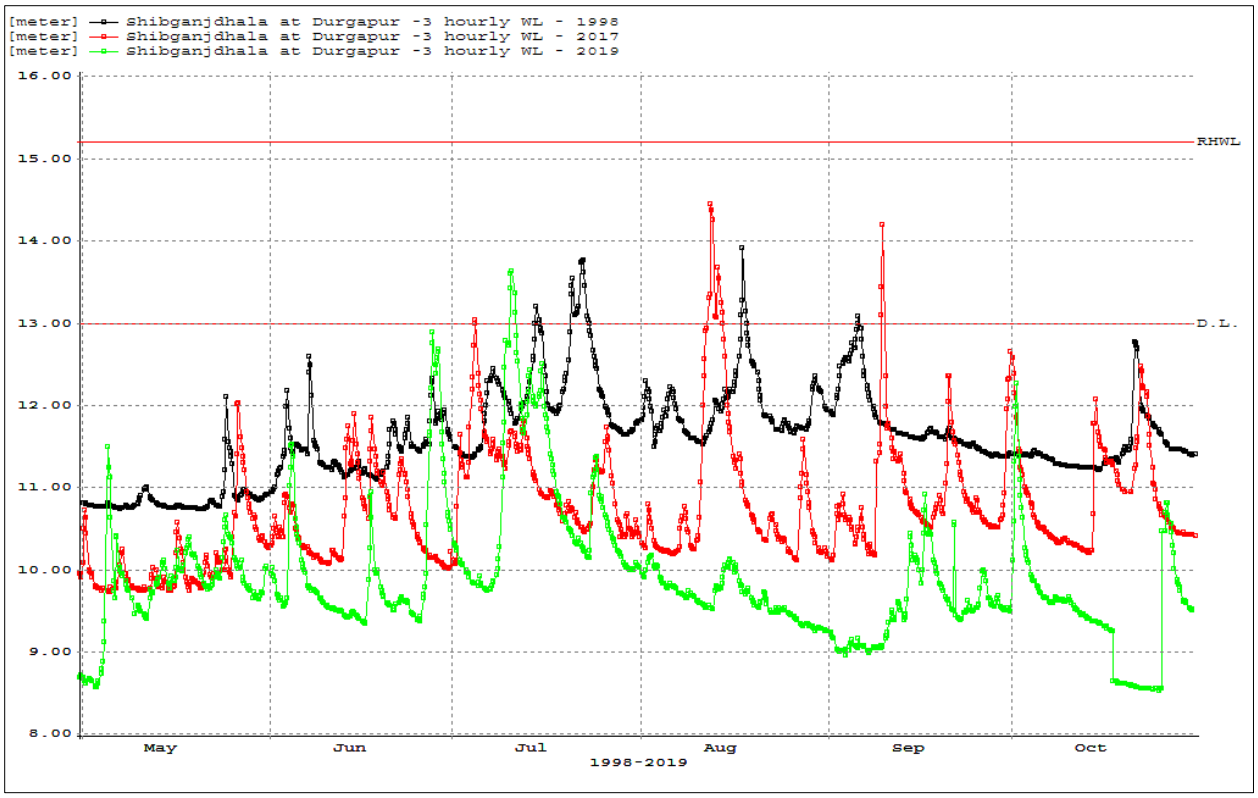


Figure 3.33: Comparison of Hydrograph on Someswari at Durgapur

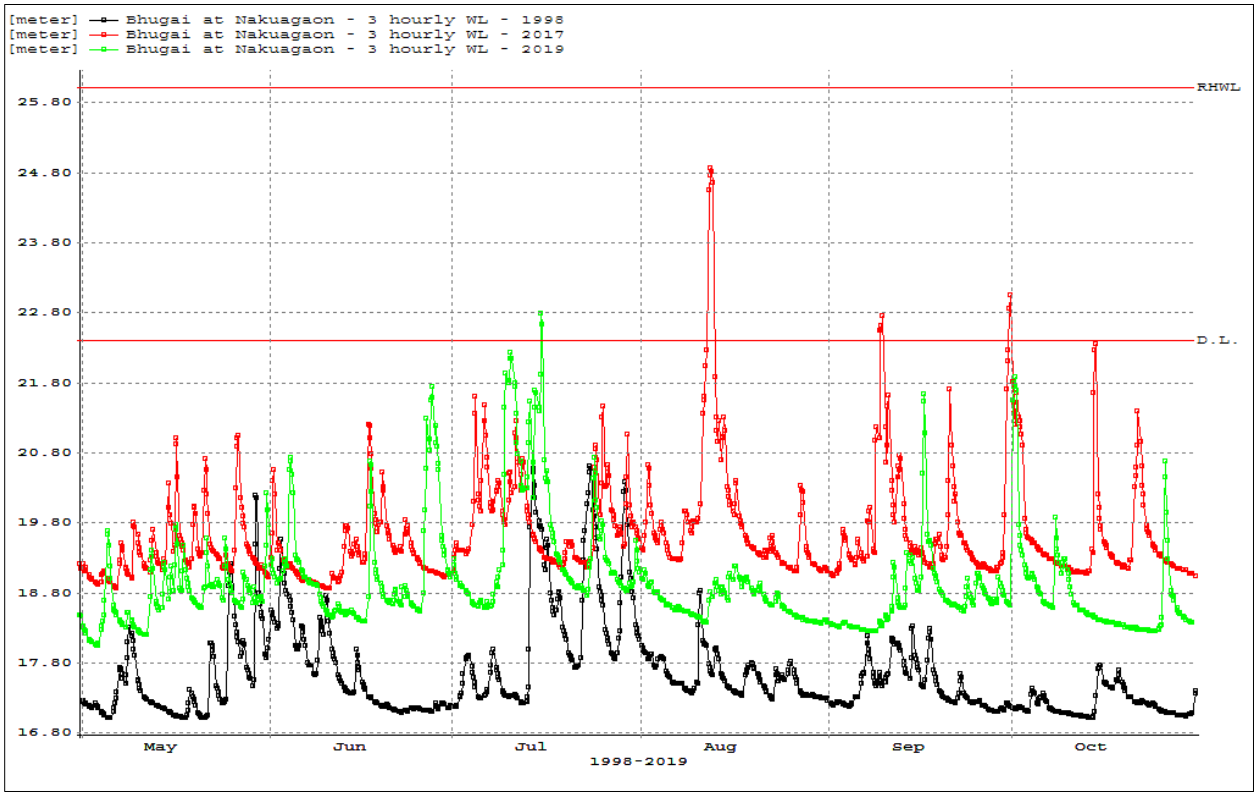


Figure 3.34: Comparison of Hydrograph on Bhugai at Nakuagaon

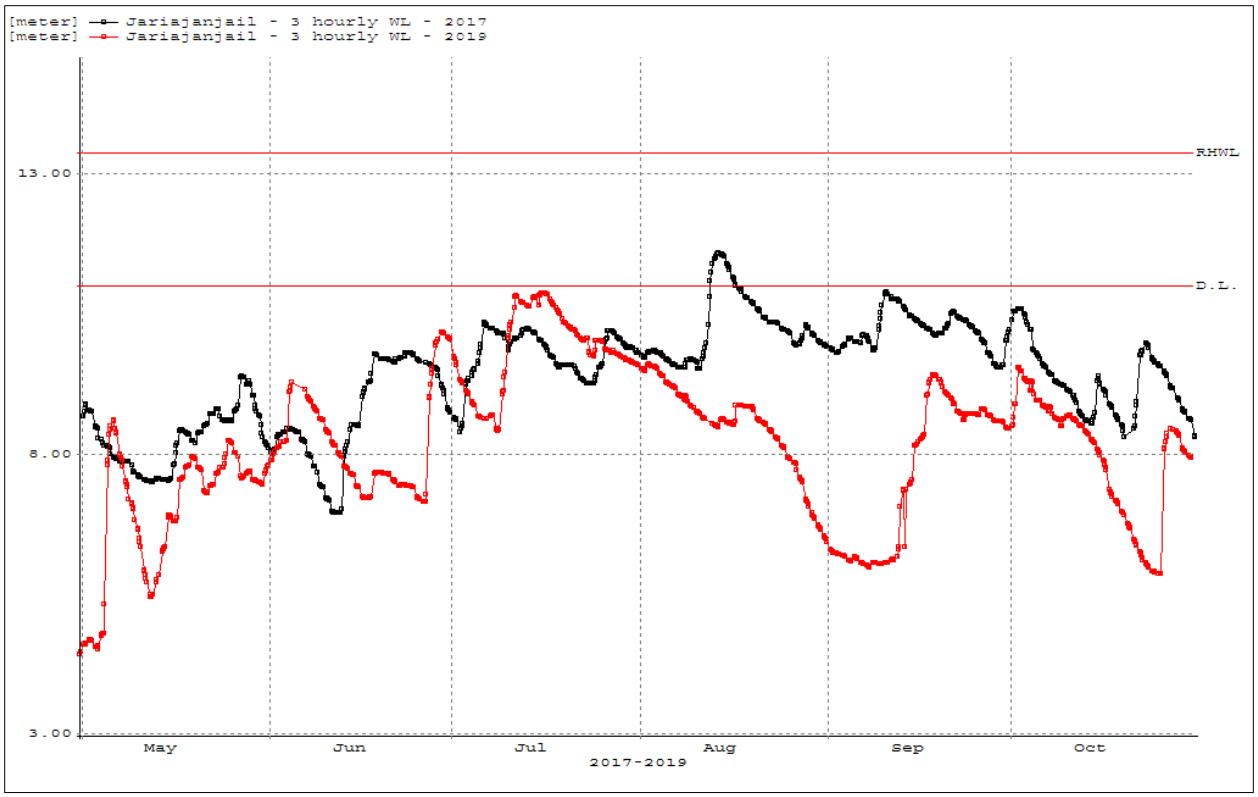


Figure 3.35: Comparison of Hydrograph on Kangsha at Jariajanjail

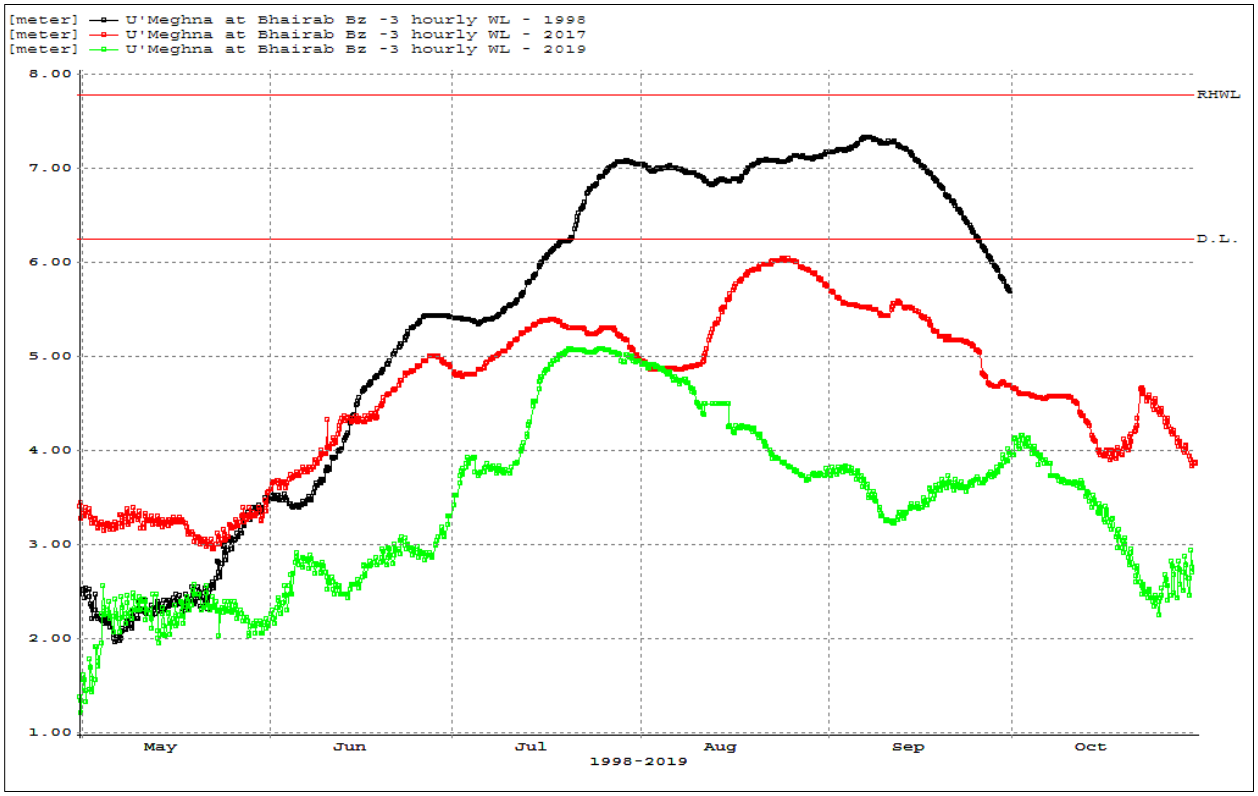


Figure 3.36: Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

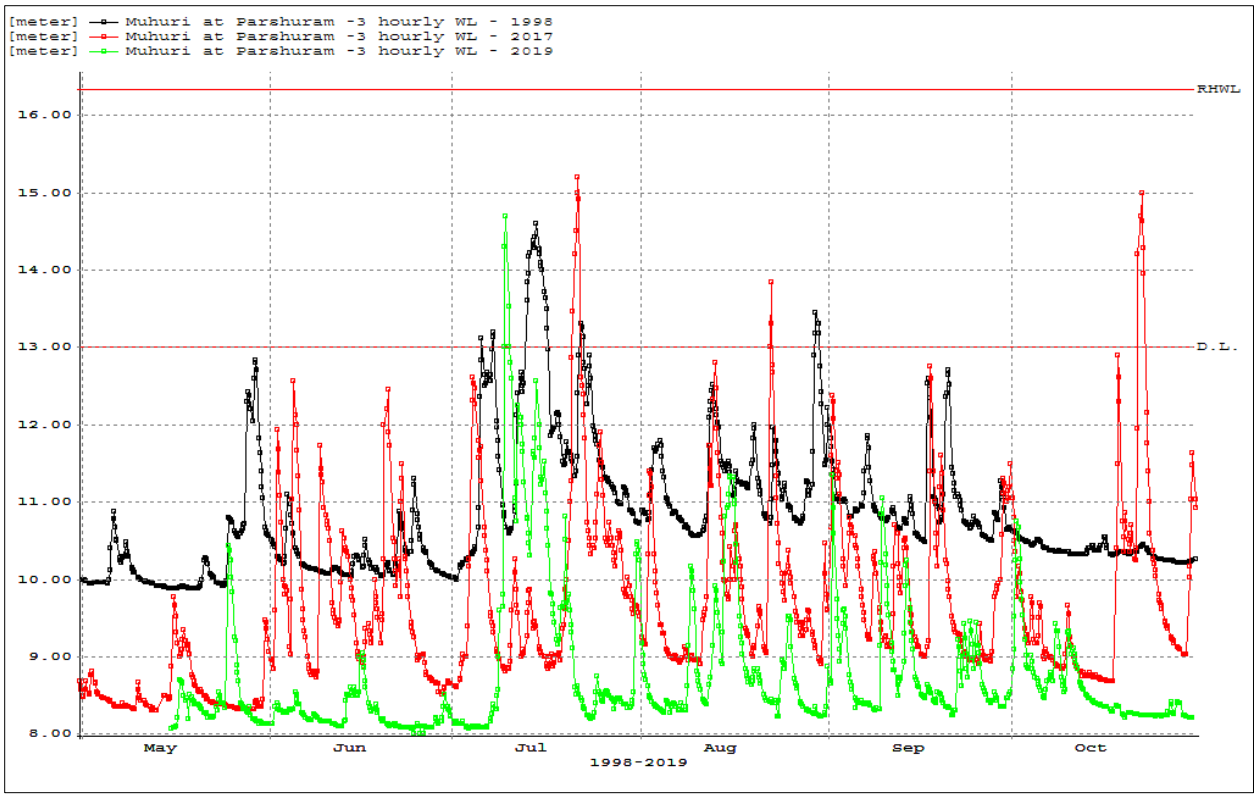


Figure 3.37: Comparison of Hydrograph on Muhuri at Parshuram

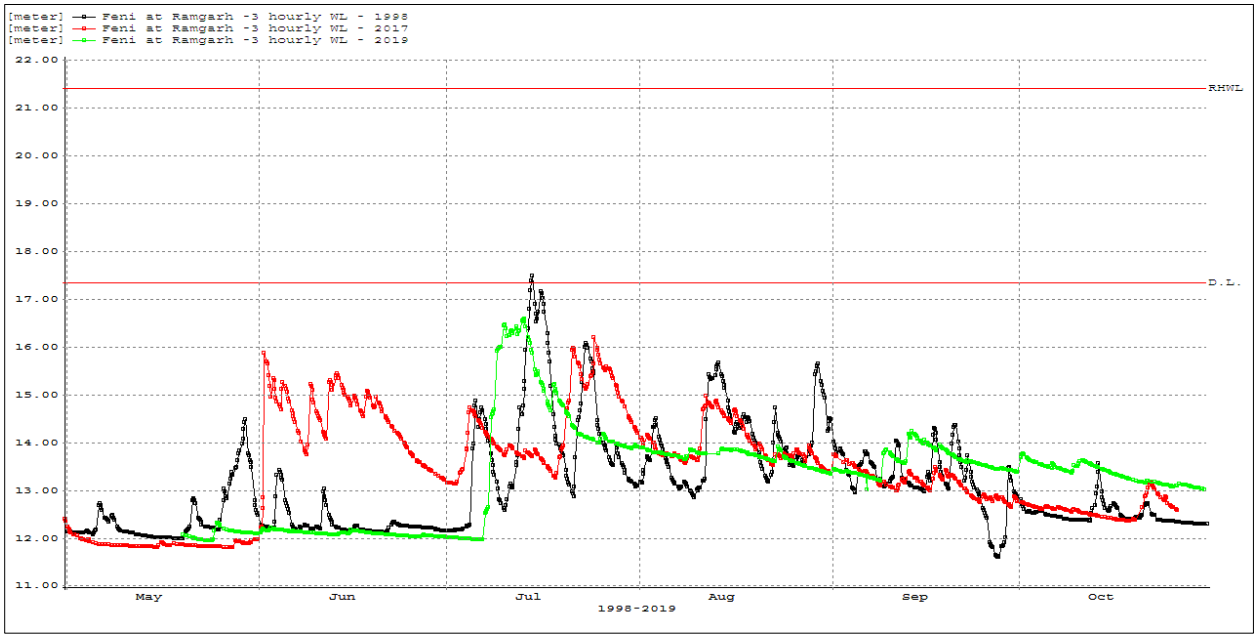


Figure 3.38: Comparison of Hydrograph on Feni at Ramgarh

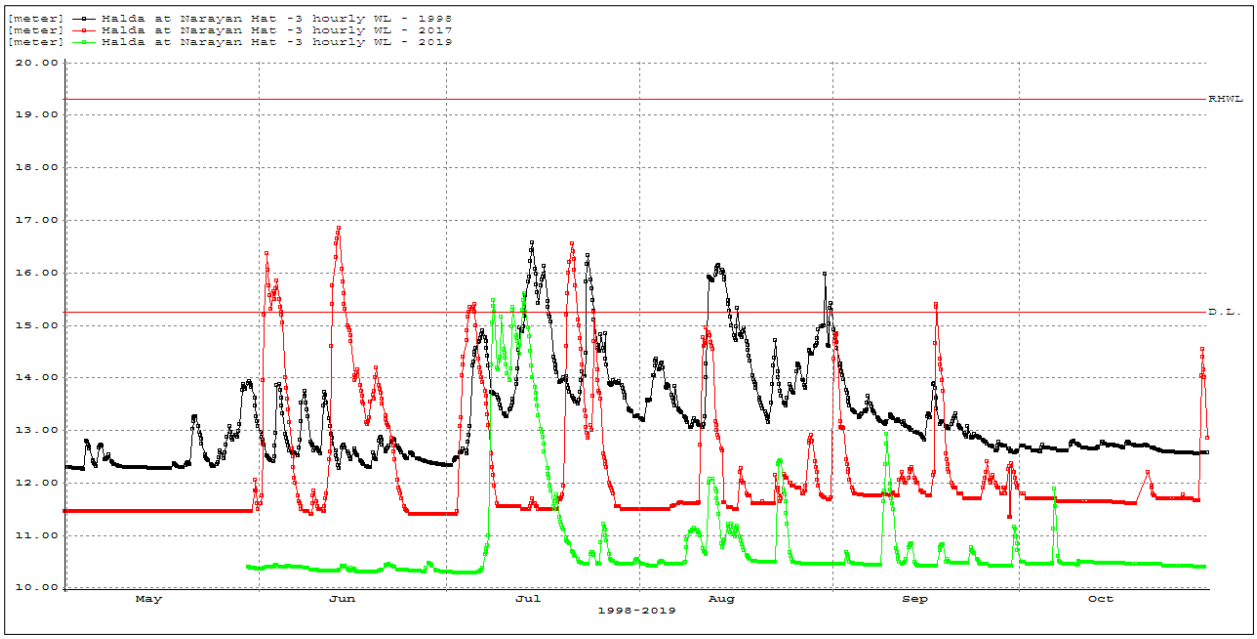


Figure 3.39: Comparison of Hydrograph on Halda at Narayanhat

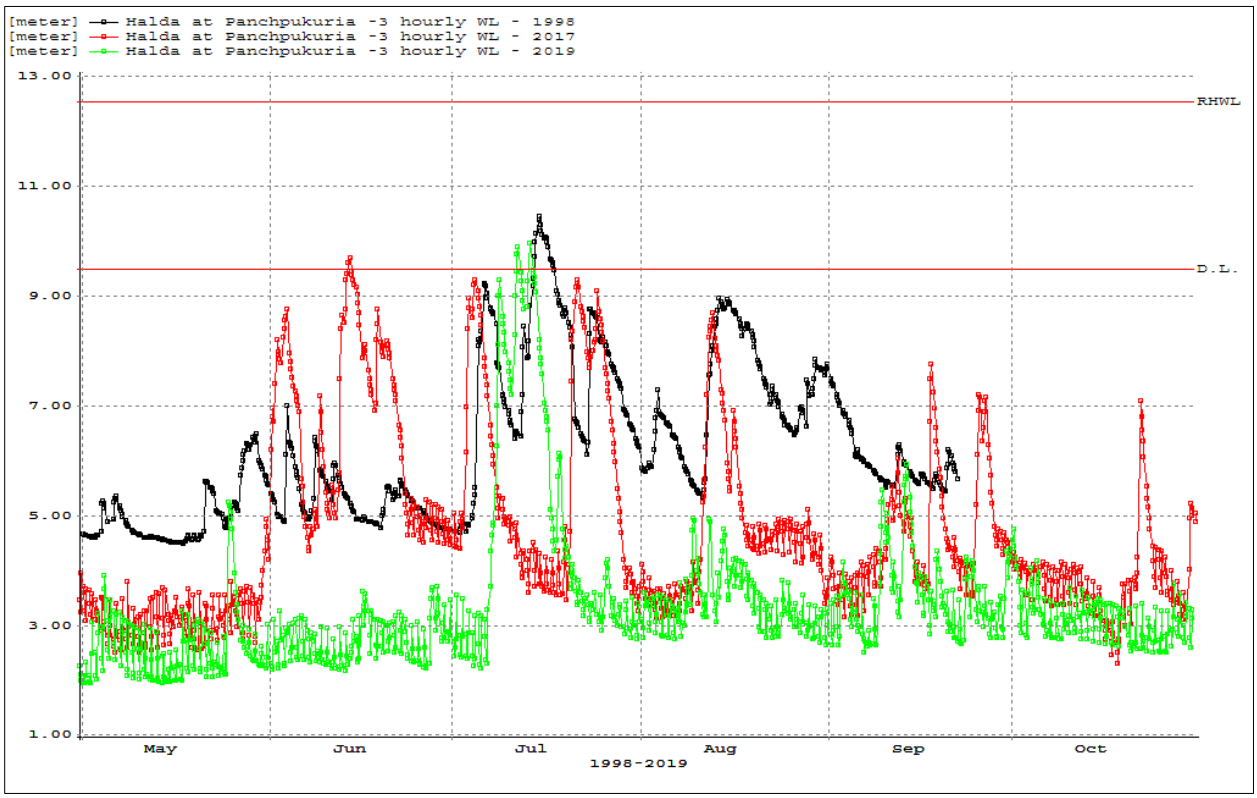


Figure 3.40: Comparison of Hydrograph on Halda at Panchpukuria

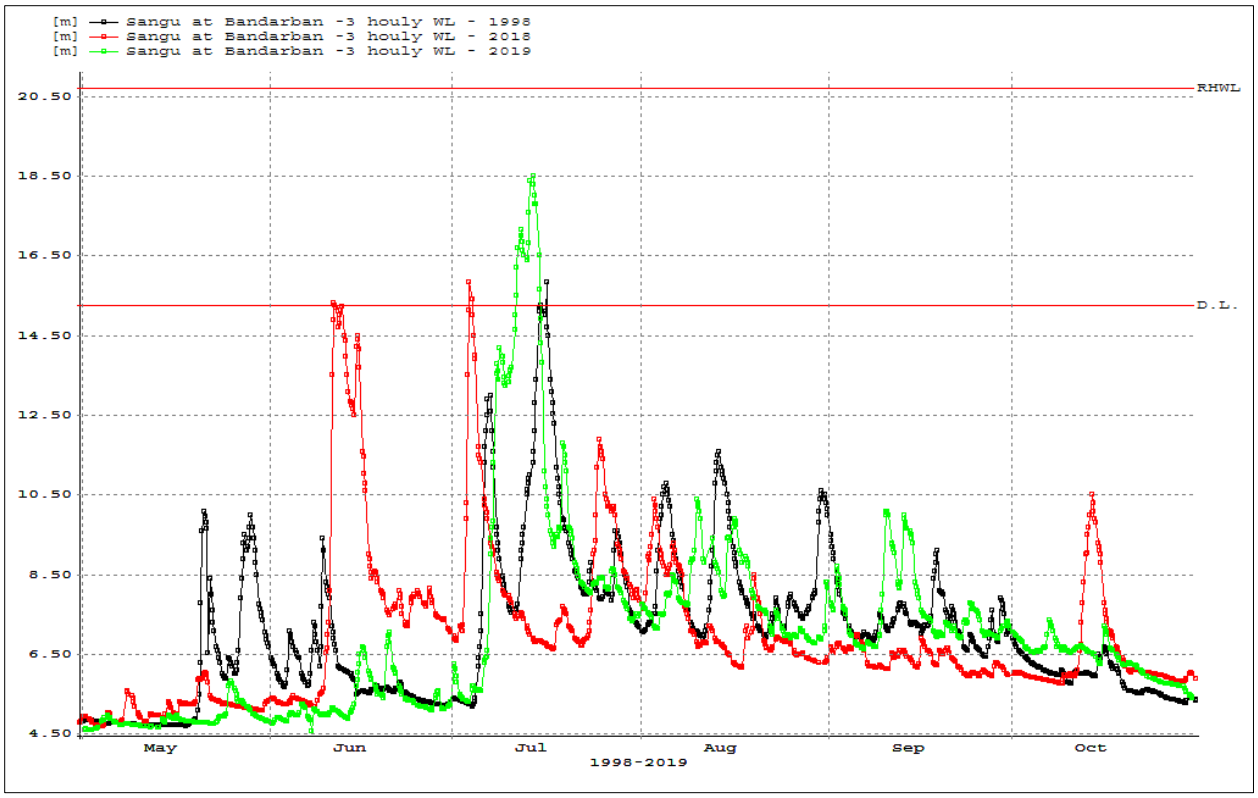


Figure 3.41: Comparison of Hydrograph on Sangu at Bandarban

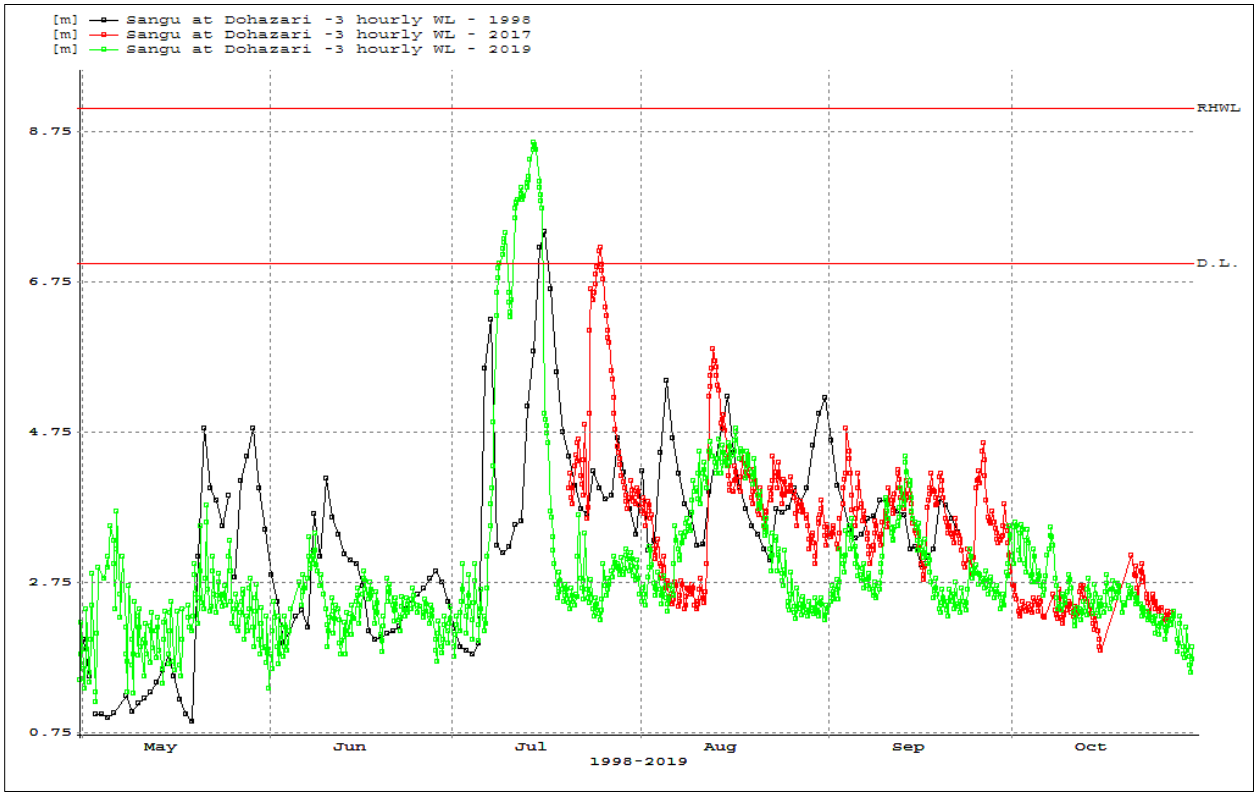


Figure 3.42: Comparison of Hydrograph on Sangu at Dohazari

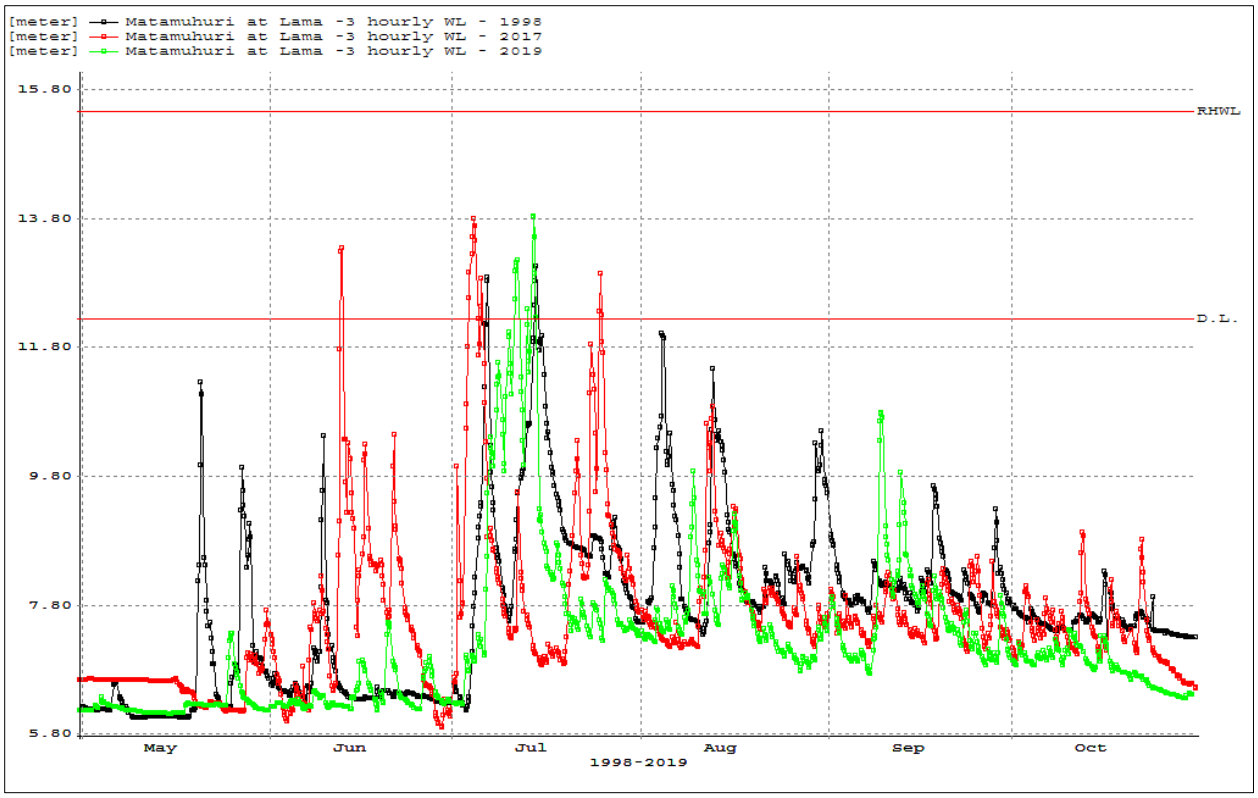


Figure 3.43: Comparison of Hydrograph on Matamuhuri at Lama

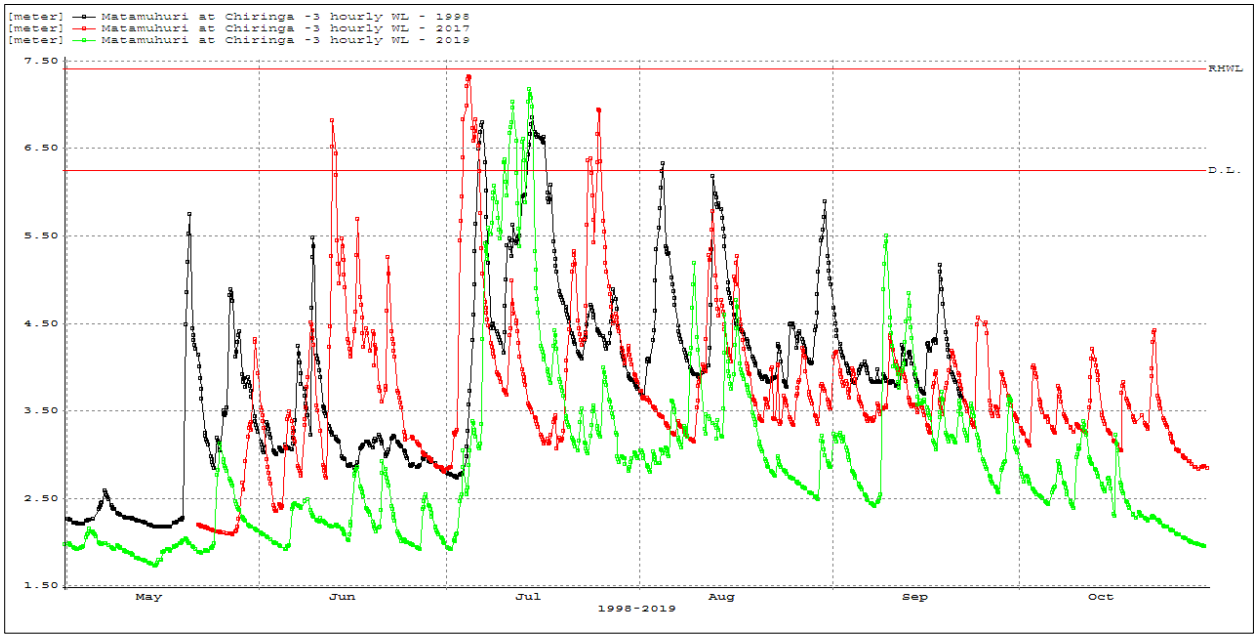


Figure 3.44: Comparison of Hydrograph on Matamuhuri at Chiringa

CHAPTER 4 : FORECAST EVALUATION, 2019

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 with experimental 4^{th} and 5^{th} day forecast in 54 stations during monsoon 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, 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 SHOURHARDO-II programme with technical support from RIMES. Currently FFWC is experimentally generating medium range 10-days probabilistic flood forecast in 37 stations of Ganges-Brahmaputra basin during monsoon and disseminating on a limited basis.

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-2015 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, 2019

4.3.1 Deterministic Forecast Performance

For deterministic forecasts, simulations were made up to 120 hours (5-days) in the forecast period. Total 46 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 94% stations are within the range of Good and Average, while for 2-days, 3-days, 4-days and 5-days forecast respectively 73%, 55%, 27% and 18% 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 95% (Average MAE 0.09m), 89% (Average MAE 0.16m), 82% (Average MAE 0.22m), 76% (Average MAE 0.28m) and 75% (Average MAE 0.33m) consistent for 24, 48, 72, 96 and 120 hours of lead time in the monsoon of 2019.

Table 4.2: Statistics for 24-hours Forecast Performance (Year, 2019)

Sl. No.	Station	MAE (m)	r^2	Performance-24hrs
1	Aricha	0.1	0.96	Good
2	Bahadurabad	0.09	0.99	Good
3	Bhagyakul	0.09	0.96	Good
4	Bhairabbazar	0.12	0.76	Average
5	Bogura	0.22	0.92	Not Satisfactory
6	Chakrahimpur	0.24	0.55	Not Satisfactory
7	Chilmari	0.12	0.98	Good
8	Chapai-Nawabganj	0.14	0.98	Good
9	Gaibandha	0.16	0.94	Average
10	Hardinge-RB	0.14	0.97	Good
11	Jagir	0.09	0.97	Good
12	Jamalpur	0.19	0.98	Average
13	Kamarkhali	0.13	0.96	Good
14	Kaunia	0.17	0.54	Not Satisfactory
15	Kazipur	0.05	1	Good
16	Kurigram	0.2	0.93	Average
17	Lakhpur	0.14	0.97	Good
18	Meghna Bridge	0.05	0.85	Average
19	Mirpur	0.11	0.91	Good
20	Mohadebpur	0.45	0.82	Very Poor
21	Moulvibazar	0.24	0.75	Not Satisfactory
22	Mymensingh	0.24	0.97	Not Satisfactory
23	Narayanganj	0.14	0.89	Average
24	Nayarhat	0.12	0.92	Good
25	Rajshahi	0.11	0.99	Good
26	Serajganj	0.09	0.98	Good
27	Sheola	0.34	0.9	Poor
28	Sherpur-Sylhet	0.11	0.87	Average
29	Singra	0.13	0.91	Good
30	Sunamganj	0.15	0.67	Not Satisfactory
31	Sylhet	0.29	0.72	Not Satisfactory
32	Taraghat	0.13	0.97	Good
33	Tongi	0.1	0.95	Good

Table 4.3: Statistics for 48-hours Forecast Performance (Year, 2019)

Sl. No.	Station	MAE (m)	r^2	Performance-24hrs
1	Aricha	0.06	0.99	Good
2	Bahadurabad	0.04	1	Good
3	Bhagyakul	0.05	0.99	Good
4	Bhairabbazar	0.06	0.93	Good
5	Bogura	0.11	0.98	Good
6	Chakrahimpur	0.13	0.85	Average
7	Chilmari	0.06	1	Good
8	Chapai-Nawabganj	0.07	0.99	Good
9	Gaibandha	0.09	0.96	Good
10	Hardinge-RB	0.06	0.99	Good
11	Jagir	0.06	0.99	Good
12	Jamalpur	0.12	0.99	Good
13	Kamarkhali	0.08	0.97	Good
14	Kaunia	0.14	0.65	Not Satisfactory
15	Kazipur	0.01	1	Good
16	Kurigram	0.12	0.96	Good
17	Lakhpur	0.08	0.99	Good
18	Meghna Bridge	0.02	0.92	Good
19	Mirpur	0.06	0.97	Good
20	Mohadebpur	0.26	0.94	Not Satisfactory
21	Moulvibazar	0.2	0.78	Average
22	Mymensingh	0.12	0.99	Good
23	Narayanganj	0.08	0.95	Good
24	Nayarhat	0.06	0.98	Good
25	Rajshahi	0.05	1	Good
26	Serajganj	0.05	0.99	Good
27	Sheola	0.17	0.97	Average
28	Sherpur-Sylhet	0.06	0.96	Good
29	Singra	0.06	0.99	Good
30	Sunamganj	0.07	0.9	Good
31	Sylhet	0.15	0.86	Average
32	Taraghat	0.07	0.99	Good
33	Tongi	0.05	0.98	Good

Table 4.4: Statistics for 72-hours Forecast Performance (Year, 2019)

Sl. No.	Station	MAE (m)	r^2	Performance-72hrs
1	Aricha	0.14	0.93	Good
2	Bahadurabad	0.17	0.97	Average
3	Bhagyakul	0.11	0.92	Good
4	Bhairabbazar	0.16	0.58	Not Satisfactory
5	Bogura	0.29	0.88	Not Satisfactory
6	Chakrahimpur	0.32	0.34	Poor
7	Chilmari	0.19	0.95	Average
8	Chapai-Nawabganj	0.21	0.95	Not Satisfactory
9	Gaibandha	0.23	0.92	Not Satisfactory
10	Hardinge-RB	0.2	0.95	Average
11	Jagir	0.12	0.95	Good
12	Jamalpur	0.28	0.95	Not Satisfactory
13	Kamarkhali	0.15	0.93	Good
14	Kaunia	0.19	0.41	Not Satisfactory
15	Kazipur	0.12	0.98	Good
16	Kurigram	0.28	0.88	Not Satisfactory
17	Lakhpur	0.21	0.94	Not Satisfactory
18	Meghna Bridge	0.06	0.83	Average
19	Mirpur	0.13	0.87	Average
20	Mohadebpur	0.59	0.7	Very Poor
21	Moulvibazar	0.39	0.44	Poor
22	Mymensingh	0.33	0.94	Poor
23	Narayanganj	0.19	0.83	Average
24	Nayarhat	0.16	0.85	Average
25	Rajshahi	0.18	0.97	Average
26	Serajganj	0.15	0.94	Good
27	Sheola	0.53	0.79	Very Poor
28	Sherpur-Sylhet	0.14	0.82	Average
29	Singra	0.17	0.89	Average
30	Sunamganj	0.21	0.46	Not Satisfactory
31	Sylhet	0.44	0.48	Very Poor
32	Taraghat	0.18	0.95	Average
33	Tongi	0.14	0.91	Good

Table 4.5: Statistics for 96-hours Forecast Performance (Year, 2019)

Sl. No.	Station	MAE (m)	r^2	Performance-96hrs
1	Aricha	0.17	0.9	Average
2	Bahadurabad	0.21	0.94	Not Satisfactory
3	Bhagyakul	0.13	0.91	Good
4	Bhairabbazar	0.19	0.4	Not Satisfactory
5	Bogura	0.39	0.81	Poor
6	Chakrahimpur	0.38	0.21	Very Poor
7	Chilmari	0.25	0.91	Not Satisfactory
8	Chapai-Nawabganj	0.29	0.88	Not Satisfactory
9	Gaibandha	0.29	0.9	Not Satisfactory
10	Hardinge-RB	0.31	0.89	Poor
11	Jagir	0.15	0.93	Good
12	Jamalpur	0.32	0.94	Poor
13	Kamarkhali	0.22	0.87	Not Satisfactory
14	Kaunia	0.21	0.18	Very Poor
15	Kazipur	0.18	0.95	Average
16	Kurigram	0.35	0.84	Poor
17	Lakhpur	0.25	0.92	Not Satisfactory
18	Meghna Bridge	0.09	0.78	Average
19	Mirpur	0.14	0.85	Average
20	Mohadebpur	0.68	0.59	Very Poor
21	Moulvibazar	0.38	0.61	Poor
22	Mymensingh	0.41	0.92	Very Poor
23	Narayanganj	0.21	0.78	Not Satisfactory
24	Nayarhat	0.2	0.79	Average
25	Rajshahi	0.29	0.91	Not Satisfactory
26	Serajganj	0.21	0.9	Not Satisfactory
27	Sheola	0.65	0.68	Very Poor
28	Sherpur-Sylhet	0.15	0.8	Average
29	Singra	0.22	0.83	Not Satisfactory
30	Sunamganj	0.26	0.33	Poor
31	Sylhet	0.54	0.29	Very Poor
32	Taraghat	0.21	0.93	Not Satisfactory
33	Tongi	0.17	0.87	Average

Table 4.6: Statistics for 120-hours Forecast Performance (Year, 2019)

Sl. No.	Station	MAE (m)	r^2	Performance-120hrs
1	Aricha	0.21	0.84	Not Satisfactory
2	Bahadurabad	0.28	0.9	Not Satisfactory
3	Bhagyakul	0.16	0.85	Average
4	Bhairabbazar	0.24	0.54	Not Satisfactory
5	Bogura	0.46	0.75	Very Poor
6	Chakrahimpur	0.44	0.14	Very Poor
7	Chilmari	0.31	0.86	Poor
8	Chapai-Nawabganj	0.41	0.81	Very Poor
9	Gaibandha	0.37	0.81	Poor
10	Hardinge-RB	0.37	0.86	Poor
11	Jagir	0.17	0.9	Average
12	Jamalpur	0.37	0.92	Poor
13	Kamarkhali	0.29	0.79	Not Satisfactory
14	Kaunia	0.17	0.39	Poor
15	Kazipur	0.23	0.91	Not Satisfactory
16	Kurigram	0.42	0.78	Very Poor
17	Lakhpur	0.3	0.89	Not Satisfactory
18	Meghna Bridge	0.11	0.73	Average
19	Mirpur	0.17	0.79	Average
20	Mohadebpur	0.75	0.49	Very Poor
21	Moulvibazar	0.5	0.87	Very Poor
22	Mymensingh	0.51	0.87	Very Poor
23	Narayanganj	0.26	0.73	Not Satisfactory
24	Nayarhat	0.24	0.72	Not Satisfactory
25	Rajshahi	0.37	0.85	Poor
26	Serajganj	0.27	0.84	Not Satisfactory
27	Sheola	0.77	0.59	Very Poor
28	Sherpur-Sylhet	0.19	0.83	Average
29	Singra	0.28	0.7	Not Satisfactory
30	Sunamganj	0.3	0.68	Not Satisfactory
31	Sylhet	0.64	0.45	Very Poor
32	Taraghat	0.24	0.91	Not Satisfactory
33	Tongi	0.19	0.85	Average

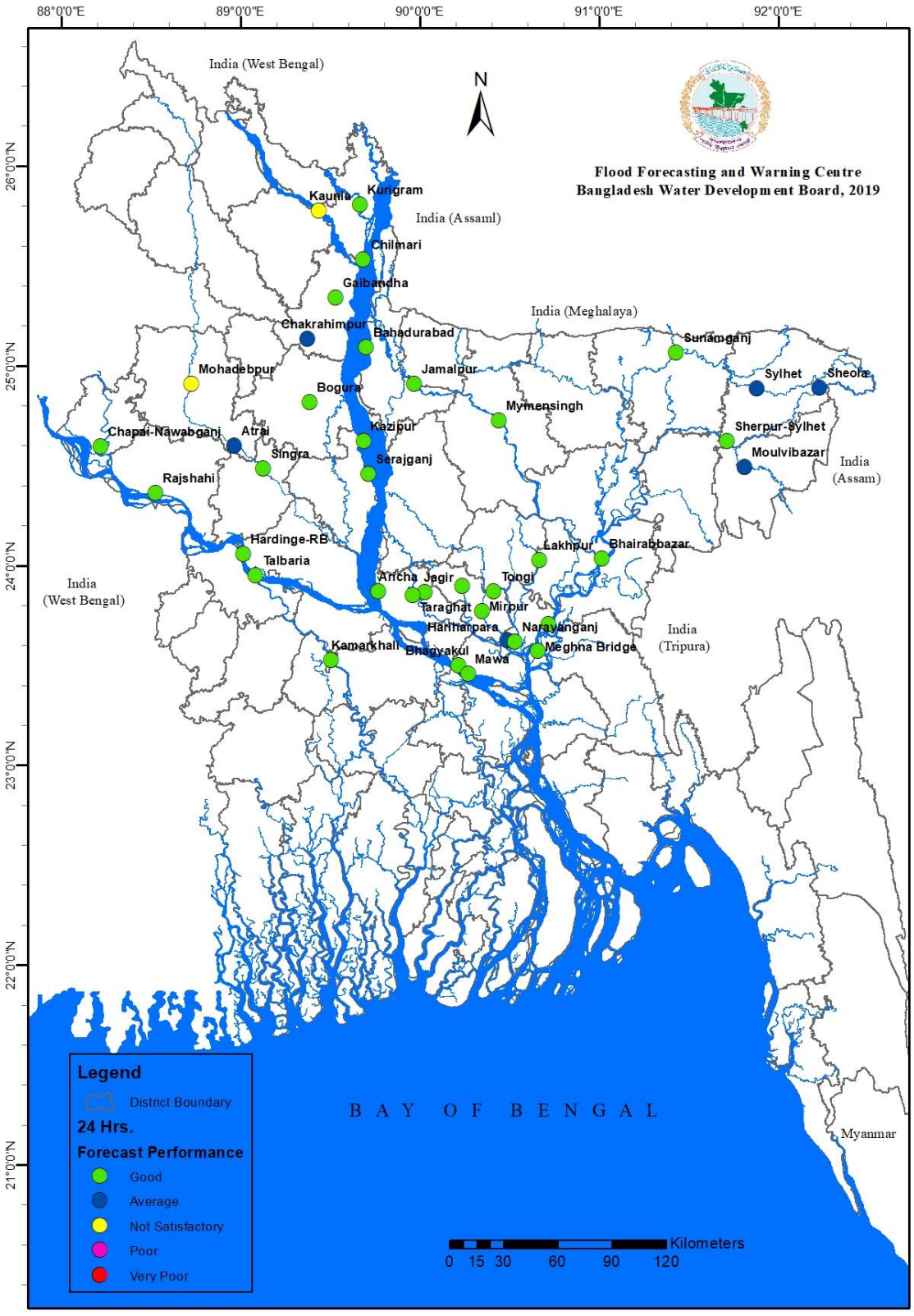


Figure 4.1 : 24-hrs Forecast Evaluation (Year, 2019)

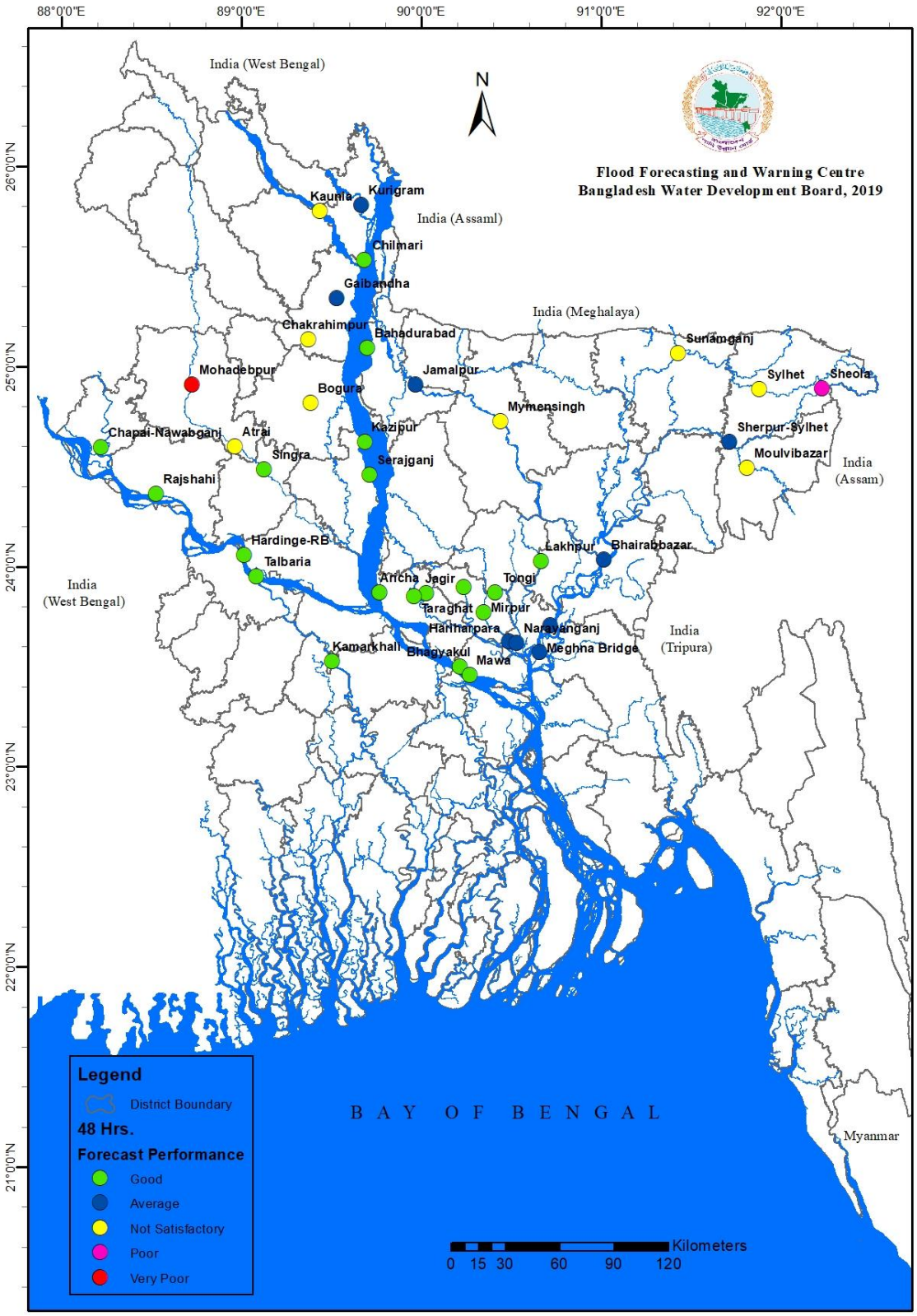


Figure 4.2 : 48-hrs Forecast Evaluation (Year, 2019)

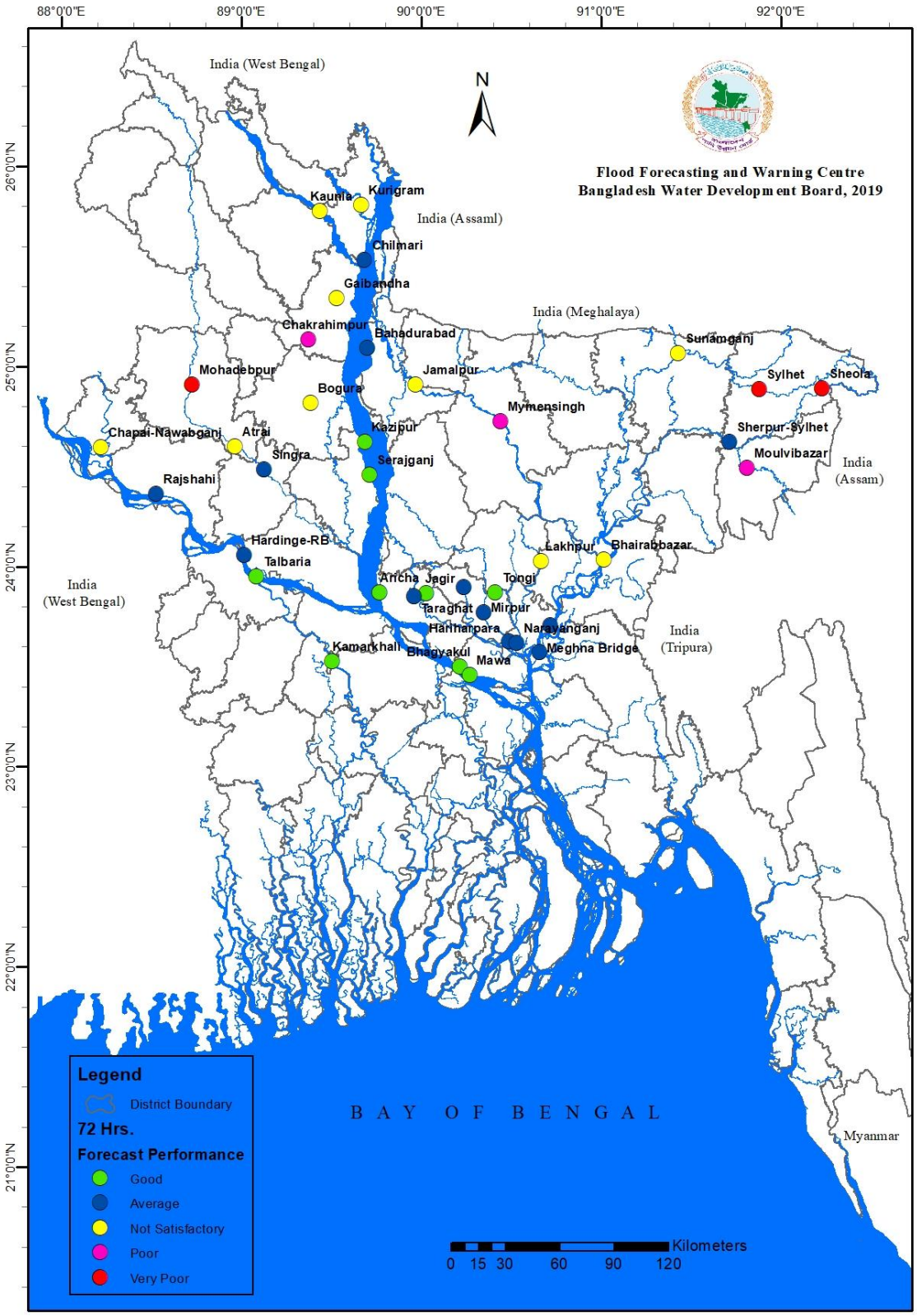


Figure 4.3 : 72-hrs Forecast Evaluation (Year, 2019)

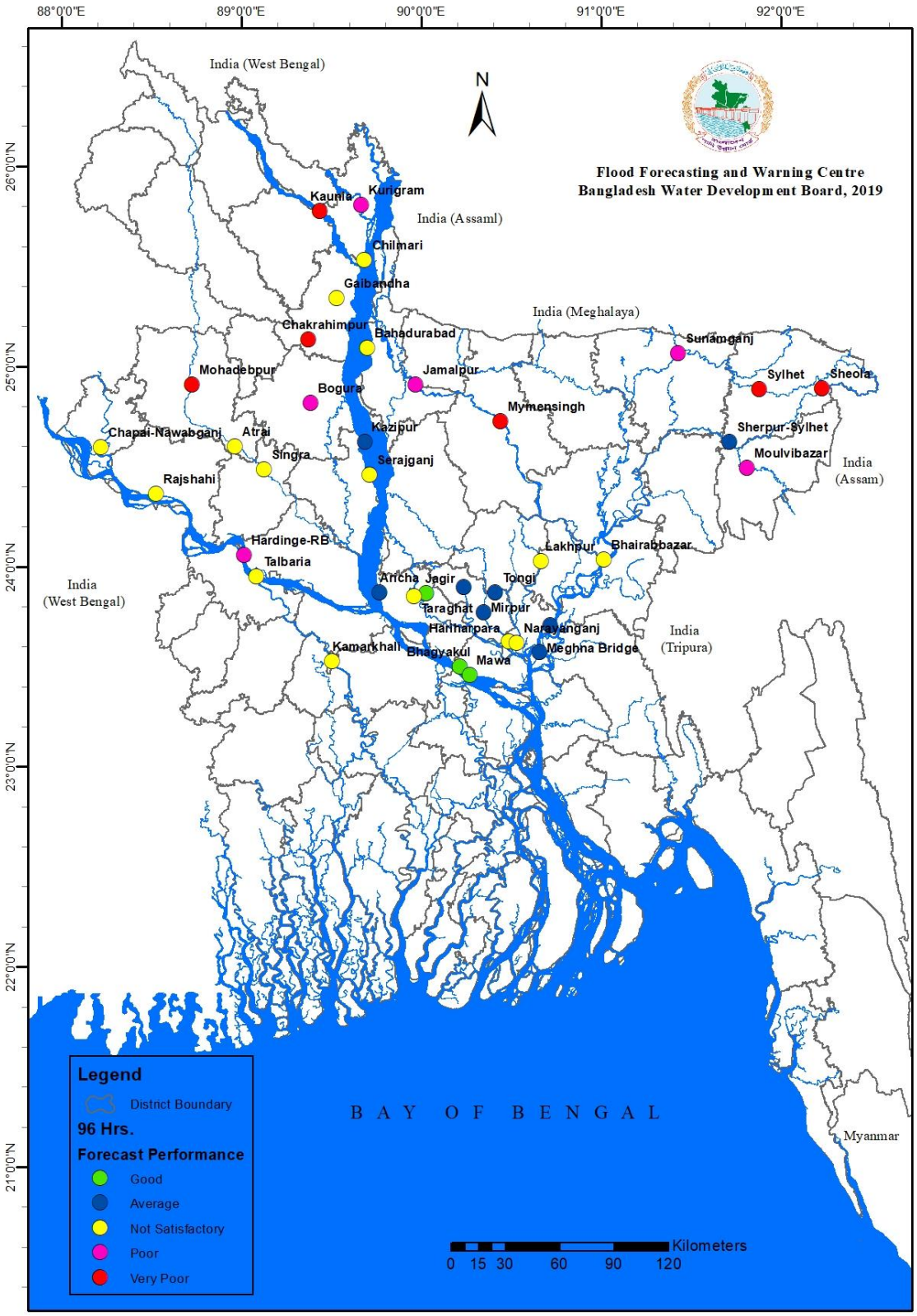


Figure 4.4 : 96-hrs Forecast Evaluation (Year, 2019)

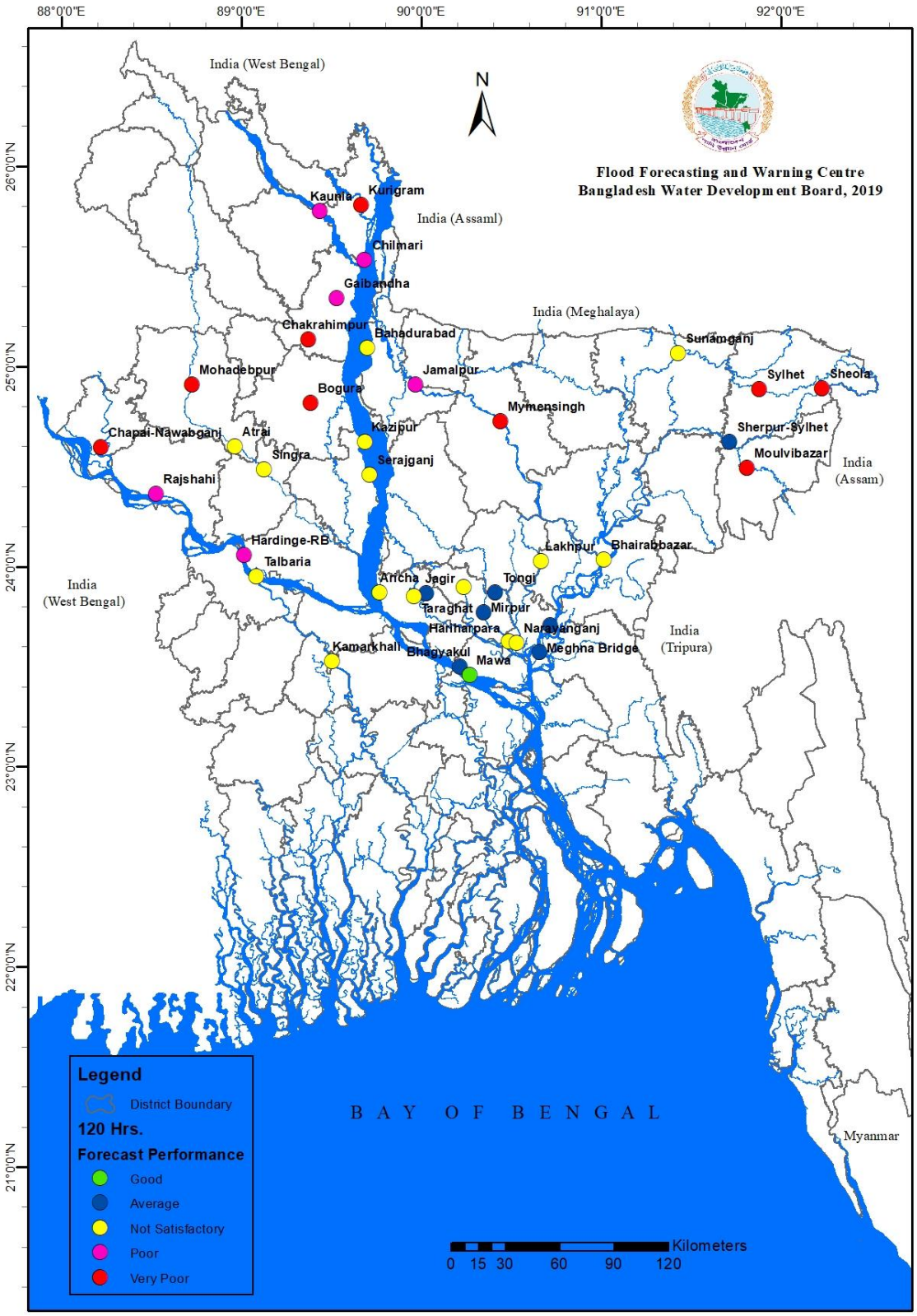


Figure 4.5 : 120-hrs Forecast Evaluation (Year, 2019)

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

CFAN (Climate Forecast Application Network) utilizes ECMWF (European Centre for Medium-Range Weather Forecasts) weather prediction data in their model to generate 51 sets of ensemble discharge forecasts data on the Brahmaputra at Bahadurabad and on the Ganges at Hardinge-Bridge 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-FFS (CFAB Flood Forecasting Study) 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 Table 4.7 to Table 4.10.

Table 4. 7 : Performance of 3-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.15	0.18	0.95	0.16	0.19	0.94	0.17	0.20	0.94
Baghbari	0.14	0.17	0.95	0.14	0.17	0.95	0.14	0.18	0.95
Bahadurabad	0.20	0.25	0.96	0.21	0.27	0.96	0.23	0.29	0.96
Bhagyakul	0.16	0.21	0.91	0.17	0.22	0.90	0.18	0.23	0.90
Bhairab Bazar	0.27	0.36	0.81	0.27	0.36	0.81	0.27	0.37	0.80
Chandpur	0.39	0.48	0.28	0.39	0.48	0.28	0.39	0.48	0.28
Demra	0.25	0.28	0.91	0.25	0.28	0.91	0.25	0.28	0.91
Dhaka	0.22	0.28	0.76	0.22	0.29	0.76	0.22	0.29	0.76
Dirai	0.41	0.50	0.76	0.41	0.50	0.76	0.41	0.50	0.76
Elashinghat	0.19	0.23	0.90	0.19	0.24	0.89	0.20	0.25	0.89
Faridpur	0.02	0.04	1.00	0.02	0.04	1.00	0.02	0.04	1.00
Goalondo	0.17	0.22	0.92	0.18	0.23	0.91	0.19	0.25	0.91
Gorai Rly. Bridge	0.45	0.58	0.92	0.45	0.59	0.92	0.47	0.62	0.92
Hardinge Bridge	0.46	0.57	0.94	0.45	0.56	0.94	0.48	0.60	0.94
Jagir	0.19	0.23	0.90	0.19	0.23	0.90	0.19	0.23	0.90
Jamalpur	0.31	0.39	0.95	0.31	0.39	0.95	0.31	0.39	0.95
Kamarkhali	0.33	0.47	0.94	0.32	0.47	0.94	0.34	0.49	0.94
Kanaighat	2.95	3.07	0.69	2.95	3.07	0.69	2.95	3.07	0.69
Kazipur	0.18	0.24	0.97	0.18	0.24	0.97	0.19	0.25	0.97

Madaripur	0.16	0.20	0.81	0.16	0.21	0.80	0.16	0.21	0.80
Mawa	0.15	0.19	0.93	0.15	0.20	0.92	0.16	0.20	0.93
Mirpur	0.23	0.33	0.67	0.24	0.34	0.67	0.24	0.34	0.67
Mohadevpur	0.59	0.85	0.71	0.59	0.85	0.71	0.59	0.85	0.71
Moulvibazar	2.74	3.55	0.04	2.75	3.55	0.04	2.75	3.55	0.04
Mymensingh	0.57	0.63	0.91	0.57	0.63	0.91	0.57	0.63	0.91
Naogaon	0.40	0.51	0.88	0.40	0.51	0.88	0.40	0.51	0.88
Narayanganj	0.23	0.28	0.75	0.23	0.28	0.75	0.23	0.28	0.75
Narsingdi	0.21	0.28	0.83	0.21	0.28	0.83	0.21	0.28	0.83
RekabiBazar	0.24	0.29	0.71	0.25	0.30	0.71	0.25	0.30	0.71
Sariakandi	0.17	0.22	0.96	0.18	0.23	0.96	0.20	0.25	0.96
Serajganj	0.13	0.17	0.96	0.13	0.18	0.96	0.15	0.19	0.96
Sheola	3.52	3.62	0.60	3.52	3.62	0.60	3.50	3.61	0.57
Sherpur	0.93	1.03	0.63	0.93	1.03	0.63	0.92	1.03	0.63
Sunamganj	0.54	0.71	0.67	0.53	0.70	0.66	0.53	0.71	0.63
Sureshwar	0.26	0.33	0.53	0.26	0.33	0.54	0.26	0.34	0.53
Sylhet	1.62	1.71	0.80	1.61	1.71	0.80	1.59	1.70	0.78
Tongi	0.20	0.24	0.89	0.20	0.24	0.89	0.20	0.24	0.89

Table 4. 8: Performance of 5-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.26	0.30	0.87	0.29	0.34	0.85	0.33	0.38	0.83
Baghbari	0.24	0.28	0.88	0.26	0.30	0.88	0.28	0.33	0.87
Bahadurabad	0.30	0.36	0.94	0.34	0.42	0.93	0.40	0.48	0.93
Bhagyakul	0.23	0.29	0.86	0.26	0.32	0.84	0.30	0.36	0.81
Bhairab Bazar	0.43	0.51	0.75	0.44	0.51	0.76	0.45	0.52	0.75
Chandpur	0.50	0.63	0.03	0.50	0.63	0.03	0.50	0.63	0.03
Demra	0.38	0.42	0.86	0.39	0.42	0.85	0.39	0.42	0.86
Dhaka	0.33	0.41	0.69	0.35	0.42	0.68	0.36	0.43	0.67
Dirai	0.56	0.71	0.58	0.56	0.71	0.58	0.56	0.71	0.58
Elashinghat	0.32	0.38	0.77	0.35	0.41	0.74	0.39	0.46	0.70
Faridpur	0.03	0.07	0.99	0.03	0.07	0.99	0.03	0.07	0.99
Goalondo	0.27	0.33	0.83	0.31	0.38	0.81	0.35	0.43	0.78
Gorai Rly. Bridge	0.65	0.79	0.84	0.67	0.82	0.84	0.71	0.88	0.83
Hardinge Bridge	0.73	0.88	0.84	0.75	0.92	0.83	0.79	0.98	0.83
Jagir	0.26	0.32	0.84	0.26	0.32	0.84	0.27	0.32	0.84
Jamalpur	0.34	0.42	0.95	0.35	0.42	0.95	0.36	0.43	0.95
Kamarkhali	0.55	0.71	0.84	0.56	0.74	0.83	0.60	0.79	0.82
Kanaighat	2.82	3.06	0.49	2.82	3.06	0.49	2.82	3.06	0.49
Kazipur	0.29	0.36	0.94	0.32	0.38	0.94	0.35	0.42	0.94

Madaripur	0.23	0.30	0.69	0.24	0.32	0.68	0.25	0.33	0.66
Mawa	0.21	0.26	0.88	0.24	0.29	0.87	0.26	0.32	0.86
Mirpur	0.34	0.44	0.61	0.35	0.45	0.60	0.36	0.45	0.59
Mohadevpur	0.71	0.98	0.63	0.71	0.98	0.63	0.71	0.98	0.63
Moulvibazar	2.69	4.79	0.01	2.69	4.78	0.01	2.74	4.83	0.01
Mymensingh	0.64	0.74	0.89	0.64	0.74	0.89	0.64	0.74	0.89
Naogaon	0.63	0.77	0.76	0.63	0.77	0.76	0.63	0.77	0.76
Narayanganj	0.34	0.41	0.61	0.35	0.42	0.60	0.36	0.43	0.61
Narsingdi	0.33	0.40	0.78	0.33	0.40	0.78	0.33	0.40	0.78
RekabiBazar	0.35	0.41	0.55	0.36	0.43	0.55	0.36	0.43	0.55
Sariakandi	0.27	0.34	0.93	0.31	0.39	0.93	0.36	0.44	0.92
Serajganj	0.21	0.27	0.92	0.25	0.32	0.91	0.31	0.39	0.90
Sheola	3.67	3.81	0.37	3.67	3.81	0.37	3.71	3.82	0.32
Sherpur	1.35	2.00	0.14	1.35	2.00	0.14	1.34	2.00	0.13
Sunamganj	0.68	0.88	0.53	0.67	0.87	0.53	0.67	0.88	0.51
Sureshwar	0.34	0.40	0.45	0.35	0.42	0.44	0.36	0.43	0.43
Sylhet	1.69	1.83	0.69	1.68	1.82	0.69	1.66	1.81	0.68
Tongi	0.31	0.37	0.82	0.32	0.38	0.82	0.33	0.39	0.82

Table 4. 9: Performance of 7-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.33	0.38	0.79	0.40	0.46	0.75	0.48	0.56	0.71
Baghbari	0.32	0.38	0.80	0.37	0.43	0.78	0.41	0.49	0.76
Bahadurabad	0.39	0.44	0.92	0.46	0.55	0.91	0.57	0.68	0.90
Bhagyakul	0.32	0.37	0.80	0.38	0.45	0.76	0.46	0.54	0.71
Bhairab Bazar	0.52	0.61	0.70	0.54	0.62	0.71	0.56	0.64	0.70
Chandpur	0.59	0.70	0.02	0.59	0.70	0.02	0.59	0.70	0.02
Demra	0.50	0.56	0.84	0.52	0.58	0.84	0.54	0.59	0.84
Dhaka	0.42	0.49	0.65	0.44	0.52	0.64	0.46	0.55	0.61
Dirai	0.73	0.91	0.38	0.73	0.91	0.38	0.73	0.91	0.38
Elashinghat	0.43	0.49	0.62	0.50	0.58	0.56	0.57	0.67	0.50
Faridpur	0.04	0.10	0.99	0.04	0.10	0.99	0.04	0.10	0.99
Goalondo	0.36	0.43	0.75	0.44	0.53	0.70	0.52	0.63	0.65
Gorai Rly. Bridge	0.83	1.00	0.72	0.88	1.07	0.72	0.95	1.16	0.71
Hardinge Bridge	0.96	1.20	0.69	1.02	1.29	0.67	1.13	1.40	0.65
Jagir	0.34	0.42	0.73	0.35	0.43	0.73	0.36	0.43	0.73
Jamalpur	0.34	0.42	0.96	0.39	0.46	0.96	0.46	0.52	0.96
Kamarkhali	0.72	0.92	0.72	0.75	0.99	0.70	0.81	1.06	0.69
Kanaighat	2.79	3.09	0.37	2.79	3.09	0.37	2.79	3.09	0.37
Kazipur	0.38	0.44	0.91	0.43	0.51	0.91	0.50	0.60	0.91
Madaripur	0.30	0.38	0.62	0.33	0.43	0.58	0.36	0.47	0.55

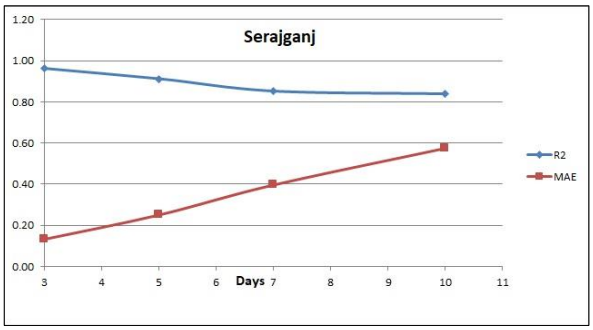
Mawa	0.28	0.33	0.85	0.34	0.40	0.82	0.41	0.48	0.79
Mirpur	0.42	0.50	0.61	0.44	0.52	0.59	0.46	0.55	0.57
Mohadevpur	0.71	0.91	0.65	0.71	0.91	0.65	0.71	0.91	0.65
Moulvibazar	2.65	5.56	0.00	2.65	5.56	0.00	2.66	5.57	0.00
Mymensingh	0.70	0.83	0.86	0.70	0.82	0.87	0.69	0.82	0.88
Naogaon	0.83	1.00	0.60	0.83	1.00	0.60	0.83	1.00	0.60
Narayanganj	0.44	0.52	0.55	0.45	0.54	0.55	0.48	0.56	0.54
Narsingdi	0.44	0.51	0.75	0.44	0.51	0.75	0.44	0.51	0.75
RekabiBazar	0.40	0.47	0.57	0.45	0.53	0.54	0.45	0.53	0.54
Sariakandi	0.37	0.42	0.90	0.44	0.52	0.90	0.52	0.63	0.89
Serajganj	0.31	0.37	0.87	0.40	0.49	0.85	0.50	0.62	0.83
Sheola	3.71	3.86	0.25	3.71	3.86	0.25	3.76	3.90	0.21
Sherpur	1.45	2.37	0.07	1.45	2.37	0.07	1.44	2.36	0.06
Sunamganj	0.78	0.96	0.47	0.77	0.95	0.47	0.76	0.94	0.47
Sureshwar	0.38	0.45	0.40	0.40	0.50	0.39	0.43	0.55	0.36
Sylhet	1.74	1.91	0.60	1.73	1.90	0.61	1.72	1.89	0.60
Tongi	0.39	0.46	0.80	0.42	0.48	0.79	0.44	0.51	0.78

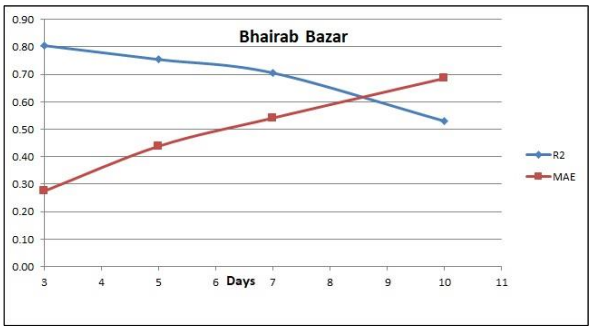
Table 4. 10: Performance of 10-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.36	0.45	0.73	0.50	0.61	0.68	0.66	0.78	0.62
Baghbari	0.38	0.48	0.72	0.48	0.58	0.69	0.59	0.71	0.67
Bahadurabad	0.43	0.54	0.89	0.63	0.74	0.89	0.85	0.94	0.88
Bhagyakul	0.37	0.45	0.76	0.52	0.60	0.70	0.66	0.76	0.61
Bhairab Bazar	0.66	0.90	0.52	0.69	0.92	0.53	0.71	0.96	0.53
Chandpur	0.59	0.72	0.16	0.59	0.72	0.16	0.59	0.72	0.16
Demra	0.69	0.79	0.75	0.74	0.83	0.75	0.80	0.88	0.75
Dhaka	0.55	0.70	0.52	0.58	0.74	0.50	0.62	0.80	0.46
Dirai	0.87	1.23	0.23	0.87	1.23	0.23	0.87	1.23	0.23
Elashinghat	0.48	0.58	0.56	0.61	0.75	0.47	0.73	0.92	0.41
Faridpur	0.07	0.14	0.98	0.07	0.14	0.98	0.07	0.14	0.98
Goalondo	0.39	0.48	0.74	0.54	0.66	0.66	0.70	0.84	0.58
Gorai Rly. Bridge	0.80	1.01	0.68	0.95	1.21	0.62	1.12	1.44	0.52
Hardinge Bridge	1.03	1.23	0.62	1.20	1.49	0.53	1.42	1.80	0.38
Jagir	0.44	0.55	0.56	0.47	0.57	0.56	0.51	0.61	0.56
Jamalpur	0.48	0.59	0.92	0.63	0.76	0.92	0.83	0.97	0.91
Kamarkhali	0.68	0.87	0.72	0.80	1.03	0.68	0.95	1.22	0.61
Kanaighat	2.44	2.80	0.32	2.44	2.80	0.32	2.44	2.80	0.32
Kazipur	0.46	0.56	0.87	0.60	0.71	0.87	0.79	0.89	0.88
Madaripur	0.37	0.47	0.62	0.46	0.56	0.57	0.56	0.66	0.50
Mawa	0.35	0.40	0.81	0.48	0.54	0.76	0.61	0.69	0.70

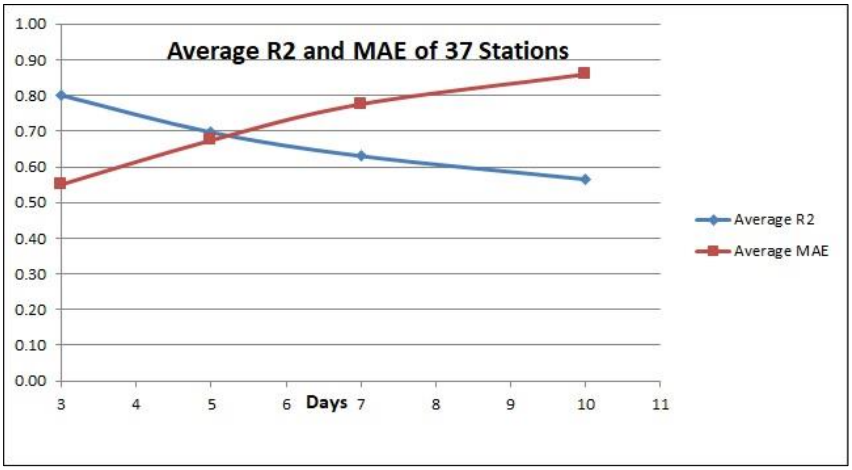
Mirpur	0.56	0.66	0.57	0.59	0.70	0.55	0.62	0.75	0.52
Mohadevpur	0.81	1.04	0.53	0.81	1.04	0.53	0.81	1.04	0.53
Moulvibazar	2.49	5.50	0.00	2.50	5.50	0.00	2.53	5.54	0.00
Mymensingh	0.80	0.98	0.80	0.86	1.02	0.81	0.94	1.08	0.82
Naogaon	0.98	1.20	0.40	0.98	1.20	0.40	0.98	1.20	0.40
Narayanganj	0.56	0.70	0.49	0.59	0.74	0.49	0.65	0.80	0.48
Narsingdi	0.63	0.81	0.52	0.63	0.81	0.52	0.63	0.81	0.52
RekabiBazar	0.50	0.67	0.47	0.65	0.80	0.42	0.65	0.80	0.42
Sariakandi	0.41	0.52	0.88	0.59	0.70	0.87	0.80	0.90	0.86
Serajganj	0.37	0.46	0.86	0.57	0.68	0.84	0.82	0.91	0.82
Sheola	3.34	3.57	0.25	3.34	3.57	0.25	3.38	3.62	0.22
Sherpur	1.43	2.43	0.07	1.43	2.43	0.07	1.41	2.43	0.07
Sunamganj	0.72	0.94	0.47	0.72	0.93	0.47	0.71	0.92	0.47
Sureshwar	0.40	0.50	0.45	0.46	0.59	0.40	0.56	0.70	0.35
Sylhet	1.61	1.82	0.51	1.60	1.81	0.51	1.59	1.80	0.51
Tongi	0.53	0.65	0.75	0.60	0.70	0.74	0.67	0.76	0.71

Following charts showing the MAE and r^2 plots for the Serajganj and Bhairabbazar for monsoon 2019, indicated that as the longer the lead tie, the r^2 is reducing and MAE increasing.





Average of MAE and r^2 of all the 37 probability based flood forecast stations plot also indicating the variability of the Forecast & Observe is increasing with the increasing lead time.



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. In the monsoon 2019, the country experienced severe flooding.

During pre-monsoon, some parts of the Haor basin of the country faced late pre-monsoon flooding during the first week of May due to a rainfall event induced by cyclone 'Fani', but it caused no notable damage to Boro crops. Most parts of the basin remained dry during the time.

In monsoon 2019, the Brahmaputra basin of the country experienced severe flooding of short to slightly longer than medium duration at low lying places. The Teesta river at Dalia and the Jamuna river at Bahadurabad and Fulchari exceeded their recorded highest water levels this year. Along the Padma river in the Ganges basin, the flood was above the moderate level at some places and of medium to slightly longer than medium duration. The Ganges river this year experienced a normal flood of short duration. The Meghna and the South Eastern Hill basins experienced severe flash flooding, however the duration was short overall with multiple peaks.

This year the flood events were centred in the first half of the monsoon i.e. June-July, except only in early October when the Ganges-Padma river created a normal flood at some places in West-Central portion of the country. Simultaneous rise of all the major rivers of the country during second to third week of July created countrywide flooding across all basins this year, which occurred in severe scale at many low-lying places and the duration varied from short to slightly longer than medium duration at low lying places of Northern, North-Western, North-Central, North-Eastern and Central regions of the country. The South-Eastern region of the country was also affected for short duration during this time. In total, 31% of the country got flood inundated this year.

5.1 BASINWISE INUNDATION STATUS

Brahmaputra Basin:

Out of 30 Water Level (WL) monitoring stations in the Brahmaputra basin, at 16 stations WL crossed and remained over their respective DLs in 2019. Flood in the Brahmaputra-Jamuna river this year came in one single wave but with an exceptionally rapid rising and large peak between 13th and 30th July. The Jamuna at Bahadurabad and Fulchari crossed their historical recorded highest peaks during this time. Flood wave in Teesta, the major

tributary of the Brahmaputra-Jamuna river, came earlier than Brahmaputra and consisted of two short duration peaks. The first between 11th and 14th July and second between 24th and 25th July. The Teesta at Dalia also crossed historical recorded highest level during the first peak. A third flood peak came in the river around mid-September but it was a localized event and all other parts of the Brahmaputra basin remained flood free.

The stations that crossed and remained over DLs during these periods are: Dharala at Kurigram for 15 days peaking 117 cm above DL; Teesta at Dalia for 7 days peaking 50 cm above DL (5 cm higher than previously recorded highest) and at Kaunia for 3 days peaking 22 cm above DL; Ghagot at Gaibandha for 16 days peaking 94 cm above DL; Brahmaputra at Noonkhawa for 10 days peaking 103 cm above DL and at Chilmari for 17 days peaking 132 cm above DL; Jamuna at both Fulchari and Bahadurabad for 18 days peaking 153 cm and 166 cm above DL respectively (22 cm and 32 cm higher than previously recorded highest respectively), at Sariakandi for 15 days peaking 128 cm above DL, at Kazipur for 14 days peaking 126 cm above DL, at Serajganj for 12 days peaking 104 cm above DL and at Aricha for 7 days peaking 44 cm above DL; Atrai at Baghabari for 15 days peaking 83 cm above DL, Karatoa at Chkrahimpur for 3 days peaking 4 cm above DL; Dhaleswari at Elashin for 17 days peaking 96 cm above DL and Old Brahmaputra at Jamalpur for 4 days peaking 19 cm above DL.

As a result of these events, low-lying areas of Kurigram, Lalmonirhat, Nilphamari, Gaibandha, Bogra, Sirajganj, Jamalpur, Tangail and Manikganj districts in the Northern, North-Western and North-Central regions of the country experienced severe flooding of short to slightly longer than medium duration during 2019. The basin as a whole experienced flooding during the month of July only.

Ganges Basin:

In the Ganges basin, out of 25 WL monitoring stations, 4 stations flowed above DL during 2019 excluding one tidal dominated station. Flood in the Padma river this year came in two waves. The first between 17th and 28th July as a result of combined rise of Ganges and Jamuna, but mostly due to the onrush of floodwater from Jamuna river. The second flood wave came between 1st to 5th October but this time due to slight overflow of the Ganges river which affected the West-Central portion of the country only.

The stations that crossed and remained over DLs during these periods are: Ganges at Hardinge Bridge for 5 days peaking 8 cm above DL; Padma at Goalundo for 17 days peaking 68 cm above DL (peaking 13 cm above DL during the second wave), at Bhagyakul for 7 days peaking 40 cm above DL and at Sureswar for 11 days peaking 11 cm above DL while Gorai at Kamarkhali for 6 days peaking 27 cm above DL.

As a result of these events, low-lying areas of Rajbari, Faridpur, Dhaka, Munshiganj Madaripur and Shariatpur districts in the Central region of the country along the Padma experienced moderate to above moderate flooding of medium duration during the first wave

in 2019. The low-lying areas of Pabna, Kushtia and Magura in the West-Central portion of the country along the Ganges experienced normal flooding of short duration during the second wave of the season. The basin as a whole experienced flooding during the month of July and October only.

Meghna Basin:

During pre-monsoon (15 March - 15 May 2019), out of 36 WL monitoring stations in the Meghna basin, at 4 stations WL crossed respective Pre-Monsoon Danger Levels (PMDL) in 2019. No station exceeded PMDL till April, but due to heavy rainfall activity within the basin induced by cyclone 'Fani' during the first week of May, flash flood occurred at some low lying places of haor basin which stayed for short period. The stations that crossed and remained over PMDLs during these periods are: Surma at Kanaighat for 1 day by 66 cm above PMDL, Sarigowain at Sarighat for 3 days by 113 cm above PMDL, Someswari at Durgapur for 1 day by 25 cm above PMDL and Kangsha at Jariajanjail for 6 days by 181 cm above PMDL. However the event caused no notable damage to Boro cropos. Most parts of the basin remained dry during the time.

Out of 27 WL monitoring stations in the Meghna basin, at 17 stations water flowed above their respective monsoon DLs during the year 2019. Flood in the basin this year came in multiple short duration peaks as usual, but all the major peaks which caused inundation were centred between June and July. There were 3 major peaks in this season. The first one occurred on 28th July for one day which affected the Surma river reach along with some Meghalayan streams. The second one was the prime peak of the season which started from 9th July until 18th July and inundated plains of almost all major river reaches including the Surma-Kushiyara along with most of their major tributaries. The third one only affected the upper portion of the Surma river reach between 22nd to 25th July.

The stations that crossed and remained over DLs during these periods are: Surma at Kanaighat, Sylhet and Sunamganj for 13, 1 and 7 days peaking 110, 5 and 39 cm above DL respectively; Kushiyara at Amalshid, Sheola and Sherpur for 8,5 and 3 days peaking 117, 46 and 5 cm above DL respectively; Manu at Manu Railway Bridge and Moulvibazar for 3 and 2 days peaking 19 and 43 cm above DL respectively; Dhalai at Kamalganj for 2 days peaking 91 cm above DL; Khowai at Ballah and Habiganj for 12 and 2 days peaking 196 and 66 cm above DL respectively; Old Surma at Derai for 4 days peaking 6 cm above DL; Jadukata at Lorergarh for 3 days peaking 71 cm above DL; Someswari at Durgapur and Kalmakanda for 2 and 19 days peaking 63 and 73 cm above DL respectively; Bhugai at Nakuagaon for 1 day peaking 39 cm above DL and Meghna at Chandpur for 15 days peaking 14 cm above DL. The Someswari at Kalmakanda (Netrokona) faced relatively longer duration flood in the river reach due to local drainage congestion. The Meghna at Chandpur in the Lower Meghna basin flowed discontinuously above DL for 15 days but only for short duration mostly due to tidal fluctuations.

As a result of these events, low-lying areas of Sylhet, Sunamganj, Moulvibazar, Habiganj and Netrokona districts in the North-Eastern region of the country experienced moderate to severe flash flooding but all of short duration in 2019, except some low-lying areas of Netrokona district due to local drainage problem. The basin as a whole experienced flooding during the month of June and July only.

South Eastern Hill Basin:

In the South Eastern Hill basin, 8 out of 9 water level monitoring stations crossed danger levels during monsoon 2019. Flood in the basin this year came in multiple short duration peaks as usual, but all the peaks which caused inundation were centred between 8th to 15th July within just above a week.

The stations that crossed and remained over DLs during these periods are: Muhuri at Parshuram for 2 days peaking 170 cm above DL; Halda at Narayanhat and Panchpukuria for 3 and 2 days peaking 35 and 46 cm above DL respectively; Sangu at Bandarban and Dohazari for 5 and 7 days peaking 325 and 160 cm above DL respectively; Matamuhuri at Lama and Chiringa for 3 and 5 days peaking 159 and 92 cm above DL respectively and Karnaphuli at Chittagong for 1 day peaking 25 cm above DL.

As a result of these events, low-lying areas of Chittagong, 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 2019. The basin experienced flooding during the month of July only.

5.2 COUNTRYWIDE INUNDATION 2019

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 2019 which was attenuated during the second week of October. It was observed from monitoring that the Brahmaputra river attained its monsoon peak on 17th July, the Jamuna on 18th July, while the Padma and Upper Meghna river system on 20th July neglecting the tidal fluctuations. The Ganges river on the other hand attained monsoon peak much later on 2nd October but it was isolated from the countrywide flood event. From areal coverage perspective, 19th July 2019, was chosen as the peak time of monsoon on which FFWC observed total number of 22 flood monitoring stations above danger levels. Figure 5.1 shows the observed inundation map for 19th of July and then 24, 48, 72, 96 and 120 hours forecasted inundation maps on the day from figures 5.2 to 5.6 respectively. The map on 19th July captures the inundation scenario of the country during monsoon 2019, except relatively small inundations at some places of the North-Eastern, South-Eastern and South-Western region of the country due to isolated and short-

term flood events. Inundated area based on this map is around 45,747 sq-km which is 31% 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.

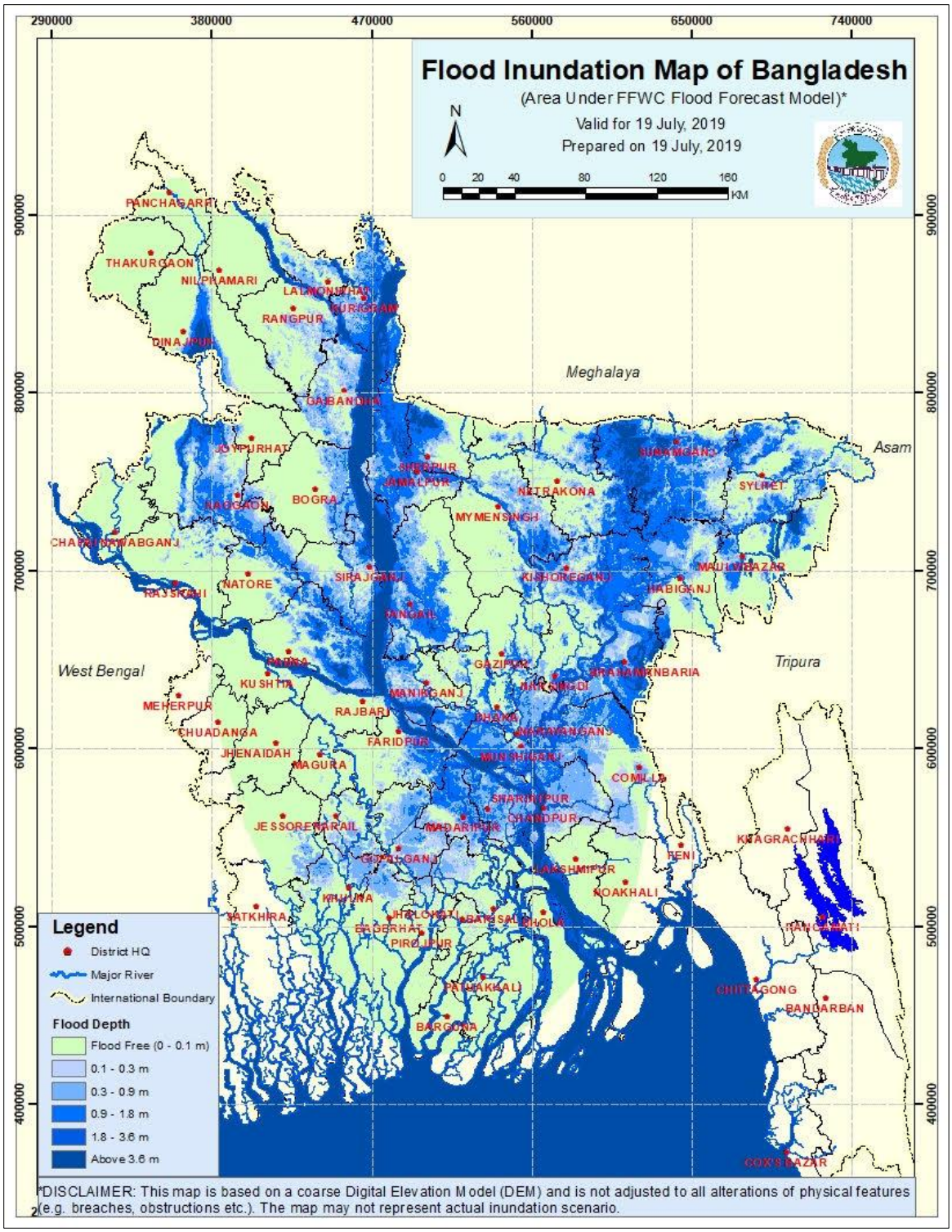


Figure 5.1 : Flood Inundation Map of Bangladesh (on 19th July 2019)

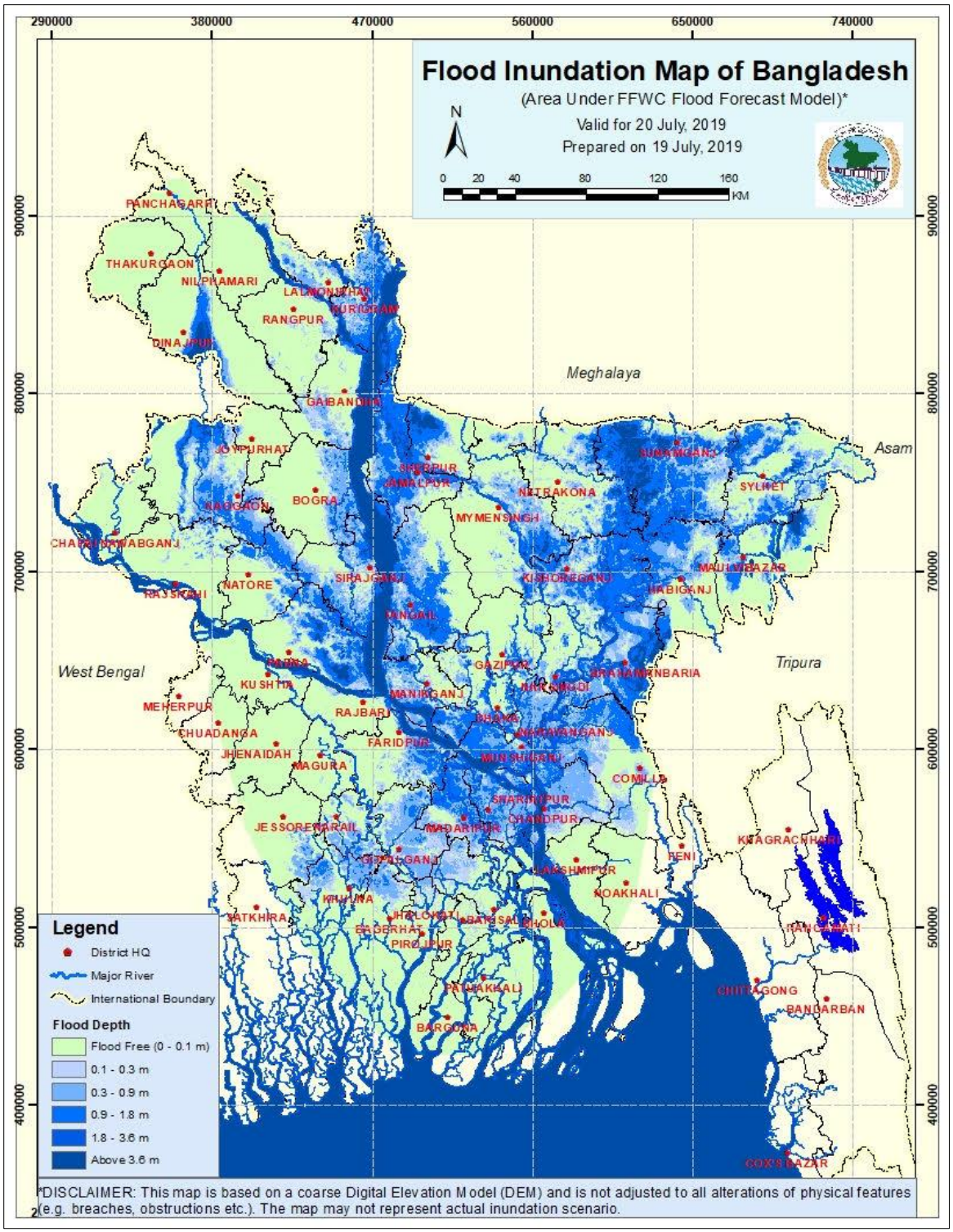


Figure 5.2 : Flood Inundation Map of Bangladesh (24hr Forecast based on 19th July 2019)

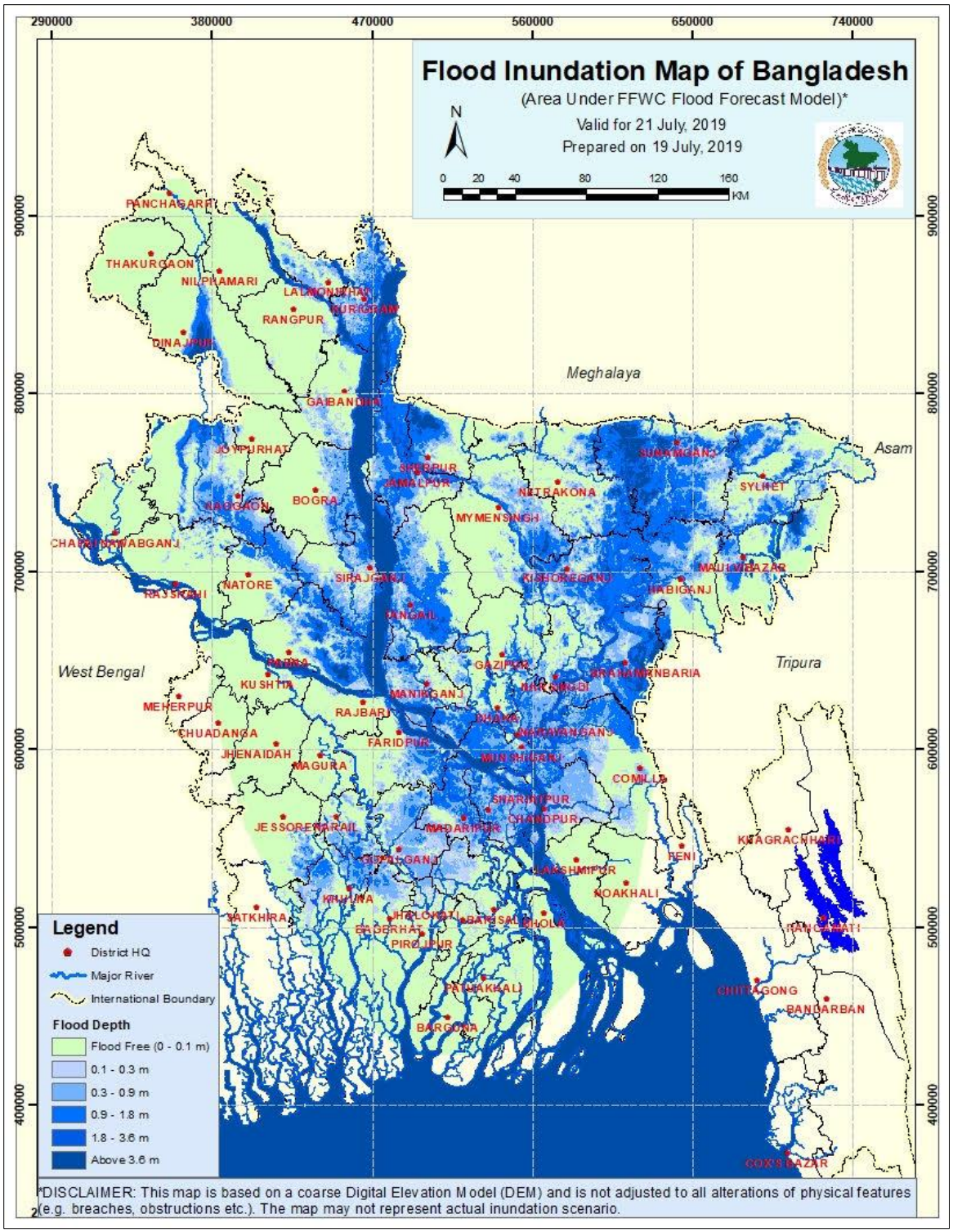


Figure 5.3 : Flood Inundation Map of Bangladesh (48hr Forecast based on 19th July 2019)

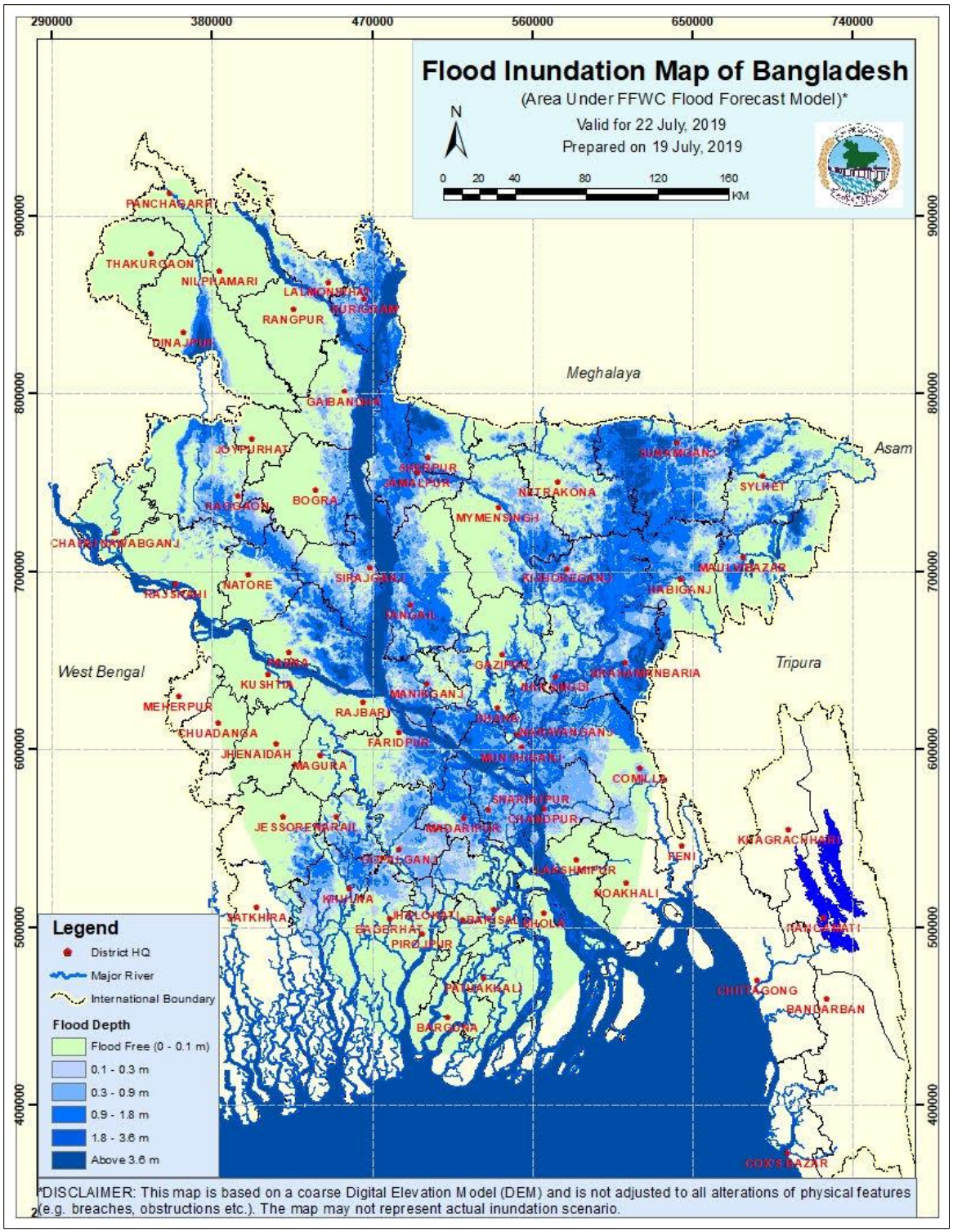


Figure 5.4 : Flood Inundation Map of Bangladesh (72hr Forecast based on 19th July 2019)

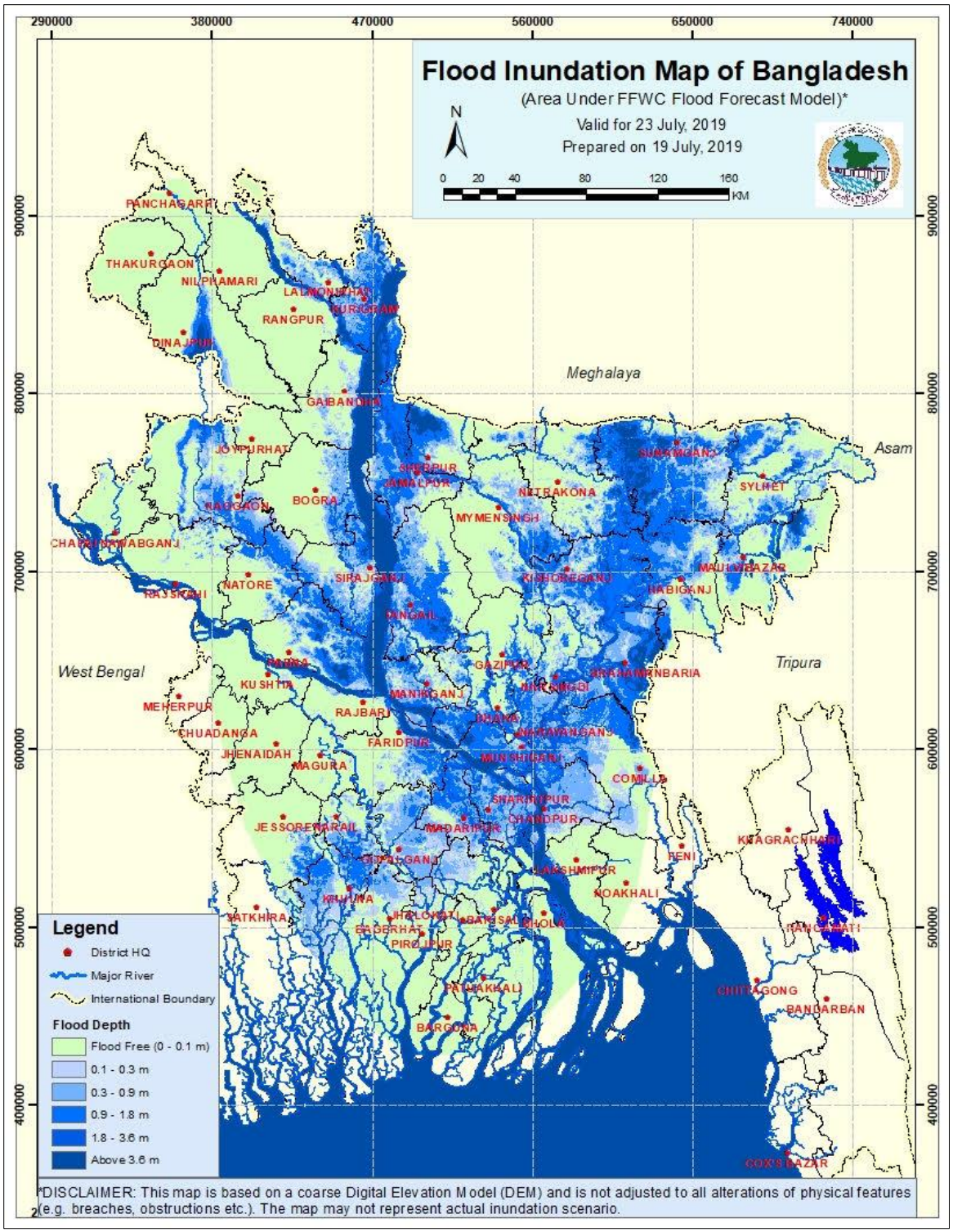


Figure 5.5 : Flood Inundation Map of Bangladesh (96hr Forecast based on 19th July 2019)

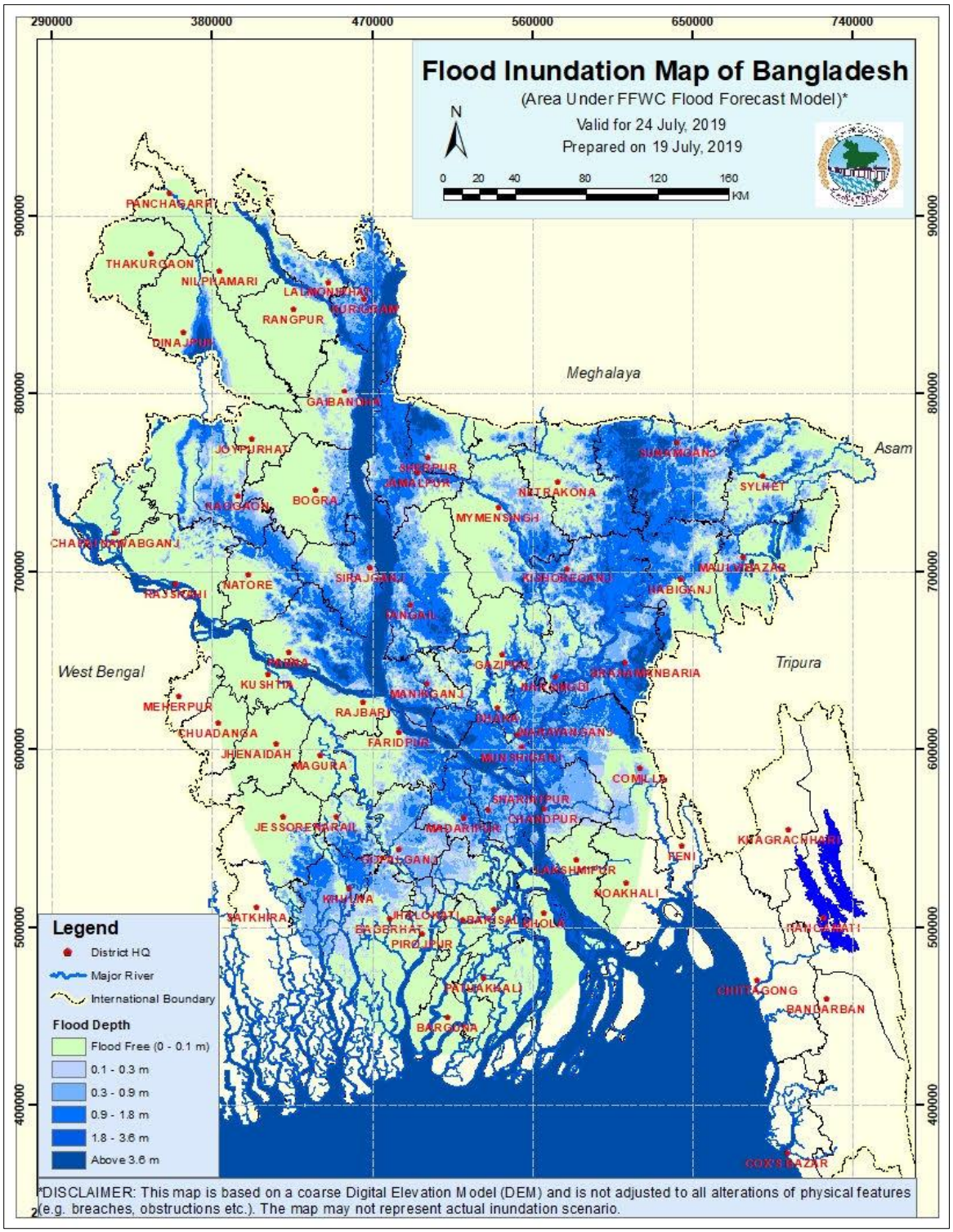


Figure 5.6 : Flood Inundation Map of Bangladesh (120hr Forecast Based on 19th July 2019)

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 2019 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 12th to 19th of July were used to cover the whole country during peak condition and compared with the FFWC flood map of 19th July, 2019 (Fig 5.7).

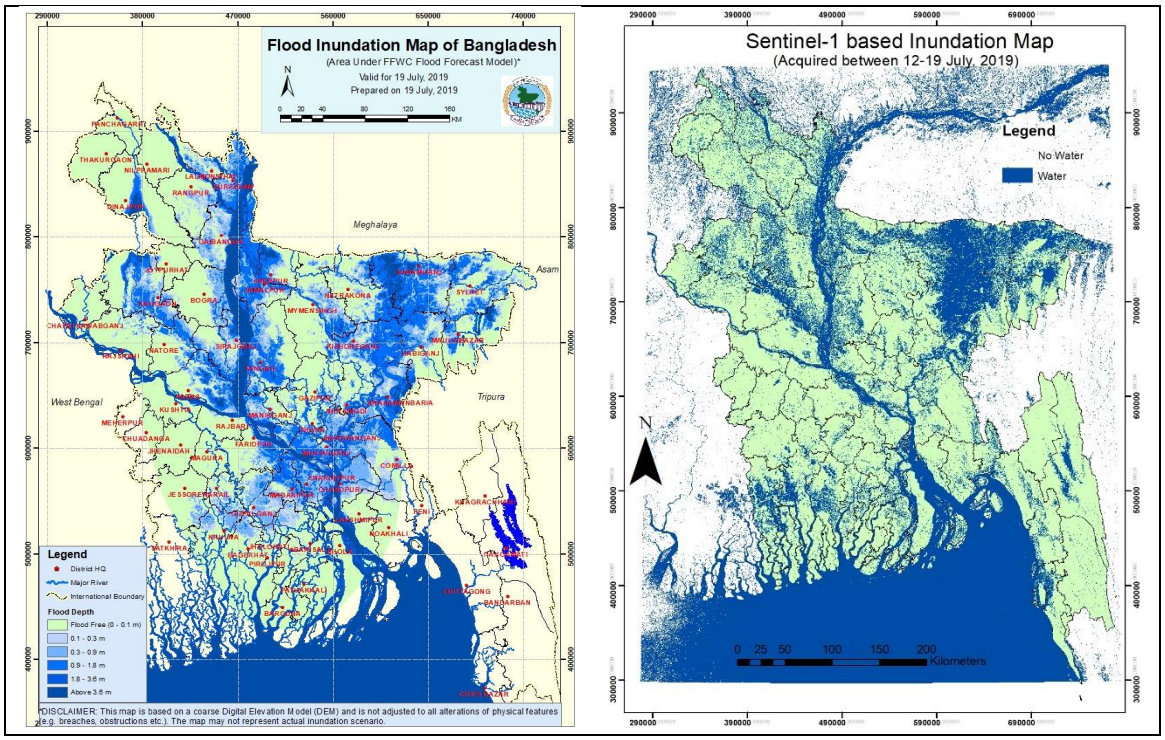


Figure 5.7 : Comparison of FFWC Flood Inundation Map (19th July 2019) with Senitnel-1 based Inundation Map (between 12th -19th July 2019)

Both of the maps are in good agreement in detecting inundated areas in North-Western, North-Central and North-eastern 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 : CHARACTERISTICS AND SPECIAL EVENTS OF 2019 FLOOD

6.1 Characteristics of 2019 Flood

The 2019 as a whole was a severe flood season inundating 31% of the whole country (45,747 sq-km approximately). However, the flood intensity varied spatially within the country and also temporally within the season.

Considering spatial variation, flood magnitudes differed to some extent across the hydrological basins. There was severe flooding this year at low lying places in the Brahmaputra basin covering the Northern, North-Western and North-Central regions of the country along the Brahmaputra-Jamuna and major tributaries. Flooding in the Ganges basin covering the North-Western and Central regions along the Ganges-Padma river was moderate to above moderate in scale. Flooding in the Meghna and South Eastern Hill basins covering the North-Eastern and South-Eastern regions respectively, were flashy in nature and occurred in moderate to severe intensity. Flood in the Brahmaputra basin this year was much severe compared to the other basins, as the flood peak was exceptionally rapid rising and large which exceeded the RHWL at Bahadurabad and Fulchari on Jamuna, along with Dalia on Teesta.

Considering temporal variation, the flood events were much concentrated rather than distributed in monsoon 2019 which created an intense flood situation in July. Normally, the seasonal inundation starts by filling up the Haor basin within the early monsoon period in June, which remains mostly dry during pre-monsoon (15 March-15 May). As monsoon gradually sets over the GBM basin, flood peaks sequentially arrive in the Meghna, South-Eastern Hill, Brahmaputra and Ganges basins in multiple flood waves generally throughout the monsoon (June-September). This year however, after the inundation of Haor basin within June that remained mostly dry during pre-monsoon, flood waves simultaneously arrived across all basins during July with great intensity which created on average nearly medium duration flooding in low lying parts but receded also in the same month. During August to September, no riverine flood situation prevailed throughout the country. Though an unusually late flood wave arrived along the Ganges river in early October, its duration was short and created normal flooding.

The notable damage due to flood this year was for the Brahmaputra-Jamuna river flood during July in the Northern and North-Central regions of the country. The unusually rapid and large flood peak of the river caused much suffering to the flood plain dwellers. Breach of embankment at points along the river in Gaibandha caused additional inundation which worsened the sufferings of people. But thankfully flood stayed for relatively less duration in total this season than other historical flood years. However, river erosions continued taking place at various scales both during and after flood throughout the country.

6.2 Special Events of 2019 Flood Season

The 2019 flood season exhibited variation in flood intensity both in spatial and temporal scale. This led to two special flooding cases this year: i.) the severe river flood of Brahmaputra-Jamuna in July, and ii) the late monsoon normal flood of Ganges river at some places in October. However aside from that, the Brahmaputra-Jamuna river flood was very rapid rising this year as compared to the other major flooding years, while the Ganges river flowed above normal level this year after decades long gap but also very late than normal in early October. These attributes further added to the uniqueness of this year's special events. The events are presented in more detail below.

6.2.1 The Severe Flood of Brahmaputra-Jamuna River

The only and severe flood of the season arrived in the Brahmaputra basin during the second week of July which was primarily a single fast rising flood wave with a very large peak. The Brahmaputra-Jamuna river swelled by 2.5-3.0 metres in 10-12 days during the passage of the flood wave and flowed a metre above DL in the upper reach. The flood condition at Bahadurabad and Fulchari along the Jamuna was much compared to the other stations. The river peaked above DL by 166 cm at Bahadurabad exceeding the previously RHWL by 32 cm, while at Fulchari the river peaked above DL by 153 cm exceeding the previously RHWL by 22 cm. During this time the major tributaries of the river also swelled significantly. After 17 July, the flood wave started receding in the upper reaches of the Brahmaputra-Jamuna river. However, another secondary scewed peak appeared between 25-27 July with a maximum of 31 cm rise at Noonkhawa. After that, the flood completely receded within the month. Table 6.1 presents WL scenario of the river during the major peak rising period.

Table 6.1: WL Scenario of the Brahmaputra-Jamuna River during the Major Peak Rising Period

Date	WL (mPWD) of Brahmaputra River		WL (mPWD) of Jamuna River		WL (mPWD) at Jamuna-Padma Confluence		Remarks
	Noonkhawa	Chilmari	Bahadurabad	Serajganj	Aricha	Goalundo	
07.07.2019	24.55	22.28	18.15	-	-	-	Initial level before arrival of flood wave
08.07.2019	-	-	-	11.63	7.09	-	
09.07.2019	-	-	-	-	-	6.77	
17.07.2019	27.53	25.02	-	-	-	-	Peak flood level
18.07.2019	-	-	21.16		-	-	
19.07.2019	-	-	-	14.34	-	-	
20.07.2019	-	-	-	-	9.84	9.33	
Total Rise (cm)	298	274	301	271	275	256	Statistics for the flood rising period
No of days to peak	10	10	11	11	12	11	
Average Rise per day (cm)	30	27	27	25	23	23	
Peak above DL (cm)	+103	+132	+166	+99	+44	+68	

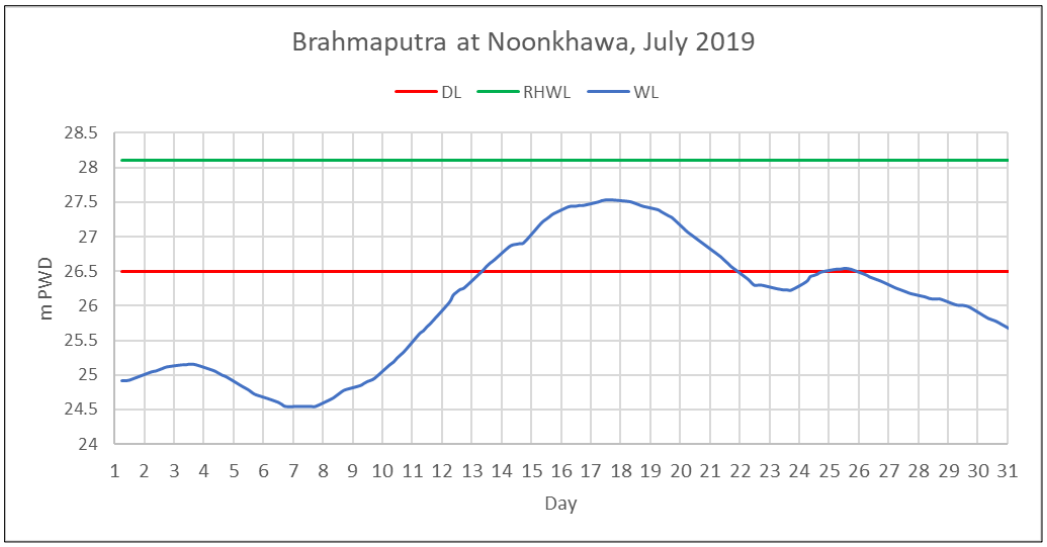


Figure 6.1 : WL Hydrograph of Brahmaputra at Noonkhawa during July-2019

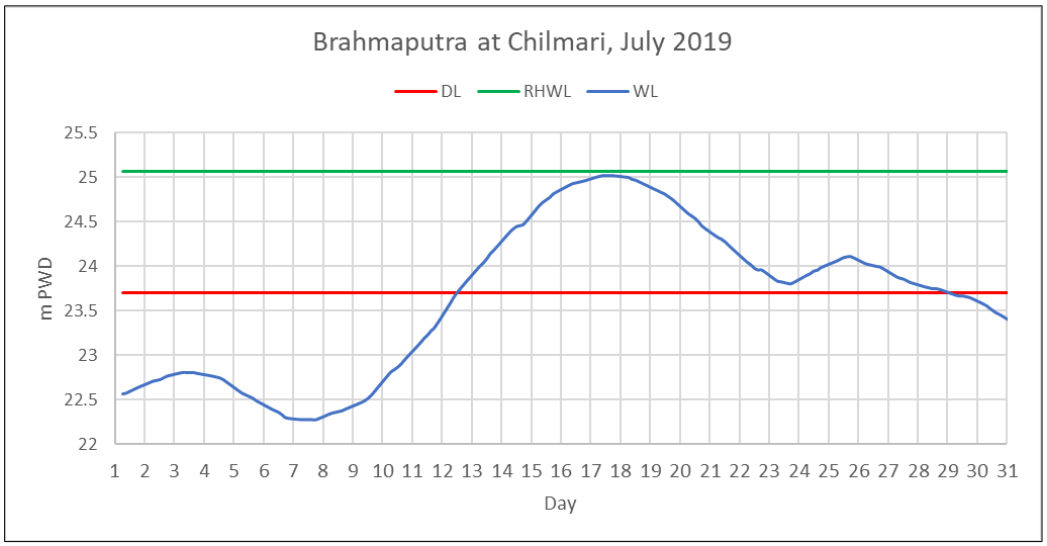


Figure 6.2 : WL Hydrograph of Brahmaputra at Chilmari during July-2019

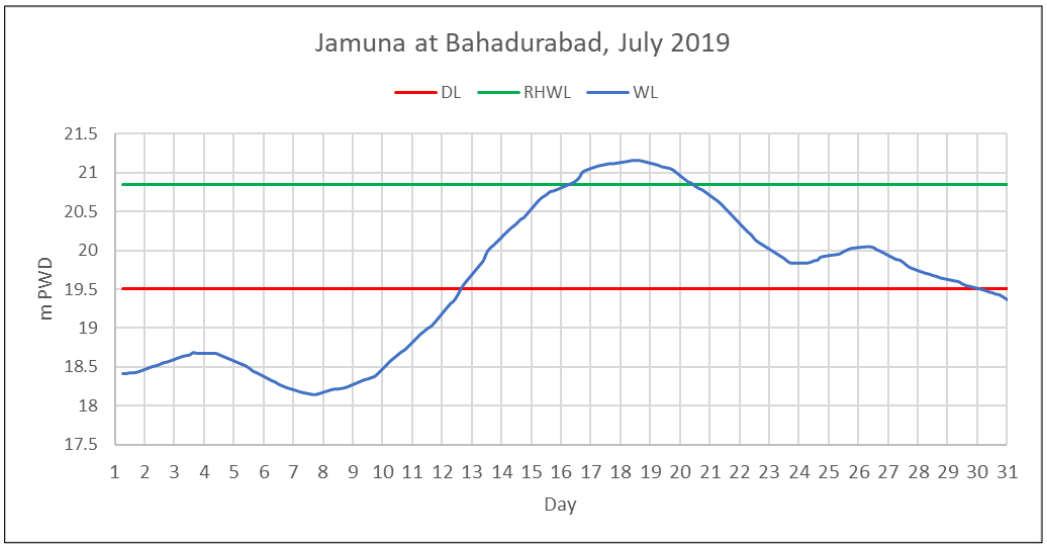


Figure 6.3 : WL Hydrograph of Jamuna at Bahadurabad during July-2019

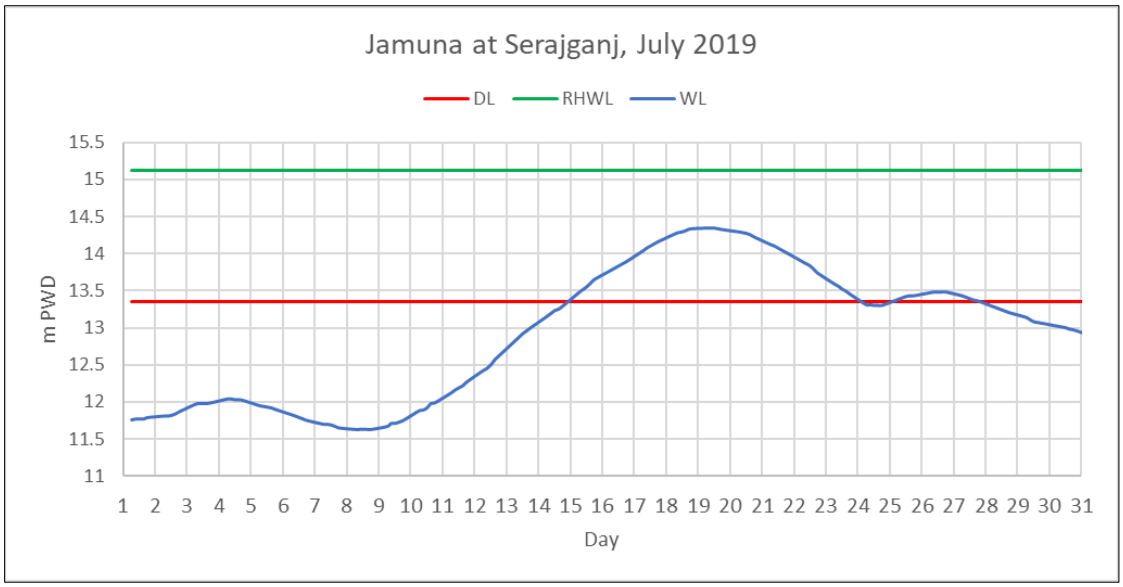


Figure 6.4 : WL Hydrograph of Jamuna at Serajganj during July-2019

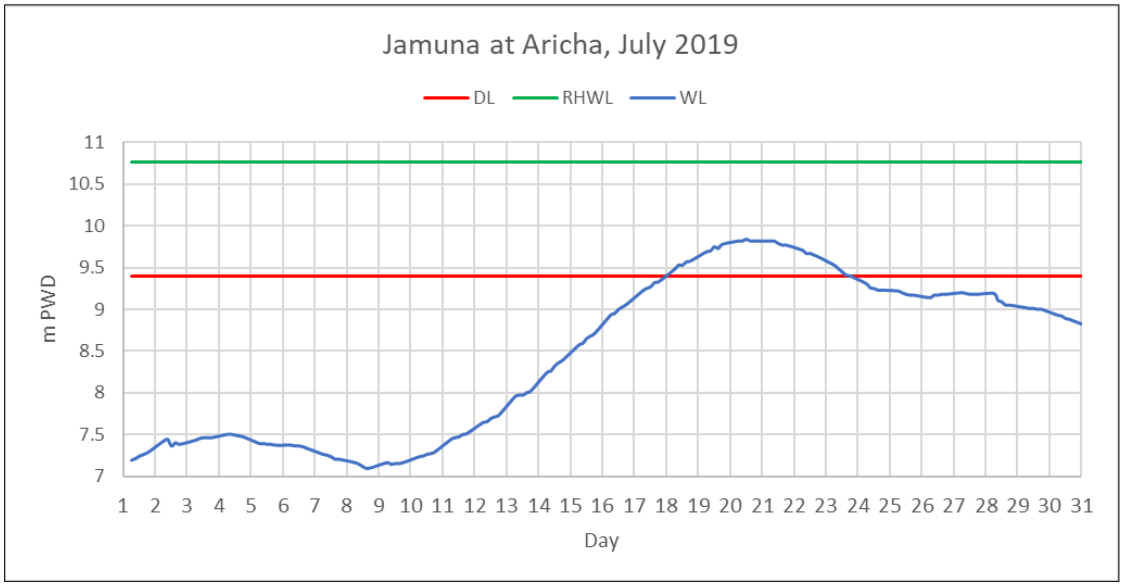


Figure 6.5 : WL Hydrograph of Jamuna at Aricha during July-2019

The event started from 7 July as the monsoon turned active over the GBM basin. Rainfall was specially more concentrated and widespread in the Assam and Meghalaya states of India along with the Sub-Himalayan West Bengal and Northern Bangladesh. This rainfall spell lasted upto 16 July which made the Brahmaputra-Jamuna rivers along with the tributaries swell greatly. Rainfall in the Indian regions during this period are presented in Table 6.2, while in the Northern Bangladesh region are presented in Table 6.3.

Table 6.2: Recorded Rainfall at Major Stations in the Sub-Himalayan West Bengal, Assam and Meghalaya of India during 07/07/2019 to 16/07/2019 (in mm)*

Date	Sub-Himalayan West Bengal			Assam (Brahmaputra Valley)				Meghalaya		Assam (Barak Valley)
	Gangtok	Darjeeling	Jalpaiguri	Dhubri	Guwahati	Tezpur	Dibrugarh	Cherrapunji	Shillong	Silchar
07.07.19	**31**	**54**	**18**	**24**	**5**	**10**	**64**	**175**	**11**	**3**
08.07.19	**30**	**139**	**13**	**14**	**21**	**9**	**8**	**158**	**14**	**6**
09.07.19	**32**	**101**	**35**	**21**	**53**	**19**	**68**	**328**	**72**	**12**
10.07.19	**4**	**71**	**62**	**20**	**50**	**29**	**61**	**259**	**192**	**9**
11.07.19	**27**	**28**	**11**	**20**	**5**	**13**	**25**	**370**	**102**	**54**
12.07.19	**36**	**93**	**140**	**38**	**4**	**10**	**7**	**170**	**22**	**81**
13.07.19	**37**	**63**	**154**	**18**	**2**	**29**	**6**	**150**	**18**	**12**
14.07.19	**27**	**32**	**204**	**49**	**2**	**1**	**20**	**51**	**4**	**80**
15.07.19	**35**	**22**	**29**	**71**	**27**	**29**	**29**	**205**	**24**	**7**
16.07.19	**9**	**6**	**29**	**5**	**5**	**23**	**18**	**86**	**9**	**6**
Total	**268**	**609**	**695**	**280**	**174**	**172**	**306**	**1952**	**468**	**270**
Intensity (mm/day)	**27**	**61**	**70**	**28**	**17**	**17**	**31**	**195**	**47**	**27**

*Source: India Meteorological Department (IMD)

Table 6.3: Recorded Rainfall at Major Stations in the Northern Region of Bangladesh during 07/07/2019 to 16/07/2019 (in mm)

Date	Northern Bangladesh					
	Kurigram	**Dalia**	**Rangpur**	**Chilmari**	**Dewanganj**	**Gaibandha**
07.07.19	81	37	55	14	10	63
08.07.19	98	63	41	22	50	27
09.07.19	96	68	56	40	80	65
10.07.19	72	148	135	60	75	28.5
11.07.19	46	18	62	40	70	40
12.07.19	48	3	9	4	30	40
13.07.19	0	25	8.5	0	10	5.5
14.07.19	47	177	45	36	50	45.5
15.07.19	57	64	46.5	44	150	96
16.07.19	9	0	11	17.5	30	25
Total	**554**	**603**	**469**	**277.5**	**555**	**435.5**
Intensity (mm/day)	**55**	**60**	**47**	**28**	**56**	**44**

It is seen from the above tables that rainfall in the plains were relatively much lower than in the mountaneous and foothill regions. Average daily rainfall intensity in Assam at the Brahmaputra and Barak river valley during the 10 days period ranged from 17-31 mm. On the other hand, average daily rainfall in the Himalayan foothill regions covering the Sub-Himalayan West Bengal and Norhtern Bangladesh ranged from 27-70 mm, while in the mountaneous region of the Meghalaya at Cherrapunji it reached as high as 195 mm on the same 10 days scale. Major portion of the rainfall in the mountaneous and hilly areas near the boundary significantly contributed to this very rapid rush of water in the Brahmaputra-Jamuna.

As for the in country monthly rainfall over the Brahmaputra basin in July, there was only 0.14% more rainfall than the normal. However, rainfall in the Northern region of the country was much higher than normal but it decreased in the plains and some stations even received less rainfall than normal. As a result, the average monthly rainfall over the basin somewhat decreased. Table 6.4 presents the in country monthly rainfall statistics over the Brahmaputra basin in July.

Table 6.4: In Country Monthly Rainfall Statistics within the Brahmaputra Basin in July

Station	Max. (mm)	Normal (mm)	Actual (mm)	Deviation (mm)	1-day max (mm)	10-days max (mm)	% of Deviation
Kurigram	969.3	530.6	647	116.4	98	554	0.14
Dalia	1137.5	687.4	781	93.6	177	603	
Kaunia	1554.5	561.3	235	-326.3	47	148	
Rangpur	1378.6	488.6	585	96.4	135	469	
Chilmari	1265.8	525.5	434.5	-91	114.5	277.5	
Dewanganj	1064	493.2	671	177.8	150	555	
Gaibandha	1164	444.9	586.5	141.6	96	435.5	
Serajganj	867.2	350.6	371.9	21.3	76.4	300	
Bogra	813.1	427.9	424.5	-3.4	70	290.5	
Jamalpur	1027.3	521.5	462	-59.5	92	400	
Mymensingh	860.3	569.3	271	-298.3	56.5	252.5	
Dhaka	694	360.2	473.5	113.3	108	357.5	
Tangail	827.4	343.1	370.3	27.2	135	324.4	

6.2.2 The Late Monsoon Normal Flood of Ganges River

Due to an enhanced active phase of the monsoon over the Ganges basin especially over Nepal and the Uttar Pradesh and Bihar states of India from second week of September till the last, the Ganges river rose significantly from second week of September till the first week of October. During this time the Ganges river in Bangladesh rose by 2.6-3.1 metres from Pankha to Hardinge Bridge. As a result, the Ganges river at Hardinge Bridge and at the Ganges-Padma confluence near Goalondo flowed above DL for 5 days during the 1st to 5th October. However the situation created normal flooding as well as stayed for short period. This is the first time in the last 16 years that the Ganges river flowed above DL. Table 6.5 presents WL scenario of the river during the major peak rising period.

Table 6.5: WL Scenario of the Ganges River during the Major Peak Rising Period

Date	WL (mPWD) of Ganges River			WL (mPWD) at Ganges-Padma Confluence	Remarks
	Pankha	Rajshahi	Hardinge Bridge	Goalundo	
12.09.2019	**-**	**-**	**-**	**7.32**	Initial level before arrival of flood wave
13.09.2019	**19.13**	**15.38**	**-**	**-**	
15.09.2019	**-**	**-**	**11.71**	**-**	
03.10.2019	**22.23**	**18.19**	**14.33**	**8.78**	Peak flood level
Total Rise (cm)	**310**	**281**	**262**	**146**	Statistics for the flood rising period
No of days to peak	**20**	**20**	**18**	**21**	
Average Rise per day (cm)	**15.5**	**14**	**15**	**7**	
Peak above DL (cm)	**-27**	**-31**	**+8**	**+13**	

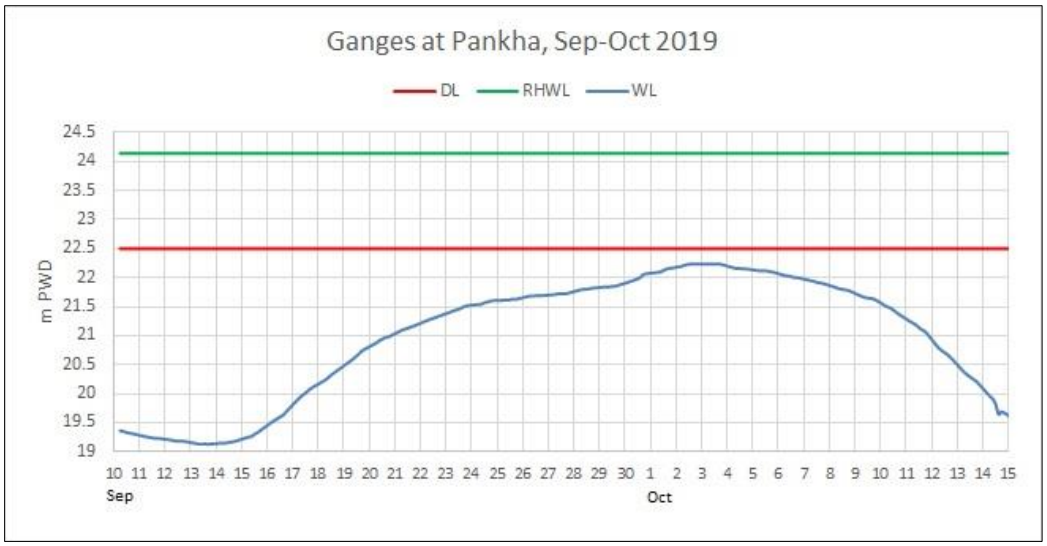


Figure 6.6 : WL Hydrograph of Ganges at Pankha during Sept-Oct, 2019

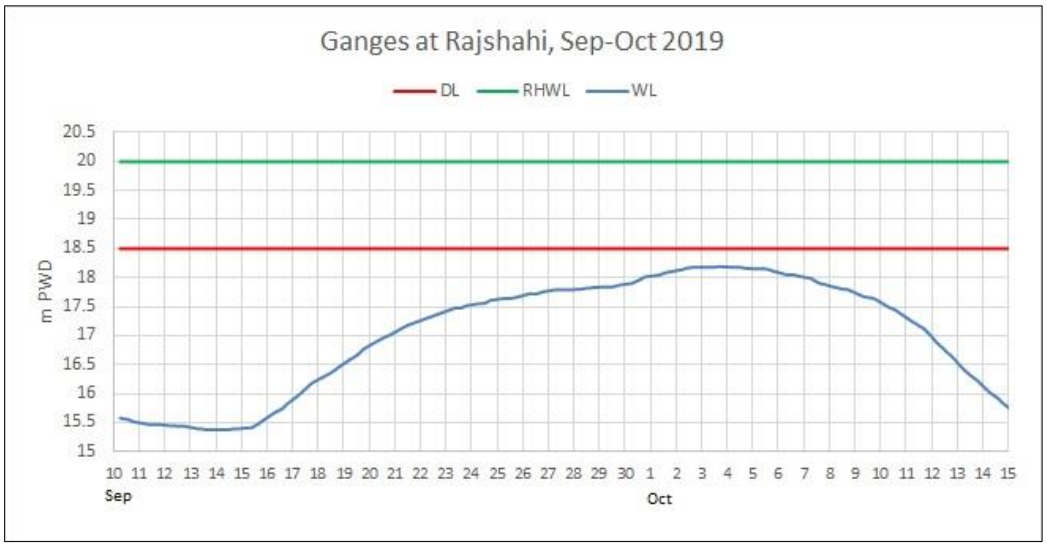


Figure 6.7 : WL Hydrograph of Ganges at Rajshahi during Sept-Oct, 2019

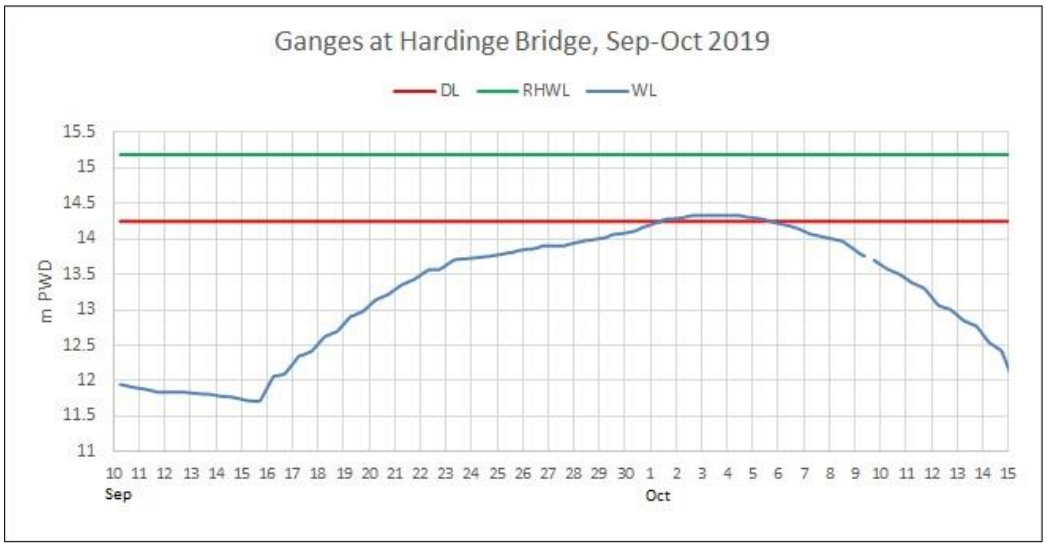


Figure 6.8 : WL Hydrograph of Ganges at Hardinge Bridge during Sept-Oct, 2019

The Ganges river at Hardinge Bridge last flowed above DL on 21 September 2003 and peaked only 3 cm above DL. After unusually long 16 years, the river flowed above DL again between 1st to 5th October this year. However, the Ganges river at Pankha and Rajshahi flowed above DL between 3rd to 9th September in 2013 just for once after 2003. It is evident from the records that the flow in the Ganges river has been greatly reduced. The primary reason behind the cause is numerous operational reservoirs in the upstream basin within India which have been constructed during the past few decades.

This is also noteworthy that for the first time in last 30 years the Ganges river flowed above DL at any station this late during a season. The last seasonal date on which the Ganges river flowed above DL at Pankha and Hardinge Bridge on was 30 September, while at Rajshahi on 1 October in the year of 1999. Figure 6.9 shows comparative hydrographs for the current and previous significant hydrological years at Hardinge Bridge which also depicts this late and unusually abrupt rise of the season.

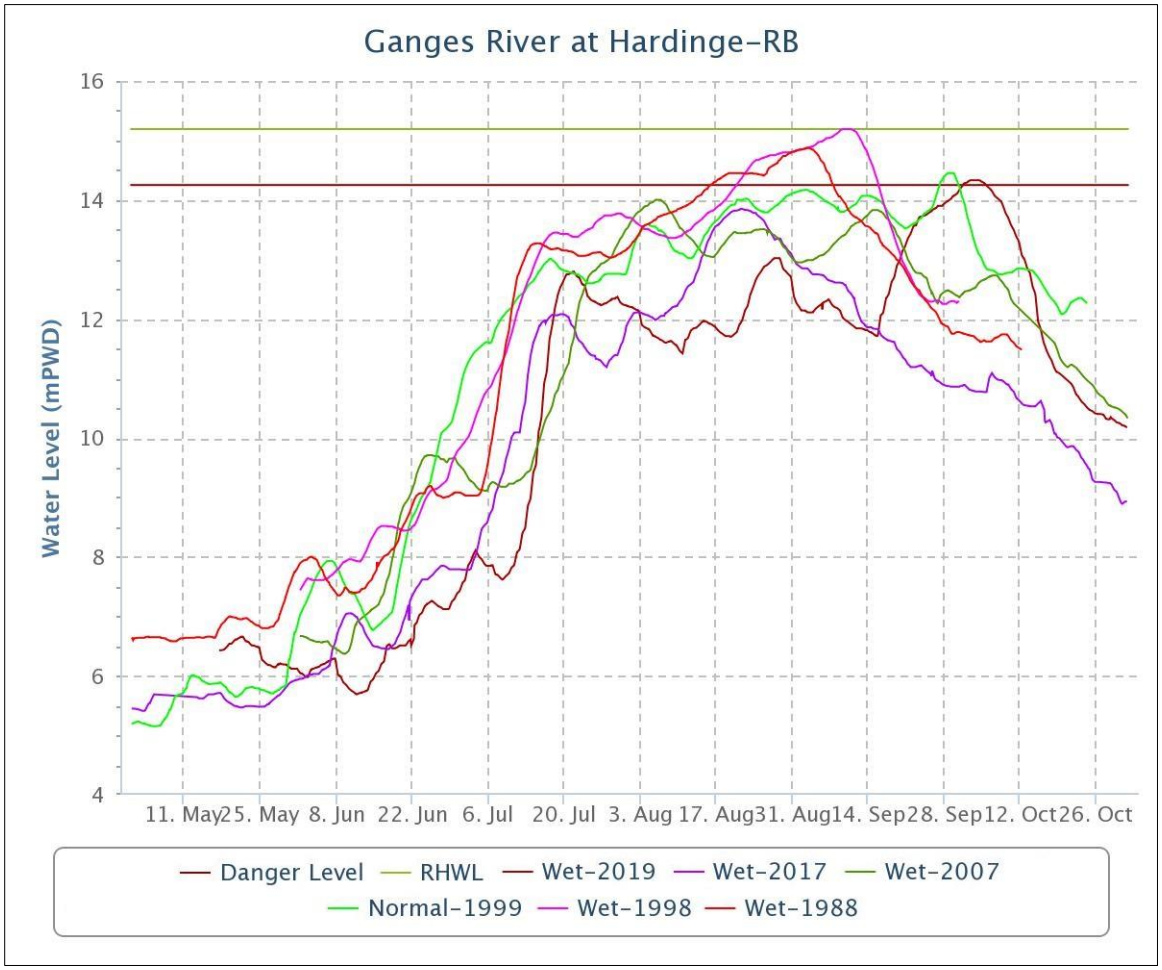


Figure 6.9 : Comparative Hydrographs of Ganges River at Hardinge Bridge

CHAPTER 7 : RESEARCH AND DEVELOPMENT

7.1 Operational Flash Flood Forecasting System for the North-Eastern Region

The experimental 3-days deterministic flash flood forecast system during the pre-monsoon period of April-May for the North East region of Bangladesh have been made operational this year which has been in practice since 2017. This system is developed under the HILIP-BWDB programme, a component of the HILIP under LGED. 10 WL and 11 rainfall stations have been added for flash flood monitoring and forecasting in addition to the regularly active stations during monsoon in the North-Eastern region. This has raised the number of WL monitoring stations to 36 and rainfall stations to 28. Consequentially, the number of flash flood forecasting stations have also been increased from to a number of 26 stations covering the Upper Meghna basin. However, the main feature of the forecasting system is that it is now coupled with Bangladesh Meteorological Department's (BMD) Weather Research and Forecasting (WRF) numerical model from which the quantitative rainfall output is converted to flow and linked with Mike11 hydrodynamic model to generate water level forecast. Sample flash flood outlook and bulletin with the list of stations have been presented in the Annexes.

Figure 7.1 : Operational Flash Flood Forecasting Stations during Pre-monsoon

7.2 Initiative with Google for Improved Flood Inundation Mapping

The flood forecasting system of FFWC is currently issued upon station-based forecasting. These station-based forecast information are then further incorporated into the countrywide flood map for spatially continuous flood forecast information by comparing the water surface

with DEM. However due to the low resolution of current DEM, some spatial accuracy has to be compromised. Moreover, recent land use changes and other dynamic features (such as breaches) are often not possible to incorporate into the DEM which further decreases the spatial accuracy of FFWC flood map to some extent.

With a view to overcoming these obstructions using latest available satellite-based technology but within limited expenses, in presence of the Secretary, MoWR and DG, BWDB at MoWR office, BWDB has officially signed a Memorandum of Understanding (MoU) with the internet based popular search engine private organization and tech giant 'Google' in March, 2019. Google has developed a satellite based improved DEM with higher spatial resolution using machine learning techniques wherein the recent land changes are also being incorporated. They have collaborated before with the Central Water Commission (CWC), Patna, India for flood mapping activities of the Ganges river reach with sufficient accuracy using this technology.

Currently the flood prone districts of Bogra of Sirajganj along the Jamuna river have been fixed as pilot area for the initiative. FFWC will provide the real time water level as well as forecast data to Google based upon which they will generate flood map for the pilot area. The system is currently under process to be launched in 2020 monsoon. Hopefully this will aid in better flood management activities at local level in future.

Figure 7.2 : MoU Signing Moment between BWDB and Google at MoWR Office

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 part of Meghna, North and South-Eastern Hill basins is vulnerable to flash flood at the beginning 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, flood inundation maps and structure-based flood forecast at 4 selected BWDB projects. 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 Haro 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 HILIP programme by 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 26 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. It is hoped that this will significantly promote flood message dissemination in near future.

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.

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 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 center itself, the services were fully not satisfactory to all corners. Area-inundation forecast have been indicative, based on a coarse DEM and old topographic maps. Information on flash flood was limited due to technological limitation and non-availability of the real time data at a much shorter interval than the usual.

The continued achievement of the FFWC is notable. It is trying hard to overcome the limitations and realities. Regional models need to 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 this year is the commencement of initiative with 'Google' for improved flood inundation mapping. Google has improved their satellite-based DEM using machine learning techniques over the years.

Under the Memorandum of Understanding (MoU) signed between BWDB and Google, FFWC generated station based forecast information will be combined with Google DEM to generate flood map. The system is expected to launch in 2020. Using this technology, it should be possible for flood inundation mapping up to union level with reasonable accuracy considering the improved spatio-temporal resolution of Google DEM.

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 2019.

As a whole the flood of 2019 was a severe one but less devastating compared to the floods of 1987, 1988, 1998, 2004, 2007 and 2017. But still the flood of the Brahmaputra-Jamuna river this year in July was one of the most severe in recorded history. The Jamuna at Fulchari and Bahadurabad exceeded the recorded highest water level this year which created locally a much more severe flood condition in low lying lands of Gaibandha and Jamalpur causing therein one of the worst floods of recorded history. However, the flood water did not stay for long duration which resulted in minimized casualty. It is noteworthy that the Jamuna at Bahadurabad after 1988, exceeded recorded highest level almost successively in 2016, 2017 and 2019. There is a growing concern about the future probable increment of flood intensity in the area.

Another notable event of the 2019 flood season is that the Ganges river after 16 long years flowed above danger level at Hardinge Bridge. Construction of numerous upstream reservoirs in India within the basin has significantly reduced the flow of Ganges in past two decades. However, this year's unusual and highly above normal rainfall during September over Nepal and Uttar Pradesh and Bihar states of India incurred great flow through Ganges. Also, this year at Hardinge Bridge the Ganges flowed above danger level from the 1st till 5th October which is the most delayed period of the year in last 30 years for such condition. In between the time of Brahmaputah-Jamuna and Ganges flood events from August through first half of September, the monsoon remained fairly inactive over the basin and flood situation was normal. The pre-monsoon flooding was late this year in May and less severe.

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2018 on major rivers were around 95%, 89%, 82%, 76% and 75% consistent on average for 24hrs, 48hrs, 72hrs, 96hrs and 120hrs 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 31% of the whole country this year (45,747 sq-km approximately) corresponding to severe flooding. Some of the regions experienced severe river bank erosion which continued both during and after the flooding.

Annex-1

EXPERIMENTAL 5 Days Forecast (24, 48, 72, 96 & 120 Hrs), FFWC, BWDB

Supported by CDMP-II

SL NO	River	Station	D.L. (meter)	Today 01-09 6:00 AM (meter)	24-hrs forecast 02-09 6:00 AM (meter)	24-hrs +Rise -fall 02-09 6:00 AM (cm)	24-hrs +above -below D.L. 02-09 6:00 AM (cm)	48-hrs forecast 03-09 6:00 AM (meter)	48-hrs +Rise -fall 03-09 6:00 AM (cm)	48-hrs +above below D.L. 03-09 6:00 AM (cm)	72-hrs forecast 04-09 6:00 AM (meter)	72-hrs +Rise -fall 04-09 6:00 AM (cm)	72-hrs +above -below D.L. 04-09 6:00 AM (cm)	96-hrs forecast 05-09 6:00 AM (meter)	96-hrs +Rise -fall 05-09 6:00 AM (cm)	96-hrs +above -below D.L. 05-09 6:00 AM (cm)	120-hrs forecast 06-09 6:00 AM (meter)	120-hrs +Rise -fall 06-09 6:00 AM (cm)	120-hrs +above -below D.L. 06-09 6:00 AM (cm)
1	Atrai	Mohadevpur	18.59	13.85	13.79	-6	-480	13.78	-1	-481	13.86	+8	-473	13.99	+12	-460	14.15	+17	-444
2	Atrai	Atrai	13.72	-	13.34	-	-38	13.31	-3	-41	13.27	-3	-45	13.25	-2	-47	13.24	-1	-48
3	Atrai	Singra	12.65	5.93	5.90	-3	-675	5.90	-1	-675	5.88	-2	-677	5.86	-2	-679	5.85	-1	-680
4	Karatoa-Atrai-GGH	Baghabari	10.40	9.00	8.91	-9	-150	8.82	-8	-158	8.75	-7	-165	8.68	-7	-172	8.61	-7	-179
5	Little Jamuna	Naogaon	15.24	11.75	11.68	-7	-356	11.67	-1	-357	11.73	+7	-351	11.82	+8	-342	11.89	+7	-335
6	Karatoya	Chakrahimpur	20.15	18.74	18.61	-13	-154	18.62	+1	-153	18.80	+18	-136	18.96	+16	-119	19.09	+13	-106
7	Karatoya	Bogra	16.32	11.96	11.90	-6	-442	11.95	+6	-437	12.06	+11	-426	12.17	+11	-415	12.25	+9	-407
8	Teesta	Kaunia	30.00	28.27	28.62	+35	-138	28.62	0	-138	28.53	-9	-147	28.47	-6	-153	28.41	-6	-159
9	Ghagot	Gaibandha	21.70	19.00	18.90	-10	-280	18.80	-10	-290	18.70	-10	-300	18.64	-6	-306	18.59	-5	-311
10	Dharla	Kurigram	26.50	24.43	24.49	+6	-201	24.49	+1	-201	24.40	-10	-210	24.28	-11	-222	24.17	-12	-233
11	Brahmaputra	Chilmari	24.00	21.35	21.35	0	-265	21.38	+3	-262	21.33	-4	-267	21.25	-8	-275	21.17	-9	-283
12	Jamuna	Bahadurabad	19.50	16.94	16.92	-2	-258	16.97	+5	-253	16.95	-2	-255	16.87	-8	-263	16.76	-11	-274
13	Jamuna	Sariakandi	16.70	14.26	14.21	-5	-249	14.23	+2	-247	14.24	+1	-246	14.19	-5	-251	14.09	-10	-261
14	Jamuna	Kazipur	14.85	-	12.88	-	-197	12.90	+2	-195	12.91	+1	-194	12.86	-5	-199	12.77	-9	-208
15	Jamuna	Serajganj	13.35	11.57	11.51	-6	-184	11.50	0	-185	11.52	+1	-183	11.48	-4	-187	11.40	-8	-195
16	Jamuna	Porabari	12.27	-	9.58	-	-269	9.55	-3	-272	9.55	0	-272	9.52	-4	-275	9.44	-8	-283
17	Jamuna	Aricha	9.40	7.92	7.78	-14	-162	7.69	-9	-171	7.64	-6	-176	7.59	-5	-181	7.53	-5	-187
18	Old Brahmaputra	Jamalpur	17.00	11.92	11.84	-8	-516	11.79	-4	-521	11.77	-2	-523	11.76	-1	-524	11.75	-1	-525
19	Old Brahmaputra	Mymensingh	12.50	6.75	6.63	-12	-587	6.53	-10	-597	6.43	-10	-607	6.35	-8	-615	6.29	-5	-621
20	Bangshi	Nayerhat	7.32	4.59	4.51	-8	-281	4.42	-9	-290	4.32	-10	-300	4.23	-9	-309	4.18	-6	-314
21	Old Dhalesari	Jagir	8.23	-	6.00	-	-223	5.93	-7	-230	5.86	-7	-237	5.80	-6	-243	5.76	-5	-247
22	Dhaleswari	Kalagachia	4.88	-	4.10	-	-78	3.98	-13	-90	3.86	-11	-102	3.79	-7	-109	3.85	+6	-103
23	Kaliganga	Taraghat	8.38	5.55	5.45	-10	-293	5.35	-9	-303	5.26	-10	-312	5.17	-9	-321	5.10	-7	-328
24	Tongi Khal	Tongi	6.08	4.51	4.45	-6	-163	4.38	-7	-170	4.29	-9	-179	4.20	-9	-188	4.12	-7	-196
25	Turag	Mirpur	5.94	4.38	4.30	-8	-164	4.19	-11	-175	4.07	-12	-187	3.97	-11	-197	3.91	-6	-203
26	Buriganga	Dhaka (Mill Barrack)	6.00	-	4.29	-	-171	4.16	-13	-184	4.03	-13	-197	3.93	-10	-207	3.90	-3	-210
27	Buriganga	Dhaka (Hariharpara)	5.79	-	4.27	-	-152	4.14	-13	-165	4.01	-13	-178	3.91	-10	-188	3.90	-1	-189
28	Balu	Demra	5.75	4.03	3.97	-6	-178	3.91	-6	-184	3.83	-8	-192	3.74	-9	-201	3.66	-8	-209
29	Lakhya	Narayanganj	5.50	4.45	4.37	-8	-113	4.27	-11	-123	4.15	-11	-135	4.06	-9	-144	4.04	-2	-146
30	Dhaleswari	Elashinghat	11.40	9.50	9.39	-11	-201	9.34	-5	-206	9.33	-1	-207	9.30	-3	-210	9.24	-6	-216
31	Lakhya	Lakhpur	5.80	3.90	3.84	-6	-196	3.80	-4	-200	3.74	-6	-206	3.67	-7	-213	3.60	-7	-220
32	Dhaleswari	Munshiganj	5.20	-	4.18	-	-102	4.05	-13	-115	3.93	-12	-127	3.85	-8	-135	3.88	+3	-132
33	Mohananda	Chapai Nawabganj	21.00	18.27	18.15	-12	-285	18.05	-10	-295	17.97	-8	-303	17.90	-7	-310	17.84	-7	-316
34	Ganges	Rajshahi	18.50	15.81	15.66	-15	-284	15.53	-14	-297	15.45	-8	-305	15.40	-5	-310	15.38	-2	-312
35	Ganges	Hardinge Br	14.25	12.2	11.98	-22	-227	11.81	-16	-244	11.67	-14	-258	11.59	-8	-266	11.54	-5	-271
36	Ganges	Talbaria	12.80	-	11.06	-	-174	10.91	-15	-189	10.78	-13	-202	10.70	-8	-210	10.65	-5	-215
37	Padma	Goalondo	8.65	7.47	7.32	-15	-133	7.23	-10	-142	7.16	-7	-149	7.11	-5	-154	7.05	-6	-160

Note :
1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 2-9-2019 6:00 A.M.
2) 48 hrs. rise/fall indicates changes in water levels from 2-9-2019 6:00 A.M. to 3-9-2019 6:00 A.M.
3) 72 hrs. rise/fall indicates changes in water levels from 3-9-2019 6:00 A.M. to 4-9-2019 6:00 A.M.
4) 96 hrs. rise/fall indicates changes in water levels from 4-9-2019 6:00 A.M. to 5-9-2019 6:00 A.M.
5) 120 hrs. rise/fall indicates changes in water levels from 5-9-2019 6:00 A.M. to 6-9-2019 6:00 A.M.
6) "+ above" means water level flowing above danger level, "-below" means water level flowing below danger level.

Page: 1 of 2

A Sample of 5-days Deterministic Forecast Bulletin

Annex-2

FLOOD FORECASTING AND WARNING CENTER, BWDB
RIVER SITUATION AS ON 18-07-2019 AT 09:00 HOURS

SL	RIVER	STATION NAME	RHWL (m PWD)	D.L. (m PWD)	W A T E R L E V E L (m PWD) 17-07-2019	18-07-2019	+ Rise - Fall in cm	Above(+) /Below(-) D.L. in cm
	BRAHMAPUTRA BASIN							
1	DHARLA	KURIGRAM	27.84	26.50	27.66	27.57	-9	+ 107
2	TEESTA	DALIA	53.05	52.60	52.55	52.23	-32	-37
3	TEESTA	KAUNIA	30.52	29.20	29.05	28.81	-24	-39
4	JAMUNESWARI	BADARGANJ	33.61	32.15	31.78	31.57	-21	-58
5	GHAGOT	GAIBANDHA	22.81	21.70	22.59	22.64	+ 5	+ 94
6	KARATOA	CHAK RAHIMPUR	21.41	20.15	19.03	19.36	+ 33	-79
7	KARATOA	BOGRA	17.45	16.30	14.73	14.69	-4	-161
8	BRAHMAPUTRA	NOONKHAWA	28.10	26.50	27.52	27.50	-2	+ 100
9	BRAHMAPUTRA	CHILMARI	25.07	23.70	25.02	24.98	-4	+ 128
10	JAMUNA	FULCHARI	21.13	19.82	21.29	21.35	+ 6	+ 153
11	JAMUNA	BAHADURABAD	20.84	19.50	21.10	21.16	+ 6	+ 166
12	JAMUNA	SARIAKANDI	19.07	16.70	17.84	17.95	+ 11	+ 125
13	JAMUNA	KAZIPUR	17.47	15.25	16.28	16.45	+ 17	+ 120
14	JAMUNA	SERAJGANJ	15.12	13.35	14.07	14.28	+ 21	+ 93
15	JAMUNA	ARICHA	10.76	9.40	9.25	9.53	+ 28	+ 13
16	GUR	SINGRA	13.67	12.65	12.20	12.45	+ 25	-20
17	ATRAI	BAGHABARI	12.45	10.40	10.62	10.86	+ 24	+ 46
18	DHALESWARI	ELASIN	12.52	11.40	11.84	12.07	+ 23	+ 67
19	OLD BRAHMAPUTRA	JAMALPUR	18.00	17.00	16.10	16.61	+ 51	-39
20	OLD BRAHMAPUTRA	MYMENSINGH	13.71	12.50	10.20	10.43	+ 23	-207
21	LAKHYA	LAKHPUR	8.70	5.80	5.51	5.72	+ 21	-8
22	BURIGANGA	DHAKA	7.58	6.00	4.56	4.68	+ 12	-132
23	BALU	DEMRA	7.13	5.75	4.96	5.04	+ 8	-71
24	LAKHYA	NARAYANGANJ	6.93	5.50	4.95	5.07	+ 12	-43
25	TURAG	MIRPUR	8.35	5.95	4.62	4.69	+ 7	-126
26	TONGI KHAL	TONGI	7.84	6.10	5.02	5.12	+ 10	-98
27	KALIGANGA	TARAGHAT	10.39	8.40	6.74	6.98	+ 24	-142
28	DHALESWARI	JAGIR	9.73	8.25	5.85	6.28	+ 43	-197
29	DHALESWARI	REKABI BAZAR	7.66	5.20	4.37	4.47	+ 10	-73
30	BANSHI	NAYARHAT	8.39	7.30	4.77	4.89	+ 12	-241
	GANGES BASIN							
31	KARATOA	PANCHAGARH	72.65	70.75	67.95	67.89	-6	-286
32	PUNARBHABA	DINAJPUR	34.40	33.50	31.31	30.43	-88	-307
33	ICH-JAMUNA	PHULBARI	30.47	29.95	28.68	28.55	-13	-140
34	TANGON	THAKURGAON	51.30	50.40	48.44	48.00	-44	-240
35	UPPER ATRAI	BHUSIRBANDAR	41.10	39.62	38.61	37.94	-67	-168
36	MOHANANDA	ROHANPUR	23.83	22.00	17.81	18.30	+ 49	-370
37	MOHANANDA	CHAPAI-NAWABGANJ	23.01	21.00	17.55	18.04	+ 49	-296
38	LITTLE JAMUNA	NAOGAON	16.20	15.25	14.76	14.96	+ 20	-29
39	ATRAI	MOHADEBPUR	19.89	18.59	18.52	18.45	-7	-14
40	GANGES	PANKHA	24.14	22.50	18.80	19.44	+ 64	-306
41	GANGES	RAJSHAHI	20.00	18.50	14.94	15.47	+ 53	-303
42	GANGES	HARDINGE BRIDGE	15.19	14.25	11.72	12.24	+ 52	-201
43	PADMA	GOALUNDO	10.21	8.65	8.76	9.01	+ 25	+ 36
44	PADMA	BHAGYAKUL	7.50	6.30	6.09	6.35	+ 26	+ 5
45	PADMA	SURESWAR	7.50	4.45	4.00	4.25	+ 25	-20
46	GORAI	GORAI RLY BRIDGE	13.65	12.75	10.01	10.55	+ 54	-220
47	GORAI	KAMARKHALI	9.48	8.20	5.89	6.26	+ 37	-194
48	ICHAMATI	SAKRA	4.69	3.95	-0.61	-1.31	-70	-526
49	MATHABHANGA	CHUADANGA	12.67	12.05	5.52	5.48	-4	-657
50	MATHABHANGA	HATBOALIA	15.13	14.50	7.40	8.07	+ 67	-643
51	KOBADAK	JHIKARGACHA	5.59	5.10	1.41	1.41	0	-369
52	KUMAR	FARIDPUR	8.76	7.50	3.99	4.13	+ 14	-337
53	ARIALKHAN	MADARIPUR	5.80	4.20	3.01	3.15	+ 14	-105
54	KIRTONKHOLA	BARISAL	3.20	2.55	1.33	1.45	+ 12	-110
55	PASHURE	KHULNA	3.48	3.05	-0.40	-0.28	+ 12	-333

Cont/2

A Sample Flood Bulletin

Annex-3

FLOOD INFORMATION CENTRE
FLOOD FORECASTING & WARNING CENTRE
BANGLADESH WATER DEVELOPMENT BOARD
WAPDA BUILDING, 8TH FLOOR, DHAKA.
E-mail: ffwcbwdb@gmail.com, ffwc05@yahoo.com, Site: http://www.ffwc.gov.bd Tel: 9553118, 9550755 Fax: 9557386

RAINFALL AND RIVER SITUATION SUMMARY AS ON JULY 18, 2019

Outlook:

- ***All the major rivers of the country are in rising trend except the Brahmaputra and rivers of North-Eastern region.***
- ***According to the information of Bangladesh Meteorological Department and India Meteorological Department, there is no chance of heavy rainfall in the upstream states of Bangladesh in next 48 hours.***
- ***The Brahmaputra river may fall, while the Jamuna may continue rising in next 24 hours. The Ganges-Padma rivers may continue rising in next 48 hours. The Lakhya river at Lakhpur may cross danger level in next 24 hours***
- ***Flood situation in Kurigram, Jamalpur and Gaibandha districts may remain stable, while flood situation in Bogra, Sirajganj, Tangail, Manikganj, Faridpur and Munshiganj districts may deteriorate in next 24 hours.***
- ***Flood situation in Netrokona, Sunamganj, Sylhet, Habiganj and Moulvibazar districts may continue improving in next 24 hours.***

Stations above Danger Levels (As on 18 July 2019, 09:00 am):

Station name	River	Today's Water Level (meter)	Rise(+)/Fall(-) (cm) during last 24 hours	Danger Level (meter)	Above Danger Level (cm)
Kanaighat	Surma	12.91	-21	12.25	+66
Sylhet	Surma	10.47	-19	10.15	+32
Sunamganj	Surma	7.63	-16	7.20	+43
Amalshad	Kushiyara	15.21	-62	14.95	+26
Sheola	Kushiyara	12.87	-37	12.50	+37
Sherpur- Sylhet	Kushiyara	8.50	-08	8.05	+45
Derai	Old Surma	6.58	-02	6.50	+08
Kalmakanda	Someswari	6.88	-16	6.60	+38
Jariajanjail	Kangsha	10.10	-15	9.95	+15
B.Baria	Titas	4.57	+07	4.45	+12
Chandpur	Meghna	3.52	-02	3.50	+02
Kurigram	Dharla	27.57	-09	26.50	+107
Gaibandha	Ghagot	22.64	+05	21.70	+94
Noonkhawa	Brahmaputra	27.50	-02	26.50	+100
Chilmari	Brahmaputra	24.98	-04	23.70	+128
Fulchari	Jamuna	21.35	+06	19.82	+153
Bahadurabad	Jamuna	21.16	+06	19.50	+166
Sariakandi	Jamuna	17.95	+11	16.70	+125
Kazipur	Jamuna	16.45	+17	15.25	+120
Serajganj	Jamuna	14.28	+21	13.35	+93
Aricha	Jamuna	9.53	+28	9.40	+13
Baghabari	Atrai	10.86	+24	10.40	+46
Elasin	Dhaleswari	12.07	+23	11.40	+67
Goalundo	Padma	9.01	+25	8.56	+36
Bhagyakul	Padma	6.35	+26	6.30	+05

RAINFALL

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

Station	Rainfall (mm)	Station	Rainfall (mm)
Ramgarh	82.0	Parshuram	57.0

Significant rainfalls (mm) recorded during last 24 hrs in Sikkim, Assam, Meghalaya & Tripura states of North-East India:

Station	Rainfall (mm)
Aizwal	55.0

General River Condition

Monitoring Water Level Station	93	Water Level Steady in last 24 hours	01
Water Levels Rise in last 24 hours	48	Total not Reported	00
Water Levels Fall in last 24 hours	44	**Above Danger Level**	**25**

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

(Md. Arifuzzaman Bhuyan)
Executive Engineer
Duty Officer, FFWC, BWDB.
Cell no: 01715040144

A Sample Flood Situation Summary

Annex-4

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 July 13, 2019

Outlook for Next 10 Days:

- Brahmaputra-Jamuna river system may continue to rise till 18th of July. **Flood situation is likely to worsen in Kurigram, Jamalpur, Gaibandha, Bogura during next 3 days. Sirajganj station may cross danger level during next 24 hours. A medium duration (>7 days or more) flooding is expected in the low lying areas of these districts.**
- Ganges-Padma River may continue to rise till 17th of July. No probability of flooding is forecasted in Ganges basin. Water level at Aricha, Bhagyakul and Goalondo may reach warning levels.
- 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। ব্রহ্মপুত্র-যমুনা নদীর অববাহিকায় কুড়িগ্রাম, জামালপুর, গাইবান্ধা, বগুড়ায় আগামী ৩ দিন বন্যা পরিস্থিতির অবনতি হতে পারে। সিরাজগঞ্জে আগামী ২৪ ঘন্টায় বিপদসীমা অতিক্রম করতে পারে।কুড়িগ্রাম, জামালপুর, গাইবান্ধা, বগুড়া, সিরাজগঞ্জ ও টাঙ্গাইল জেলার নিম্নাঞ্চলে সল্প-মধ্য মেয়াদী (৭ দিন বা তার বেশি) বন্যা পরিস্থিতির সৃষ্টি হতে পারে।
- গঙ্গা-পদ্মা নদীর পানি সমতল বৃদ্ধি পেতে পারে। আপাতত গঙ্গা নদীর অববাহিকায় বিপদসীমা অতিক্রমের সম্ভাবনা নেই।পদ্মা নদীর অববাহিকায় আরিচা, ভাগ্যকুল ও গোয়ালন্দে পানি সমতল সতর্কসীমায় পৌঁছাতে পারে।
- ঢাকার চারপাশের নদীসমূহের পানি সমতল বৃদ্ধি পেতে 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-5

Forecast made on: 13-07-2019 (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]			13-07	14-07	15-07	16-07	17-07	18-07	19-07	20-07	21-07	22-07	23-07	Forecast type
River	Station	D.L	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	
Jamuna	Bahadurabad	19.50	19.81	20.09	20.30	20.49	20.64	20.75	20.84	20.89	20.86	20.85	20.87	Upper Range
				20.08	20.26	20.41	20.51	20.60	20.64	20.64	20.60	20.56	20.53	Lower Range
				20.08	20.28	20.45	20.59	20.69	20.74	20.76	20.74	20.71	20.69	Mean
Jamuna	Sariakandi	16.70	16.59	16.90	17.14	17.34	17.47	17.57	17.65	17.71	17.70	17.69	17.71	Upper Range
				16.90	17.11	17.26	17.38	17.45	17.50	17.50	17.48	17.45	17.43	Lower Range
				16.90	17.12	17.30	17.42	17.52	17.58	17.60	17.60	17.58	17.56	Mean
Jamuna	Kazipur	14.85	15.26	15.58	15.81	15.97	16.13	16.27	16.39	16.47	16.47	16.45	16.47	Upper Range
				15.57	15.79	15.91	16.03	16.13	16.19	16.20	16.18	16.15	16.12	Lower Range
				15.57	15.80	15.94	16.08	16.21	16.29	16.33	16.33	16.30	16.28	Mean
Jamuna	Serajganj	13.35	12.82	13.25	13.54	13.76	13.97	14.15	14.28	14.38	14.39	14.37	14.39	Upper Range
				13.24	13.52	13.69	13.84	13.97	14.05	14.07	14.05	14.01	13.97	Lower Range
				13.24	13.53	13.72	13.91	14.07	14.17	14.22	14.22	14.20	14.17	Mean
Jamuna	Aricha	9.40	7.95	8.40	8.79	9.05	9.27	9.44	9.55	9.63	9.66	9.65	9.65	Upper Range
				8.40	8.76	8.99	9.17	9.30	9.38	9.42	9.42	9.38	9.34	Lower Range
				8.40	8.77	9.02	9.22	9.38	9.48	9.53	9.54	9.52	9.49	Mean
Ganges-Padma	Hardinge Bridge	14.25	8.86	9.21	9.68	10.05	10.31	10.43	10.47	10.33	10.16	10.05	9.95	Upper Range
				9.20	9.47	9.84	10.03	10.14	10.09	9.98	9.84	9.67	9.42	Lower Range
				9.20	9.55	9.94	10.22	10.38	10.37	10.24	9.97	9.81	9.63	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-6

FLOOD INFORMATION CENTRE, FLOOD FORECASTING & WARNING CENTRE
BANGLADESH WATER DEVELOPMENT BOARD, WAPDA BUILDING, 8TH FLOOR, DHAKA

E-mail: ffwcbwdb@gmail.com, ffwc05@yahoo.com, Website: http://www.ffwc.gov.bd Tel: 9553118, 9550755 Fax: 9557386

Flash Flood Forecast Bulletin for North East Region as on 15-Apr...9 (Morning)

Station Name	River Name	Experimental		15-April-2019			16-April-2019				17-April-2019				18-April-2019	
		DL (PM) (mMSL)	RHWL (PM) (mMSL)	Observed 9:00 AM (mMSL)	Forecast 9:00 PM (mMSL)	12-Hr R/F (cm)	Forecast 9:00 AM (mMSL)	24-Hr R/F (cm)	Forecast 9:00 PM (mMSL)	36-Hr R/F (cm)	Forecast 9:00 AM (mMSL)	48-Hr R/F (cm)	Forecast 9:00 PM (mMSL)	60-Hr R/F (cm)	Forecast 9:00 AM (mMSL)	72-Hr R/F (cm)
Kanaighat	Surma	10.89	14.8	3.73	3.70	-3	3.68	-5	3.65	-8	3.63	-10	3.61	-12	3.59	-14
Sylhet	Surma	8.29	10.31	1.38	1.37	-1	1.37	-1	1.37	-1	1.36	-2	1.36	-2	1.35	-3
Sunamganj	Surma	6.04	7.89	1.13	1.13	0	1.13	0	1.13	0	1.13	0	1.13	0	1.12	-1
Amalshid	Kushiyara	13.04	15.82	6.38	6.32	-6	6.28	-10	6.23	-15	6.18	-20	6.12	-26	6.07	-31
Sheola	Kushiyara	10.69	13.76	4.38	4.34	-4	4.31	-7	4.27	-11	4.24	-14	4.21	-17	4.17	-21
Sherpur	Kushiyara	7.79	8.44	2.84	2.82	-2	2.80	-4	2.79	-5	2.77	-7	2.75	-9	2.73	-11
Markuli	Surma-Meghna	5.94	7.36	2.40	2.38	-2	2.37	-3	2.35	-5	2.34	-6	2.32	-8	2.31	-9
Sarighat	Sarigowain	10.69	13.61	3.51	3.51	0	3.50	-1	3.50	-1	3.49	-2	3.49	-2	3.48	-3
Manu-RB	Manu	16.44	19.96	12.35	12.31	-4	12.30	-5	12.29	-6	12.28	-7	12.28	-7	12.27	-8
Moulvi-Bazar	Manu	9.54	12.5	5.23	5.14	-10	5.17	-7	5.09	-14	5.09	-14	4.96	-27	4.99	-24
Ballah	Khowai	21.34	24.82	19.41	19.32	-9	19.24	-17	19.18	-23	19.13	-28	19.10	-31	19.07	-34
Habiganj	Khowai	8.64	11.04	4.20	4.08	-12	3.96	-24	3.86	-34	3.77	-43	3.71	-49	3.66	-54
Kamalganj	Dhalai	19.04	20.72	15.19	15.08	-11	14.99	-20	14.90	-29	14.83	-36	14.78	-41	14.73	-46
Khaliajuri	Baulai	4.14	5.31	1.12	1.17	+5	1.18	+6	1.19	+7	1.21	+9	1.22	+10	1.23	+11
Nakuagaon	Bhogai-Kangsa	20.79	22.6	17.67	17.68	+1	17.68	+1	17.69	+2	17.69	+2	17.69	+2	17.68	+1
Lourergorh	Jadukata	5.94	7.15	1.94	1.96	+2	1.96	+2	1.96	+2	1.95	+1	1.94	0	1.93	-1
Durgapur	Someswari	10.79	13.38	8.04	8.04	0	8.04	0	8.03	-1	8.03	-1	8.03	-1	8.03	-1
Jariajanjail	Bhogai-Kangsa	6.34	8.97	4.05	4.08	+3	4.10	+5	4.12	+7	4.14	+9	4.14	+9	4.13	+8
Azmiriganj	Kalni	4.54	7.17	1.95	1.94	-1	1.92	-3	1.91	-4	1.89	-6	1.88	-7	1.86	-9
Fenchuganj	Kushiyara	7.74	10.84	3.52	3.50	-2	3.48	-4	3.46	-6	3.44	-8	3.42	-10	3.40	-12
Gowainghat	Sari-Gowain	8.64	11	-	-	-	-	-	-	-	-	-	-	-	-	-
Islampur	Dhalagang	10.24	12.79	5.80	5.79	-1	5.78	-2	5.76	-4	5.75	-5	5.73	-7	5.72	-8
Kalmakanda	Someswari	4.89	5.61	1.36	1.39	+3	1.41	+5	1.43	+7	1.45	+9	1.47	+11	1.48	+12
Muslimpur	Jhalukhali	6.44	9.44	1.11	1.11	0	1.10	-1	1.10	-1	1.09	-2	1.08	-3	1.07	-4
Sutang_RB	Sutang	4.94	7.05	3.99	3.91	-8	3.82	-17	3.74	-25	3.67	-32	3.61	-38	3.55	-44

Note :- *(PM)* : *Pre-Monsoon*
R/F : *Rise/Fall*
mMSL : *metre Mean Sea Level*

Sample Operational 3-days Flash Flood Forecast Bulletin for the NE Region

Annex-7

FLOOD INFORMATION CENTRE
FLOOD FORECASTING & WARNING CENTRE
BANGLADESH WATER DEVELOPMENT BOARD
WAPDA BUILDING, 8TH FLOOR, DHAKA.
E-mail: ffwcbwdb@gmail.com, ffwc05@yahoo.com, Site: http://www.ffwc.gov.bd Tel: 9553118, 9550755 Fax: 9557386

RAINFALL AND RIVER SITUATION SUMMARY IN HAOR REGION AS ON APRIL 30, 2019

- ***The major rivers in the North-Eastern region of the Country are in rising trend.***
- ***According to the information of Bangladesh Meteorological Department and Indian Meteorological Department, there is chance of medium to heavy rainfall in places of the North-Eastern part of the Country and adjoining parts of Assam, Meghalaya and Tripura states of India in next 48 hours.***
- ***Water level of the major rivers in the North-Eastern region of the Country; the Surma, Kushiyara and Jadukata may rise rapidly in next 24 hours but will remain below danger level.***

Stations above Danger Levels (As on 30 April 2019, 09:00 am): Nil

Station name	River	Today is Water Level (meter)	Rise(+)/Fall(-) (cm) during last 24 hours	Danger Level (meter)	Above Danger Level (cm)
-	-	-	-	-	-

RAINFALL

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

Station	Rainfall(mm)	Station	Rainfall(mm)
Lorergarh	97.0	Sylhet	70.0
Kanaighat	58.0	Chattak	56.0

Significant rainfalls (mm) recorded during last 24 hrs in Sikkim, Assam, Meghalaya & Tripura region of North-East India:

Station	Rainfall(mm)	Station	Rainfall(mm)
Cherrapunji	133.0	Slichar	33.0

General River Condition

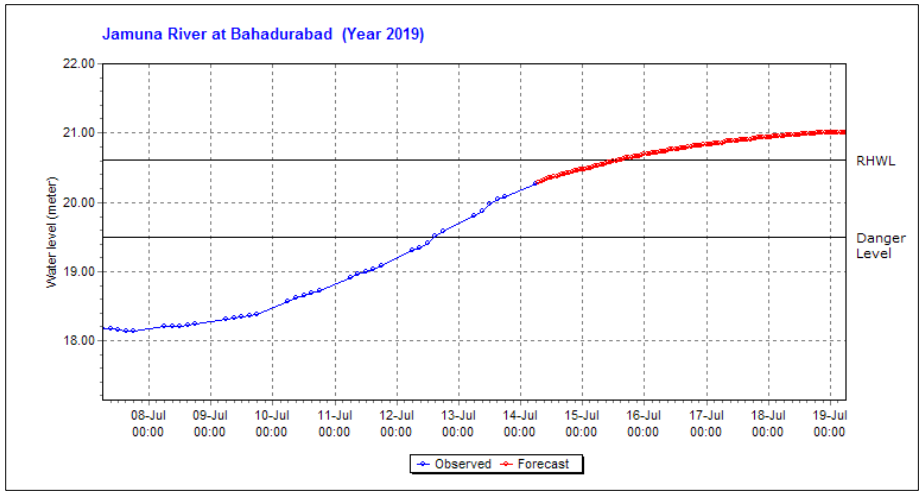
Monitored Water Level Station	39	Inactive Gauge	01
Rise	32	Gauge Reading Missing	02
Fall	04	Total Not Reported	03
Steady	0	Above Danger Level	0

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

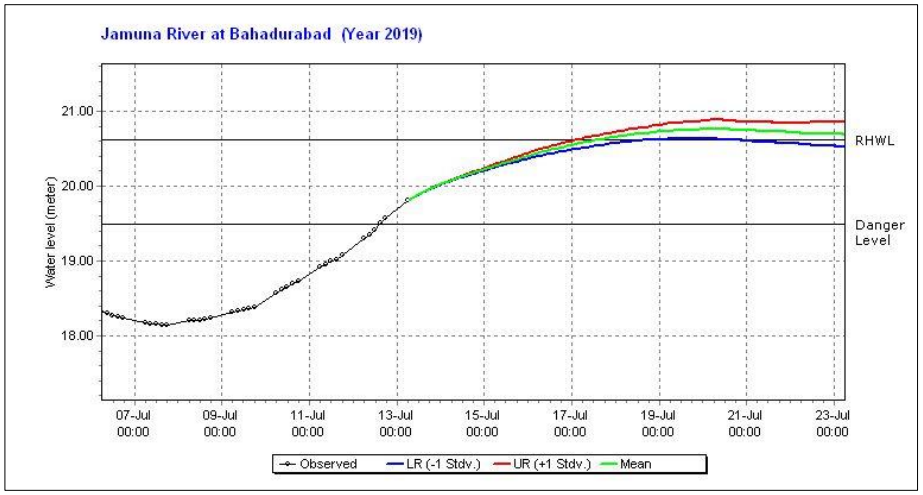
(Md. Arifuzzaman Bhuyan)
Executive Engineer
Duty Officer, FFWC, BWDB.
Cell no: 01715040144

Sample Flash Flood Outlook for the NE region

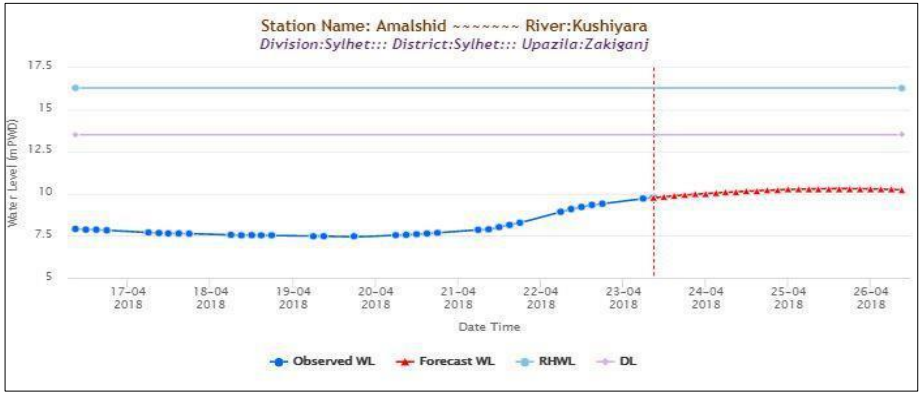
Annex-8



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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