fmisc
Bihar

Flood Management Improvement Support Centre

Flood Report 2013

Towards a Culture of Preparedness for Better Flood Management

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Water Resources Department
Government of Bihar

ACKNOWLEDGEMENT

Once again, like previous years the end of the season 'Flood Report, 2013' is ready for publication and I feel gratified to acknowledge the untiring and meticulous effort put forth by FMISC team in preparing this Report in time.

FMISC is running two projects simultaneously, the first one is **FMIS Phase 2** and another one is **Bihar Kosi Flood Recovery Project.** The *World Bank* is the driving and guiding force in both the projects. The Bank is supporting us not only financially but is providing a lot of opportunities in our capacity building, technical assistance and knowledge enhancement. The contribution of World Bank is highly acknowledged. We specially thank Mr. Abedalrazq Khalil, Task Team Leader, Dr. S. Rajagopal and Dr. S.T. Chari, both WB Consultants for their continued support in implementing the FMIS Phase 2 Programme We also heartily thank another WB Team, Mr. Deepak Singh, Task Team Leader, Mr. M.K. Goel, Mr. Alok Patnaik and Mr. Prabir Joardar, Water Resources Consultant in steering the Bihar Kosi Flood Recovery Project.

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I express my heartfelt gratitude to Sri Arun Kumar Singh, IAS, Principal Secretary, WRD; Smt. Harjot Kaur, IAS, Project Director, BAPEPS who always guided, inspired, and enlightened the FMISC team in achieving its objectives and goals.

Finally, I express my sincere and deepest gratitude to Shri Vijay Kumar Choudhary, Hon'ble Minister, Water Resources Department, Government of Bihar, for his guiding vision and encouraging support.

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Acronyms

ALTM	Airborne Laser Terrain Mapper
AOI	Area of Interest
ASAR	Airborne Synthetic Aperture Radar
AWiFS	Advance Wide Field Sensor
CWC	Central Water Commission
DEA	Department of Economic Affairs
DEM	Digital Elevation Model
DFID	Department For International Development
DOES	Directorate of Economics and Statistics
DL	Danger Level
DMD	Disaster Management Department
DMSP	Disaster Management Support Program
DRF	Daily Rainfall
DSC	Decision Support Centre
EAMS	Embankment Asset Management System
FMIS	Flood Management Information System
FMISC	Flood Management Improvement Support Centre
GDP	Gross Domestic Product
GSDP	Gross State Domestic Product
GFCC	Ganga Flood Control Commission
GIS	Geographic Information System
GoB	Government of Bihar
GoI	Government of India
GoN	Government of Nepal
HFL	Highest Flood Level
IMD	India Meteorological Department
LISS	Linear Imaging Self Scanning
LiDAR	Light Detection and Ranging
LPA	Long Period Average
MODIS.	Moderate Resolution Imaging Spectroradiometer
NRSC	National Remote Sensing Centre
RS	River Stage
RTDAS	Real Time Data Acquisition System
SRTM	Shuttle Radar Topography Mission
TAC	Technical Advisory Committee
TOR	Terms of Reference
WRF	Weather Research and Forecasting
WGS 84	World Geodetic System 1984
WiFS	Wide Field Sensor
WRD	Water Resources Department

1.0 Preamble

Flood Management Improvement Support Centre (FMISC), Patna, like previous six years in sequence, presents the end of the season **'Flood Report 2013'**. This is the seventh in line since its inception. The focus area of FMISC now covers 24 districts of Bihar including entire north Bihar covering all 21 districts and three districts of Patna, Bhagalpur and Munger adjoining river Ganga in south Bihar in FMIS Phase 2. This year, till September, the rainfall was below 30% normal. However, there was good rain in October. This was 197.1 mm against the normal of 64.8 mm, as reported by Meteorological Centre, India Meteorological Department.

Even at the flood front, the situation was, by and large, normal and less eventful. This year river Ganga was relatively in high spate and there were pressure reported at Raghopur site in the d/s of 5.695 km of Left dowel embankment under Bhagalpur district. The pressure was also reported on spur no. 5, 6 and 7 on the left embankment of river Ganga near Ismailpur-Bindtoli. There were some problems in P. D. Ring Bund on Gandak river and in Lagar Laghu Bund in front of Gogri Narainpur embankment on river Ganga. Eventually, nothing serious happened and the embankments were saved with the untiring effort by the engineers of the department. River Ganga, this year, attained **new Highest Flood Level of 34.50 m at Bhagalpur** crossing earlier HFL of 34.20 m reported in year 2003.

This report, like previous years' reports has last fourteen years flood history in short including flood events of this year. Hydrologic analyses, comparison between observed rainfall and three days' forecasted rainfall, and isohyets maps based on rainfall record have been prepared to better understand the rainfall pattern. Key information products with other important maps like *maximum inundation extent map*, *flood intensity map* along with *value added inundation maps* have also been included and analyzed in this report. A brief report on the components of FMIS phase 2 and WRD components of Bihar Kosi Flood Recovery Project have also been added.

Before flood year 2013, flood calendar was also published by Water Resources Department and was strictly followed. FMISC like previous years provided support to Technical Advisory Committee (TAC) of Water Resources Department, GoB by providing assistance with the satellite images of pre-flood and post-flood scenarios showing changes in the river regime of major rivers of north Bihar in planning the anti-erosion and river training works to be undertaken before the flood of 2014 with the help of satellite imageries. FMISC also supported in clearance of FMP schemes by GFCC with the FMIS inputs in the form of useful satellite pictures.

Under Capacity Building activity of the FMIS Phase 2 project, a team comprising of two officers of Water Resources Department, Er. Indubhushan Kumar, then Superintending Engineer, Planning and Monitoring Circle-1 and Dr. Saroj Kumar Verma, then Assistant Director, FMISC attended "World Environmental and Water Resources Congress, 2013" at Cincinnati, USA which was organised by '**Environmental and Water Resources Institute (EWRI)**' under the aegis of ***American Society of Civil Engineers (ASCE)*** in May, 2013. The engineers came across the distinguished experts from all over the globe and participated in lectures and sessions in the different fields of *water resources* and *environment*. A 15 days training on flood forecast and inundation modeling was also conducted during 10th February to 26th February 2014 by M/s DHI (India) Water & Environment, New Delhi who are the Consultant for on-going flood forecasting and inundation modeling in Bagmati-Adhwara basin in north Bihar as per the contract agreement.

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FMISC website; highly acclaimed all across, is being improved further by a web hosting infrastructure, which includes a web server, database server and NAS (Network Attached Storage) media. This will effectively manage the heavy load on the website during peak hours, and ensure effective availability and performance.

FMISC, in addition to FMIS Phase 2 implementation programme, has also been assigned to take up implementation of **Bihar Kosi Flood Recovery Project** under **Bihar Aapda Punarniwas Evam Punarnirman Society (BAPEPS).** This society is under the administrative control of the State Planning and Development Department and have a *Project Management Unit (PMU)* responsible for the implementation of the Project. Component C of the project (BKFRP) is for WRD under which **"Strengthening Flood Management Capacity focusing on building capacity on flood forecasting, flood erosion management and limited structural measures in Kosi basin"** are being monitored by FMISC**.** The objective of this component is to strengthen the overall flood forecasting and flood and sediment management capacity in Bihar by enhancing knowledge, understanding, and capacity of flood and sediment management. This will be achieved by implementing both structural and non-structural measures, mainly focusing on the Kosi River Basin, but with several activities benefiting flood management in the state as a whole. A **Project Implementation Unit** (PIU) has also been established in WRD to monitor and accelerate the implementation of the Component 'C' of BKFRP undertaken by WRD.

2.0 Profile of FMIS Focus Area and Socio-Economic Profile of Bihar

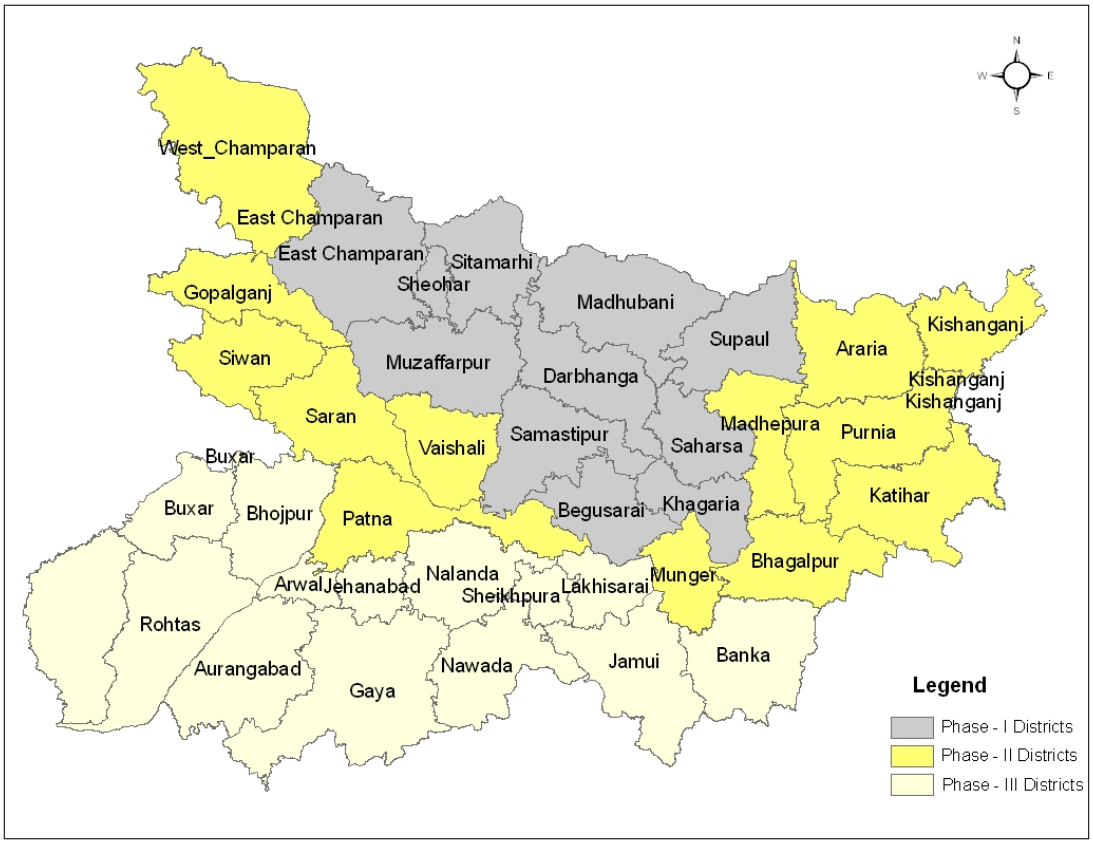
2.1 Profile of FMIS Focus Area

FMIS focus area covers the most flood prone districts in the State consisting of all the 21 districts of north Bihar and 3 districts adjoining river Ganga in south Bihar viz Patna, Munger and Bhagalpur as shown in the map 2.1

The area is bounded by Himalayan foot hills and terai region of Nepal in the north, Mahananda on the east, river Ganges on the south and river Ghaghra on the west. The area comprises of rich alluvial plains of Indo-Gangetic plain. It comprises the tract of alluvial plains north of Ganga, falling between the Ganga and Indo-Nepal border having general slope from north-west to south-east and is drained by the rivers Ghaghra, Gandak, Burhi Gandak, Bagmati- Adhwara group of rivers, Kamla-Balan, Kosi and Mahananda which finally drain into the river Ganga.

2.2 The Geographical Features of Bihar and Focus Area

Bihar lies between latitude $24^0$20'10" N to $27^0$31'15" N and longitude $83^0$19' 50" E to 88^0 17' 40" E. The total geographical area of Bihar is 94,163 sq.km. The FMIS focus area comprising 21 districts in north Bihar and 3 districts (adjoining river Ganga) of south Bihar for phase II lies approximately between latitude $27^0$32'7" N to $24^0$53'2" N and longitude $83^0$47'15" E to $88^0$16'5" E with the geographical area of about 60,119 sq. km. The geographical coverage is as shown in the figure below and the colored area is FMIS focus area.



Map 2.1 Focus Area of FMIS (All 21 districts of north Bihar & 3 districts of south Bihar)

The total geographical area of north Bihar is approximately 52,928 sq. km. comprising of 21 Districts namely Muzaffarpur, East Champaran, Sitamarhi, Seohar, Saharsa, Supaul, Darbhanga, Madhubani, Khagaria, Samastipur, Begusarai, Araria, Madhepura, Purnea, Katihar, Kishanganj, Saran, Gopalganj, West Champaran, Vaisali and Siwan, all of which are covered under the FMIS Focus Area.

The geographical area in south Bihar is approximately 41,235 sq. km. comprising 17 districts namely Rohtas, Buxar, Kaimur, Bhojpur, Arwal, Patna, Jahanabad, Aurangabad, Gaya, Nalanda, Sheikhpura, Nawada, Lakhisarai, Munger, Jamui, Bhagalpur and Banka. Some major rivers lying within this region are Sone, Punpun, Kiul etc. However, out of 17 districts only three districts viz Patna, Munger and Bhagalpur are covered under the FMIS Focus Area.

The soil of Focus area is sandy alluvial, rich in lime and often contains high proportion of clay. There are pockets where soils are calcareous with high proportion of calcium carbonate. The soils are among the most fertile in India and can support a variety of crops with appropriate land and water management.

2.3 Climate and Rainfall

Bihar has monsoon type tropical climate with high temperature and medium to high rainfall. The temperatures are lowest during December-January with an average minimum of 8^0C to 10^0C and maximum of 24^0C to 25^0C. The temperatures in the hottest months of April to June are varying from minimum of 23^0C to 25^0C to the maximum of 35^0C to 38^0C.

The mean annual rainfall for the State is about 1270 mm varying from 1170 to 1580 mm in Focus area. Most of the rainfall (80% to 90%) is received from mid-June to mid-October. The late September-October rains (locally known as 'Hathia'), though only 50 to 100 mm in quantity, are very crucial to agriculture in the region and their timing and distribution make all the difference between plenty and scarcity.

2.4 River System of Bihar

2.4.1 North Bihar

Important rivers namely Ghaghra, Gandak, Burhi Gandak, Kosi and Mahananda etc. drain directly into river Ganga, the master drain flowing from west to east, whereas Bagmati-Adhwara, Kamla-Balan etc. drain into the Ganga through the Kosi.

The Ghaghra, Gandak and Burhi Gandak rivers of north Bihar are now more or less stabilized. It is believed that river Gandak has travelled from near Burhi Gandak on the east to its present course on the west in course of last several hundred years. In this process of shifting, it has created numerous chaurs (saucer like depressions) and mauns (deep horse-shoe shaped water bodies formed due to avulsions/cut-offs) in the basin. The other north Bihar rivers such as the Bagmati, Adhwara group of rivers, Kamla-Balan and Kosi are still very unstable due to steep slopes in their upper reaches and high silt charges and are always exerting tremendous pressure on the embankments within which they are presently contained at enormous cost and efforts. The Kosi river is known to have shifted from near Purnea on the east to its present course on the west, before it was embanked. However, this river tried to move towards east from its present course after the Kusaha breach in Aug 2008, but was brought back to its present course in Jan 2009 by adopting suitable river diversion measures. In its lateral travel of about 120 km. in course of about two centuries, the Kosi has created a number of swamps and marshy lands in the basin, apart from depositing coarse silt and sand in almost entire area.

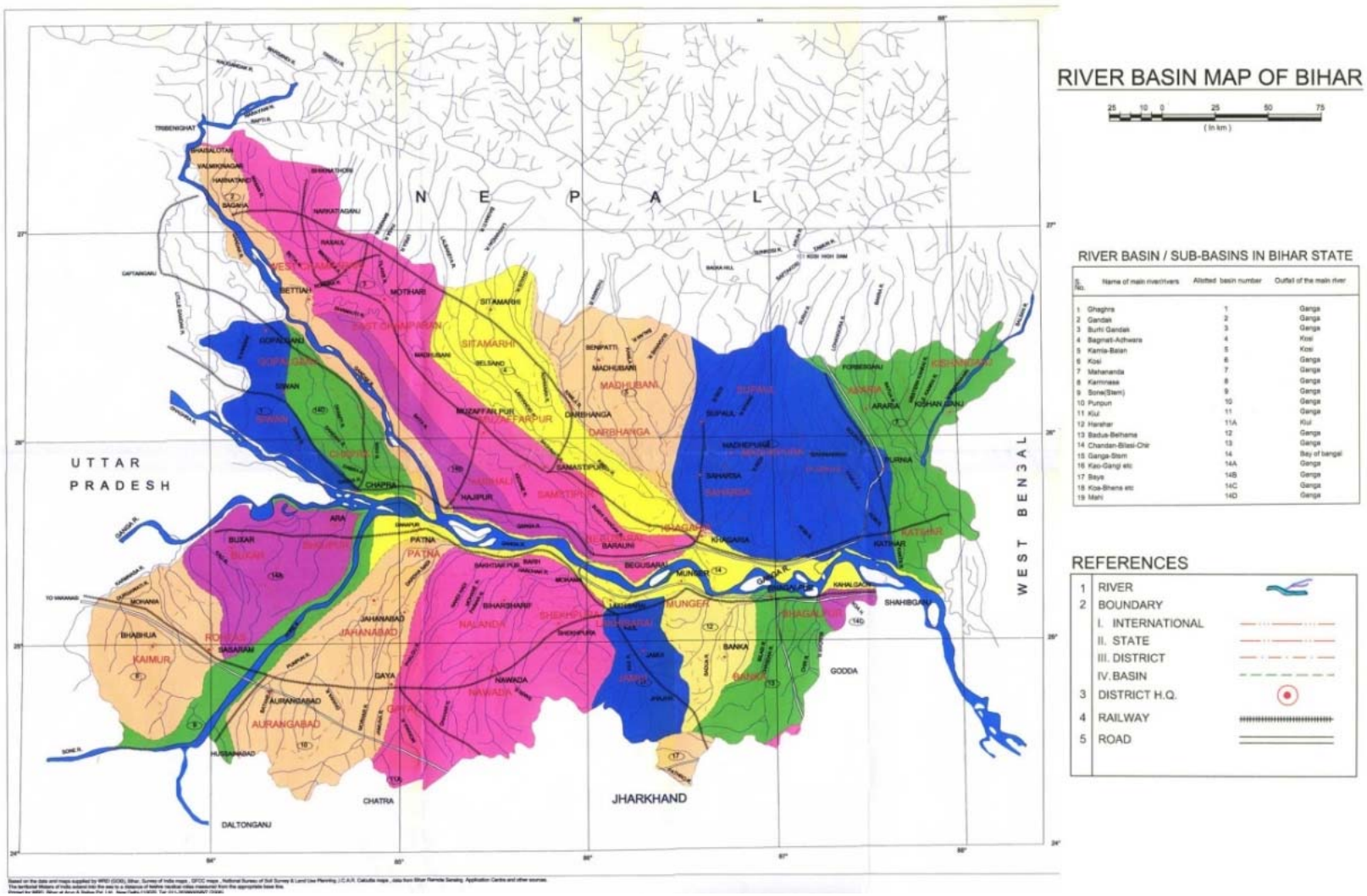
The major rivers of north Bihar have Himalayan origin and considerable portion of their catchments lie in the glacial region. They are, therefore, snow-fed and perennial in flow. These rivers have catchments in the Himalayan region in Nepal. Some of them have catchments even in Tibet. They receive very copious rainfall during monsoon which causes rise in discharge of these rivers by 50 to 90 times higher than fair weather flows. This causes frequent flooding of a large portion of north Bihar during monsoon.

2.4.2 South Bihar

This tract of land is drained mainly by rivers which are rainfed, having their origins either in the Vindhyachal hills or in the hills of Chhotanagpur and Rajmahal. These rivers are either dry or carry scanty discharges in non-monsoon months. Karmanasa, Sone, Punpun, Kiul, Badua, Chandan etc. are the important rivers of this region which fall ultimately into river Ganga.

A peculiar phenomenon in this region is the formation of Tal. The southern bank of the Ganga is naturally formed as a levee obstructing the drainage of the land on the south of it, which extends up to the foot of Chhotanagpur hills. The natural slope of this land is from south to north, i.e. from foot hills of the Chhotanagpur hills to Ganga. There are several rivers

in this tract which drain the rain water of the tract and accumulate them behind the high bank of Ganga. This has resulted in formation of tals viz. Mokama group of Tals, the area just on the south of the high Ganga bank extending from Fatuha to Barahia, which comprises of Fatuha Tal, Bakhtiyarpur Tal, Barh Tal, More Tal, Mokama Tal, Barahiya Tal and Singhaul Tal. These Tals also receive backwater of the Ganga when the latter is in high spate. Therefore, the Tals get submerged in water during monsoon season and are thus deprived from kharif cultivation in most of the area. Even after the monsoon season, entire area does not get drained into the Ganga quickly. However, bumper rabi & hot weather crops are grown in the Tal area when it gets freed from submergence in time.



Map - 2.2 River Basin Map of Bihar

2.5 Socio-Economic Profile of Bihar

Bihar is one of the most populous states of India. High proportion of population below the poverty line and its special social and economic situation pose challenges for the development of the state. However, over the years in recent past, by means of several socio-economic measures, it has taken a leap forward and is now growing at a fast pace as will be evident from the following indicators.

2.5.1 Human development index indicator

	Bihar		INDIA
	2001	**2011-12** **2012-13**	**2011**
Per Capita income (in Rupees)	6,850	24,681* 28,317	60,972*
Literacy Rate	47%	63.82%	74.04%
	(M-54.68%, F-33.12%)	(M-73.39%, F-53.33%)	(M-82.14%, F-65.46%)
Infant Mortality Rate/1000 child born	56(2008)	48(2010)	47(2010)
			44(2011)

Source: Director of Statistics, GOB, Census report 2001/2011

**trak.in (2011-12)*

2.5.2 Demography

	Bihar		INDIA
	(2001)	**2011**	**2011**
Total population crore	8.30 crore	10.38 crore	121.02
Density of population (per sq km)	881	1102	382
Sex Ratio (per 1000 male)	921	916	940
% Population in rural area	89.54	88.70	68.84
% population in urban area	10.46	11.30	31.16
Population growth	25.07%	28.43%	17.64%

Source: Census report 2001, 2011(provisional)

2.5.3 Agriculture

The State has plenty of plain and fertile cultivable land of 64.41 lakh hectare which is almost 70% of its geographical area. The soil is mostly alluvium and very fertile, most suitable for multiple cropping and irrigated agriculture.

The ultimate created and utilized irrigation potential of the state at the end of 11th Five Year Plan i.e 2012 is shown in table below:

*Table 2.4.3-Ultimate, Created and Achieved Irrigation Potential of the State

(Area in Lakh Ha)

	Type of Irrigation	Ultimate Potential	Created Potential (upto 2012)	Utilised Potential
(a)	Major-Medium Irrigation	53.53	28.86	16.36
(b)	Minor Irrigation			
(i)	Surface Irrigation (including Ahars & Pynes)	15.44	5.191	2.358
(ii)	Ground Water Schemes (mostly privates hallow tube well)	48.57	28.99	26.75
	Total	117.54	63.041	45.468

*Source: - Agriculture Road Map, Govt of Bihar 2012

The created potential under major & medium irrigation increased to 29.13 L.ha by March 13 due to creation of additional potential of 0.27 L.ha during 2012-13. The actual utilization also increased to 17.596 L.ha under major & medium irrigation during 2012-13.#

Source : प्रशासनिक प्रतिवेदन, जल संसाधन विभाग, बिहार (2012–13)

2.6 Flood Typology

Conventionally the typology of flood management classes is based on flood type, source area, warning time, flood duration and recession, and impact on agriculture. FMISC has identified four classes of floods which can be classified as

Class I: Flash floods – floods from Nepal rainfall, lead time is short (8 hours) in Kamla Balan, recession is fast,

Class II: River floods – lead time 24 hours, recession is 1 week or more,

Class III: Drainage congestion in river confluence- lead time > 24 hours, lasting full rainy season, no Kharif cultivation,

Class IV: Permanent water logging - shrinkage in area only in Feb, local rainfall, micro-relief aspects.

Another classification which has been identified by FMISC resulted into four classes of Floods, which are following:

Not affected <10% area inundated.

Low Flood 11%-30% area inundated.

Medium Flood	31%- 60% area inundated.
High Flood	> 60% area inundated

2.7 Occurrence of Floods in River Systems

A study has been made to see the flood stages in various river systems during floods in FMISC focus area. It was found that early flood takes place during the month of May-June in river Bagmati, Kosi and river Kamla. Thereafter flood generally comes in river Burhi Gandak in the month of mid July. During these months river Ganga generally remains low but by September river Ganga, the master drain, also rises making the flood problem more acute. However, during the year 2011 flood period, Ganga was constantly high after mid July and reached the HFL of 34.17 m on 19.08.2011 at Bhagalpur. In the year 2013 also, the river Ganga remained aggressive almost during entire flood period from Ara to Kahalgaon and new highest flood level (HFL) of 34.50m was attained on 04-09-2013 at Bhagalpur crossing earlier HFL of 34.20m in 2003.

2.7.1 Floods since Year 2000 in the FMISC Focus Area

Floods have caused devastation and acute human sufferings frequently since the dawn of civilization and man had to live with floods since time immemorial. The impact of flood was perhaps not felt to the same extent in the past as is felt now. This was due to the fact that there were smaller living population and pressure of industrial activities and other development works in the flood plains was far less compared to the present day activities. The flood problem was accentuated due to ever increasing encroachments on the flood plains by the growing population to meet its requirements of food and fiber. The destruction of forests for reclaiming areas for occupation and for obtaining fuel for domestic requirements had also caused changes in river regime. All these have resulted in an anomalous situation in spite of protection measures carried out so far in the State with a substantial investment on flood management works, flood damages have gone on increasing instead of decreasing. A brief summary of flood based on the Water Resources Department Annual Flood Report in chronological order from the year 2000 is given as follows:

2000- Bagmati left embankment at chain 273 near village Madhkaul was cut by anti-social elements. Embankment at chain 311 near village Madar was breached on 6/8/2000. Again in the last week of September and first week of October at km 11, 12, 20, 35.5 and 48 were cut by the villagers. Incidents of embankment cut have been reported earlier also. This was done to bring silt to raise land by the villagers. Kamla-Balan and Bhutahi-Balan catchments received heavy rainfall during first and last week of July resulting in unexpected rise of water. Slope of left embankment of Kamla-Balan embankment between km 89-90 in a length of 200 m was damaged. Spur at 2.80 km of Eastern Kosi Afflux Bund was punctured in the night of 4/8/2000 in a length of 20 m and the nose was washed away due to heavy pressure of river. A new nose and shank was constructed in a length of 563 m and spur was made safe. The spur at km 14.5 was also damaged in half of its length in the night of 29/9/2000. Experts from head quarter camped at the site and brought it under control. Sikarhata Majhari Bund of western Kosi embankment between Km 6-7 was damaged in the night of 13/8/2000 but was saved by doing flood fighting work. Heavy pressure on spur at km 78.30 of eastern Kosi embankment was overcome by undertaking flood fighting works.

2001-Left bank of river Burhi Gandak at Rampurwa Pulwar, Pakridayal, Enarwa Ghat Mainpurwa and right embankment at Bihkhiya, Chakarniya, Bairiya, Koral, and Balochak was experiencing pressure but was saved by timely flood fighting. In Burhi Gandak left embankment at 69-70 km at village More, the bed bar, which was earlier constructed, was

damaged due to heavy local rainfall and pressure over embankment. Burhi Gandak right embankment at 98-99 km at village Phulwaria was cut by the anti-social elements on 17/9/2001. The right embankment of Bagmati river at Kothia and Surgahi and left embankment at Kansar, embankments were experiencing heavy pressure throughout the entire flood season but were saved by timely flood fighting. No breach in this reach occurred. In western Kosi embankment at Ghoghardiha, Jamalpur embankment at 30.105 km and at Sikhta Manjhari, there were pressure over embankment which was safely overcome by timely flood fighting. In western Kosi embankment at 2.25 km, the D-part of spur nose was damaged. Bhutahi-Balan right embankment breached due to overtopping at 20.91 Km, 21.01 km, 21.4 km 22 km, and 60.7 km in the first week of October.

2002-Kamla Balan left embankment at km 81.20 (Bugras) was cut by anti-social elements in a length of 30 m which increased to 50 m. Overtopping was reported in Kamla Balan left embankment at km 38 at Bhadhuar on 23/7/2002 at 39 km near Bhadhuar sluice, at 50.5 km near Pipraghat, 51 km at junction point of rail cum road bridge and embankment and 74.8 km in Asma village on 23/07/02. Kamla Balan right embankment at km 37 near village Banaur and km 64 at village Thengha were cut by anti-social elements in a length of 30 m which increased to 300 m. Bagmati right afflux bank embankment at ch. 1025 near village Dharampur was cut by the villagers on 23/7/02. Bagmati left embankment near ch. 145 of Sirsia ring bund at 20 to 30 ch. and 29 to 32.5 ch. breached due to overtopping. Bagmati left embankment between ch. 145 to 149 was cut by villagers on 23/7/ 02. Khiroi left embankment at 7 km at village Masartharia and 5.25 km near Maasma and Khiroi right embankment at 12 km near Belwara Milki village and at 3 km near Bagwasa village breached due to overtopping on 24/7/02. Western Kosi embankment at 29 to 30 km below Kasba Bharda was cut by anti-social elements at 2 places.

2003- Maximum discharge of 389000 cusec passed through river Kosi whereas discharge in excess of 250000 cusec passed four times which resulted in continuous pressure on spurs/embankments. This resulted into damage of spurs in western Kosi embankment at 25.57, 15.80 and 15.30 km. On 1/8/2003 due to high discharge in the river, the right embankment of Bagmati river at Surgahi site at chain 112-123 breached in 50 ft. which increased to 1100-2000 ft. On 1/8/2003 anti-social elements cut Kamla Balan right embankment at km 66.50 in a length of 50 ft. Status of flood in the rivers other than Ganga, and Gandak remained normal. In river Ganga the HFL at Bhagalpur surpassed the year 1978 record of 34.18 m and was at 34.20 m level while in Patna at Ghandighat the HFL was observed as 50.12 m in 2003 against HFL of 50.27 m recorded in 1994. This heavy flooding in Ganga resulted in damage to the road network in Samastipur district. In river Gandak the maximum discharge 6,69,750 cusecs passed through Valmikinagar barrage on 31/7/03.

2004- 2004 flood in the state of Bihar was unprecedented which proved to be very grave and damaging. Catchments area of north Bihar rivers received heavy rainfall in the first week of July itself which not only broke last three years flood record but also surpassed the 1987 flood year. Flood level at Dubbadhar site on river Bagmati surpassed all time high flood level by about 1.18 m. Similarly Burhi Gandak river on 15.7.04 and Kamla Balan river on 10.7.04 touched all time high flood level. This itself speaks about the fury of flood in the year 2004. The embankments of north Bihar breached at many places resulting in flood inundation in a vast area of north Bihar. Unprecedented flood in river Bagmati, Burhi-Gandak, Kamla and Bhuthi-Balan and Adhwara group of rivers breached the embankments at many places and there was loss of life and property in a large scale. In river Kosi, situation by and large remained normal and a maximum discharge of 286375 cusecs passed on 10.7.04.

2005 – The flood situation during 2005 was normal in comparison to the devastating flood of 2004. Whereas there were 63 numbers of breaches during 2004 flood, only 8 breaches occurred during the year resulting in flood inundation in Madhubani and Katihar districts only. Left and right embankments of Kamla also breached at seven places during this year. Bhutahi Balan left embankment at km 21.22 and 22.80 was cut by the anti-social elements and due to flash flood, embankment was damaged at few places.

2006- The flood situation during 2006 was normal. Whereas there were 63 numbers of breaches during 2004 flood, this year only one breach occurred. Left embankment of Kamla was breached near village Asma at km 75.70 by anti-social elements but fortunately there was no loss of life or property. Flood situation in other places remained normal by and large.

2007- 2007 floods will be remembered for high degree of rainfall which was even more than year 2004 flood period. Districts of Champaran, Gopalganj, Siwan, Madhubani, Darbhanga, Muzaffarpur, Samastipur, bore the fury of flood to a large extent. But fortunately compared to 2004 floods, there were fewer numbers of breaches (32 nos. in Bihar) in 2007 as compared to 63 in year 2004. Unprecedented flood in river Bagmati, Burhi-Gandak, Kamla and Bhutahi-Balan and Adhwara group of rivers breached the embankments at many places and there was loss of life and property. In river Kosi, situation by and large remained normal.

2008- There was an unprecedented flood due to a breach near 12.9 km of Eastern Kosi Afflux Embankment near Kushaha village in Nepal on 18th August 2008 which very soon took the shape of a catastrophe leading to the miseries to lakhs of people in Sunsari and Saptari districts of Nepal, and Supaul, Madhepura, Araria, Saharsa, Katihar and Purnia districts of Bihar. River Kosi entirely changed its course but this was again tamed to its earlier course by WRD after tremendous effort keeping in line with the advice of Kosi Breach Closure Advisory Committee (KBCAT).

2009-The floods this year remained normal except few breaches such as Tilaktajpur on right embankment of river Bagmati under Runnisaidpur block of Sitamarhi District, Gobindpur site of Labha Choukia Paharpur embankment of Mahananda river and Sallehpur Tandeshpur site of Gandak river. The loss to life and property was brought to minimum by undertaking rescue and relief measures.

2010- The flood situation this year remained quite normal with normal average rainfall. Only a few cases of breaches were reported viz Saran embankment in a length of 200 m between 122.75 km and 122.95 km near Simaria village both due to sharp change in the river course.

2011- The floods this year remained normal except with a few exceptions such as damage of nose of spur no-9 between Ismailpur and Bindtoli and that of revetment in 30 m length near Kazikoria of Raghopur village u/s of Vikramshila Setu and at spur no-9 and spur no-7 in a length of 138 m and 65 m respectively in d/s of Vikramshila Setu under Gopalpur block of Bhagalpur district, both on left embankment of river Ganga. It is worth mentioning that H.F.L. attained by river Ganga at Bhagalpur this year was recorded as 34.17 m on 19.08.2011 against the H.F.L. of 33.26 m recorded last year on 03.09.2010. There was unprecedented flood in river Sone also with a max^m discharge of 9,58,000 cusec on 25.9.11 at Indrapuri Barrage whereas the same was 61,130 cusec last year on 14.7.10.

2012- No major flood was reported during this year although Ganga water spread in one sq.km. area in two feet depth near Raghopur village of Bhagalpur district for few days. Gandak remained in spate since the beginning of monsoon and kept on exerting pressure on both its embankments. The incessant pressure on Gandak right embankment, especially in Pipra-Piprasi reach was so enormous that round the clock vigil and protection work had become necessary. The problem was accentuated by eroded length of spur at Dhuniawapatti at 26.75 km of PP right embankment. FMISC even prepared a probable inundation map in anticipation of possible threat to this portion of the embankment in the month of August. Gandak remained furious all through the early months of monsoon.

Heavy rain in the catchment of Burhi Gandak resulted in overbank flow in smaller rivers and rivulets causing some flash flood in West Champaran, where overtopping on railway track was reported at Sikta railway station.

Continuous high level of Ganga exerted pressure on some of the protecting structures along its left bank in Bhagalpur, Vaishali and Samastipur Districts. Ismailpur Bindtoli Embankment on left bank of river Ganga; situated downstream from Vikramshila setu in Bhagalpur District suffered immense pressure and was almost on the verge of collapse between spur no. 5-6. Another probable inundation map was prepared to alert administration for any eventualities that could have occurred due to a possible breach on this site. Incessant threat on the left bank of Ganga upstream of Vikramshila setu at Raghopur- Khairpur site kept the department on its heels. The dowel at left bank of river Ganga at Chandpur-Dhamaun-Rasalpur in Samastipur district had to be strengthened continuously to save it from breach/overtopping.

2013- Although no major flood was recorded this year, the salient features of this year's flood may be listed as below:

- Discharge of river Gandak was continuously above 1.0 lakh cusec for 84 days.
- Discharge of river Kosi was continuously above 1.0 lakh cusec for 79 days
- The new HFL of river Ganga was attained to 34.50 on 04-09-2013m at Bhagalpur.
- The forecast of Havoc Rainfall & the Phylin Cyclone put everybody on full alert and any untoward happening was averted by timely proper action & preparedness.
- The spurs at Ghoraiya & Pujaha sites (Bloc-Bairia) at left bank of Gandak river in W. Champaran were damaged partially which were restored by flood fighting work round the clock.
- The spurs no- 9,10,11 & 12 at Pultegaura in Nepal were threatened by Kosi flood, but they were saved .
- Various sites of different embankments such as Buxar-Koelwar-Ganga, Gogri-Narayanpur, Sanha-Gorgama, Bisua Zamindari bundh, Chandpur-Dhamaun in Samastipur, Sinhama, Khirpur-Raghopur, Ismailpur-Bind Toli were under constant attack by Ganga during flood period.

2.8 Flood Characteristics of Focus Area

FMIS Phase-I focus area earlier comprised of only eleven districts of North Bihar namely Muzaffarpur, Sitamarhi, Sheohar, East Champaran, Madhubani, Darbhanga, Samastipur, Begusarai, Khagaria, Saharsa, and Supaul. FMIS Phase-II focus area now comprises of all the districts under FMIS Phase-I; and remaining ten districts of North Bihar viz West Champaran, Gopalganj, Siwan, Saran, Vaishali, Madhepura, Araria, Kishanganj, Purnea and Katihar i. e. all the 21 districts of North Bihar besides three districts of South Bihar namely

Bhagalpur, Munger and Patna. In the meantime it was decided to prepare spatial database for whole Bihar by including remaining 11 districts of South Bihar namely Nalanda, Gaya, Nawada, Aurangabad, Jehanabad, Arwal, Bhojpur, Buxar, Rohtas, Bhabhua, Lakhisarai, Sheikhpura, Jamui and Banka. A study has been made with the help of data obtained from DMD, Patna vide Table 2.8.1 below to see the frequency of flood events in the development blocks of these districts in terms of inundation during 1987 to 2013 (27 years).

Table 2.8.1 Frequency of Flood Events in Bihar during 1987-2013.

Sl No	Name of Districts	Number of Blocks affected out of last 27Years (1987 to 2013)			
		16Years and more	11Years – 15 Years	6Years – 10 Years	1Years – 5 Years
FMIS Phase-I Focus Area					
1	Muzaffarpur	5	3	2	6
2	Sitamarhi	6	6	6	0
3	Sheohar	1	2	1	1
4	East Champaran	-	10	9	9
5	Madhubani	2	8	9	5
6	Darbhanga	6	6	6	2
7	Samastipur	3	3	7	9
8	Begusarai	2	3	2	9
9	Khagaria	6	1	-	-
1	Saharsa	5	1	-	3
1	Supaul	6	0	1	5
Total of FMIS Phase-I Focus Area		42	43	43	49
Additional Area of FMIS Phase-II					
1	W. Champaran	3	4	8	3
1	Gopalganj	3	2	-	9
1	Siwan	-	-	-	15
1	Saran	-	2	6	10
1	Vaishali	-	3	3	11
1	Madhepura	2	-	6	4
1	Araria	2	7	-	-
1	Kishanganj	-	5	2	-
2	Purnea	3	1	5	4
2	Katihar	5	6	5	2
2	Bhagalpur	5	6	5	-
2	Munger	-	1	3	5
2	Patna	2	3	8	9
Sub Total		25	40	51	72
Total of FMIS Phase-II Focus Area		**67**	**83**	**94**	**121**
Rest Districts of Bihar added in FMIS Ph-2					
2	Nalanda	-	-	9	11
2	Gaya	-	-	-	-
2	Nawada	-	-	-	-
2	Aurangabad	-	-	-	-
2	Jehanabad	-	-	-	-
3	Arwal	-	-	-	-
3	Bhojpur	-	2	4	8
3	Buxar	-	-	2	7
3	Rohtas	-	-	-	-
3	Bhabhua	-	-	-	-
3	Lakhisarai	-	2	1	2
3	Sheikhpura	-	-	-	-
3	Jamui	-	-	-	-
3	Banka	-	-	-	-
Sub Total		-	4	16	28
Total for Whole Bihar		**67**	**87**	**110**	**149**

(Source: Disaster Management Department, Bihar)

The table above indicates that out of 413 blocks in FMIS Phase-II focus area, there are as many as 67 blocks that are most frequently flood affected and 87 blocks are frequently flood affected in terms of no. of times they were affected by floods in last 27 years.

2.9 Loss of Life and Public Property during last 10 years

Loss of public property and animal lives due to floods since year 2004 as obtained from Disaster Management Department; Government of Bihar is given in table below:

Loss of Public Property

Year	Number of Affected									Crop Damaged (Rs Lac)	House Damaged		Public Property Damaged (in Rs. Lac)	Deaths	
	District	Blocks	Village	(in Lac)		Area (in Lac ha.)					Total	Value (in Rs. Lac)		Human	Animal
				Human	Animal	Agric	Non- Agric	Total	Cropped						
2013 (P)	20	116	4540	69	5	15	5	20	6	10572	156986	2506	1661	231	6464
2012	11	28	277	2.4	0.08	0.9675	0.1	1.07	0.3	300	473	159.52	162.20	15	0
2011	25	166	3577	71.43	6.627	35.42	2.877	38.197	3.439	10295.7	851	6904.44	153.67	249	183
2010	9	44	679	7.18	3.57	1.602	0.39	1.992	0.101	311.92	6868	704.87	169.2	32	0
2009	16	91	1546	22.03	1.346	1.71	9.339	11.05	0.475	2182.57	7674	528.15	530.1	97	2
2008	18	116	2585	49.952	12.166	6.40495	2.11922	8.8242	3.67211	3420.25	297916	8451.4	9771.96	258	878
2007	22	269	18832	244.42	27.13	13.323	5.51	18.833	10.603	7683782	784328	83144.52	64241.52	1287	2423
2006	14	63	959	10.89	0.1	1.52	0.297	1.81	0.87	706.63	18,637	1,225.03	8,456.17	36	31
2005	12	81	1,464	21.04	5.35	3.343	1.261	4.6	1.35	1,164.50	5,538	382.79	305	58	4
2004	20	211	9,346	212.99	86.86	20.99	6.010	27.00	13.99	52,205.64	9,29,773	75,809.51	1,03,049.60	885	3272

Source: (Disaster Management Department, Bihar website: http://www.disastermgmt.bih.nic.in/) &

Provisional figures based on Form-IX dated 15.10.2013.

2.10 District-Wise Damage Statistics for Flood – 2013

Sl. No.	District	Number of Affected Blocks	Nos. of Affected village	Cropped Area (Lakh hect.)	Estd. Crop damage (Rs. Lac)	No. of houses/ huts damaged (Fully /Partially)						Estimate d Value of house damage In (Rs. Lac)	Public Properties damage (Rs. Lac)	Live Lost (Nos)		
						Pucca (F)	Pucca (P)	Kachcha (F)	Kachcha(P)	Huts	Total			Human		Animal
														Flood	Others	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FMIS Phase-I Area (11 Districts)																
1.	Muzaffarpur	4	53	0.05	63.00	0	0	22	0	0	22	3.75	-	7	-	-
2.	Sitamarhi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.	Sheohar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.	E.Champaran	3	22	0.05	21.60	-	-	50	-	-	50	-	-	2	-	-
5.	Madhubani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6.	Darbhanga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7.	Samastipur	4	75	0.22	35.00	-	-	188	-	60	248	-	-	11	-	-
8.	Begusarai	7	186	1.10	97.63	-	-	-	-	-	-	-	-	22	-	2
9.	Khagaria	4	78	-	-	-	-	-	-	-	-	-	-	7	-	-
10.	Saharsa	4	29	-	-	-	-	41	-	679	720	23.12	-	-	-	-
11.	Supaul	6	104	1.30	0.51	-	-	-	-	2111	2111	211.70	-	2	-	21
Total for FMIS Phase-I Area (11 Dstricts)		**32**	**547**	**2.72**	**217.74**	**0**	**0**	**301**	**0**	**2850**	**3151**	**238.57**	**-**	**51**	**0**	**23**
Additional area in FMIS Phase-II (13 Districts)																
12.	W. Champaran	-	-	-	-	-	-	-	-		-	-	-	-	-	-
13.	Gopalganj	4	314	0.40	47.64	-	-	198	208	108	514	61.21	27.50	-	-	-
14.	Siwan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15.	Saran	4	264	-	-	-	-	-	-	-	-	-	-	4	-	-
16.	Vaishali	6	100	1.32	110.00	-	-	-	186	-	186	6.00	-	17	-	2
17.	Madhepura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18.	Araria	6	247	0.07	1173.30	-	-	202	98180	5790	104172	1979.14	1477.12	14	-	-
19.	Kishanganj	7	557	0.06	365.76	-	-	1339	1007	-	2346	2.85	6.50	5	-	-
20.	Purnea	3	23	-	-	-	-	186	-	-	186	6.0	-	17	-	2
21.	Katihar	10	991	0.16	457.90	-	-	104	373	107	584	8.50	30.00	14	-	-
22.	Bhagalpur	12	297	0.36	3979.25	-	-	-	14	81	95	2.80	-	25	-	5
23.	Munger	6	310	0.13	3787.66	-	-	4832	9027	30734	44593	40.00	-	22	-	6422
24.	Patna	8	105	-	-	-	-	-	-	-	-	-	-	7	-	2
Sub Total		**66**	**3208**	**2.50**	**9921.51**	**0**	**0**	**6861**	**108995**	**69820**	**152676**	**2106.50**	**1541.12**	**125**	**0**	**6433**
Total for FMIS Phase-II Focus Area (24 Districts)		**98**	**3755**	**4.22**	**10139.25**	**0**	**0**	**7162**	**108995**	**72670**	**155827**	**2345.07**	**1541.12**	**125**	**0**	**6456**

District-wise flood damage statistics as obtained from Disaster Management Department; Government of Bihar for Flood 2013 for Phase-II Focus area and rest area of Bihar is given below:-

Rest 11 Districts added in FMIS Ph-II																
25.	Nalanda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26.	Gaya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27.	Nawada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28.	Aurangabad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29.	Jehanabad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30.	Arwal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31.	Bhojpur	6	314	0.32	433.00	-	-	159	175	823	1148	202.00	120.00	30	-	9
32.	Buxar	5	55	0.05	-	-	-	10	20	-	30	-	-	4	-	-
33.	Rohtas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34.	Bhabhua	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35.	Lakhisarai	3	48	0.14	-	-	-	-	-	127.	127	0.80	-	2	-	1
36.	Sheikhpura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37.	Jamui	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38.	Banka	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub Total		**14**	**417**	**0.51**	**433**	**0**	**0**	**169**	**195**	**950**	**1305**	**202.80**	**120.00**	**36**	**0**	**10**
Grand Total (For Whole Bihar)		**112**	**4172**	**4.73**	**10572.25**	**0**	**0**	**7331**	**109190**	**73620**	**157132**	**2547.87**	**166.12**	**161**	**0**	**6466**

(Source: Disaster Management Department, Bihar, Patna (Cumulative Form-IX dated 15.10.2013(P))**)**

3.0 ACTIVITIES OF FMISC DURING 2013 FLOODS

3.1 Activities of FMISC in 2013 during Flood Season

Like previous years, this year too, FMIS Centre, Patna with all its resources and as per its mandate was ready and prepared for the flood season 2013. The satellite data for north Bihar, which were received in FMISC, Patna from NRSC, Hyderabad, were further processed, value added and disseminated almost same day or next day to the user/stakeholder departments like WRD, DMD, GFCC, Agriculture Department, NRSC, CWC etc. as per their needs.

3.1.1 Flood Control Cell at FMISC

Similar to previous years, FMISC was ready to face any emergent situation during flood. The Centre started working in two shifts, from 7 a.m. to 2 p.m. and from 2 p.m. to 9 p.m. daily including holidays during flood period, i.e., 15th June 2012 to 15th Oct 2012. This year too FMIS Centre geared up with its limited personnel and resources at its disposal and started collecting daily data of rainfall & river Water Levels, maps and satellite images etc. from all possible sources. Flood bulletins were issued daily to all concerned after incorporating all these information and data in the bulletin and were also posted on the website of FMISC.

There was continuous liaison with Water Resources Department and Disaster Management Department and value added maps were provided as and when required in shortest possible time.

3.1.2 Information disseminated by FMIS Centre

3.1.2.1 Information Generated

Yet another rainy season and FMISC was again ready to face any situation and to provide logistic support to the stakeholders.

This year the sky condition was not conducive to satellite based observation. Hence our main tool, i.e., satellite images were scarcely available, leaving us with little scope for authenticating field reports. Still we kept trying to get usable images available from whatever source possible.

3.1.2.2 The Flood Scenario

As there were not much rain, the flood situation in Bihar was almost normal. In the 2nd last week of July, the nose of spur no. 8 near Godhahia village at 1.5 km of P.D. Ring bund of river Gandak under Bairia block of West Champaran was damaged. This was contained by continuous flood protection work. This year river Ganga was relatively more in spate and there were pressure reported at Raghopur site in the d/s of 5.695 km of Left dowel embankment under Bhagalpur district. The pressure was also reported on spur no. 5, 6 and 7 on the left embankment of river Ganga near Ismailpur-Bindtoli. On 7th August, 13, abandoned embankment in front of left embankment at 0.3 km of river Burhi Gandak under Khagaria district breached and water spread in Majhla village. On 3rd September, Gogri Narainpur embankment was damaged in 10 m in between 37-38 km due to breach in Lagar Laghu Bund in front of Gogri Narainpur embankment. Highest Flood Level (HFL) of river Ganga at Bhagalpur crossed earlier HFL of 34.20 m reported in year 2003 to 34.50 m on 04.09.2013.

On the whole the season was less eventful on the flood front this year.

3.1.3 Contribution of FMIS Centre to Technical Advisory Committee (TAC), WRD and GFCC in taking decisions for Anti-Erosion Works for the Year 2014.

This year too, meeting of TAC of WRD to approve Flood Protection Measures proposed in the different rivers was held in the Conference Hall of FMISC. FMISC GIS specialist provided pre and post flood maps showing changes in the river regime at specific sites of major rivers of north Bihar like Gandak, Kosi, Kamla, Bagmati, Burhi Gandak and in some stretches of Ganga in the meeting. This value addition to our GIS databank came handy in deciding Anti-erosion works at critical locations. The important schemes at critical locations submitted by field officers to TAC were scrutinized with the help of these maps.

All such schemes, referred to GFCC for clearance, and to be proposed for approval by Flood Control Board were examined with FMIS inputs in the form of latest satellite pictures. This helped a lot in judicious decision making at State level and High Level Committees.

3.1.4 Present Status of Important Activities of FMIS Phase 2 Project :

3.1.4.1 Flood Forecast and Inundation Modeling of Bagmati-Adhwara Basin in north Bihar

The objective of this consultancy is to equip WRD, Bihar with a comprehensive model/ suite of models for improved flood forecasting in the Bagmati-Adhwara river basin in north Bihar up to Hayaghat and piloting detailed inundation mapping in an area of 1800 sq. km. based on DEM available from LIDAR survey data to predict extent, time of arrival, duration and depth at the community level and to predict inundation extent in rest of the basin area in north Bihar based on SRTM data.

This work was assigned to M/s DHI (India) Water & Environment, New Delhi on 1st March 2012. Three reports namely Inception Report, Design Report and Initial Model have been approved by High Level Expert Committee/ Schemes Review Committee. The Consultant has submitted Draft Final Report, which is under review. It is expected to start flood forecasting in the coming season through this model.

3.1.4.2 EAMS: Embankment Asset Management System of Bagmati Adhwara Basin

EAMS work was taken up in June 13 and is in advanced stage of development. Its Design Report has already been approved by Standing Review Committee. It is expected the beta-version of EAMS will shortly be prepared and the work is likely to be completed by Oct 2014. The consultant of this work is Egis-India Ltd.
The objective of the EAMS is to integrate and provide on-line access to all the legacy and relevant data needed on embankment. This will also support flood management functions and improve embankment safety programme.

3.1.4.3 Conducting River cross-section and Embankment Asset Survey in Bagmati-Adhwara Basin

The work was taken up in Jun 14 and is under progress. The cross section of the Bagmati-Adhwara rivers are expected by the end of May 14. The work is being done by WAPCOS Ltd. Inception Report has been submitted by WAPCOS and likely to be considered by Standing Review Committee.

This will provide all data on channel design, embankment layout and land cover, channel long section (Thalweg), disposition of associated structure etc. which become an integral part of EAMS & Flood Forecast model being developed under separate consultancies.

3.1.4.4 Creation of Spatial Database for Bihar

The main objective of this project is to create a GIS database containing thirteen layers for all the 38 districts of Bihar. The important layers are that of Administrative layer, Road & Rail network layers, Drainage layer, Canal & Embankment layer etc.

Last year this work was given to M/s SCIENCE Dehradun to prepare GIS database for 21 districts of north Bihar & 3 districts of south Bihar which was the focus area of FMISC Phase-II. This work has since been completed.

Additional work to cover database for remaining 14 districts of South Bihar has also been taken up through same agency i.e M/s SCIENCE by extending their previous contract.

The work is nearing completion.

4.0 FMISC Website:

4.1 Present Profile of Website:

The FMISC website is an information dissemination interface. The presentation of the information is in text & graphical maps. The main motto of the FMISC website is to provide the user with a platform where they can get flood information related to any particular area.

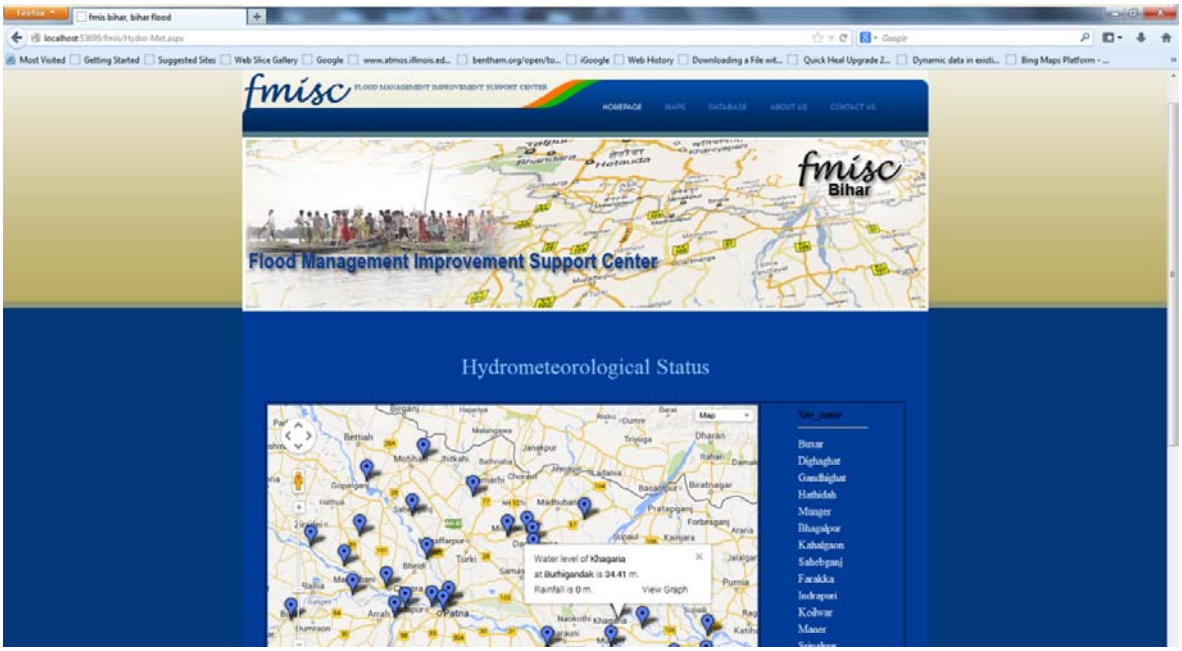


Fig : List of Gauge Station and Marker shows Gauge Station's name and their Current Rainfall and Water levels status.

FMIS website includes:

- ***Daily hydro-meteorological status*** of north Bihar rivers, having DL (Danger level), WL (Water level) and RF (Rainfall) in their catchments during the flood season i.e. 15th of June to 15th of October.

- ***Gate Status :*** Gate opening position of Kosi and Gandak Barrage.
- ***MODIS*** satellite data showing current river status.

- ***Embankments news:*** Flashes embankments status.

- ***Daily flood bulletins*** are issued every day during the flood season. These bulletins contain summarized information about the observed rainfall, water level and basin wise maximum forecasted rainfall for 3 days obtained from IMD.
- ***Inundation maps*** for WRD and DMD, show aerial extent of flood water spread. The inundation extent is derived from RADARSAT Layers/Imagery provided by NRSC in processed 1 bit image format.
- ***Monthly E-Bulletin*** is published every month during flood season. This is an in house production and gives a brief account of activities of FMISC.

- ***End of Season Flood Report is*** also published at the end of flood season.

- ***District level rainfall forecast of 5 days for Bihar and Jharkhand*** as obtained from IMD are included on daily basis during flood season.

- ***Orange bulletins*** issued by Flood Forecast Monitoring Directorate, Central Flood Control Room, Central Water Commission. These bulletins contain summarized information about high flood situation.

- ***Important links, Photo Gallery, Weather Widget are also included in the website.***

4.2 Future Profile:

The salient features of the future website will be:

4.2.1 Generating Inundation Map:

FMISC is trying its best to meet the myriad demands of Thematic maps and Imageries. Under these circumstances the website will have an important role in catering to increasing demands of customized maps and other information products. It is, therefore, mandatory to have web pages that will allow the users to generate maps and other information products as per their needs.
FMISC decided to choose Map Server which will provide the platform for sharing GIS resources, such as maps, with user community, Today, it is common place to see maps or other geographic information integrated seamlessly into websites. Map Server helps us to put our geographic information on the Web, where we need an application that simply displays a map or a more sophisticated one that incorporates specialized GIS tools. Access to the GIS server is embedded inside the web application and typically hidden from the user of the application.

4.2.2 Display of Hydromet Data.

An automatic information system is necessary in flood warning and prediction for the most efficient transfer of information to the interested authorities so that steps to prevent and reduce flood damage may be taken. Such an information warning and forecasting system is to be supported by Hydrometeorological Information System (HMIS).

It is therefore proposed to display Hydromet data on FMISC Website showing rainfall and water level data as on date and during the flood period in both text and graphical form at different sites maintained by (a) **CWC**, Govt. of India (b) **WRD**, Govt. of Bihar, and (c) **DSO**, Govt. of Bihar.

4.2.3 Display of EAMS Features:

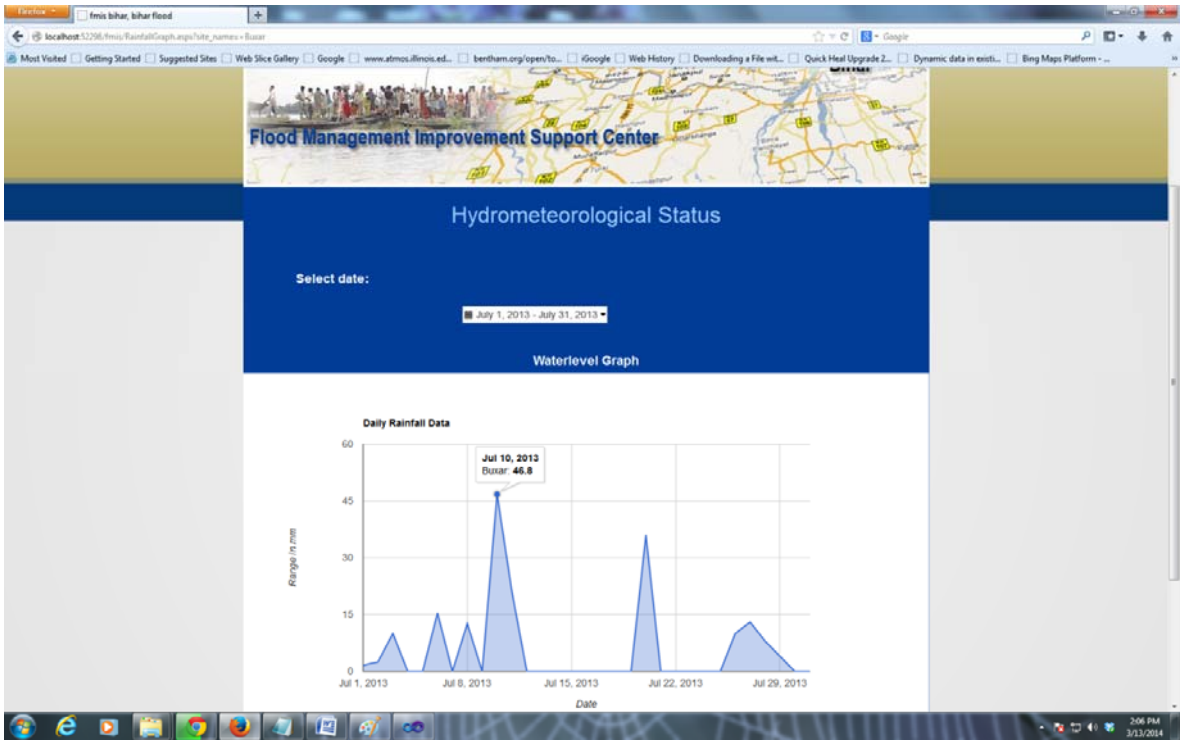
The web based EAMS (Embankment Asset Management System) for Bagmati-Adhwara Basin is being designed to provide various stakeholders various modules that will allow them to manage embankments and its assets, have access to the latest information related to embankment and flood situations especially during the monsoon season and take informed decision.

The EAMS is being developed presently. Its relevant features shall be put on FMISC website as soon it is finally ready for use.

The development of User Interfaces will be done in such a way to provide the greatest number of people with access to various EAMS functionalities for the purpose of managing embankment and its assets. It will describe the functionality of the system from the user's perspective and explain how the user would be able to use EAMS systems and its associated subsystems. The user interface will be developed by combining the database theories and key technologies of WebGIS.

The WebGIS tool is the core of the EAMS and will be mainly used for Data Viewing, Analysis and overlaying of Data from various sources. It will have the ability to upload and download the various Datasets and users will be provided the facility to generate specialized alerts and notification. The WebGIS will have the functionality to create predefined reports and graphs.

The EAMS is an interactive web based GIS solution that can be accessed through the web browsers. Developed on using ArcGIS server technology, the tools and software to be used for the development process will be mainly by using JavaScript and HTML5 scripts. The description of the following functionalities will be provided for users from within the web based GIS solution.


Flood Management Improvement Support Center
Hydrometeorological Status
Select date:
July 1, 2013 - July 31, 2013
Waterlevel Graph
Daily Rainfall Data
Jul 10, 2013
Buxar: 46.8
Range in mm
60
45
30
15
0
Jul 1, 2013
Jul 8, 2013
Jul 15, 2013
Jul 22, 2013
Jul 29, 2013
Date

5.0 2013 Floods –Hydrologic Analysis

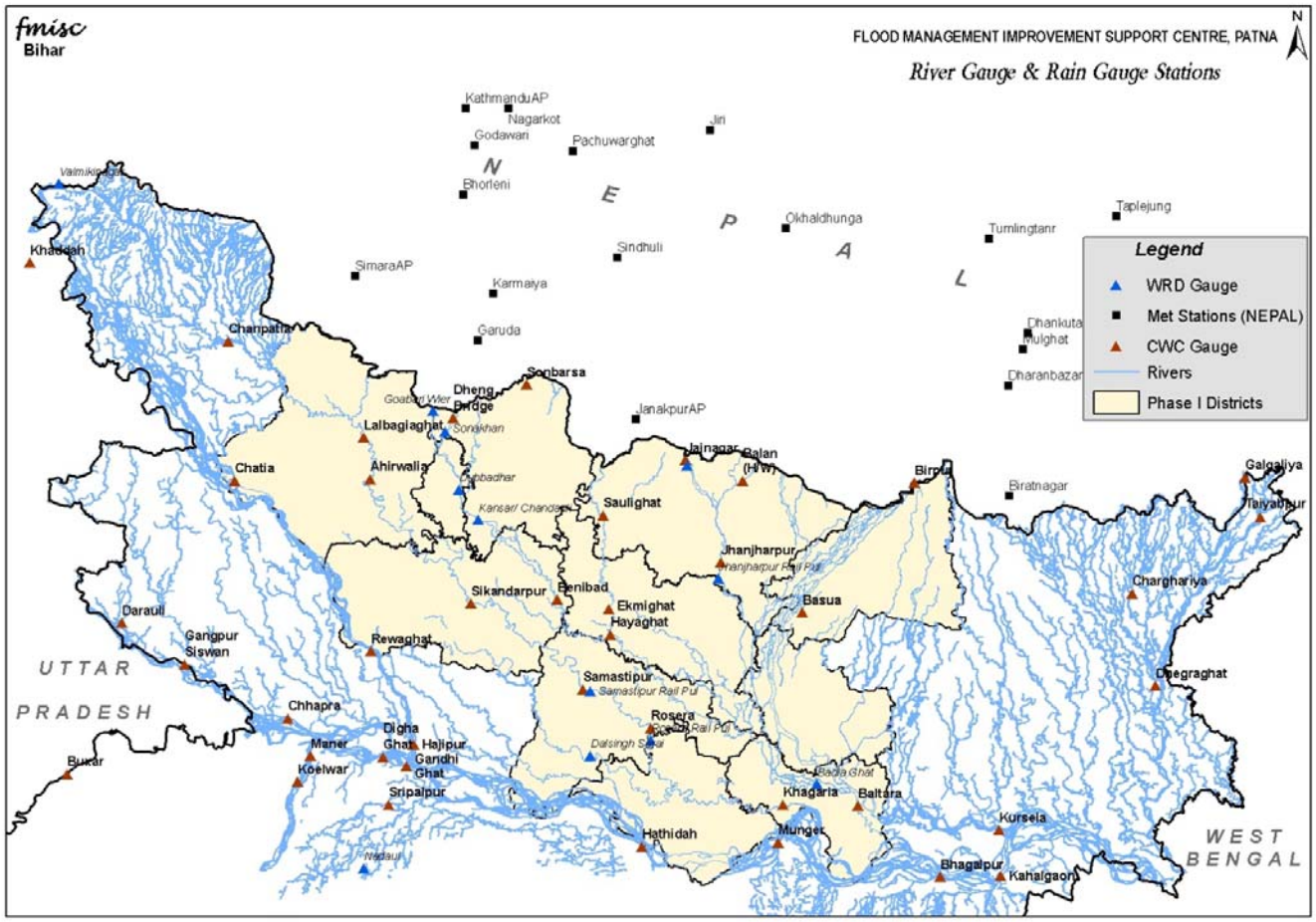
Flood Management Improvement Support Center, Bihar collects hydrological and hydro-meteorological data from different, Government Agencies mainly for Burhi Gandak, Bagmati, Kamla and Kosi rivers. As the GIS data base available with FMIS Centre is for only 11 districts of North Bihar (Phase-I Focus Area), hence various maps and analysis could be carried for these 11 districts only. The Table 5.0 below shows Gauge Stations along with their location, data type and source from where these data are collected. Map 5.0 shows the locations of the stations mentioned in the Table 5.0

Table 5.0 Basin wise List of River Gauge and Rain Gauge

Sl. No.	Gauge station	Location		Maintained by	Type of data	Mode of data acquisition
		Basin/River	(Nepal/ Bihar)			
1	2	3	4	5	6	7
1.	Simara	BurhiGandak	Nepal	GON	DRF	*www.mfd.gov.np*
2.	Lalbegiaghat	BurhiGandak	Bihar	CWC, GoI	DRF& RS	*Email*
3.	Sikandarpur	BurhiGandak	Bihar	CWC, GoI	DRF& RS	*Email*
4.	Samastipur	BurhiGandak	Bihar	CWC, GoI	DRF& RS	*Email*
5.	Rosera	BurhiGandak	Bihar	CWC, GoI	DRF& RS	*Email*
6.	Khagaria	BurhiGandak	Bihar	CWC, GoI	DRF& RS	*Email*
7.	Kathmandu	Bagmati	Nepal	GON	DRF	*www.mfd.gov.np*
8.	Nagarkot	Bagmati	Nepal	GON	DRF	*www.mfd.gov.np*
9.	Garuda	Bagmati	Nepal	GON	DRF	*www.hydrology.gov.np*
10.	Godavari	Bagmati	Nepal	GON	DRF	*www.hydrology.gov.np*
11.	Karmaiya	Bagmati	Nepal	GON	DRF	*www.hydrology.gov.np*
12.	Bhorleni	Bagmati	Nepal	GON	DRF	*www.hydrology.gov.np*
13.	Sonakhan	Bagmati	Bihar	WRD, GoB	RS	*Flood News*
14.	Dubbadhar	Bagmati	Bihar	WRD, GoB	RS	*Flood News*
15.	Kansar	Bagmati	Bihar	WRD, GoB	RS	*Flood News*
16.	Benibad	Bagmati	Bihar	CWC, GoI	DRF& RS	*Email*
17.	Hayaghat	Bagmati	Bihar	CWC, GoI	DRF& RS	*Email*
18.	Kamtaul	Bagmati/Khiroi	Bihar	CWC, GoI	DRF& RS	*Email*
19.	Sonbarsa	Bagmati/Khiroi	Bihar	DOES, GoB	DRF	*Messenger*
20.	Ekmighat	Bagmati/ Darbhanga-Bagmati	Bihar	CWC, GoI	RS	*Email*
21.	Jainagar	Kamla	Bihar	DOES, GoB	DRF	*Messenger*
22.	Janakpur	Kamla	Nepal	GON	DRF	*www.mfd.gov.np*

23.	Sindhuli	Kamla	Nepal	GON	DRF	*www.hydrology.gov.np*
24.	Jainagar	Kamla	Bihar	WRD, GoB	RS	*Flood News*
25.	Jhanjharpur railpul (u/s)	Kamla	Bihar	WRD, GoB	RS	*Flood News*
26.	Jhanjharpur railpul (d/s)	Kamla	Bihar	CWC, GoI	DRF& RS	*Email*
27.	Okhaldunga	Kosi	Nepal	GON	DRF	*www.mfd.gov.np*
28.	Taplejung	Kosi	Nepal	GoN	DRF	*www.mfd.gov.np*
29.	Dhankutta	Kosi	Nepal	GoN	DRF	*www.mfd.gov.np*
30.	Dharan	Kosi	Nepal	GoN	DRF	*www.mfd.gov.np*
31.	Mulghat	Kosi	Nepal	GON	DRF	*www.hydrology.gov.np*
32.	Jiri	Kosi	Nepal	GON	DRF	*www.hydrology.gov.np*
33.	Pachuwarghat	Kosi	Nepal	GoN	DRF	*www.hydrology.gov.np*
34.	Tumlingtar	Kosi	Nepal	GoN	DRF	*www.hydrology.gov.np*
35.	Basua	Kosi	Bihar	CWC, GoI	DRF& RS	*Email*
36.	Baltara	Kosi	Bihar	CWC, GoI	DRF& RS	*Email*
37.	Kursela	Kosi	Bihar	CWC, GoI	DRF& RS	*Email*
38.	Kahara	Kosi	Bihar	DOES, GoB	DRF	*Messenger*
39.	Biratnagar	Mahananda	Nepal	GoN	DRF	*www.mfd.gov.np*
40.	Dhengraghat	Mahananda	Bihar	CWC, GoI	DRF& RS	*Email*

Note: DRF: Daily Rainfall Fall
DRF & RS: Daily Rainfall and River stage.
DOES: Directorate of Economics and Statistics



Map 5.0 Locations of River-Gauge and Rain-Gauge Stations

5.1 Rainfall

Looking at the pattern of this year's south- west monsoon we can infer that first shower of monsoon occurred on 16th June. However, there was progressively deficient rain during the months of June, July, August and September months. A definite shift in the rainfall pattern was observed as during the months of October heavier rainfall was recorded. This is evident form the table 5.1.2 which shows normal rain fall with marginal deficiency during June 2013. In following month of July, August, and September the rain is considerably deficient. Month of October shows a large departure from the normal at 211.7%.looking at the overall picture of rainfall statistics, we find that by and large the rainfall during 2013 monsoon had been normal. Table 5.1.3 shows the district wise monthly monsoon as observed and normal on long period average (LPA) basis. Figure shows the graphical representation of the same.

Table 5.1.1 IMD Weekly/ Seasonal Distribution on regional Scale

Excess	Percentage departure of realised rainfall from normal rainfall is + 20% or more.
Normal	Percentage departure of realised rainfall from normal rainfall is between - 19 % to + 19 %.
Deficient	Percentage departure of realised rainfall from normal rainfall is between – 20 % to - 59 %.
Scanty	Percentage departure of realised rainfall from normal rainfall is between – 60 % to - 99 %.
No rain	Percentage departure of realised rainfall from normal rainfall is– 100 %

Table 5.1.2 Monthly Statistics of Rainfall in monsoon 2013

Month	Normal	Actual	%Departure ((3-2)/2 x100)
1	**2**	**3**	**4**
June'2013	169.0	165.0	-2.4
July'2013	341.3	195.0	-42.9
August'2013	289.1	209.3	-27.6
September'2013	223.3	144.0	-35.5
October'2013	61.6	192.0	211.7
June-Oct' 2013	1084.3	905.3	-16.51

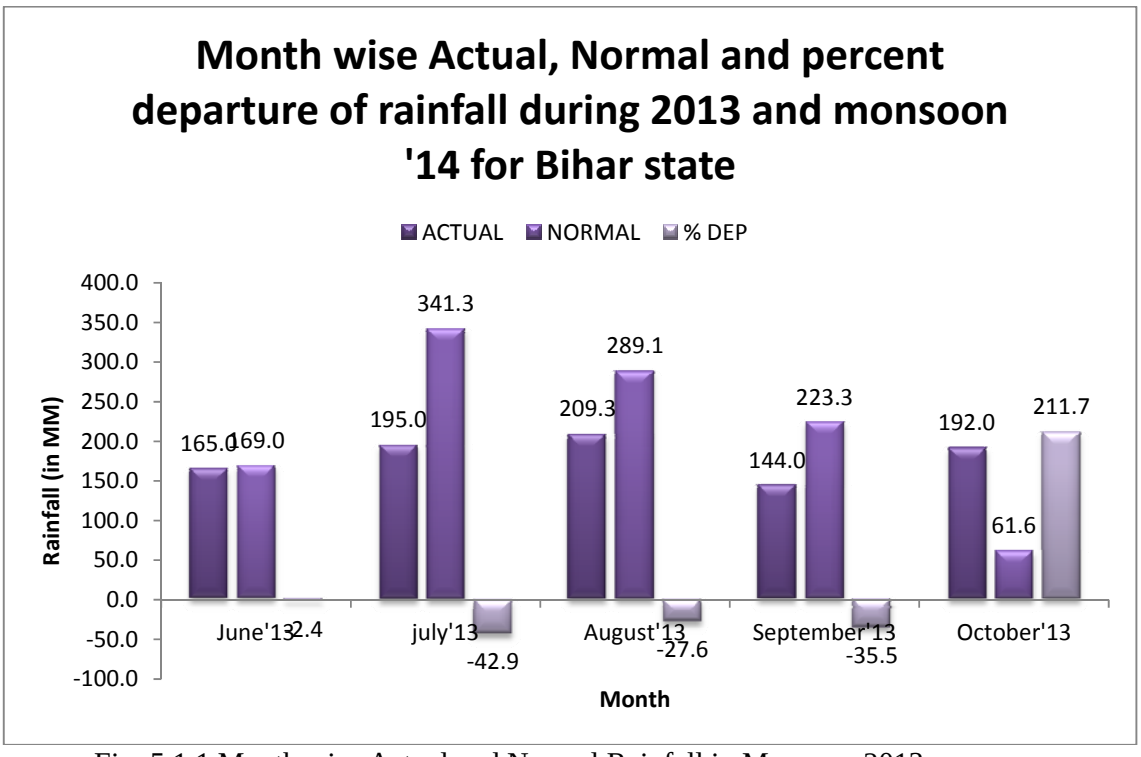


Fig: 5.1.1 Month wise Actual and Normal Rainfall in Monsoon 2013

Table 5.1.3 Monthly Monsoon Rainfall (mm) observed in Bihar in 2013

S.N.	DISTRICT	June	July	August	September	October*
1	Patna	131.3	66.0	185.3	184.0	188.6
2	Nalanda	91.4	78.0	309.3	158.5	165.8
3	Bhojpur	214.1	85.0	219.6	115.5	295.9
4	Buxar	83.6	148.0	175.2	71.8	149.2
5	Rohtas	98.9	182.0	350.2	167.5	112.5
6	Kaimur	60.1	170.0	229.8	211.5	95.0
7	Gaya	60.8	67.0	167.4	128.1	152.1
8	Jehanabad	82.3	97.0	245.8	122.3	107.7
9	Arwal	117.9	198.0	255.6	132.0	147.9
10	Nawada	23.8	67.0	224.9	124.4	127.4
11	Aurangabad	111.0	67.0	276.9	112.5	116.5
12	saran	179.6	100.0	166.6	92.3	243.8
13	Siwan	238.9	119.0	315.4	160.2	382.8
14	Gopalganj	206.0	111.0	172.4	68.2	230.3
15	Muzaffarpur	163.2	78.0	122.6	79.0	230.9
16	East Champaran	199.5	188.0	202.7	123.4	227.5
17	West Champaran	317.4	361.0	208.9	122.7	138.7
18	Sitamarhi	63.2	102.0	141.7	115.3	167.2
19	Seohar	99.5	162.0	128.0	89.0	162.4
20	Vaishali	21.2	152.0	111.1	97.0	172.7
21	Darbhanga	130.6	158.0	149.2	136.8	207.3
22	Madhubani	284.3	136.0	72.3	96.6	190.9
23	Samastipur	107.3	130.0	95.8	146.0	214.5
24	Munger	113.5	253.0	201.0	123.6	176.0
25	Lakhisarai	26.5	113.0	124.0	141.0	84.0
26	Shekhpura	33.8	171.0	123.4	48.5	132.3
27	Jamui	130.1	186.0	246.3	116.2	201.9
28	Begusarai	166.8	198.0	86.2	91.0	224.8
29	Khagaria	106.0	208.0	181.7	215.6	146.5
30	Bhagalpur	153.8	171.0	266.8	160.4	294.7
31	Banka	79.4	192.0	332.2	203.4	287.0
32	Saharsa	86.8	330.0	173.0	285.8	144.6
33	Supaul	335.6	308.0	177.9	191.1	171.5
34	Madhepura	406.8	168.0	197.3	224.9	301.6
35	Purnia	368.2	281.0	216.9	190.9	214.1
36	Kishanganj	503.0	1030.0	469.7	326.8	121.4
37	Araria	391.5	623.0	347.1	136.5	233.3
38	Katihar	282.1	154.0	282.3	148.1	320.7

***upto Oct 23**

5.1.1 Isohyet Map:

Isohyets have been drawn covering the whole area of Bihar for each monsoon month from June '13 to October 13'vide Maps 5.1.3, 5.1.4, 5.1.5, 5.1.6,5.1.7 and 5.1.8 show the overall picture of rainfall distribution these five months which are explained below:

June 2013 (MapNo.5.1.3) During the month of June the rainfall concentration is in Madhepura district in the east and Bhojpur area in the west. Central Bihar in general and Vaishali district in particular faced a near drought situation.

July 2013 (Map.No. 5.1.4) The storm seems to have shifted towards far east with rain concentration in the districts of Kishanganj and Araria. Most of other places experienced dry spell with Patna being the worst hit district.

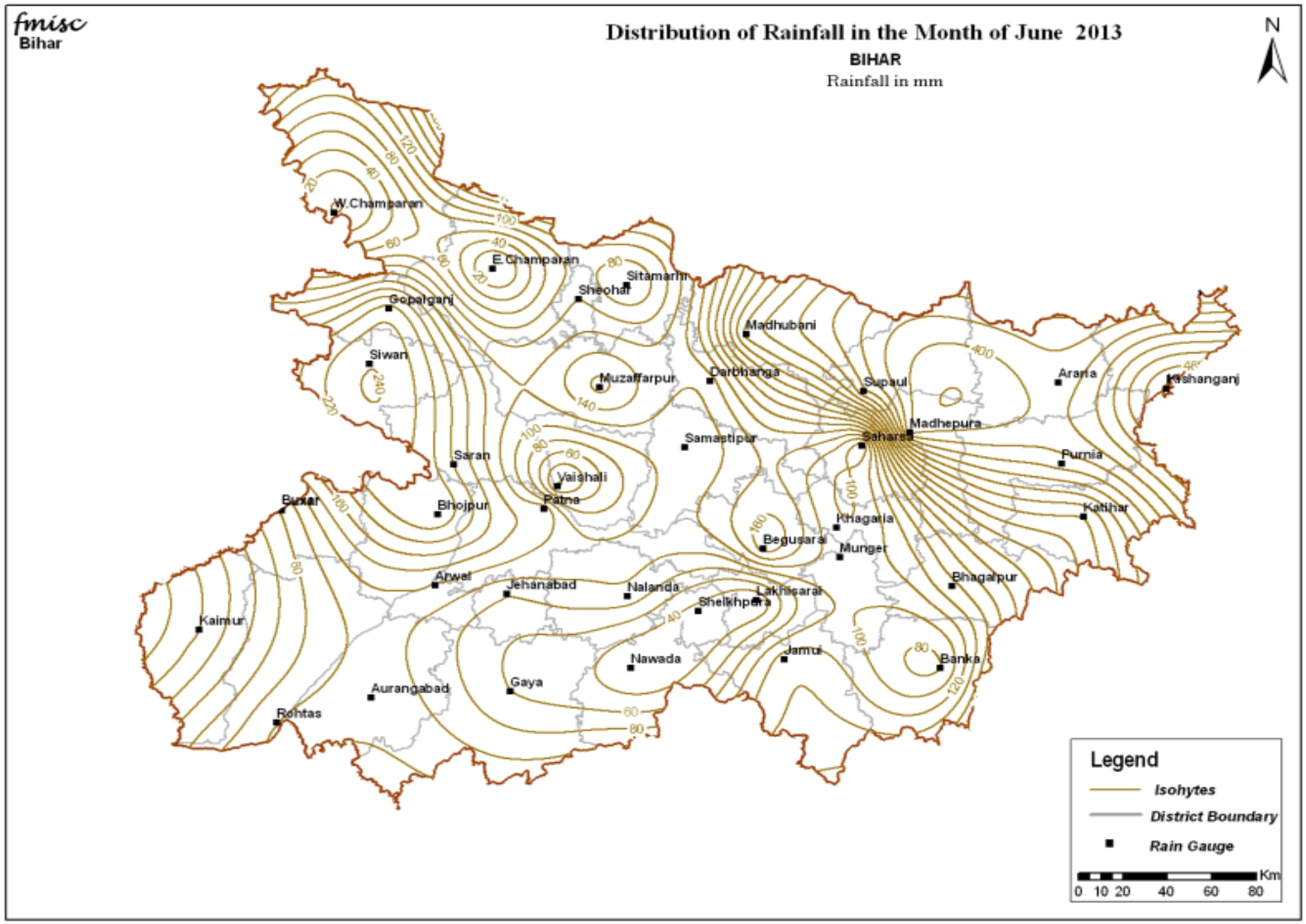
August 2013 (Map.NO.5.1.5) Barring central Bihar Districts, Bihar in general had better monsoon rain particularly south Bihar. However, the deficiency to normal continued.

September 2013 (Map. No5.1.6) Almost uniform rain occurred during September all over Bihar except in Muzaffarpur , Gopalganj ,and Buxar districts.

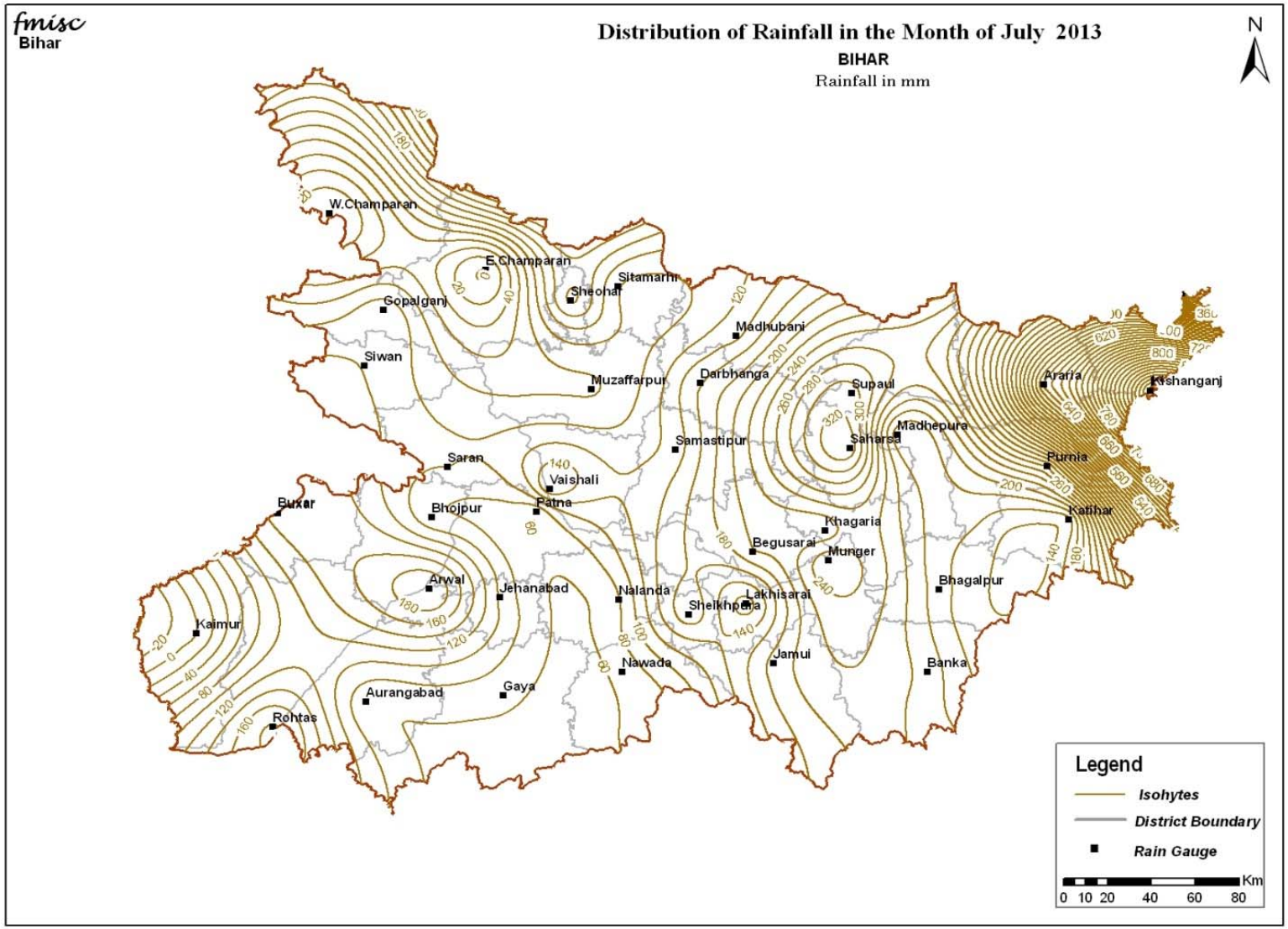
October 2013 (Map.No.5.1.7) The pattern of monsoon rains seems to have changed during October. There was widespread rainfall all over Bihar, compensating the deficiency in the earlier months. The rainfall had been fairly uniform and heavy in this month.

June 2013 to October 2013 (Map.No.5.1.8) The average rainfall during the 2013 monsoon was marginally deficient. Eastern part had shown good rainfall. Some districts like Sitamarhi Vaishali and Rohtas have shown dry spell.

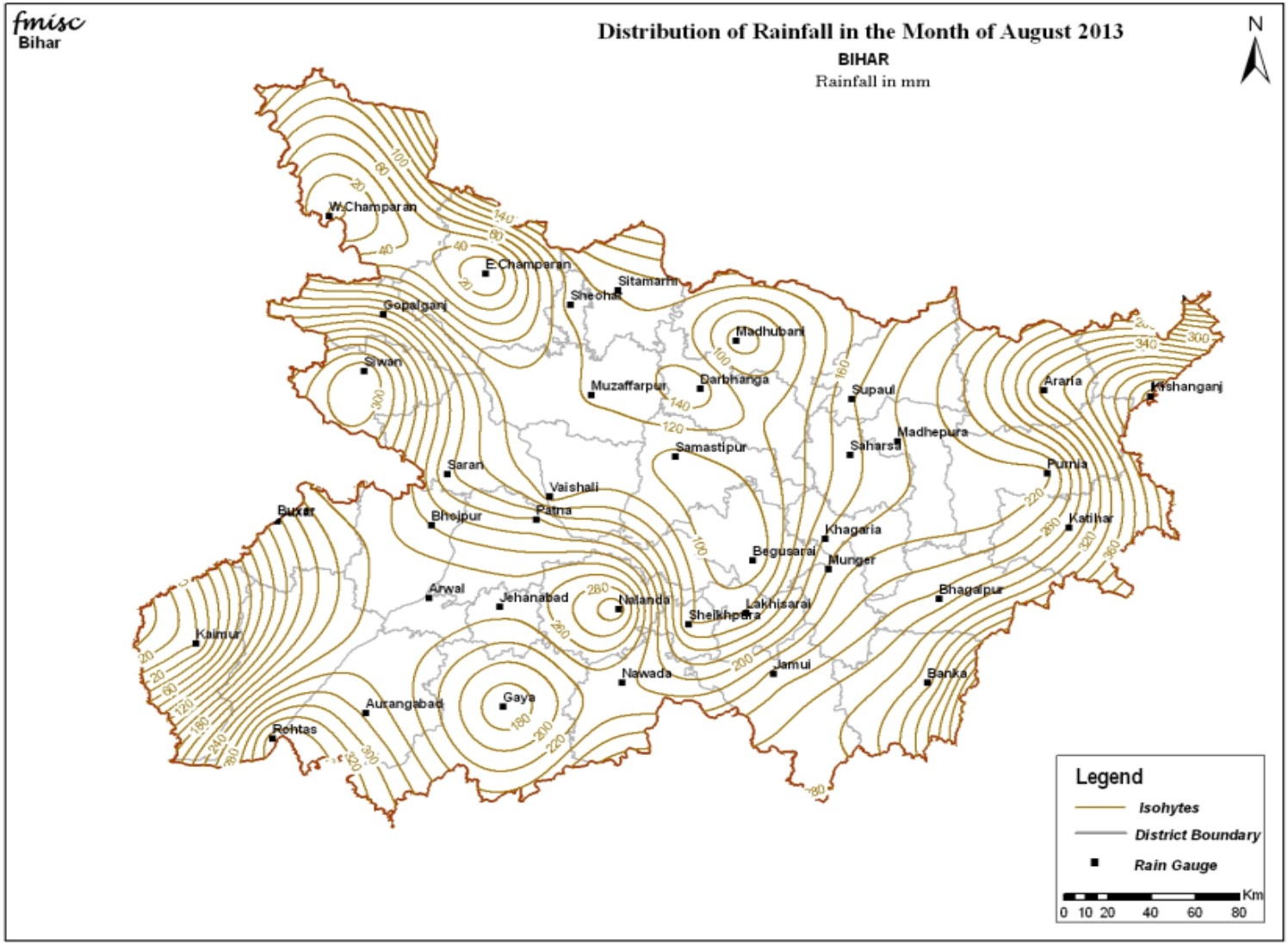
Map: 5.1.2


fmisc
Bihar
Distribution of Rainfall in the Month of June 2013
BIHAR
Rainfall in mm
N
W.Champaran
E.Champaran
Sitamarhi
Sheohar
Gopalganj
Madhubani
Siwan
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saharsa
Samastipur
Purnia
Saran
Vaishali
Patna
Bhojpur
Buxar
Katihar
Khagaria
Begusarai
Munger
Bhagalpur
Arwal
Jehanabad
Nalanda
Lakhisarai
Sheikhpura
Kaimur
Nawada
Jamui
Banka
Gaya
Aurangabad
Rohtas
Legend
Isohytes
District Boundary
Rain Gauge
Km
0 10 20 40 60 80

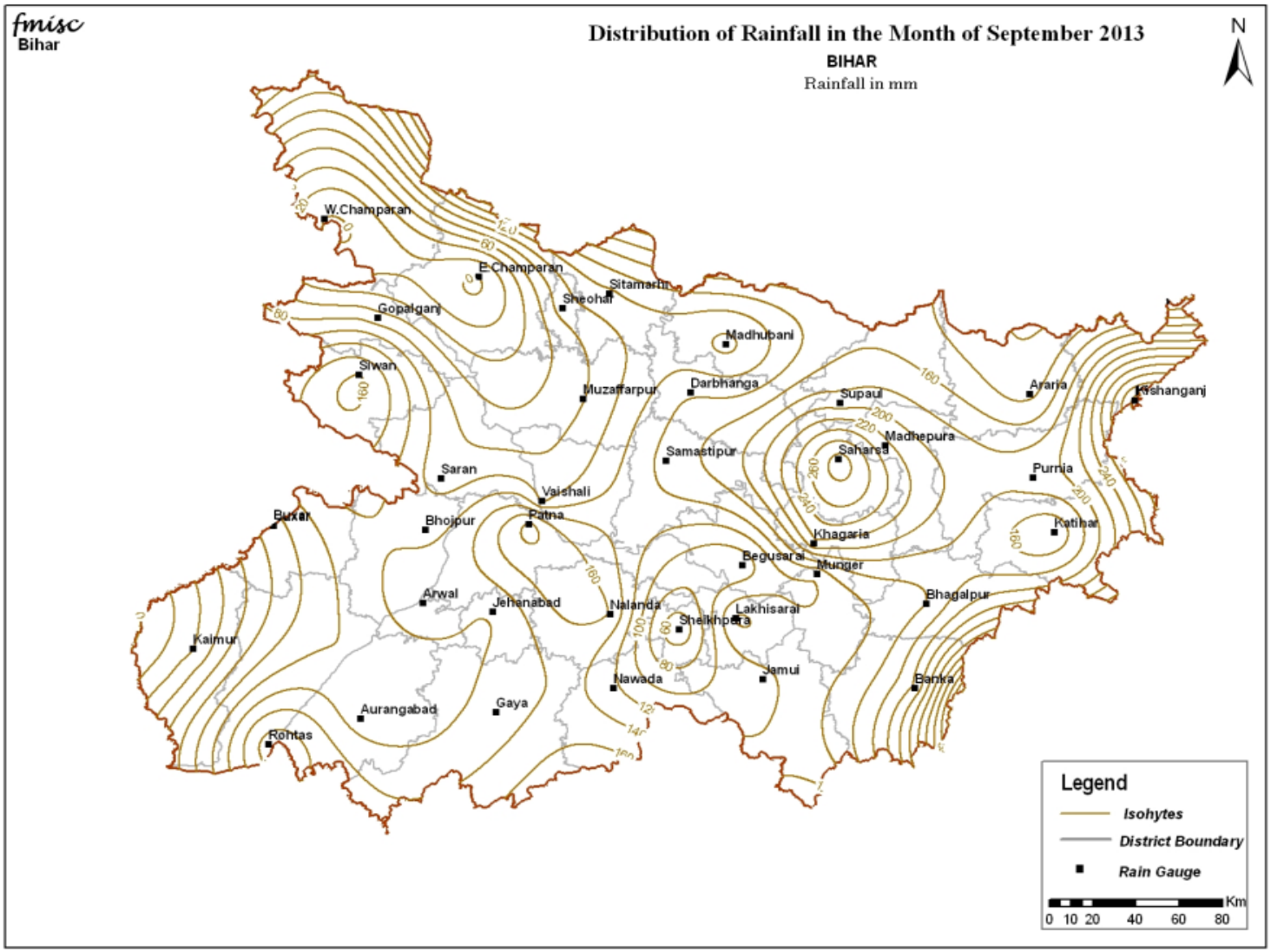
Map: 5.1.3


fmisc
Bihar
Distribution of Rainfall in the Month of July 2013
BIHAR
Rainfall in mm
N
W.Champaran
E.Champaran
Sitamarhi
Sheohar
Gopalganj
Madhubani
Siwan
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saharsa
Samastipur
Saran
Vaishali
Patna
Purnia
Katihar
Buxar
Bhojpur
Khagaria
Begusarai
Munger
Bhagalpur
Arwal
Jehanabad
Nalanda
Lakhisarai
Sheikhpura
Kaimur
Jamui
Banka
Nawada
Aurangabad
Gaya
Rohtas
Legend
Isohytes
District Boundary
Rain Gauge
Km
0 10 20 40 60 80

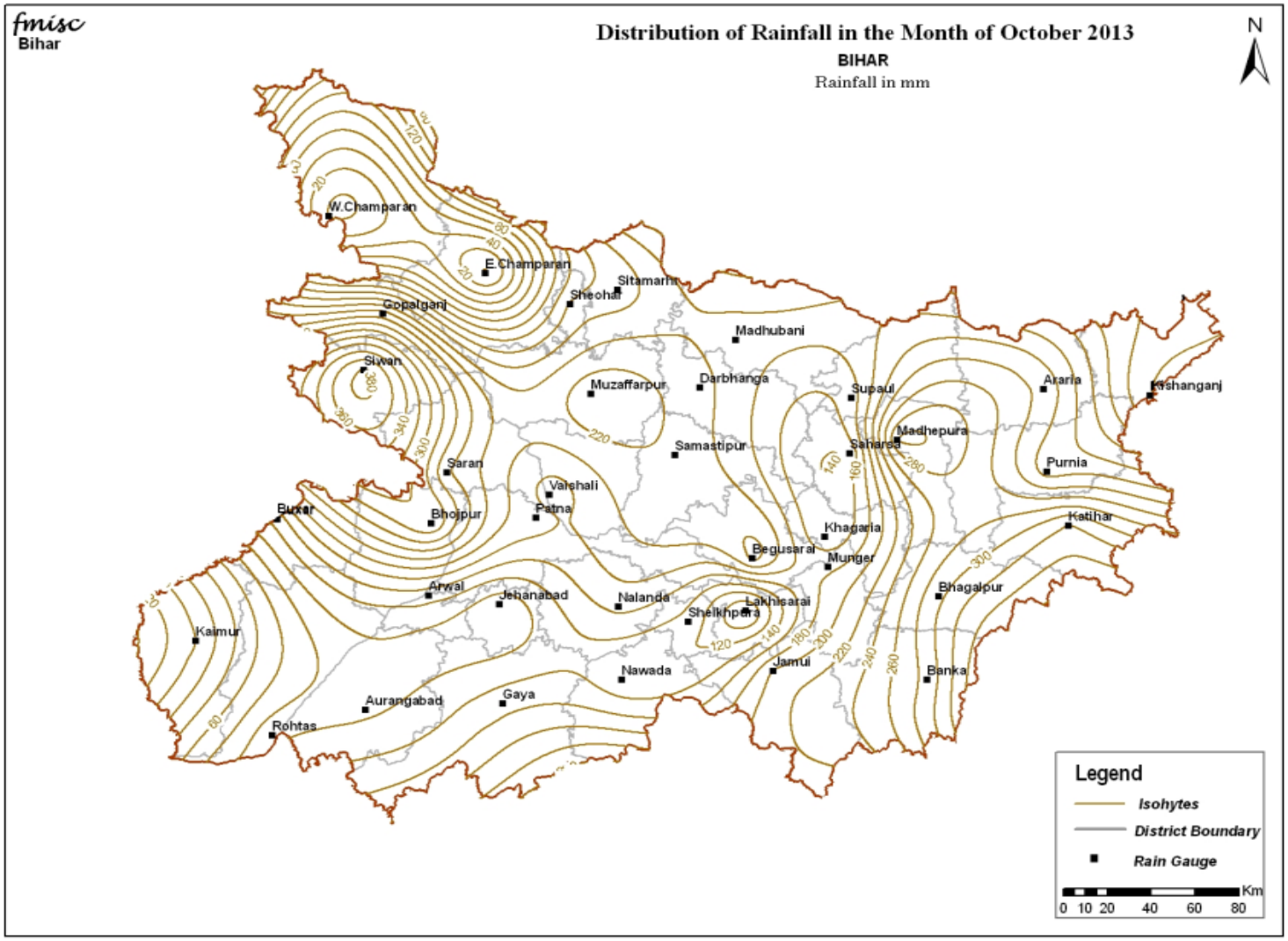
Map: 5.1.4


fmisc
Bihar
Distribution of Rainfall in the Month of August 2013
BIHAR
Rainfall in mm
N
W.Champaran
E.Champaran
Sitamarhi
Sheohar
Gopalganj
Madhubani
Siwan
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saharsa
Samastipur
Saran
Vaishali
Patna
Bhojpur
Buxar
Purnia
Katihar
Khagaria
Begusarai
Munger
Bhagalpur
Arwal
Jehanabad
Nalanda
Lakhisarai
Sheikhpura
Kaimur
Nawada
Jamui
Banka
Aurangabad
Gaya
Rohtas
Legend
Isohytes
District Boundary
Rain Gauge
Km
0 10 20 40 60 80

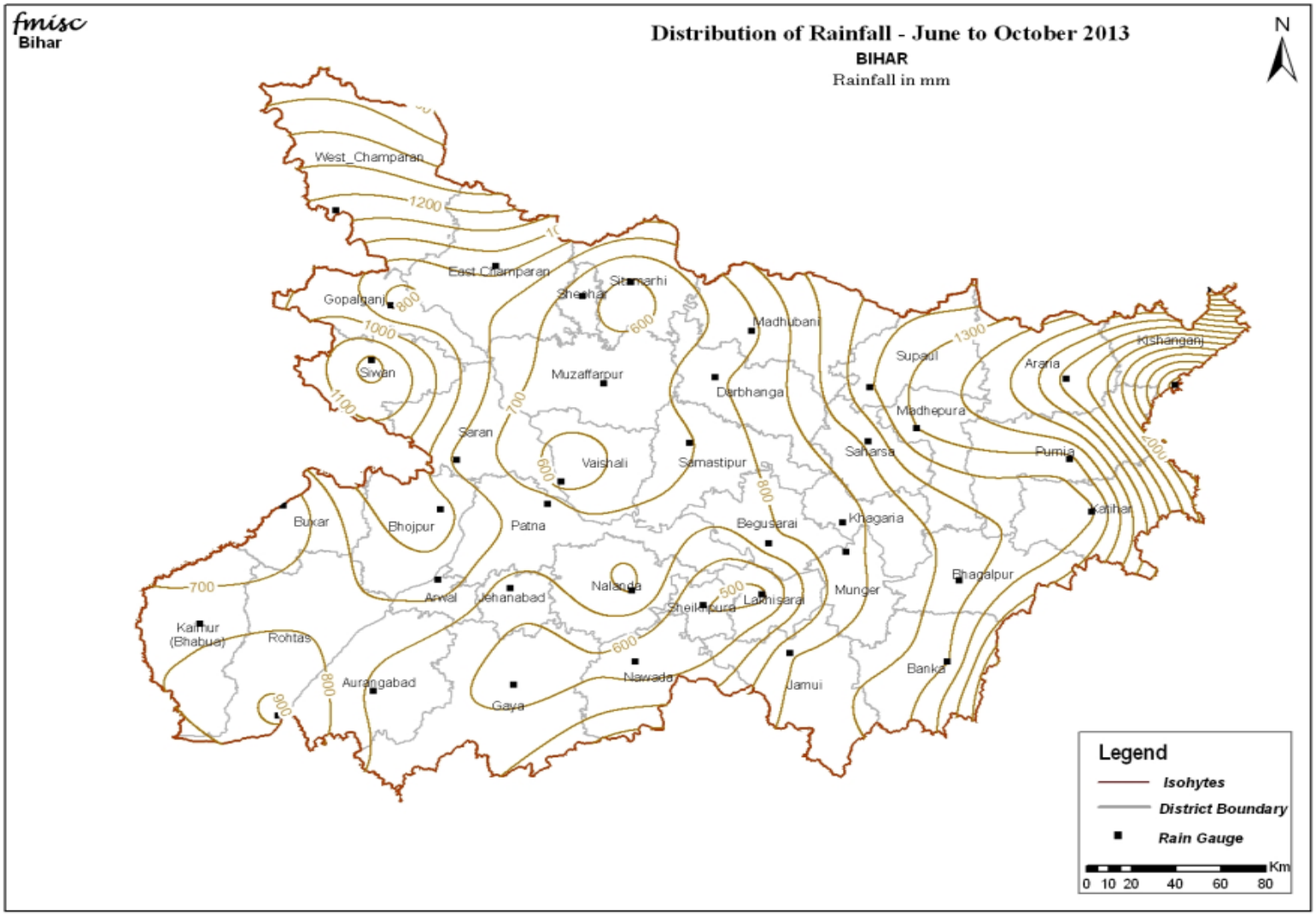
Map: 5.1.5


fmisc
Bihar
Distribution of Rainfall in the Month of September 2013
BIHAR
Rainfall in mm
N
W.Champaran
E.Champaran
Sitamarhi
Sheohar
Gopalganj
Madhubani
Siwan
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saharsa
Samastipur
Saran
Vaishali
Purnia
Buxar
Bhojpur
Patna
Katihar
Khagaria
Begusarai
Munger
Arwal
Jehanabad
Nalanda
Sheikhpura
Lakhisarai
Bhagalpur
Kaimur
Jamui
Nawada
Banka
Aurangabad
Gaya
Rohtas
Legend
Isohytes
District Boundary
Rain Gauge
Km
0 10 20 40 60 80

Map: 5.1.6


fmisc
Bihar
Distribution of Rainfall in the Month of October 2013
BIHAR
Rainfall in mm
N
W.Champaran
E.Champaran
Sitamarhi
Sheohar
Gopalganj
Madhubani
Siwan
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saharsa
Samastipur
Saran
Purnia
Vaishali
Buxar
Bhojpur
Patna
Katihar
Khagaria
Begusarai
Munger
Arwal
Jehanabad
Nalanda
Lakhisarai
Bhagalpur
Sheikhpura
Kaimur
Jamui
Nawada
Banka
Aurangabad
Gaya
Rohtas
Legend
Isohytes
District Boundary
Rain Gauge
Km
0 10 20 40 60 80

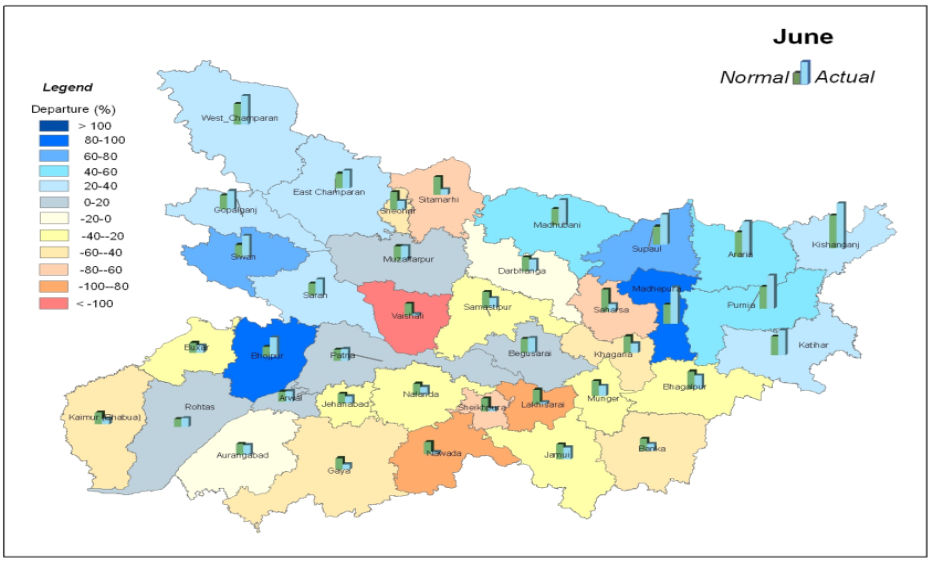
Map: 5.1.7


fmisc
Bihar
Distribution of Rainfall - June to October 2013
BIHAR
Rainfall in mm
N
West_Champaran
East Champaran
Sitamarhi
Sheohar
Gopalganj
Madhubani
Siwan
Muzaffarpur
Darbhanga
Supaul
Araria
Kishanganj
Madhepura
Saran
Vaishali
Samastipur
Saharsa
Purnia
Katihar
Buksar
Bhojpur
Patna
Begusarai
Khagaria
Bhagalpur
Nalanda
Arwal
Jehanabad
Sheikhpura
Lakhisarai
Munger
Kaimur (Bhabua)
Rohtas
Aurangabad
Gaya
Nawada
Jamui
Banka
1200
1100
1000
900
800
700
600
500
1300
Legend
Isohytes
District Boundary
Rain Gauge
Km
0 10 20 40 60 80

5.1.2 Actual Rainfall, Normal Rainfall and Percentage Departure.

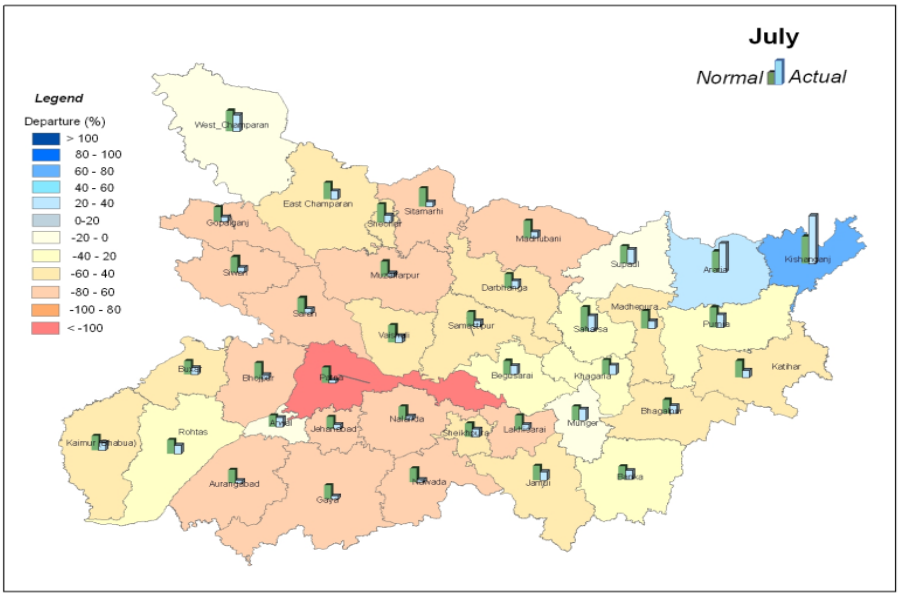
Map showing district wise actual and normal rainfall for all the 38 districts of Bihar are displayed below vide Map No.5.1.9 to 5.1.14. The maps also show percentage departure from normal rainfall for each month from June' 13 to October '13. Based on these data, end of season scenario cumulative actual & normal rainfall and percentage departure from June to Oct'13 is shown in map 5.1.14

Map 5.1.8 District wise Actual, Normal Rainfall and % Departure for June'13



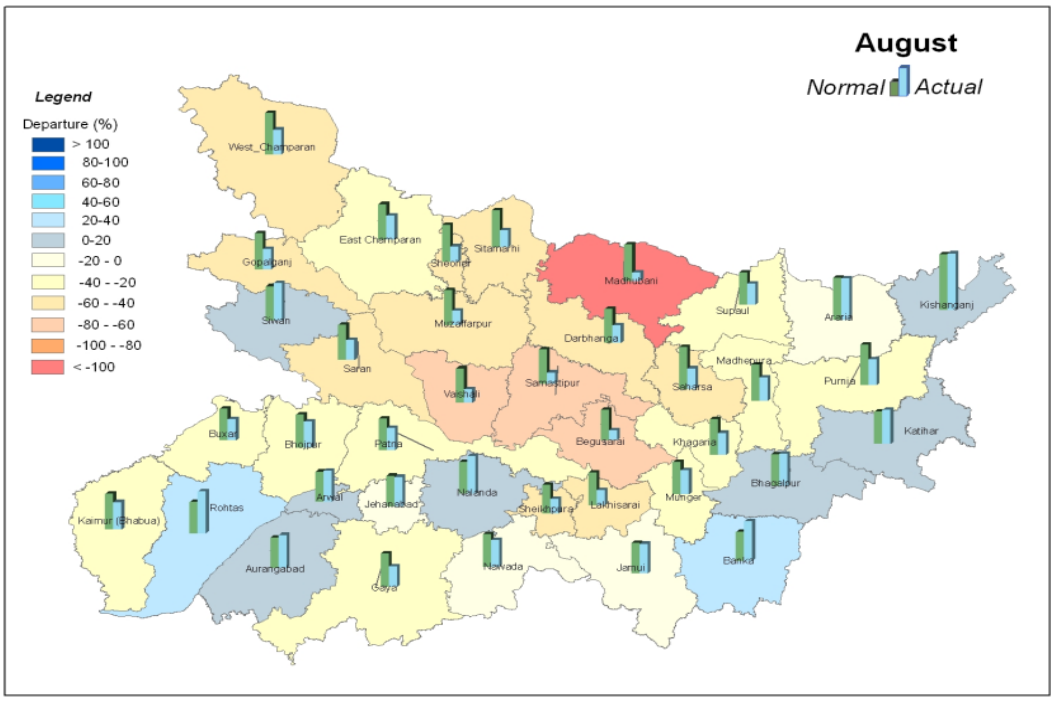
During June 2013 unlike last Season, the rainfall in Districts bordering Nepal had been above normal, southern districts were deficient in rain.

Map 5.1.9 District wise Actual, Normal Rainfall and % Departure for July'13



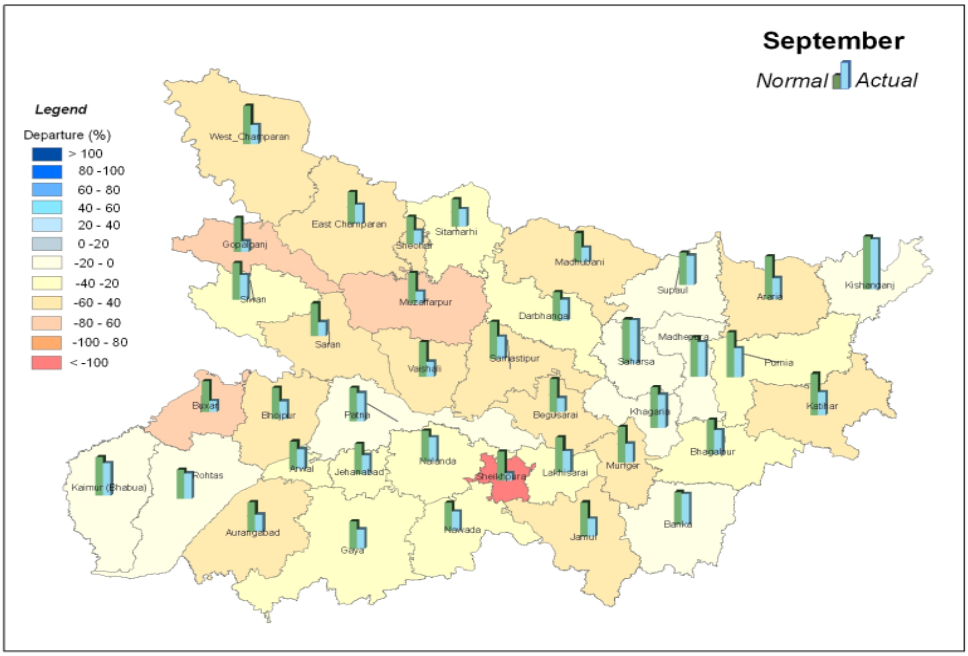
During July 2013, except districts in north east, the rainfall recorded had been deficient with southern portion being worst hit.

Map 1.1.10 District wise Actual, Normal Rainfall and % Departure for August'13



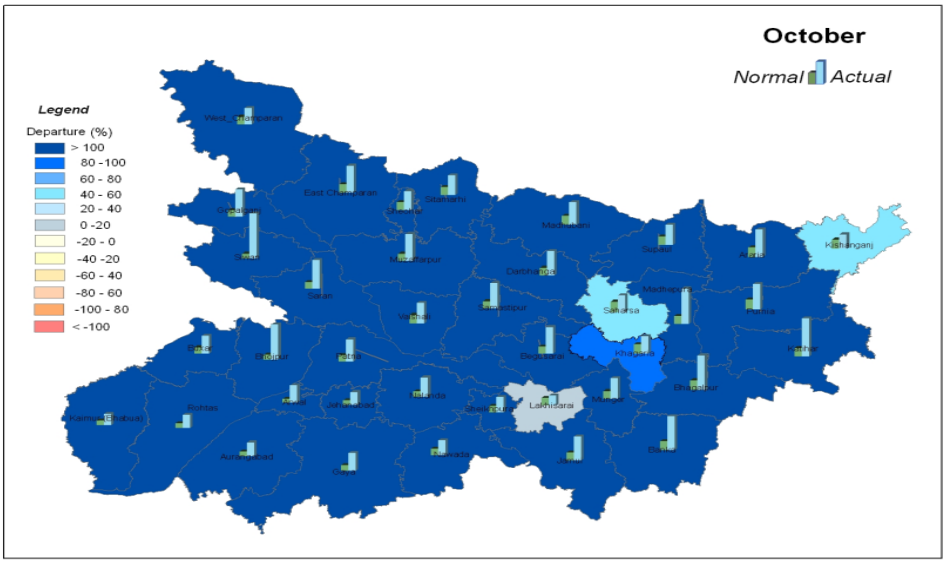
During August 2013, situation improved in south Bihar. However, north Bihar recorded marginal improvement.

Map 5.1.11 District wise Actual, Normal Rainfall and % Departure for September'13



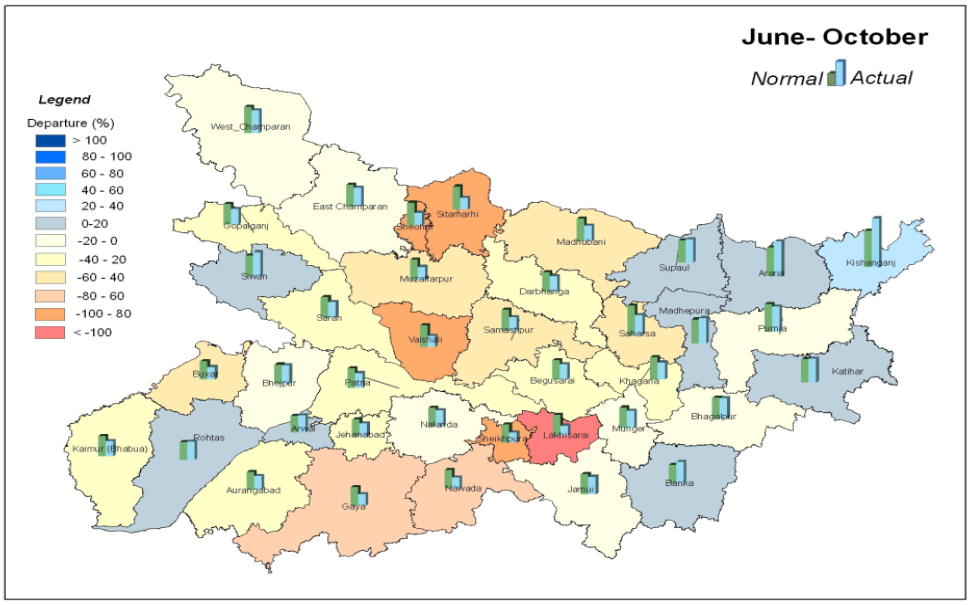
The deficient rain condition prevailed all over Bihar during September 2013.

Map 5.1.12 District wise actual, normal rainfall and % departure for October '13



A clear shift was observed during October 2013 which recorded high departure from the normal values of rainfall. Which shows an obvious shift in rainfall pattern which now lasted till October.

Map 5.1.13 District wise End of Season Scenario of Rainfall (June'13 to October'13)



The overall picture of rainfall in Bihar can be termed as fair as the departure from the normal are not alarming. Eastern portion rainfall has been normal, western portion had also showed good rainfall. As usual southern portion was deficient in rain.

5.2 Effect of Rainfall in Nepal on the river-stages in Bihar

The catchment area of the rivers in North Bihar primarily lie in Nepal. To better understand the effect of rainfall in upper catchment on the river gauge close to the Indo-Nepal border for the river basin of FMISC AOI at Lalbegiaghat on Burhi Gandak, Sonakhan on Bagmati, Jainagar on Kamla and Basua on Kosi was considered. For each basin graph of daily river water levels vis-a-vis daily average rainfall of the locations mentioned below are shown in Fig. 5.2.1 to 5.2.4.

Name of basin	**Part under consideration**	**Rain-gauge stations considered for averaging**
1	2	3
BurhiGandak	Up to Lalbegiaghat	Simara
Bagmati	Up to Sonakhan	Kathmandu, Godavari, Karmaiya, Bhorleni, Garuda
Kamla	Up to Jainagar	Sindhuligadhi
Kosi	Up to Basua	Okhaldunga, Chatra, Mulghat, Taplejung, Dhankutta, Jiri, Pachuwarghat,Tumlingtar

Since the rainfall stations are less in number, the correlation between average rainfall and water level of different rivers may not be truly matching because of temporal and spatial variability.

Number of rain-gauge stations is too less to account for the aerial variability of rainfall. Therefore, instead of using rigorous methods, simple arithmetic mean has been used for averaging the rainfall.

Some of the data of water levels as well as rainfall are missing which is evident from the water level plot. However, the rainfall data which is shown as bar chart seem to be continuous.

5.2.1 Conclusions:

There exists some correlation between the rainfall in the basin and the water level at the outlet. As the rainfall magnitude rises, so the water level at the outlet will also rise with a time lag. The time lag between the rainfall and the peak flow at the outlet can be found out by the two time series of rainfall and water levels. An approximate estimate can also be made through synthetic unit hydrograph.

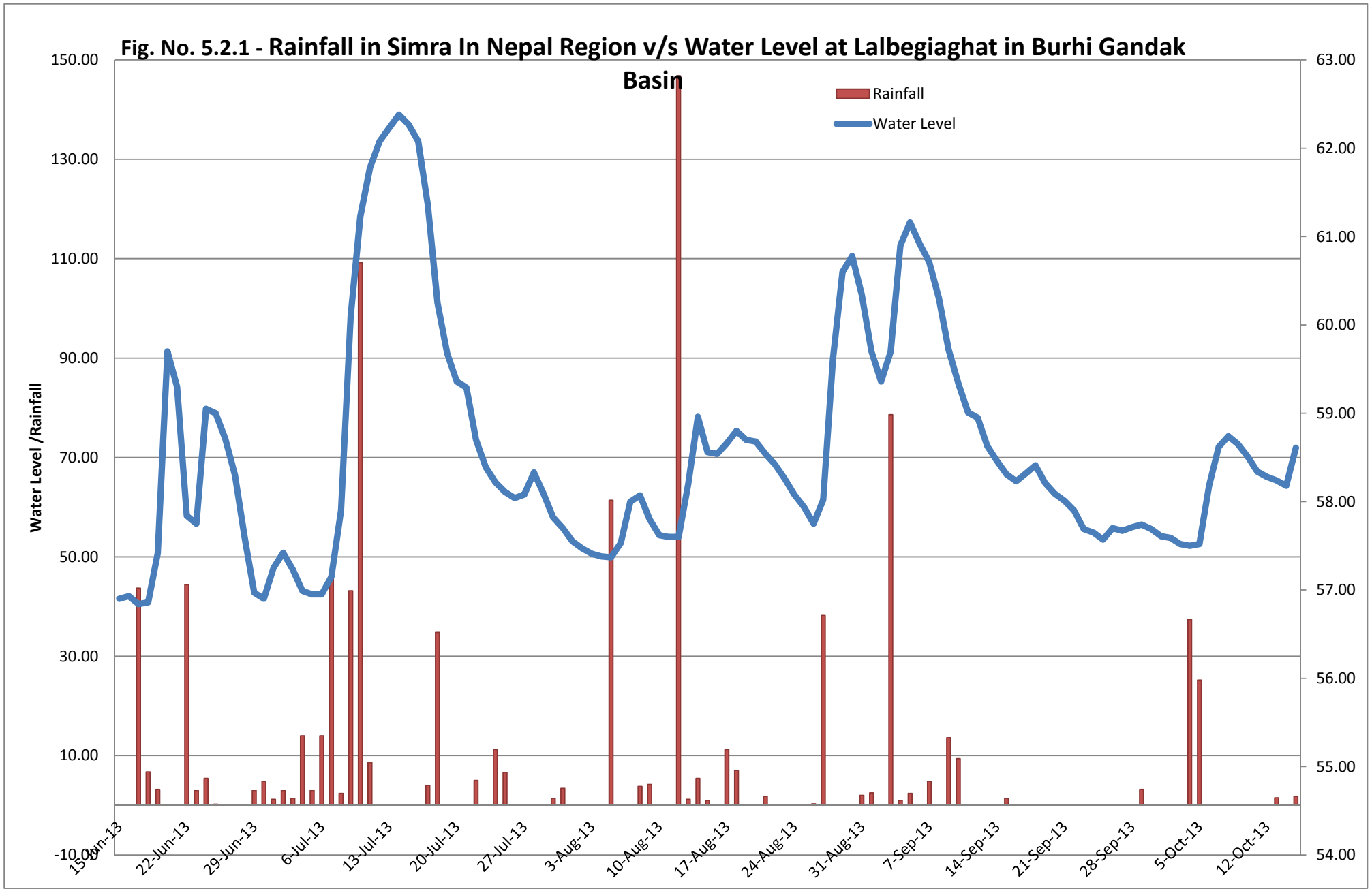


Fig. No. 5.2.1 - Rainfall in Simra In Nepal Region v/s Water Level at Lalbegiaghat in Burhi Gandak Basin
Rainfall
Water Level
Water Level /Rainfall
150.00
130.00
110.00
90.00
70.00
50.00
30.00
10.00
-10.00
63.00
62.00
61.00
60.00
59.00
58.00
57.00
56.00
55.00
54.00
15-Jun-13
22-Jun-13
29-Jun-13
6-Jul-13
13-Jul-13
20-Jul-13
27-Jul-13
3-Aug-13
10-Aug-13
17-Aug-13
24-Aug-13
31-Aug-13
7-Sep-13
14-Sep-13
21-Sep-13
28-Sep-13
5-Oct-13
12-Oct-13

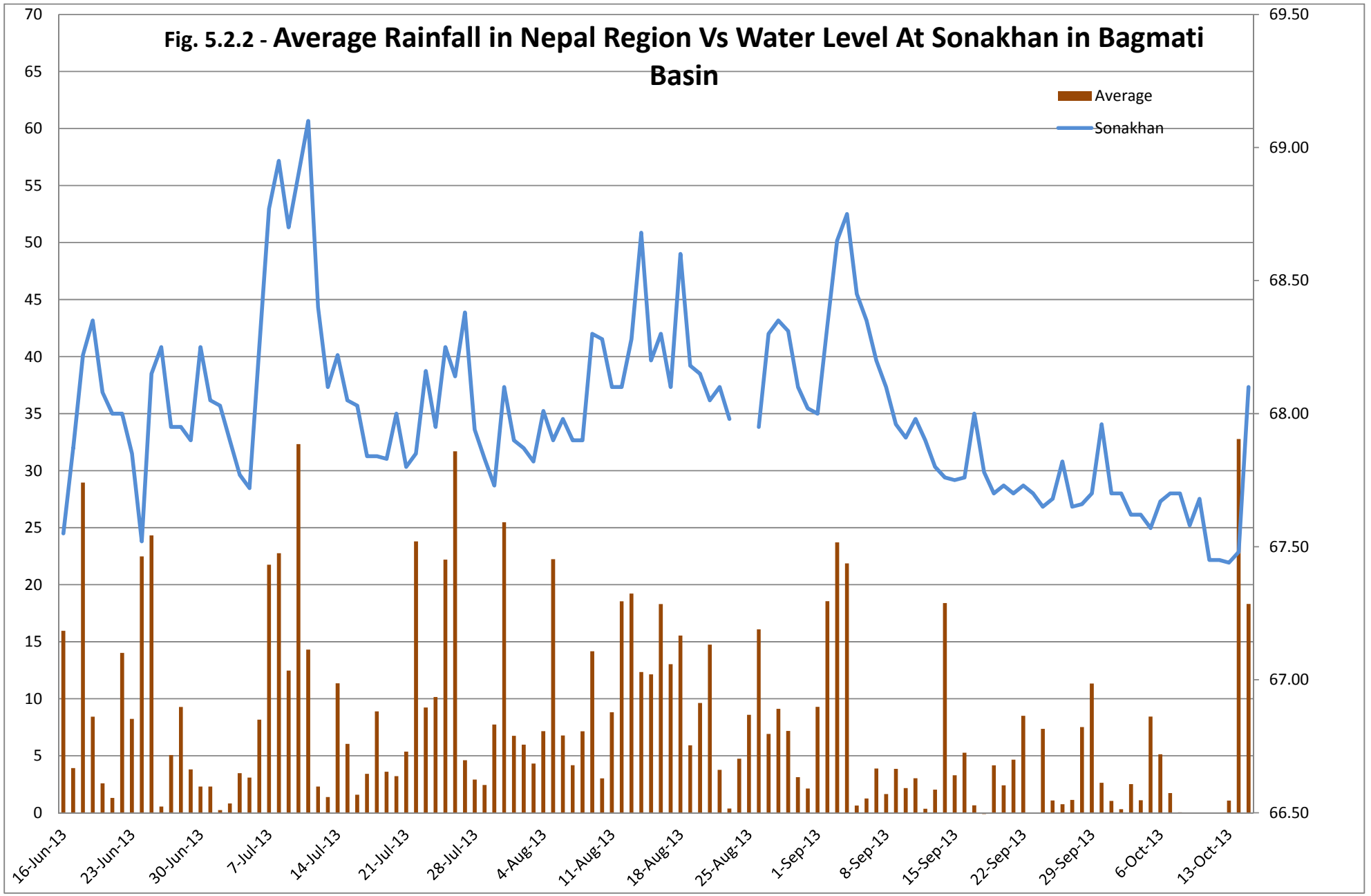
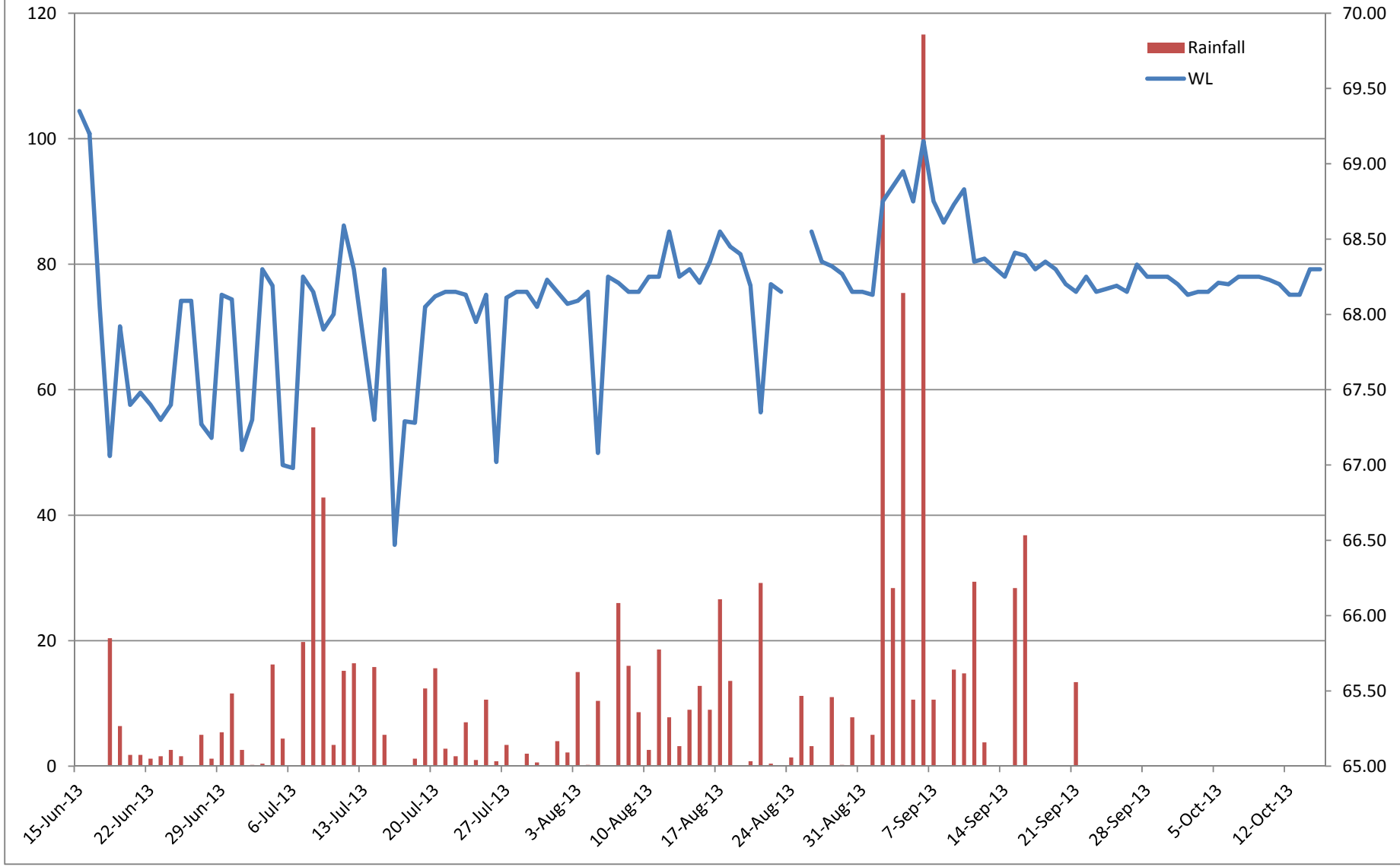


Fig. 5.2.2 - Average Rainfall in Nepal Region Vs Water Level At Sonakhan in Bagmati Basin
Average
Sonakhan
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
69.50
69.00
68.50
68.00
67.50
67.00
66.50
16-Jun-13
23-Jun-13
30-Jun-13
7-Jul-13
14-Jul-13
21-Jul-13
28-Jul-13
4-Aug-13
11-Aug-13
18-Aug-13
25-Aug-13
1-Sep-13
8-Sep-13
15-Sep-13
22-Sep-13
29-Sep-13
6-Oct-13
13-Oct-13

Fig. 5.2.3 - Average Rainfall in Nepal Region Vs Water Level At Jainagar in Kamla Basin



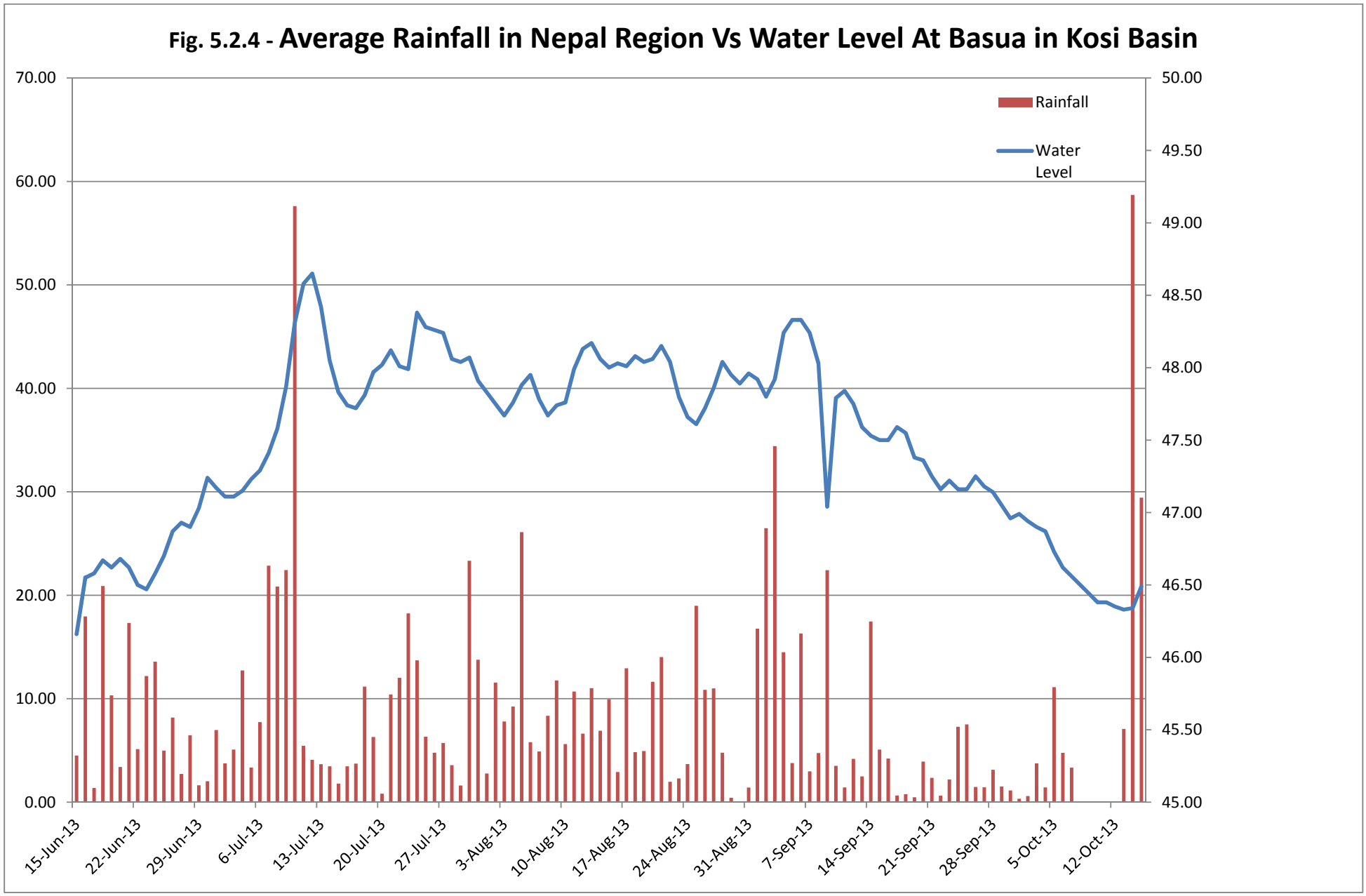


Fig. 5.2.4 - Average Rainfall in Nepal Region Vs Water Level At Basua in Kosi Basin
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
50.00
49.50
49.00
48.50
48.00
47.50
47.00
46.50
46.00
45.50
45.00
Rainfall
Water Level
15-Jun-13
22-Jun-13
29-Jun-13
6-Jul-13
13-Jul-13
20-Jul-13
27-Jul-13
3-Aug-13
10-Aug-13
17-Aug-13
24-Aug-13
31-Aug-13
7-Sep-13
14-Sep-13
21-Sep-13
28-Sep-13
5-Oct-13
12-Oct-13

5.3 Rainfall Forecast:

The Indian Meteorological Department (IMD), New Delhi has been providing rainfall forecast data covering a vast areas in Nepal and India which entirely covers the focus area of Flood Management Improvement Support Center (FMISC).

The forecast are received by FMISC under the Memorandum of Understanding (MoU) between FMISC, Bihar and IMD, New Delhi. The forecast are done using the Weather Research and Forecasting (WRF) model, which is a next generation meso scale numerical weather prediction system designed to serve both operational forecasting as well as atmospheric research needs.

WRF model rainfall forecast, from IMD Delhi is for 9km x 9km resolution. Efforts are on to make it 3km x 3km resolution which will increase the total number of grids covering the area from 1386 to 5544. FMISC Bihar receives rainfall forecast via e-mail on daily basis for 24 hours, 48 Hours and 72 Hours. Consequently. FMISC issues daily flood information bulletin for the benefit of various stakeholders.

A study has been done by FMISC to compare the model forecast and the recorded average rainfall by evaluating the correlation coefficients for observed and model-predicted values for two catchments in Kosi and two in Bagmati namely Basua and Taplejung in Kosi basin and Benibad and Kathmandu in Baghmati basin. The average of the forecasted values at stations lying nearby the observation stations have been taken for evaluation. The forecast stations taken for study are shown in Map 5.3.1 and Table 5.3.1

For this purpose partial duration series for observed rainfall over 15 mm were chosen and correlation coefficient were calculated. Except at Basua where correlation coefficient were found to be satisfactory e.g 0.74 for 24 Hours forecast, 0.45 for 48 Hours forecast and 0.68 for 72 Hours, and at Kathmandu, 0.69 for 48 Hours, all other places have shown very poor correlation. A summary of Correlation Coefficient between observed vs forecasted rainfall for these stations are tabulated in Table 5.3.2. Graphs showing average forecasted rainfall vs observed rainfall are also presented at fig 5.3.1 to 5.3.4.

To obtain better correlation, the data reliability has to be checked and more observations will be required. A better network of automatic rain gauge station has to be designed and executed.

5.3.1. Conclusions

From the above discussion we can conclude that Weather Research and Forecasting (WRF) model need further improvement as the correlation coefficient between forecasted and measured (actual) rainfall shows a very low value in most of the cases.

In order to improve the forecast, suggestions have come from various sources. All the suggestions seems to be based on thumb rules. For realistic solution use of sound statistical methods have to be applied.

It is expected that with the introduction of 3km x 3km resolution grid, the forecast will improve. The rain gauge network has also to be improved on scientific basis. The available data also lacks consistency. Hence, before using the available data, it should be subjected to consistency test.

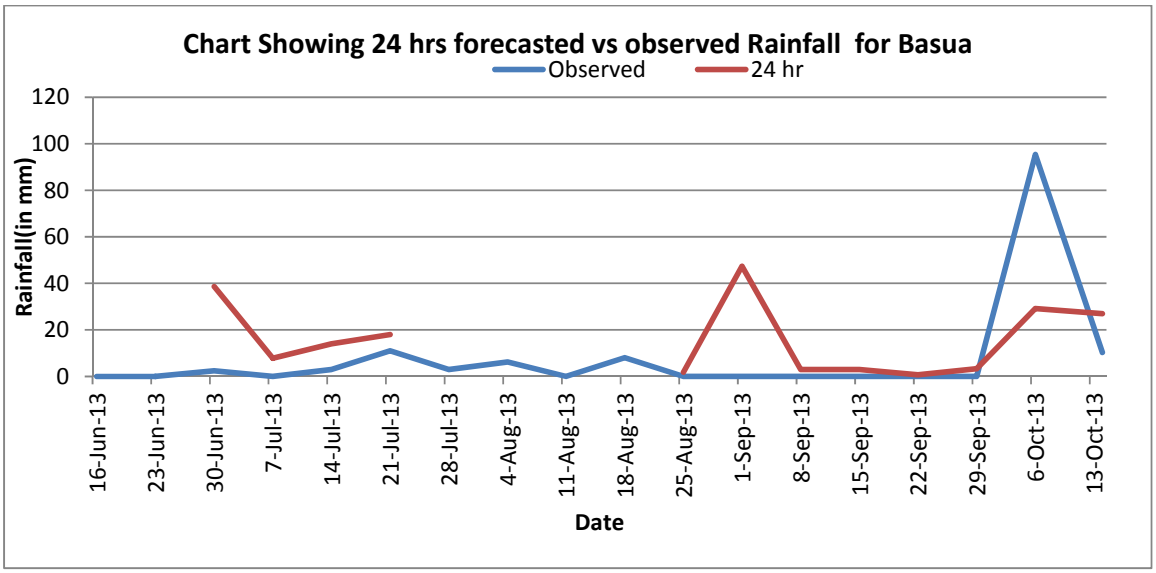
Table 5.3.2 - Summary of Correlation coefficient between observed Vs. forecasted rainfall in Kosi and Bagmati basin

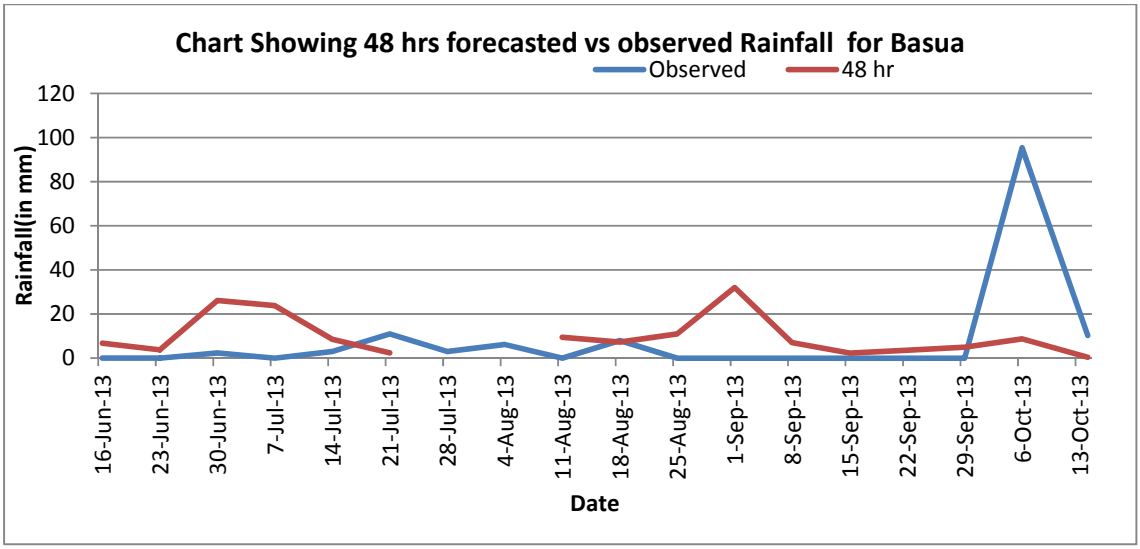
Correlation Coeff. $r = \frac{1}{n} \sum \left(\frac{x - \bar{x}}{S_x} \right) \left(\frac{y - \bar{y}}{S_y} \right)$

Station / Basin	Period	Correlation coefficient
Basua / Kosi	**24 Hr**	**0.74**
	48 Hr	**0.447**
	72 Hr	**0.68**
Taplejung/ Kosi	**24 Hr**	**0.38**
	48 Hr	**0.30**
	72 Hr	**-0.19**
Kathmandu/ Bagmati	**24 Hr**	**-0.032**
	48 Hr	**0.69**
	72 Hr	**0.12**
Banibad /Bagmati	**24 Hr**	**0.1134**
	48 Hr	**-0.15**
	72 Hr	**-0.145**

Abstract of correlation coefficient

Forecast Interval	Kosi Basin		Bagmati Basin	
	Basua	**Taplejung**	**Kathmandu**	**Banibad**
24 Hr	0.74	0.38	-0.032	0.1134
48 Hr	0.447	0.30	0.69	-0.15
72 Hr	0.68	-0.19	0.12	-0.145





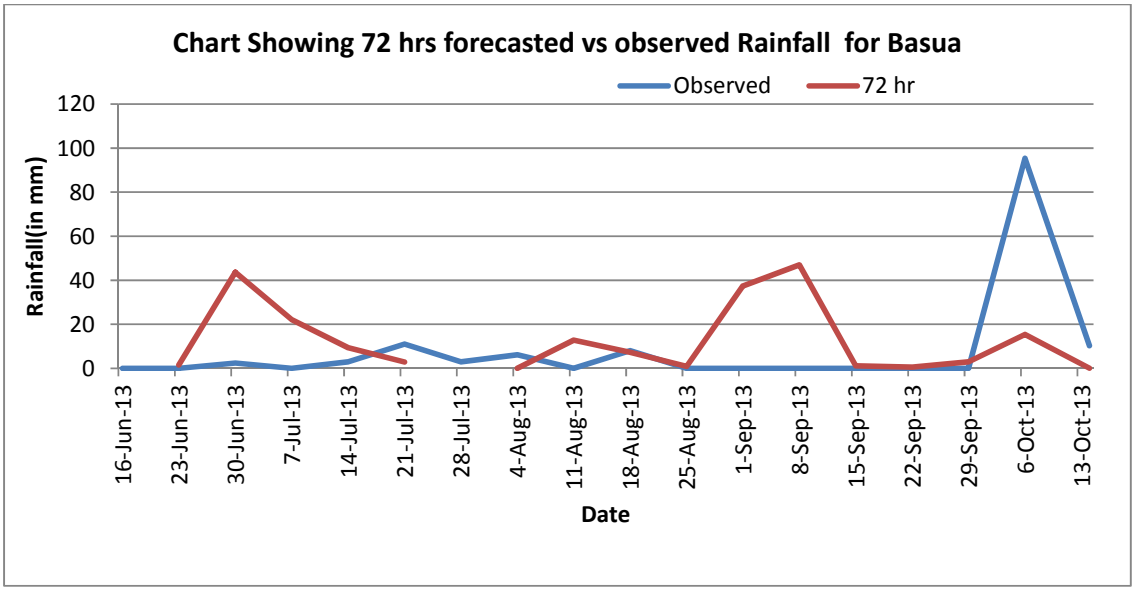
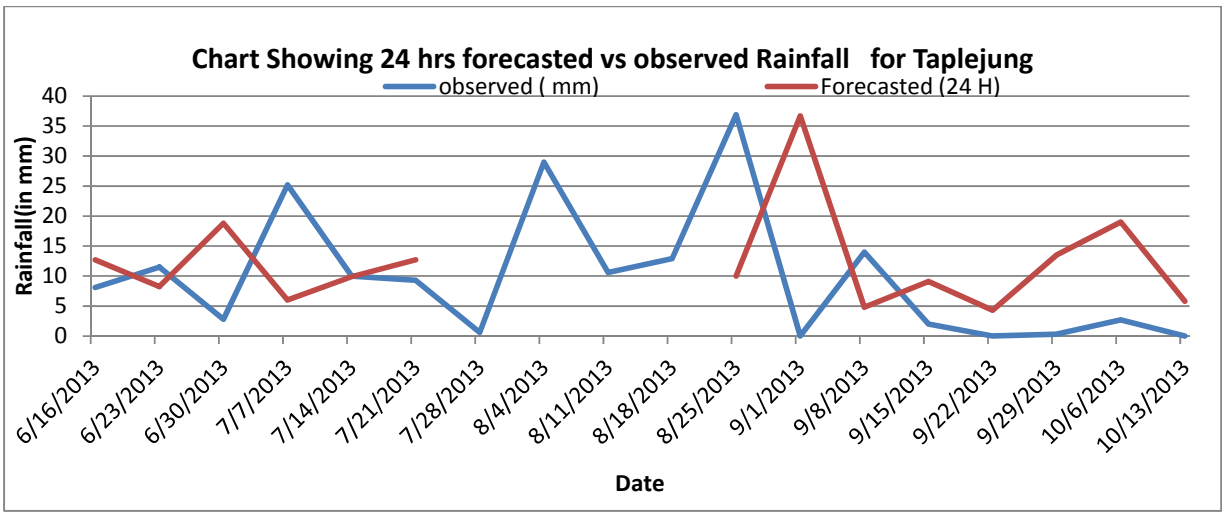
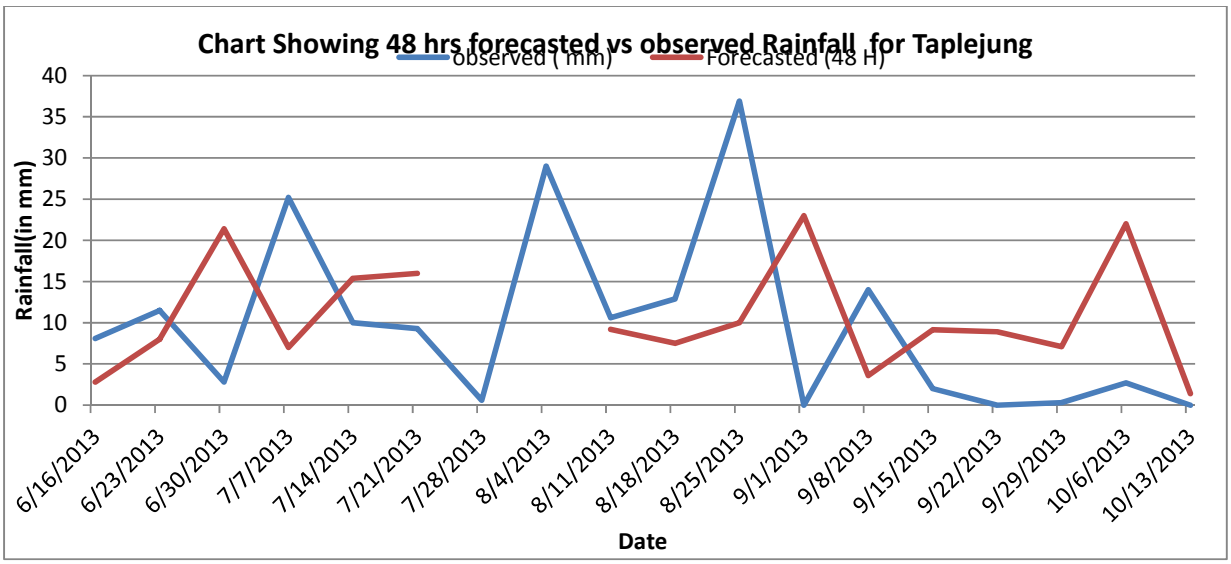


Fig. 5.3.1 – Average Forecasted Rainfall vs Observed Rainfall at Basua (Kosi Basin)





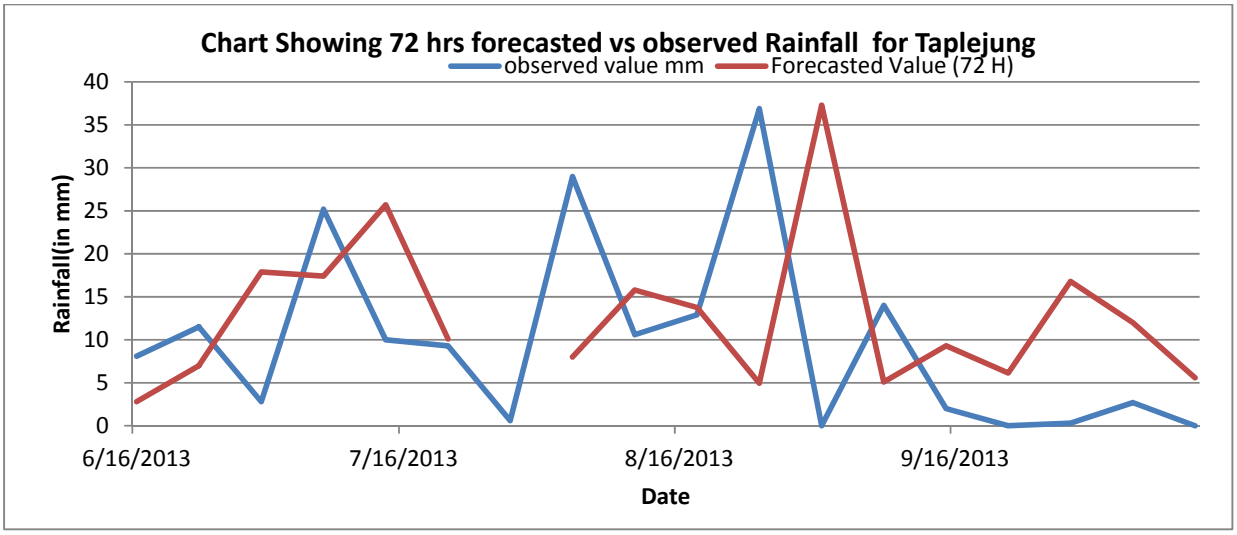
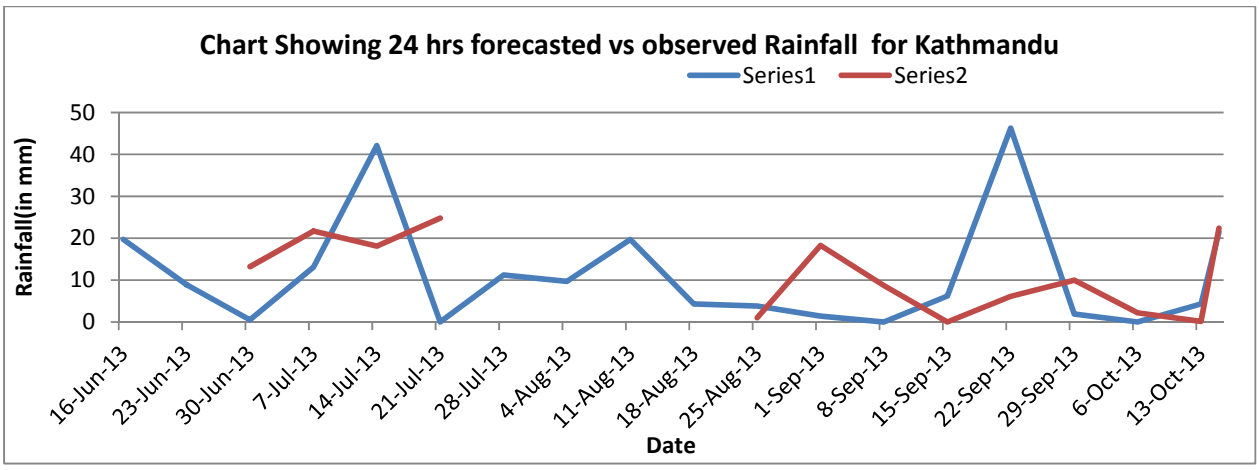
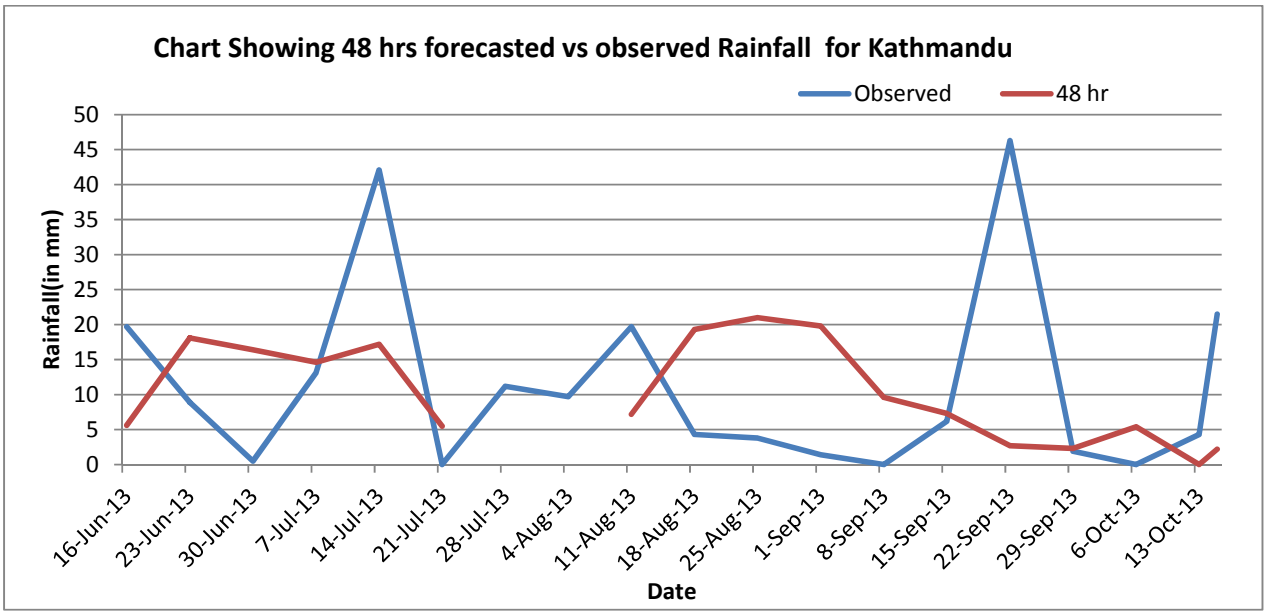


Fig 5.3.2 - Average Forecasted Rainfall vs Observed Rainfall at Taplejung (Kosi Basin)





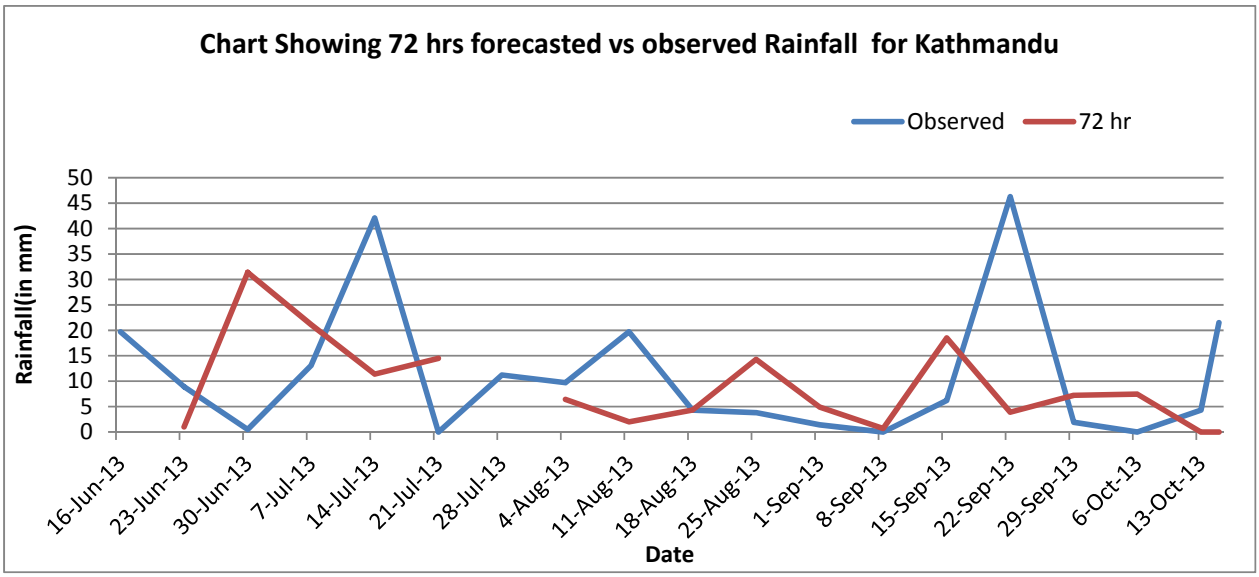
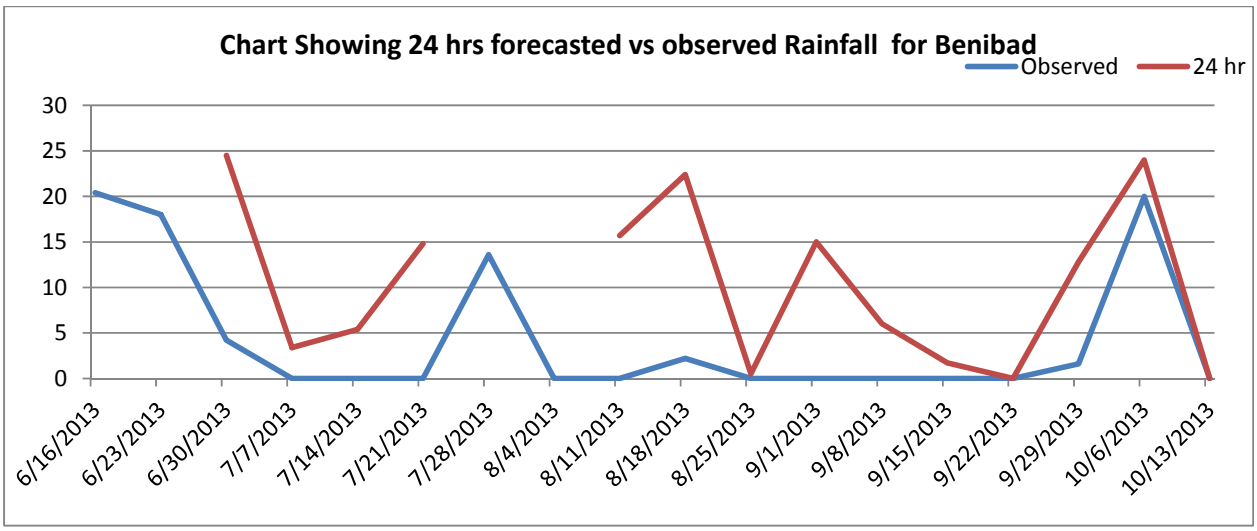
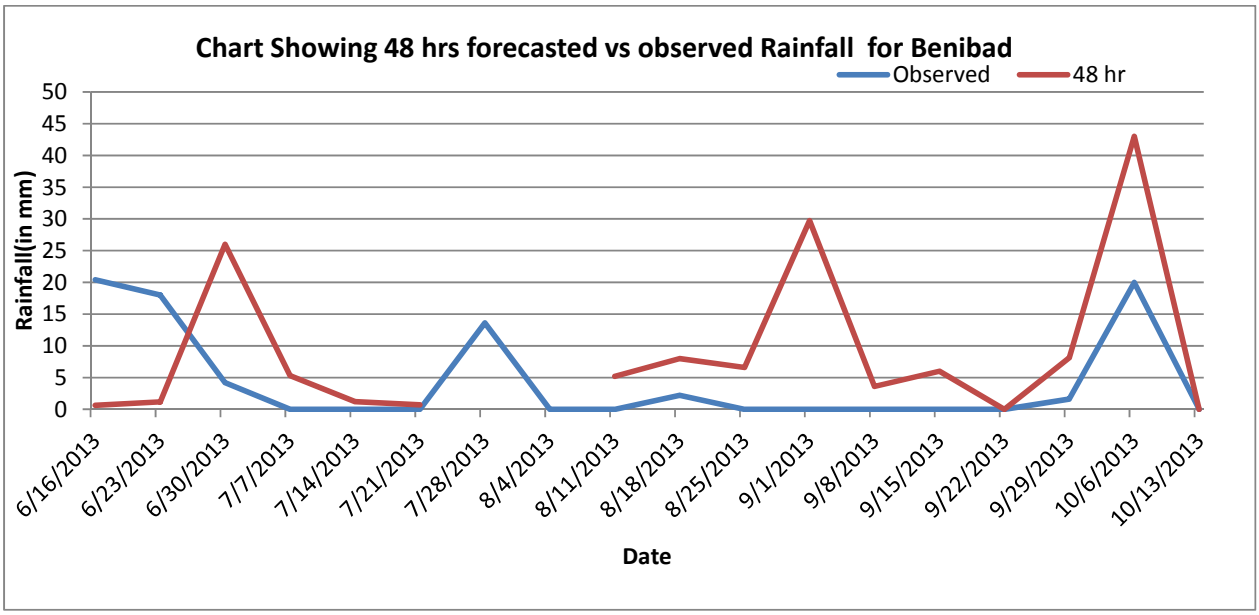


Fig 5.3.3 - Average Forecasted Rainfall vs Observed Rainfall at Kathmandu (Bagmati Basin)





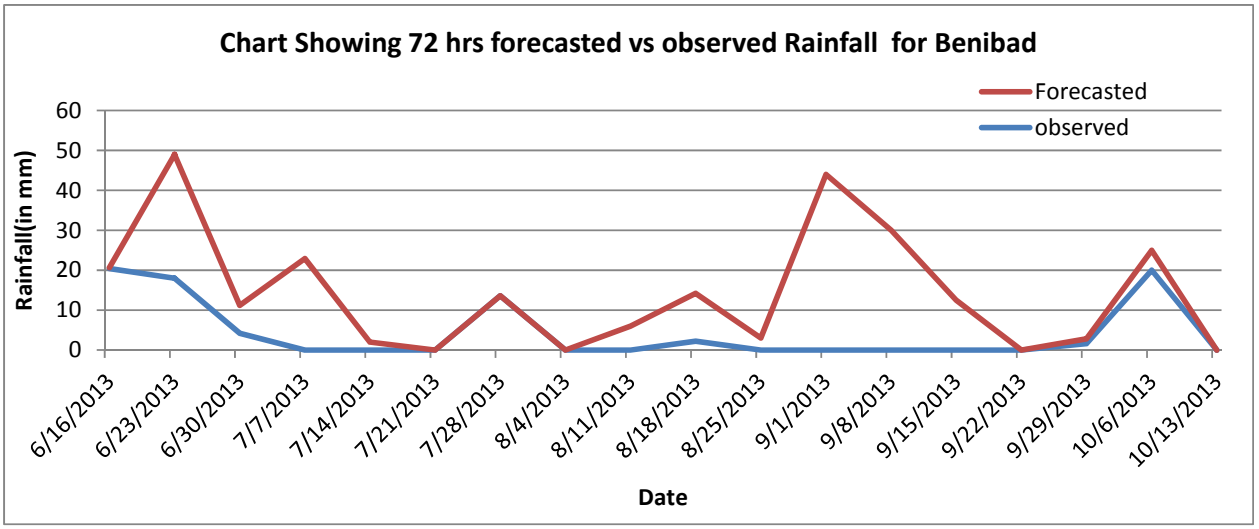
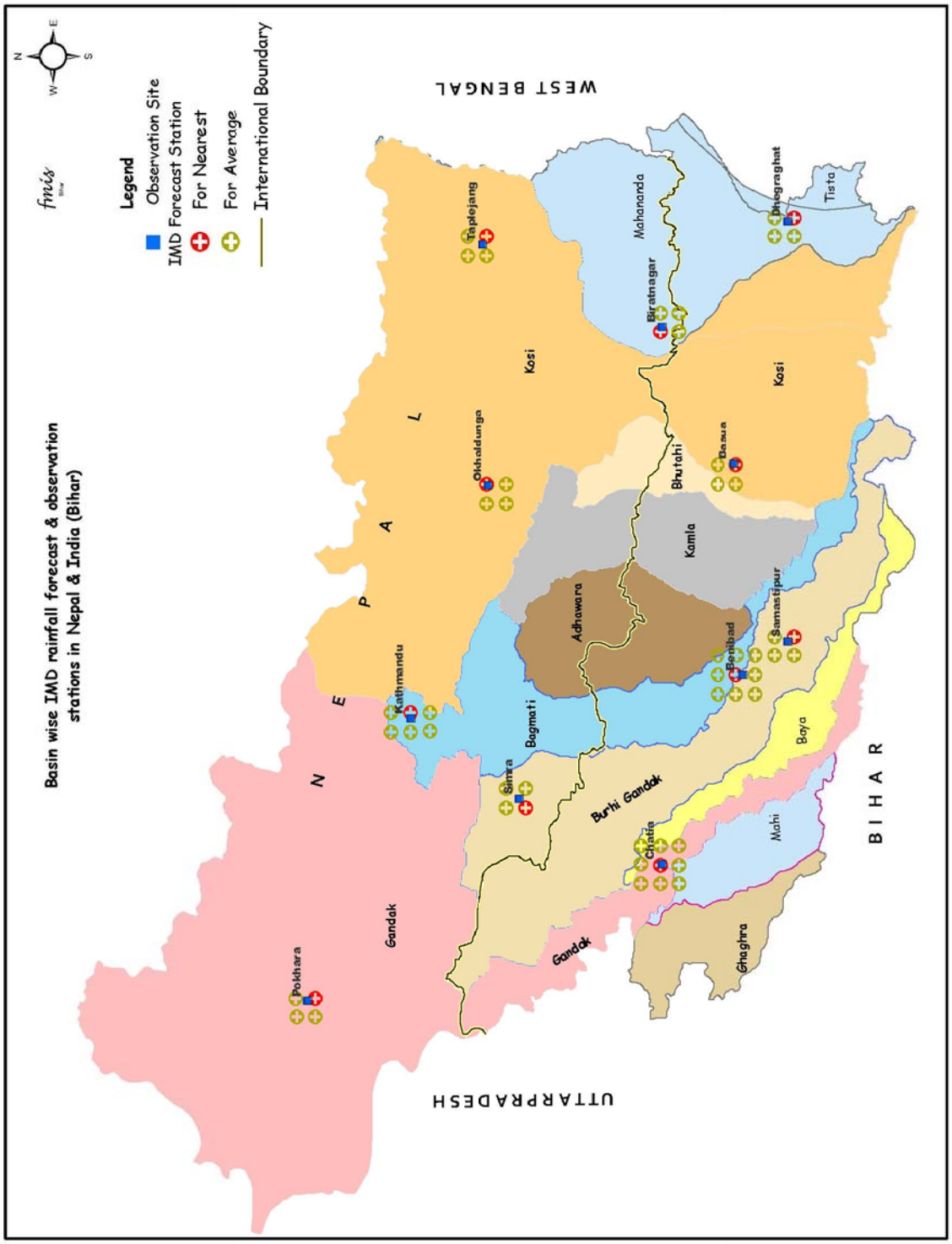


Fig 5.3.4 - Average Forecasted Rainfall vs Observed Rainfall at Benibad (Bagmati Basin)



Map 5.3.5 Basinwise IMD rainfall forecast stations and observation stations in Nepal and India (Bihar)

Table 5.3.1 : Names of Stations taken for comparison with WRF model forecast

N	Name of Basin	Region	Name of Station	Position	WRF model Station Name	Position	Forecast stations for av
1	Gandak	Nepal	Pokhara	84.00E 28.2N	F-659	84.015E 28.16N	F- 616, 615, 660, 659
		India (Bihar)	Chatia	84.66E 26.48N	F-949	84.62E 26.48N	F-906, 905, 904, 950, 94 992
2.	Burhi-Gandak	Nepal	Simra	84.98E 27.17N	F-1088	84.93E 27.14N	F-1089, 1088, 1133, 113
		India (Bihar)	Samastipur	85.74E 25.86N	F-1470	85.76E 25.83N	F-1427,1426, 1471, 147
3.	Bagmati	Nepal	Kathmandu	85.37E 27.7N	F-1314	85.4E 27.69N	F-1271, 1270, 1269, 131
		India (Bihar)	Benibad	85.58E 26.08N	F-1385	85.58E 26.11N	F-1342, 1341, 1340, 138 1430, 1429, 1428
4.	Kosi	Nepal	Taplejung	87.67E 27.35N	F-2410	87.70E 27.32N	F-2367, 2366, 2411, 241
		Nepal	Okhaldunga	86.5E 27.32N	F-1838	86.50E 27.32N	F- 1794, 1793, 1838, 18
		India (Bihar)	Basua	86.60E 26.12N	F-1869	86.6E 26.11N	F-1826, 1825, 1870, 186
5.	Mahananda	Nepal	Biratnagar	87.27E 26.48N	F-2181	87.24E 26.48N	F- 2181, 2180, 2225, 22
		India (Bihar)	Dhengraghat	87.78E 25.86N	F-2438	87.8E 25.83N	F- 2395, 2394, 2439, 24

6.0 Objectives and Features of Bihar FMIS Phase-I and Phase-II (TF 096841)

6.1 Aims and Objectives

The Government of Bihar has identified improvement of flood control as a priority area for World Bank engagement in the State. The World Bank – Government of Bihar Partnership Matrix (2006) prioritizes the improvement of the institutional capacity for delivering better flood management and drainage services, as a key action for accelerating agriculture productivity in north Bihar. The **Flood Management Information System (FMIS**) now **Flood Management Improvement Support (FMIS)**, identified for entry-level and short-term bank engagement in Bihar, is designed to generate and disseminate timely and customized information to move the sector agencies from disaster response to improved disaster preparedness and to effectively support flood control and management in the flood prone areas of the State of Bihar. Improved flood management that will protect the poorest farmers and tribal groups located in the low value lands in the flood plains, is also in line with the Bank/DFID partnership policy of extending Bank's support to state reforms that could lead to lasting poverty reduction.

The development of FMIS is planned in four stages: Flood hazard characterization & emergency response; improved flood preparedness and community participation; Flood hazard mitigation**;** and Integrated flood management. The technical improvements in flood forecasting, inundation modeling and warning, and embankment management are also coupled with expanded institutional and community linkages and expanding geographic coverage (from the most flood-prone 11 districts in north Bihar in the first stage to the whole flood prone area in the third stage). The fourth stage aims to develop integrated flood/drainage/irrigation management through upgrading FMIS into a Water Resources Information System, implementing operational community based flood management and operationalizing regional flood knowledge base and management plans.

The first module has been implemented and made operational during 2007 flood season, with focus on flood hazard characterization and operational flood management information products, supplemented by improved flood forecast, a flood website for public dissemination and access, updated flood control manuals, plans for upgrading hydrologic measurements and telemetry, and training. Providing and disseminating information tools has moved sector agencies capacity from disaster response to improved disaster preparedness and to effectively support flood control and management in the flood prone areas of the State of Bihar. The FMIS in the first stage had covered the focus area from Burhi Gandak river in the west & Kosi river in the east in north Bihar which has most flood prone area in the State presently.

The subsequent stages of FMIS development would cover substantially enhanced functions and products, supported by improved hydrologic observations and telemetry,

more reliable and longer term rainfall forecasts, enhanced flood forecast and inundation prediction with better models, Airborne Synthetic Aperture Radar (ASAR) surveys for real-time inundation information during floods, close-contour surveys of the flood plain, mapping flood plain geomorphology including micro-relief to understand and improve drainage, improved communication links and information flow, risk and vulnerability analysis, institutional and community outreach mechanisms, and real-time flood data dissemination. The fully upgraded FMIS would support preparation of master plan for flood control and drainage, irrigation improvement, and overall water sector development in Bihar State.

6.2 FMIS Phase–I Objectives

FMIS Phase-I objectives were: To move from disaster response to improved disaster preparedness, to improve the lead time of the forecasts, develop a focal point in an institutional (e.g. a multi-disciplinary Flood Management Information System Cell) framework and information (e.g. a web-portal for Bihar Flood Management) setting, as well as improved information flow (e.g. bulletins, improved use of email/internet/cell phones) and sector preparedness (by updating flood manuals).

Along with a substantive effort of planning the development and rehabilitation of the flood and drainage control infrastructure, in the short term, there is a compelling need for adopting new technological approaches to improve the decision process before, during and after the flood events and the use and allocation of available resources.

In the short-term FMIS would help strengthen existing institutional capacity and arrangements for flood management in the state and make extensive use of modern technology (e.g. satellite remote sensing, Geographic Information System [GIS], Internet, forecast models, etc.). Relevant outcomes of the technical assistance are the strengthening of flood knowledge base and analysis, the dissemination and outreach of operational flood management information and the improvement of flood preparedness.

6.3 Activity Completion Report for Phase I

The project components included:

i) Development of FMIS
ii) Improved flood forecasting
iii) Bihar Flood Information Website
iv) Updated flood control manual
v) Training
vi) Plan for upgrading hydrologic measurements and telemetry.

The ‘Activity Completion Report’ received from the World Bank mentions that FMIS has been set up. FMIS website has been developed and hosted. The website (http://fmis.bih.nic.in) is operational providing public access to flood data. FMIS officers have been trained. The FMIS has addressed information needs for early warning and emergency response of three key Departments: Water Resources Department, Disaster Management Department and Agriculture Department. The Central and State Agencies linkages (linkage between WRD, GOB, and NRSC/ IMD / SOI/ CWC and GFCC) have been strengthened. In nut shell, almost all the project activities have been successfully completed and the project outputs and outcomes have been substantially realized with the

disbursement to the tune of about 93 percent of the total project cost. The Bank has expressed its pleasure over the WRD's commitment for sustaining the FMIS by supporting continued operation with substantial augmentation of systems and staff.

6.4 FMIS Phase II

A proposal for FMIS Phase II for the Grant of nearly Rs 11.92 crore (3.03 million US $) with extended focus area covering whole of North Bihar, with the objective of improved flood forecasting and early spatial warning etc was submitted to the Bank via Department of Economic Affairs, Ministry of Finance, Govt. of India in June 2008. The Bank took up preparation of the project through its mission in April 2009 and extensive consultation with stakeholders & field visits were conducted by the Bank in this process. In the meantime DEA in April 2009 (letter no- F. No. 16/03/2008-FB-II dt 17.04.2009, serial no 5) downscaled the Grant request to US $ 1.5 million only with assurance to scale it up to the original request of 3.03 million US $ if the recipient shows good disbursement at a faster pace during project implementation. The project was then restructured by reducing the scope/ geographic coverage area of many activities to accommodate within this limited budget. The agreement for TA (Technical Assistance) of 1.5 Million US $ (nearly Rs. 675 lac) DFID, UK Grant was signed between DEA (Department of Economic Affairs), GOI and the World Bank on 31.05.2010 and administrative approval of Bihar Cabinet was received on 18.01.2011. Initially it was planned to end on 31.12.2012 which has been extended till Nov' 2014.

Funding / Financing of the FMIS Ph –II Project

The original cost of the development of the project is estimated as Rs 825.00 lac out of which Rs. 675.00 lac (nearly US $ 1.5 million) would come from Technical Assistance (TA) from the World Bank and rest Rs. 150 lac would come from state contribution to the project. The State contribution includes Rs. 130.15 lac already disbursed from 01.07.2008 to 31.07.2010 to continue the functioning of the FMISC and Rs. 19.85 lac has been kept to obtain various satellite data from NRSC and for other miscellaneous expenditure. Recently Additional Grant for 0.3 million US $ has been received from the Bank through DEA & MOF of GOI resulting in **Revised Cost of Grant to 1.8 million US $** (Nearly Rs **1050.00** lac).

Ph –II Project Components

The Technical Assistance has the following three components:

Component A: Institutional Strengthening for Flood Management

This component includes support for the institutional strengthening of FMIS Centre essential to achieve and sustain the aims of the project. The centre would also act as focal point on flood information and analysis in the Water Resources Department (WRD), as well as links to stakeholder agencies (in particular, the Disaster Management Department). The support to be provided for strengthening would be setting up emergency flood control rooms, including office and equipment upgradation, improved connectivity, video conferencing facility, as well as training and other capacity building and moving to a comprehensive strategy for modernizing policy, institutional, and technical aspects of flood management in Bihar. A Panel of Experts will be constituted to help improve quality of the entire project, as well as special studies and international training. The two proposed focus areas are:

A1. Capacity Building and Training

i) This includes support for improving flood management through strengthening of FMIS Center by recruitment of specialist staff, office upgrading, equipment including connectivity upgrading, and incremental operational expenses, building on the current FMIS Centre, as a focal point to provide state-of-the-art flood information and analytical services to flood-related departments of GoB.

ii) Strengthening the Hydrology Directorate of Water Resources Department, through recruitment of specialist staff, office upgrading, equipment including connectivity upgrading, and incremental operational expenses, to improve their current activities and interface with the FMIS Center. In addition, WRD offices will be strengthened, including higher-level offices in flood-affected areas, and field offices in the targeted area of Bagmati-Adhwara basin through office and equipment upgrading including connectivity, critical specialist staff and incremental office expenses.

A2 Flood management strategy and planning

An Integrated Flood Management Plan will be developed for the Bagmati basin by considering flood issues with other interlinked water resources management issues. In addition, this activity would support special studies to upgrade flood management manuals and outline larger-scale institutional strengthening for the Water Resources Department.

Component B: Development of Flood Management Information Systems

This Component includes support for the development of a modern flood management information system for Bihar, with an initial demonstration in selected areas of the Bagmati-Adhwara basin. This also includes support for improving the spatial knowledge base for flood management, developing and using models for forecasting flood flow and inundation, and the establishment of a much-needed embankment asset management system. Support also provides for associated consultancies, surveys, satellite imagery and other data procurement, and related operating expenses. The proposed focus areas are:

B1 Improve Knowledge Base for Flood Management

This sub-component supports following activities to strengthen the knowledge base to improve flood management:

i) Support for critical topographic and other surveys (e.g. cross-sections/ longitudinal sections of embankments and river) in the focus areas of the Bagmati-Adhwara basin.

ii) Support will be provided to immediately upgrade the inadequate and very outdated monitoring network for precipitation, flood flows, and sediment by setting up RTDAS (Real Time Data Acquisition System).

iii) Support will also be provided for the development of a satellite imagery-based spatial database covering flood-prone north Bihar.

B2 Improve Modeling/Analysis for Flood Warning

This activity supports :

i) Flood Forecasting and Inundation Modeling in the Bagmati-Adhwara basin (enhancing the present system of stage-level warnings based on gauge-to-gauge correlation). Both traditional and innovative modeling approaches will be attempted.

ii) Studies on river course migration and analysis of flood hazard/risk/vulnerability.

B3 Establish an Embankment Asset Management System

The embankment system in north Bihar is extensive, but suffers from extensive problems of inadequate maintenance, exacerbated by the lack of any systematic inspection programs and techniques and data to assess current embankment status or prioritize embankment investments. This activity will support the development of a systematic Embankment Asset Management System (EAMS) for Bagmati-Adhwara basin supported by detailed modern surveys of the embankment status in the Bagmati-Adhwara basin that is partially embanked and where substantial investments for new embankments are planned. WRD is currently considering the use of limited number of PC Tablets for capturing inspection data using Inspection Check List. The EAMS would be developed in such a way so as to have capability to incorporate these data for integrating into the Embankment Database using Levee Inspection System (LIS) developed by US Army Corps of Engineers (USACE).

Community participation for embankment surveillance and to update embankment safety information in the EAMS will be piloted.

Component C: Community-Based Flood Risk Management in Targeted Areas

This Component will include support for the planning and implementation of community-based flood management in selected areas of the Bagmati-Adhwara basin. This will include support for consultancies, communication systems, and associated operating expenses. The proposed focus areas are:

C1. Planning Community Outreach for Flood Management

This sub-component will support the planning for community outreach for effective flood management, focused on the situation on the ground in the targeted areas of the Bagmati-Adhwara basin. Technical assistance will be provided to develop strategies to improve community awareness, preparedness, and response, including institutional arrangements and tools for improved early warning communication and dissemination and for community reporting of flood problems.

C2. Enhancing Community Participation for Flood Management

This sub-component will support the implementation of efforts to improve community participation for selected flood-prone areas of the Bagmati-Adhwara basin. This will include support for technical assistance, communication tools, and community participation to demonstrate the “last mile” connectivity and involving the WRD, Disaster Management

Department, District administration, and other institutions. Synergies with the existing Bank-financed Bihar Livelihoods Project are also being explored.

6.5 Capacity Building

Under Capacity Building activity of the FMIS Phase- II project, a study tour to USA was undertaken by four officers of WRD from 20th June to 2nd July 2012 under leadership of Joint Director on the invitation of FMIS Phase- II Task Team Leader Dr. Winston Yu of World Bank. The purpose of the tour was to study the know-how of maintenance and up-keeping of embankments in USA, and the tools used for this purpose, like Levee Inspection Tools, Levee Screening Tools, National Levee Database etc and the activities undergoing in United States Army Corps of Engineers (USACE) and United States Geological Survey (USGS), both lead organizations engaged in the flood management activities in USA. The experiences were rich enough and some recommendations have been made to the department based on these experiences. Like National Database of embankments in USA, a similar database of embankments in Bihar also needs to be prepared. We are contemplating this activity under EAMS activity of FMIS Phase II.

6.6 Current Status of FMIS Phase II:

As per the World Bank guidelines, to implement the project a Procurement Plan was prepared in which the major components have been sliced into easy executable activities/ sub activities called packages. The detailed description about the status of ongoing key activities is as below:

- Most of the works involved in ***office & equipment upgradation*** have been completed. Under its package Pk-13, to support day-to-day activities of FMISC, professional staff have been hired who are satisfactorily rendering their services in FMISC.
- MoU for ***Development of DEM*** (Digital Elevation Model) by LiDAR (Light Detection and Ranging) for delineated 1800 sq km in Bagmati-Adhwara basin was signed with NRSC. As per the MoU, payment was made to NRSC and data has been received and being used in the Flood Forecast & Inundation Modeling study under Pk.29.
- For activity ***Conducting River Cross Section and Embankment Asset Survey in Bagmati –Adhwara Basin,*** Contract has been signed in January 2014 and work is in progress.
- For ***Real Time Data Acquisition System (RTDAS) for Bagmati and Adhwara group of rivers basins in Bihar:*** After rejection of all the three bids received during 1st IFB due to non-responsiveness, fresh Bid Document was prepared and sent to World Bank for approval. But now this work has been dropped due to paucity of fund.
- Contract for '***Development of Flood Forecast and Inundation Modeling System in Bagmati-Adhwara basin***' was signed on 01/03/2012. Inception Report, Design Report & Initial model reports have been received & approved. Also the proportionate payment has been made to the consultant, DHI, New Delhi.
- Contract for '***Development of Spatial Database and Application for Bihar Flood Planning Management'*** - was signed on 06/07/2012 to cover 21 districts of North Bihar and 3 districts of South Bihar which was the focus area of Ph-I & Ph-II of FMIS. Inception Report, Priority Dataset & DFR has been received & approved. The

proportionate payment has been made to the consultant SCIENCE, Dehradun. Final Report has been approved and payment is in progress.

- Contract for ***Development of Spatial Database for 14 districts of South Bihar and Application for Bihar Flood Planning Management'*** was signed on 30-August-2014 to cover the remaining 14 districts of South Bihar. Inception Report & Priority Dataset has been received & approved. The proportionate payment has been made to the consultant SCIENCE, Dehradun. DFR and Final Report has been received and is under review.
- The contract for consultancy services for ***River Behavior Analysis*** (Gandak, Burhi Gandak & Bagmati) was signed. Though Inception Report was approved, further deliverables could not be submitted by the consultant. This contract was therefore terminated due to non performance.
- For activity ***Embankment Asset Management System (EAMS),*** contract was signed on 28th June 2013. Inception Report and Design Report has been approved. Interim report on Web-GIS and Beta version of EAMS are expected by July 2014.
- **To develop approach, protocols and mechanisms for "Community Participation in Embankment Surveillance and Piloting in Select Communities"** has been dropped due to paucity of fund. However community participation component part is being done in house by recruiting Community Participation Specialist. This part of community participation shall be the input for EAMS.

6.7 Financial Progress:

Allotment received : **9.5 crore**

(2.5 crore in 2010-11+ 2.0 crore in 2011-12+ 2.0 crore in 2012-13 + 3.0 crore in 2013-14)

Disbursed till 31.03.2014: **5.49 Crore**