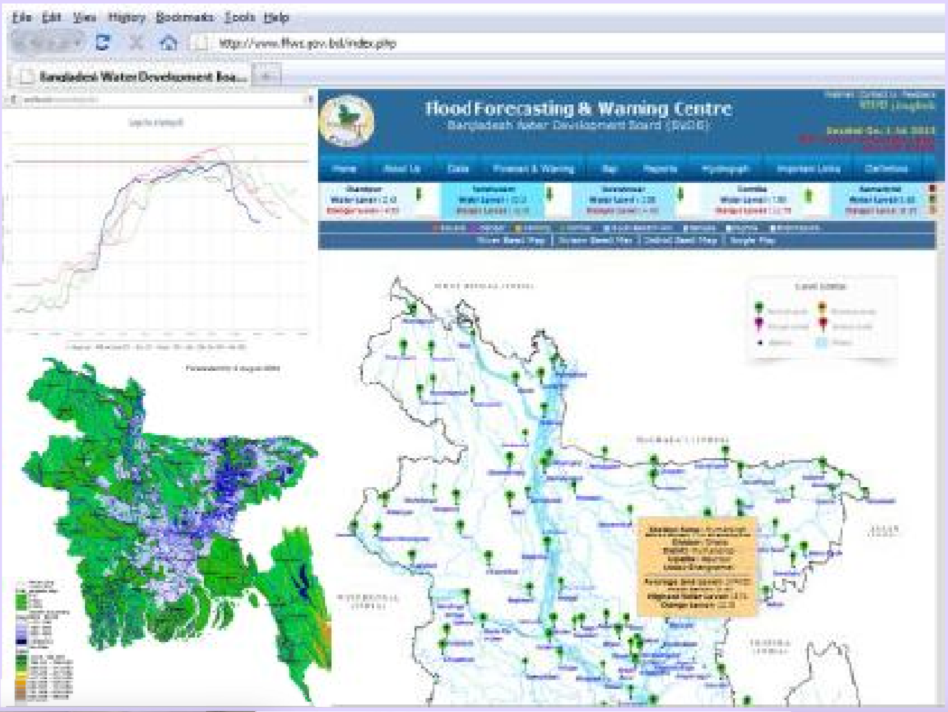
ANNUAL FLOOD REPORT 2014



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

Annual Flood Report 2014

Flood Forecasting and Warning Centre
Bangladesh Water Development Board
WAPDA Building
Motijheel C/A
Dhaka-1000

Phone : 9550755; 9553118

Fax : 9557386

Email ; ffwcbwdb@gmail.com ; ffwc05@yahoo.com

Web : *www.ffwc.gov.bd*

Compilation and Editing:
Md. Amirul Hossain, Executive Engineer, FFWC, BWDB

Contribution:

Md. Sazzad Hossain, Sub-Divisional Engineer, FFWC, BWDB

Md. Arifuzzaman Bhuyan, Sub-Divisional Engineer, FFWC, BWDB

Ripon Karmaker, Assistant Engineer, FFWC, BWDB

Review:
Md. Mosaddeque Hossain, Superintending Engineer, PFFC, BWDB

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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) and Flood Forecasting and Warning Center (FFWC) is being carried out this. The FFWC was established in 1972 and is fully operative in the flood season, from April to October every year, 7-days a week following the Standing Orders for Disaster (SOD) of the Government of the Peoples Republic 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 MoDMR, MoA, BMD, DDM, DAE etc during the 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 gratefully acknowledge the valuable advice and leadership of Director General, BWDB for his interest, continuous drive and suggestion. The valuable suggestions and encouragement provided by the ADG (Planning), Chief Engineer, Hydrology and Superintending Engineer, Processing & Flood Forecasting Circle, Hydrology, BWDB to improve the quality of works of the center.

The services of Flood Information Centers (FICs) established at the Division Offices of BWDB, Gauge Reader's, Wireless operators, local communities, NGOs 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 2014. 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.

Collaborative programmes with Regional Integrated Multi-hazard Early Warning System (RIMES), with financial support from USAID through SHHOURHADO-II programme of CARE Bangladesh, the 10-daily probability based flood forecast has been strengthening. Voice SMS, text SMS and bangle e-mail has been practiced in few locations to improve community level flood early warning dissemination. Flash Flood Guidance has been practiced in Sunamgonj and Jaliapalong, Ukhia, Coxs Bazar.

With the support from the Comprehensive Disaster Management Programme, Phase-II (CDMP-II), supported by a number of donors under UNDP, managed by the Ministry of Disaster Management and Relief, following improvement and advancements have been made;

- Deterministic flood forecast lead time extended from 3-days to 5-days and number of flood forecast points increased upto 54 locations.
- Structure based forecast for few BWDB projects and Dhaka-Mawa Highway
- Upgraded/updated easy to operate and more user friendly web-site with bangle flood warning message
- Flood warning dissemination through Interactive Voice Response(IVR) method using mobile phone(number 10941)
- Improved flood message display system in Bangla for the WAPDA Building
- Piloting Flash Flood Forecast in few stations of North Eastern zone.

Community based flood early warning generation and dissemination has been practiced during 2014 flood around Serajgonj in collaboration with Deltares(the Netherlands), RIMES and few NGOs with support from the Embassy of the Kingdom of the Netherlands, Dhaka. Evaluation was conducted how the local community benefitted using flood early warning and it indicated resources of Tk 30,000/ to Tk 150,000/ saved per person.

Using the Jason-2 satellite (a NASA-French joint initiative) data of upper catchment water elevation on the Ganges and Brahmaputra rivers, flood forecast upto 8-days lead time has been experimentally generated at 9 locations of Brahamaputra and Ganges basins. Trend of forecasted water level was found satisfactory.

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

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

Finally, I sincerely thank and acknowledge my colleagues of the FFWC whose earnest and sincere co-operation made it possible to publish this Annual Flood Report-2014.

(Md. Amirul Hossain)
Executive Engineer
Flood Forecasting & Warning Centre
BWDB, Dhaka.

Executive Summary

Considering the total area of inundation the flood 2014 may be considered as average one. The flood duration was short in places of south east and moderate in the north, north east and central part. No flash flood experienced during pre-monsoon (uto mid May). During monsoon (June to September) few places of south east and north east hit by the Flash Flood. The Brahmaputra and Meghna Basin experienced the monsoon flood from the third week of August 2014. The upper portion of Ganges Basin at all the monitoring points rivers were flowed below their respective DLs throughout the monsoon. The evaluation of flood forecast in all 54 stations based on the coefficient of determination and mean absolute error indicated that for 24hrs (1-day) forecast 98.15% for the stations are within the range of Good and Average. For 5-days forecast 59.26% stations are in the range of Good and Average for the monsoon of 2014. Specially few stations near boundary showing poor to very poor performance with low value of coefficient of correlation.

Considering the rainfall recorded at the BWDB observation points, the country as a whole received 15.6% less rainfall than normal during the monsoon-2014 (May to October). The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 25.1%, 3.2%, 15.3% and 19.8% less rainfall than the normal value respectively. The Country experienced more rainfall than the normal during the month of August and September. In October rainfall was much less than the normal. The Ganges Basin recorded more rainfall than the normal value in June. Basin wise monthly percent 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	-41.19%	-7.25%	-23.13%	-35.56%
June	-19.12%	37.46%	-11.56%	17.74%
July	-65.4%	-17.02%	-42.76%	-51.64%
August	19.6%	-3.5%	26.77%	5.1%
September	19.28%	Same	20.0%	16.98%
October	-82.2%	-68.63%	-70.67%	-68.86%

BWDB Data 2014

Professionals of the FFWC has been fully dedicated and committed to generate and disseminate flood forecasting and warning services on daily basis during the monsoon despite of limited resources, technology, short of logistics and lack of professional staff.

Extended lead time of flood forecsaat from upto 5-days, structure based flood forecast for few projects, more user friendly-upgarded-easy to operate web-site with bangla flood warning message and mobile based dissemination system known as Interactive Voice Response (IVR) has been practiced during flood of 2014. Experimental generation of flood forecast upto 8 days using sattelite data (free download) also been tried in few places of the Ganges and Brahmaputra basins, trend was found satisfactory.

During the monsoon-2014, maximum flooded area was 25% of the whole country (15,650 sq-km approximately). In few places experienced river bank errosion, flash flood and tidal flood in the coastal zone.

List of Abbreviations

ADG	Additional Director General
ADPC	Asian Disaster Preparedness Centre
BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CB	Cell Broadcast
CDMP	Comprehensive Disaster Management Programme
CEGIS	Centre for Environmental Geographical Information Services
CFAB	Climate Forecast Application Bangladesh
CARE	Cooperative for American Relief Everywhere
CFAN	Climate Forecast Application Network
DG	Director General
DL	Danger Level
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
FFWC	Flood Forecasting and Warning Centre
GM	General Model
GBM	Ganges Brahmaputra Meghna
IWM	Institute of Water Modelling
IVR	Interactive Voice Response
MAE	Mean Absolute Error
MoDMR	Ministry of Disaster Management and Relief
MODIS	Moderate-resolution Imaging Spectra-radiometer
MoWR	Ministry of Food Water Resources
NGO	Non-Government Organization
MSL	Mean Sea Level
RIMES	Regional Integrated Multi-hazard Early Warning System
SOD	Standing Order on Disaster
SSB	Single Site Band
SPARRSO	Space Research and Remote Sensing Organization
UNDP	United Nations Development Porgramme
USAID	United States Agency for International Development
WL	Water Level

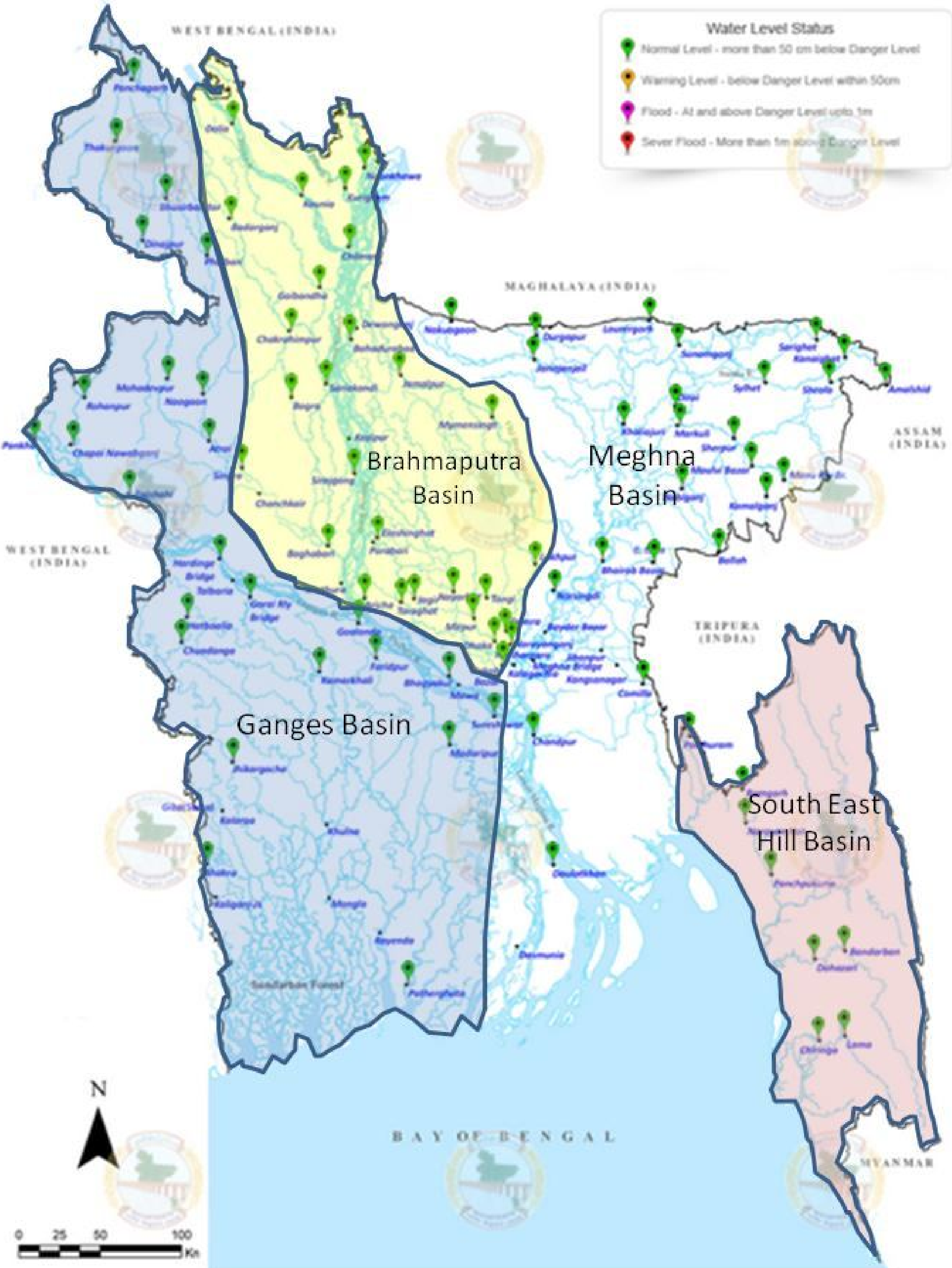


Figure 1 : Basin Map of Bangladesh with Water Level Gauge Stations

CHAPTER 1: INTRODUCTION

1.1. THE PHYSICAL SETTING

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

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

1.2. THE RIVER SYSTEM

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

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

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

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

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

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

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

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

1.3. ACTIVITIES OF FFWC

The importance of the flood forecasting and warning is recognized as a vital non-structural measures to aid the mitigating the loss of lives, crops and properties caused by the annual flood occurrence. The Flood Forecasting and Warning Centre, under the Directorate of Processing and Flood Forecasting Circle, Hydrology, BWDB carries out monitoring of 85 (73 previous and 12 added in 2014) representative water level stations and 56 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, forecast for 24, 48, 72, 96 and 120 hours at (38+16) 54 monitoring points, special flood report along with different graphical and statistical presentation during the monsoon season. The Centre is also involved in preparation of flood status report at national level, weekly bulletin during dry season bulletin, monthly and annual flood reports. The Centre is responsible as a focal point in respect of flood from the month of April to November as per Government order for generating flood forecast and warning that are issued with the flood bulletin and also provide support services to DDM, BMD and SPARRSO during cyclonic disaster.

OUTPUTS of the FFWC

- **Rainfall Distribution Map.**
- **Daily Flood Bulletin & River situation summary**
- **Forecast bulletin & Hydrograph**
- **Warning message**
- **River situation map**
- **Special outlook**
- **Structure based flood forecast**
- **Countrywide coarse flood inundation map**
- **Dhaka city flood inundation map**
- **Comparison Hydrographs for various years**

Step by step development has been made in the flood forecasting and warning services in Bangadesh, 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 coastal zone, the southern part. The Supermodel covers about 82,000 km^2 of entire country, except the coastal zone of the 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 data base management is being done with a well-managed server based (Widows 2000) LAN–Operating System installed with desk top 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 extend Lead Time upto 3-days
- Improved dissemination

2005-07 - Probabilistic medium range FF with lead time upto 10-days initiated at 18 points/locations

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

From 2012 – 14 - Strengthening and Improvement of FFWS
- FF at 54 locations on 29 rivers with Extended Lead Time upto 5-days
- Structure based FF for 4-selected projects upto 5-days lead time
- Probabilistic FF lead time upto 10-days expanded at 38 points/locations
- Improved and more user friendly web-site with Bangla language
- IVR system for dissemination based on mobile phone introduced
- Improved LAN and display

2014 – FF at 9 location with lead time upto 8 days Using free satellite (JASON - 2 of NASA) water elevation data, on pilot basis in Ganges and Brahmaputra Basins in the north, north-west and central part.

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (85 WL stations and 56 rainfall stations) is collected by SSB wireless, fixed & mobile telephone from the BWDB hydrological network. WL for non-tidal stations are collected five times daily at 3 hourly intervals during day time from 6:00 AM to 6:00 PM, and for tidal stations collected hourly. Rainfall is collected daily period beginning at 9 AM. The data collections at FFWC are usually completed by 10:30 A.M. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through internet, e-mail, and from BMD.

Essential Information's: Estimation of WL at the model boundaries and rainfall for the catchments are required input to the model upto the time of Forecast (24, 48, 72, 96 & 120hrs). For the rainfall estimation, satellite images from NOAA and IMD is used. In addition a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

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

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 and from 2013 all the mobile operators started the IVR.

The flood forecast is intended to find predicted WL at specific points few 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.

Mode of Dissemination

- E-mail
- Website
- Media, print & electronic
- Telephone, Mobile, Fax
- Hard/print copy
- Lobby display
- SMS text and voice
- (IVR) through mobile (no 10941)

1.5. NATURE AND CAUSES OF FLOODING

1.5.1. CAUSATIVE FACTORS

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

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

- *The geographic location and climatic pattern:* Bangladesh is located at the foot of the highest mountain range in the world, the Himalayas, which is also the highest precipitation zone in the world. This rainfall is caused by the influence of the south-west monsoon. Cherapunji, highest rainfall in the world, is located a few kilometers north east of the Bangladesh border
- *The confluence of three major rivers, the Ganges, the Brahmaputra and the Meghna:* the runoff from their vast catchment (about 1.72 million km^2) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are about 310 major and minor rivers in the country. The total annual runoff of surface water flowing through the rivers of Bangladesh is about 12,000 billion cubic meters.
- *Man-made environment:* the construction of embankments in the upstream catchments reduces the capacity of the flood plains to store water. The unplanned and unregulated construction of roads and highways in the flood plain without adequate opening creates obstructions to flow.
- *The influence of tides and cyclones*: the frequent development of low pressure areas and storm surges in the Bay of Bengal can impede drainage. The severity of flooding is greatest when the peak floods of the major rivers coincide with these effects.
- *Long term environmental changes:* climate changes could influence the frequency and magnitude of flooding. A higher sea level will inhibit the drainage from the rivers to the sea and increase the impact of tidal surges. Deforestation in hilly catchments causes more rapid and higher runoff, and hence more intense flooding.

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

1.5.2. STATISTICS OF FLOODING

Many parts of the Asia during monsoon frequently suffer from severe floods. Some parts of India and Bangladesh experience floods almost every year with considerable damage. The floods of 1954, 1955, 1974, 1987, 1988, 1998, 2004 and 2007 all caused enormous damages to properties and considerable loss of life. The floods of 1987, 1988 1998, 2004 and 2007 flood caused heavy damages. During the monsoon 2014, the flood was an average one and stayed for short duration in South Eastern Hill Basin-flash flood and short to medium in other three basins, the Brahmaputra, the Ganges, and the Meghna. NO flash flood hit upto May in the North East and South East. Flood affected districts (part of full, on the low-lying areas) are of Kurigram, Lalminiorhat, Nilphamary, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur, Rajbari, Faridpur, Narayangonj, Munshigonj, Madaripur, Sariatpur, Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, Brahmmanbaria, Habigonj, Chittagong, and Cox's Bazar. Percent of total area of Bangladesh affected by the flood are available since 1954 is 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	1976	28,300	19	**1998**	**1,00,250**	**68**
1955	50,500	34	1977	12,500	8	1999	32,000	22
1956	35,400	24	1978	10,800	7	2000	35,700	24
1960	28,400	19	1980	33,000	22	2001	4,000	2.8
1961	28,800	20	1982	3,140	2	2002	15,000	10
1962	37,200	25	1983	11,100	7.5	2003	21,500	14
1963	43,100	29	1984	28,200	19	2004	55,000	38
1964	31,000	21	1985	11,400	8	2005	17,850	12
1965	28,400	19	1986	6,600	4	2006	16,175	11
1966	33,400	23	1987	57,300	39	**2007**	**62,300**	**42**
1967	25,700	17	**1988**	**89,970**	**61**	2008	33,655	23
1968	37,200	25	1989	6,100	4	2009	28,593	19
1969	41,400	28	1990	3,500	2.4	2010	26,530	18
1970	42,400	29	1991	28,600	19	2011	29,800	12
1971	36,300	25	1992	2,000	1.4	2012	17,700	20
1972	20,800	14	1993	28,742	20	2013	15,650	10.6
1973	29,800	20	1994	419	0.2	2014	36,895	25
1974	52,600	36	1995	32,000	22			
1975	16,600	11	1996	35,800	24			

CHAPTER 2 : RAINFALL SITUATION

During the monsoon-2014 (May to Oct), the country experienced as a whole 15.6% less rainfall than normal. The Brahmaputra, Ganges, Meghna & South Eastern Hill basins received 25.1%, 3.2%, 15.3% and 19.8% less rainfall than the normal value respectively. Comparison of the basin and country average of normal and actual rainfall for the monsoon-2014 (May to October) is presented in the bar chart. Considering monthly value, all the basins recorded less rainfall than their respective normal during May-October period. All basins received less rainfall than their normal rainfall during the month of May, July and October. The. Monthly normal and actual rainfall of all the basins and the country average are shown in Table 2.1.

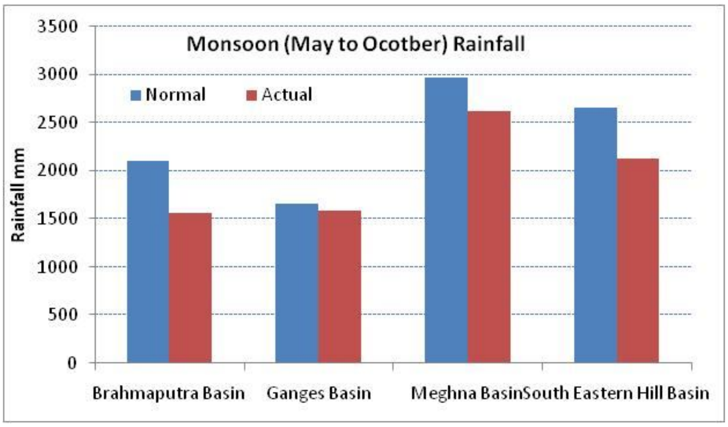


Table 2.1: Rainfall statistics for the monsoon 2014 over the four Basins

Month	Brahmaputra Basin(mm)		Ganges Basin(mm)		Meghna Basin(mm)		South Eastern Hill Basin(mm)		Monsoon average (mm)	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
May	315.4	185.5	191.8	177.9	491.0	377.5	290.4	187.14	2348.4	1981.8
June	433.5	350.6	327.0	449.5	621.0	549.2	599.8	706.3		
July	496.1	171.3	397.8	330.1	650.5	372.1	728.5	352.3		
August	346.5	414.4	330.1	318.5	566.4	718.5	536.9	564.5		
Sept	359.5	428.8	287.9	287.5	451.9	542.3	317.9	263.9		
October	155.6	27.68	120.1	37.68	194.7	57.1	183.4	57.09		
Total	2106.6	1568.6	1654.7	1589.1	2975.5	2616.7	2656.9	2131.2		
% More/ Less	25.1% less		3.2% less		15.3% less		19.8% less		15.6% less	

Rainfall situation of the country for the monsoon-2014(May to September) is described in the following sections.

2.1 MAY

<u>Important Rainfall Information for May 2014</u>

Monthly Maximum at Sheola 657.0 mm

1-day maximum at Sheola: 182.0 mm

10-day maximum at Sheola: 449.0 mm

The country, as a whole, experienced rainfall less than normal during the month of May 2014. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill recorded 41.19%, 7.25%, 23.13% and 35.55% less rainfall than their respective monthly normal value. The summery of rainfall situation of the country during May 2014 is shown in the Table 2.2.

Table 2. 2 : Summary of the rainfall situation during the month of May 2014

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	12	11	11
Average Rainfall (mm) of the basin:	175.84	165.81	377.45	187.14
%More(+)/Less(-) than the Normal:	-41.19%	-7.25%	-23.13%	-35.55%
Number of Stations above Normal Rainfall:	1	4	2	2
Highest 1-day Maximum Rainfall with Stations:	Dalia (167mm)	Panchagarh (147.50 mm)	Sheola (182mm)	Chittagong (177mm)
Number of Rain Fed Flood* Stations:	1	0	3	1

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

In Brahmaputra basin, out of 11 rainfall monitoring stations, all the stations except Dalia received less rainfall than their normal. The Basin received 41.26% less rainfall than their normal during the month May 2014.

In Ganges basin, out of 17 rainfall monitoring stations, all the stations except Panchagarh, Satkhira, Faridpur and Patuakhali received less rainfall than their normal value of the month May 2014. The basin as a whole received 13.53% less rainfall than the normal during the month May-2014.

In the Meghna basin, out of 12 rainfall monitoring stations, all the stations except Sheola and Comilla received less rainfall than their normal value of the month. At Sheola 1day maximum rainfall is recorded. The Basin received 23.13% less rainfall than their monthly normal during the month of May 2014.

In the South Eastern Hill basin, all the stations except Rangamati and Chittagong received less rainfall than their normal value of the month. The Basin received 35.55% less rainfall than their monthly normal during the month of May 2014.

Summary of the rainfall situation of the country is presented in Table 2.2. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, as many as 5 stations were crossed the threshold value in this month. Those stations are Dalia, Kanaighat, Sylhet, Sheola and Chittagong.

The Isohyets of the actual rainfall of the month of May-2014 is shown in the Figures 2.1.

2.2 JUNE

Important Rainfall Information for June, 2014

Maximum, at Chittagong : 1427.0 mm
1-day maximum, at Tangail : 270.0 mm
10-day maximum, at Chittagong : 1060.0 mm

The country, as a whole, recorded more rainfall than normal during the month of June-2014. The Ganges and South Eastern Hill basins recorded 37.46%, and 17.74% more rainfall, where the Brahmaputra and the Meghna basin recorded 19.12% and 11.56% less rainfall than their respective monthly normal rainfall during the month of June-2014. The summery of the rainfall situation for June 2014 is shown in the Table 2.3.

Table 2. 3: Summary of the rainfall situation during the month of June 2014

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	12	11	11
Average Rainfall (mm) of the basin:	350.58	449.48	549.20	706.27
%More(+)/Less(-) than the Normal:	-19.12%	+37.46%	-11.56%	+17.74%
Number of Stations above Normal Rainfall:	3	7	3	8
Highest 1-day Maximum Rainfall with Stations:	**Tangail 270mm**	Khulna **175 mm**	**Sunamganj 218 mm**	Chittagong **269 mm**
Number of Rain Fed Flood* Stations:	2	4	7	10

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

In Brahmaputra basin, out of 12 rainfall monitoring stations, three stations Dewanganj, Bogra and Tangail were recorded more rainfall than the monthly normal. The Basin received 19.12% less rainfall than their normal during the month June 2014.

All the monitoring stations in the Ganges Basin were recorded rainfall above their monthly normal except(7 stations) Dinajpur, Rajshahi, Jessore, Barisal and Patuakhali(5 stations). One day maximum rainfall of 175 mm was recorded at Khulna. Ten day consecutive maximum rainfall of 673.2 was recorded at Khulna. The Basin received 37.46% more rainfall than their monthly normal rainfall during the month of June 2014.

In the Meghna basin, out of 11 rainfall monitoring stations, all stations were recorded less rainfall than the normal except Habiganj, Chandpur and Comilla(3 stations). One day maximum of 218 mm and the 10-day consecutive maximum rainfall of 511mm recorded at Sunamganj. The Meghna basin as a whole received 11.56 % less rainfall than the normal rainfall during the month of June-2014.

In the South Eastern Hill basin, 8 rainfall monitoring stations received more rainfall than their normal rainfall for the month of June-2014 except Parshuram, Bandarban and Cox' Bazar (2 stations). One day maximum of 269 mm was recorded at Chittagong. The 10-day consecutive maximum rainfall of 1060 mm was also recorded at Chittagong. The basin as a whole recorded 17.74% more rainfall than the normal rainfall during the month of June 2014.

Summary of the rainfall situation of the country is presented in the Table 2.3. Total 23 stations in the country recorded 10-day consecutive rainfall more than 300mm. The maximum 1-day rainfall of 269 mm and the 10-day consecutive maximum rainfall of 1060.0 mm was recorded at Chittagong.

The Isohyets of the actual rainfall of the month of June-2014 are shown in the Figure 2.2.

2.3 JULY

Important Rainfall Information for July 2014
Maximum at Sunamganj: 900 mm
1-day maximum at Sunamganj: 200.0 mm
10-day maximum at Cox's Bazar: 573.0 mm

The country, as a whole, experienced rainfall less than normal during the month of July 2014. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basins received 65.4%, 17.02%, 42.76% and 51.64% less rainfall than their respective monthly normal value. The summery of the rainfall situation of the country during the month of July 2014 is shown in the Table 2.4.

Table 2. 4: Summary of the rainfall situation during the month of July 2014

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	17	12	11
%More(+)/Less(-) than the Normal:	**-65.4%**	**-17.02%**	**-42.76%**	**-51.64%**
Number of Stations above Normal Rainfall:	0	3	0	0
Highest 1-day Maximum Rainfall with Stations:	Mymensingh **70.0 mm**	Khulna **130.0mm**	Sunamganj **200.0mm**	Cox's Bazar **128.00 mm**
Number of Rain Fed Flood* Stations:	0	0	2	2
Name of Rain Fed Flood* Stations:	-	-	Durgapapur	Cox's Bazar

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

In Brahmaputra basin, all the stations received less rainfall than their normal. The Basin received 65.4% less rainfall than their normal during the month July 2014. Monthly 10-day maximum rainfall of 136.6 mm was recorded at Mymensingh.

In Ganges basin, Jessore, Khulna, Faridpur and Patiuakhali (3 stations) received less rainfall than their normal. The basin as a whole received 17.02% less rainfall than its normal during the month of July-2014. One day maximum rainfall of 200mm at Sunamgonj and 10-day consecutive maximum rainfall of 433 mm was recorded at Khulna.

In Meghna basin, all the stations recorded less rainfall than their normal value of the month. The Basin recorded 42.76 % less rainfall than their normal during the month of July 2014. One day maximum rainfall of 128 mm and ten day consecutive maximum rainfall of 573 mm were recorded at Cox' Bazar.

In South Eastern Hill basin, all the stations received less rainfall than their normal rainfall. The basin as a whole received 51.64% less rainfall than its normal rainfall during the month of July 2013. One day maximum rainfall of 128 mm and 10-day consecutive maximum rainfall of 573mm was recorded at Cox' Bazar. This rainfall caused local flood due to rainfall at the area.

Summary of the country's rainfall situation is presented in Table 2.5. Total 3 stations recorded more than 300 mm rainfall for 10-day period. Maximum 10-day rainfall recorded at Cox's Bazar of 573 mm. 1-day maximum rainfall recorded 128.0 mm in Cox' Bazar. Rain fed flood situation developed at Durgapur (Netrokona district) and Cox's Bazaar.

A map with isohyets of the actual rainfall of July-2014 is shown in the Figure 2.3.

2.4 AUGUST

Important Rainfall Information for August 2014
Maximum at Sunamganj : 1477.0 mm
1-day maximum at Sunamganj: 275 mm
10-day maximum at Sunamganj: 907 mm

The intensity of rainfall in the Brhamaputra, the Brahmaputra, the Meghna and the South Eastern Hill basin was moderate at most of the places during the month of August 2014. Out of 4 hydrological basins 3 received more rainfall and one received less rainfall than their respective monthly normal rainfall in this month. The Brahmaputra, the Meghna and the South Eastern Hill basin received 19.6%, 26.9% and 5.1% more and the Ganges basin received 3.5% less monthly rainfall than their respective normal rainfall of the month.

Table 2. 5: Summary of the rainfall situation during the month of August 2014

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	12	11	11
Basin average rainfall at August, 2014(mm):	414.4	318.5	599.1	564.5
%More(+)/Less(-) than Normal:	19.6%	-3.5%	26.77%	5.1%
No. of Stations above Normal Rainfall:	6	5	7	7
Highest 1-day Maximum Rainfall Stations:	Dalia (177 mm)	Pabna (105 mm)	Sunamganj (275 mm)	Sandwip (256 mm)
No of Rain Fed Flood* Stations:	5	0	6	8

*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 6 out of 12 rainfall monitoring stations in the Brahmaputra basin; 5 out of 12 rainfall stations in the Ganges basin; 8 out of 12 rainfall stations in the Meghna basin and 7 out 11 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Sunamganj in the Meghna Basin is the daily highest rainfall recorded station.

The Table 2.5 shows that all 5 stations in the Brhamaputra basin, 6 stations in the Meghna Basin and 8 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 Isohyets of the actual rainfall of the month of August-2014 is shown in the Figure 2.4.

2.5 SEPTEMBER

Important Rainfall Information for September 2014	
Maximum at Sunamganj	**: 1146.0 mm**
1-day maximum at Kaunia	**: 300.0 mm**
10-day maximum at Sunamganj:	**820.0 mm**

The country, as a whole, experienced rainfall more than the normal value except the South Eastern Hill basin during the month, September 2014. Among the four hydrological basins of the country, the Brahmaputra, the Ganges and the Meghna basins received 19.6%, same and 20.0% more rainfall basin received and South Eastern Hill basin received 16.98% less rainfall than their respective monthly normal rainfall during the September 2014. Table 2.6 represents the summary of rainfall situation all through the country during the month of September 2014.

Table 2. 6: Summary of the rainfall situation during the month of September 2014

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	12	12	11	11
Basin average rainfall at September,2014(mm):	428.83	287.53	512.82	263.93
%More(+)/Less(-) than Normal:	+19.6 %	same	+20%	-16.98 %
No. of Stations above Normal Rainfall:	8	2	8	4
Highest 1-day Maximum Rainfall Stations:	Kaunia (300 mm)	Dinajpur (148 mm)	Comilla (180 mm)	Cox's Bazar (140 mm)
No of Rain Fed Flood* Stations:	9	1	6	1

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

The above table shows that 8 out of 13 stations in the Brahmaputra, 2 out of 11 stations in the Ganges basin, 8 out of 12 stations in the Meghna and 4 out 11 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations in the Brahmaputra basin the daily highest rainfall recorded at Kaunia. The monthly maximum rainfall recorded at Sunamgonj 1146.0mm, exceeded its previous maximum for September-2014(previous max 1130.0mm).

The table also shows that all the nine stations in the Brahmaputra basin, one station in the Ganges Basin, six stations in the Meghna basin and one station in the South Eastern Hill basin received more than 300 mm rainfall in 10-day period. As a result, some parts of Kurigram, Lalmonirhat, Jamalpur, Rangpur, Dinajpur, Khulna, Sunamganj, Sylhet, Habiganj, Moulvibazar, Netrokona were affected by rain feed flood during the month of September 2014. It is to be mentioned here that 300 mm or more rainfall in 10-Day period may cause rain fed flood.

The Isohyets of actual rainfall for September-2014 is shown in the Figure 2.5.

2.6 OCTOBER

All the four hydrological basins of the country received less rainfall than their monthly normal in October-2014. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill Basins received 82.20 %, 68.63%, 70.67% and 68.86% less rainfall than their monthly normal rainfall respectively during October-2014. At Sunamganj the 1-day maximum rainfall recorded 90 mm in October 2014. The summary of the rainfall for the month of October-2014 is presented in Table 2.7

Important Rainfall Information for October 2014
Monthly Maximum at Patuakhali : 128.5 mm
1 day maximum at Patuakhali: 93.6 mm
10 day maximum at Faridpur: 128.0 mm

Table 2. 7: Summary of Rainfall for the month of October-2014

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	12	12	11	11
Average Rainfall (mm) of the basin:	27.68	37.68	57.10	57.09
%More(+)/Less(-) than the Normal:	**82.20 % less**	**68.63 % less**	**70.67 % less**	**68.86 % less**
Number of Stations above Normal Rainfall:	-	-	-	-
Highest 1-day Maximum Rainfall with Stations:	Bogra 85.5 mm	Faridpur 47.5 mm	Sunamganj 90 mm	Panchpukuria 45 mm
Number of Rain Fed Flood* Stations:	0	0	0	0

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

In Brahmaputra basin, out of 12 rainfall monitoring stations, all stations recorded less rainfall than the normal and The Basin received 82.2% less rainfall than their normal during the month October 2014. At Dewanganj Station, no rainfall recorded in the month of October-2014.

In Ganges basin, out of 12 rainfall monitoring stations, all stations except Faridpur recorded less rainfall than the normal rainfall of the month. The basin as a whole received 68.63% less rainfall than the normal during the month of October-2014.

In the Meghna basin, out of 11 rainfall monitoring stations, all stations recorded less rainfall than the normal value of the month. The Basin received 70.67% less rainfall than their monthly normal during the month of October 2014.

In the South Eastern Hill basin, all rainfall monitoring stations received less rainfall than their normal rainfall. The Basin as a whole recorded 68.86% less rainfall than the normal rainfall during the month October 2014.

A map with the Isohyets of actual rainfall for the month of October-2014 is shown in the Figure 2.6.

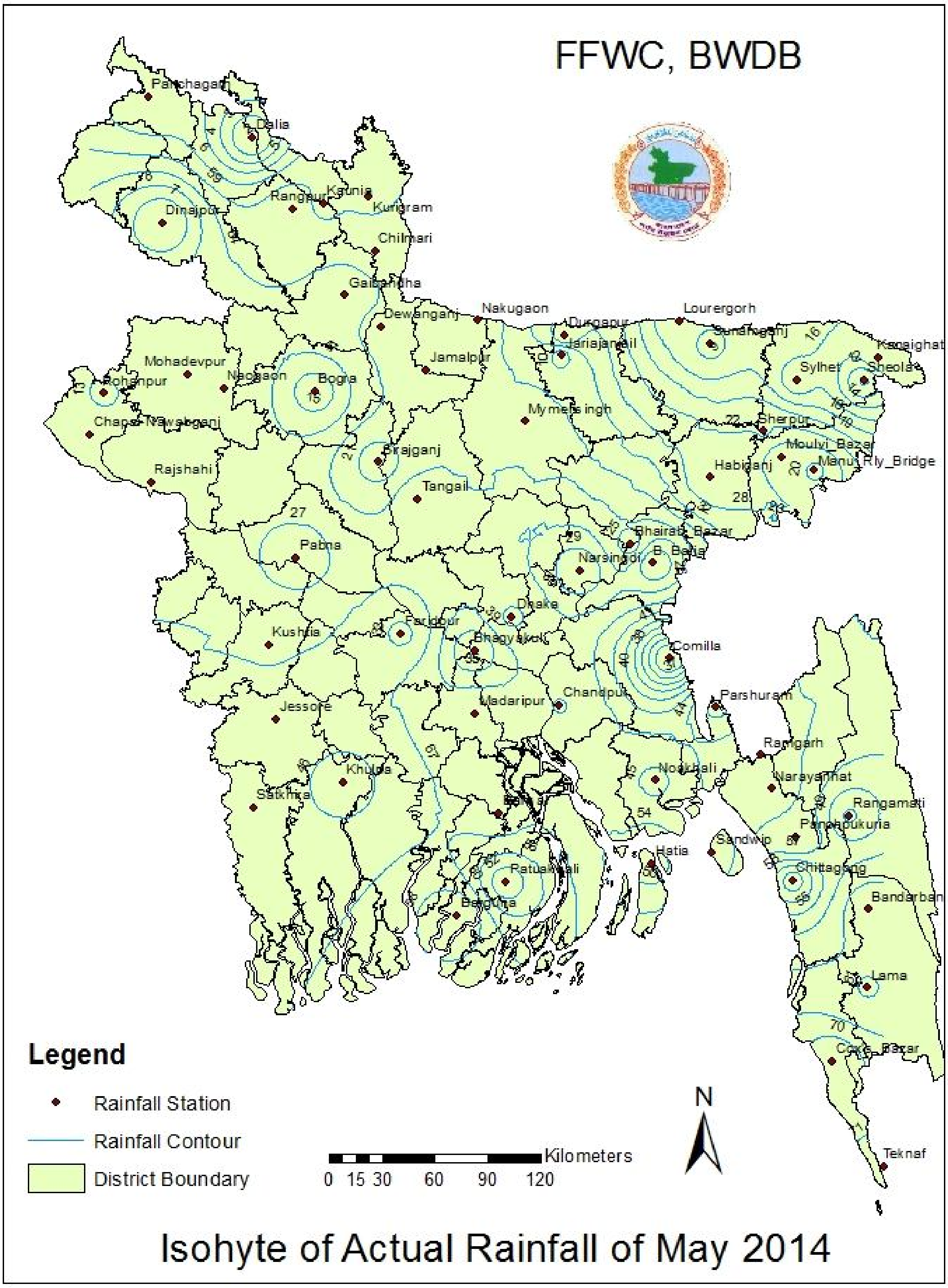


Figure 2.1 : Isohyets of Actual Rainfall (May 2014)

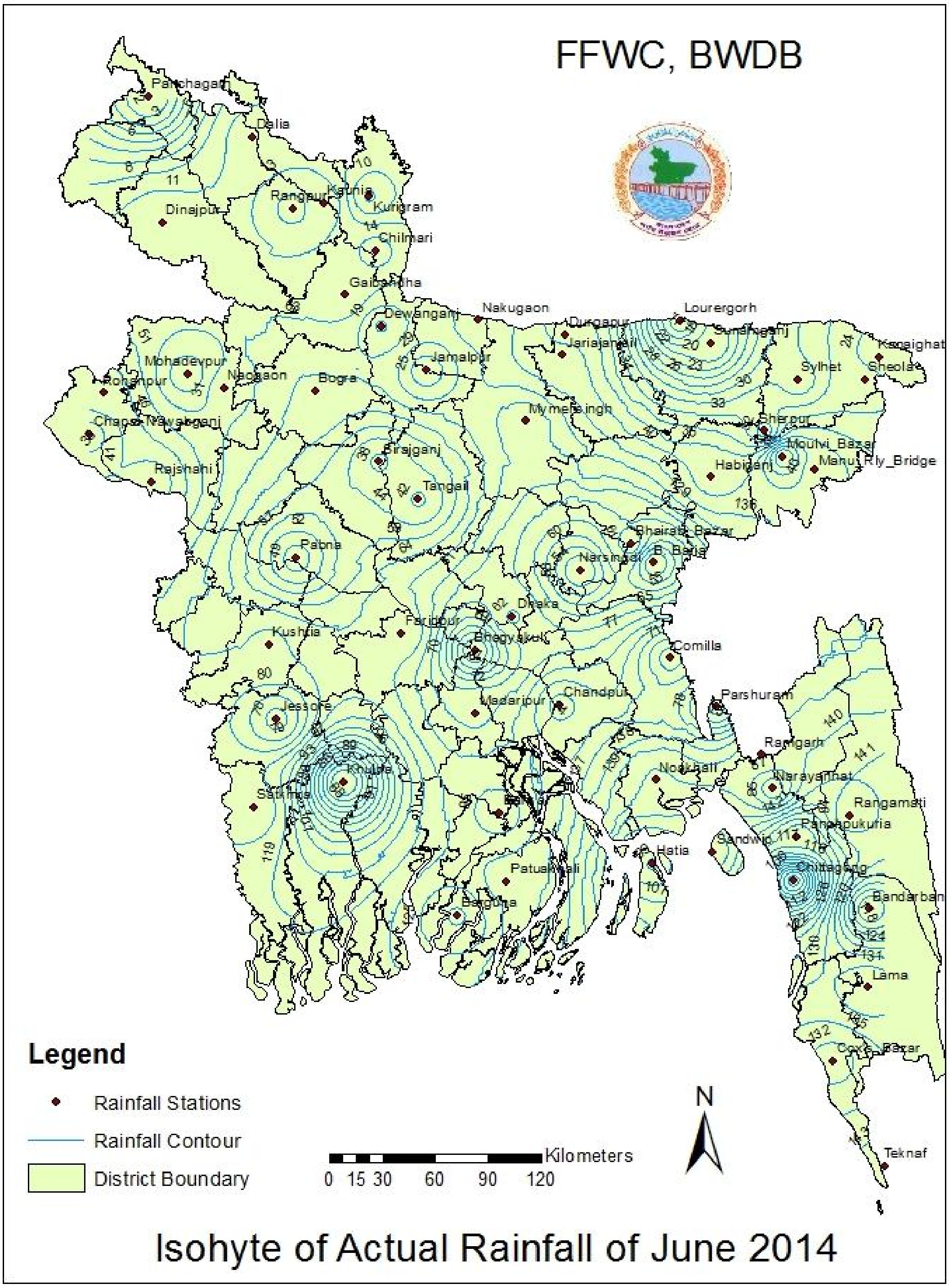


Figure 2.2 : Isohyets of Actual Rainfall (June 2014)

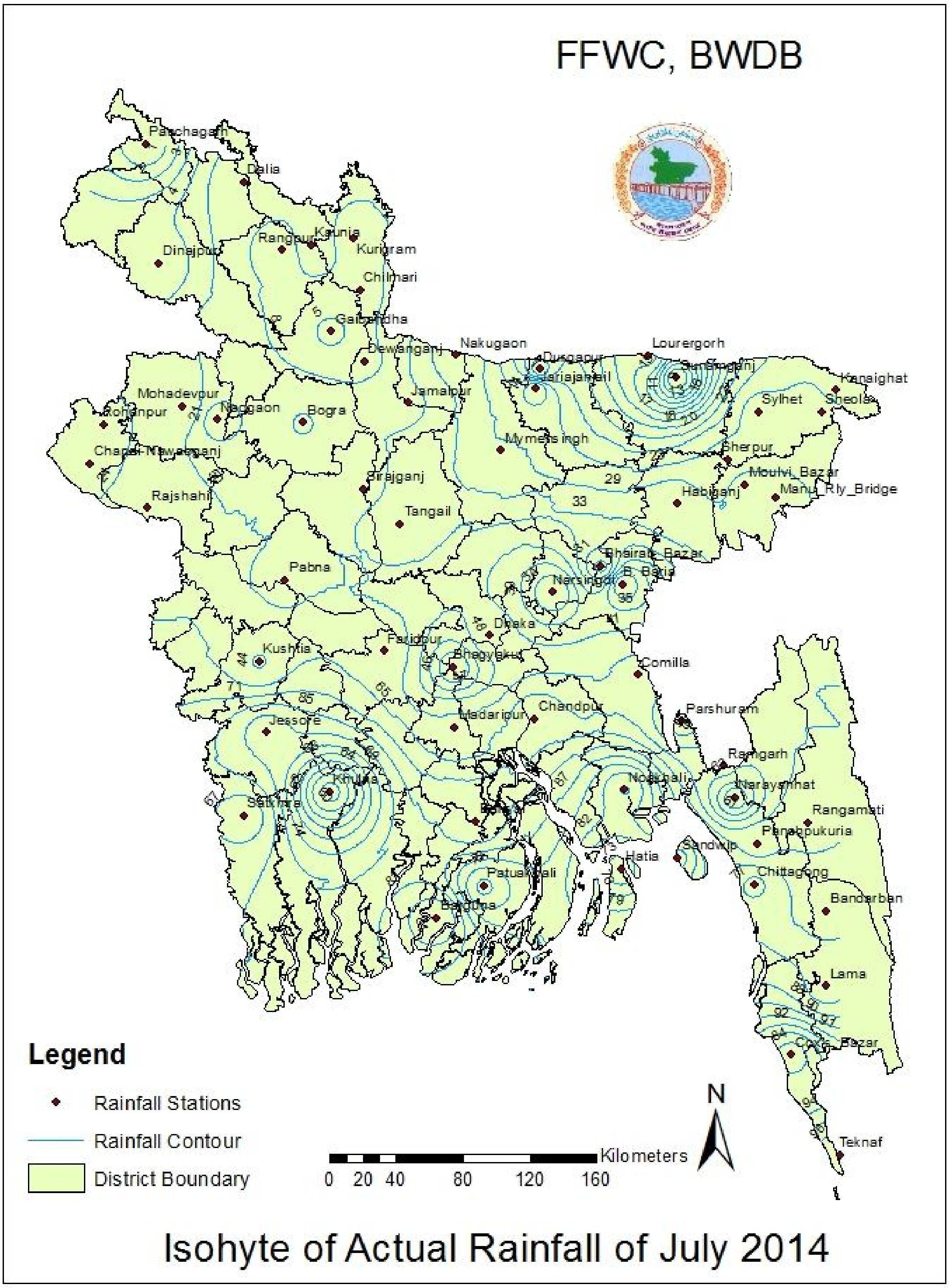


Figure 2.3 : Isohyets of Actual Rainfall (July 2014)

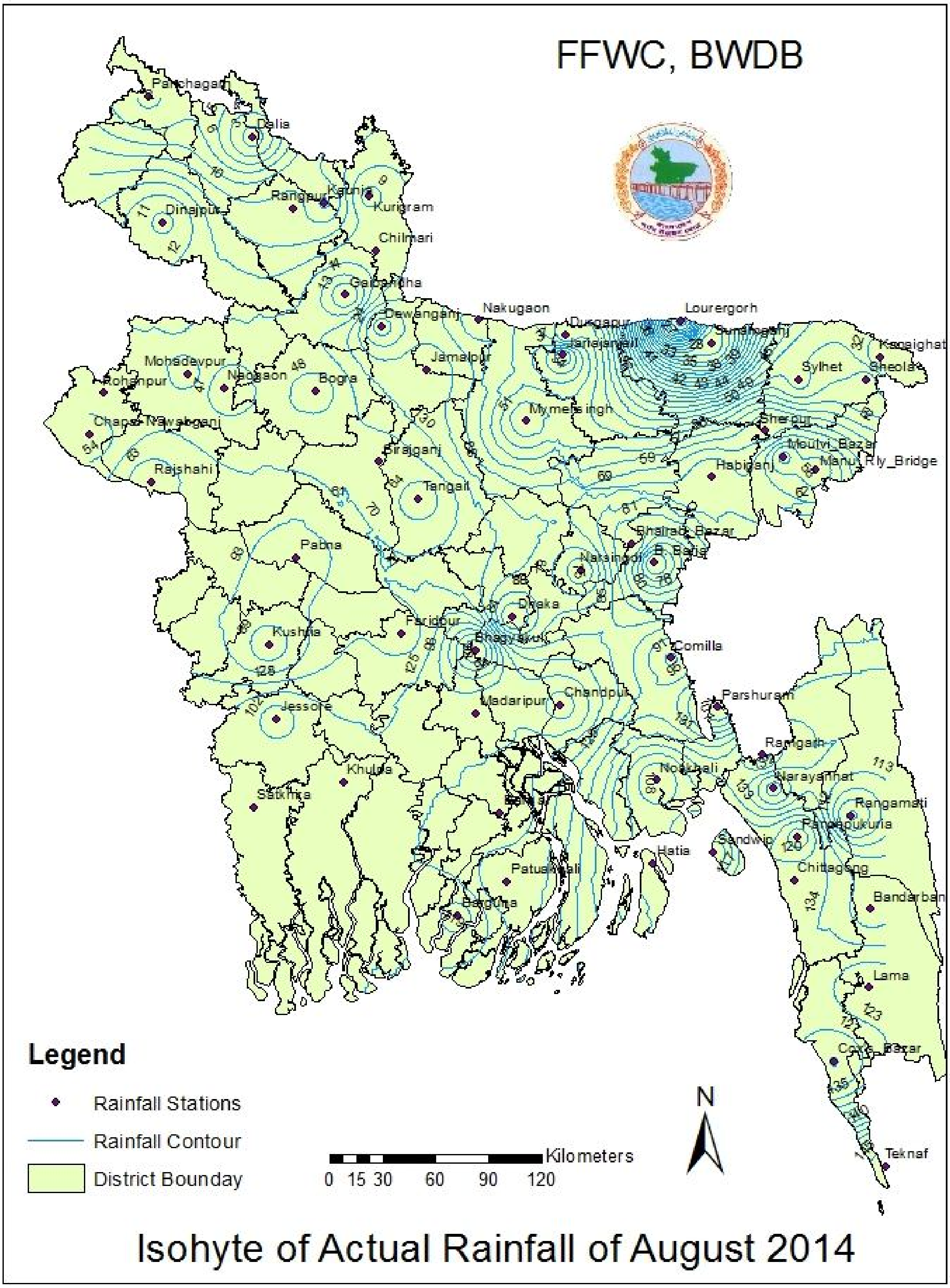


Figure 2.4 : Isohyets of Actual Rainfall (August 2014)

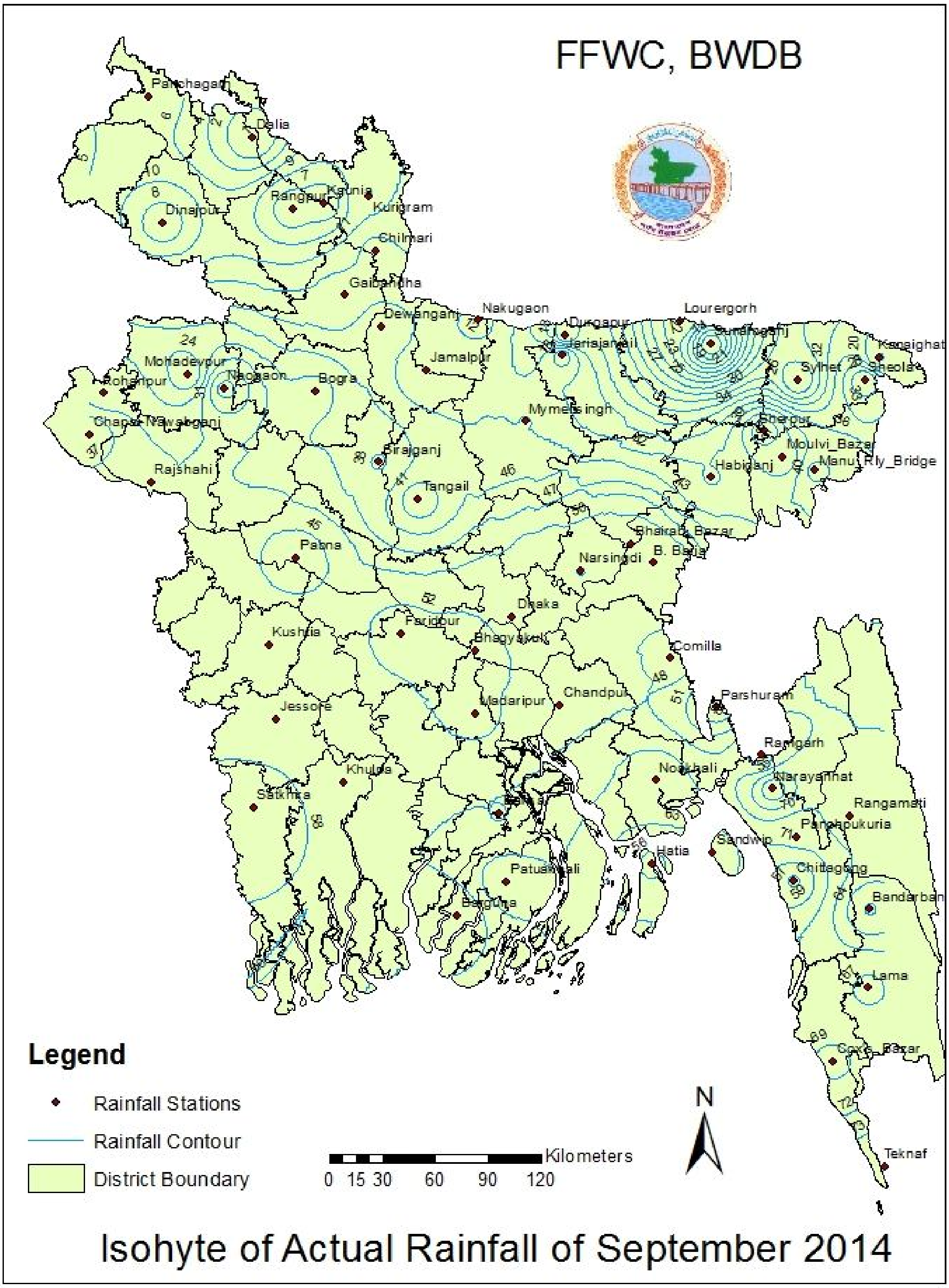


Figure 2.5 : Isohyets of Actual Rainfall (September 2014)

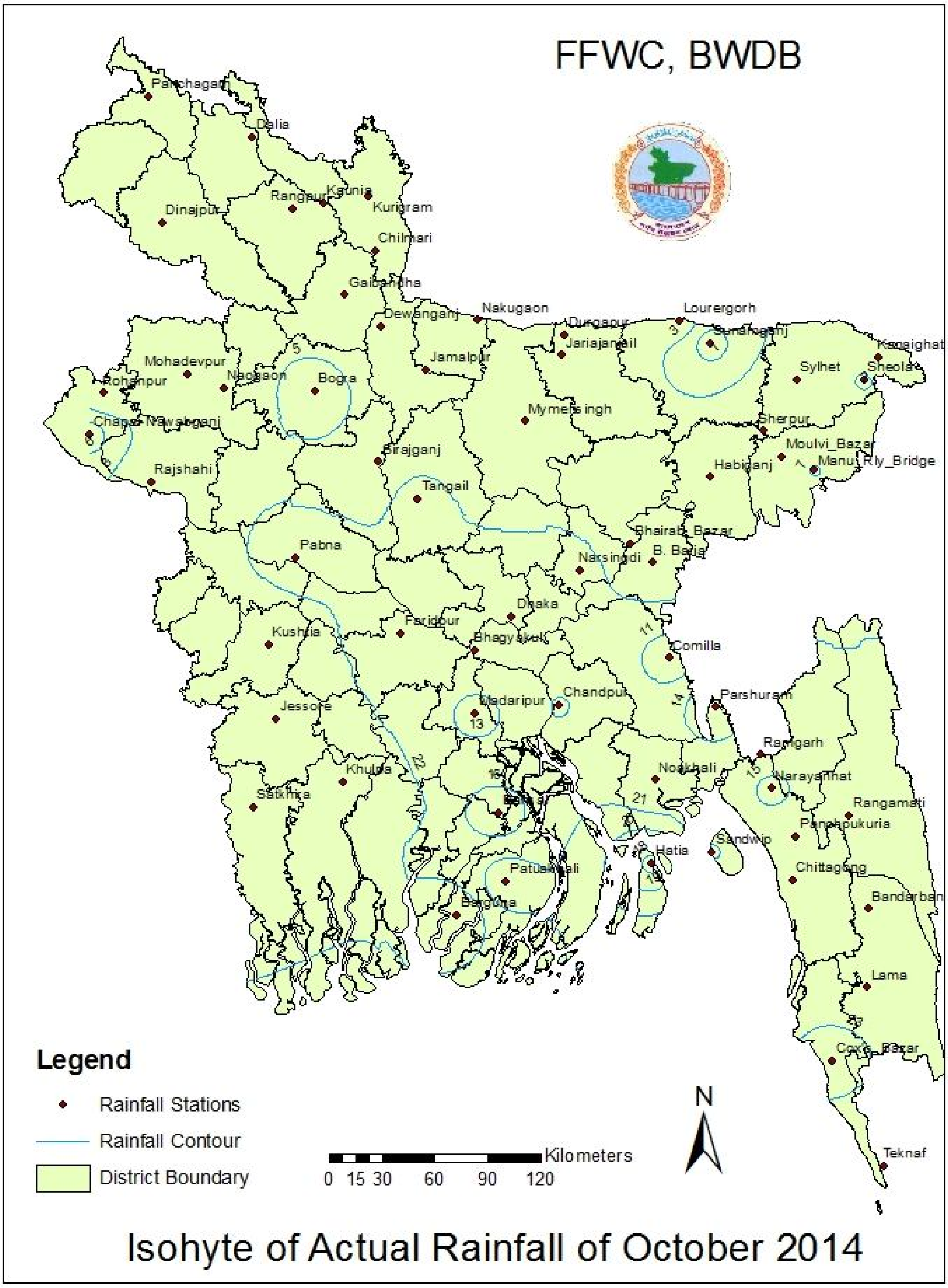


Figure 2.6 : Isohyets of Actual Rainfall (October 2014)

CHAPTER 3 : RIVER SITUATION

Considering the total area of inundation during the flood 2014 may considered as average one. The flood duration was short in places of south east and moderate in the north, north east and central part. No flash flood experienced during pre-monsoon (uto mid May). The Brahmaputra and Meghna Basin experienced the monsoon flood from the third week of August 2014. The upper portion of Ganges Basin at all the monitoring points rivers were flowed below their respective DLs throughout the monsoon. Basin wise WL situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 28 Water Level (WL) monitoring stations in this basin, at 17 stations river WL was crossed their respective Danger Levels (DL). Water Level of Brhamaputra Basin started to rise from the second week of August 2014 and caused a medium duration of flood for this basin. This flood situation lasted 1 to 15 days for the basin. As a result, low-lying areas of Kurigram, Lalminiorhat, Nilphamari, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur, Madaripur, Shariotpur, Manikgonj, Munshignj, Rajbari, Faridpur, Shylhet, Sunamganj, Netrokona and Narayangonj districts were flooded for short to medium period of flood. A comparative statement of WL for current year 2014 and historical events of 1988 and 1998 for the Brahmaputra Basin is shown in the Table 3.1. The details of the river situation in this basin are described in the following sections:

The Dharla at Kurigram

The WL of Dharla river at Kurigram registered its monsoon peak during the monsoon 2014, in last week of August. It crossed the DL once during the monsoon 2014 and flowed above DL for 4 days. WL at Kurigram attained peak of 26.95mPWD on 28th August at 12:00 hours, which was 45 cm above the DL (26.50 m).

The Teesta at Dalia and Kaunia

The Teesta river is flashy in nature. The WL of river Teesta showed several peaks during the monsoon both at Dalia and Kaunia. At Dalia WL crossed its DL mark for 11 times during the monsoon (once in June, four times in July, four times in August and twice in September), highest peak on 27th August of 52.74mPWD, which was 34cm above its DL (52.40m). At Dalia it flowed above DL for 20 days throughout the monsoon period. At Kaunia WL of the river Teesta did not cross the DL during the mosoon-2014, attained the peak of 28.95m on 27th August which was 105cm below the DL(30.0m) at this point.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha crossed the DL at 18th August 2014 and flowed above the DL for 14 days between 18th August to 1st September with peak of 22.36 m on 10th July, which was 66cm above its DL(21.70m).

The Jamuneswari at Badargonj

The Jamuneswari at Badargonj didn’t cross the DL and attained the peak of 31.56 mPWD (DL 32.16m) on 23rd September at 6:00 hours. During the whole monsoon this station was recorded with other several low peaks.

The Brahmaputra at Noonkhawa and Chilmari

The river Brahmaputra at Noonkhawa and Chilmari observed sharp rise and fall at several times. At Noonkhawa WL of the Brhamaputra river attained the peak of 27.25mPWD on 28th August at 09:00 hours, which was at the DL (27.25mPWD) at this point. At Chilmari, Water level crossed the Dl at 18th August and continued to flow above DL up to 23th August. Just after one day, water level again crossed the DL at 25th August and continued to flow above Dl for rest of the month. At Chilmari, the water flowed above the DL for 13 days and the peak WL of the Brahmaputra river was recorded 24.49mPWD on the 28th August-2014, which was 49cm above its DL(24.00m).

The Jamuna at Bahadurabad, Sariakandi, Serajgonj and Aricha

The WL of river Jamuna at Bahadurabad, Sariakandi, Serajgonj & Aricha demonstrated similar trends as Brahmaputra at Noonkhawa and Chilmari. At Bahadurabad the Jamuna flowed above DL for 14 days from 18th August to 31st August, with the peak of 20.21mPWD on 29th August, which is 71cm above the DL(19.50m) at this point. At Sariakandi the Jamuna flowed above the DL from 16th August to 4th September, for 20 days, with a peak of 17.69mPWD on 29th August 12:00 hours, which was 99 cm above the DL (16.70 m). At Serajgonj the Jamuna flowed above DL from 16th August to 4th September for 15 days with peak of 13.79mPWD, on 29th August at 15:00hrs, which is 44cm above the DL(13.35m). At Aricha the WL of the Jamuna river crossed the DL with peak WL of 9.58mPWD on 29th August, which was 18cm above the DL(9.40m) and remained above DL for 11 days.

The Atrai at Baghabari

The WL of river Atrai at Baghabari flowed above DL for 19 days from 18th August to 5th September 2014, with the peak of 11.53mPWD on 31st August, which is 113cm above the DL(10.40m) at this point.

The Dhaleswari at Elashin

The WL of river Dhaleswari at Elashin flowed above DL for 19 days from 19th August to 6th September 2014, with the peak of 12.31mPWD on 31st August, which is 191cm above the DL(10.40m) 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, but remained below the respective DLs at both the stations. At Jamalpur the peak WL recorded of 16.33mPWD on 1st September which is 67cm below the DL at this point(DL 17.0m). At Mymensingh the peak WL recorded was 11.25mPWD on 6th September, which was 125cm below the DL (12.5m) at this point.

The Lakhya at Lakhpur and Narayanganj

The WL of Lakhya river at Lakhpur and Narayanganj showed a similar trend to that of the Buriganga and crossed their respective DLs. The Lakhya river at Lakhpur crossed their respective DL twice at 25th August and continued to flow above DL up to 12th September for 25 days and again crossed the DL from 26th September to 30th September for 5 days. It attained its monsoon peak of 6.75mPWD 1st September, which 95cm above the DL (DL 5.8m). Lakhya river at Narayanganj crossed their respective DL at 27th August and continued to flow above DL up to 7th September for 14 days. It attained its monsoon peak of 5.90mPWD 1st September, which 40cm above the DL (DL 5.5m).

The Rivers around Dhaka

Stations near or around Dhaka city like Buriganga at Dhaka, and the Turag at Mirpur attained the peak of the monsoon during the August and September in this year. Except Mirpur, all the river around Dhaka city flow Flowed below their respective DLs. The Buriganga at Dhaka, and the Balu at Demra recoded their highest peak of 5.11 mPWD (DL 6.0m) on 31st August, 5.54m (DL 5.75m) on 1st September 2014 respectively. The Turag at Mirpur crossed its respective DL at 31st August and continued to flow above DL for 4 days up to 3rd September, with a peak of 6.0 mPWD which is 6cm above the DL (5.94 mPWD).

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 crossed the DL at 28th August and continued to flow above DL up to 5th September for 9 days with peak of 8.81 m on 2nd September, which was 41 cm above its DL(8.40 m) at Taraghat.

Comparative hydrographs for the year of 2014, 2007 & 1998 of few stations of the Brahmaputra basin are shown in Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12 and 3.13.

Table 3. 1 : Comparison of Water Level of 2014 and Historical Events of 1988 & 1998 of Some Important Stations in the Brahmaputra Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2014	1998	1988	2014	98	88
1	Dharla	Kurigram	27.66	26.50	26.95	27.22	27.25	4	30	16
2	Teesta	Dalia	52.97	52.40	52.74	52.20	52.89	20	-	8
3	Teesta	Kaunia	30.52	30.00	28.95	29.91	30.43	-	-	38
4	Jamuneswari	Badargonj	33.00	32.16	31.56	33.00	32.80	-	6	5
5	Brahmaputra	Noonkhawa	28.10	27.25	27.25	27.35	NA	1	-	NA
6	Brahmaputra	Chilmari	25.06	24.00	24.49	24.77	25.04	13	22	15
7	Ghagot	Gaibandha	22.81	21.70	22.36	22.30	22.20	14	51	17
8	Jamuna	Bahadurabad	20.62	19.50	20.21	20.37	20.62	14	66	27
9	Jamuna	Serajgonj	15.12	13.35	13.79	14.76	15.12	13	48	44
10	Jamuna	Aricha	10.76	9.40	9.58	10.76	10.58	11	68	31
11	Old Br.putra	Jamalpur	18.00	17.00	16.33	17.47	17.83	-	31	8
12	Old Br.putra	Mymensingh	14.02	12.50	11.25	13.04	13.69	-	33	10
13	Buriganga	Dhaka	7.58	6.00	5.11	7.24	7.58	-	57	23
14	Lakhya	Narayangonj	6.71	5.50	5.90	6.93	6.71	14	71	36
15	Turag	Mirpur	8.35	5.94	6.00	7.97	NA	4	70	NA
16	Tongi Khal	Tongi	7.84	6.08	5.72	7.54	NA	-	66	NA

3.2 THE GANGES BASIN

In this basin out of 23 WL monitoring stations, 4 stations exceeded their respective DLs, during the monsoon 2014. The rivers flowed above DL are Little Jamuna at Naogaon for 5 days, Padma at Goalondo for 13 days, at Bhagyakul for 11 days and at Sureswar for 17 days. The low lying areas of Rajbari, Faridpur, Panchagr, Thakurgain, Dinajpur, Manikgonj, Munshigonj, Sariatpur and Noagaon districts was affected by normal flooding during the month of August and September for short ot medium periods. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul and Goalundo. All other rivers flowed below their respective DLs. A comparative statement of WL for 2014 and historical events of 1998 & 1988 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below:

The Karatoa at Panchagarh

The karatoa river at Panchgarh showed a sharp rise and fall during the monsoon and didn't cross the DL with a peak flow of 69.6 mPWD at 9th June, which was 115 cm below the respective DL (70.75 m)

The Punarbhaba at Dinajpur

The WL of river Punarbhaba at Dinajpur showed sharp rise and fall during the monsoon, but did not cross the DL in the flood season of 2014. The peak WL of 31.47mPWD was recorded on 27th August, which was 203cm below of its DL (33.50m).

The Tangon at Thakurgaon

The Tangon river is flashy in nature and showed various small peaks during the monsoon but never crossed its respective Danger Level with highest peak of 49.49mPWD on 22th Sptember 6:00 hours, which was 91 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 (Upazila – Chirirbandar, District –Dinajpur) also showed similar trend of Punarbhaba, did not cross the DL. It had a peak value of WL 38.92mPWD on 23th September at 06:00hour, which was 70cm below the DL(39.62m). The Atrai at Mohadevpur (Noagaon District) also flowed below the DL with peak of 17.07mPWD on 24th September, which is 253cm below the DL(19.6m).

The Mohananda at Chapai-Nawabgonj

This river showed a gradual rise and fall in water level throughout the monsoon and did not cross the DL. It attained its peak of 20.09m on 21st August at 6:00 hours, which was 91cm below its DL (DL21.00m) at Chapai-Nawabgonj.

The Little Jamuna at Naogaon

The Little Jamuna river at crossed its respective Danger Level for 5 days, 24th September to 28th September 2014, with highest peak of 15.71mPWD on 25th Sptember 6:00 hours, which was 47 cm above the Danger level (15.24 m).

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

The river at Pankha showed a gradual rise and fall in the whole season of flood in 2014 but did not cross the respective DL. At Pankha the peak of 20.94m during the day of 21st August, which was 156 cm below the DL (22.50m) at this point. At Rajshahi, the Ganges showed nearly similar trend as at Pankha and also flowed below its respective DL. It attained its peak of 17.45m on 22th August at 15:00 hours, which was 105cm below its DL (DL18.50m) at Rajshahi. At Hardinge Bridge, water level did not cross the respective Danger Level and it attained its peak of 13.31m on 22th August, which was 94 cm below its DL (14.25m) at this point.

The Ganges/ Padma at Goalundo

At Goalondo river WL started to rise in month of September and it flowed above the DL for 13 days from 21st August to 2nd September 2014. The WL of the river Padma at Goalondo attained its yearly peak of 8.92mPWD on the 31st August, which was 27 cm above its DL (8.65m) at this point.

The Padma at Bhagyakul and Sureswar

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma crossed the DL on 23th August to 2nd September for 11 days. The WL of the river attained its highest yearly peak water level of 6.57 mPWD on 31st August, which was 27cm above the DL (6.30m) at Bhagyakul. The Padnma at Sureswar crossed the DL for 17 days in the month of August and September 2014. At sureswar point, the WL crossed the DL thrice, 23th August to 31th August for 9 days, 1st and 2nd September for 2 days, 5th September to 10th September for 6 days. The WL of the river attained its highest yearly peak water level of 4.85 mPWD on 1st September, which was 40cm above the DL (4.45m) at Sureswar.

The Gorai at Gorai Railway Bridge and Kamarkhali

The WL of river Gorai at Gorai Railway Bridge and Kamarkhali showed steady rise during July to September in the monsoon-2014. 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 11.76 mPWD on 24th of August, which was 99cm below the DL (12.75m) at Gorai Rail Bridge. Gorai river at Kamarkhali did not cross the DL. The WL of the river attained its highest yearly peak of 7.78 mPWD on 24th of August, which was 44cm below the DL (8.20m) at Kamarkhali station.

The Arialkhan at Madaripur

At Madaripur the WL of the river Arialkhan showed similar trend of rise and fall of the river Padma. The WL of Arialkhan at Madaripur flowed below the DL. The WL attained its highest peak of 3.76 m on the 1st of September, which was 41cm below the DL (4.17m) at Madaripur.

Comparative hydrographs for few important stations for the year of 2014, 2007 & 1998 of the Ganges basin are shown in figures 3.14 to 3.20.

Table 3.2 : Comparison of Water Level of 2014 and Historical Events of 1988 & 1998 of Some Important Stations in Ganges Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger Level		
					2014	1998	1988	2014	98	88
1	Punarbhaba	Dinajpur	34.40	33.50	31.47	34.09	34.25	-	3	4
2	Ganges	Pankha	22.97	22.50	20.94	24.14	NA	-	66	NA
3	Ganges	Rajshahi	20.00	18.50	17.45	19.68	19.00	-	28	24
4	Ganges	Hardinge Bridge	15.04	14.25	13.31	15.19	14.87	-	27	23
5	Padma	Goalundo	10.01	8.50	8.92	10.21	9.83	13	68	41
6	Padma	Bhagyakul	7.58	6.00	6.57	7.50	7.43	11	72	47
7	Gorai	Gorai Rail Bridge	13.65	12.75	11.76	13.45	13.65	-	25	25
8	Gorai	Kamarkhali	9.48	8.20	7.78	NA	NA	-	NA	NA
9	Arialkhan	Madaripur	5.80	4.17	3.76	NA	NA	-	NA	NA
10	Kobodak	Jhikorgacha	5.59	4.11	4.09	NA	NA	-	NA	NA

3.3 THE MEGHNA BASIN

Many rivers of this basin entered from the hilly catchment of India and are flashy in nature. Out of 25 WL monitoring stations in the Meghna basin, at 16 stations flowed above their respective DLs, these are Surma River at Kanaighat, Sylhet and Sunamganj, Kushyara River at Sheola and Sherpur, Sarigowain river at Sarighat, Khowai river at Habigonj and Bullah, Dhalai river at Kamalgonj, Old Surma river at Derai, Baulai river at Khaliajuri, Bhugai river at Nakuagaon, Jadukata river at Lorergarh, Someswari river at Durgapur, Kangsha River at Jariajanjail and Titas river at Brahmanbaria for less than 1 day to 13 days. As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2014.

Comparative statement of WL and days flowed above the DL for 2014 and historical events of 1998 and 1988 for this basin for selected stations are shown in Table 3.3.

The Surma at Kanaighat

As a flashy river, WL of the river Surma at Kanaighat (Sylhet district) showed several peaks during the monsoon-2014. WL flowed above its DL at Kanaighat during 23th June for less than one day, 16^{th} August to 27^{th} August for 11 days and 25^{th} Septmber to 28^{th} September for 4 days and flowed total more than 15 days above DL. It attained its highest peak of 13.99mPWD on 18^{th} August at 06:00 hours, which was 79cm above the DL(13.20 m) at Kanaighat.

Surma at Sylhet

The WL of river Surma at Sylhet crossed the DL for one day at 26^{th} August 2014 and it showed the similar trend as Kanaighat. It attained the monsoon with peak WL of 11.35mPWD on 26^{th} August 9.00 hours, which was 10cm above its DL (11.25m).

The Surma at Sunamgonj

The WL of the river Surma at Sunamgonj crossed the DL four times at 23rd June for one Day, 8th July to 11th July for 4 Days, 15th August to 29th August for 15 days and 23th September to 29th September for 7 days in total 27 days in this monsoon-2014. The WL of Surma at Sunamgonj recorded its highest peak of 9.18mPWD on 25th August, which was 93cm above its DL (8.25m).

The Kushiyara at Sheola and Sherpur

The Kushiyara river at Sheola and Sherpur (Sylhet district) observed similar rise and fall trend throughout the monsoon 2014. At Sheola it flowed above the DL for 1 day at 9th September. It attained its highest peak of 13.55 mPWD on 9th September at 15:00hrs, which was 5 cm above its DL (13.50 m). At Sherpur the river flowed with a gradual rise and fall trend and crossed the DL several times in the month of August and September in this monsoon. It remained above DL for total 11 days where 3 days in August and 8 days in September. It attained its yearly highest peak of 9.18mPWD on 25th August, which was 18cm above its DL (9.00 m).

The Sarigowain at Sarighat

As the flashy river the Sarighat on Saigowain river in Netrokona district, showed several peaks during the monsoon 2014 and crossed the respective DL for 5 times in the month of July (once), August (twice) and September(twice). It attained monsoon highest peak of 13.3mPWD on 6th October at 18:00hours, which was 50cm above its DL (12.80 m).

The Manu at Manu Railway Bridge and Moulvi Bazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvibazar observed several peaks during the monsoon-2014. The WL of Manu river did not cross the DL at Manu Railway Bridge with a peak flow of 17.85mPWD, which is 15 cm below the DL(18.0mPWD). At Moulvibazar the WL of Manu didn’t cross the DL, flowed with peak of 11.58mPWD, which was 17cm below its DL(11.75m) at this point.

The Khowai at Habigonj and Bullah

As the flashiest river in Bangladesh, the Khowai at Habigonj showed several peaks during the monsoon 2014, The WL at Habigonj crossed its DL twice for 2 days in 22nd and 23rd June and 15th August for one day. The WL recorded its yearly highest peak of 10.8 m on 23rd June, which was 130 cm above its DL (9.50m). At Ballah the WL of Khowai crossed the DL 8 times and flowed above DL with peak of 24.57 m on 30th August at 15:00 hours, which is 293cm above the DL (21.64m).

The Dhalai at Kamalgonj

The WL of the flashy river Dhalai at Kamalganj flowed above its DL thrice for 2 days in month of May and once in September with monsoon peak of 20.25mPWD on 4th August at 6:00hours, which was 43 cm above its DL(19.82m) at this point.

The Old Surma at Derai

As the flashy river, the Derai on Old Surma crossed the DL thrice in the monsoon period with monsoon highest peak of 7.3 mPWD on 28th August at 18:00hours, which was 30cm above its DL (7.0 m). It flowed above DL for 23 days in the month of July, August and September.

The Bhugai at Nakuagaon

As flashy river the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks during the monsoon 2014. It flowed above its DL for 2 days at 8th and 9th July, 3 days at 12th, 14th, and 16th August and 3 days at 22nd, 23rd and 26th September in the monsoon 2014. It attained monsoon highest peak of 24.91mPWD at 8th July 18.00 hours, which was 251cm above its DL (22.40m) at this point.

The Jadukata at Lorergarh

As the flashy river the lorergarh in Netrokona district, showed several peaks during the monsoon 2014, crossed its DL for four times for 1 day at 9th July, for 4 days at 13th, 14th, 24th and 25th August and for 2 days at 22nd and 23rd September. It attained monsoon highest peak of 10.74mPWD on 23rd September at 18:00hours, which was 221cm above its DL (8.53 m).

The Someswari at Durgapur

As the flashy river the Durgapur in Netrokona district, showed several peaks during the monsoon 2014, crossed its DL for several times and flowed above DL for 9 days in the month of July, August and September. It attained monsoon highest peak of 15.5mPWD on 23th September at 18:00hours, which was 250cm above its DL (13.0 mPWD).

The Kangsha at Jariajanjail

As flashy river the Kangsha at Jariajanjail in Netrokona district showed several peaks during the monsoon 2014, crossed the DL several times and remained above DL for total 54 days in the monsoon period where 8 days in June, 11 days in July, 16 days in August, 16 days in September and 3 days in October. It attained its yearly highest peak of 12.15 mPWD on 23th September at 15:00hours, which was 240cm above its DL (9.75mPWD).

The Titas at Brahmanbaria

The Titas River at B. Baria point started to flow at above its DL twice for 17 days, once from 24th August to 9th September and again for 2days from 29th and 30th September with monsoon peak of 5.96 mPWD on 31st August at 18:00hours, which was 46cm above its DL (5.5 mPWD) at this point. At this point the river remained above DL for 19 days during August and September-2014.

Comparative hydrographs for few stations the year of 2014, 2007 & 1998 of rivers of the Meghna basin are shown in figures 3.21 to 3.36.

Table 3. 3: Comparison of Water Level of 2014 and Historical Events of 1988 & 1998 of Some Important Stations in Meghna Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2014	1998	1988	14	98	88
1	Surma	Kanaighat	15.58	13.20	13.99	15.00	15.10	15	73	75
2	Surma	Sylhet	11.95	11.25	11.35	11.72	11.95	1	14	21
3	Surma	Sunamgonj	9.46	8.25	9.18	8.90	9.03	27	56	62
4	Kushiyara	Amalshid	18.28	15.85	15.74	17.60	17.50	-	54	65
5	Kushiyara	Sheola	14.60	13.50	13.55	14.14	14.09	1	37	80
6	Kushiyara	Sherpur	9.68	9.00	9.18	NA	NA	10	NA	NA
7	Jariajanjail	Kangsha	13.37	9.75	12.15	NA	NA	50	NA	NA
8	Manu	Manu Railway Bridge	20.42	18.0	17.85	18.63	18.95	-	6	66
10	Manu	Moulvi Bazar	15.50	11.75	11.58	11.68	13.01	-	-	25
11	Khowai	Habiganj	12.00	9.50	10.8	11.44	11.06	3	8	14
12	Upper Meghna	Bhairab Bazar	7.66	6.25	6.05	7.33	7.66	-	68	68
13	Gumti	Comilla	13.56	11.75	11.27	12.79	11.80	-	17	17

3.4 THE SOUTH EASTERN HILL BASIN

The South Eastern Hill basin is constituted with the basin areas of the hilly rivers like the Muhuri, the Halda, the Sangu, the Matamuhuri and the Feni in the South Eastern Part of the country. The WL of the rivers Muhuri, Halda and Matamuhuri crossed their respective DLs in this monsoon-2014. As a result, a short duration flood occurred at Parshuram on Muhuri, Narayanhat on Halda river and Chiringa on Matamuhuri river during the monsoon 2014. As a result, low lying areas of Chittagong, Bandarban and Cox's Bazar were slightly affected by the flood for very short duration. All other rivers of this basin flowed below their respective DLs. WL of different river are described in following sections. A comparative statement of water level and days flowed above the DLs for the monsoon-2014 and historical events of 1998 and 1988 for this basin are shown in the Table 3.4.

The Muhuri at Parshuram

The Muhuri river in Feni, Noakhali district is a flashy one flowed above the DL for 3 days at 22nd, 23rd and 24th June, for 2 days at 14th and 15th August and for 2 days at 23rd and 24th September (total 7 days above DL). It attained its highest peak 13.68m on 14th August, which was 68cm above its DL (13.00 m).

The Halda at Narayanhat

As it is a flashy river, the WL of the river Halda (a flashy river) at Narayanhat under Hathazari upzilla also showed several peaks during this monsoon. It crossed danger mark 2 times during the monsoon-2014, for 4 days from 20th to 23rd June and for 2 days at 14th and 15th August, with peak of 16.70 mPWD (monsoon peak) on 14th August, which was 145 cm above the DL(15.25 m) at Narayanhat.

The Halda at Panchpukuria

The river here observed several peaks like Narayanhat, but flowed below its DL during the monsoon 2014. At Panchpukuria it attained its highest peak of 9.01mPWD on 28th June at 6:00 hours, which was 49 cm below its DL (9.50 m).

The Sangu at Bandarban and Dohazari

It is a flashy river, showed several peaks. The river flowed below the DL at Banarban and Dohazari in this monsoon-2014. At Bandarban the peak recorded was 11.0 mPWD on 15th August at 18:00 hours, which was 425 cm below its DL (15.25m). At Dohazari the highest peak was recorded 5.3m on 15th August at 06:00 hours, which was 170 cm below its danger mark (7.00 m) at this point.

The Matamuhuri at Lama and Chiringa

The river observed several peaks DL in the monsoon-2014. At Lama the peak recorded was 11.36 mPWD on 27th July at 12:00 hours, which was 89cm below its DL(12.25m). At Chiringa recorded highest peak of 6.01m on 21st July at 12:00 hours, which was 26 cm above the DL (5.75 m), flowed above the DL for less than one day in this monsoon-2014.

The Feni at Ramgarh

The WL of river Feni at this point observed several peaks and flowed below its DL during the monsoon-2014. The highest peak WL attained by the river was 16.93 m on 30th August 6:00 hours , which was 44cm below its DL (17.37m) at this point.

Table 3. 4 : Comparison of Water Level of 2014 and Historical Events of 1988 and 1998 of Some Important Station in South Eastern Hill Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					2014	98	88	2014	98	88
1	Muhuri	Parshuram	15.03	13.00	13.68	14.60	12.42	7	9	48
2	Halda	Narayanhat	18.05	15.25	16.7	16.57	NA	6	21	NA
3	Halda	Panchpukuria	11.55	9.50	9.01	10.44	10.05	-	4	6
4	Sangu	Bandarban	20.38	15.25	11.0	15.25	16.80	-	1	3
5	Sangu	Dohazari	9.05	7.00	5.30	7.42	NA	-	2	NA
6	Matamuhuri	Lama	15.45	12.25	11.36	13.05	12.18	-	2	-
7	Matamuhuri	Chiringa	6.83	5.75	6.01	6.85	NA	1	5	NA
8	Feni	Ramgarh	21.41	17.37	16.93	17.50	NA	-	1	NA

Comparative hydrographs for the year of 2014, 2007 and 1998 of few stations of the South Eastern Hill Basin are shown in Figures 3.37 to 3.42.

3.5 RECORDED HIGHEST WATER LEVEL

The peak water level of all the water level monitoring stations under FFWC with the date during the monsoon 2014 s shown in the following table.

Table 3.5: Recorded Peak Water Level with Date during the monsoon 2014

SL No	River name	Station	Peak WL-2014 (m)	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	26.95	28/08/2014
2	TEESTA	DALIA	52.74	27/08/2014
3	TEESTA	KAUNIA	28.95	27/08/2014
4	JAMUNESWARI	BADARGANJ	31.56	23/09/2014
5	GHAGOT	GAIBANDHA	22.36	29/08/2014
6	KARATOA	CHAK RAHIMPUR	20.38	27/09/2014
7	KARATOA	BOGRA	14.92	01/07/2014
8	BRAHMAPUTRA	NOONKHAWA	27.25	28/08/2014
9	BRAHMAPUTRA	CHILMARI	24.49	28/08/2014
10	JAMUNA	BAHADURABAD	20.21	29/08/2014
11	JAMUNA	SARIAKANDI	17.69	29/08/2014
12	JAMUNA	SERAJGONJ	13.79	29/08/2014
13	JAMUNA	ARICHA	9.58	29/08/2014
14	GUR	SINGRA	12.27	26/09/2014
15	ATRAI	BAGHABARI	11.53	31/08/2014
16	DHALESWARI	ELASIN	12.31	31/08/2014
17	OLD BRAHMAPUTRA	JAMALPUR	16.33	01/09/2014
18	OLD BRAHMAPUTRA	MYMENSINGH	11.25	06/09/2014
19	LAKHYA	LAKHPUR	6.75	01/09/2014
20	BURIGANGA	DHAKA	5.11	31/08/2014
21	BALU	DEMRA	5.54	01/09/2014
22	LAKHYA	NARAYANGONJ	5.90	31/08/2014
23	TURAG	MIRPUR	6.0	01/09/2014
24	TONGI KHAL	TONGI	5.72	02/09/2014
25	KALIGANGA	TARAGHAT	8.81	02/09/2014
26	DHALESWARI	JAGIR	8.4	04/09/2014
27	DHALESWARI	REKABI BAZAR	5.07	31/08/2014
28	BANSHI	NAYARHAT	5.82	02/09/2014
	GANGES BASIN			
29	KARATOA	PANCHAGARH	69.6	09/06/2014
30	PUNARBHABA	DINAJPUR	31.47	27/08/2014
31	ICH-JAMUNA	PHULBARI	28.55	23/09/2014
32	TANGON	THAKURGAON	49.49	22/09/2014
33	UPPER ATRAI	BHUSIRBANDAR	38.92	23/09/2014
34	MOHANANDA	ROHANPUR	20.03	23/08/2014
35	MOHANANDA	CHAPAI-NAWABGANJ	20.09	21/08/2014
36	LITTLE JAMUNA	NAOGAON	15.71	25/09/2014
37	ATRAI	MOHADEBPUR	17.07	24/09/2014
38	GANGES	PANKHA	20.94	21/08/2014
39	GANGES	RAJSHAHI	17.45	22/08/2014
40	GANGES	HARDINGE BRIDGE	13.31	22/08/2014
41	PADMA	GOALONDO	8.92	31/08/2014
42	PADMA	BHAGYAKUL	6.57	31/08/2014
43	PADMA	SURESWAR	4.85	01/09/2014
44	GORAI	GORAI RAIL BRIDGE	11.76	24/08/2014
45	GORAI	KAMARKHALI	7.78	24/08/2014
46	ICHAMATI	SAKRA	3.25	02/04/2014

SL No	River name	Station	Peak WL-2014 (m)	Date
47	MATHABHANGA	CHUADANGA	8.43	25/08/2014
48	MATHABHANGA	HATBOALIA	11.53	25/08/2014
49	KOBADAK	JHIKORGACHA	4.09	22/08/2014
50	KUMAR	FARIDPUR	4.89	01/09/2014
51	ARIALKHAN	MADARIPUR	3.76	01/09/2014
	MEGHNA BASIN			
52	SURMA	KANAIGHAT	13.99	18/08/2014
53	SURMA	SYLHET	11.35	26/08/2014
54	SURMA	SUNAMGONJ	9.18	25/08/2014
55	KUSHIYARA	AMALSHID	15.74	09/09/2014
56	KUSHIYARA	SHEOLA	13.55	09/09/2014
57	KUSHIYARA	SHERPUR	9.18	08/09/2014
58	KUSHIYARA	MARKULI	7.81	27/06/2014
59	SARIGOWAIN	SARIGHAT	13.3	23/09/2014
60	MANU	MANU RAILY BRIDGE	17.85	04/09/2014
61	MANU	MOULVI BAZAR	11.58	09/05/2014
62	KHOWAI	BALLAH	24.57	30/08/2014
63	KHOWAI	HABIGONJ	10.8	23/06/2014
64	DHALAI	KAMALGONJ	20.25	04/09/2014
65	OLD SURMA	DERAI	7.30	28/08/2014
66	BAULAI	KHALIAJURI	8.82	28/07/2014
67	BHUGAI	NAKUAGAON	24.91	08/07/2014
68	JADUKATA	LORERGARH	10.74	23/09/2014
69	SOMESWARI	DURGAPUR	15.5	23/09/2014
70	KANGSHA	JARIAJANJAIL	12.15	23/09/2014
71	TITAS	B. BARIA	5.96	31/08/2014
72	MEGHNA	BHAIRAB BAZAR	6.05	29/08/2014
73	MEGHNA	NARSINGDI	5.36	01/09/2014
74	GUMTI	COMILLA	11.27	23/06/2014
75	GUMTI	DEBIDDAR	7.47	25/06/2014
76	MEGHNA	CHANDPUR	4.25	31/08/2014
	SOUTH EASTERN HILL BASIN			
77	MUHURI	PARSHURAM	13.68	14/08/2014
78	HALDA	NARAYAN HAT	16.7	14/08/2014
79	HALDA	PANCHPUKURIA	9.01	23/06/2014
80	SANGU	BANDARBAN	11.0	15/08/2014
81	SANGU	DOHAZARI	5.3	15/08/2014
82	MATAMUHURI	LAMA	11.36	21/07/2014
83	MATAMUHURI	CHIRINGA	6.01	21/07/2014
84	FENI	RAMGARH	16.93	14/08/2014

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

Sl. No.	River	Station	Danger Level (m)	Recorded highest WL (m) before 2014 flood (date)	WL (Date) Exceeding previous Highest WL (m)
1	Dharla	Kurigram	26.50	27.66 (14.07.96)	-
2	Teesta	Dalia	52.40	52.97 (29.07.72)	-
3	Teesta	Kaunia	30.00	30.52 (06.01.68)	-
4	Brahmaputra	Noonkhawa	27.25	28.10	-
5	Brahmaputra	Chilmari	24.00	25.07 (23.08.62)	-
6	Jamuna	Bahadurabad	19.50	20.62 (30.08.88)	-
7	Jamuna	Serajgonj	13.35	15.12 (30.08.88)	-

8	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
9	Old Brhamaputra	Jamalpur	17.00	18.00 (31.07.54)	-
10	Old Brhamaputra	Mymensingh	12.50	13.71(1.09.88)	-
11	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
12	Lakhya	Narayangonj	5.50	6.93 (10.09.98)	-
13	Turag	Mirpur	5.94	8.35 (10.09.88)	-
14	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-
15	Kaliganga	Taraghat	8.38	10.37(2.09.88)	-
16	Punarbhaba	Dinajpur	33.50	34.40	-
17	Padma	Pankha	21.50	24.14 (07.09.97)	-
18	Padma	Rajshahi	18.50	20.00(13.09.1910)	-
19	Padma	H- Bridge	14.25	15.19 (10.09.98)	-
20	Padma	Goalundo	8.50	10.21 (03.08.08)	-
21	Padma	Bhagyakul	6.00	7.58	-
22	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
23	Surma	Kanaighat	13.20	15.58(26.06.12)	-
24	Surma	Sylhet	11.25	12.44 (19.07.04)	-
25	Surma	Sunamgonj	8.25	9.75 (20.07.04)	-
26	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
27	Kushiyara	Sheola	13.50	14.60 (09.09.08)	-
28	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
29	Manu	Moulvi Bazar	11.75	13.25 (8.06.93)	-
30	Khowai	Habigonj	9.50	12.00 (18.06.07)	-
31	Someswari	Durgapur	13.00	15.58 (28/07/2007)	-
32	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
33	Gumti	Comilla	11.75	13.56 (23.07.93)	-
34	Muhuri	Parshuram	13.00	16.33 (13.09.04)	-
35	Halda	Narayanhat	15.25	19.30 (13.08.99)	-
36	Halda	Panchpukuria	7.00	12.54(27.06.03)	-
37	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
38	Sangu	Dohazari	5.75	9.05	-
39	Matamuhuri	Lama	12.25	15.46 (12.08.99)	-
40	Matamuhuri	Chiringa	5.75	7.03 (10.07.97)	-
41	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

WL - Water Level

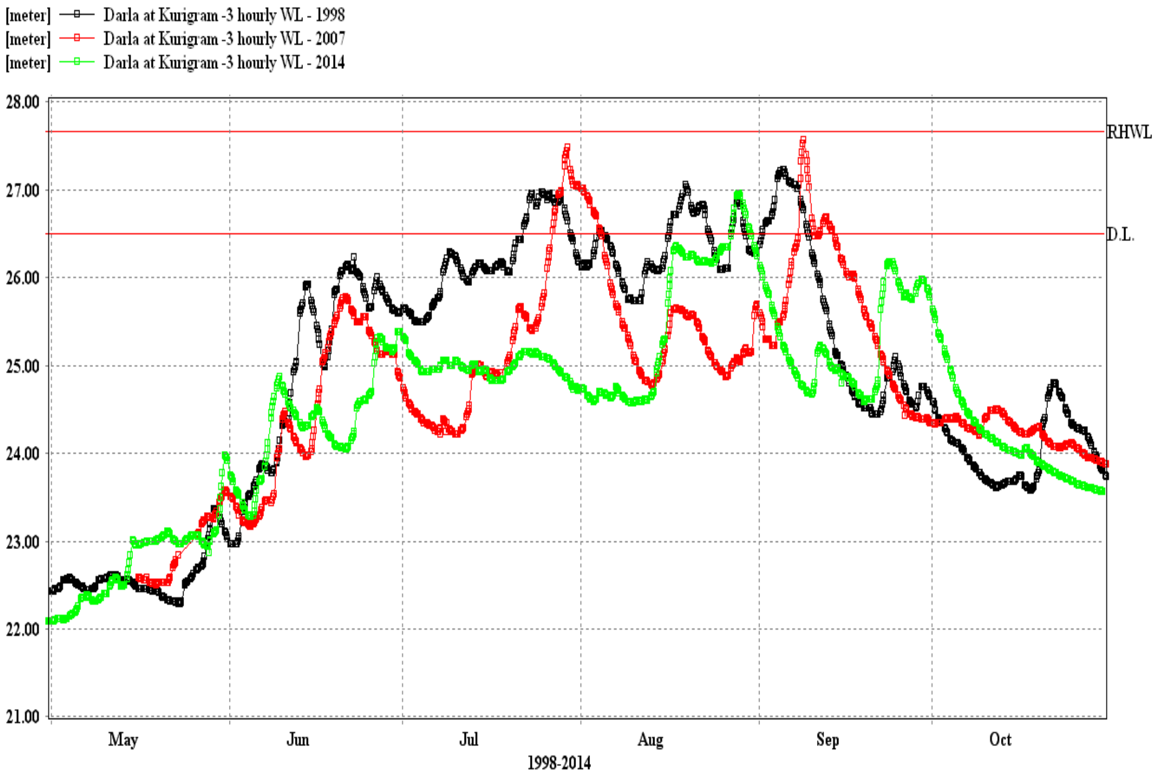


Figure 3.1 : Comparison of Hydrograph on Dharla at Kurigram

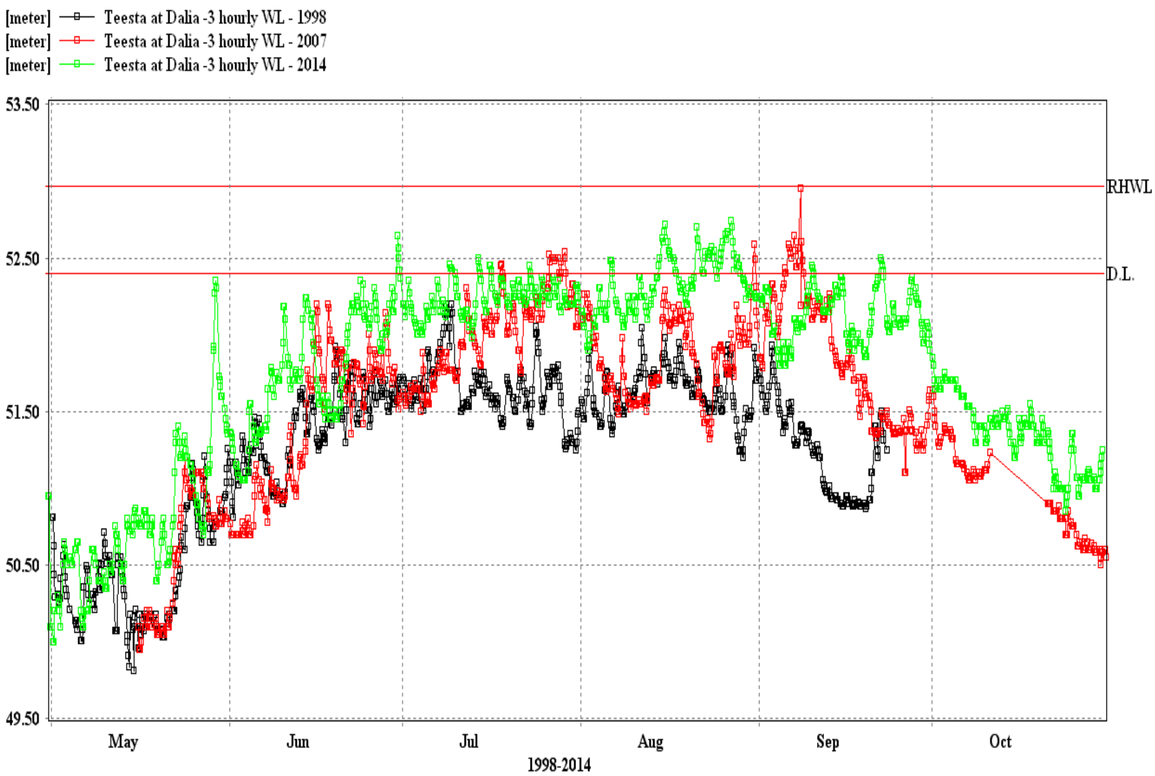


Figure 3.2 : Comparison of Hydrograph on Teesta at Dalia

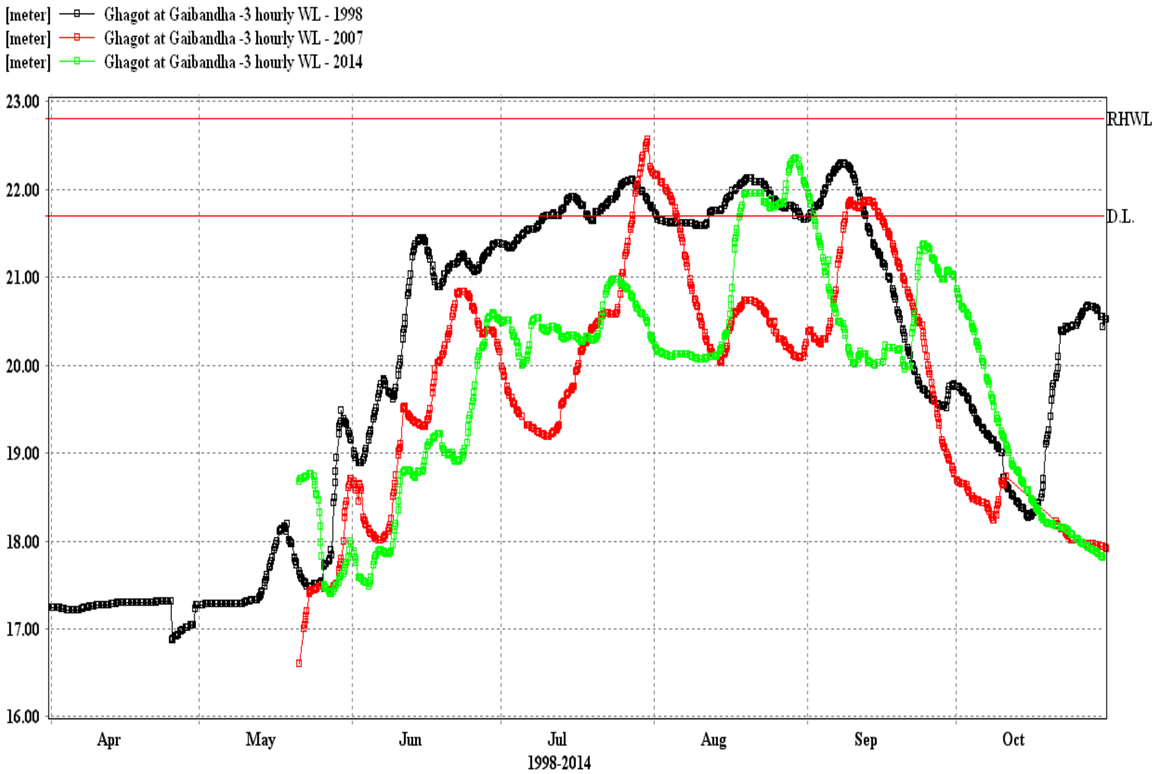


Figure 3.3 : Comparison of Hydrograph on Ghagot at Gaibandha

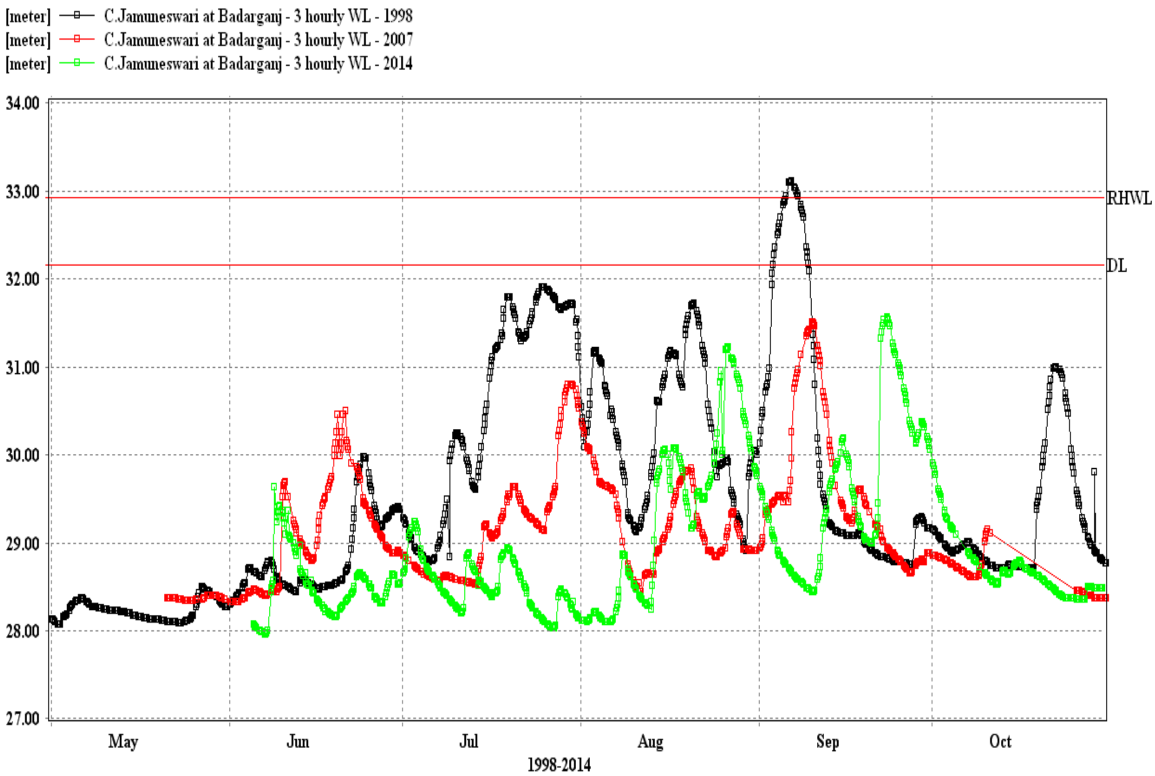


Figure 3.4 : Comparison of Hydrograph on Jamunesweri at Badargonj

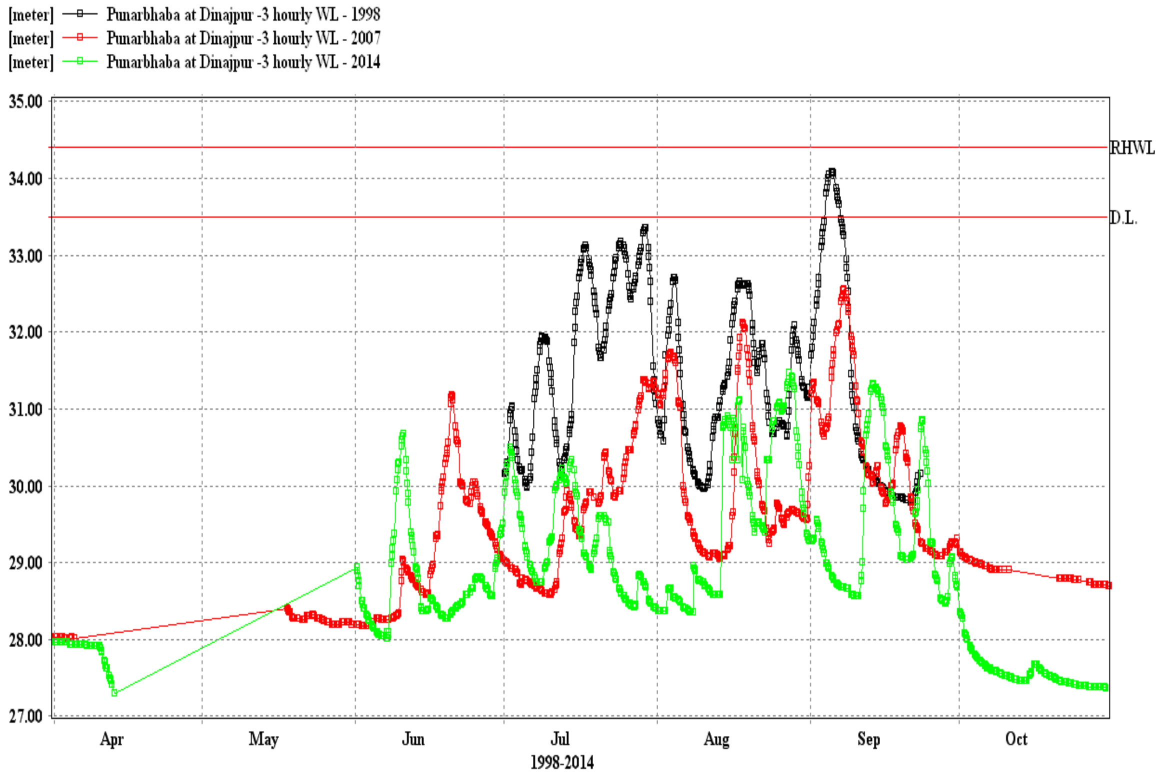


Figure 3.5 : Comparison of Hydrograph on Punurbhoba at Dinajpur

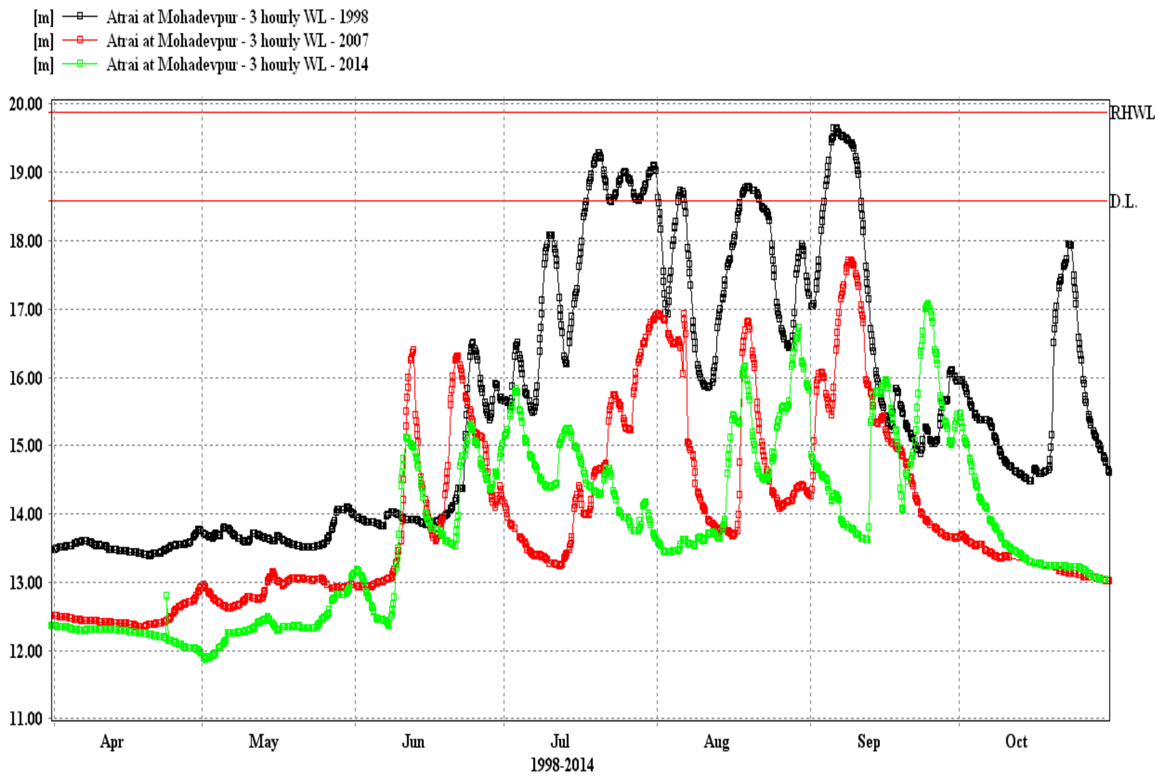


Figure 3.6 : Comparison of Hydrograph on Atrai at Mohadevpur

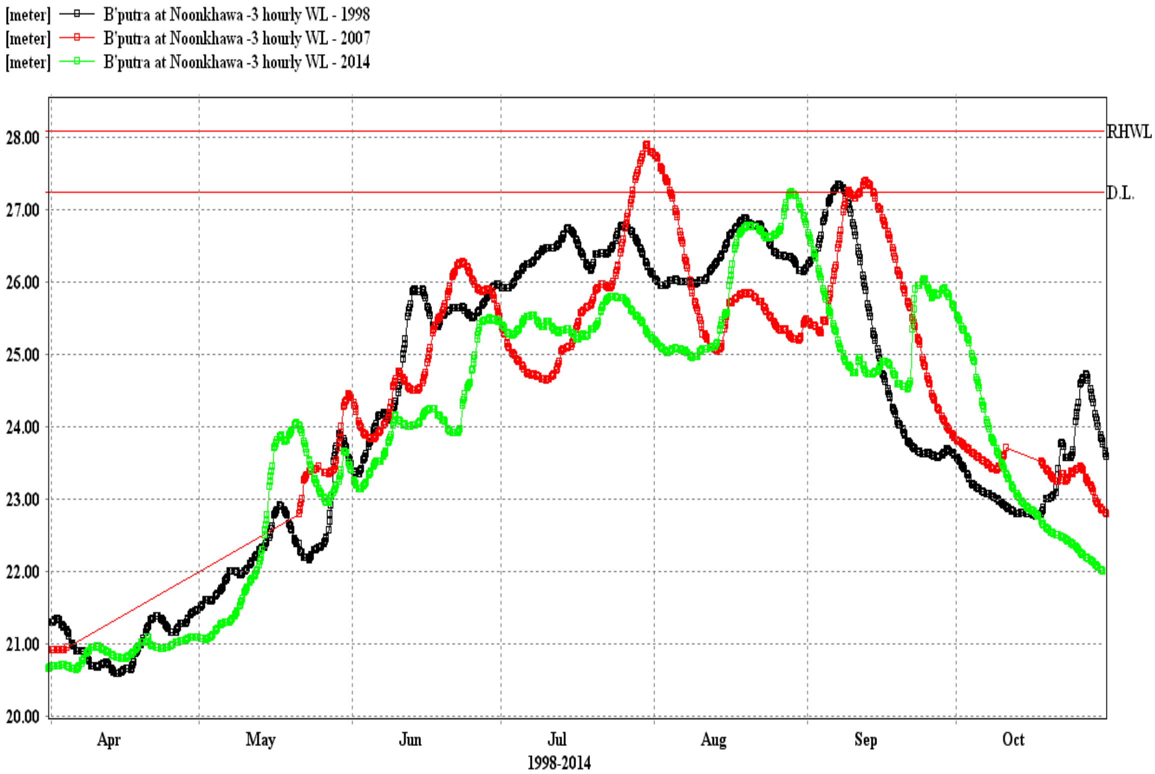


Figure 3.7 : Comparison of Hydrograph on Brahmaputra at Noonkhawa

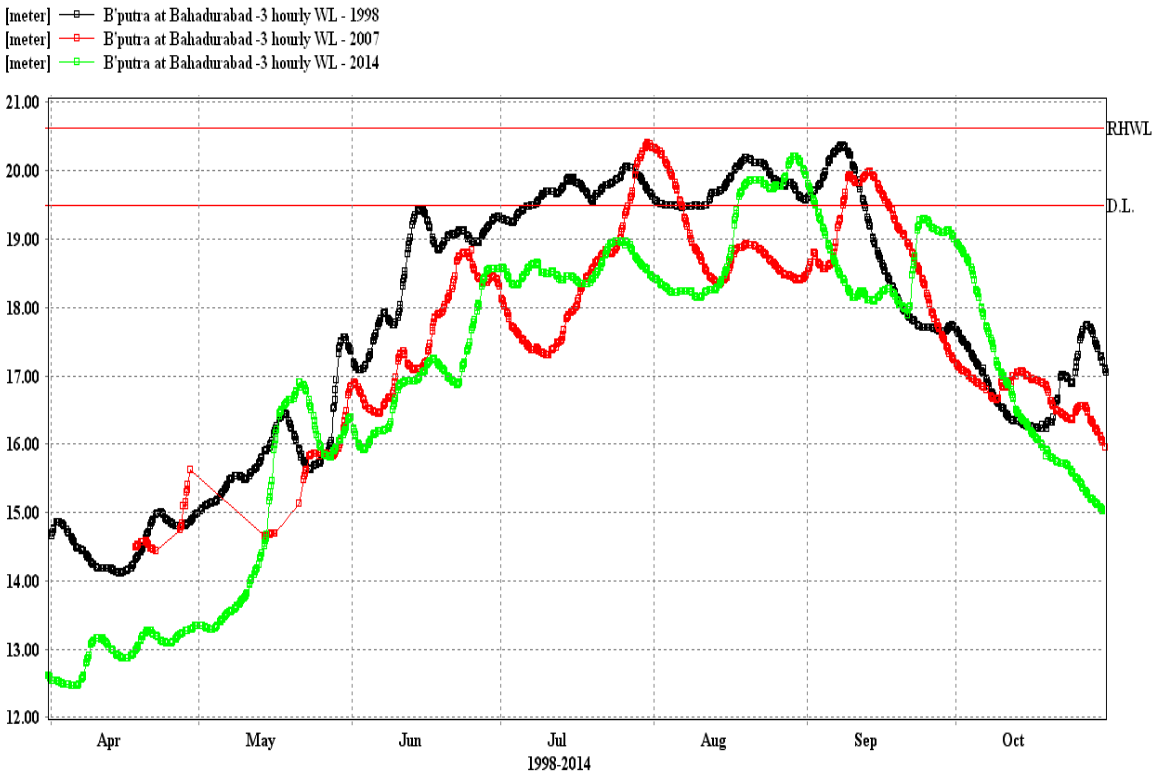


Figure 3.8 : Comparison of Hydrograph on Brahmaputra at Bahadurabad

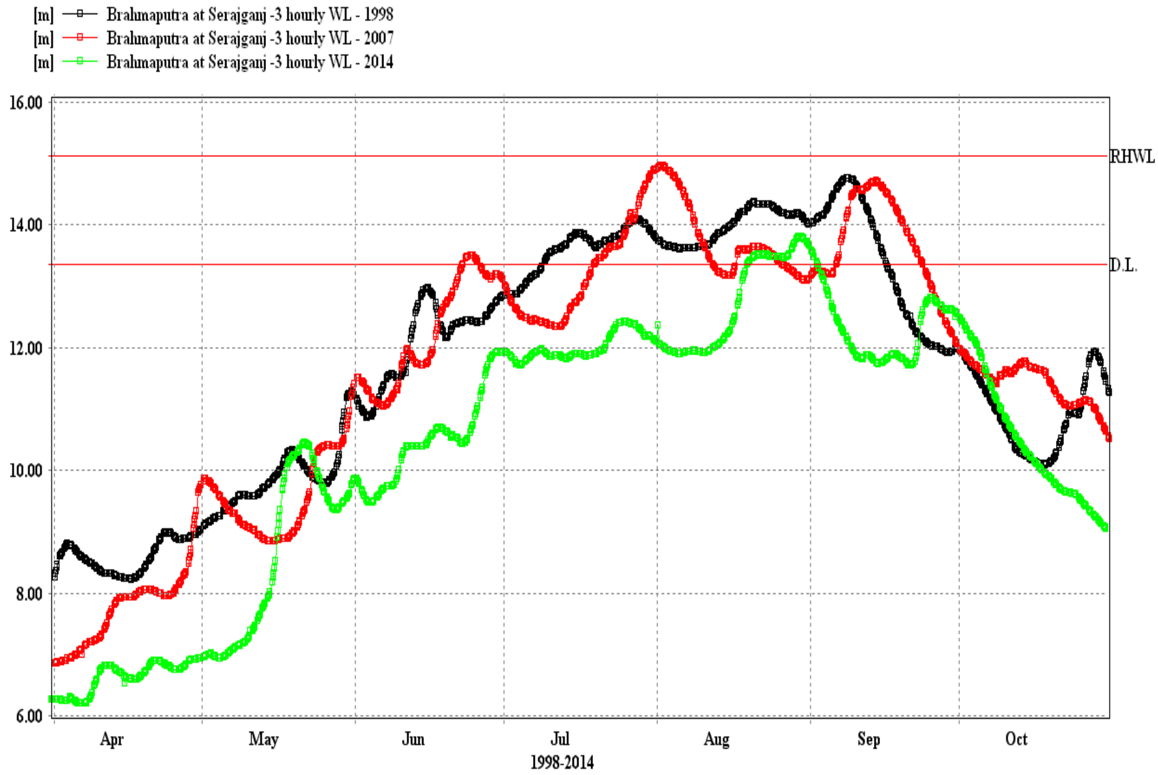


Figure 3.9 : Comparison of Hydrograph on Jamuna at Serajgonj

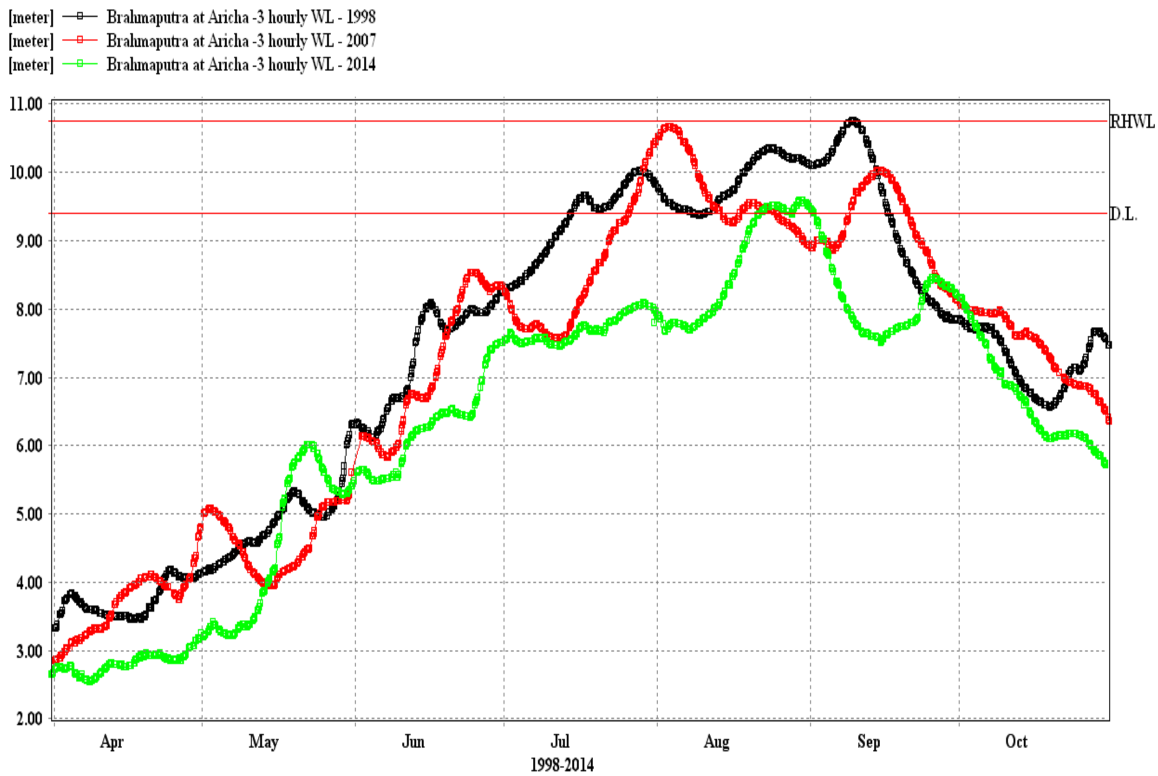


Figure 3.10 : Comparison of Hydrograph on Jamuna at Aricha

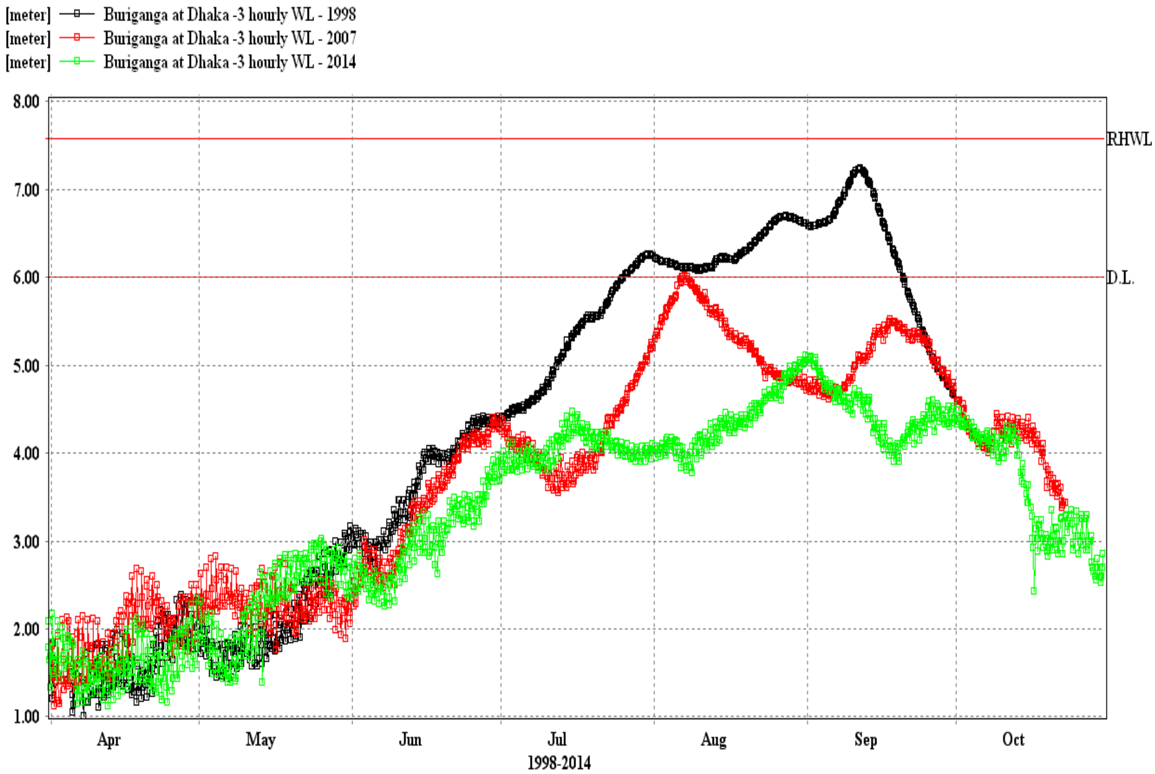


Figure 3.11 : Comparison of Hydrograph on Buriganga at Dhaka(Milbarak)

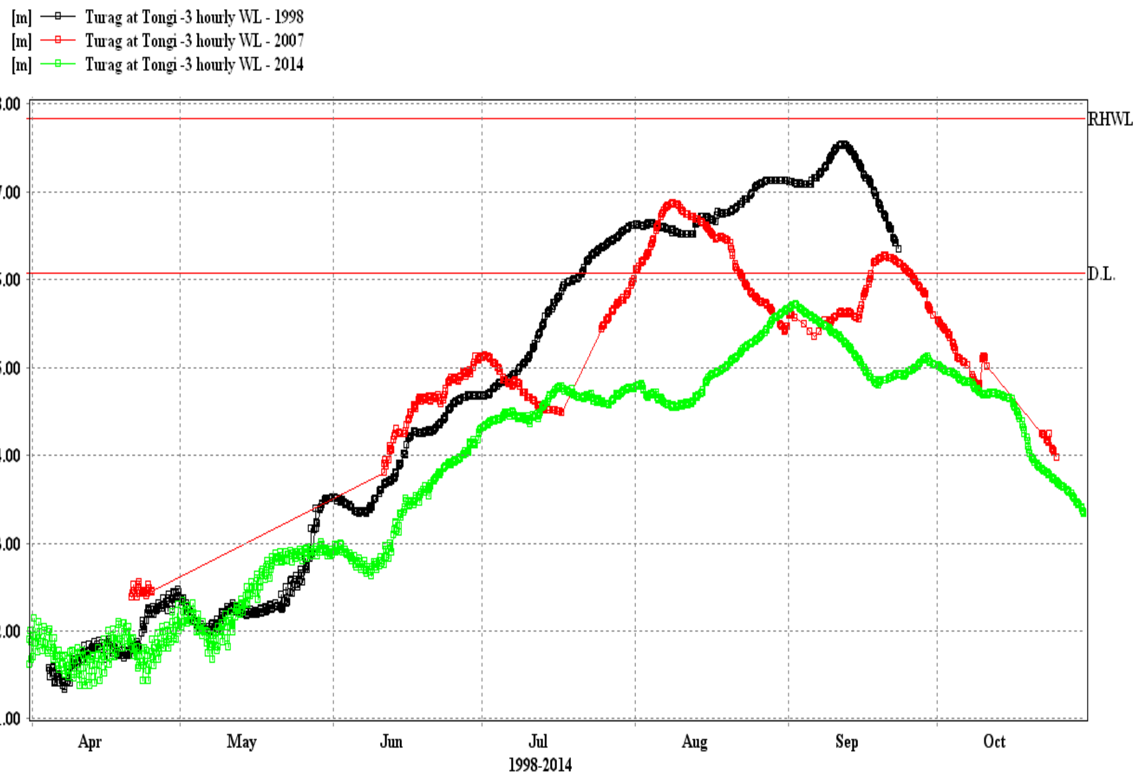


Figure 3.12 : Comparison of Hydrograph on Tongi Khal at Tongi

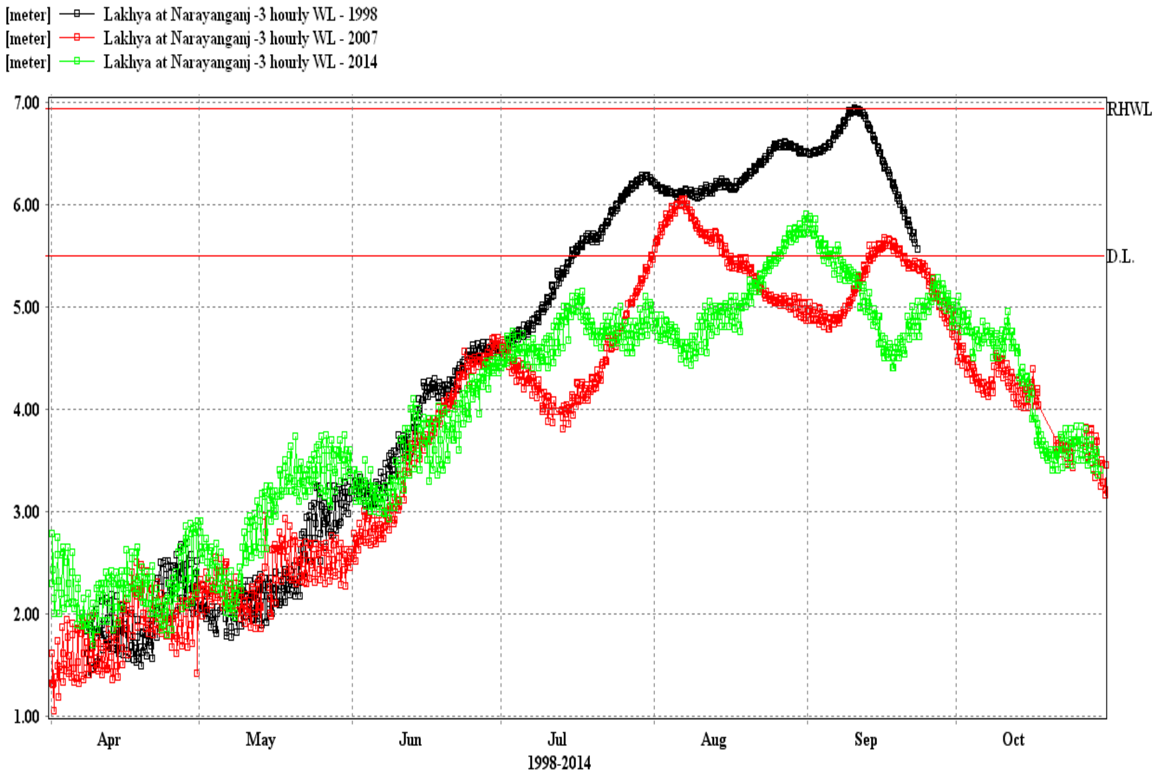


Figure 3.13 : Comparison of Hydrograph on Lakhya at Narayangonj

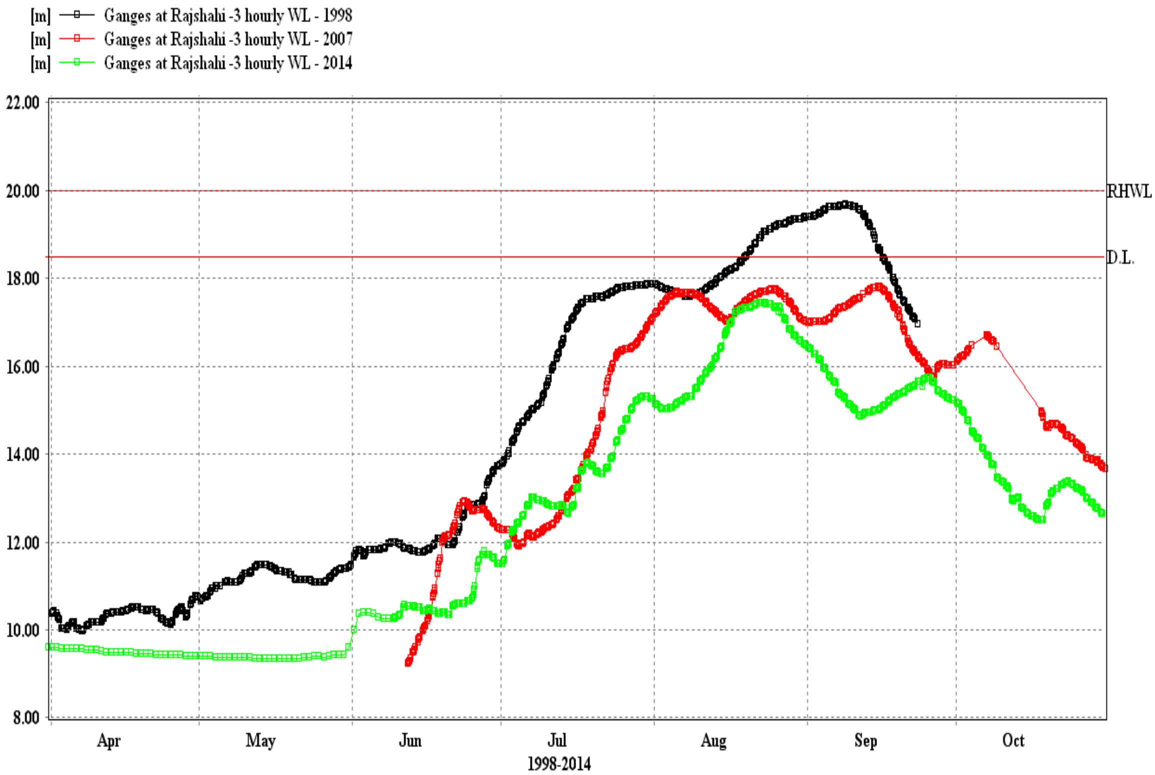


Figure 3.14 : Comparison of Hydrograph on Ganges at Rajshahi

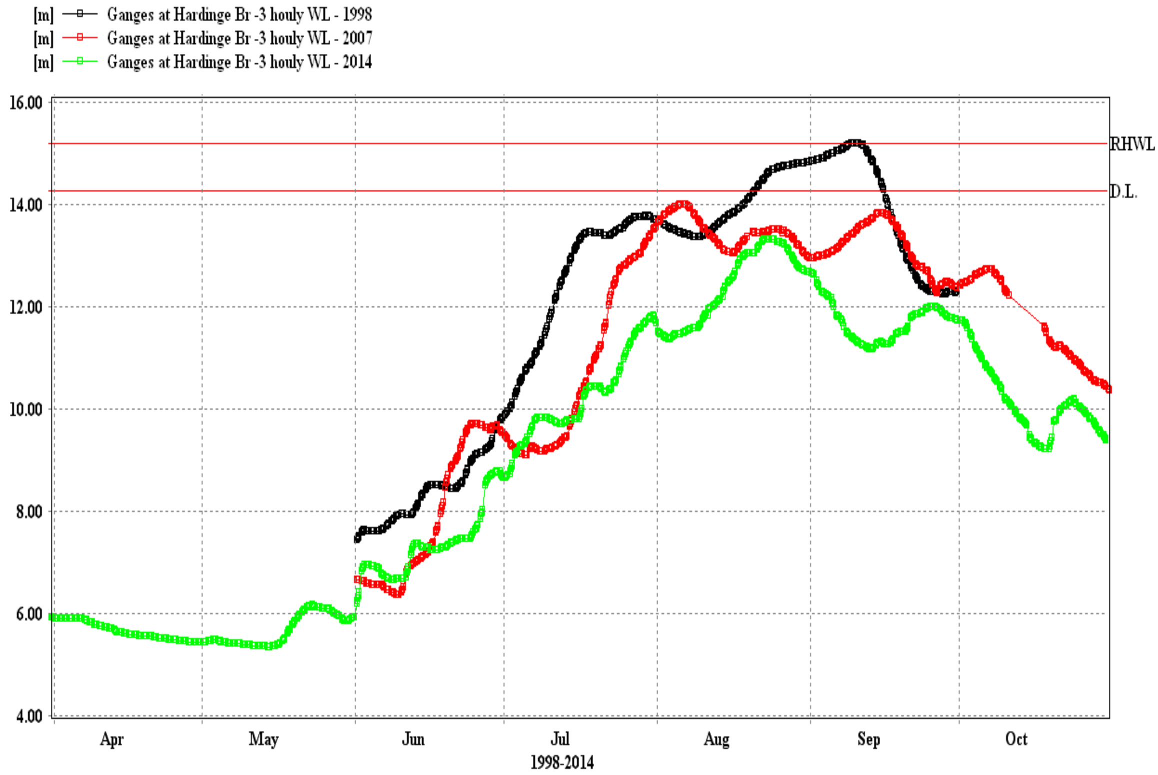


Figure 3.15 : Comparison of Hydrograph on Ganges at Hardinge Bridge

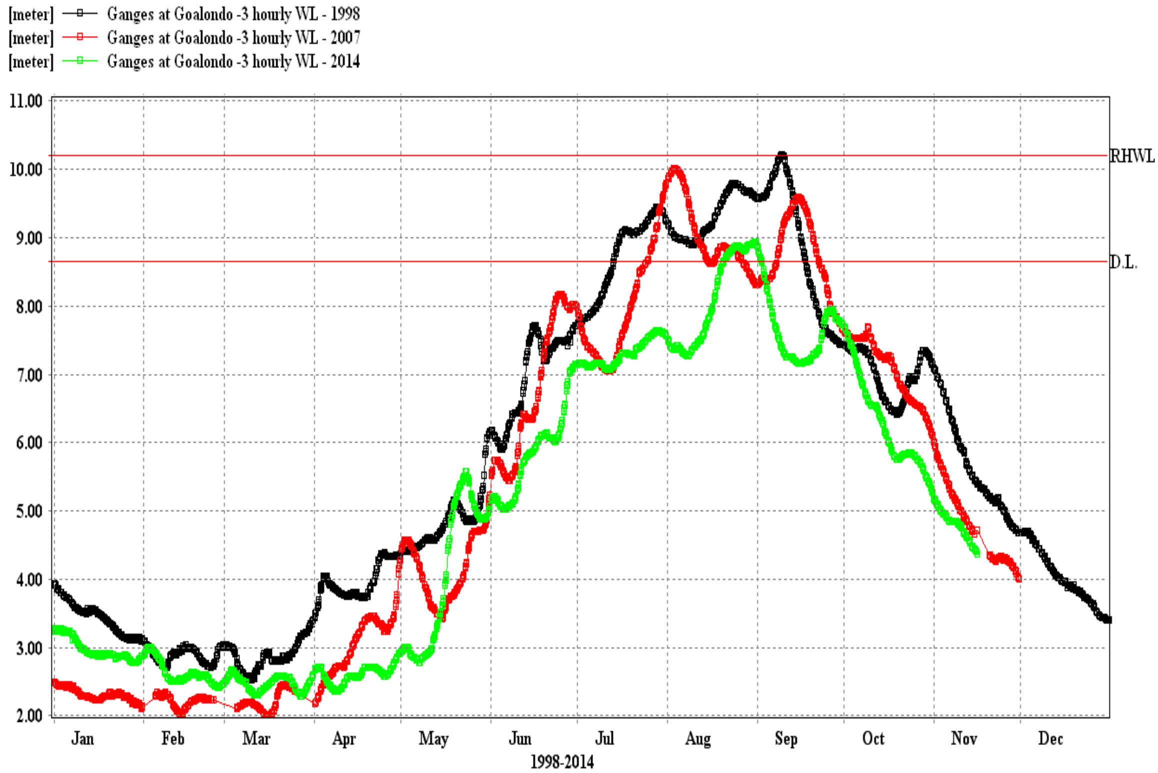


Figure 3.16 : Comparison of Hydrograph on Padma at Goalondo

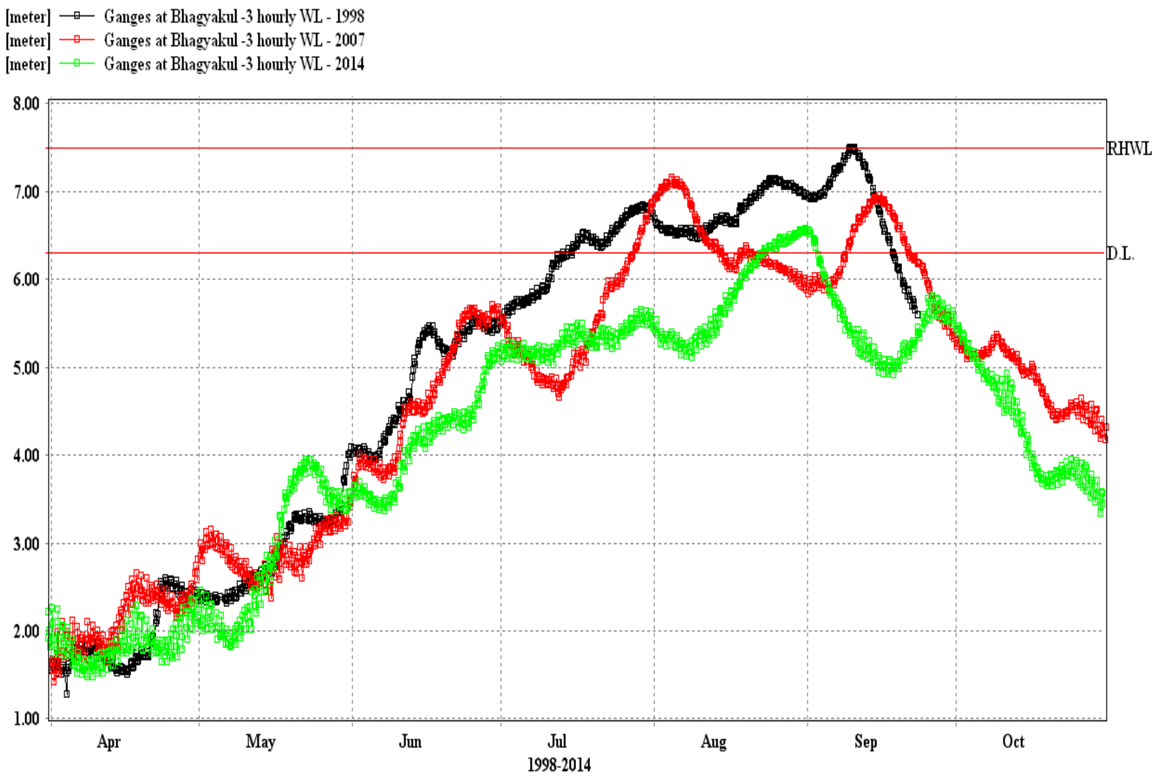


Figure 3.17 : Comparison of Hydrograph on Padma at Bhagyakul

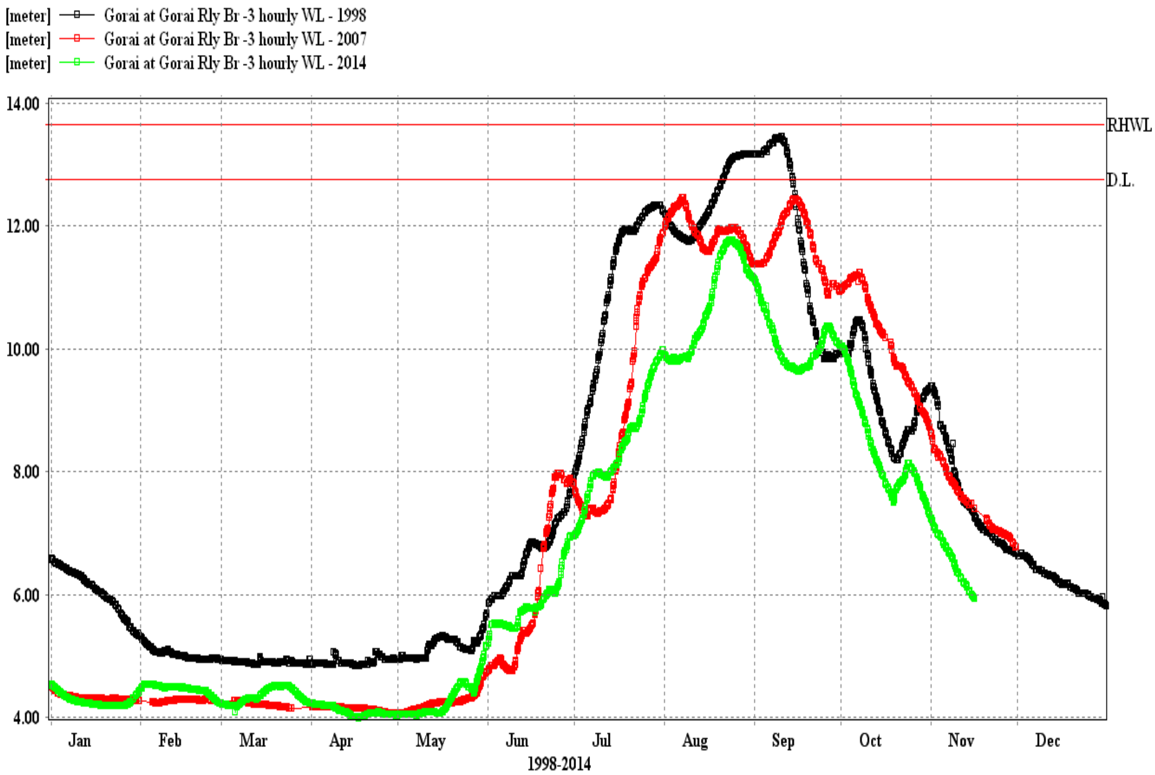


Figure 3.18 : Comparison of Hydrograph on Gorai at Gorai Railway Bridge

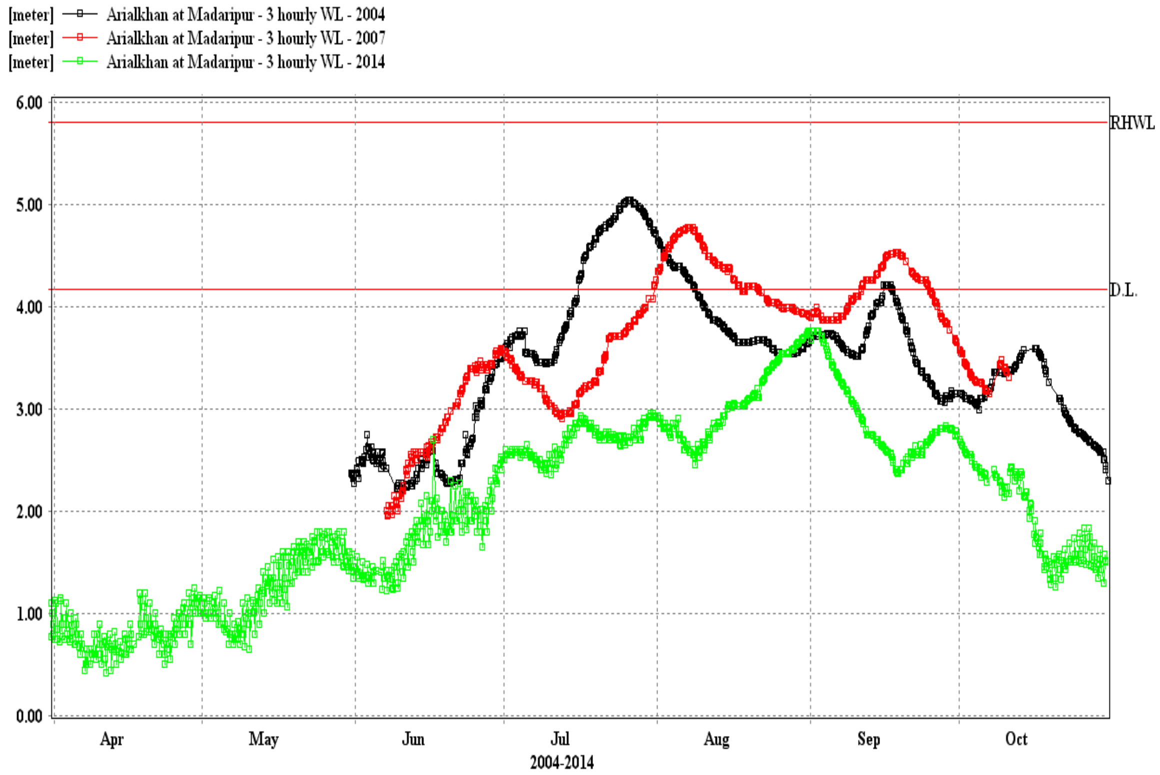


Figure 3.19 : Comparison of Hydrograph on Arialkhan at Madaripur

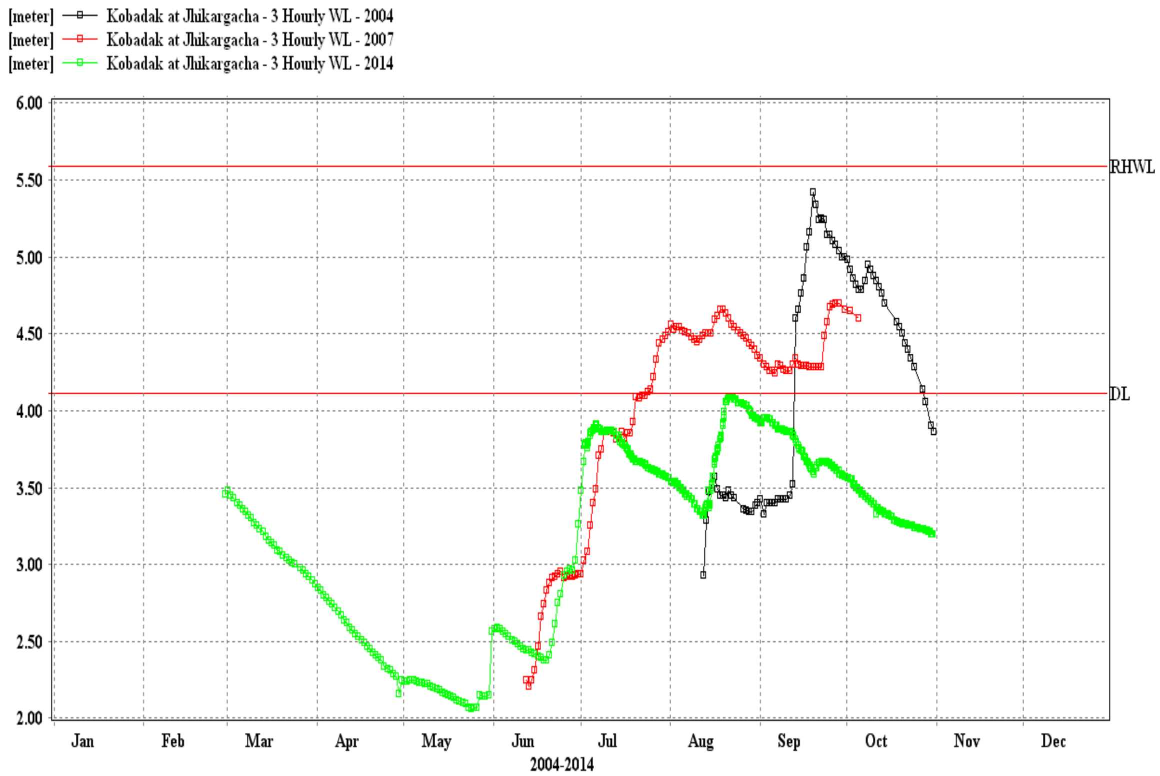


Figure 3.20 : Comparison of Hydrograph on Kobodak at Jhikorgacha

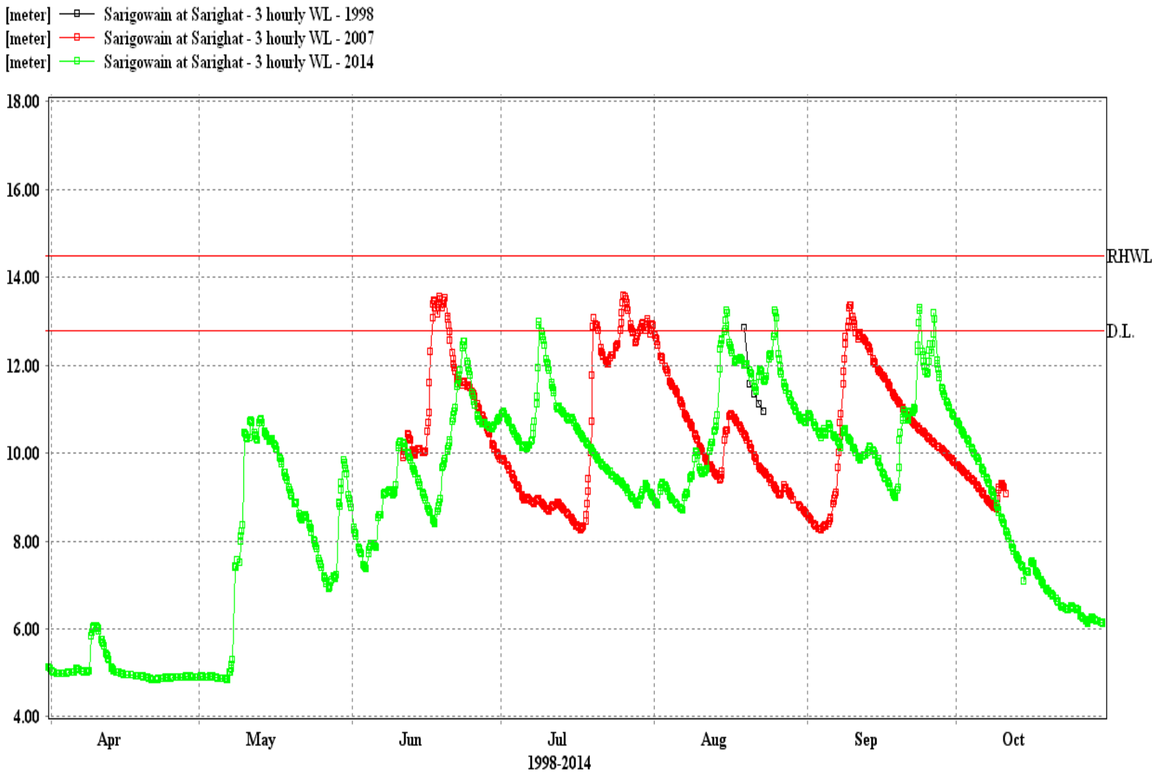


Figure 3.21 : Comparison of Hydrograph on Sarigoain at Sarighat

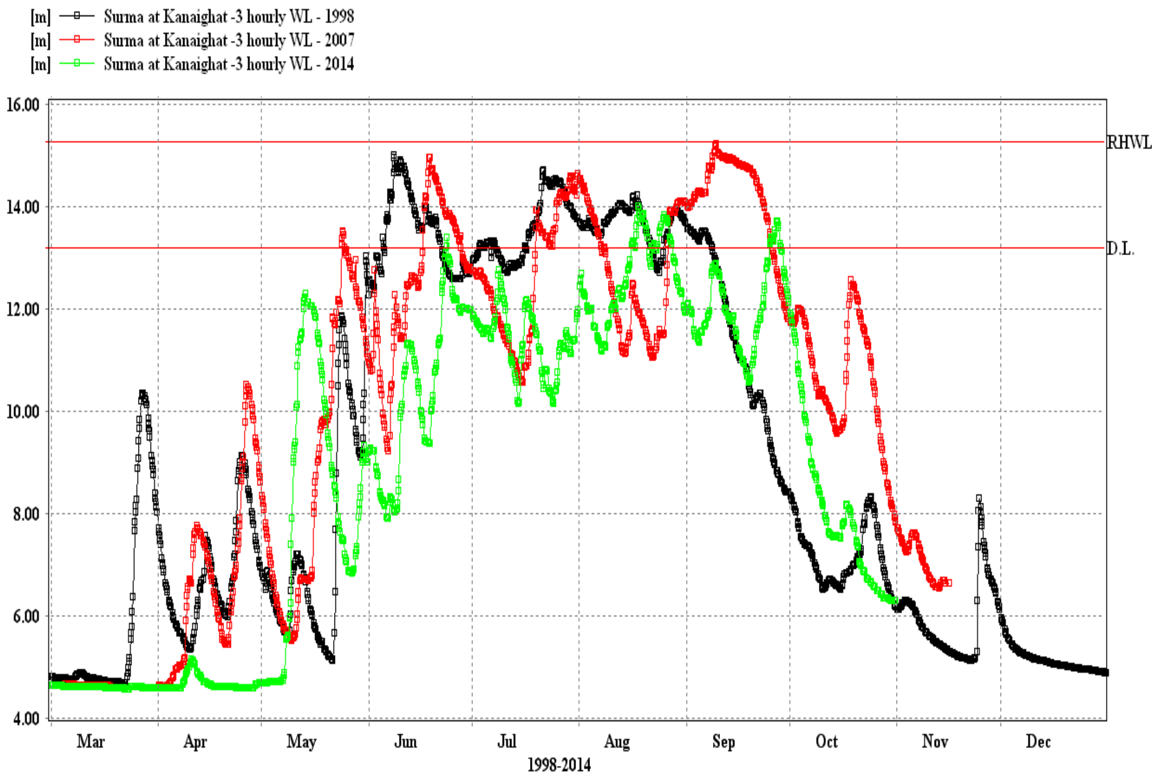


Figure 3.22 : Comparison of Hydrograph on Surma at Kanaighat

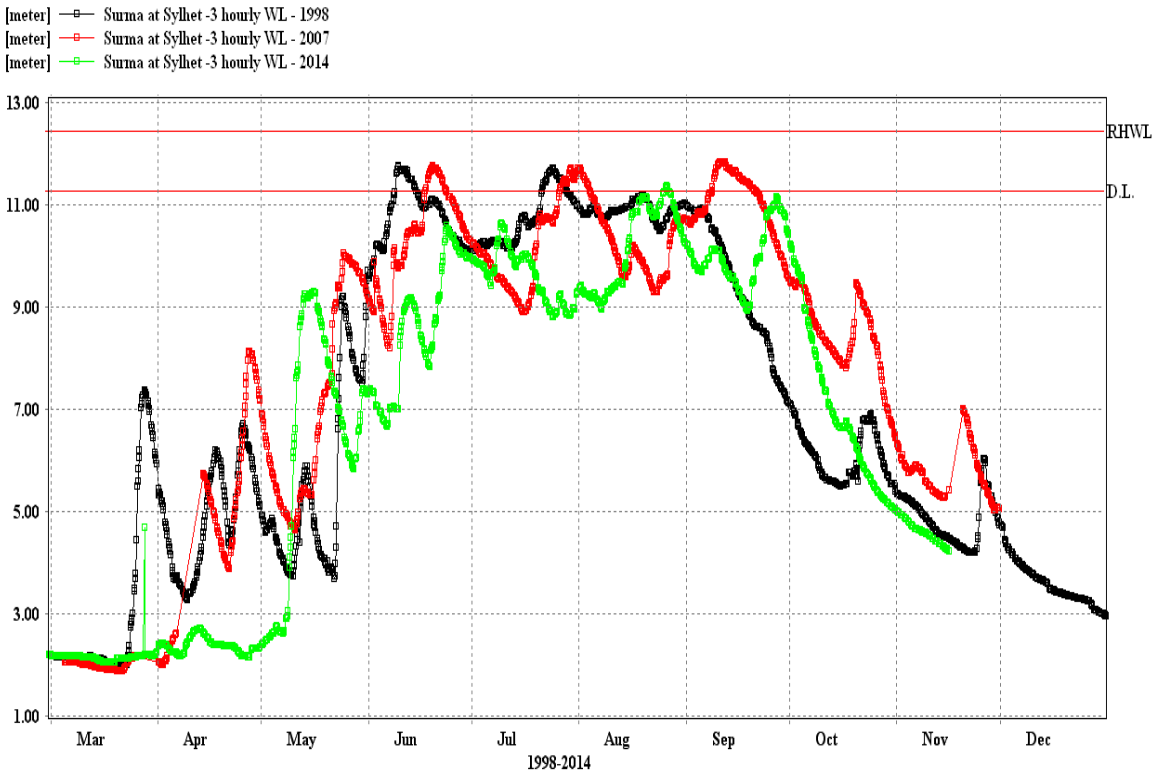


Figure 3.23 : Comparison of Hydrograph on Surma at Sylhet

Figure 3.24 : Comparison of Hydrograph on Surma at Sunamganj

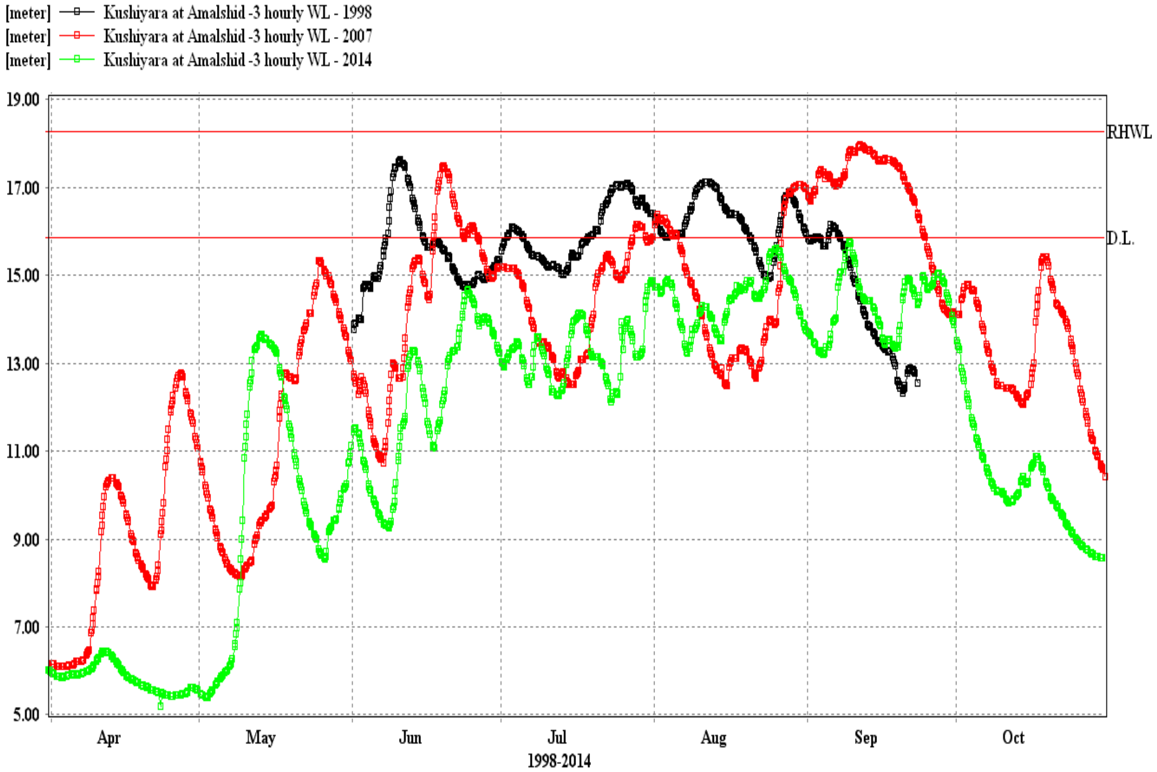


Figure 3.25 : Comparison of Hydrograph on Kushiyara at Amalshid

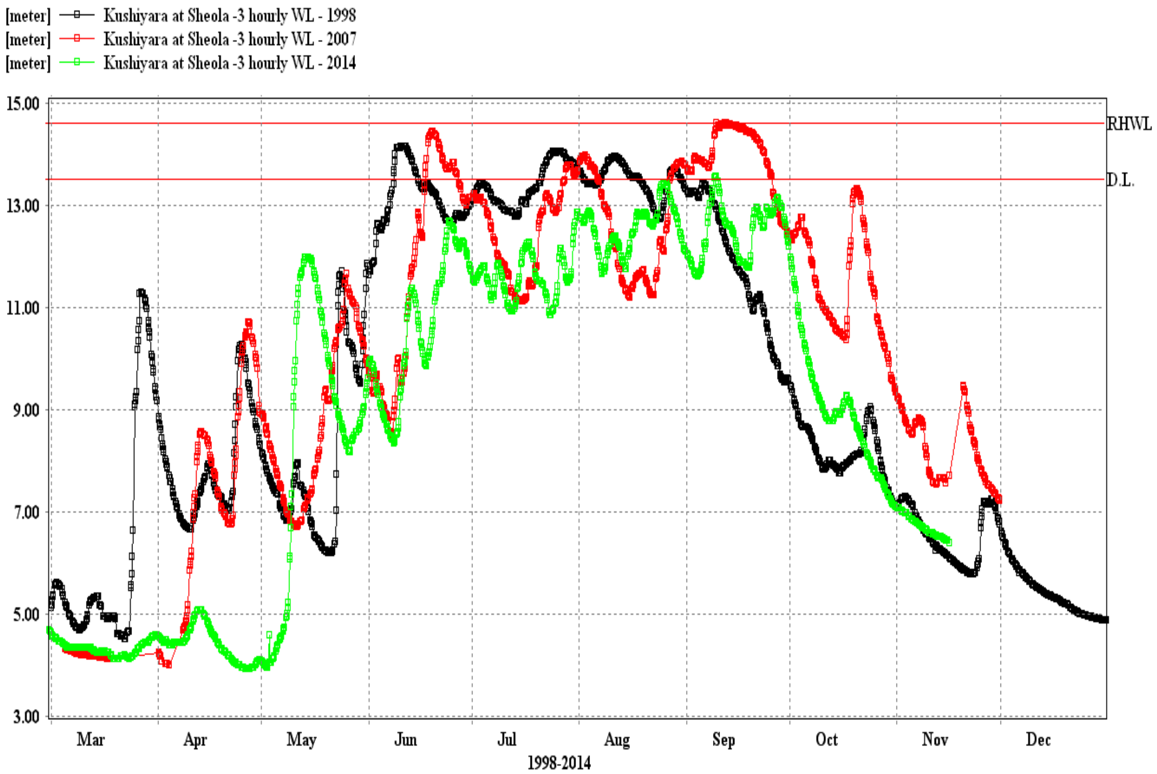


Figure 3.26 : Comparison of Hydrograph on Kushiyara at Sheola

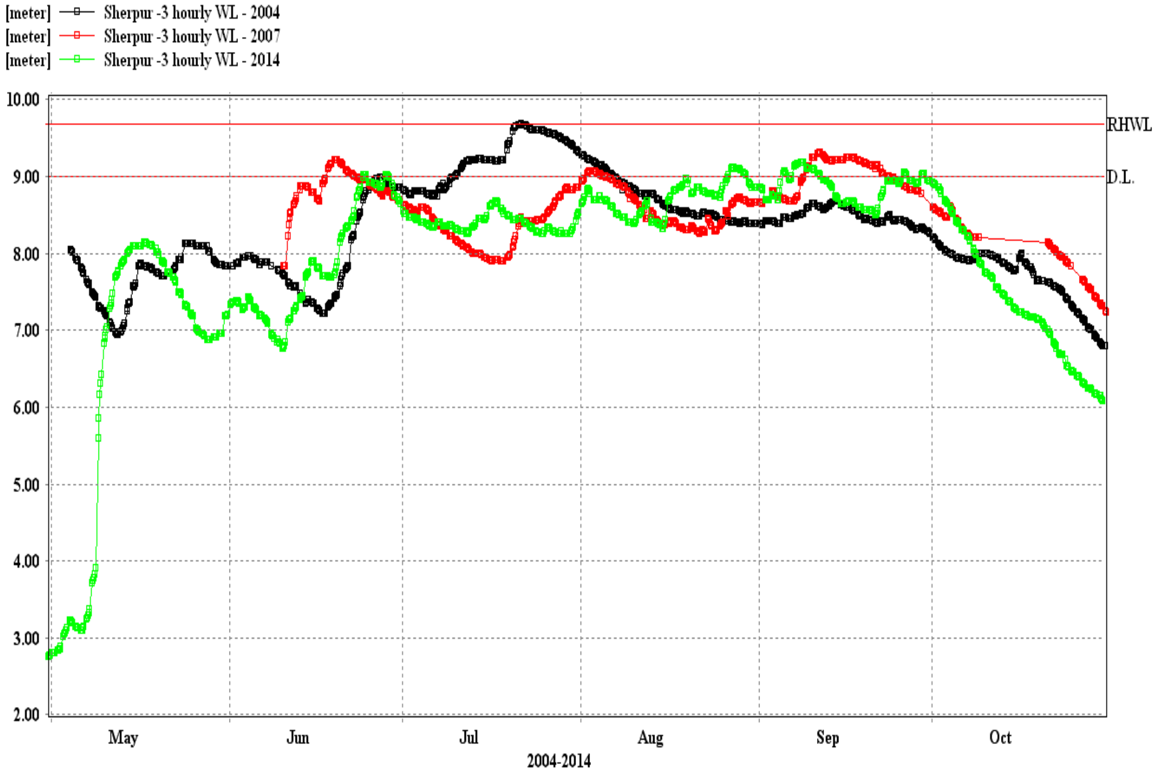


Figure 3.27 : Comparison of Hydrograph on Kushiyara at Sherpur

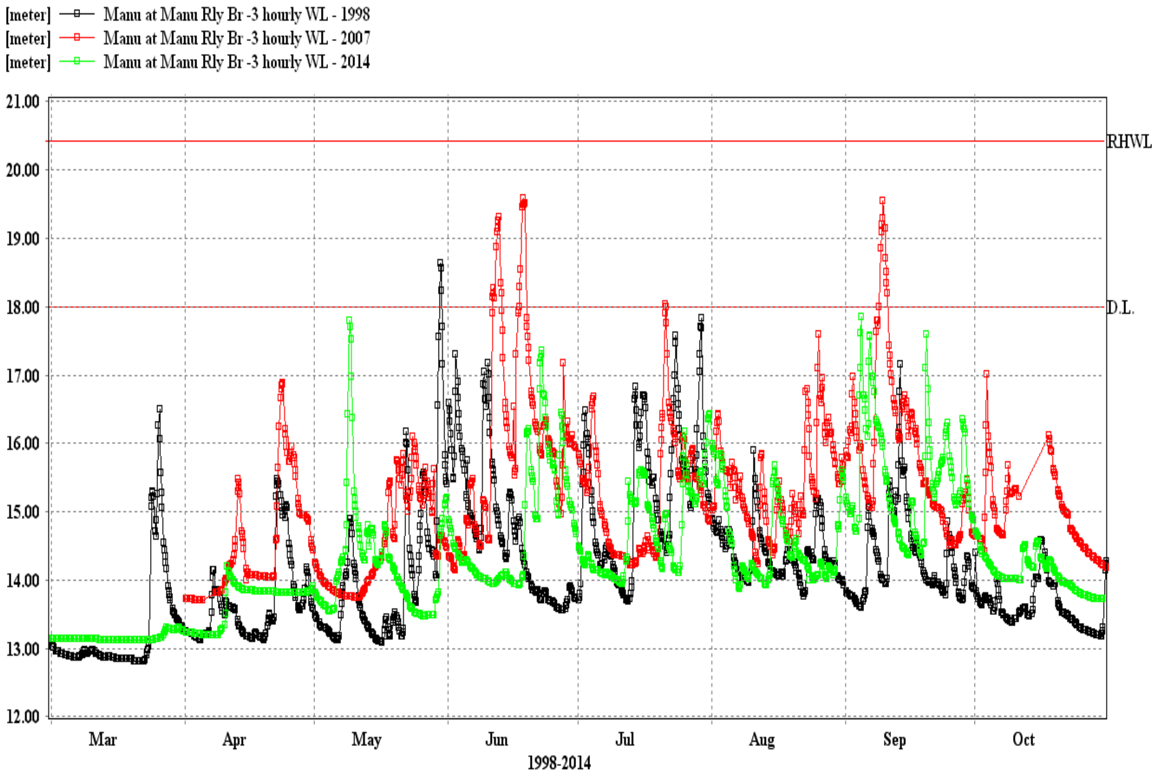


Figure 3.28 : Comparison of Hydrograph on Manu at Manu Rail Bridge

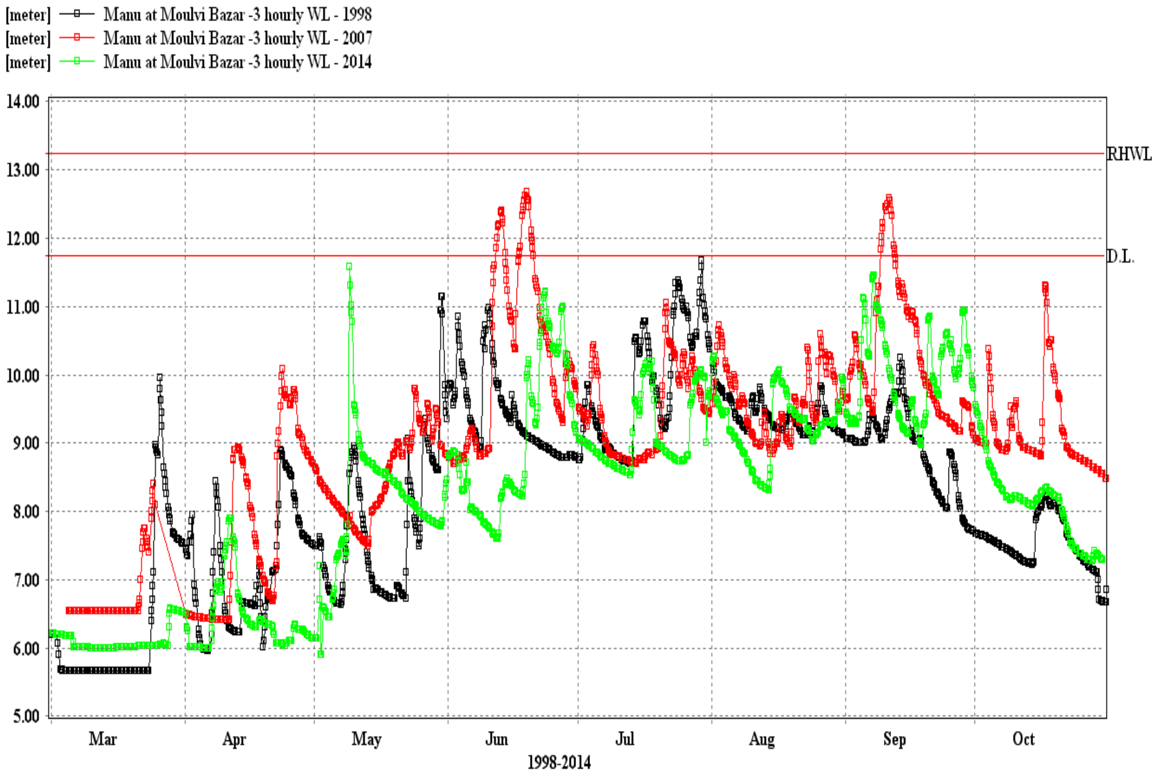


Figure 3.29 : Comparison of Hydrograph on Manu at Moulvibazar

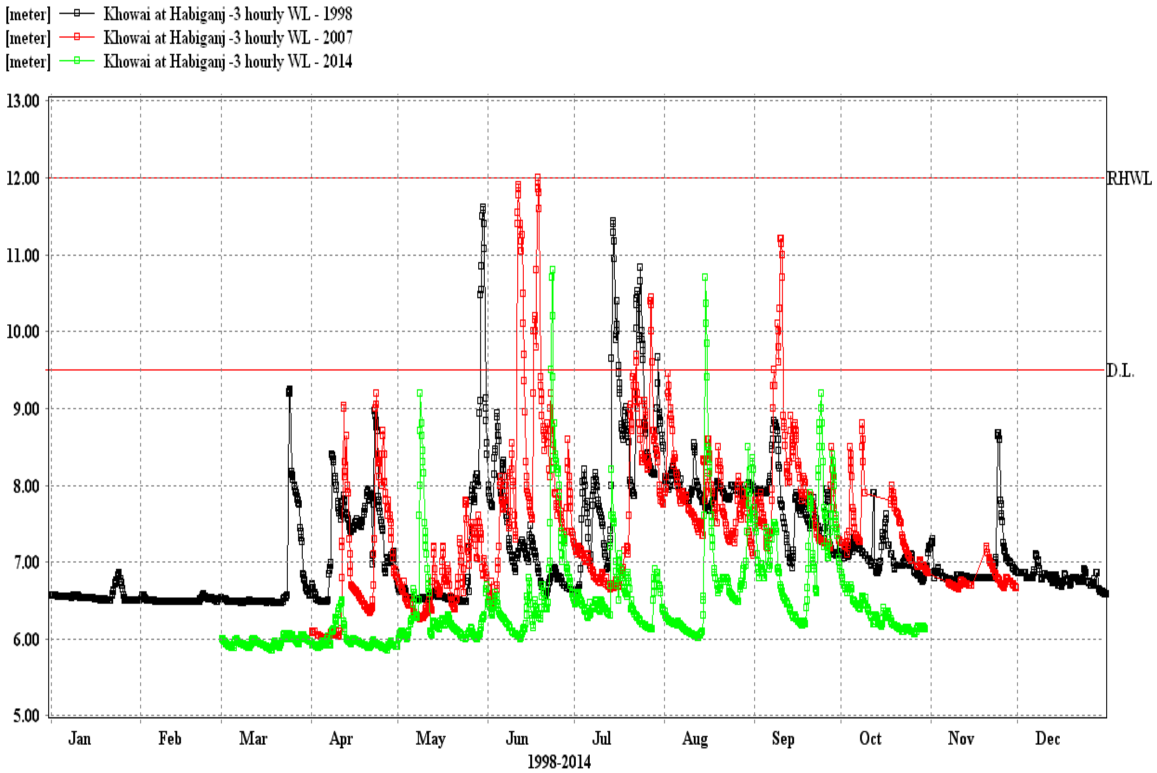


Figure 3.30 : Comparison of Hydrograph on Khowai at Habigonj

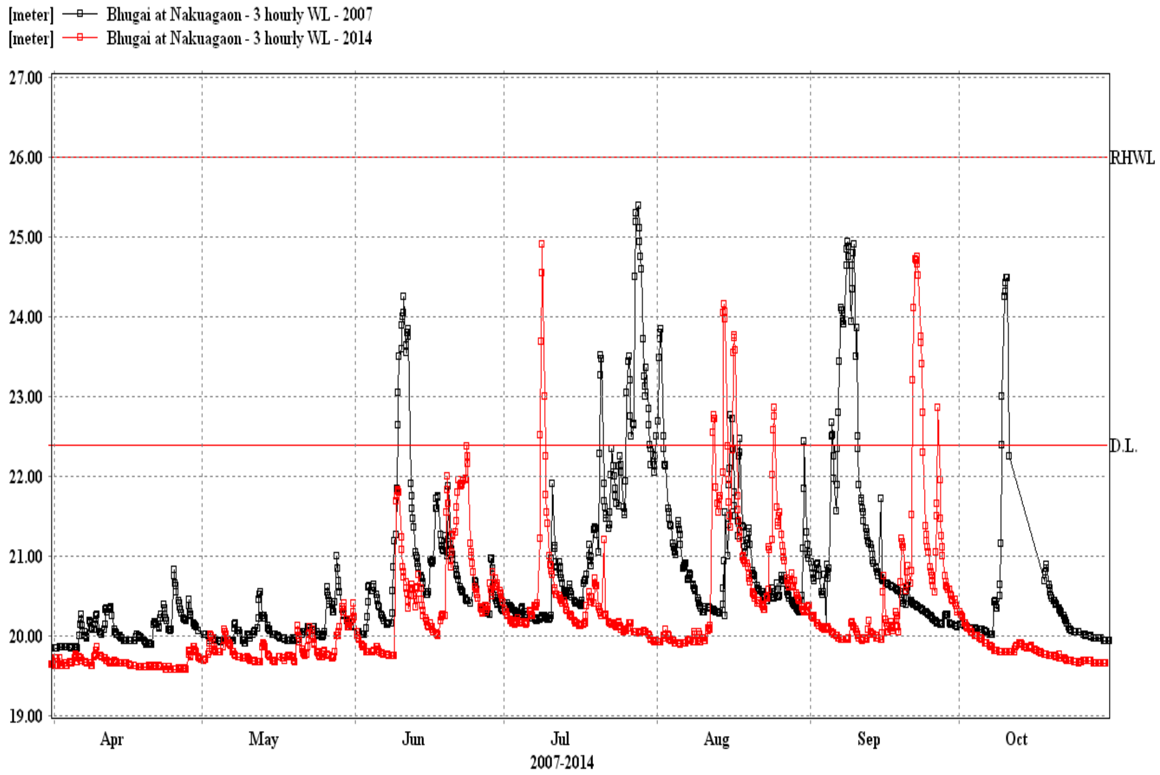


Figure 3.31 : Comparison of Hydrograph on Bhugai at Nokuagaon

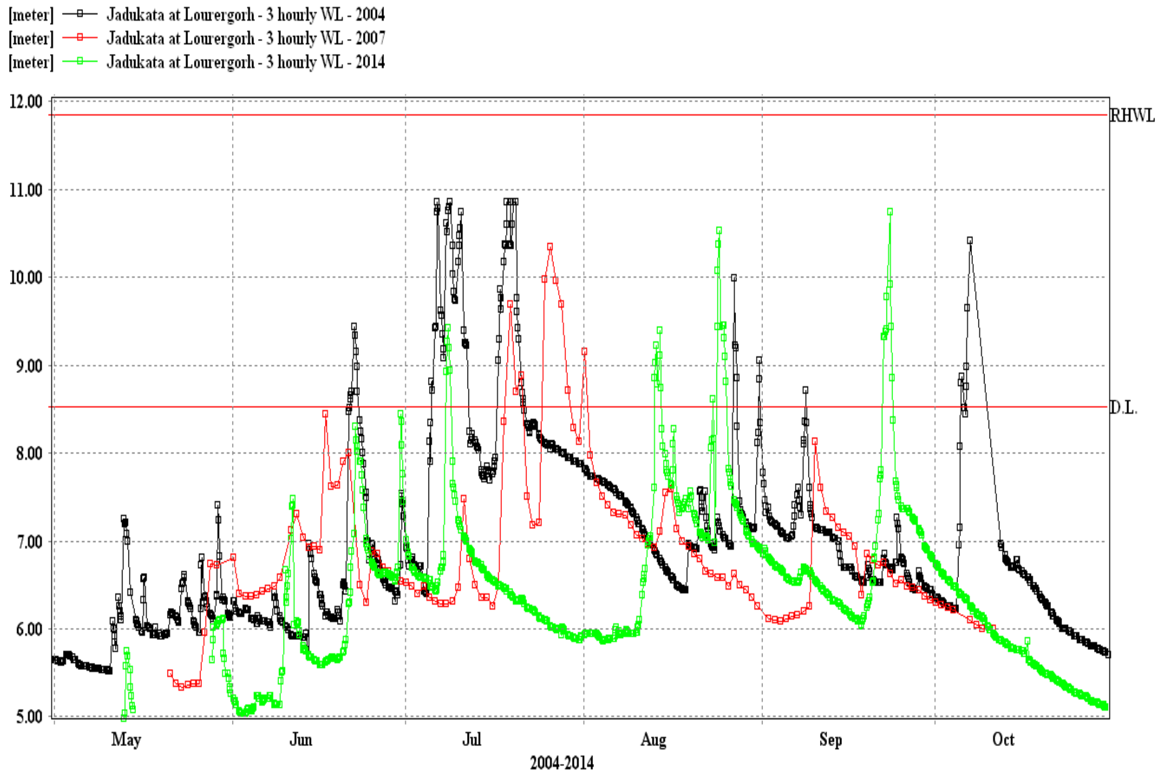


Figure 3.32 : Comparison of Hydrograph on Jadukata at Lorergarh

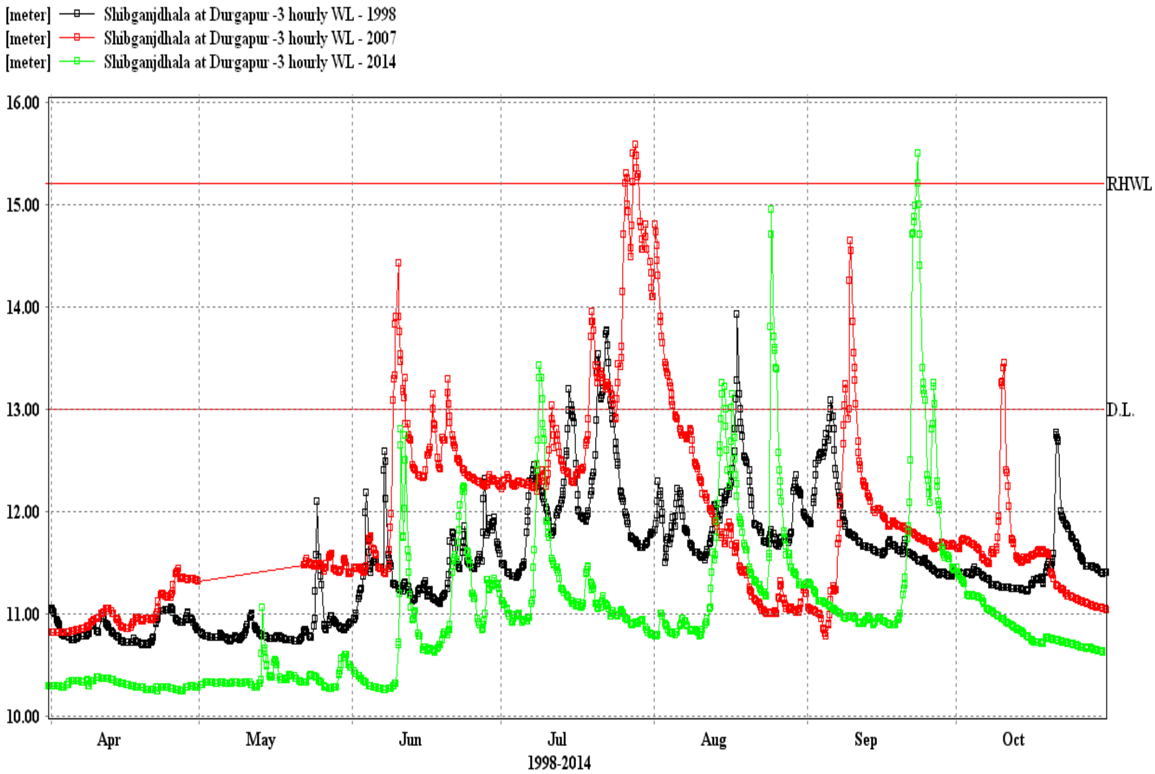


Figure 3.33 : Comparison of Hydrograph on Someswari at Durgapur

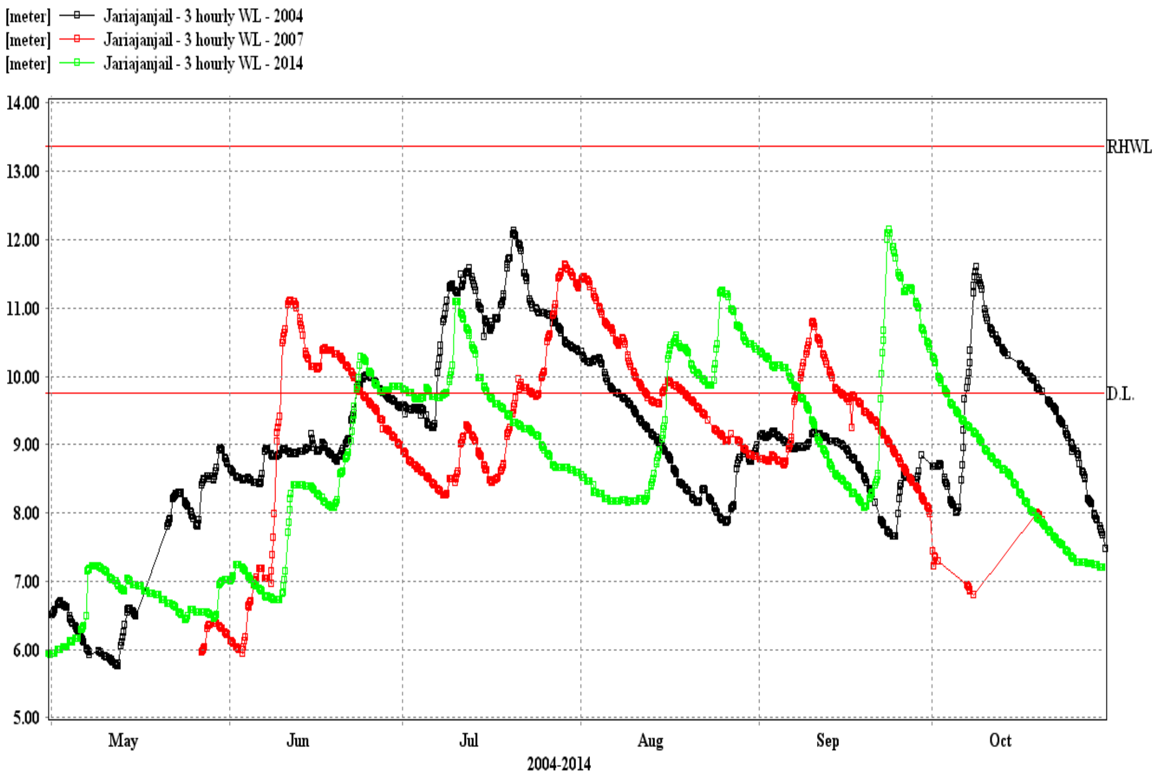


Figure 3.34 : Comparison of Hydrograph on Kangsha at Jariajanjail

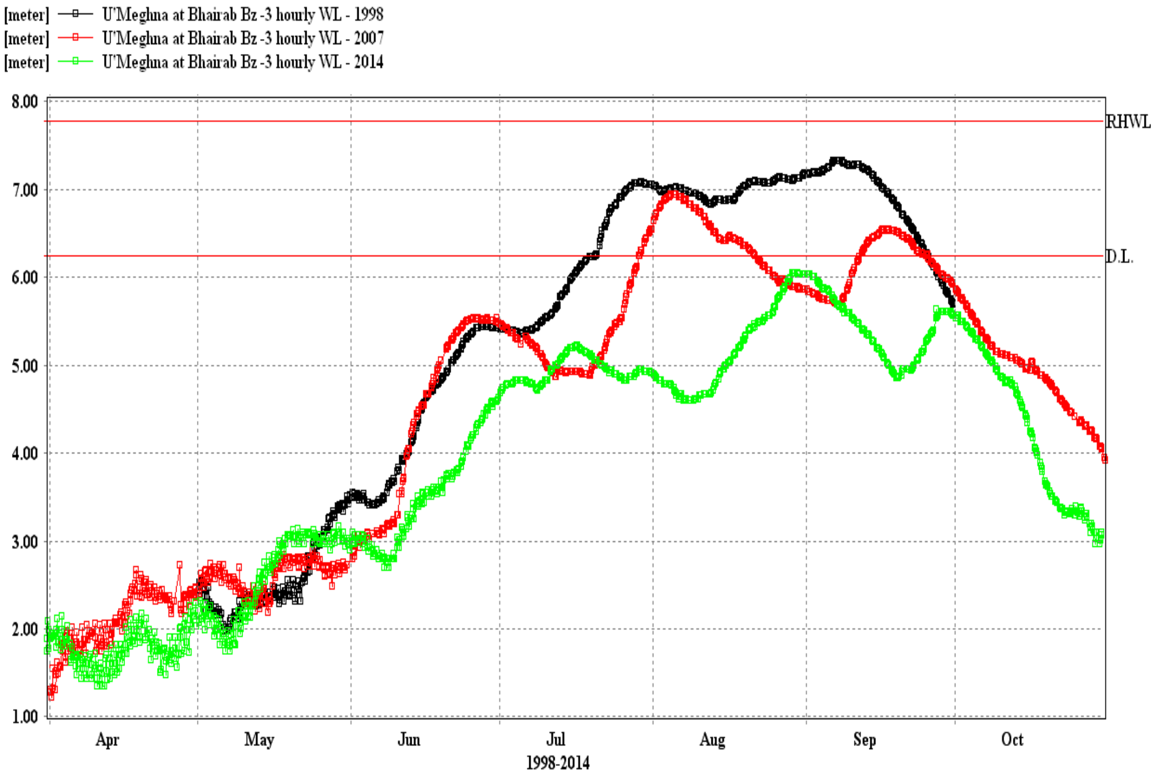


Figure 3.35 : Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

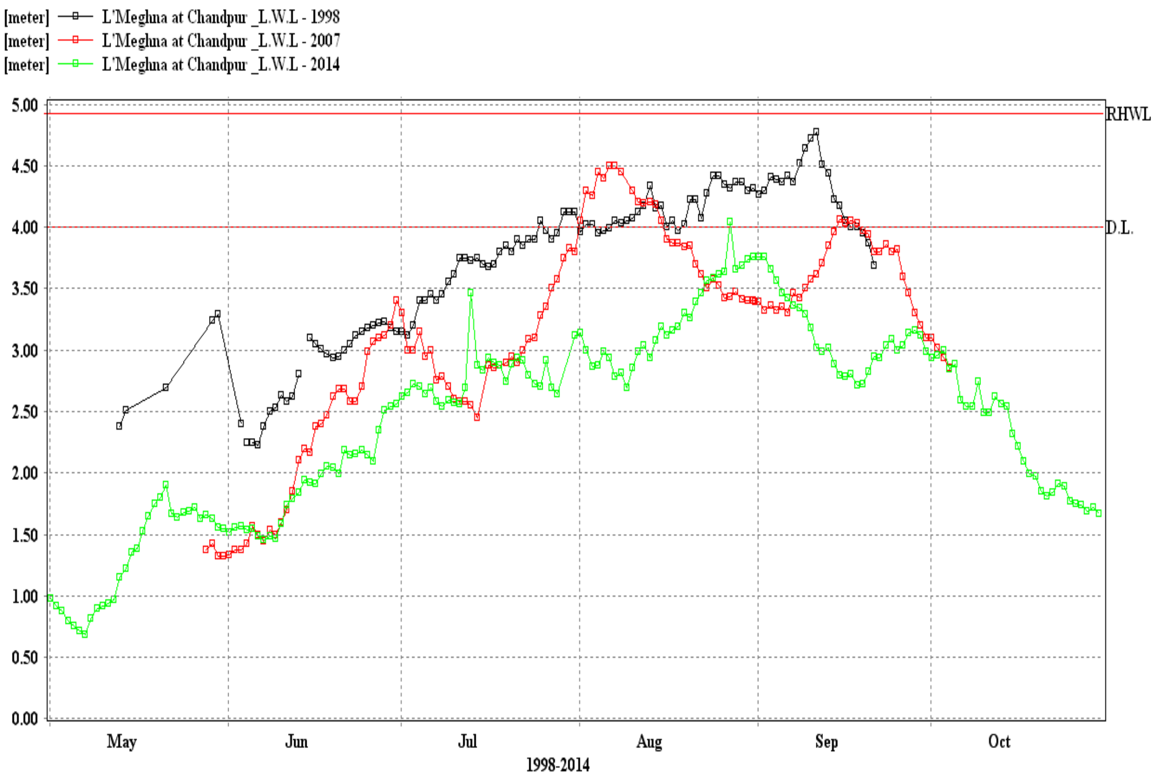


Figure 3.36 : Comparison of Hydrograph on Lower Meghna at Chandpur

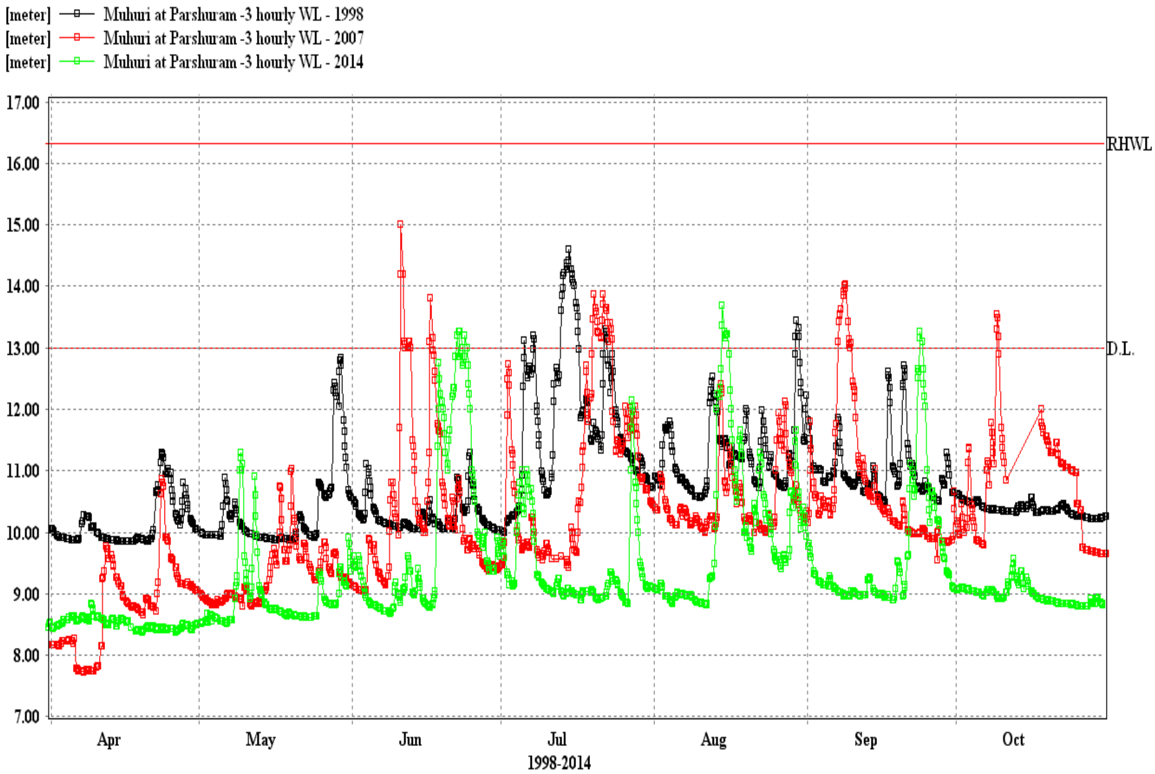


Figure 3.37 : Comparison of Hydrograph on Muhuri at Parshuram

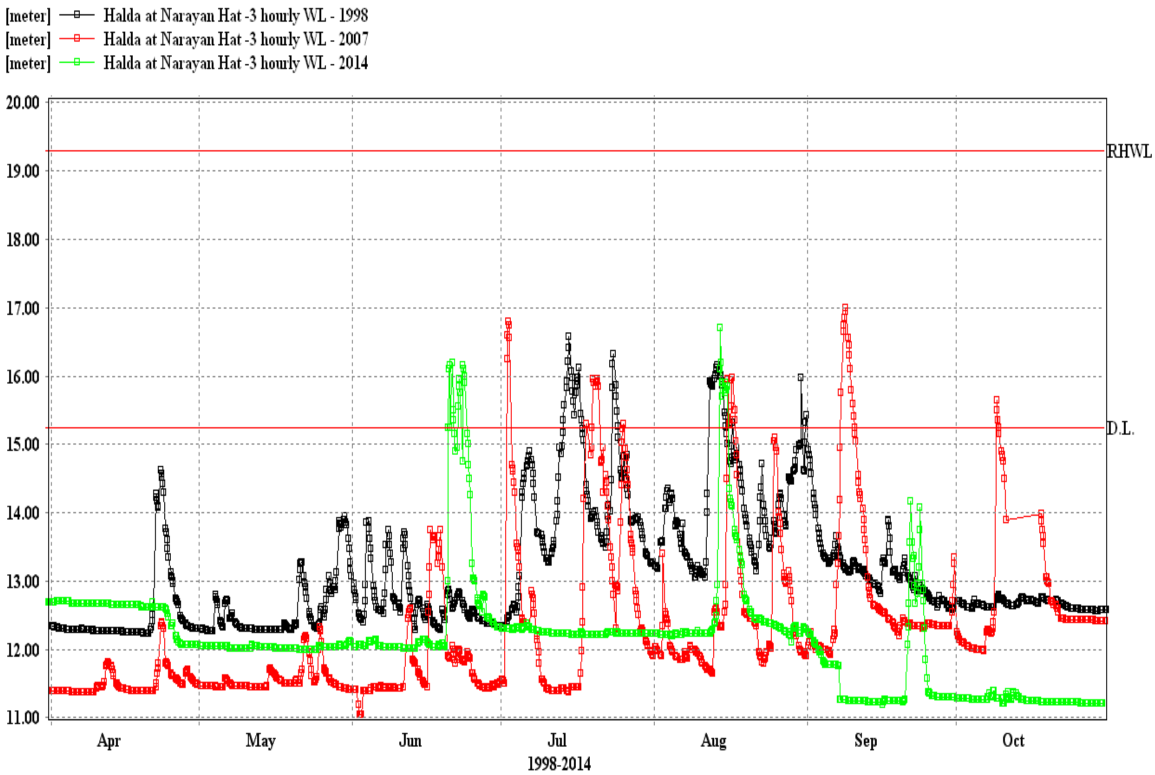


Figure 3.38 : Comparison of Hydrograph on Halda at Narayanhat

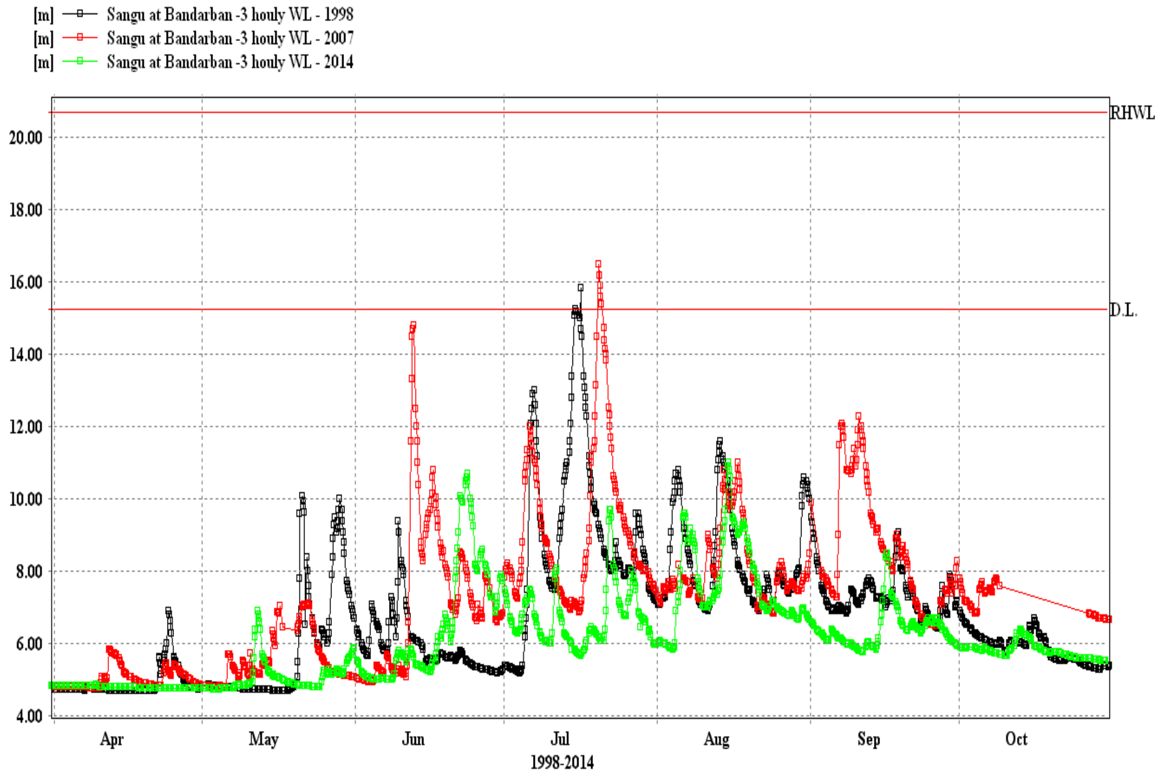


Figure 3.39 : Comparison of Hydrograph on Sangu at Bandarban

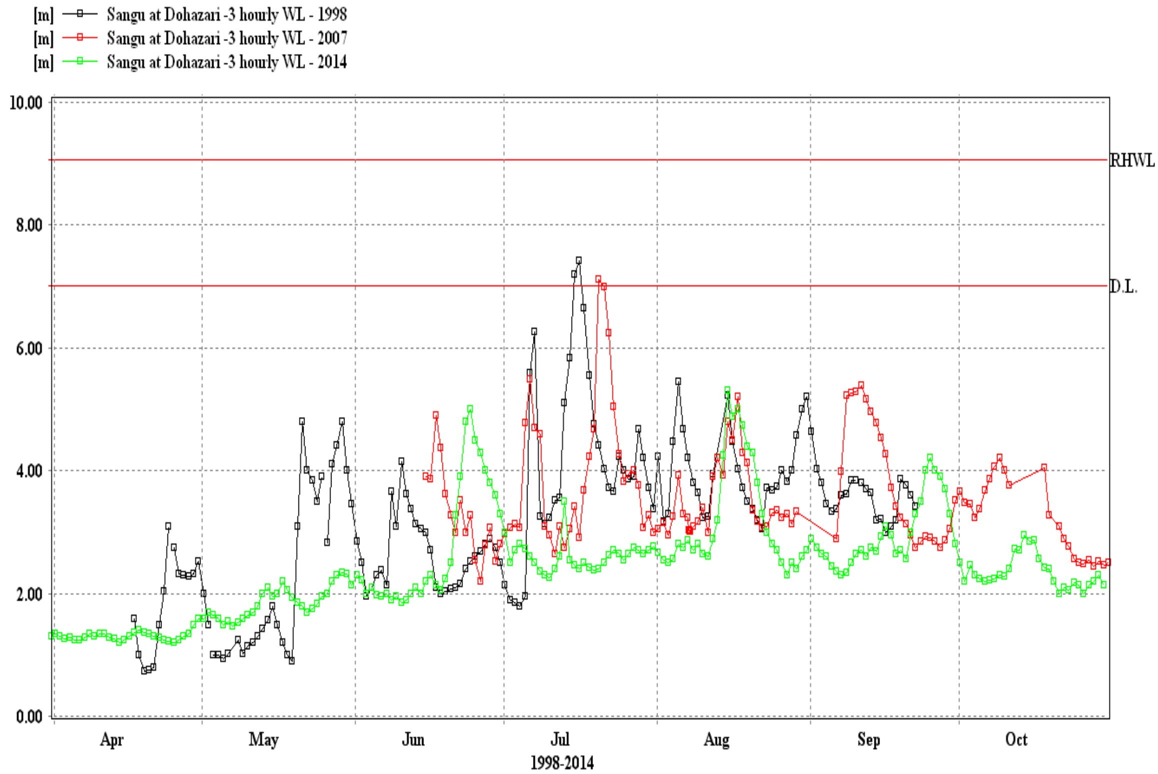


Figure 3.40 : Comparison of Hydrograph on Sangu at Dohazari

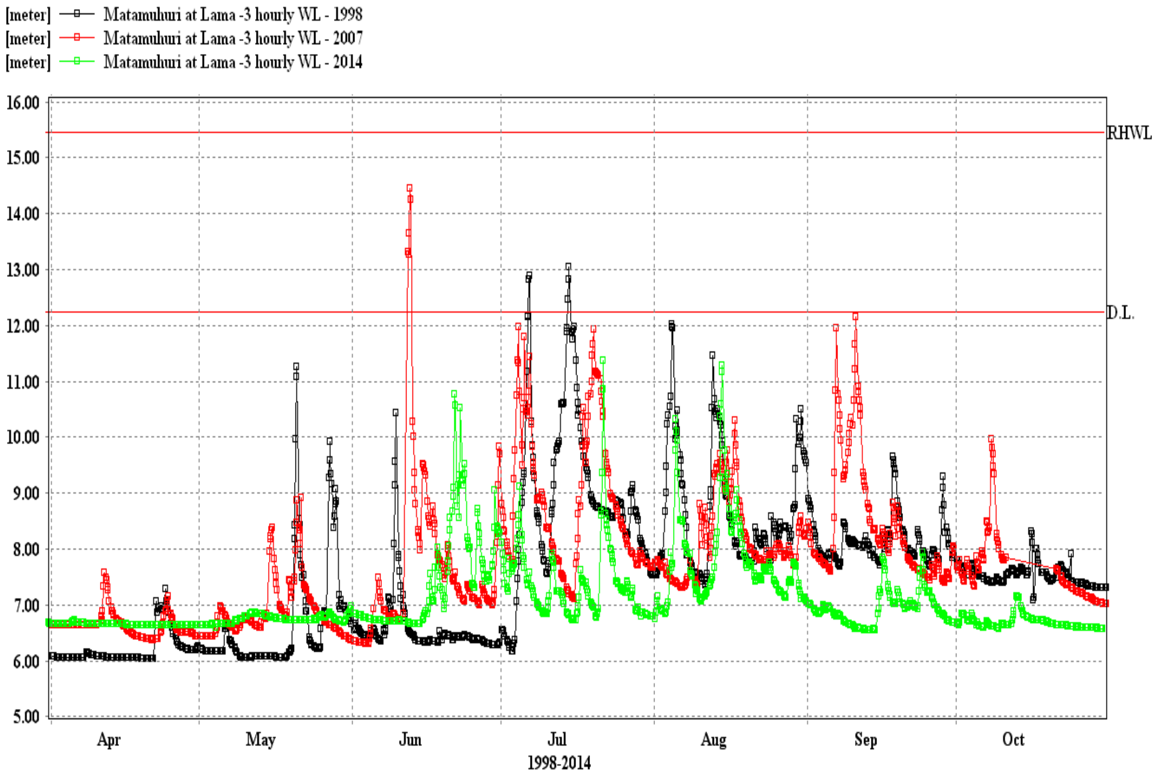


Figure 3.41 : Comparison of Hydrograph on Matamuhuri at Lama

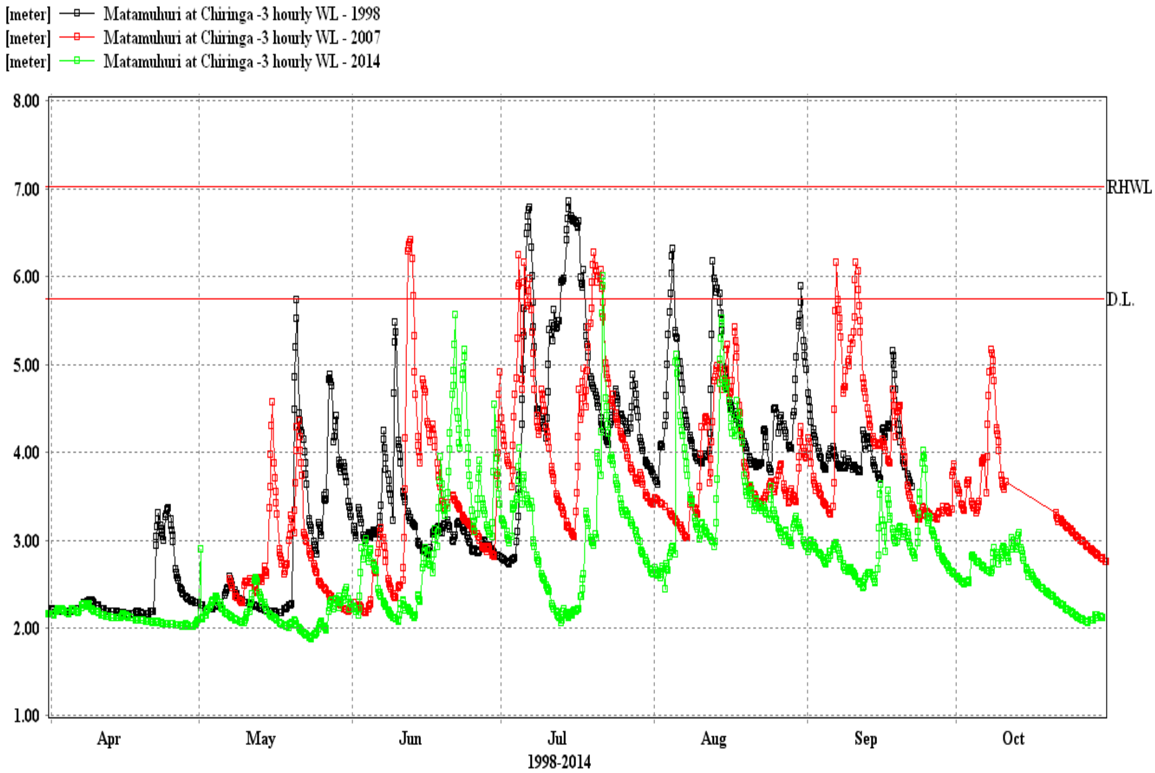


Figure 3.42 : Comparison of Hydrograph on Matamuhuri at Chiringa

CHAPTER 4:
FLOOD FORECAST EVALUATION, 2014

4.1 GENERAL

BWDB mandated for flood forecasting and warning services in Bangladesh (BWDB Act-2000) and FFWC under BWDB is being carried out this through preparation of flood forecasting, early warning and its dissemination. Flood forecasting models of FFWC are developed on MIKE 11, one-dimensional modeling software used for the simulation of WLs and discharges in the river network and flood plains. Till 2012 the model based flood forecast had been generated and disseminated upto 72hrs lead time flood forecast. There are needs and expectations for increasing lead time of forecast for various reasons and ther are demand from many corners. A research initiative was started from July 2011 to increase lead time for deterministic flood forecast upto 5 days (upto 120 hours) from 3-days and to extend the Flood Forecast to few selected BWDB projects with support from CDMP-II under the then Ministry of Food and Disaster Management (MoFDM) (from middle of 2012 under Ministry of Disaster Management and Relief - MoDMR). Accordingly 5-days (2 additional days of lead time) extended lead time deterministic flood forecast has been generated and disseminated on regular basis since June 2013. Experimentally Flash flood forecast with 48-hours lead time on pilot basis on selected points on the north eastern zone of Bangladesh has been generated and disseminated during April May (the flash flood threat for the Boro paddy harvest period).

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tire overlapping forecast system with improved lead time during monsoon season 2003 and 2004, which showed a success in forecasting the discharges at Hardinge Bridge station of Ganges and Bahadurabad stations of Brahmaputra rivers of Bangladesh. From March 2006 – June 2009, CARE-Bangladesh and United States Agency for International Development (USAID), Dhaka supported the program with an objective to technology transfer and capacity building for sustainable end-to-end generation and application through pilot projects at selected sites. Medium range 10-day lead time probability based flood forecast to a limited number of places (only 18 points) on experimental basis was initiated under the project. After the termination of the support from the USAID-CARE in 2009, this has been continued with technical support from the RIMES. Another initiative has been started from July 2012 to expand the number of points upto 38 locations for medium range 10-day lead time probability based flood forecast to increase the area coverage along with Flash Flood Guidance (FFG) on experimental basis at Sunamgonj and Coxs Bazar with support from USAID through CARE-Bangladesh under SHOURHARDO-II programme with technical partner RIMES.

This chapter discuss about the evaluation of the flood forecast for the monsoon of 2014.

4.2 EVALUATION CRITERIA OF FLOOD FORECAST PERFORMANCE

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

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

4.2.1 MEAN ABSOLUTE ERROR (MAE)

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

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

Where,

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

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

n is the number of *Observed/Forecast* levels

4.2.2 CO-EFFICIENT OF DETERMINATION, 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:

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

Where,

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

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

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

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

n is the number of *Observed/Forecast* levels

4.3 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2014 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 of 120 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour, 72-hour, 96 hours and 120 hours intervals. Usually, the forecast quality gradually deteriorates with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases. This means that forecasts are the best at 24-hour interval followed by 48-hour interval and so on. Summary of the performance of flood forecast for 2014 monsoon is presented in Table 4.2. Result of the statistical analysis and performance on the basis of the aforesaid scale for all the 54 stations/locations are presented in Table 4.3, Table 4.4, Table 4.5, Table 4.6, Table 4.6 and Table 4.7. Figures from 4.1 to 4.5 are shown the performance of forecasted WL based on the observed WL for 24, 48, 72, 96 and 120 hours for the 54 forecast points.

4.4 FORECAST STATISTICS AND MODEL PERFORMANCE, 2014

4.4.1 Deterministic forecast performance

For deterministic forecast, simulations were made for maximum 120 hrs. The forecast quality gradually deteriorated where forecast intervals were moved further away from the time of forecast. Usually as lead time increases the accuracy (variation of forecast & observe value) decreases. Flood Forecast generated at 54 stations/points located within the model area (including some boundary stations) are evaluated. The forecast statistics along with their performance are provided in Tables 4.2 to 4.7 and in Figures 4.1 to 4.5. From the tables it may be seen that for 1-day forecast 98.15% for the stations are within the range of Good and Average. For 5-days forecast 59.26% stations are in the range of Good and Average for the monsoon of 2014. Specially few stations near boundary showing poor to very poor performance.

Table 4. 2: Summary of forecast performance at 54 stations upto 5-days forecast for 2014 flood

Forecast Lead time	Number of stations/points (% of 54 – total points)				
	Good	Average	NS	Poor	Very Poor
Day-1 Forecast (24 hrs)	50(92.59%)	3 (5.56%)	1(1.85%)	0	0
Day-2 Forecast(48 hrs)	38(70.37%)	11(20.37%)	3 (5.56%)	2 (3.7%)	0
Day-3 Forecast(72 hrs)	27(50.0%)	14(25.93%)	5(9.26%)	6(11.1%)	2 (3.70%)
Day-4 Forecast(96 hrs)	20(37.04%)	13(24.07%)	9(16.67%)	6(11.11%)	6(11.11%)
Day-5 Forecast(120 hrs)	11(20.37%)	21(38.89%)	6(11.11%)	4(7.41%)	12(22.22%)

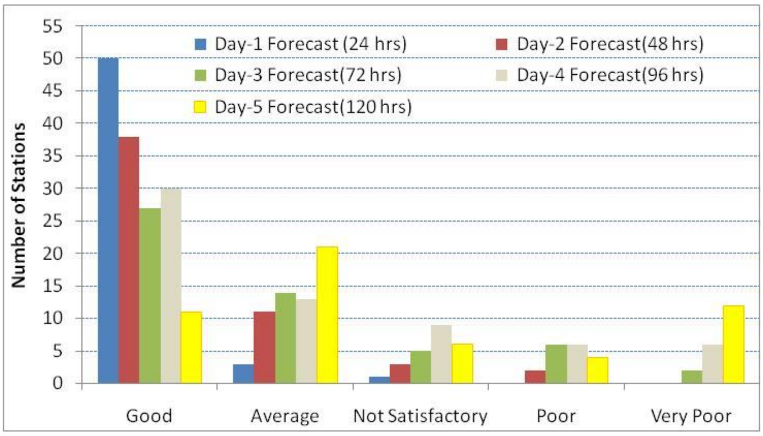


Figure 4.1: Performance of the flood forecast up to 5 days based on the Mean Absolute Error(MAE) and Co-efficient of Determination (total forecast stations 54)

Table 4. 3 : Statistics for 24- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-24hr
1	Aricha	0.05	0.98	Good
2	Bahadurabad	0.06	0.98	Good
3	Baider Bazar	0.08	0.97	Good
4	Bhagyakul	0.04	0.98	Good
5	Bhairabbazar	0.04	0.98	Good
6	Bogra	0.07	0.96	Good
7	Chakrahimpur	0.10	0.94	Good
8	Chilmari	0.13	0.91	Good
9	Demra	0.07	0.96	Good
10	Dhaka-Milbarak	0.08	0.95	Good
11	Goalundo	0.06	0.96	Good
12	Gorai-RB	0.04	0.98	Good
13	Hariharpara	0.08	0.95	Good
14	Hardinge-BR	0.07	0.98	Good
15	Jamalpur	0.07	0.94	Good
16	Kamarkhali	0.05	0.92	Good
17	Kaunia	0.15	0.87	Average
18	Kazipur	0.09	0.92	Good
19	Kurigram	0.09	0.94	Good
20	Mawa	0.07	0.98	Good
21	Meghna Road Br	0.11	0.95	Good
22	Mirpur	0.09	0.98	Good

Sl. No.	Station	MAE (m)	r^2	Performance-24hr
23	Mohadevpur	0.14	0.89	Average
24	Mymensingh	0.09	0.94	Good
25	Naogaon	0.06	0.96	Good
26	Narayangonj	0.12	0.92	Good
27	Nayarhat	0.08	0.97	Good
28	Porabari	0.10	0.97	Good
29	Rajshahi	0.17	0.93	Good
30	Serajgonj	0.08	0.97	Good
31	Sheola	0.17	0.85	Average
32	Sunamgonj	0.10	0.98	Good
33	Sylhet	0.03	0.98	Good
34	Talbaria	0.07	0.98	Good
35	Taraghat	0.15	0.95	Good
36	Tongi	0.08	0.98	Good
37	Atrai	0.07	0.97	Good
38	Baghabari	0.07	0.97	Good
39	C-Nawabganj	0.09	0.95	Good
40	Singra	0.05	0.98	Good
41	Derai	0.04	0.97	Good
42	Elashin	0.07	0.97	Good
43	Gaibandha	0.09	0.96	Good
44	Jagir	0.09	0.98	Good
45	Kalagachia	0.11	0.94	Good
46	Khaliajuri	0.09	0.96	Good
47	Lakhpur	0.08	0.94	Good
48	Markuli	0.09	0.93	Good
49	Porabari(Mathura)	0.04	0.98	Good
50	Moulvibazar	0.25	0.68	Not Satisfactory (NS)
51	Narsingdi	0.07	0.98	Good
52	Munshiganj	0.09	0.96	Good
53	Sariakandi	0.10	0.94	Good
54	Sureswar	0.08	0.97	Good

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

Sl. No.	Station	MAE (m)	r^2	Performance-48hr
1	Aricha	0.09	0.96	Good
2	Bahadurabad	0.1	0.95	Good
3	Baider Bazar	0.09	0.96	Good
4	Bhagyakul	0.07	0.96	Good
5	Bhairabbazar	0.10	0.94	Good
6	Bogra	0.20	0.82	Average
7	Chakrahimpur	0.11	0.93	Good
8	Chilmari	0.18	0.84	Average
9	Demra	0.1	0.95	Good
10	Dhaka-Milbarak	0.12	0.92	Good
11	Goalundo	0.09	0.95	Good
12	Gorai-RB	0.09	0.96	Good
13	Hariharpara	0.12	0.93	Good
14	Hardinge-BR	0.10	0.97	Good
15	Jamalpur	0.19	0.84	Average
16	Kamarkhali	0.08	0.92	Good

17	Kaunia	0.25	0.67	NS
18	Kazipur	0.11	0.91	Good
19	Kurigram	0.10	0.93	Good
20	Mawa	0.10	0.96	Good
21	Meghna Road Br	0.12	0.93	Good
22	Mirpur	0.11	0.96	Good
23	Mohadevpur	0.29	0.64	NS
24	Mymensingh	0.17	0.84	Average
25	Naogaon	0.26	0.67	NS
26	Narayangonj	0.15	0.82	Average
27	Nayarhat	0.09	0.95	Good
28	Porabari	0.11	0.95	Good
29	Rajshahi	0.19	0.87	Average
30	Serajgonj	0.09	0.95	Good
31	Sheola	0.32	0.35	Poor
32	Sunamgonj	0.15	0.86	Average
33	Sylhet	0.19	0.84	Average
34	Talbaria	0.09	0.96	Good
35	Taraghat	0.16	0.92	Good
36	Tongi	0.11	0.94	Good
37	Atrai	0.09	0.93	Good
38	Baghabari	0.09	0.94	Good
39	C-Nawabganj	0.21	0.83	Average
40	Singra	0.09	0.96	Good
41	Derai	0.10	0.93	Good
42	Elashin	0.11	0.94	Good
43	Gaibandha	0.21	0.86	Average
44	Jagir	0.12	0.91	Good
45	Kalagachia	0.11	0.94	Good
46	Khaliajuri	0.11	0.94	Good
47	Lakhpur	0.14	0.90	Good
48	Markuli	0.17	0.85	Average
49	Porabari(Mathura)	0.09	0.94	Good
50	Moulvibazar	0.32	0.39	Poor
51	Narsingdi	0.13	0.90	Good
52	Munshiganj	0.14	0.92	Good
53	Sariakandi	0.10	0.94	Good
54	Sureswar	0.09	0.95	Good

NS - Not Satisfactory

Table 4. 5 : Statistics for 72- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-72hr
1	Aricha	0.1	0.94	Good
2	Bahadurabad	0.13	0.91	Good
3	Baider Bazar	0.10	0.95	Good
4	Bhagyakul	0.12	0.93	Good
5	Bhairabbazar	0.10	0.92	Good
6	Bogra	0.37	0.39	Poor
7	Chakrahimpur	0.12	0.92	Good
8	Chilmari	0.19	0.80	Average
9	Demra	0.11	0.93	Good
10	Dhaka-Milbarak	0.19	0.82	Average
11	Goalundo	0.11	0.93	Good

12	Gorai-RB	0.2	0.86	Average
13	Hariharpara	0.19	0.83	Average
14	Hardinge-BR	0.12	0.95	Good
15	Jamalpur	0.27	0.65	NS
16	Kamarkhali	0.09	0.92	Good
17	Kaunia	0.35	0.37	Poor
18	Kazipur	0.17	0.81	Average
19	Kurigram	0.29	0.63	NS
20	Mawa	0.11	0.94	Good
21	Meghna Road Br	0.12	0.92	Good
22	Mirpur	0.12	0.95	Good
23	Mohadevpur	0.35	0.35	Poor
24	Mymensingh	0.27	0.64	NS
25	Naogaon	0.36	0.37	Poor
26	Narayangonj	0.22	0.65	NS
27	Nayarhat	0.18	0.85	Average
28	Porabari	0.13	0.93	Good
29	Rajshahi	0.19	0.86	Average
30	Serajgonj	0.10	0.94	Good
31	Sheola	0.47	0.29	Very Poor
32	Sunamgonj	0.22	0.86	Average
33	Sylhet	0.34	0.30	Poor
34	Talbaria	0.11	0.94	Good
35	Taraghat	0.17	0.82	Average
36	Tongi	0.15	0.90	Good
37	Atrai	0.10	0.90	Good
38	Baghabari	0.10	0.92	Good
39	C-Nawabganj	0.29	0.63	NS
40	Singra	0.10	0.94	Good
41	Derai	0.17	0.83	Average
42	Elashin	0.15	0.91	Good
43	Gaibandha	0.29	0.70	Poor
44	Jagir	0.17	0.82	Average
45	Kalagachia	0.12	0.93	Good
46	Khaliajuri	0.13	0.90	Good
47	Lakhpur	0.17	0.84	Average
48	Markuli	0.19	0.80	Average
49	Porabari(Mathura)	0.12	0.91	Good
50	Moulvibazar	0.42	0.30	Very Poor
51	Narsingdi	0.17	0.80	Average
52	Munshiganj	0.15	0.90	Good
53	Sariakandi	0.11	0.92	Good
54	Sureswar	0.12	0.93	Good

Table 4. 6 : Statistics for 96- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-96hr
1	Aricha	0.12	0.92	Good
2	Bahadurabad	0.17	0.87	Average
3	Baider Bazar	0.11	0.93	Good
4	Bhagyakul	0.13	0.92	Good
5	Bhairabbazar	0.12	0.90	Good
6	Bogra	0.42	0.29	Very Poor
7	Chakrahimpur	0.15	0.90	Good

8	Chilmari	0.19	0.79	Average
9	Demra	0.13	0.92	Good
10	Dhaka-Milbarak	0.20	0.80	Average
11	Goalundo	0.13	0.91	Good
12	Gorai-RB	0.25	0.62	NS
13	Hariharpara	0.22	0.69	NS
14	Hardinge-BR	0.13	0.93	Good
15	Jamalpur	0.32	0.36	Poor
16	Kamarkhali	0.13	0.90	Good
17	Kaunia	0.43	0.26	Very Poor
18	Kazipur	0.24	0.63	NS
19	Kurigram	0.32	0.38	Poor
20	Mawa	0.13	0.92	Good
21	Meghna Road Br	0.13	0.91	Good
22	Mirpur	0.14	0.93	Good
23	Mohadevpur	0.37	0.32	Poor
24	Mymensingh	0.32	0.34	Poor
25	Naogaon	0.46	0.26	Very Poor
26	Narayangonj	0.28	0.49	NS
27	Nayarhat	0.23	0.65	NS
28	Porabari	0.16	0.91	Good
29	Rajshahi	0.20	0.79	Average
30	Serajgonj	0.13	0.92	Good
31	Sheola	0.52	0.21	Very Poor
32	Sunamgonj	0.27	0.66	NS
33	Sylhet	0.38	0.28	Poor
34	Talbaria	0.13	0.92	Good
35	Taraghat	0.19	0.79	Average
36	Tongi	0.19	0.82	Average
37	Atrai	0.16	0.82	Average
38	Baghabari	0.14	0.90	Good
39	C-Nawabganj	0.35	0.36	Poor
40	Singra	0.14	0.90	Good
41	Derai	0.18	0.79	Average
42	Elashin	0.16	0.84	Average
43	Gaibandha	0.45	0.18	Very Poor
44	Jagir	0.23	0.63	NS
45	Kalagachia	0.14	0.90	Good
46	Khaliajuri	0.17	0.80	Average
47	Lakhpur	0.23	0.66	NS
48	Markuli	0.24	0.79	NS
49	Porabari(Mathura)	0.17	0.82	Average
50	Moulvibazar	0.50	0.19	Very Poor
51	Narsingdi	0.18	0.74	Average
52	Munshiganj	0.17	0.82	Average
53	Sariakandi	0.14	0.90	Good
54	Sureswar	0.14	0.91	Good

Table 4. 7 : Statistics for 120- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-120hr
1	Aricha	0.13	0.90	Good
2	Bahadurabad	0.19	0.80	Average
3	Baider Bazar	0.14	0.91	Good

4	Bhagyakul	0.15	0.91	Good
5	Bhairabbazar	0.17	0.82	Average
6	Bogra	0.51	0.17	Very Poor
7	Chakrahimpur	0.19	0.78	Average
8	Chilmari	0.21	0.74	Average
9	Demra	0.14	0.90	Good
10	Dhaka-Milbarak	0.20	0.79	Average
11	Goalundo	0.15	0.90	Good
12	Gorai-RB	0.27	0.58	NS
13	Hariharpara	0.34	0.39	Poor
14	Hardinge-BR	0.14	0.91	Good
15	Jamalpur	0.47	0.21	Very Poor
16	Kamarkhali	0.19	0.72	Average
17	Kaunia	0.56	0.17	Very Poor
18	Kazipur	0.36	0.21	Poor
19	Kurigram	0.39	0.31	Poor
20	Mawa	0.15	0.92	Good
21	Meghna Road Br	0.18	0.76	Average
22	Mirpur	0.15	0.91	Good
23	Mohadevpur	0.49	0.19	Very Poor
24	Mymensingh	0.48	0.26	Very Poor
25	Naogaon	0.52	0.18	Very Poor
26	Narayangonj	0.35	0.30	Poor
27	Nayarhat	0.28	0.52	NS
28	Porabari	0.19	0.80	Average
29	Rajshahi	0.27	0.62	NS
30	Serajgonj	0.16	0.91	Good
31	Sheola	0.63	0.11	Very Poor
32	Sunamgonj	0.47	0.22	Very Poor
33	Sylhet	0.38	0.28	Very Poor
34	Talbaria	0.13	0.90	Good
35	Taraghat	0.20	0.76	Average
36	Tongi	0.19	0.76	Average
37	Atrai	0.18	0.72	Average
38	Baghabari	0.18	0.81	Average
39	C-Nawabganj	0.49	0.21	Very Poor
40	Singra	0.17	0.82	Average
41	Derai	0.19	0.72	Average
42	Elashin	0.19	0.79	Average
43	Gaibandha	0.53	0.12	Very Poor
44	Jagir	0.27	0.54	NS
45	Kalagachia	0.15	0.90	Good
46	Khaliajuri	0.19	0.74	Average
47	Lakhpur	0.28	0.58	NS
48	Markuli	0.29	0.72	NS
49	Porabari(Mathura)	0.21	0.79	Average
50	Moulvibazar	0.62	0.10	Very Poor
51	Narsingdi	0.21	0.72	Average
52	Munshiganj	0.19	0.79	Average
53	Sariakandi	0.21	0.82	Average
54	Sureswar	0.16	0.86	Average

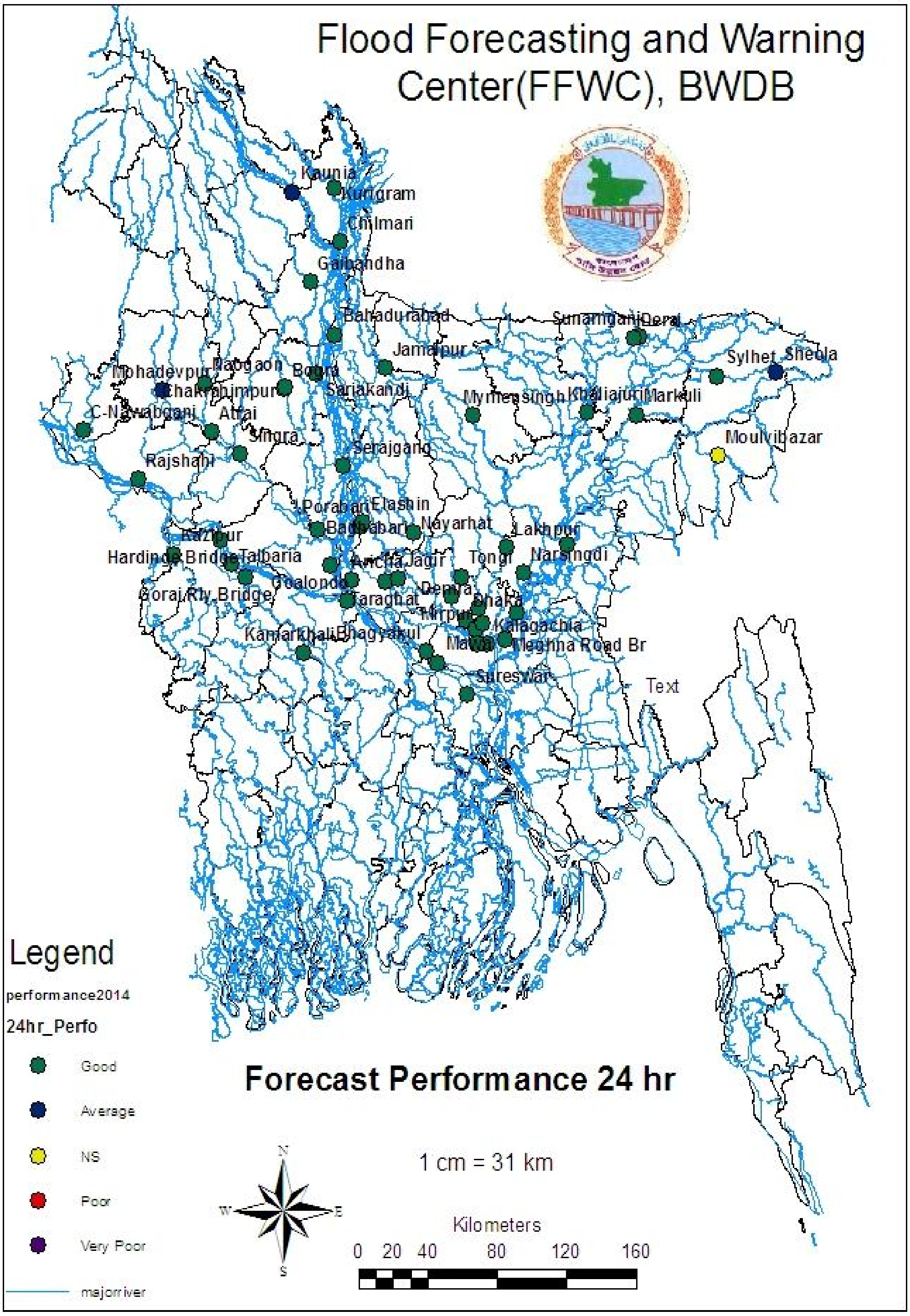


Figure 4.2 : Forecast Evaluation 24 hour (Year, 2014)

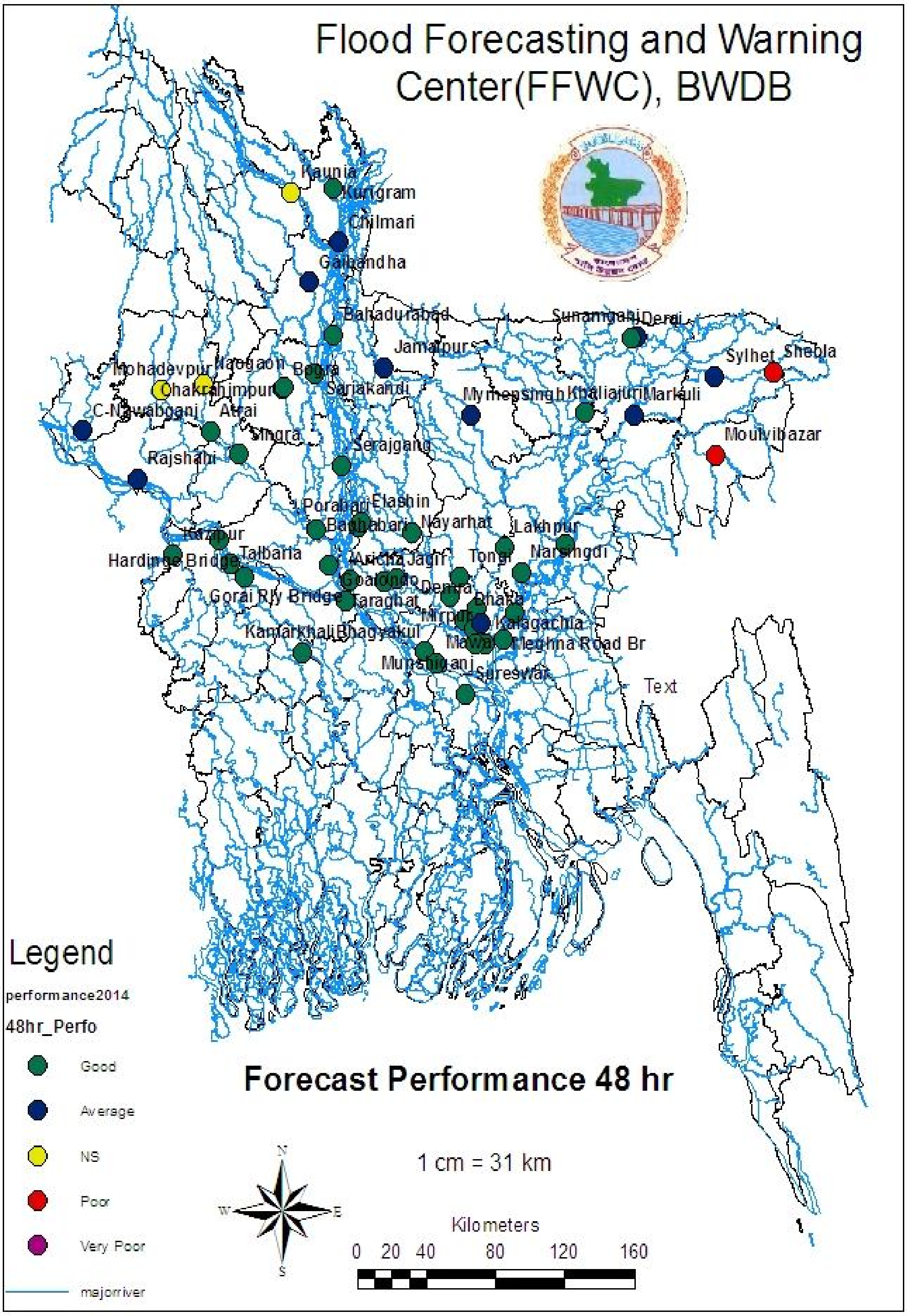


Figure 4.3 : Forecast Evaluation 48 hour (Year, 2014)

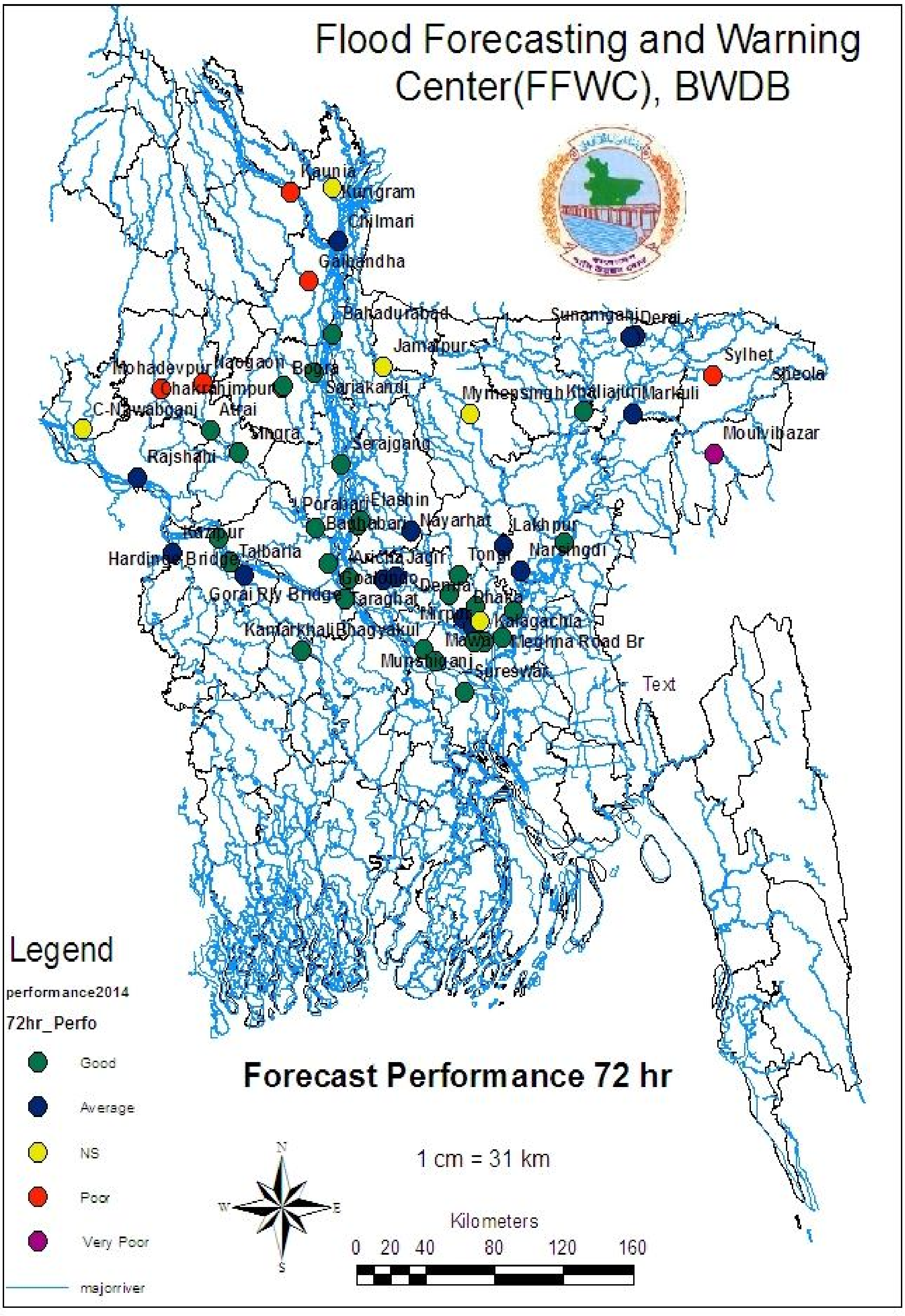


Figure 4.4 : Forecast Evaluation 72 hour (Year, 2014)

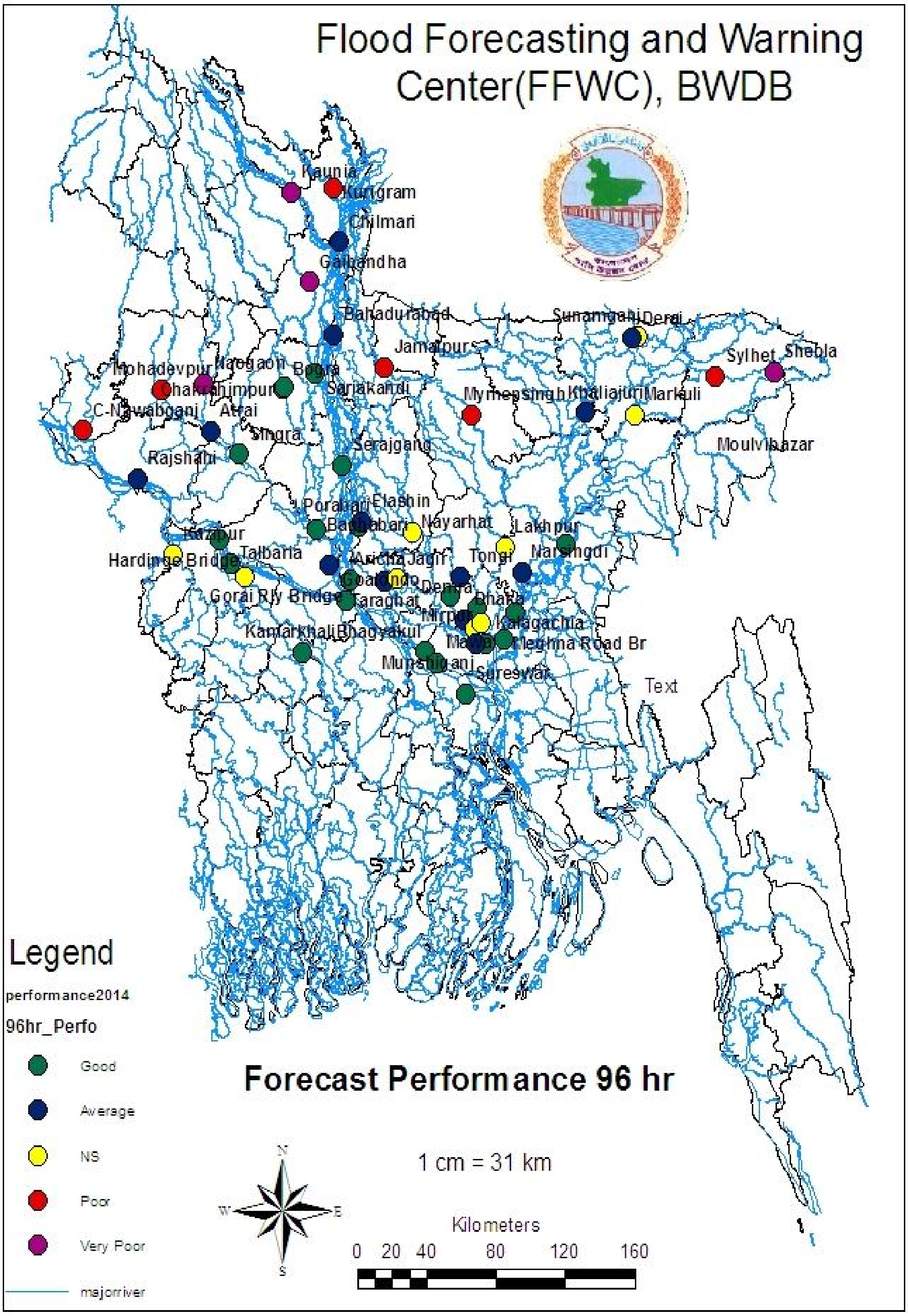


Figure 4.5 : Forecast Evaluation 96 hour (Year, 2014)

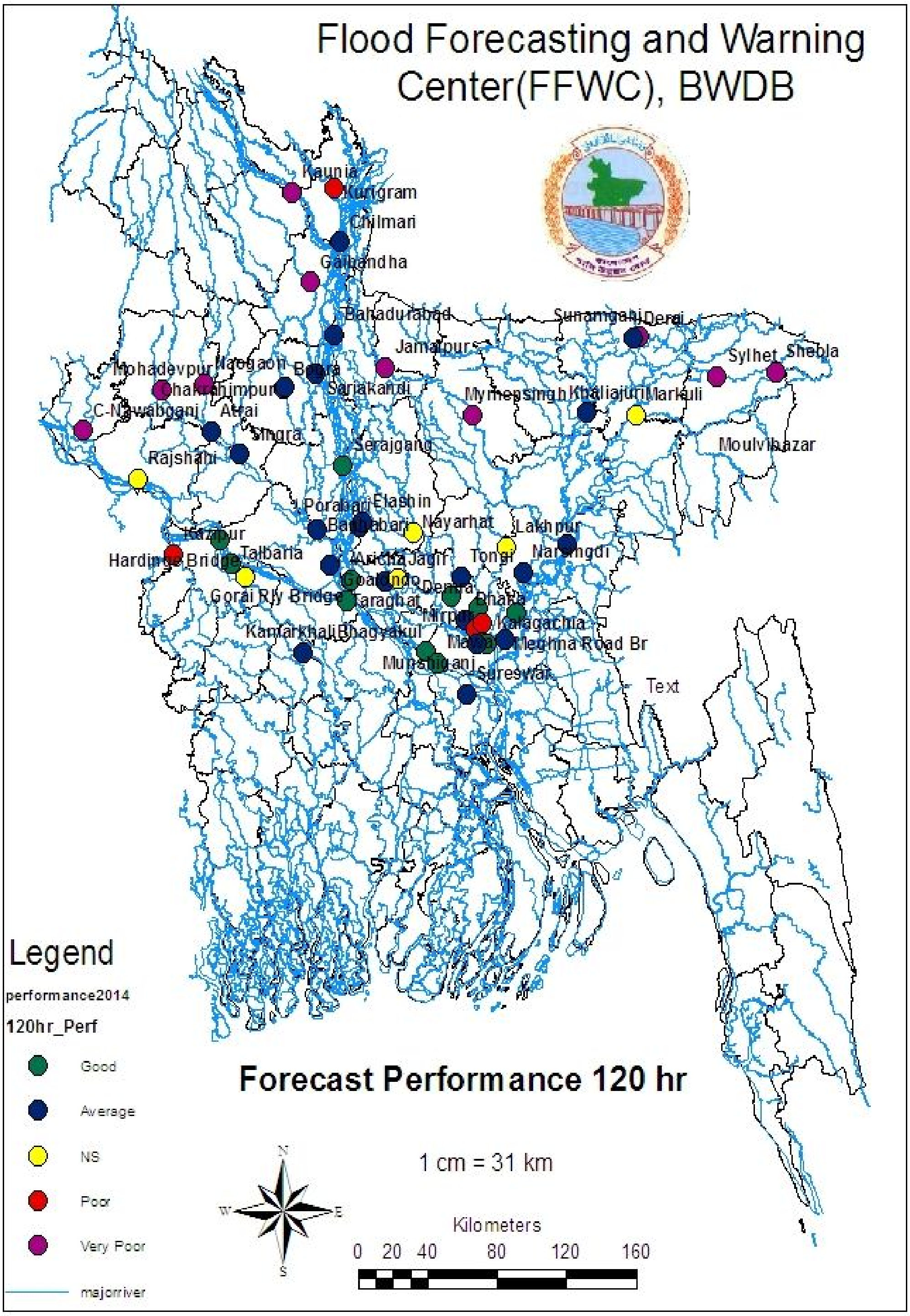


Figure 4.6 : Forecast Evaluation 120 hour (Year, 2014)

4.4.2 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 flood 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. The extended lead-time flood forecast has been initiated at 18 locations during 2005-07 period. This has been expanded to 38 locations since 2013 with technical partnership with RIMES-Bangkok and financial support from USAID through CARE-Bangladesh under SHOUHARDO-II programme.

In addition to existing 24, 48, 72, 96 and 120 hrs lead time deterministic flood forecast, CFAN model generates medium range upto 10 days lead-time probabilistic flood forecasts with mean, upper bound and lower bound WL at 37 locations listed below on experimental basis. The Mean Water Level forecast made from the mean discharge and the mean rainfall forecast of all 51 ensemble series. The Upper bound and Lower bound water corresponds to +1 standard deviation from the mean and -1 standard deviation from the mean respectively.

The statistics of forecast performance based on the MAE, RMSE and R^2 for 3-days, 5-days , 7-days and upto 10 days time scale for the 37 number of stations under FFWC system have been presented through Table 4.5 to Table 4.8.

Table 4. 8 : Performance of 3-day Probabilistic Forecast

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	0.34	0.48	0.82	0.24	0.37	0.82	0.24	0.37	0.81
Baghbari	0.27	0.33	0.87	0.27	0.31	0.87	0.30	0.34	0.85
Bahadurabad	0.72	1.02	0.39	0.45	0.61	0.51	0.44	0.56	0.48
Bhagyakul	0.24	0.33	0.79	0.19	0.27	0.78	0.20	0.28	0.76
Bhairabbazar	0.15	0.18	0.93	0.15	0.18	0.93	0.15	0.18	0.93
Chandpur	0.30	0.39	0.29	0.30	0.39	0.29	0.30	0.39	0.29
Demra	0.16	0.18	0.85	0.16	0.19	0.84	0.16	0.19	0.84
Dhaka	0.11	0.14	0.89	0.12	0.15	0.88	0.12	0.16	0.86
Dirai	0.37	0.49	0.49	0.37	0.49	0.49	0.37	0.49	0.49
Elashinghat	0.43	0.60	0.75	0.33	0.49	0.74	0.32	0.49	0.71
Faridpur	0.09	0.15	0.91	0.09	0.15	0.91	0.09	0.15	0.91
Goalondo	0.31	0.44	0.80	0.22	0.35	0.80	0.24	0.36	0.78
Gorai-RB	0.29	0.37	0.96	0.26	0.32	0.97	0.44	0.54	0.96
Hardinge Bridge	0.37	0.49	0.92	0.35	0.45	0.93	0.60	0.73	0.91
Jagir	0.12	0.14	0.98	0.10	0.13	0.98	0.11	0.13	0.98
Jamalpur	0.42	0.53	0.81	0.41	0.52	0.80	0.41	0.55	0.79
Kamarkhali	0.18	0.24	0.98	0.18	0.21	0.98	0.31	0.38	0.97
Kanaighat	1.26	1.66	0.39	1.26	1.66	0.39	1.26	1.66	0.39
Kazipur	0.54	0.74	0.55	0.36	0.49	0.63	0.37	0.48	0.60
Madaripur	0.16	0.22	0.79	0.16	0.22	0.77	0.16	0.23	0.76

Mawa	0.21	0.27	0.85	0.16	0.22	0.85	0.17	0.23	0.83
Mirpur	0.12	0.15	0.95	0.13	0.16	0.95	0.13	0.17	0.94
Mohadevpur	0.68	0.89	0.31	0.69	0.90	0.30	0.69	0.89	0.31
Moulvibazar	0.88	1.19	0.25	0.88	1.19	0.25	0.89	1.20	0.25
Mymensingh	0.39	0.47	0.83	0.39	0.47	0.83	0.41	0.50	0.81
Naogaon	0.44	0.58	0.73	0.44	0.59	0.73	0.44	0.58	0.74
Narayanganj	0.15	0.18	0.82	0.16	0.19	0.80	0.16	0.19	0.79
Narsingdi	0.12	0.15	0.91	0.12	0.15	0.91	0.12	0.15	0.91
Rekabi Bazar	0.11	0.14	0.89	0.12	0.15	0.87	0.12	0.15	0.87
Sariakandi	0.60	0.82	0.51	0.38	0.52	0.62	0.36	0.48	0.59
Serajganj	0.60	0.78	0.59	0.39	0.53	0.65	0.35	0.48	0.65
Sheola	1.30	1.77	0.35	1.31	1.77	0.35	1.33	1.81	0.35
Sherpur	0.31	0.48	0.31	0.31	0.48	0.31	0.29	0.37	0.51
Sunamganj	0.30	0.44	0.61	0.31	0.44	0.62	0.31	0.44	0.62
Sureshwar	0.26	0.34	0.51	0.23	0.32	0.52	0.23	0.32	0.51
Sylhet	0.66	0.87	0.51	0.66	0.87	0.51	0.66	0.87	0.51
Tongi	0.10	0.12	0.93	0.10	0.13	0.93	0.10	0.13	0.93

Table 4. 9 : Performance of 5-day Probabilistic Forecast

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	0.66	0.96	0.62	0.40	0.58	0.68	0.37	0.49	0.70
Baghbari	0.51	0.63	0.65	0.47	0.56	0.66	0.48	0.58	0.63
Bahadurabad	0.94	1.28	0.40	0.57	0.70	0.49	0.48	0.60	0.44
Bhagyakul	0.43	0.55	0.67	0.27	0.34	0.70	0.31	0.39	0.66
Bhairabbazar	0.22	0.27	0.82	0.21	0.26	0.81	0.21	0.26	0.79
Chandpur	0.42	0.55	0.05	0.42	0.55	0.05	0.42	0.55	0.05
Demra	0.24	0.27	0.70	0.25	0.28	0.69	0.25	0.29	0.65
Dhaka	0.19	0.23	0.76	0.18	0.23	0.74	0.20	0.25	0.69
Dirai	0.50	0.65	0.29	0.50	0.65	0.29	0.50	0.65	0.29
Elashinghat	0.78	1.08	0.61	0.60	0.87	0.58	0.52	0.74	0.52
Faridpur	0.15	0.22	0.80	0.15	0.22	0.80	0.15	0.22	0.80
Goalondo	0.65	0.94	0.58	0.40	0.62	0.59	0.41	0.57	0.55
Gorai-RB	0.53	0.75	0.85	0.44	0.56	0.86	0.70	0.88	0.84
Hardinge Bridge	0.69	1.01	0.71	0.59	0.77	0.73	0.92	1.15	0.67
Jagir	0.24	0.31	0.95	0.19	0.24	0.95	0.18	0.23	0.94
Jamalpur	0.67	0.79	0.65	0.61	0.75	0.63	0.60	0.80	0.59
Kamarkhali	0.39	0.49	0.91	0.29	0.38	0.92	0.54	0.65	0.90
Kanaighat	1.50	1.92	0.24	1.50	1.92	0.24	1.50	1.92	0.24
Kazipur	0.82	1.21	0.38	0.56	0.80	0.42	0.51	0.62	0.43
Madaripur	0.32	0.40	0.60	0.27	0.34	0.58	0.30	0.38	0.53
Mawa	0.39	0.50	0.69	0.27	0.35	0.70	0.29	0.37	0.65
Mirpur	0.20	0.25	0.89	0.21	0.25	0.88	0.22	0.27	0.85
Mohadevpur	0.85	1.07	0.14	0.85	1.08	0.13	0.86	1.08	0.13
Moulvibazar	1.17	1.65	0.01	1.18	1.65	0.01	1.15	1.56	0.02
Mymensingh	0.56	0.67	0.65	0.57	0.68	0.64	0.60	0.73	0.62
Naogaon	0.54	0.70	0.58	0.55	0.71	0.57	0.55	0.71	0.58
Narayanganj	0.20	0.25	0.68	0.22	0.27	0.66	0.24	0.29	0.60
Narsingdi	0.18	0.24	0.78	0.18	0.24	0.78	0.18	0.24	0.78
Rekabi Bazar	0.19	0.24	0.77	0.20	0.25	0.68	0.20	0.25	0.68
Sariakandi	1.06	1.69	0.30	0.63	1.01	0.38	0.48	0.62	0.45
Serajganj	1.03	1.62	0.37	0.63	0.96	0.46	0.48	0.60	0.52

Sheola	1.56	2.01	0.22	1.57	2.01	0.23	1.58	2.04	0.22
Sherpur	0.40	0.53	0.36	0.40	0.53	0.37	0.40	0.54	0.37
Sunamganj	0.41	0.60	0.43	0.41	0.60	0.44	0.42	0.60	0.44
Sureshwar	0.43	0.54	0.25	0.37	0.47	0.22	0.38	0.49	0.17
Sylhet	0.87	1.12	0.32	0.87	1.12	0.32	0.88	1.13	0.32
Tongi	0.16	0.20	0.84	0.16	0.20	0.83	0.17	0.21	0.81

Table 4. 10 : Performance of 7-day Probabilistic Forecast

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	1.11	1.59	0.47	0.67	1.04	0.47	0.53	0.78	0.45
Baghbari	0.69	0.86	0.52	0.63	0.77	0.51	0.63	0.76	0.48
Bahadurabad	0.91	1.14	0.31	0.67	0.82	0.33	0.58	0.75	0.27
Bhagyakul	0.64	0.85	0.56	0.36	0.52	0.54	0.38	0.45	0.54
Bhairabbazar	0.30	0.37	0.71	0.28	0.35	0.69	0.27	0.34	0.65
Chandpur	0.48	0.61	0.04	0.48	0.61	0.04	0.48	0.61	0.04
Demra	0.30	0.34	0.56	0.31	0.36	0.54	0.33	0.38	0.49
Dhaka	0.27	0.33	0.72	0.25	0.31	0.69	0.25	0.31	0.63
Dirai	0.59	0.78	0.18	0.59	0.78	0.18	0.59	0.78	0.18
Elashinghat	1.10	1.44	0.55	0.81	1.18	0.49	0.65	0.97	0.43
Faridpur	0.20	0.28	0.69	0.20	0.28	0.69	0.20	0.28	0.69
Goalondo	1.02	1.44	0.47	0.59	0.92	0.45	0.52	0.72	0.40
Gorai-RB	0.79	1.07	0.77	0.48	0.61	0.81	0.81	1.01	0.76
Hardinge Bridge	0.94	1.30	0.64	0.64	0.81	0.67	1.06	1.30	0.56
Jagir	0.43	0.53	0.90	0.32	0.43	0.90	0.28	0.37	0.88
Jamalpur	0.94	1.12	0.46	0.86	1.05	0.42	0.87	1.09	0.37
Kamarkhali	0.61	0.82	0.81	0.35	0.46	0.85	0.66	0.80	0.80
Kanaighat	1.71	2.08	0.15	1.71	2.08	0.15	1.71	2.08	0.15
Kazipur	1.31	2.13	0.19	0.79	1.22	0.22	0.62	0.78	0.27
Madaripur	0.45	0.59	0.57	0.36	0.46	0.49	0.37	0.47	0.39
Mawa	0.56	0.71	0.62	0.36	0.50	0.57	0.37	0.46	0.51
Mirpur	0.30	0.36	0.85	0.28	0.34	0.82	0.29	0.35	0.77
Mohadevpur	0.90	1.10	0.11	0.90	1.11	0.11	0.92	1.13	0.10
Moulvibazar	1.26	1.57	0.00	1.27	1.58	0.00	1.27	1.58	0.00
Mymensingh	0.69	0.82	0.53	0.68	0.82	0.51	0.71	0.88	0.48
Naogaon	0.58	0.74	0.50	0.60	0.75	0.49	0.59	0.75	0.50
Narayanganj	0.25	0.32	0.61	0.27	0.33	0.57	0.29	0.35	0.50
Narsingdi	0.25	0.31	0.71	0.25	0.31	0.71	0.25	0.31	0.71
Rekabi Bazar	0.27	0.35	0.72	0.25	0.31	0.61	0.25	0.31	0.61
Sariakandi	1.74	2.93	0.13	0.99	1.65	0.16	0.67	0.96	0.22
Serajganj	1.38	2.14	0.29	0.77	1.13	0.36	0.58	0.76	0.38
Sheola	1.81	2.25	0.09	1.82	2.26	0.10	1.84	2.30	0.09
Sherpur	0.50	0.68	0.18	0.51	0.68	0.18	0.51	0.68	0.19
Sunamganj	0.48	0.68	0.38	0.49	0.68	0.39	0.50	0.68	0.39
Sureshwar	0.51	0.65	0.30	0.43	0.53	0.23	0.38	0.50	0.18
Sylhet	1.02	1.28	0.23	1.03	1.28	0.24	1.04	1.29	0.23
Tongi	0.21	0.26	0.76	0.22	0.27	0.75	0.24	0.28	0.69

Table 4. 11 : Performance of 10-day Probabilistic Forecast

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	1.42	2.02	0.32	0.86	1.33	0.32	0.71	0.93	0.32
Baghbari	1.01	1.28	0.30	0.93	1.14	0.29	0.88	1.09	0.26
Bahadurabad	1.07	1.34	0.15	0.78	0.94	0.12	0.75	0.93	0.10
Bhagyakul	0.89	1.14	0.37	0.52	0.75	0.35	0.50	0.60	0.32
Bhairabbazar	0.39	0.48	0.60	0.38	0.46	0.57	0.35	0.44	0.52
Chandpur	0.42	0.57	0.16	0.42	0.57	0.16	0.42	0.57	0.16
Demra	0.40	0.46	0.35	0.43	0.49	0.32	0.45	0.51	0.28
Dhaka	0.40	0.50	0.65	0.36	0.44	0.61	0.35	0.42	0.54
Dirai	0.76	1.08	0.04	0.76	1.08	0.04	0.76	1.08	0.04
Elashinghat	1.35	1.72	0.40	1.05	1.45	0.36	0.89	1.22	0.30
Faridpur	0.26	0.35	0.51	0.26	0.35	0.51	0.26	0.35	0.51
Goalondo	1.34	1.87	0.31	0.78	1.22	0.30	0.66	0.86	0.27
Gorai-RB	1.27	1.65	0.73	0.74	0.92	0.73	0.84	1.07	0.60
Hardinge Bridge	1.53	2.02	0.68	0.98	1.25	0.64	1.12	1.40	0.47
Jagir	0.69	0.83	0.82	0.56	0.68	0.81	0.49	0.59	0.77
Jamalpur	1.19	1.40	0.36	1.12	1.27	0.32	1.08	1.28	0.28
Kamarkhali	0.87	1.17	0.69	0.51	0.62	0.73	0.74	0.92	0.65
Kanaighat	1.82	2.19	0.06	1.82	2.19	0.06	1.82	2.19	0.06
Kazipur	2.49	3.95	0.05	1.67	2.80	0.04	1.28	2.25	0.03
Madaripur	0.56	0.69	0.53	0.41	0.53	0.44	0.44	0.53	0.32
Mawa	0.71	0.85	0.44	0.45	0.62	0.41	0.47	0.57	0.34
Mirpur	0.43	0.53	0.77	0.40	0.48	0.73	0.38	0.46	0.67
Mohadevpur	0.86	1.06	0.18	0.86	1.07	0.18	0.87	1.07	0.17
Moulvibazar	1.34	1.61	0.01	1.35	1.61	0.01	1.36	1.62	0.00
Mymensingh	0.98	1.16	0.34	0.94	1.11	0.32	0.96	1.15	0.27
Naogaon	0.71	0.90	0.24	0.73	0.92	0.23	0.73	0.92	0.23
Narayanganj	0.37	0.46	0.43	0.39	0.46	0.38	0.41	0.47	0.32
Narsingdi	0.36	0.45	0.55	0.36	0.45	0.55	0.36	0.45	0.55
Rekabi Bazar	0.39	0.50	0.65	0.33	0.41	0.53	0.33	0.41	0.53
Sariakandi	2.28	3.72	0.03	1.43	2.46	0.04	1.08	1.96	0.03
Serajganj	2.06	3.24	0.13	1.31	2.16	0.13	0.94	1.52	0.12
Sheola	2.03	2.43	0.03	2.04	2.45	0.03	2.07	2.48	0.03
Sherpur	0.58	0.81	0.08	0.58	0.82	0.08	0.58	0.81	0.10
Sunamganj	0.62	0.86	0.20	0.64	0.87	0.21	0.64	0.87	0.21
Sureshwar	0.57	0.72	0.29	0.42	0.55	0.25	0.41	0.51	0.20
Sylhet	1.17	1.45	0.10	1.18	1.46	0.10	1.18	1.47	0.10
Tongi	0.28	0.36	0.67	0.30	0.36	0.64	0.31	0.37	0.58

Following charts showing the MAE and r^2 plots for the Aricha on the Brahmaputra River and Bhairabbazar on the Meghna River for monsoon 2014, indicated that as the longer the lead time, the r^2 is reducing and MAE increasing.

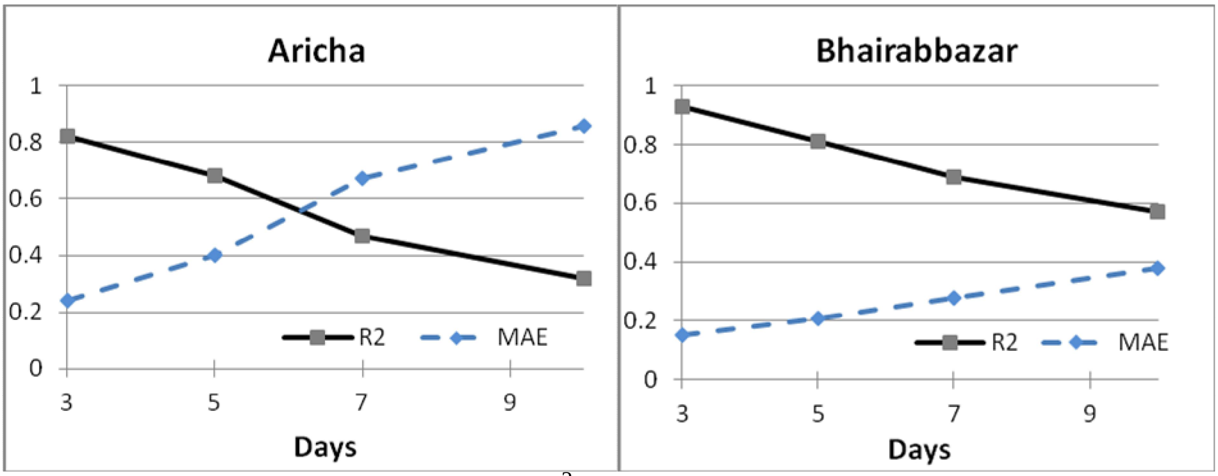


Figure 4. 7 : Chart showing MAE and R^2 upto 10-days probabilistic Forecast for Aricha and Bhairab Bazar

Average of MAE and r^2 of 32 probability based flood forecast stations plot also indicating the variability of the Forecast vs Observe is increasing with the increasing lead time.

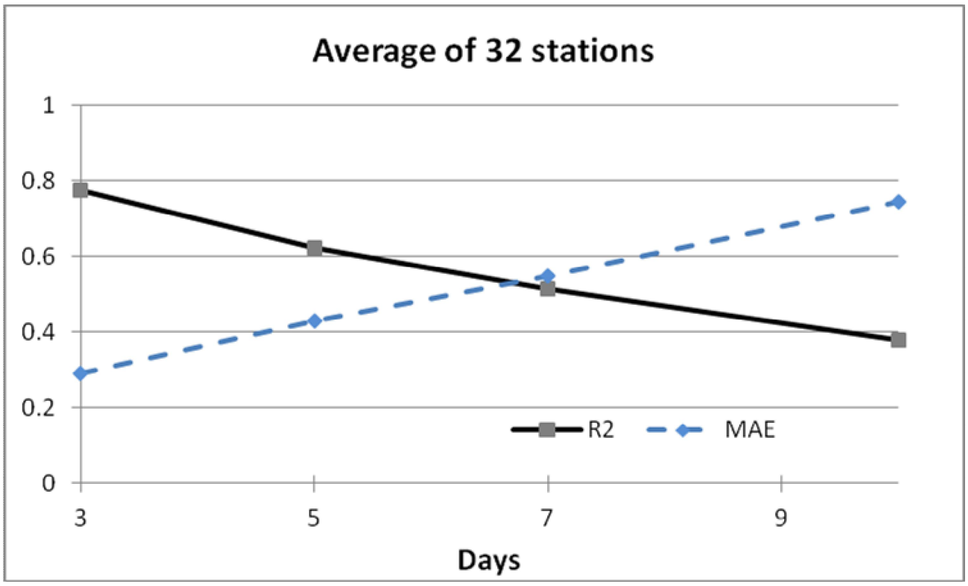


Figure 4. 8 : Chart showing average of MAE and R^2 upto 10-days probabilistic Forecast for 32 stations

CHAPTER 5 : INUNDATION STATUS

The country as a whole experienced average flooding during the monsoon-2014. The flood during 2014 was not a severe one and stayed for short (1-day) to medium duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin. During the monsoon-2014 there was no flash flood in the North-Eastern part and South-Eastern part of the country in pre monsoon, upto mid May.

Out of 23 Water Level (WL) monitoring stations in the Brahmaputra basin, at 16 stations WL was crossed the respective DLs, these are Dharla at Kurigram for 4 days, Teesta at Dalia for 20 days, Ghagot at Gaibandha for 14 days, Korotoa at Chakrahimpur for 4 days, Brahmaputra at Noonkhawa for 1 days and Chilmari for 13 days, Jamuna at Bahadurabad for 14 days, Sariakandi for 20 days, Serajganj for 15 days and Aricha for 11 days, Atrai at Baghabari for 19 days, Dhaleswari at Elashin for 19 days, Lakhya at Lakhpur for 25 days and Narayanganj for 14 days and Turag at Mirpur for 4 days during August and September. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj districts were flooded for short to medium period.

In the Ganges basin out of 23 WL monitoring stations, at 4 stations river exceeded their respective DLs during monsoon 2014, these are Goalondo on Ganges/ Padma, Bhagyakul on Padma, Sureswar on Padma and Little Jamuna at Naogaon during the monsoon 2014. The WL of river Padma at Goalondo was flowed over respective DL for 13 days Bhagyakul for 11 days and Sureswar for 17 days. The low lying areas of Rajbari, Faridpur, Manikgonj, Munshigonj, Sariatpur and districts was affected by flooding during August September. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul WL gauge stations.

Out of 25 WL monitoring stations in the Meghna basin, at 15 stations flowed above their respective DLs, these are Kanaighat, Sylhet and Sunamganj on Surma River, Sheola and Sherpur on Kushyara River, sarighat on Sarigowain River, Habigonj and Bullah on Khowai river, Kamalganj on Dhalai river, Derai on Old Surma Course, Nakuakaon on Bhugai River, Lorergarh on Jadukata River, Durgapur on Someswari River, Jariajanjail on Kangsha River and Brahmanbaria on Titas River for less than 1 day (Surma at Sylhet and Kushiyara at Sheola) to 54 days (Kangsha at Jariajanjail). As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2014.

In the South Eastern Hill basin WL of the rivers Muhuri, Halda and Matamuhuri crossed their respective DLs for 1 to 7 days during this monsoon-2014. As a result, short duration flood occurred at Parshuram (Muhuri), Narayanhat (Halda river) and Chiringa (Matamuhuri river) during the monsoon 2014. Total 3 WL monitoring stations in the South Eastern Hill basin crossed DLs during the Monsoon-2014.

In flood period, Flood Inundation Map has been developed at FFWC as a part of routine output based on the result file/data of the Flood Forecasting Model and digital elevation map (DEM). This was done by using MIKE 11 FF module and GIS, where the results were found from MIKE 11 Rainfall-Runoff and Hydrodynamic modelling simulation. In addition to that rainfall surface of Situation Map for past 24 hours has also been developed in the FFWC on routine basis. Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country. A detail and authentic DEM shall improve significantly showing inundation status map. Sample of Flood Inundation Maps based on 24 hrs, 48 hrs, 72 hrs, 96 hrs and 120 hrs forecast respectively are presented in the following pages (Fig 5.46, 5.47, 5.48, 5.49 and 5.50 respectively).

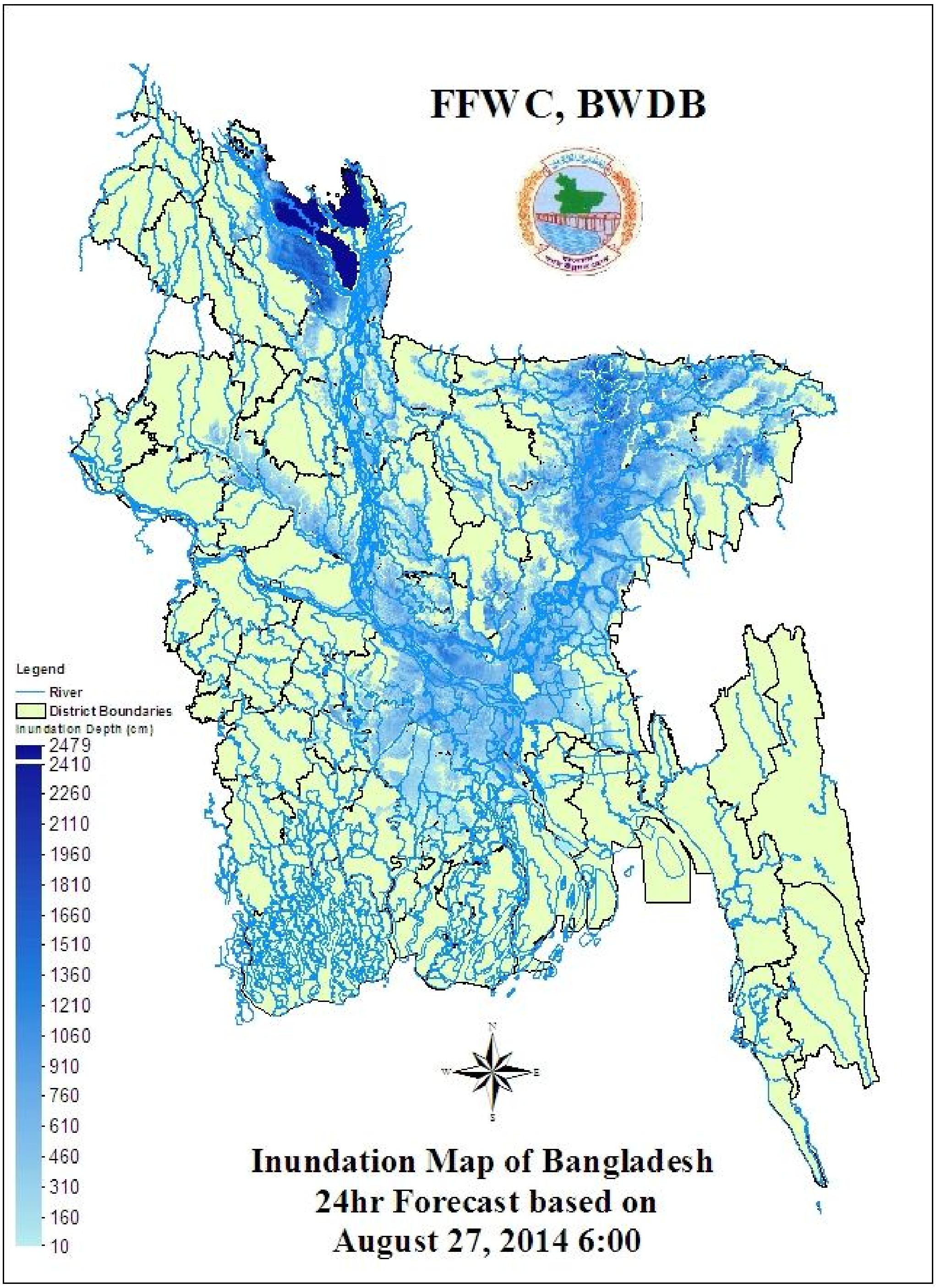


Figure 5.1 : Flood Inundation Map of Bangladesh (24hr Forecast Based on 27 August 2014)

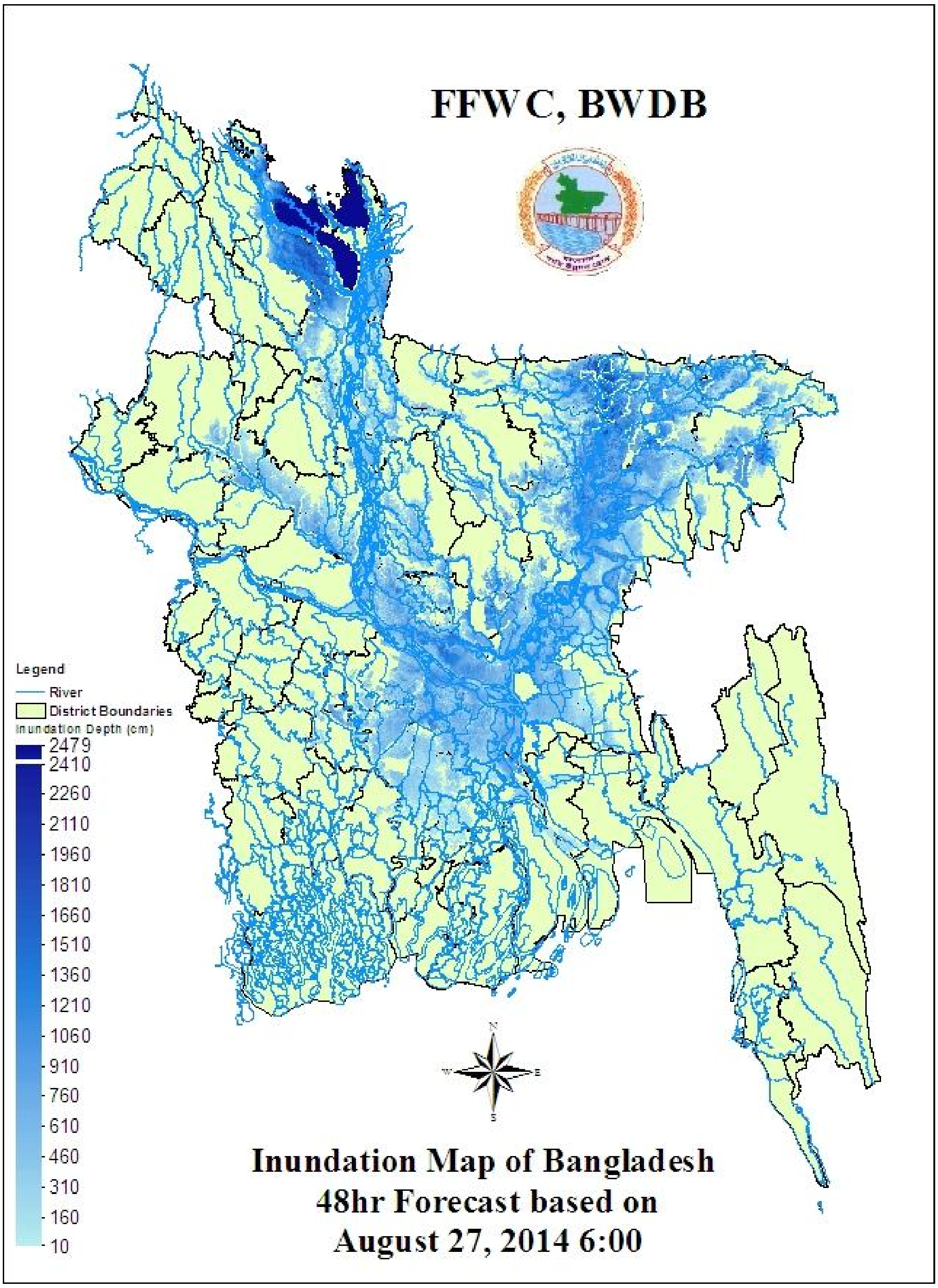


Figure 5.2 : Flood Inundation Map of Bangladesh (48hr Forecast Based on 27 August 2014)

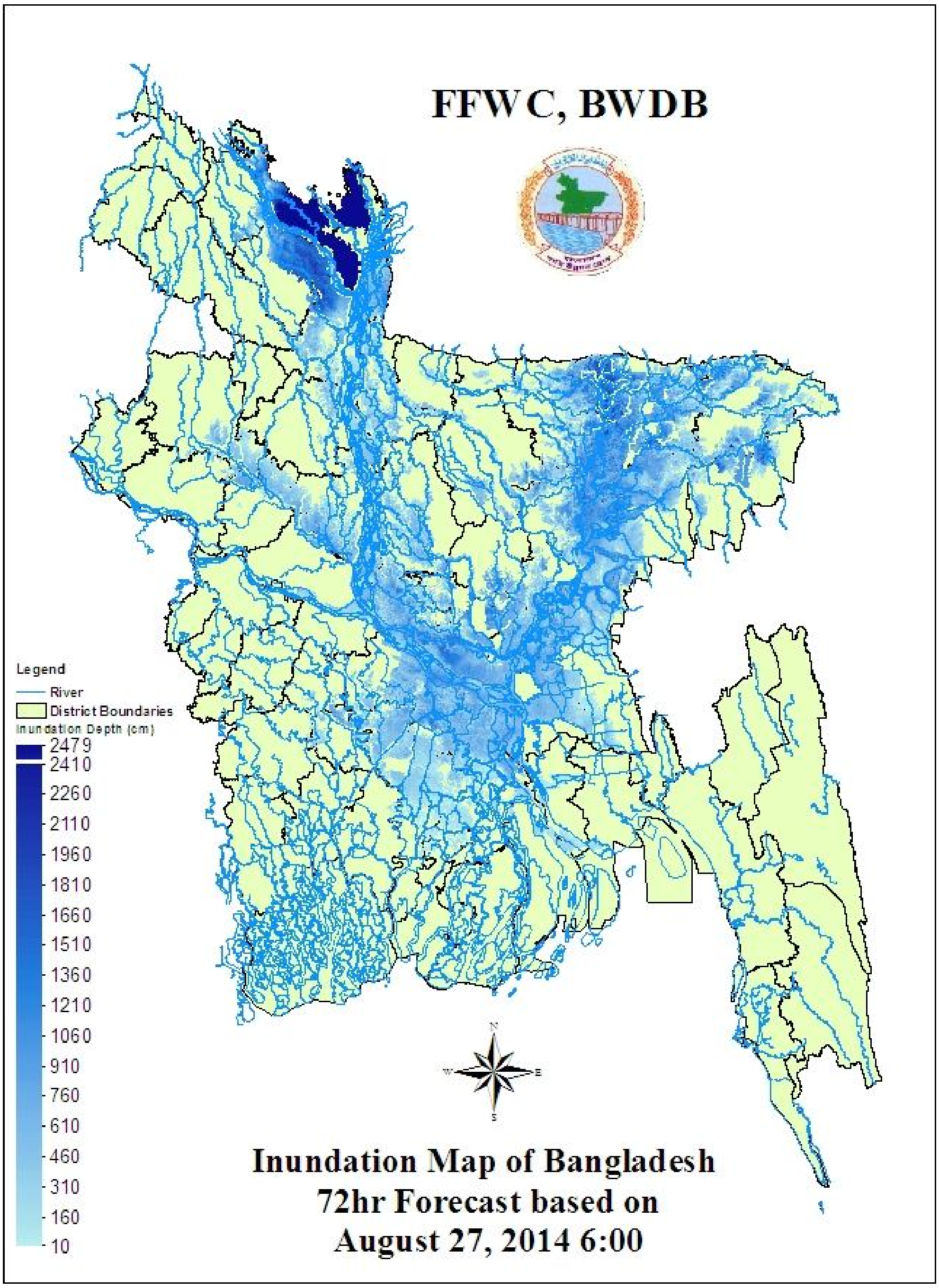


Figure 5.3 : Flood Inundation Map of Bangladesh (72hr Forecast Based on 27 August 2014)

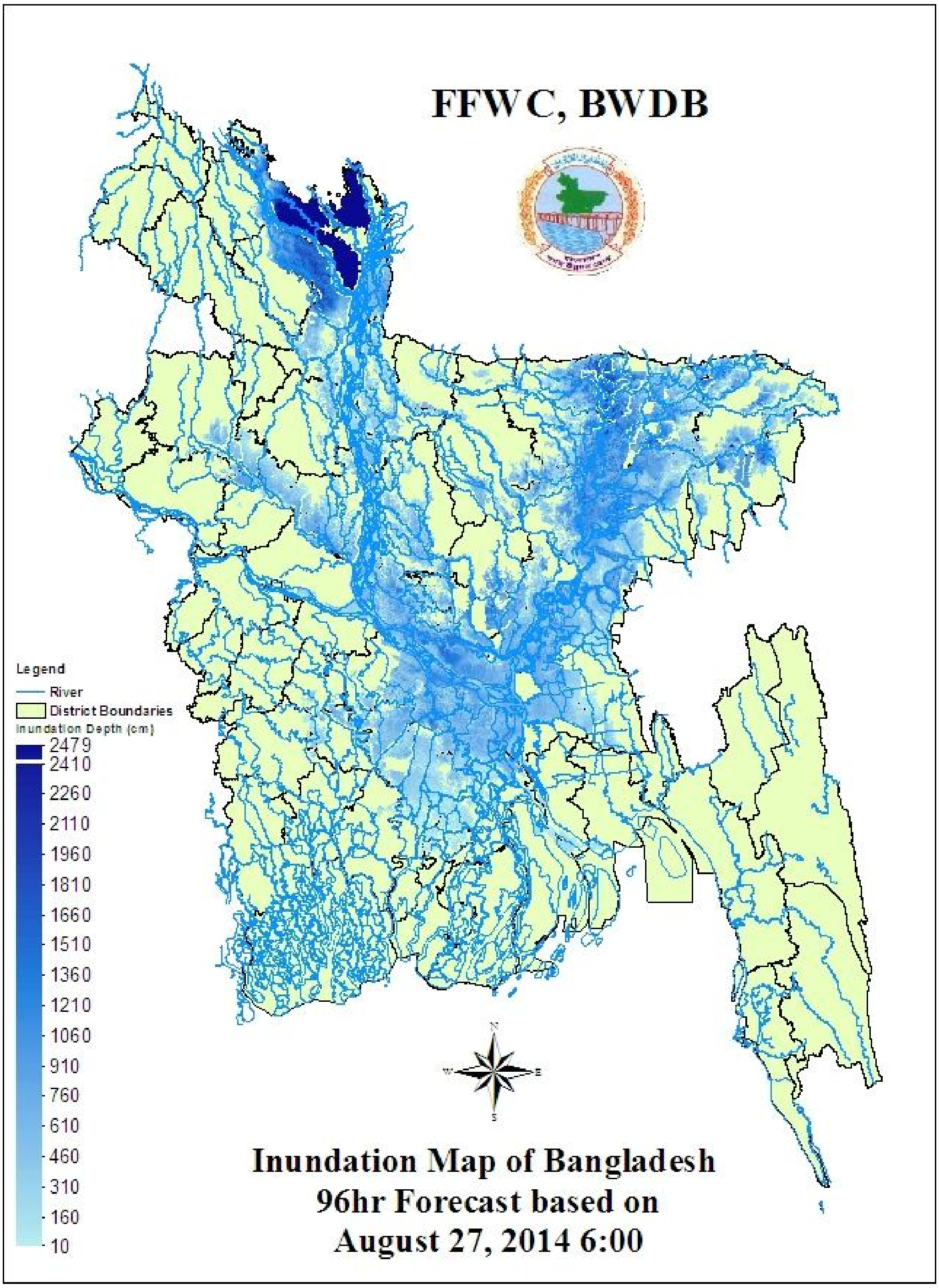


Figure 5.4 : Flood Inundation Map of Bangladesh (96hr Forecast Based on 27 August 2014)

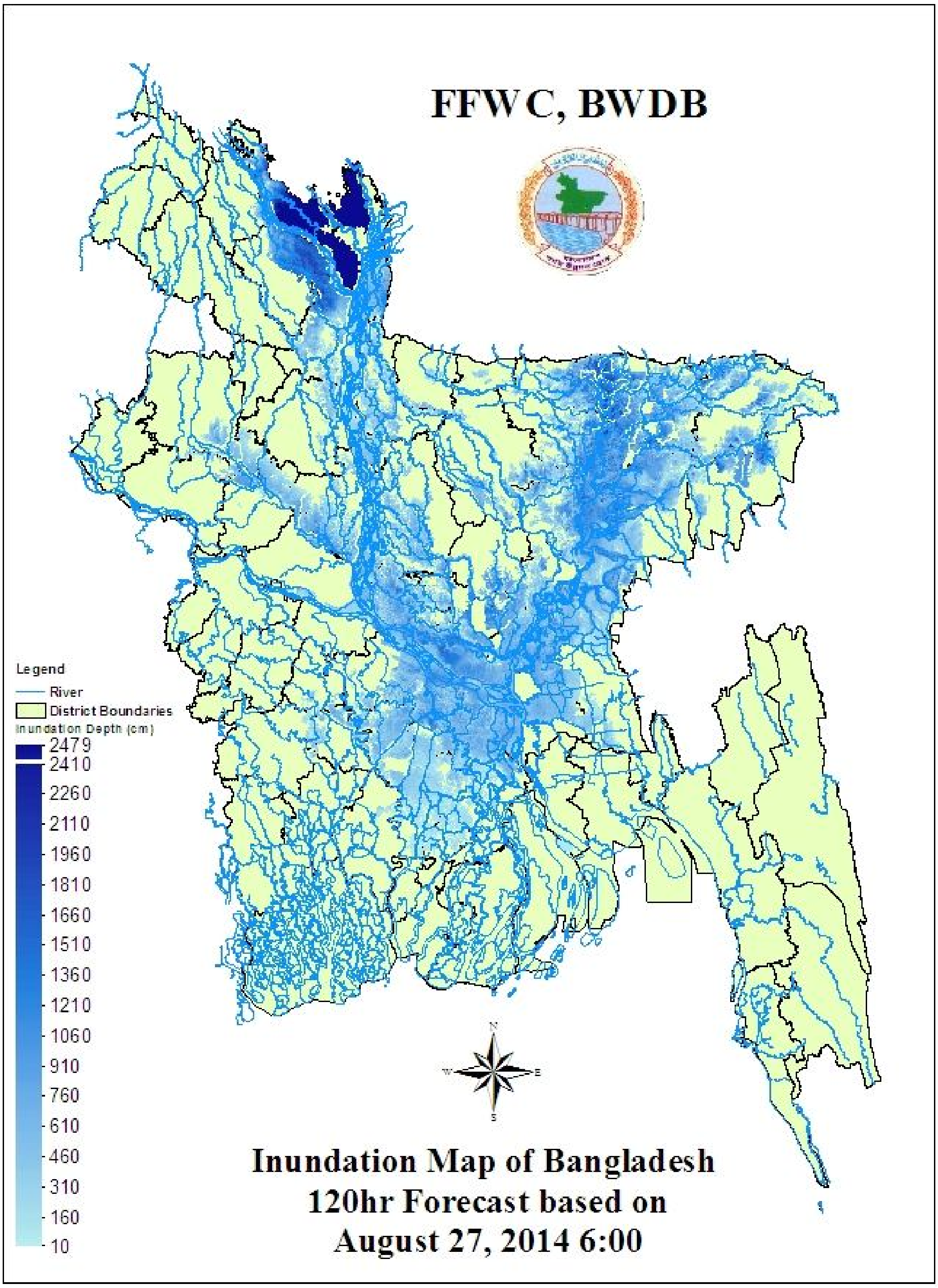


Figure 5.5 : Flood Inundation Map of Bangladesh (120hr Forecast Based on 27 August 2014)

CHAPTER 6: RESEARCH AND DEVELOPMENT

6.1 Development of Flash Flood Forecasting System

RIMES in collaboration with FFWC under the SHOUHARDO-II program of CARE Bangladesh supported by USAID. Two pilot areas Sylhet and Cox's Bazar were selected for the pilot phase to incorporate in the flash flood guidance and advisory system. Flash flood event data analysis, statistical analysis including Rainfall threshold analysis has been carried out and thresholds for triggering flash floods has been identified in flash flood pilot areas. Establishment of Real Time rainfall station in Sylhet and Cox's Bazar (Figure 6.1) to feed real time data in the flash flood guidance system has been completed in 2014. Furthermore, web based flash flood guidance and dissemination system was developed and operationalized in the pre-monsoon period of 2014. This is the only web based flash flood guidance system that FFWC has ever had. Figure 6.2 shows a screenshot of the Flash Flood Guidance system portal. The sample bulletin (partial) uploaded and disseminated to pilot sites are shown in Figure 6.3. Figure 6.4 showed sample Flash Flood Forecast graphics and bulletin.

Figure 6.1: Installation of Automatic Rain gauge in Sylhet

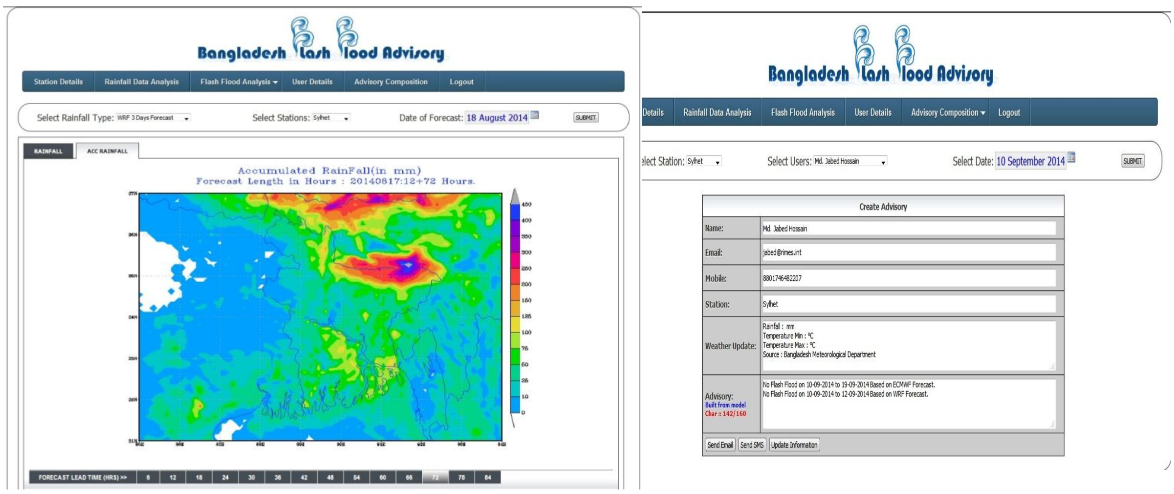


Figure 6.2: Screenshot of Flash Flood Guidance web-portal

Accumulated Rainfall of Sylhet (mm)			
Duration (hrs)	18-08-2014	19-08-2014	20-08-2014
24	28	87.91	56.78
48	56	115.91	144.69
72	56	143.91	172.69
120	56	143.91	200.69
168	56	143.91	200.69
240	56	143.91	200.69
Advisory	NFF	FFW	FFW

Flash Flood Advisory	
FFW: Flash Flood Warning	Flash Flood Warning on 19-08-2014 to 20-08-2014
FFA: Flash Flood Alert	-
NFF: No Flash Flood	No Flash Flood on 18-08-2014

Create Advisory

Figure 6.3 : Module for analysis of flash flood potential

(red for flash flood warning; yellow for alert; green for no flood threat)

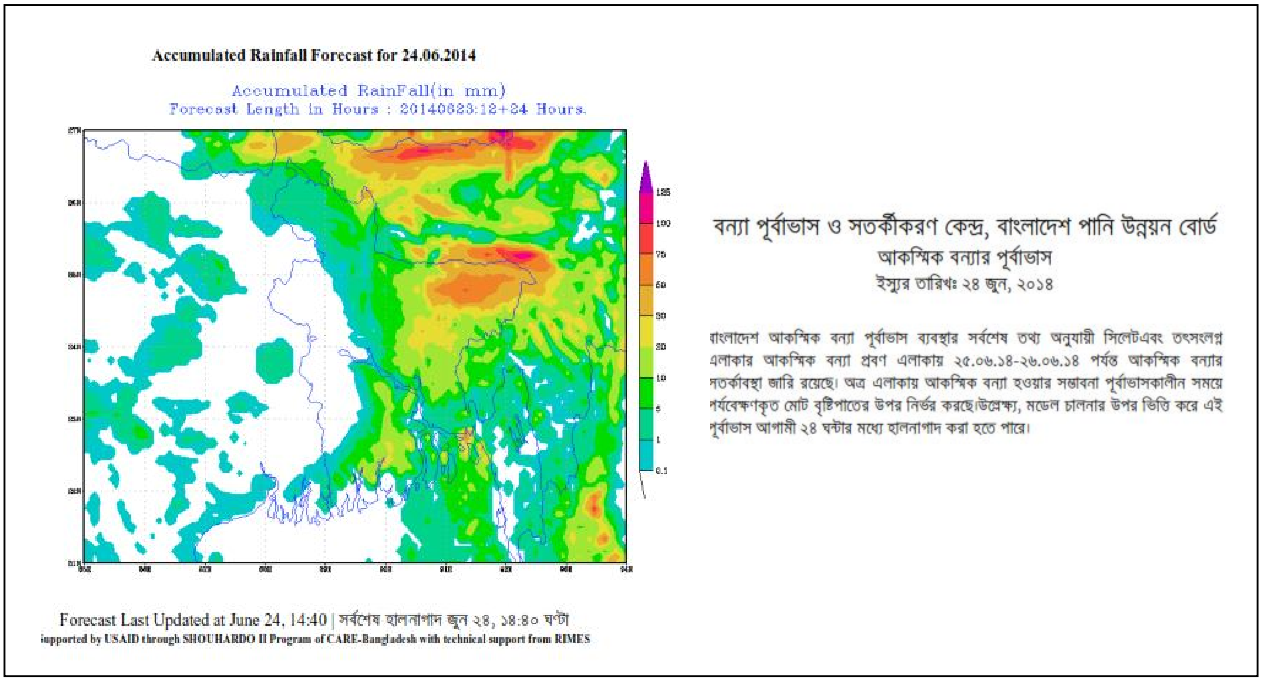


Figure 6.4 : Sample Flash Flood Forecast graphics and bulletin

6.2 Mobile Services for Early Warning

The FFWC together with technical and implementation partnerships completed a seven months pilot to support early warning preparation, communication and response using mobile services in two unions of Belkuchi and Chowhali upazila under Sirajganj District. The project was supported by the Government of the Netherlands (Netherlands Enterprize Agency) and Cordaid.

The two methods chosen were Voice Message Broadcast (VMB) for top down warning dissemination from national to district and local levels simultaneously and Short Message System (SMS) for bottom up water level data collection from the local to national level.

Additionally, the available 5-day forecast warning message content was made more localised (union level). Furthermore, 20 volunteers were trained along with project staff and government officials, building their capacity to understand and react effectively to the warnings. These innovations were tested in the pilot with full governmental support from the FFWC of BWDB. Deltares, Netherlands led the project and RIMES locally based at the FFWC, acted as the linking pin between activities at the FFWC and implementation by the NGOs. Apart from being a supplemental donor, Cordaid arranged for implementation at the community level by supervising a strong partnership of national and local NGOs (Concern Universal Bangladesh (CUB), Practical Action Bangladesh (PA) and Manob Mukti Songstha (MMS).Additional technical support was provided by HKV consultants.

The evaluation after the 2014 flood showed the successful impact of the project at the community and governmental levels. The national level forecast information was further localized and made accessible at the local level. Community people (estimated 5960 households) received, understood (80% had high understanding) and trusted (78% had very high trust) the information from the VMB, utilizing it to prepare for the upcoming floods and reduce their losses. Overall it is estimated that the warnings through VMB reached 45% of the targeted population both directly and indirectly in the pilot areas. The average savings per household (due to the early warning) were estimated atBDT 37,000. These warnings allowed communities to prepare for the upcoming threat resulting in large savings to their livelihood. Figure 6.5shows the sector wise savings utilizing the flood warning, the fisheries, livestock and agriculture sectors experienced the highest savings.

This evaluation also revealed many ways to further improve the system in terms of the warning message content, communication, institutional dissemination pathways, end users response, and towards ensuing financial sustainability. For VMB these included, increasing the number of recipients of VMB and volunteers, increasing the frequency of messages, repeating important parts of the message and disseminating at specific times of the day. For warning content these included working towards delivering more location specific information with inundation depths, increased lead times and an outlook (action orientated) message. The potential of the existing Digital Centres (DC) and Disaster Management Information Centres (DMIC) at the Department of Disaster Management (DDM) should be utilised together with the local Bangladesh Water Development Boards (BWDB) offices, to move to a more decentralised process for warning generation, interpretation and dissemination. A warning communication strategy is required between the key institutions FFWC (BWDB), DDM and the NGOs for consistent and effective warning dissemination. To enhance the effectiveness of communities' response, further awareness raising and knowledge, financial and resource support mechanisms are needed at the local level. These results will be utilised in the second piloting phase of the project in 2015 to further improve the warning communication at the local level.

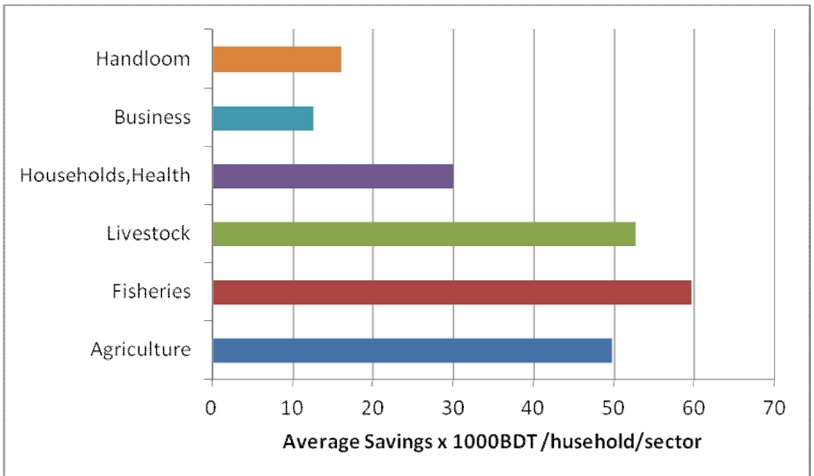


Figure 6.5: Average savings (x1000 BDT) sector wise per respondents household

6.3 JASON-2 Satellite Based Flood Forecast (Experimental)

JASON-2 is a joint NASA-French Satellite mission that measures water levels or water elevation and provides the data relatively promptly within 24 hours (may known as near real time) for users to use. Interested users may find more information on JASON-2 at the web-site http://www.nasa.gov/mission_pages/ostm/main/index.html. Near real-time data on JASON-2 is made available at a publicly accessible ftp site at ftp://avisoftp.cnes.fr/. Using four JASON-2 virtual stations(VS) (192, 079, 014 and 155) on the transboundary (upper catchment outside Bangladesh) region of Ganges and three JASON-2 VS (166, 053 and 242) (Figure 6.6) on the transboundary region of Brahmaputra river, it is possible to generate water level forecast upto 8 days lead time at Hardinge Bridge and Bahadurabad. The VS are defined as the specific location on the river that is over-passed by JASON-2 (Figure 6.7 below for specific location and numbering of VSs). Technical support has been extended by the IWM, University of Washington (UW), Seattle, USA, and the SERVIR programme of NASA.

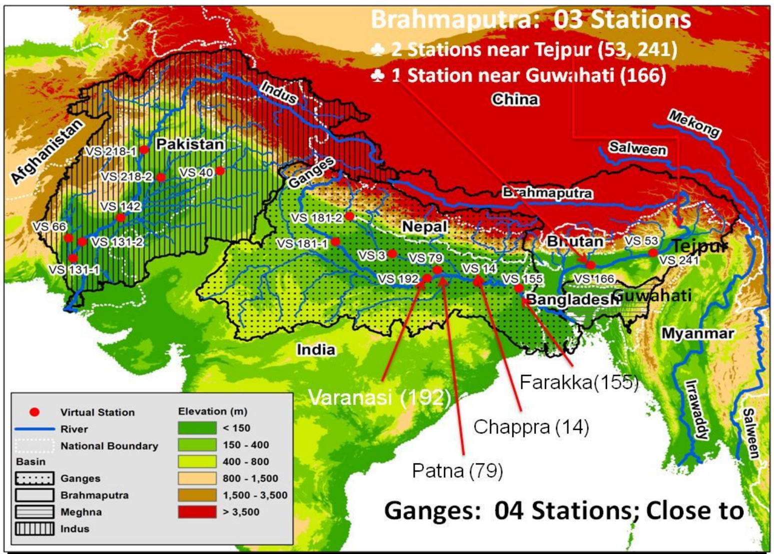


Figure 6.6: Location of the JASON-2 VS

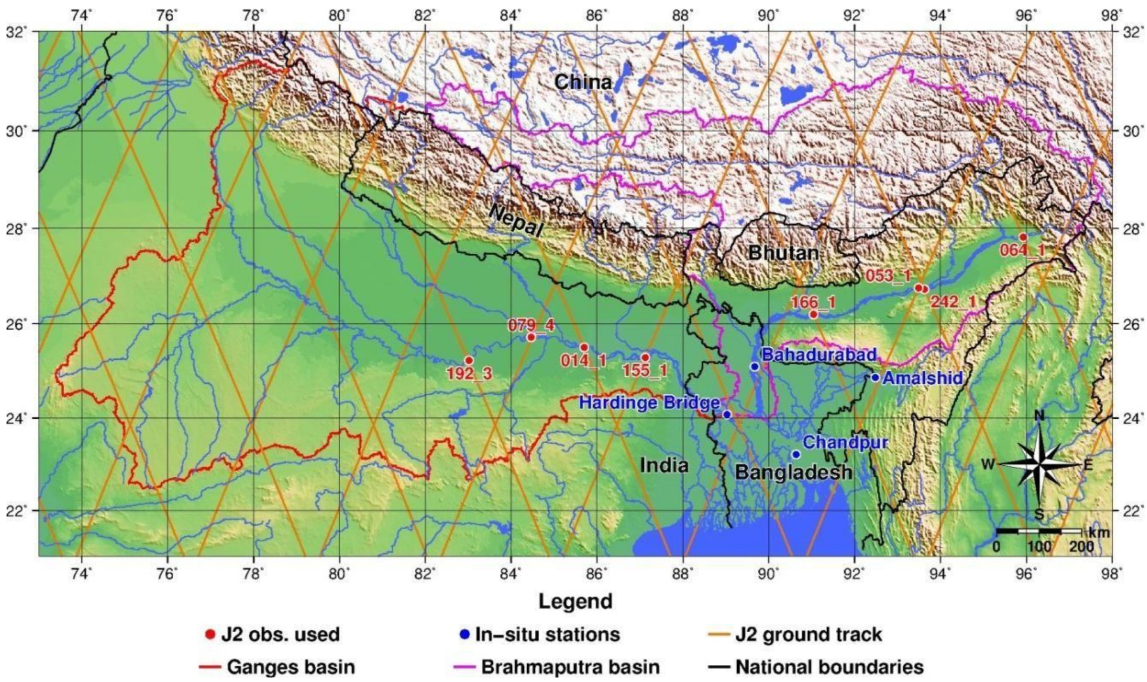


Figure 6.7: Location of the JASON-2 VSs on the transboundary region of Ganges and Brahmaputra rivers for generating upto 8 day forecast at Hardinge Bridge and Bahadurabad.

Upto the 8-day forecast for Bahadurabad and Hardinge bridge is generated based on trend forecast derived from a period spanning 2008-2013 (6 years) during which JASON-2 flew over the Ganges-Brahmaputra basins. JASON-2 data pertains to the GDR (Geophysical Data Record) and not the IGDR (Interim Geophysical Data Record). While producing forecast using this data some human judgment was also applied. All water level data of JASON-2 and observed station are in meters relative to the EGM08 datum, which is supposed to be consistent with the regional mean sea level. Datum of observed stations at Bahadurabad on the Jamuna and at Hardinge Bridge on the Gange is in mPWD.

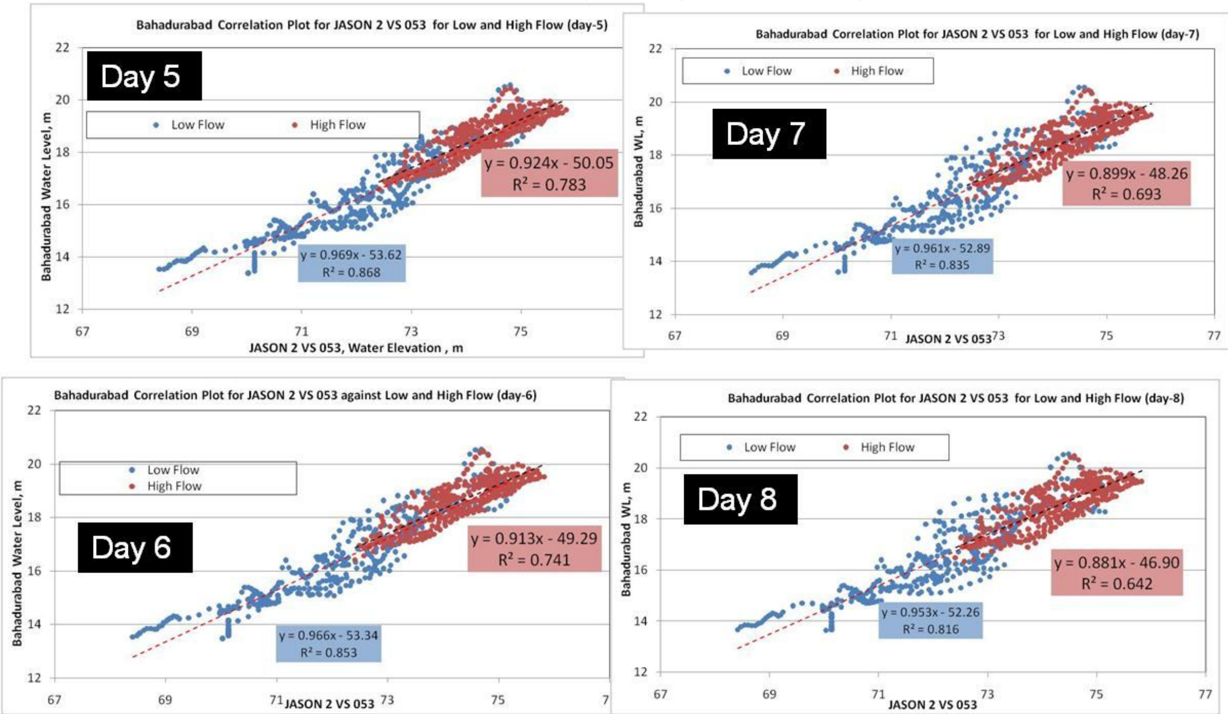


Figure 6.8: Correlation plots for 5 to 8 days Bahadurabad on Brahmaputra River in Bangladesh and Virtual Station 053 of JASON-2 on upper catchment.

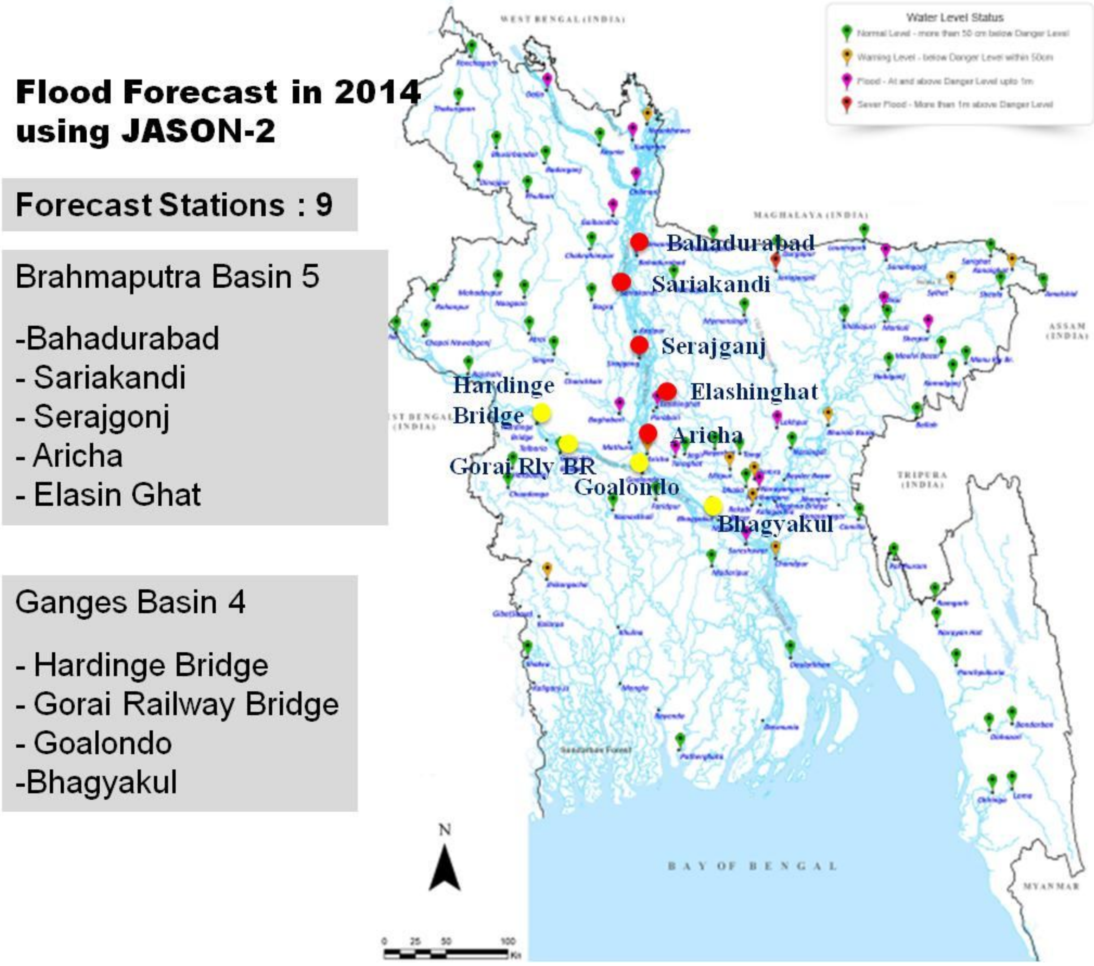
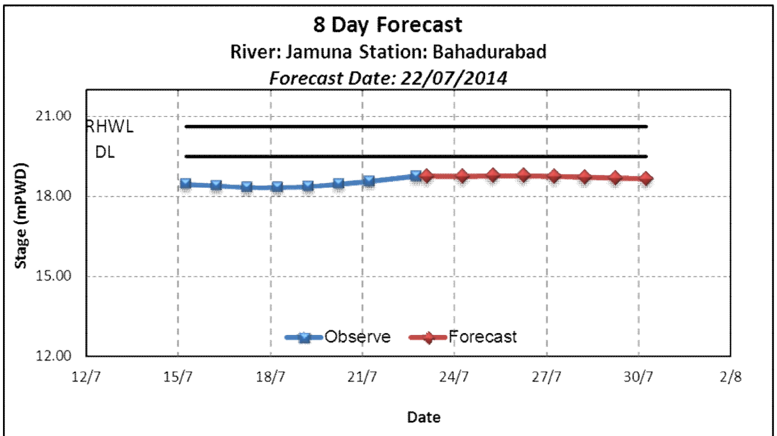
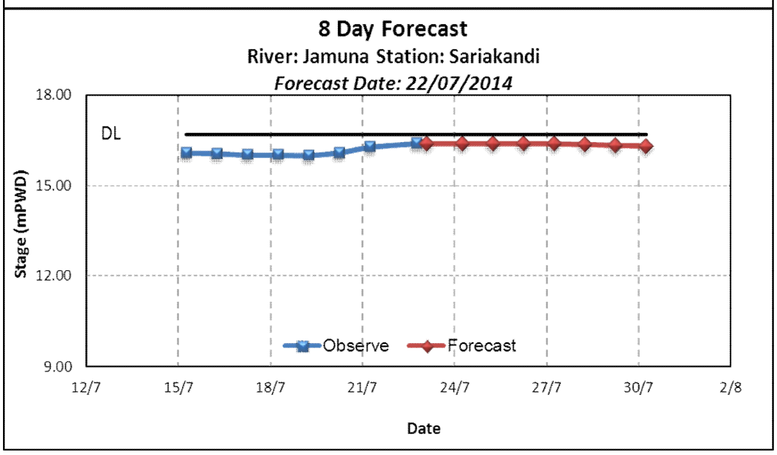


Figure 6.9 : Location of the Flood Forecast stations with 8-days lead time using Jason-2 data





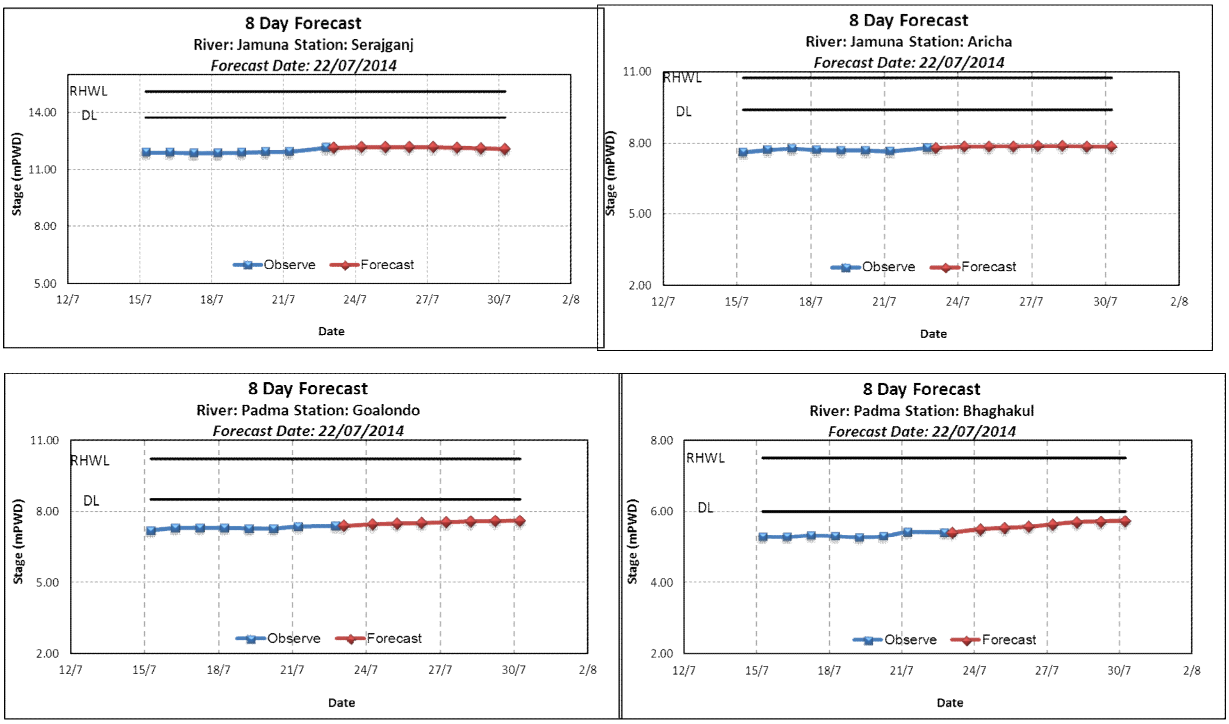


Figure 6.10 : Sample Hydrographs upto 8 days lead time flood forecast using Jason-2 satellite data

6.5 Comparison between FFWC and Satellite based Inundation Map

It is a difficult to verify the FFWC model based flood inundation map with the real situation. In this case, satellite image can play vital role. There are many satellite agencies available which can provide nationwide flood inundation map of Bangladesh for comparison with model based map. One of these popular satellite products is MODIS image provided by NASA (http://modis.gsfc.nasa.gov/). The **Moderate-resolution Imaging Spectra-radiometer** (**MODIS**) is a payload scientific instrument launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250m, 5 bands at 500m and 29 bands at 1 km). They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere. MODIS data will improve the understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. Effort was made to compare the flood inundation status of Bangladesh during flood 2014 using MODIS images and Flood Map generated using flood model of the FFWC.

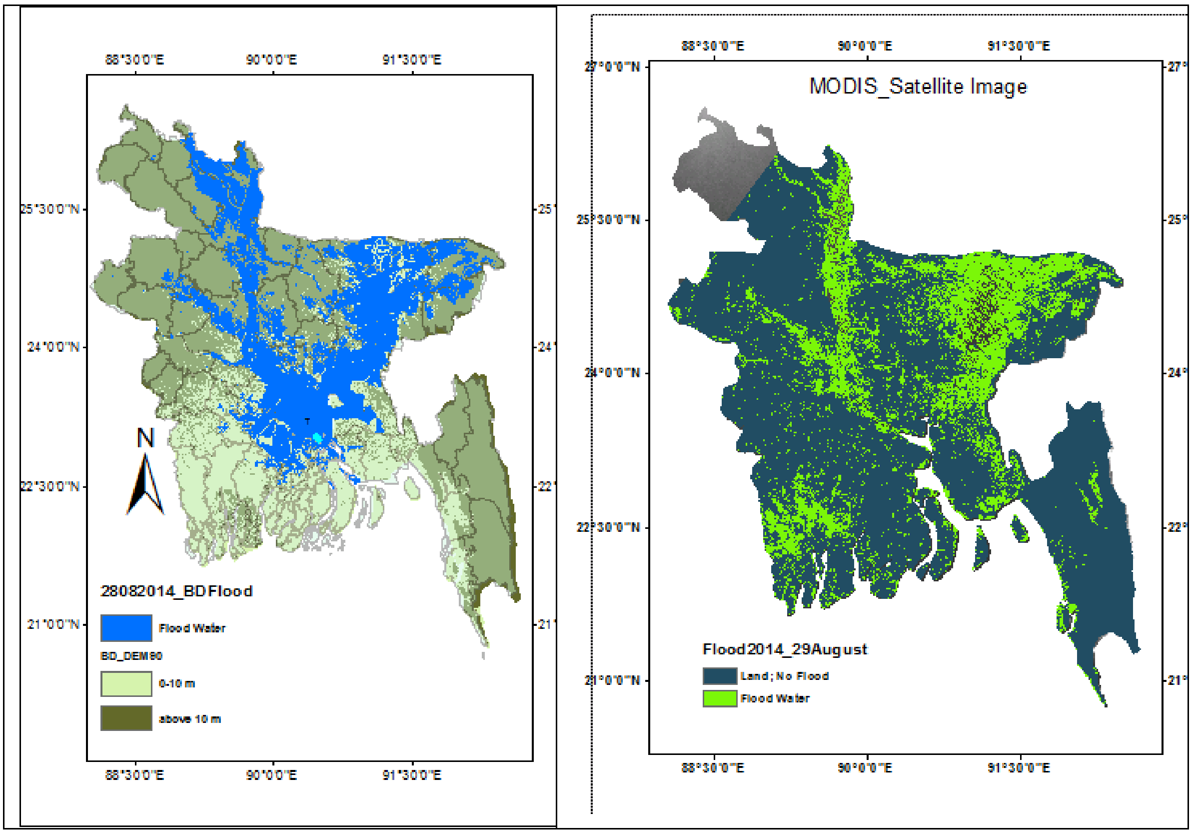


Figure 6.11 : Comparison between inundation map using MIKE 11 (Left) and inundation map using MODIS (Right).

FFWC generated flood inundation map of 29 August, 2014 was compared with the MODIS image of the same date (29 August, 2014) and presented in the figure 6.6. From the figures it is shown that the model based inundation extent/areas have good agreement with the MODIS image in many locations especially in the north, north-central, central and eastern part of the country. The inundation maps also indicating dissimilarities in inundation in few areas of the country – overestimation (south-central) and underestimation (south-eastern) were observed while comparing the MODIS image of flooding and flood map generated using flood model of the FFWC. This is a gross comparison of nationwide inundation area with the satellite image that can be used to validate the MIKE11-GIS based inundation map in FFWC although the areas and depth of inundation need to be identified more accurately.

MODIS can play a vital role in the development of validated flood inundation models able to predict flood hazard areas accurately enough to assist policy makers in making sound decisions concerning the protection of vulnerable people.

CHAPTER 7: CONCLUSIONS

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 of about 2300 mm, the range varies from about 1500 mm in the north-west 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 adversely affected. The characteristic of rivers varies 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.

FFWC, BWDB monitored the flood situation during the monsoon and also beyond the monsoon if situation demand. The FFWC has issued daily flood bulletin from May to October with a forecast lead-time of 24hrs, 48hrs and 72hrs, 96 hrs and 120 hrs (upto 5 days) along with warning messages and flood inundation maps. The extend deterministic flood forecast lead time upto 5-days from 3-days, experimental flash flood forecast on pilot basis for Sunamgonj and Sylhet districts and expand the deterministic flood forecast to few selected BWDB projects known as structure based flood forecast upto 5 days lead time institutionalized, established as mainstream services. Updated/improved, more user friendly web-site has been in operation since June-2012 (beginning of monsoon). The upgraded web-site having easy to operate menu and Bangla language option is added with flood warning message in Bangla. Mobile based IVR system improved dissemination significantly. Also 16 new flood forecasting points has been added in the system. These are the new efforts to make more localized flood forecast. All these improvement have been done with financial support from Comprehensive Disaster Management Programme (Phase–II), CDMP-II under Ministry of Disaster Management and Relief.

In addition to deterministic flood forecasts upto 5-days lead time, FFWC issued medium range upto 10-days lead-time probabilistic forecasts at 38 locations in experimental basis utilizing ECMWF weather prediction data over the GBM basins to generate 51 sets of ensemble discharge forecasts on the Brahmaputra at Bahadurabad and on the Ganges rivers at Hardinge-Bridge. Flash flood guidance and advisory system developed at two pilot areas, Sylhet and Cox's Bazar. A web based flash flood guidance and dissemination system was developed and operationalized in the pre-monsoon period of 2014. This has been carried out with technical partnership RIMES under the SHOUHARDO-II program of CARE Bangladesh supported by USAID.

The special type of flood bulletin has been issued during the critical time and disseminate through different mass media, news agencies, fax, e-mail, web-site and Interactive Voice Response (IVR) through mobile phone. The IVR system using mobile is a new way of dissemination started since July 2011, anyone can call 10941 number from mobile and hear a short voice message on flood warning in Bangla. The information has been used by various communities and organizations: national and international disaster management operators, many Government agencies, departments, NGOs and BWDB itself.

FFWC has attempted to use satellite based information of the upper catchment with free download facility for extending the flood forecast lead time upto 8 days. In 2014, experimentally used Near Real Time Jason-2 Satellite Altimeter Data under SERVIR programme of NASA to generate flood forecast upto 8 days in 5 stations of the Brahmaputra Basin and 4 stations of the Ganges Basin (total 9 stations), which has improved the capacity of FFWC in early warning. Trend was found satisfactory.

Community based flood information generation and dissemination has been tested in two locality of Serajgonj district with partnership of Deltares, HKV the Netherlands. The two methods chosen for dissemination were Voice Message Broadcast (VMB) for top down warning dissemination from national to district and local levels simultaneously and Short Message System (SMS) for bottom up water level data collection from the local to national level. Evaluation indicated these end-to-end warnings allowed communities to prepare for the upcoming threat resulting in significant savings of properties from flood.

An effort was made to compare the flood inundation status of Bangladesh during flood 2014 using MODIS images and Flood Map generated using flood model of the FFWC. Comparing two inundation maps both similarities and dissimilarities were observed. Further research and development is necessary to improve the inundation maps.

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

The continued achievement of the FFWC is notable. It is trying hard to overcome the limitations and realities. Regional models need to have developed to provide regional flood forecasting and warning. Moreover, flood inundation map needs to develop further. The FFWC of BWDB took the privileged to reflect the flood situation as accurate and reliable as possible. All these combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2014.

As a whole the flood of 2014 was fairly normal compare to devastating flood of 1987, 1988, 1998, 2004 and 2007. The maximum flooded area was 25% of the whole country (36,900 sq-km approximately).

Evaluation indicated that, for 1-day forecast 98.15% for the stations are within the range of Good and Average. For 5-days forecast 59.26% stations are in the range of Good and Average for the monsoon of 2014. Few stations near of boundary showed poor performance. 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.