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fmis
Bihar

Flood Report 2007

Flood Management Information System Cell

Water Resources Department
Government of Bihar

Preface

Bihar is India's most flood prone state with its rivers having 65 percent of their catchment area in Nepal and the Tibetan plateau and only 35 % in Bihar. It was felt that there is substantial scope for improving the flood management practices in the state by introducing the use of Remote Sensing, Geographic Information System (GIS) and modeling techniques. Keeping this in mind, the Flood Management Information System (FMIS) was established as a Water Sector partnership matrix between the World Bank and the Govt. of Bihar. The present publication is the first annual report of the Flood Management Information System Cell (FMISC) that gives a brief account of the 2007 floods and demonstrates the usefulness of modern technological tools like GIS and Remote Sensing in Flood management. This report covers the most flood-prone parts of North Bihar from Burhi-Gandak River in the West to Kosi River in the East, covering about 26000 sq. km.

The FMIS Project had in its focus, area covering the districts of East Champaran, Sheohar, Sitamarhi, Muzaffarpur, Madhubani, Darbhanga, Samastipur, Supaul, Saharsa, Khagaria and Begusarai. To monitor the rainfall and consequential flood events in the catchment area of Burhi-Gandak, Bagmati, Kamala, Adhwara Group Rivers and river Kosi, the FMISC functioned in an emergency mode from the 15th June to 20th October 2007. During this period, information and data regarding observed rainfall, 3 day rainfall forecast, river gauge levels, trends forecasts of CWC and WRD gauge-sites within the focus area were collected and sent to the National Remote Sensing Agency, Hyderabad which in turn, delivered near real time satellite imageries and inundation layers. Based on the data collected, number of information products such as flood inundation maps, flood duration maps, breach maps along with statistics related to the District and Block levels were prepared in Real Time and disseminated to all Stakeholders.

The report includes a brief history of floods in the FMIS focus area from 1997 to 2006 with special emphasis on the flood events of 2007. The work on FMIS is yet to be completed. But it has shown its great utility - not in forecasting floods as yet - but for example in ensuring that the flood relief measures are commensurate with the actual damage incurred. Some valuable lessons were learned by the FMISC during the devastating monsoon of 2007. These are being incorporated in its future course of action. I hope the report is found to be useful by all the stakeholders.

Ajay Nayak, IAS
Secretary,
Water Resources Department,
Govt. of Bihar

ACKNOWLEDGEMENTS

The Annual Flood Report-2007 of FMIS has been diligently and meticulously prepared keeping in mind that it is a first. A number of individuals and agencies have been instrumental in supporting the project and in the preparation of this report.

We would like to acknowledge the contribution of the World Bank which has played a major role in coordinating and capacity building of FMIS and especially Mr Javier Zuleta and Dr ST Chari. We are also grateful to the DFID with whose funding the project has been taken up. National Remote Sensing Agency, Hyderabad, India Meteorological Department, Delhi and Patna, Central Water Commission, Ganga Flood Control Commission, Department of Disaster Management, GoB and Department of Agriculture, GoB have constantly been cooperating with the cell and have given valuable suggestions in the preparation of this report.

Sh. Braj Bhushan Prasad Singh the then Chief Engineer Planning and Monitoring, Sh. Binay Krishna Chief Engineer, Planning and Monitoring, Water Resources Department, Sh Ashram Rai Superintending Engineer, flood monitoring, Water Resources Department also needs special mention for the timely cooperation and coordination during the flood season.

The FMISC team is acknowledged for its dedicated work in uncharted waters and to come up with this debut report.

Finally, our sincere and deepest gratitude to Shri Ramashray Prasad Singh, the Hon'ble Minister, Water Resources Department, Government of Bihar, for his unstinted support and Shri A.K Sinha, the then Principal Secretary, Water Resources Department, Government of Bihar and Sri Asangba Chuba Ao, the then Joint Secretary, Water Resources Department cum Project Director, FMIS, Government of Bihar under whose able guidance and constant encouragement this project has been made possible.

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Acronyms

ALTM	Airborne Laser Terrain Mapper
AOI	Area of Interest
ASAR	Airborne Synthetic Aperture Radar
AWiFS	Advance Wide Field Sensor
CMIE	Centre for Monitoring Indian Economy
CWC	Central Water Commission
DEM	Digital Elevation Model
DFID	Department For International Development
DL	Danger Level
DMD	Disaster Management Department
DMSP	Disaster Management Support Program
DRF	Daily Rainfall
DSC	Decision Support Centre
FMIS	Flood Management Information System
FMISC	Flood Management Information System Cell
GDP	Gross 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
Met.	Meteorological
MM5	Mesoscale Model 5
NRSA	National Remote Sensing Agency
RS	River Stage
SRTM	Shuttle Radar Topography Mission
WGS 84	World Geodetic System 1984
WiFS	Wide Field Sensor
WRD	Water Resources Department

Report of 2007 Flood Season by FMIS

1.0 Purpose And Overview Of Annual Report

This 'Report of 2007 Flood Season', is the first Annual Report published by the FMIS Cell. It is intended to give a brief account of the floods which occurred during 2007 and the use of modern technology like GIS and Remote Sensing in flood mapping in terms of inundation, duration and maximum extent of inundation. It will serve as a source of information and a reference document for FMISC Technical Committee and Advisory Committee and also for key stakeholders, such as Disaster Management Dept., Agriculture Dept. and WRD. The key objective of this exercise is to attempt to make this report coherent and standardized so much so for the reader to get the most comprehensive picture of the flood issues, benefits and stakes. It aims to fulfill two primary roles : a summary of the flood year 2007 and a collection of important data on the flood regime primarily through inundation maps, maximum flood duration maps, maximum inundation extent maps and flood frequency maps etc. These data will, in time, accumulate to provide a primary regional resource for flood research and the collection of historical reference material.

The main text of the Report is laid out in such a way that there is a logical progression from the creation of awareness of the nature and history of FMISC Focus Area, towards a specific evaluation of events in 2007. A special feature of the report is flood inundation mapping, maximum inundation map and duration of inundation map generated with the help of modern technology such as GIS and Remote Sensing. Another interesting study has been carried out with Forecasted Rainfall, Observed Rainfall and Water Level at various points of Bagmati River on the same time scale.

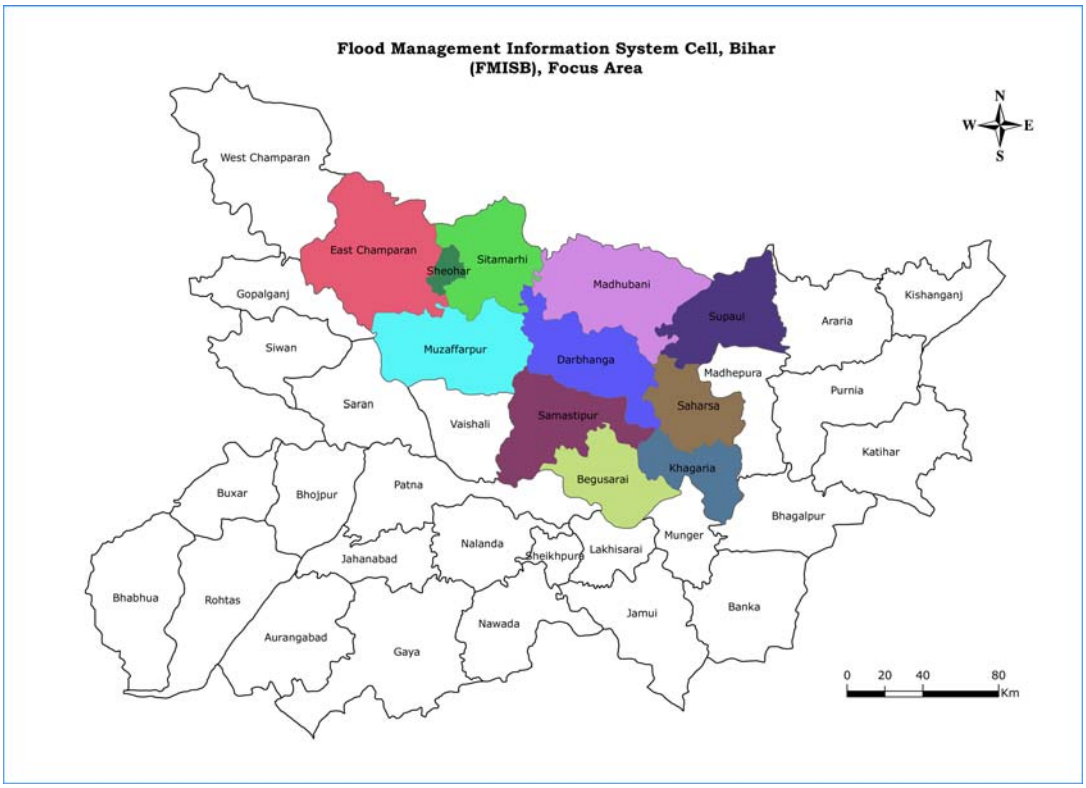
2.0 Flood hazard in Focus area

FMIS focus area is the most flood prone area in the State which covers Burhi Gandak River in the west to Kosi River in the east. This area has been taken as a pilot project, the success of which can be extended to whole of the North Bihar and ultimately to whole of the State. Furthermore this area is the saucer shaped area between the embanked river of Gandak and River Kosi.

2.1 The physiography

The FMIS focus area lies between latitude $27^0$02' N to $25^0$15' N and longitude $84^0$28' E to $86^0$53'E. The total geographical area is about twenty six thousand Sq. Km. (26,000)

2.2 FMIS FOCUS AREA



Map 2.1 Study Area - (11 Districts of North Bihar)

The area is bounded by Himalayan foot hills and terai region of Nepal on the north, Kosi on the east, river Ganges on the south and River Gandak 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, Burhi Gandak, and Kosi falling into the Ganga and Bagmati- Adhwara, Kamla-Balan etc. which also drain into the Ganga through the Kosi.

Rivers in FMIS focus area 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 river Kosi also shifted from near Purnea on the east to its present course on the west where it has been contained between the embankments. In its lateral travel of about 120 Km. in course of about two centuries, the Kosi has created a number of depressions chaurs and mauns in the Basin, apart from depositing coarse silt and sand in almost the entire area.

The major rivers of the Focus area have Himalayan origin and a considerable portion of their catchments lie in the Himalayan region in Nepal. They receive very copious rainfall during monsoon when discharges of these rivers are about 80 to 90 times larger than fair weather flows. This causes frequent flooding of a large portion of the area. Despite existence of flood embankments on most of them, about 73.63 per cent of the geographical area of North Bihar is considered to be prone to flooding, liable to be flooded if spill occurs from higher contour in India and mainly in Nepal.

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.

The total geographical area of Focus area is approximately 26000 sq Km comprising of eleven Districts namely Muzaffarpur, East Champaran, Sitamarhi, Sheohar, Saharsa, Supaul, Darbhanga, Madhubani, Khagaria, Samastipur and Begusarai.

2.3 Climate And Rainfall

FMIS area 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 minima 23^0C to 25^0C and maxima 35^0C to 38^0C.

The mean annual rainfall for the State is about 1270 mm varying from 1170 to 1580 mm in the 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. A striking feature of this year rainfall pattern concerned with Sikandarpur in Muzaffarpur where a total of 3900.3mm occurred during 15th June to 18th October 2007.

2.4 Socio-Economic Context

Bihar is one of the most populous state of India, but economically one of the most backward. Along with a very high proportion of population below the poverty line, the different social and economic indicator below amply reflects the precarious position of Bihar among the Indian States.

Human development index indicator

	India	**Bihar**
Per Capita income	16707	6850
Literacy Rate	65.38%	47.5%
Infant Mortality Rate (SRS 2006)	60	60
Gross enrolment ration (6-14 yrs, %)	65	47

Source: Director of Statistics , GOB
Census report 2001

As indicated above Bihar has a very dismal performance among the states of India- its per capita income (net GDP at factor cost at current prices) stands at a mere Rs. 6850 as against Rs.16707 for India as a whole. The state has the lowest literacy rate among the major states of India-47.5 percent as against the national average of 65.38 percent. The Child mortality rate is 60 for both Bihar and India. The gross enrolment ratio stands 47 for Bihar against 65 for India.

Agriculture

Bihar has a large alluvial river valley area. Against the backdrop of such generous natural resource in irrigation sector the overall percentage of net area irrigated in Bihar is about 38% of, irrigation is largely seasonal and protective.

	India	Bihar
Percentage income from agriculture	29.93#	38.16#
Potential created in million hectare (mha) (Major and Medium irrigation:>2000ha)	37.05#	2.833*
Ultimate irrigation potential, (mha) (Major and Medium irrigation:>2000 ha)	58.47#	5.36*

Annual Plan 2006-07, GOB
* Annual plan report of WRD, Bihar 2007-08

The acute poverty and backwardness can be traced to the backwardness of both in agricultural and industrial sectors. The reasons for the extreme backwardness of agriculture are both institutional and technological. Where as structural and institutional factors have been operating as a powerful barrier to the agrarian transformation, the technological factors such as poor development of infrastructure like irrigation and power, non-availability of modern inputs, low value of credit and poor extension services, etc. have also contributed much to the dismal performance of the state's agricultural sector.

Demography

	India	Bihar
% Population in rural area	72.2	89.6
Density of population (per sq km)	324	880
% Population below poverty line	26.10	42.60

Source: Annual Plan 2006-07, GOB
Census report 2001

The major explanation of the state's backwardness and poverty, however, has to be traced to the rural sector. With about 89.6 percent of the population in rural areas (as against 72.2 percent for India as a whole), it is the most rural state in the country, next only to Assam. About 42.60 percent of the state population is below poverty line as against about 26.10 percent for India as a whole.

One of the obvious reasons for the economic backwardness and poverty of Bihar is its high density of population 880 persons per sq. km to 324 per sq km for whole of India. (2001). In the wake of wide spread poverty, a substantial number of poor people go outside the state in search of livelihood.

The State's backwardness is probably more related to its socio-economic-political structures. Floods in large parts of the plains of Bihar, especially in north Bihar, are recurring features and cause havoc destroying crops and the quality of land, and

threatening the conditions of life and livestock due to large-scale displacement. These factors add to woos of Bihar. Flood in North Bihar is a perennial problem. Every year, almost 22 districts get flooded, causing huge loss of property, lives, farmlands and infrastructure. A disaster management system equipped with data, technology and resources can meet ravages of cyclic natural disasters. Water logging in substantial parts of the command area of north Bihar is another chronic problem with adds up to the socio economic backwardness of Bihar

2.5 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 have identified 4 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 raining season, no Kharif season agriculture
Class IV:	Permanent water logging - shrinkage in area only in Feb, local rainfall, micro-relief aspects.

Another classification which has been identified by FMIS 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.

2.6 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. There after flood generally comes in River Burhi Gandak 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. A peculiarity of this year's flood is regarding the river Bagmati in which flood remained high even during the month of September –October.

2.6.1 Floods In Last Ten Years in The FMIS Focus Area

Floods have caused devastation and acute human sufferings frequently since the dawn of civilization and man has 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 pressures 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 where, inspite 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 Resourced Department Annual Flood Report in chronological order during (1997-2006) is given as follows:

1997 - During this year rainfall in the catchments of all the river basins was generally normal. Gandak, Kosi, Bagmati and Mahananda rivers experienced floods from first week of July. In the mid of July maximum discharge caused tremendous pressure to the embankment/ structures resulting in wide spread damage. Bagmati right embankment at Kothia village, Bagmati afflux bund at Mausurha closure, right embankment of Burhi Gandak at Beria Thoral, Govindpur and Paharpur, Kamla Balan river at 65.5 Km, were partially damaged. Afflux bund and main eastern Kosi embankment were damaged at few places which were protected by undertaking flood fighting works. Besides these few places at Burhi Gandak, Bagmati, Kamla and Kosi, river embankments faced severe erosion which was protected by flood fighting works.

1998- In 1998 rainfall started by the first week of July and extended upto end of September. The rainfall was by and large normal but the length of flood period was extended. Maximum discharge in the first week of July in most of the river in North Bihar caused excessive pressure on the embankment along the rivers resulting in damages at several places which were encountered by doing flood fighting works. Burhi Gandak right embankment at Beria Koral, Govindpur, Ahok Ghat Sikhaul, Rampurwa Burhi Gandak Left embankment at Enerwa , Seuri, Aolapur, Mainpurwa**,** Bagmati right Embankment at Surgahi, Kothia, Mausaura closure bund Bagmati left embankment at ch. 101-405 near Belsund were partially damaged which were successfully repaired by timely flood fighting. Kamla Balan right embankment at 73.6 km was breached in a length of 15 ft. and at 42.75 km, 65 km were cut by the anti social elements. Also Khiroi embankment at 17, 18, 9.25 km were damaged by anti social elements. Badlaghat Nagar Para embankment at Malpa, Lalpur, Prayani, Karachin Badlaghat embankment at Chatar, Amni, Saidpur were damaged at some places. Adhwara right embankment at ch. 16, left embankment at ch. 140 breached due to high pressure which was controlled by flood fighting works. Right and left Brandi embankment at ch. 165 and 400.75 km. respectively were cut by anti social elements. Eastern Kosi embankment, afflux bund and western embankment at few places were damaged which were protected by flood fighting works.

1999-This year rainfall in June was more than normal rainfall. In July Bagmati basin experienced more than normal rainfall. In August no significant rainfall observed in month of October the rainfall was more than normal rainfall in the focus area. Due to more than normal rainfall the spur in Kosi river experiences threat throughout the flood season. But timely flood fighting kept the river within the embankment. In the Burhi Gandak the right embankment at Suratpur, Sikhaula and at left embankment at Tatitola, Pehsara, Bihulia, Mirzapur, Rajhwara, Bore-Jairam, Satmalpur, Begumpur and Balapur were threaten by flood water but timely flood fighting kept the embankment safe. In Bagmati river right embankment at Kothia and Surgahi site felt high pressure similarly at left embankment at ch. 314 to 329 and ch 397 to 405. Right embankment was kept safe by flood fighting but for the left embankment retire bund was constructed to keep the river safe from flooding the area. In Kamla-Balan right embankment 8 to 10 km., 12.7 to 13.5 km and 58.6 km felt high tension and pressure which was overcome by flood fighting. In October due to excessive rainfall 55.5 km the embankment breached in 215 ft length. Same way Kamla-Balan left embankment at 27 km, 31 to 42 km, 44.7 km 46 km 49.6 km 57 km 59.42 to 61.25 km 62 km, 65.4 km 66.6 km, 67.5 km and at 82 km it was under threat which was overcame by flood fighting but the villagers purposely cut at 60 km 63.5 km 65.3 km 78.5 km 82 km and 86.75 km so that they could allow the river to gush in the fertile silt into their field. Buthi-Balan at 8 km the right embankment

breached and caused loss to the area. And at left embankment at 16 km. great pressure was overcame by flood fighting.

2000- Bagmati left embankment at chain 273 near village Madhkaul was cut by villagers. 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 and48 were cut by the villager. Incident of embankment cut have been reported earlier also. This was done to bring silt to raise land by the villagers. Kamla-Balan and Bhuthi-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, expert from head quarter camped at the site and brought under control. Sikarhata Majhari Bund of western Kosi embankment between Km 6-7 was damaged in the night of 13/8/2000 but saved by doing flood fighting work. Heavy pressure on Spur at km 78.30 of Eastern Kosi embankment was overcome by undertaking flood fighting work.

2001- Left bank of river Burhi Gandak at Rampurwa Pulwar, Pakridayal, Enarwa Gaht Mainpurwa and right embankment at Bihkhiya, Chakarniya, Bairiya, Koral, and Balochak was experiencing pressure but was saved by timely flood fighting. Burhi Gandak left embankment at 69-70 km at village more the bed wall which was earlier constructed damaged due to heavy local rainfall and pressure over embankment. Burhi Gandak at right embankment at 98-99 km at village Phulwaria anti social element cut the embankment on 17.9.2001. The Right embankment of Bagmati River at Kothia and Surgahi and at 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. 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. Western Kosi embankment at 2.25 km the D-part of spur nose was damaged. Bhuthi-Balan right embankment breached due to overtopping at 20.91 Km, 21.01 km, 21.4 km 22 km, and 60.7 km in first week of October.

2002-Kamla Balan left embankment at km 81.20 (Bugras) was cut by villagers in a length of 30 m which increased to 50 m. Overtopping 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 Pipra ghat, 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 villagers, piping and 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 the embankment was breached due to overtopping. Bagmati left embankment between ch. 145 to 149 was cut by villagers on 23.7 02. Kiroi left embankment at 7 km at village Masartharia and 5.25 km near Maasma and Kiroi right embankment at 12 km near Belwara Milki village and at 3 km near Bagwasa village it breached due to overtopping on 24.7.02. Western Kosi embankment at 29 to 30 km below Kasba Bharda was cut by villages at 2 places.

2003- Maximum discharge of 389000 Cusec passed through river Kosi where as 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 through the river 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 antisocial elements cut Kamla Balan right embankment at km 66.50 in a length of 50 ft. Status of flood in other rivers except Ganga, Gandak remain normal. In river Ganga the HFL at Bhagalpur surpassed the 1978 record of 34.18 and was 34.20 level and at Patna at Ghandighat the HFL level of 1994 (50.27) was observed as 50.12 in 2003 due to 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 in much respect 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 which was the maximum flood producing 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 it self speaks about the fury of flood in year 2004. Many places in the embankment of North Bihar were breached resulting in flood inundation in a vast area of North Bihar area. Unprecedented flood in river Bagmati, Burhi-Gandak, Kamla and Bhuthi-Balan and Adhwara groups of river 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. Where there was 63 numbers of breaches during 2004 flood, where as only 8 breaches occurred during the year resulting in flood inundation in Madhubani and Katihar districts only. Left and right embankment of Kamla was breached at seven places during this year. Bhuthi Balan left embankment at km 21.22 and 22.80 was cut by the antisocial elements and due to flash flood embankment was damaged at few places.

2006- The flood situation during 2006 was normal. Where there was 52 numbers of breaches during 2004 flood, this year only 1 breach occurred. Left embankment of Kamla was breached near village Asma at km 75.70 by antisocial elements but fortunately there was no loss of life or property. Flood situation in other places remained normal by and large.

2.7 District-Wise Damage Statistics For 2007 Flood

District-wise flood damage statistics as obtained from Disaster Management Department, Bihar for 2007 flood for FMIS focus area is given below:-

Sl. No.	District	Blocks	No. of effected village	Cropped Area (Lakh hect.)	Estd. Crop damage (Rs. Lac)	No. of house damaged fully /partially	Estimated Value of house damage In (Rs. Lac)	Public Properties damage (Rs. Lac)	Lives lost (Nos) Human		
									Flood	Others	Animal
1.	Muzaffarpur	15	1704	1.24	12,663.00	65550	11,073.00	24,951.00	104		190
2.	Sitamarhi	17	806	0.51	7,803.94	103193	16,084.85	63,618.25	33		104
3.	Saharsa	6	184	0.26	985.82	16412	935.25	140.38	35		
4.	E.Champaran	27	1159	1.58	15,400.00	52840	8,278.31		96		28
5.	Supaul	6	94	0.25	574.84	15000	300.00	17.75	1		
6.	Darbhanga	18	2104	1.75	6,606.10	83127	13,106.14	18,271.02	140		405
7.	Madhubani	20	836	1.39	7,936.23	96362	9,116.45	25,733.68	49	16	33
8.	Samastipur	19	842	1.25	16,710.07	29391	775.00	17,896.46	157	20 (Boat Accident)	75
9.	Sheohar	5	150	0.25	693.00	50728	6,477.10	105.00	4		
10.	Khagaria	7	203	0.50	8,507.33	32500	8,507.33	372.00	101	21 (Boat Accident)	71
11.	Begusarai	11	346	0.94	16,057.84	40740	11,773.10	444.00	54	4 (Boat Accident)	15
Total		**151**	**8428**	**9.92**	**93,938.17**	**585843**	**86,426.53**	**151,549.54**	**774**	**61**	**921**

Source: (http:// disastermgmt.bih.nic.in/)

2.8 Flood Characteristics Of Focus Area

FMIS focus comprises of Muzaffarpur, East Champaran, Sitamarhi, Sheohar, Saharsa, Supaul, Darbhanga, Madhubani, Khagaria, Samastipur and Begusarai. A study has been made with the help of data obtained from DMD to see the flood events that took place in the development Blocks of these districts in term of inundation during 1987 to 2006 (20years). A summary of the findings is given below

Sl. No.	Name of Districts	No. of Blocks affected more than 11 years out of 20 years	No. of Blocks affected 5 to 11 years out of 20 years	No. of Blocks affected less than 5 years out of 20 years
1.	Muzaffarpur	5	5	6
2.	East Champaran	2	14	13
3.	Sitamarhi including Sheohar	9	5	4
4.	Madhubani	3	12	9
5.	Darbhanga	6	10	4
6.	Supaul	5	2	5
7.	Samastipur	3	5	14
8.	Saharsa	5	1	3
9.	Begusarai	1	5	10
10	Khagaria	6	1	-
	Total	45	60	68

The table indicates that there are as many as 45 blocks of FMIS focus area which are chronically flood affected in terms of flood inundation.

2.9 Loss Of Public Property In Last 10 Years

Year	Number of Affected									Crop Damaged	House Damaged		Public Property Damaged (in Rs. Lac.)	Deaths	
				(in Lac)		Area (in Lac. ha.)					Total	Value (in Rs. Lac.)			
	District	Blocks	Village	Human	Animal	Agriculture	Non Agriculture	Total	Cropped					Human	Animals
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	6.01	27.00	13.99	52,205.64	9,29,773	75,809.51	1,03,049.60	885	3272
2003	24	172	5,077	76.02	11.96	9.943	5.14	15.08	6.10	6,266.13	45,262	2,032.10	1,035.16	251	108
2002	25	6	8,318	160.18	52.51	14.45	5.244	19.69	9.4	51,149.61	419,014	52,621.51	40,892.19	489	1450
2001	22	194	6,405	90.91	11.7	9.042	2.91	11.95	6.5	26,721.79	222,074	17,358.44	18,353.78	231	565
2000	33	213	12,351	90.18	8.09	6.57	1.476	8.05	4.43	8,303.70	343,091	20,933.82	3,780.66	336	2568
1999	24	150	5,057	65.66	13.58	6.79	1.66	8.45	3.04	24,203.88	91,813	5,384.95	5,409.99	243	136
1998	28	260	8,347	134.7	30.93	17.59	7.53	25.12	12.84	36,696.68	199,611	5,503.70	9,284.04	381	187
1997	26	169	7,043	69.65	10.11	12.46	2.25	14.71	6.55	5,737.66	174,379	3,056.67	2,038.09	163	151

Source: Disaster Management Department

(http:// disastermgmt.bih.nic.in/)

3.0 FMIS Objective

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 improve 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.

3.1 Benefits

3.1.1 Strengthening Flood Knowledge Base and Analysis

This would include flood hazard characterization, analysis of historical floods, development of GIS databases with archived and current remote sensing and GIS data and improved flood and inundation forecast modeling.

3.1.2 Development and Implementation of the FMIS

The information system would be designed with optimum data sets, and developed and implemented. Full-fledged information products (hydrologic status map, predicted and actual flood inundation maps, seasonal flood map showing frequency and duration, and flood hazard map) are planned in 2007 flood season. The information would be disseminated through bulletins, flood website, community outreach programmes, etc. FMIS would be developed and operated by the FMIS created within WRD for flood data collection, analysis and dissemination.

3.1.3 Improved Flood Forecast And Predicted Inundation Modeling

Appropriate methodologies would be developed to improve flood forecasting with increased lead-time, and to map expected inundation (depth, duration and extent) in gauged and ungauged rivers in the selected basin, using existing hydrologic and hydraulic data. Key inputs would be the rainfall forecasts up to 3 days or more from IMD, and detailed Digital Elevation Modeling using Shuttle Radar Topography Mission (SRTM) data.

3.1.4 Dissemination and Outreach

This includes review of current flood information stakeholders, information flow and institutional arrangements, review of modern international websites for flood management and developing Bihar Flood Information Website, and providing

information access through Bulletins (monthly, weekly, for specific events), and community reach through public news media , cell phones, etc.

3.1.5 Flood Website

A world-class website would be designed and implemented to host relevant information on current floods for access by all stakeholders. Current information would include rainfall observations and forecasts from IMD/NCMRWF, flood level/inflow forecast from CWC, flood inundation maps from FMIS, and data sets from global information providers, either directly on the website or through linkage to other websites.

3.1.6 Improvement of Flood Preparedness

The existing flood contingency plans of key state agencies would be reviewed, and updated to improve use of available flood information. The sub components include updating flood manuals and training.

3.1.7 Updated Flood Control Manuals

The existing flood management manuals in key agencies such as Water Resources Department, Disaster Management Department, and Agriculture would be reviewed and updated, taking note of proposed project components, and general improvements in emergency flood management response seen in other flood prone areas in the country and outside.

3.1.8 Training

Appropriate training in specialized image processing and GIS software and FMIS and other project components would be provided to FMISC staff, and training in integration of FMIS products in flood management would be planned for stakeholders up to community level.

3.1.9 Plan For Upgrading Hydrologic Measurements, Telemetry And FMIS

Technical assistance through consultancy services would evaluate existing data collection networks, and plan improvements in hydrologic observations and data communication modalities to enhance forecast reliability and lead-time. This plan would be part of the future development and expansion of FMIS. Enhancements to FMIS design and operation would be planned.

3.2 Overview

The comprehensive FMIS would be developed in four stages. The first module to be implemented and operational zed during 2007 flood season, will focus on flood hazard characterization and operational flood management information products, supplemented by improved flood forecast and inundation modeling, 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 will move 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 would cover the focus area from

Burhi Gandak river in the west and Kosi river in the east in North Bihar that is most flood prone in the State.

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 floodplain 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.

3.3 Current Status

FMIS activities are at a various stages of execution. Flood knowledge base is now wider and enriched. FMISC is receiving MM5 rainfall forecast from IMD regularly and those are being analysed .Flood forecasting Model is being developed by consultants from Indian Institute of technology [IIT], Delhi and it is expected that this will be completed soon. Our institutional capacity in terms of hardware and human resource has increased considerably. A prototype FMIS software has been installed successfully at FMISC. Five engineers have undergone training on GIS. Flood products in term of Flood inundation Maps, Breach maps, Maximum inundation Maps have been prepared at FMISC indigenously and disseminated. Other information products like daily Flood bulletin and e- Bulletin have been issued regularly. FMISC is keeping an eye on daily flood levels in various rivers, observed rainfall and forecasted rainfall in the Focus area.

3.4 Expected status by project closure.

The expected status of FMISC by project closure is to develop and implement a comprehensive FMIS to effectively support flood control and management in the flood prone areas of Bihar State. In the short-term, this will be achieved by flood hazard characterization and operational flood management information products, supplemented by improved flood forecast modeling, a flood website, updated flood control manuals, plans for upgrading hydrologic measurements, telemetry and FMIS, and training.

The project will benefit flood management in north Bihar through strengthening of flood knowledge base and analysis, the dissemination and outreach of operational flood management information and the improvement of flood preparedness.

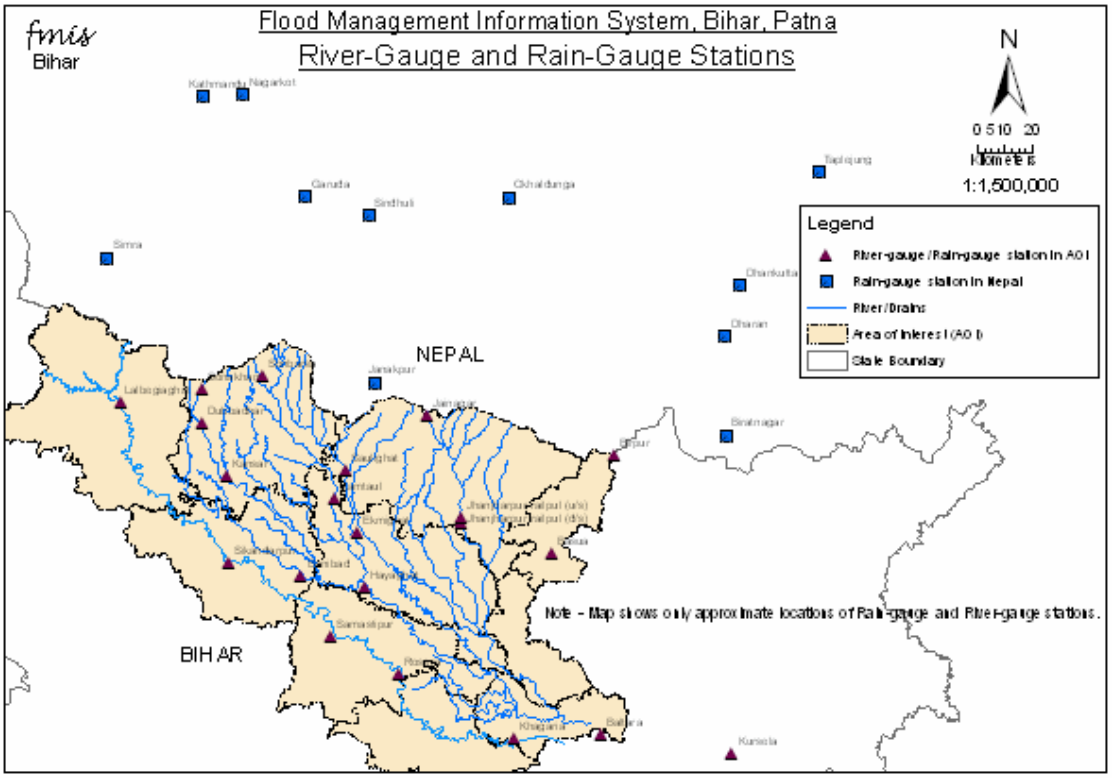
4.0 2007 Floods –Hydrologic analysis

Area of interest (AOI) of Flood Management Information System Bihar receives flood water from vast areas of Nepal through four main streams viz Burhi Gandak, Bagmati, Kamla and Kosi. The FMIS Cell received daily rainfall / river water level data of some stations falling in these basins whose details are as follows.

Sl. No.	Name of measuring station	Location		Maintained by	Type of data	Mode of data acquisition
		Basin/River	(Nepal/ Bihar)			
1	2	3	4	5	6	7
1	Simara	Burhi Gandak	Nepal	GoN	Daily Rainfall	Web site[2]
2	Kathmandu	Bagmati	Nepal	GoN	Daily Rainfall	Web site[2]
3	Nagarkot	Bagmati	Nepal	GoN	Daily Rainfall	Web site[2]
4	Garuda	Bagmati	Nepal	GoN	Daily Rainfall	Telephone[3]
5	Janakpur	Kamla	Nepal	GoN	Daily Rainfall	Web site[2]
6	Sindhuli	Kamla	Nepal	GoN	Daily Rainfall	Telephone[3]
7	Okhaldunga	Kosi	Nepal	GoN	Daily Rainfall	Web site[2]
8	Taplejang	Kosi	Nepal	GoN	Daily Rainfall	Web site[2]
9	Dhankutta	Kosi	Nepal	GoN	Daily Rainfall	Web site[2]
10	Biratnagar	Kosi	Nepal	GoN	Daily Rainfall	Web site[2]
11	Dharan	Kosi	Nepal	GoN	Daily Rainfall	Web site[2]
12	Lalbegiaghat	Burhi Gandak	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
13	Sikandarpur	Burhi Gandak	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
14	Samastipur	Burhi Gandak	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
15	Rosera	Burhi Gandak	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
16	Khagaria	Burhi Gandak	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
17	Sonakhan	Bagmati	Bihar	WRD, GoB	River Stage	Flood News[5]
18	Dubbadhar	Bagmati	Bihar	WRD, GoB	River Stage	Flood News[5]
19	Kansar	Bagmati	Bihar	WRD, GoB	River Stage	Flood News[5]
20	Benibad	Bagmati	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
21	Hayaghat	Bagmati	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
22	Kamtaul	Bagmati/Khiroi	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
23	Sonbarsa	Bagmati/Khiroi	Bihar	CWC, GoI	DRF & RS[1]	Flood News[5]
24	Saulighat	Bagmati/ Darbhanga Bagmati	Bihar	CWC, GoI	DRF & RS[1]	Flood News[5]
25	Ekmighat	Bagmati/ Darbhanga Bagmati	Bihar	CWC, GoI	River Stage	Email[4]
26	Jainagar	Kamla	Bihar	WRD, GoB	River Stage	Flood News[5]
27	Jhanjharpur railpul (u/s)	Kamla	Bihar	WRD, GoB	River Stage	Flood News[5]
28	Jhanjharpur railpul (d/s)	Kamla	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
29	Basua	Kosi	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
30	Baltara	Kosi	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
31	Kursela	Kosi	Bihar	CWC, GoI	DRF & RS[1]	Email[4]
32	Birpur	Kosi	Bihar	CWC, GoI	DRF & RS[1]	Flood News[5]

[1] Daily Rainfall and River stage,
[2] www.mfd.gov.np,
[3] from CWC
[4] from CWC,
[5] Daily flood News of Water Resources Dept. GoB

Location of the above stations is depicted in the map below.



Map 4.1 Map showing River Gauge and Rain Gauge Stations

4.1 Rainfall

Area of interest (AOI) received the first monsoon rainfall before the formal beginning of the monsoon season i.e.; 15th June. Heavy rainfall was registered on 15th (142.20 mm at Simara in Nepal) and 16th June (126.40mm at Sikandarpur, 144.00mm at Kamtaul, 116.40mm at Jhanjharpur, 231.00 mm at Baltara and 105.00mm at Kursela all in Bihar). July has been the wettest month having maximum rainy days. August seems to have received three isolated storms. In September some of the stations recorded extremely high rainfall. For example, Sikandarpur in Bihar received 453.00mm cumulative rainfall in 24 hours on 26th September. This station observed 150.60mm on 25th and 151.00mm on 27th September. Thus, it forms the maximum 24-hr, 48-hr and 72-hr cumulative rainfall observed this year in the AOI. Second maximum 24-hr cumulative rainfall was observed at Simara in Nepal (312.00mm) on 5th September. The monsoon season came to the end in the beginning of October with only a few millimeter cumulative rainfalls observed at most locations in this month. Exceptionally, Sikandarpur observed 449.60mm in October up to 18th. The following Table compiles monthly / monsoon rainfall as well as number of rainy days observed at different stations falling in the concerned basins. This compilation is based on the daily rainfall data received from local Division of Central Water Commission and the Nepal website www.mfd.gov.np.

Monthly / monsoon rainfall (mm) observed in the river basins of AOI _ flood 2007

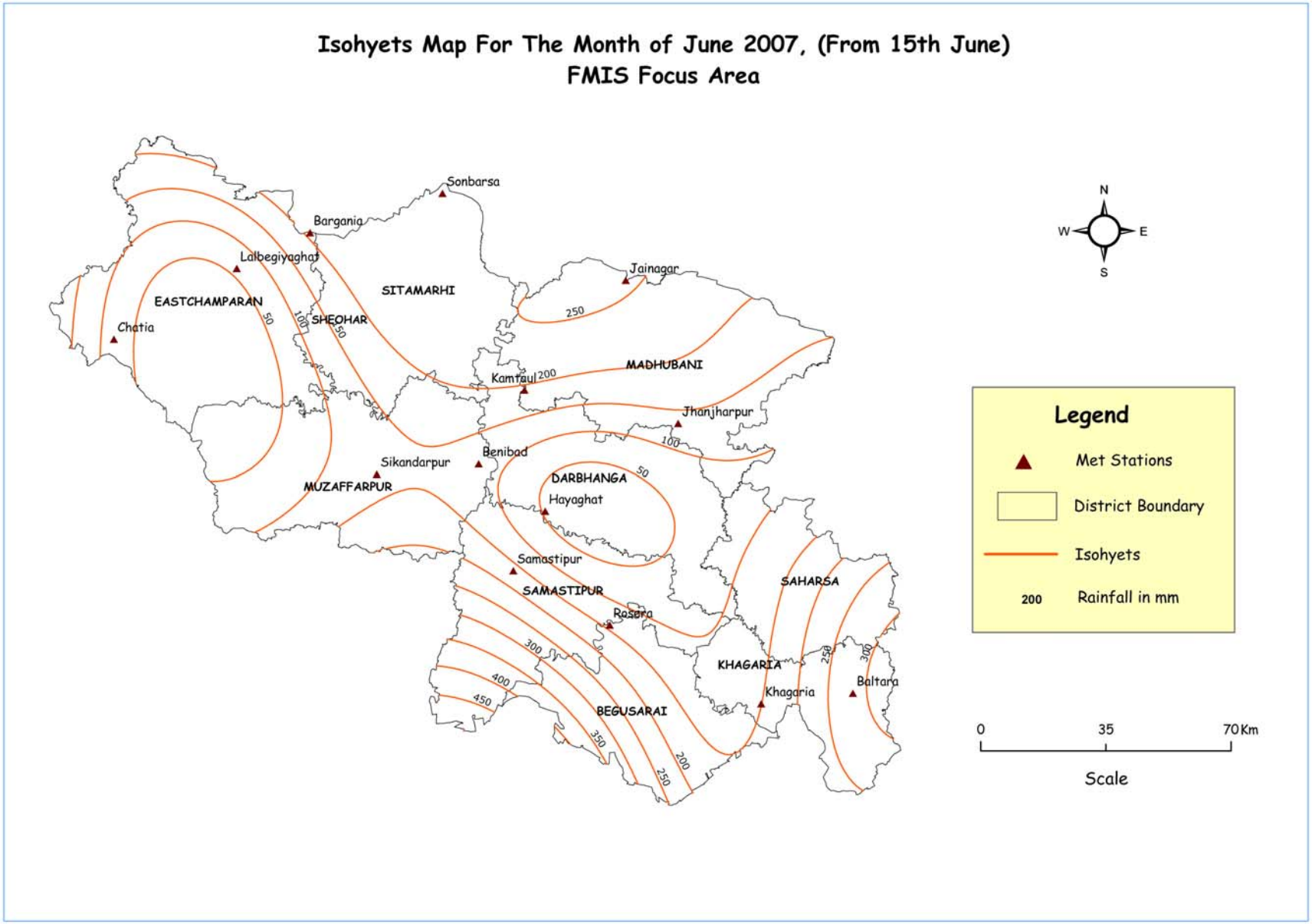
River Basins	Rain-Gauge Stations	Monthly Rainfall					Monsoon 2007		Normal Monsoon Rainfall
		June (from 15th)	July	August	September	October (up to 18th)	Total	No. of rainy days	
1	2	3	4	5	6	7	8	9	10
Burhi Gandak	*Simara*	291.60	862.20	665.70	739.30	27.60	2586.40	64	1497.40
	Lalbegiaghat	61.10	562.40	983.90	572.60	76.80	2256.80	63	
	Sikandarpur	136.40	1023.00	1106.40	1230.08	449.60	3945.48	66	
	Samastipur	165.20	630.20	383.60	542.00	49.80	1770.80	66	
	Rosera	141.00	459.60	394.40	394.20	34.20	1423.40	62	
	Khagaria	149.40	611.50	214.60	309.50	55.60	1340.60	49	
Bagmati	*Kathmandu*	134.00	234.50	226.16	329.70	18.30	942.66	87	1125.60
	Nagarkot	231.40	226.80	353.35	422.60	1.20	1235.35	72	1554.30
	Benibad	125.20	620.20	323.20	530.50	103.00	1702.10	59	
	Hayaghat	46.20	640.50	379.20	691.40	85.80	1843.10	76	
	Kamtaul	193.00	528.00	448.10	422.50	148.90	1740.50	53	
	Sonbarsa	216.20	810.80	509.80	316.00	53.40	1906.20	50	
	Saulighat	NA	NA	577.80	629.60	133.70			
Kamla	Jainagar	253.90	622.40	226.00	245.00	34.60	1381.90	55	
	Jhanjharpur	133.60	544.40	593.70	428.10	25.50	1725.30	64	
Kosi	*Okhaldunga*	140.30	508.90	250.00	420.30	49.80	1369.30	88	1401.60
	Taplejang	109.40	456.10	323.40	305.90	116.60	1311.40	101	1404.60
	Dhankutta	82.10	253.00	93.20	166.00	19.80	614.10	72	722.50
	Biratnagar	211.80	424.10	521.80	375.80	1.60	1535.10	75	1522.50
	Dharan	204.50	573.40	305.50	387.60	145.30	1616.30	88	
	Basua	117.80	397.43	342.50	375.00	10.40	1243.13	64	
	Baltara	285.00	374.40	230.60	243.40	47.00	1180.40	53	
	Kursela	244.00	343.20	197.60	151.60	2.20	938.60	55	
	Birpur	NA	NA	386.20	446.00	6.60			

Notes:
1. Rain-gauge stations written in italics are located in Nepal.
2. Monthly / monsoon rainfall have been calculated using daily rainfall obtained from CWC and Nepal web site www.mfd.gov.np. Underlined figures for Sonbarsa and Jainagar have been taken from Directorate of Statistics.
3. Source of Normal Monsoon Rainfall is the Nepal web site www.mfd.gov.np

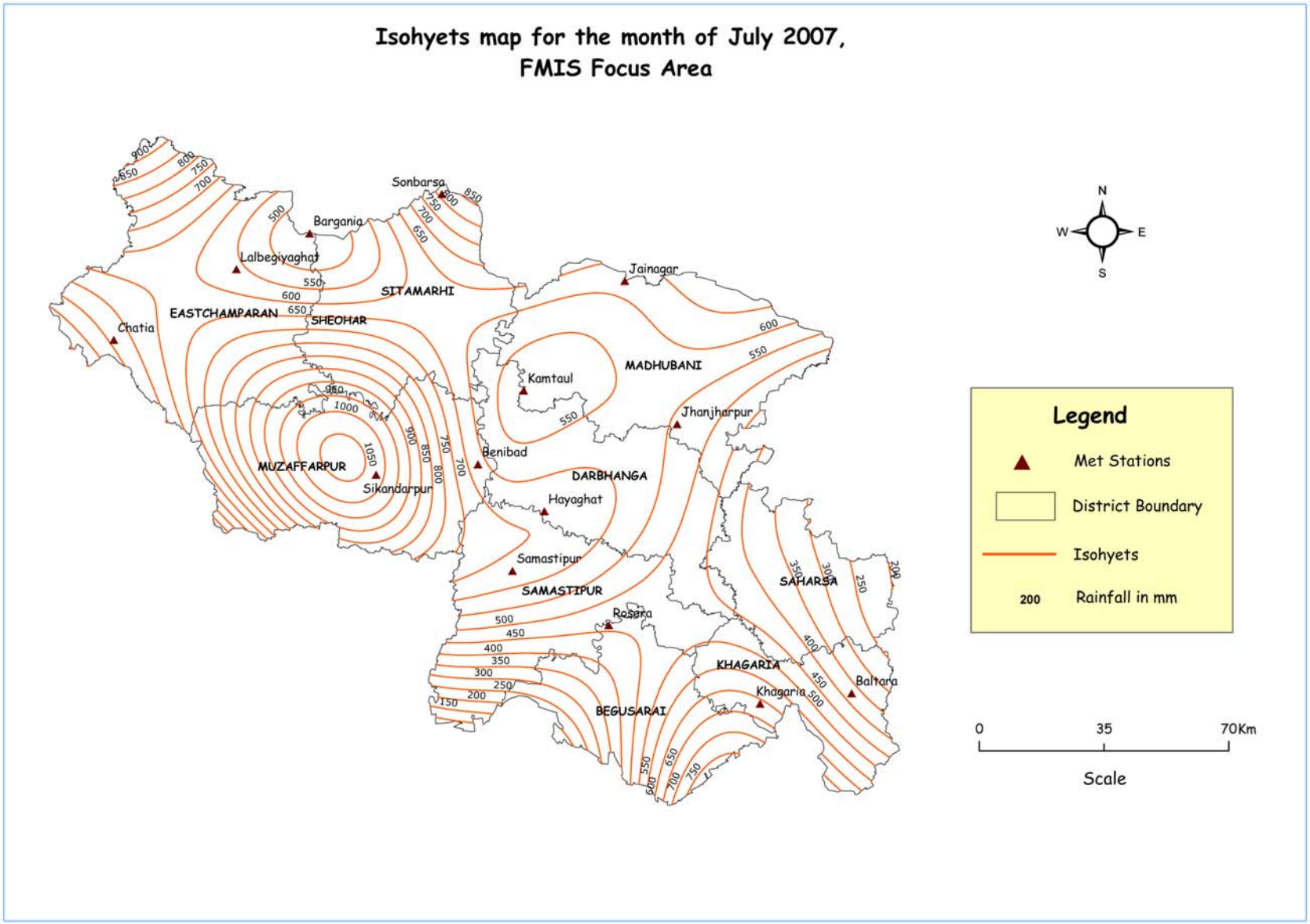
A word of precaution note here is that there have been a few days on which data was not available. Those gaps have not been filled up. So, similar information from the parent source may be a little different.

If we look at the above Table, we find that most of the places have received rainfall on more than 50% days of the monsoon period. Taplejung in Nepal had maximum (101) rainy days. If we compare this monsoon rainfall with the Normal Monsoon Rainfall, it reveals that the monsoon has been more active in the western part of the area (Burhi Gandak basin). Eastern part (Kosi basin) received less than the Normal rainfall. Sikandarpur received 3945.00mm cumulative monsoon rainfall which is more than three times the Normal Monsoon Rainfall of the area. Below are the contours drawn with the rainfall figures given in the above Table. The June rainfall is taken from 15^{th} of the month and the October rainfall is only upto 18^{th} of the month.

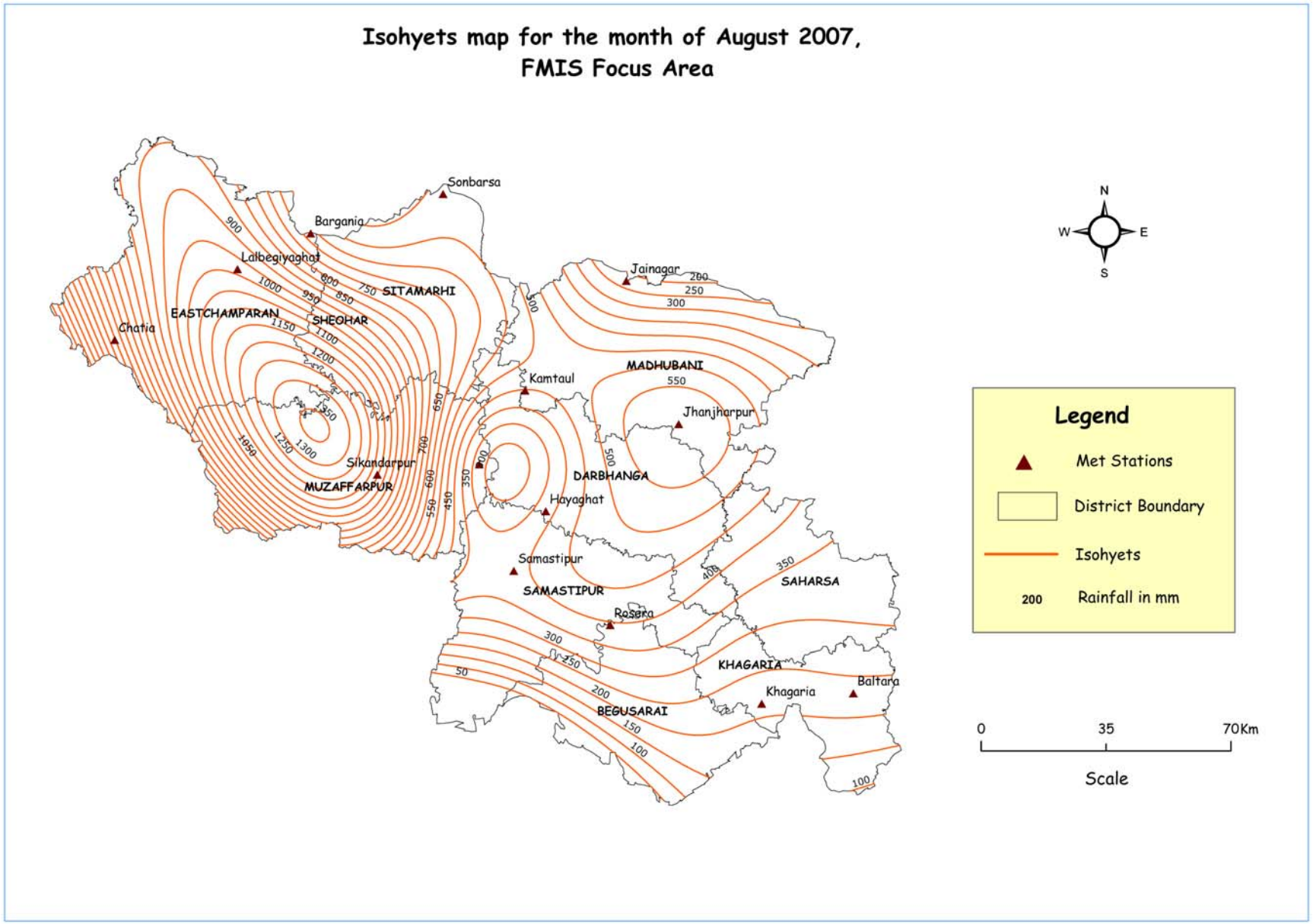
Map 4.2 Isohyets of Rainfall in June 2007 (15th to 30th)



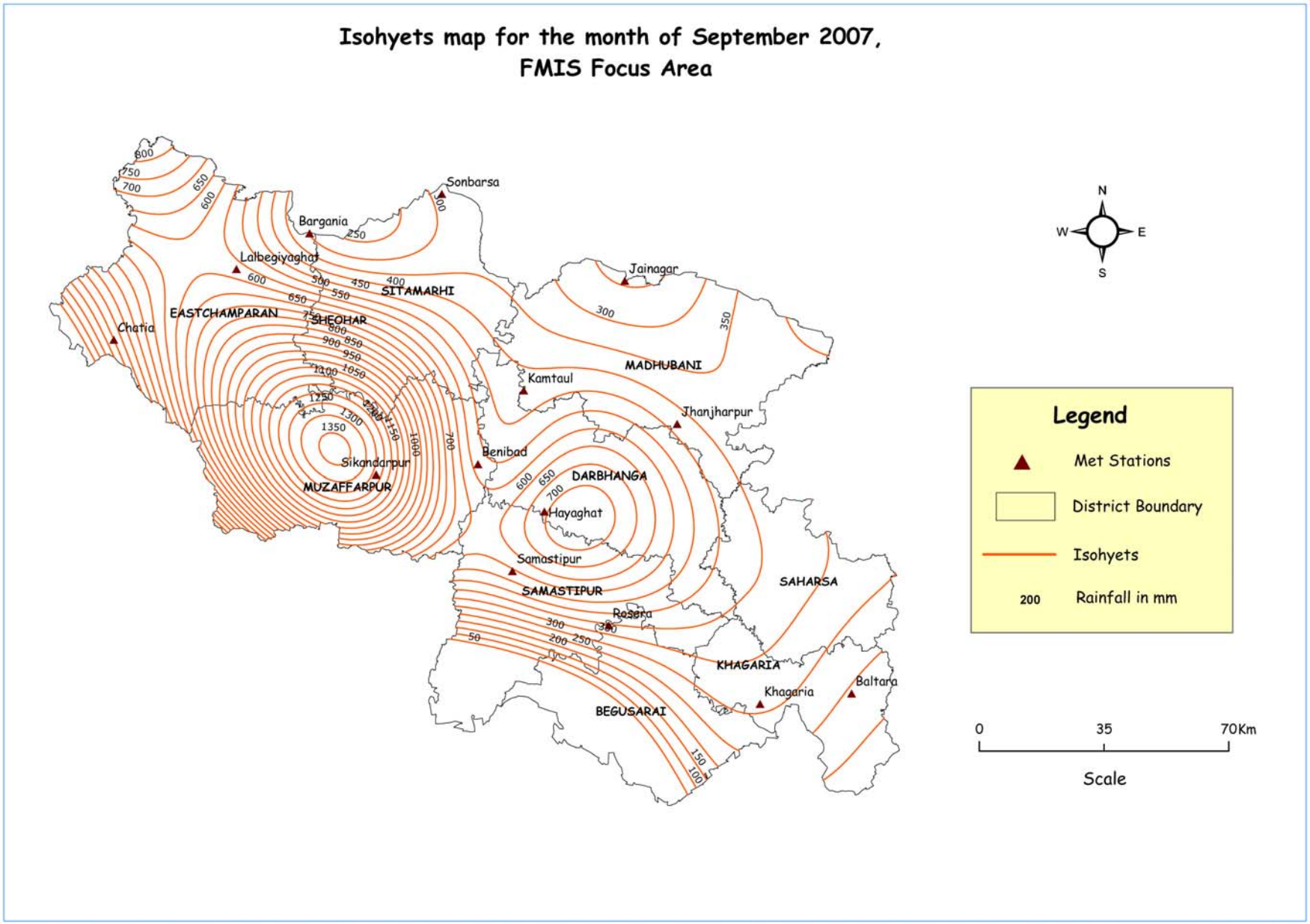
Map 4.3 Isohyets of Rainfall in July 2007



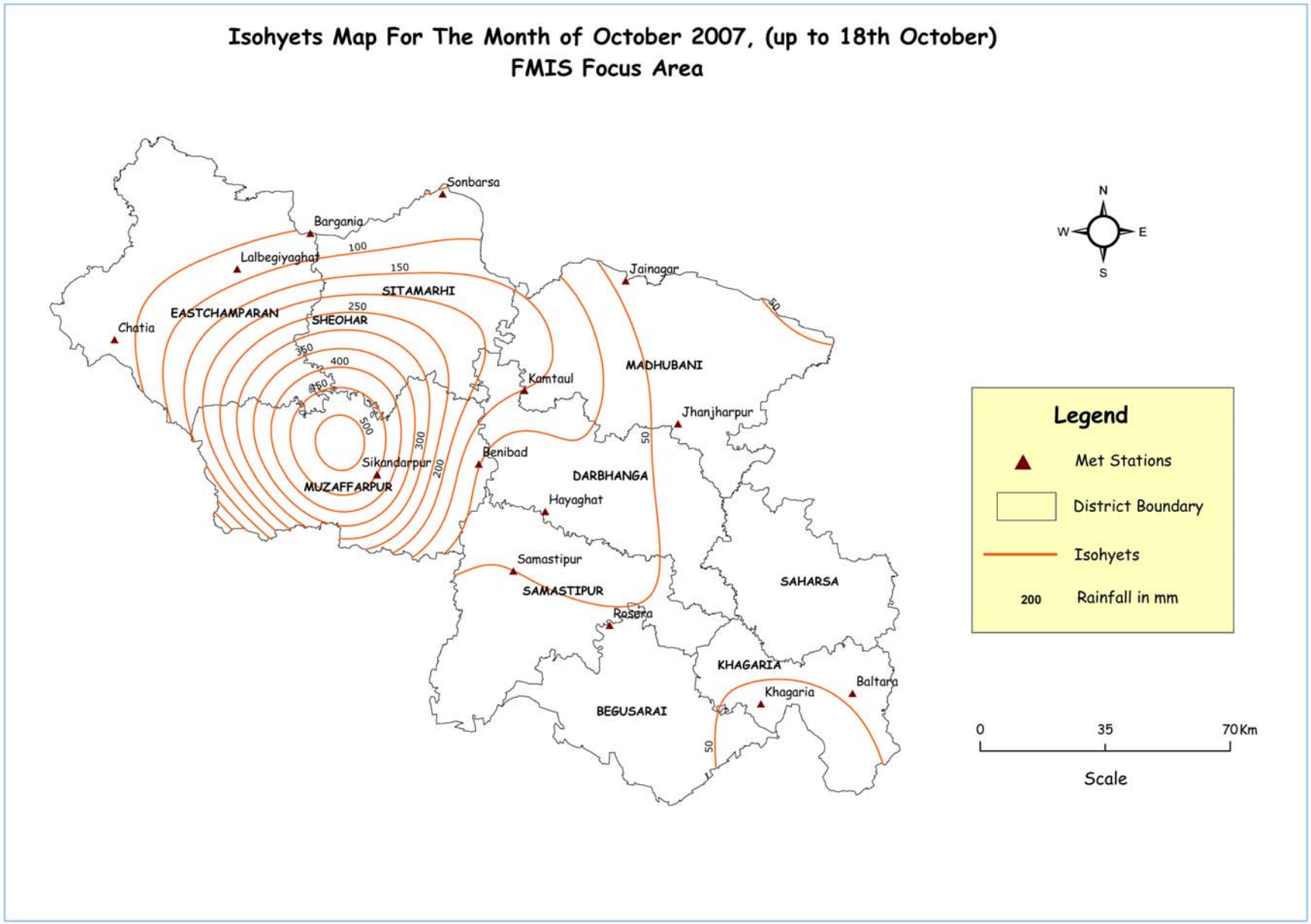
Map 4.4 Isohyets of Rainfall in August 2007



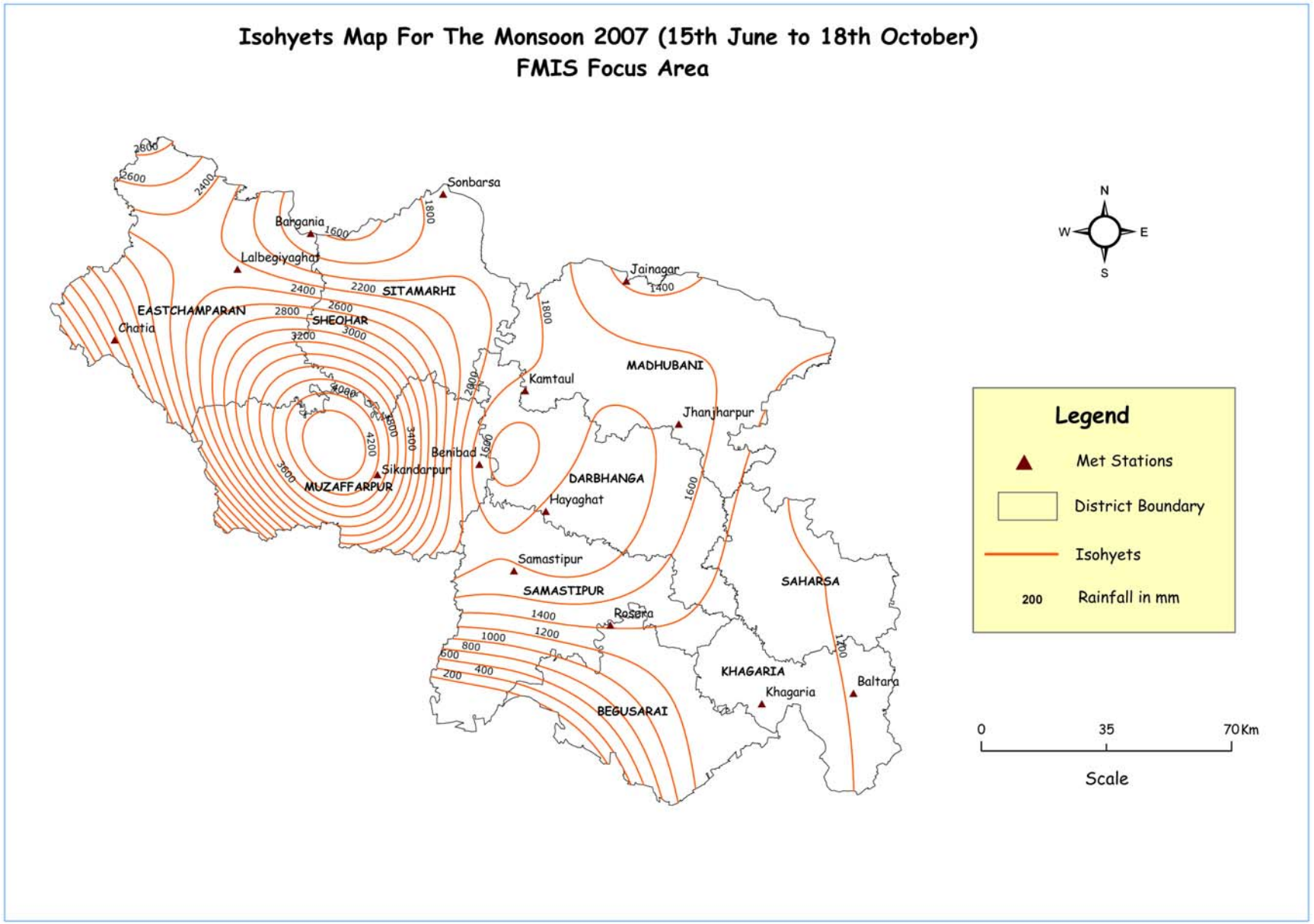
Map 4.5 Isohyets of Rainfall in September 2007



Map 4.6 Isohyets of Rainfall in October 2007 (upto 18th)



Map 4.7 Isohyets of Rainfall in Monsoon Season 2007 (15th June to 18th October)

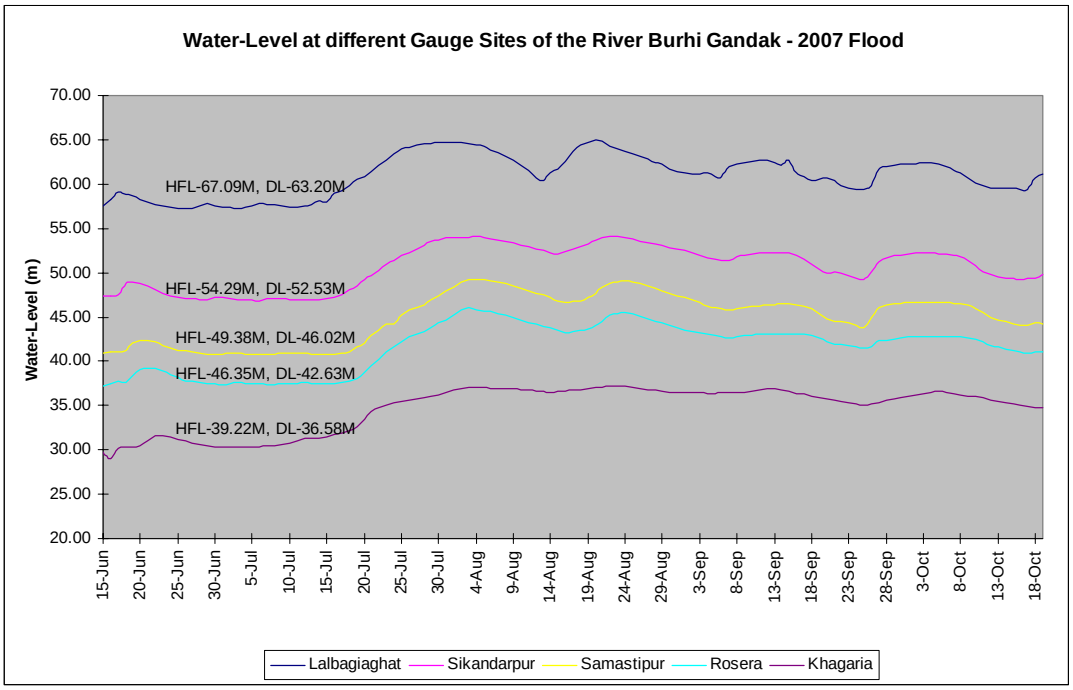


4.2 River Stages

Daily water-levels measured (at 6:00 AM) at different gauge stations on four major rivers of the AOI have been chronologically plotted. They are discussed below.

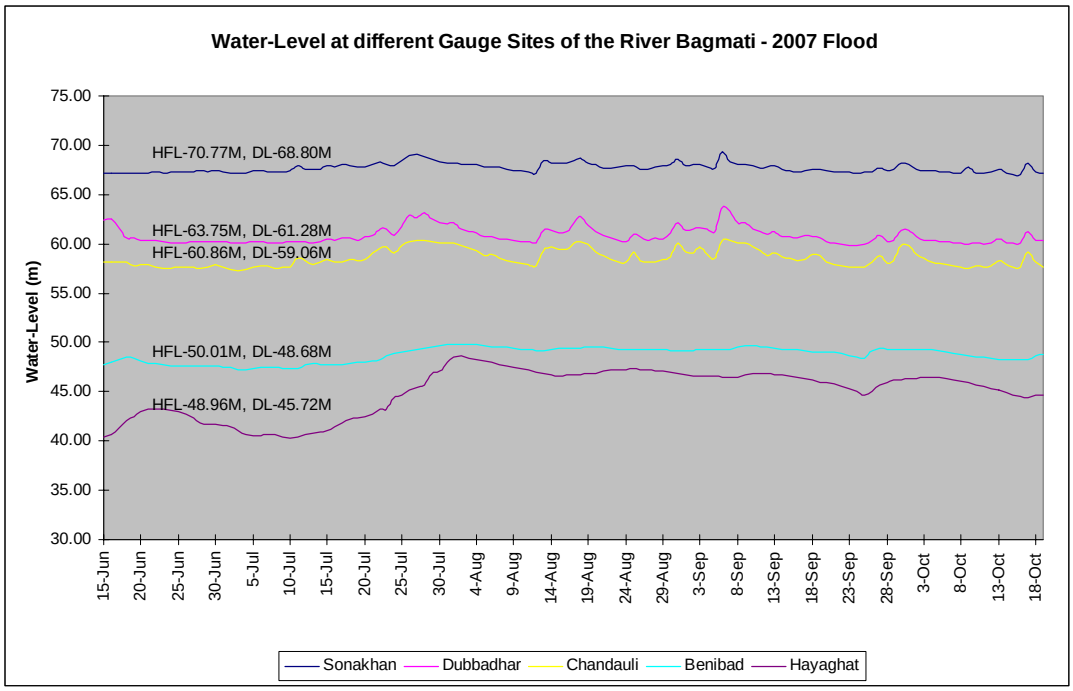
4.2.1 Burhi Gandak

Lalbegiaghat, Sikandarpur, Samastipur, Rosera and Khagaria are five gauge-stations located in sequence from up-stream to down-stream on the river Burhi Gandak. Chronological plot of water-levels at the upper-most station Lalbegiaghat shows sharp peaks and valleys which signifies the quick response of catchments at this location. Gradually the plots at down-stream stations have smoothened. Parallel pattern up to Rosera may be due to insignificant contribution of intermediate tributaries. Khagaria plot is relatively more smooth which may be due to the effect of local run-off and spill of adjoining rivers.



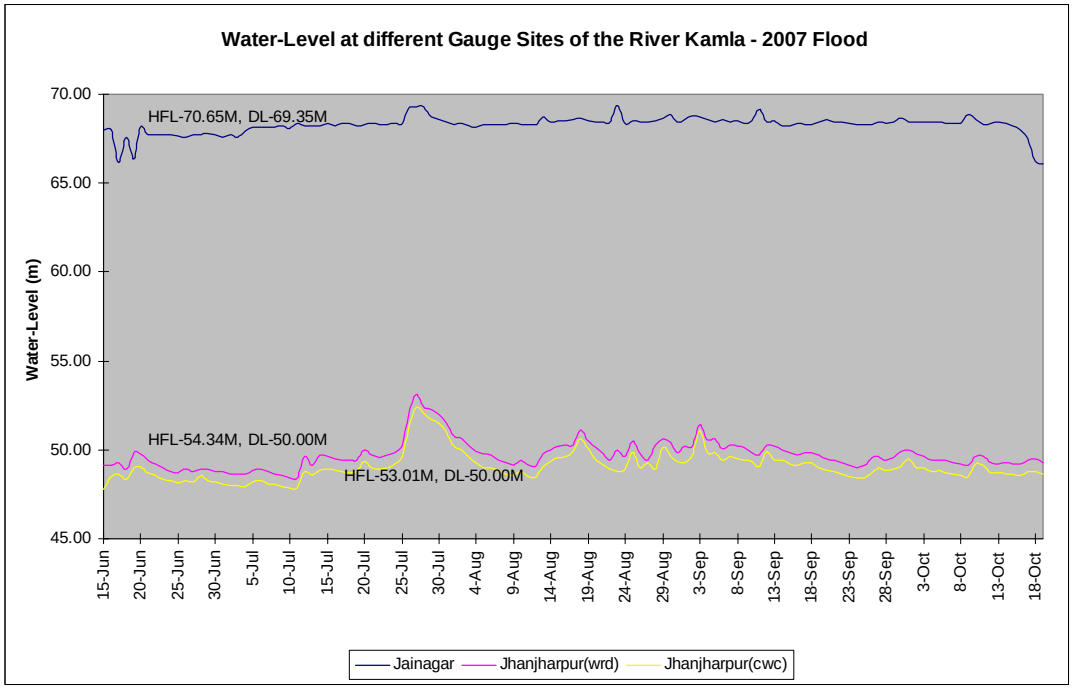
4.2.2 Bagmati

Sonakhan, Dubbadhar, Chandauli/Kansar, Benibad and Hayaghat are five gauge-stations located in sequence from up-stream to down-stream on the river Bagmati. Chronological plot of water-levels at the upper stations shows less rise and fall at Sonakhan in comparison with that at Dubbadhar and Chandauli. At Benibad plot is much smooth which may be due to the routing effect as well as run-off contribution of tributaries. The nature of Hayaghat plot is quite different which shows the effect of major tributary-Khiroi.



4.2.3 Kamla

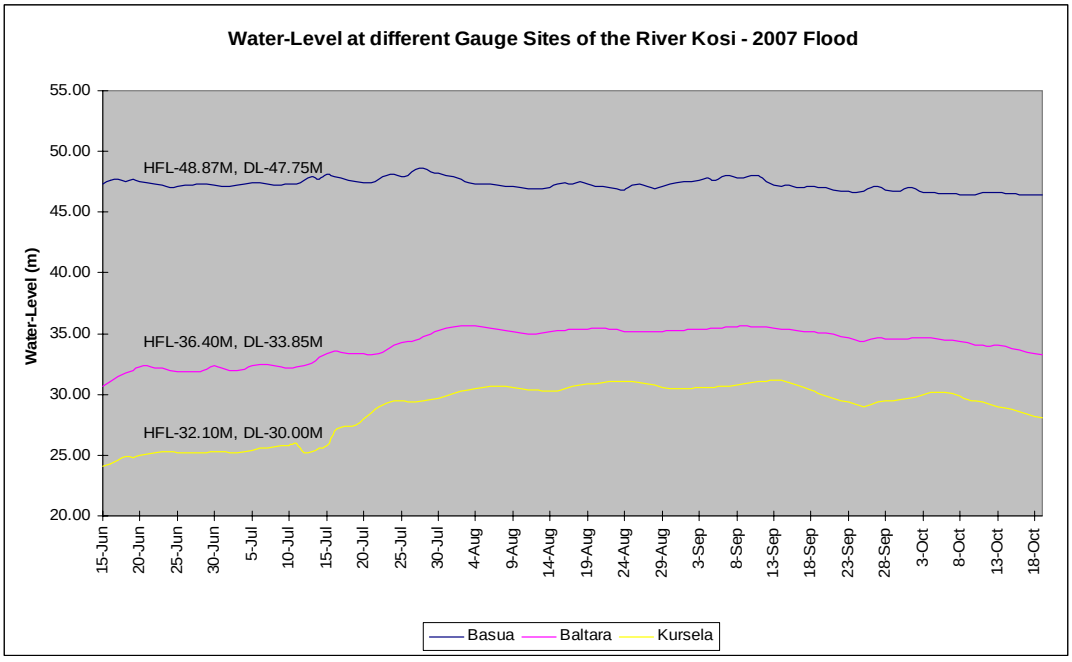
Jainagar (weir site), Jhanjharpur railpul (maintained by WRD), and Jhanjharpur (down-stream maintained by CWC) are three gauge-stations located in sequence from up-stream to down-stream on the river Kamla.



Chronological plot of water-levels at these stations shows that Jainagar plot has small rise and fall. This may be due to the effect of gate operation of Jainagar weir. Water-level pattern at u/s and d/s of Jhanjharpur railpul is quite parallel. Average afflux of 0.63m has been observed during the flood season 2007 with a maximum of 1.33m and minimum of 0.11m. Water-level fluctuation is more at Jhanjharpur than that at Jainagar which seems the effect of intermediate tributaries.

4.2.4 Kosi

Basua, Baltara, and Kursela are three gauge-stations located in sequence from up-stream to down-stream on the river Kosi. Chronological plot of water-levels at these stations shows that Basua plot is rougher in comparison with that at Baltara. The magnitude of rise and fall at Basua is less than that at Baltara. Smooth pattern of Baltara plot may be attributed to the large storage capacity of channel between Basua and Baltara. Water-levels at Kursela seem to be effected by the flow of Bagmati tributary.



4.3 Effect of rainfall in the Nepal region on the river-stages in Bihar

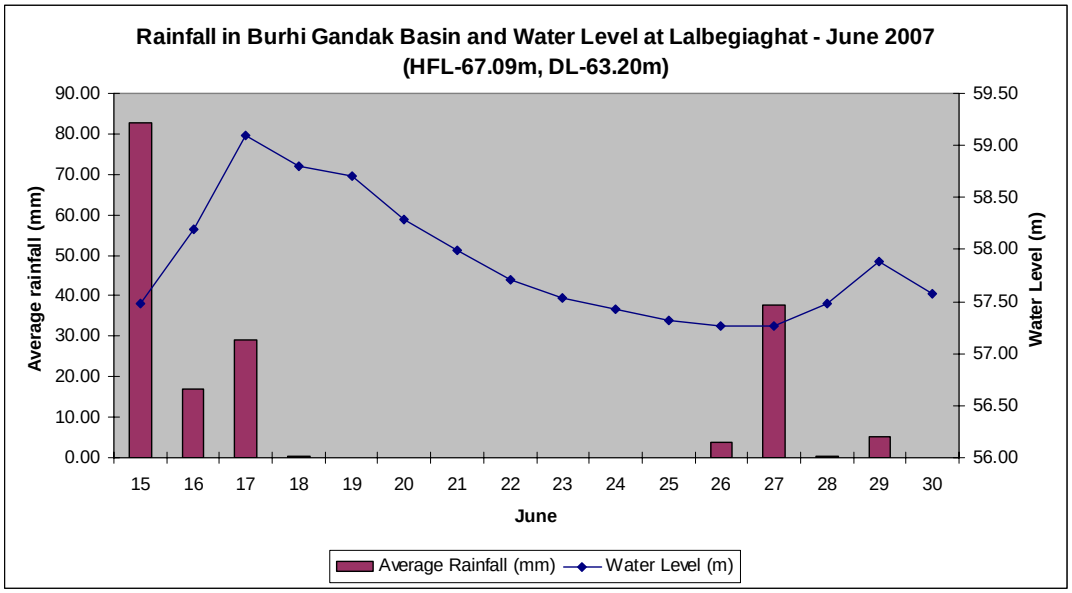
River gauge stations in AOI close to the Indo-Nepal border are Lalbegiaghat on Burhi Gandak, Sonakhan on Bagmati, Jainagar on Kamla and Basua on Kosi. Daily river water levels measured at these stations vis-a-vis daily average rainfall of the respective basin above these locations have been plotted on the same charts. Rain-gauge stations considered for averaging are as follows:

Name of basin	Part under consideration	Rain-gauge stations considered for averaging
1	2	3
Burhi Gandak	Up to Lalbegiaghat	Simara, Lalbegiaghat
Bagmati	Up to Sonakhan	Simara, Kathmandu, Nagarkot, Garuda
Kamla	Up to Jainagar	Janakpur, Sindhuli, Okhaldunga
Kosi	Up to Basua	Okhaldunga, Taplejang, Dhankutta, Biratnagar, Dharan, Basua

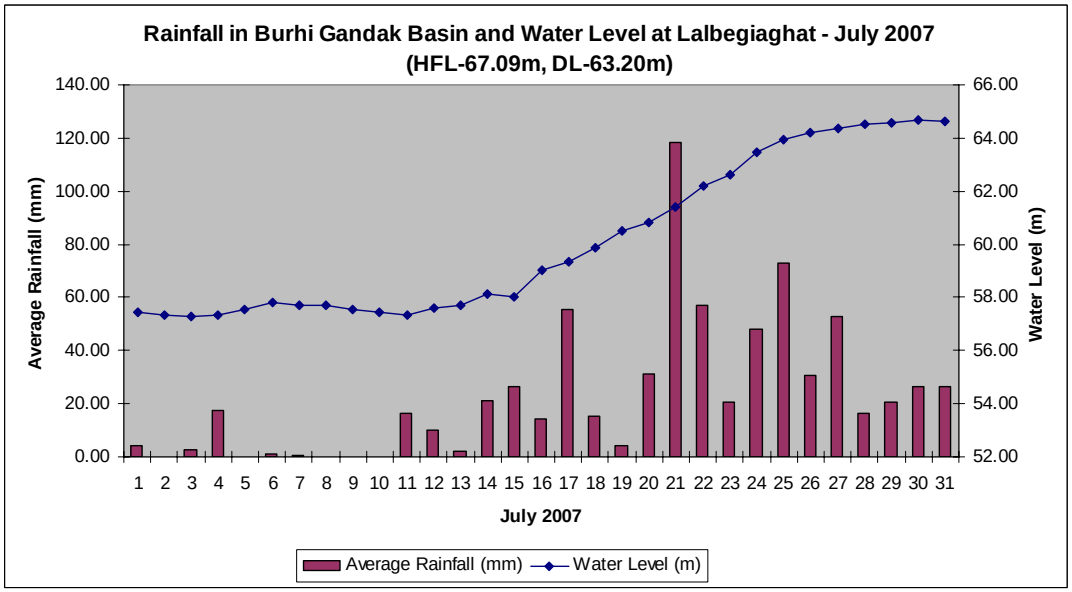
Number of rain-gauge stations is too less to account for the aerial variability of rainfall. Therefore, in stead of using rigorous methods simple arithmetic mean has been used for averaging the rainfall. Basin wise rainfall pattern and corresponding water level are discussed in the following paragraphs.

4.3.1 Burhi Gandak

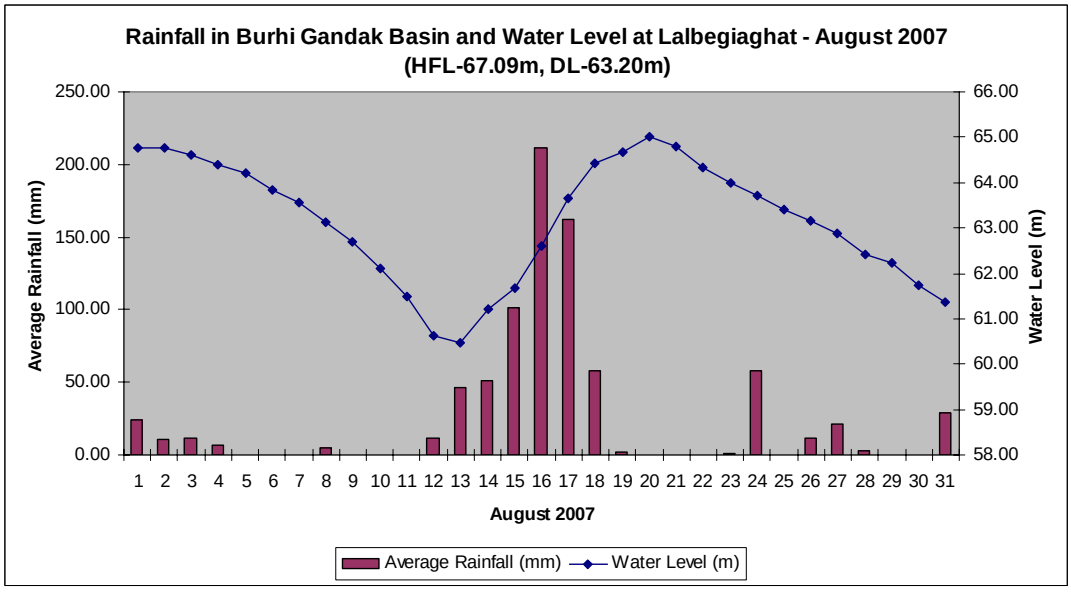
Big spell of rainfall (average 82.70mm) was observed on the very first day of the flood season (15th June to 15th October). The river rose from 57.48m on 15th to 59.10m on 17th in June. This followed continuous receding till 27th when an average rainfall of 37.60mm caused further rise for two succeeding days.



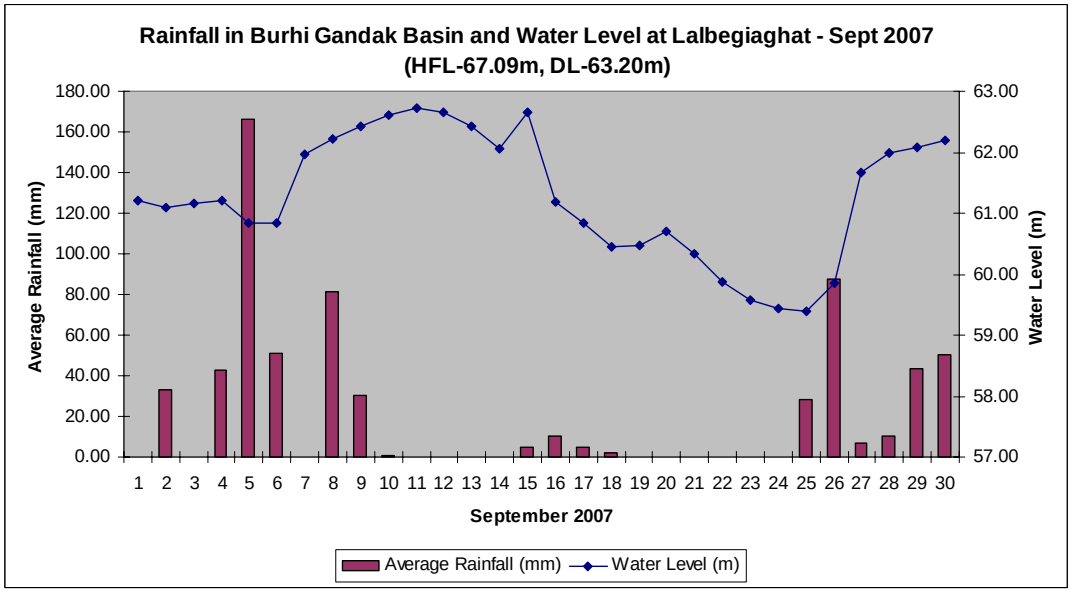
Then continuous rainfall took place from 11th July to 4th August during which river water level continuously rose from 57.34m to 64.75m.Maximum average rainfall of 118.20mm during this period was observed on 21st July. Water level started receding on 2nd August and continued till 13th August when it reached 60.46m.



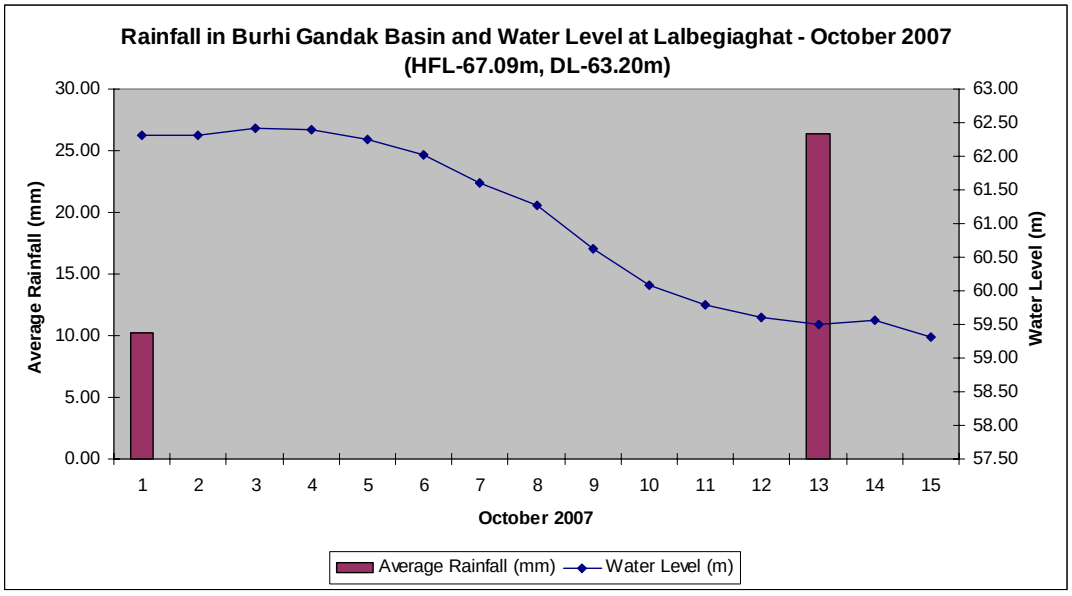
An isolated heavy storm took place between 12th to 19th August. Average value was 11.7mm on 12th August, it continuously increased and maximum of 211.40mm was observed on 16th , then started decreasing and a minimum of 2.10mm was observed on 19th. This resulted in steep rise in the river water level from 60.46m on 13th to 65.01m on 20th August. In September, three spells of rainfall of relatively low magnitude occurred when average daily rainfall was less than 100mm except on 5th September (when it was 166.10mm). This caused several rise and fall in river water level. Maximum was 62.73m on 11th and minimum 59.40m on 25th September.



Three steep rises were marked on 6-7, 14-15 and 26-27 September. A steep fall was also observed on 16-17 September. It is difficult to justify the steep rise of 14-15 as the rainfall on the preceding days is nil. There might be a high rainfall concentrated in small area which could not be noticed by the two rain gauge stations.

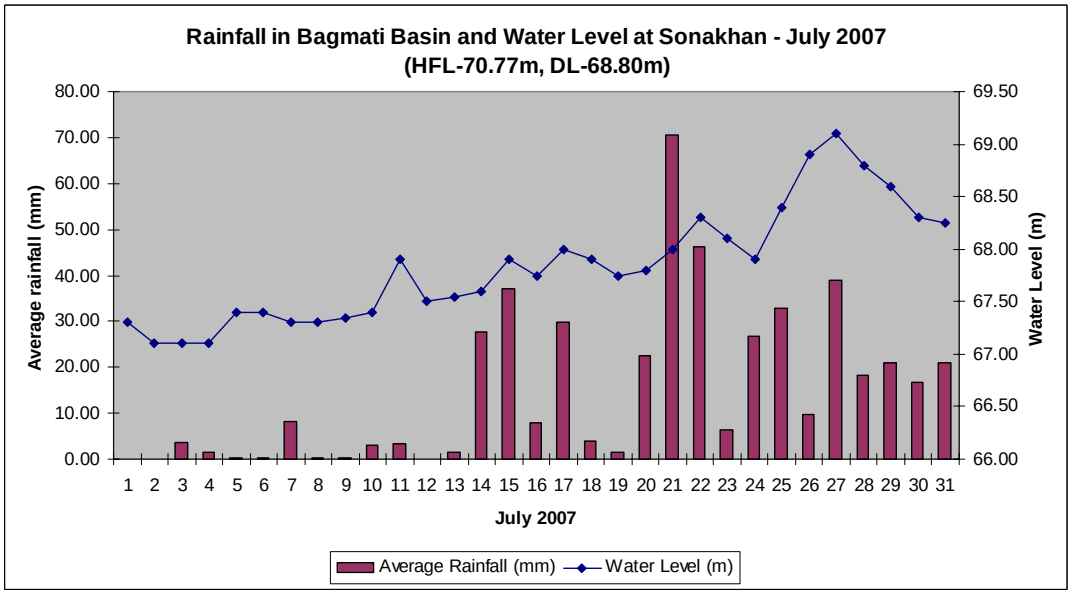


Last of three spells ended on 1st October. Thereafter only one rainy day on 13th was observed till 15th October. This did not have any noticeable effect on the river water level. Water level observed on 15th October was 59.31m.



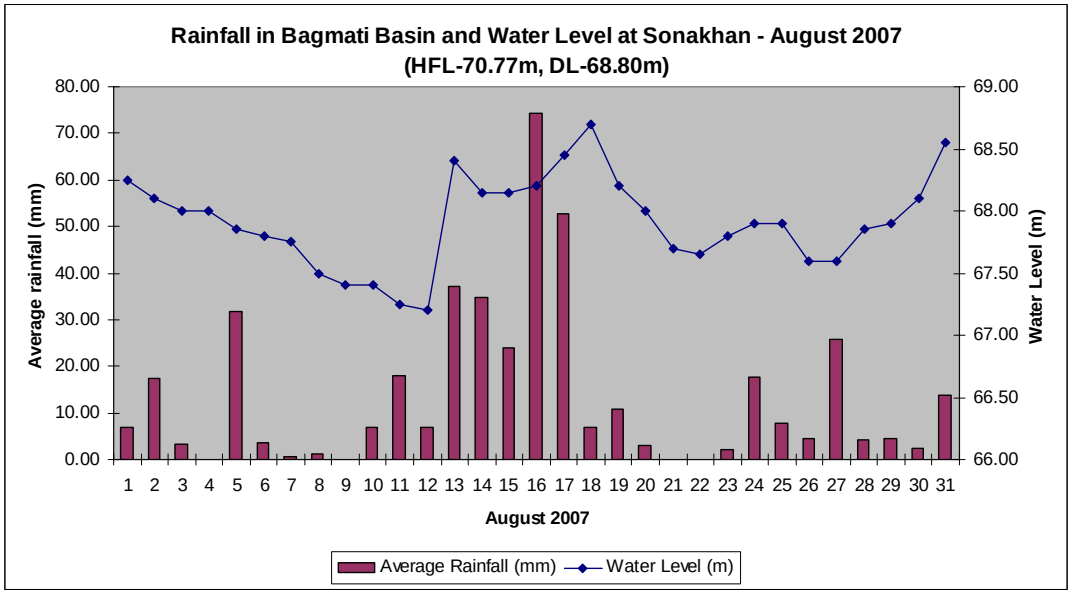
4.3.2 Bagmati

Like Burhi Gandak basin, Bagmati also received good amount of rainfall (average 65.5mm) on 15th June (first day of the monsoon season) which is reported to have caused sudden rise in the water level and consequent damage. There was continuous rainfall from 23rd to 28th June, maximum being 78mm on 25th. River water level at Sonakhan is available from 23rd only which shows slow but continuous rise in the month of June from 67.20m to 67.40m.

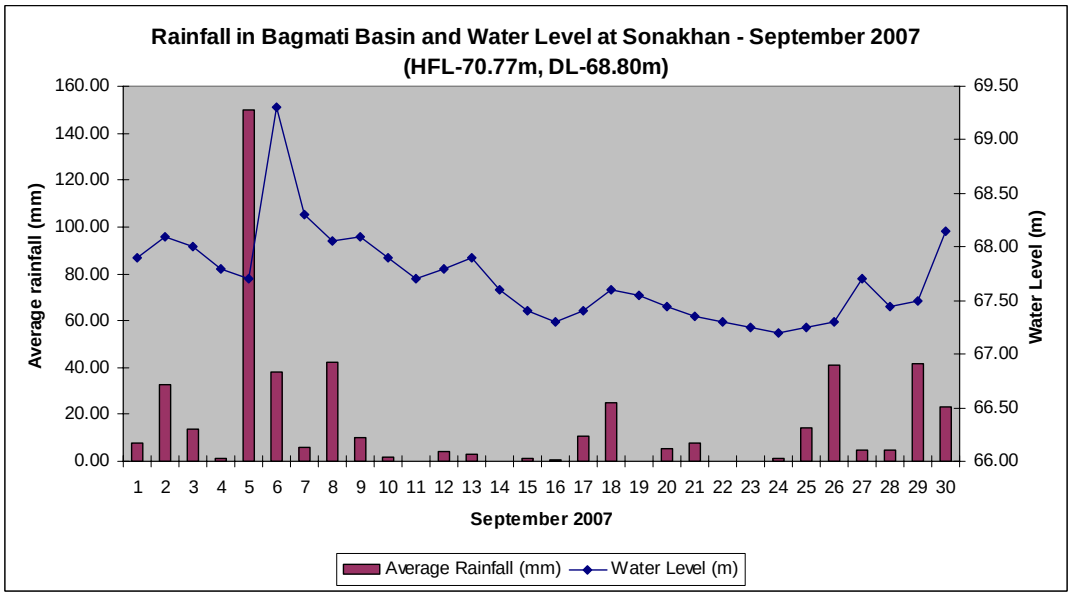


In July, there has been regular rainfall (28 rainy days) which kept the river water level continuously rising. Maximum average rainfall of 70.50mm was observed on 21st. Rise

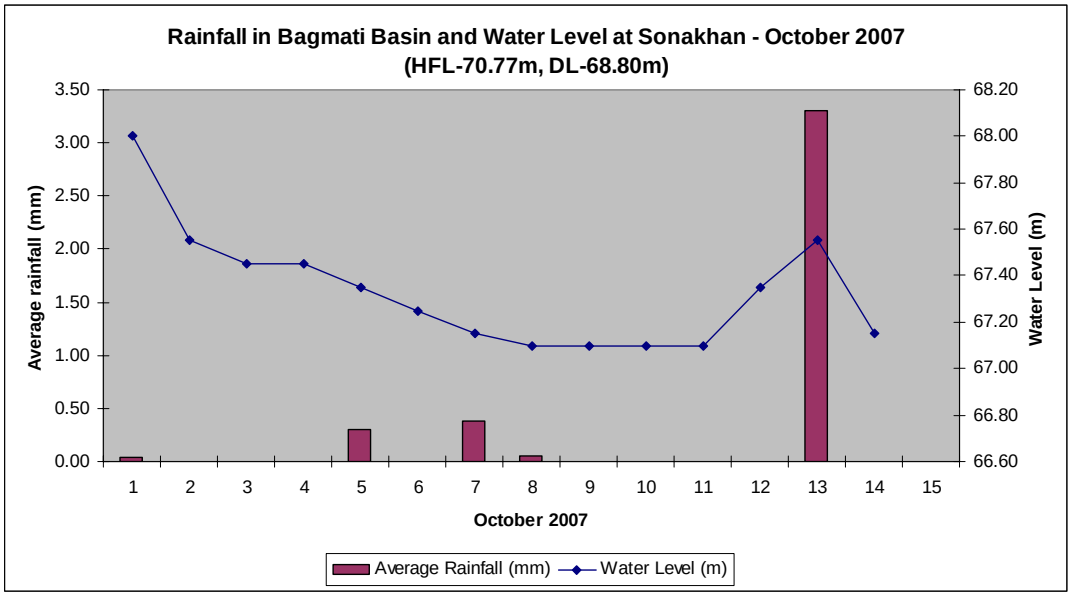
was steep from 27th to 29th when level went from 67.90m to 69.10m. It is interesting to note that most of the time effect of rainfall has been observed on the same day.



In August also, there has been regular rainfall with 27 rainy days. However, rainfall from 10th to 20th August has resulted in significant rise in water level. On 12-13 level rose from 67.20m to 68.40m and on 18th it reached to 68.70m. Again it is interesting to note the rise from 67.60m on 27th to 68.55m on 31st when the rainfall observed was quite low. In September, maximum average rainfall of 149.73mm (season's maximum) was observed on 5th which caused steep rise in water level from 67.70m on 5th to 69.30m on 6th. During the rest of the month, rainfall was low and the water level decreasing except the last week when slight rise was marked.

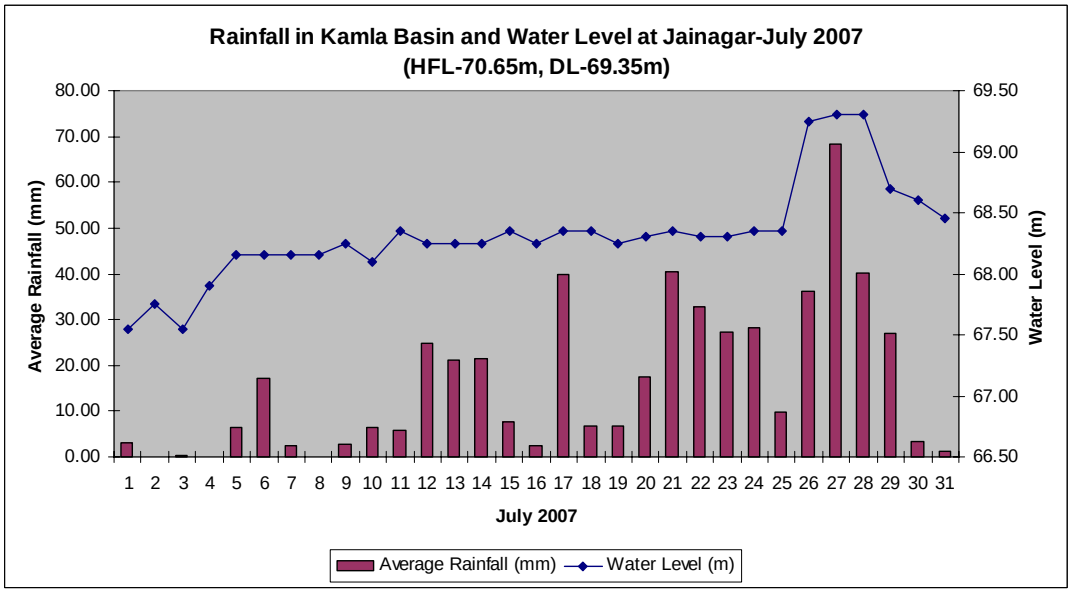


In October there was almost no rainfall up to 15th, however, rise in the water level of 0.45m was observed on 11-13th. It seems four rain gauge stations could not capture the rainfall occurred in some pockets.

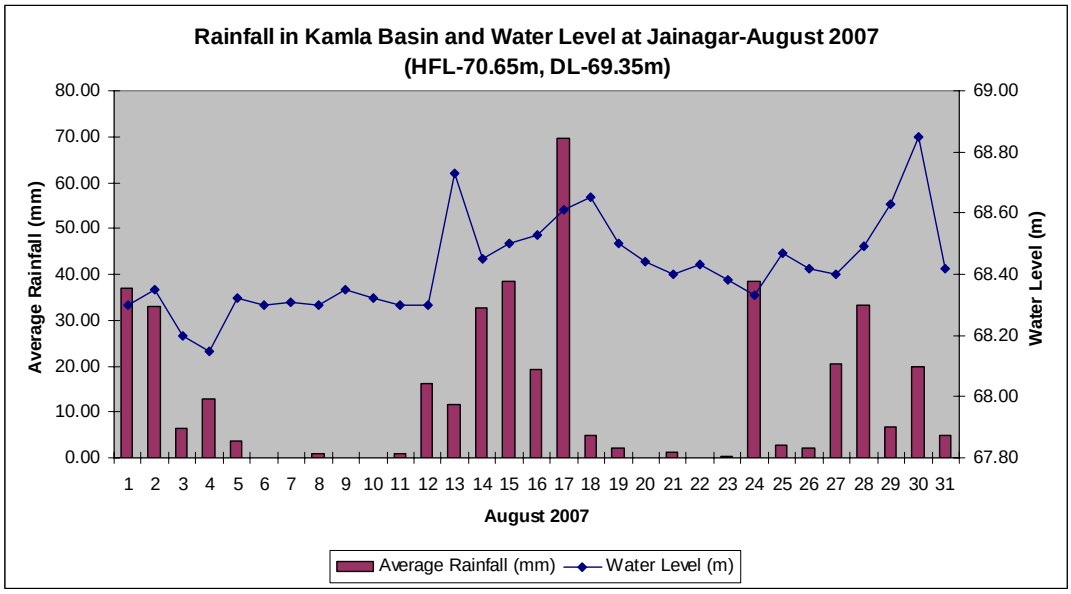


4.3.3 Kamla

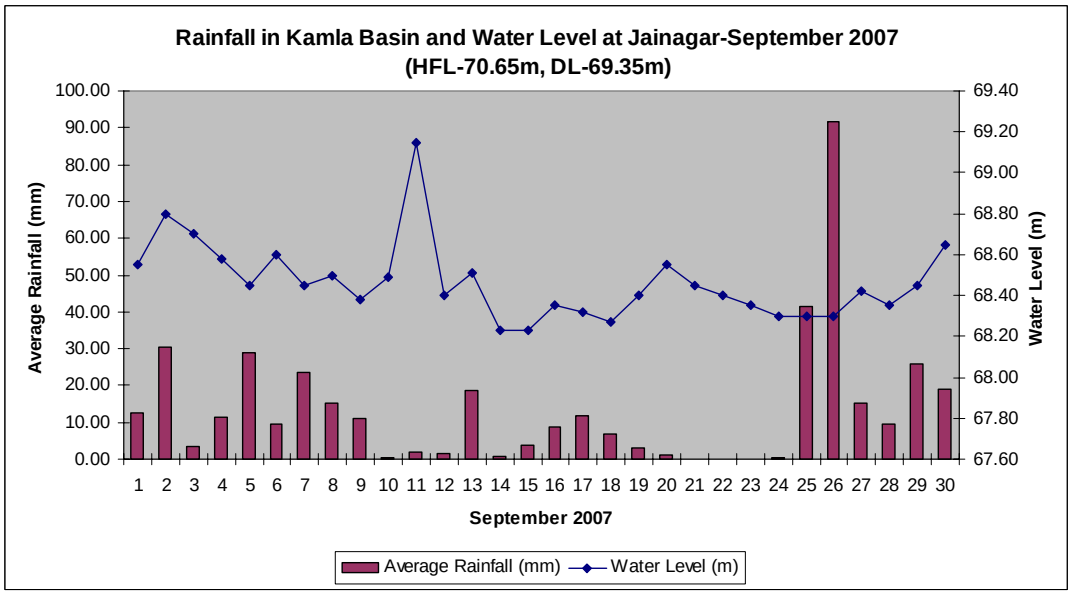
First rainfall of high magnitude was observed on 16th June which was swayed to Bihar portion. At Kamtaul 144mm and at Okhaldunga 29mm rainfall was observed. There was 27 rainy days in July. Maximum rainfall of the month (average daily rainfall of 68.25mm) was observed on 27th. A rise in water level of 0.60m was observed between 3rd to 5th and 0.90m between 25-26th. It is interesting to note that there was no significant rainfall preceding these events. Water level was almost static between 5th to 25th .



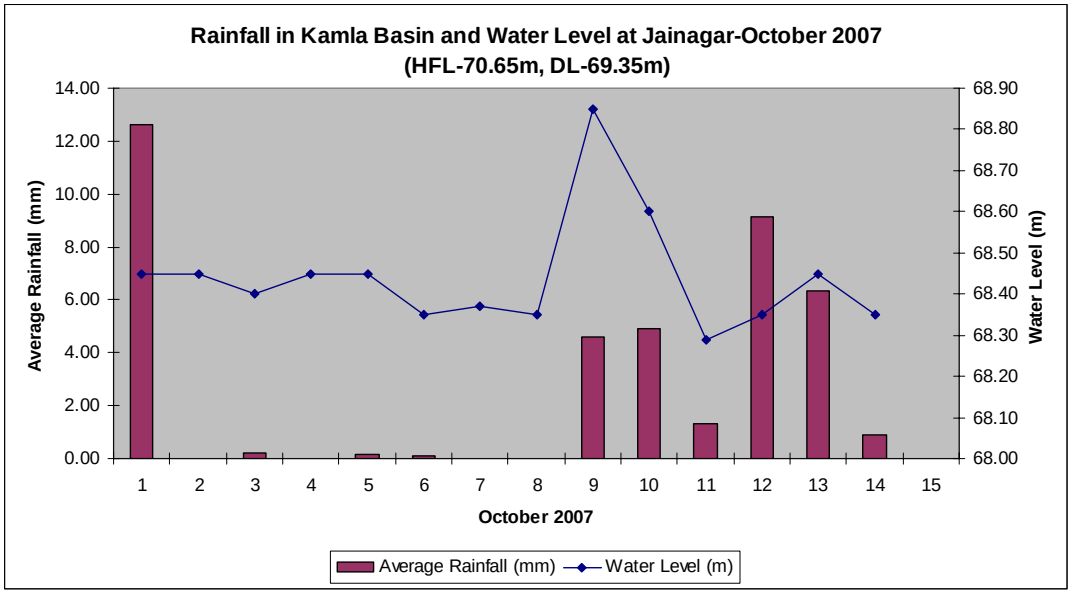
In August three isolated storms can be identified in the following plot. Maximum daily rainfall was observed on 17th. Steep rises of water level between 12-13th and 27-30th are not commensurate with the rainfall observed. The rainfall of 17th is also not reflected in the rise of water level.



Similar is the story of September. Steep rise of water level on 10-11th is not matching with the observed rainfall. High magnitude rainfall of 26th is not adequately felt in the rise of water level.

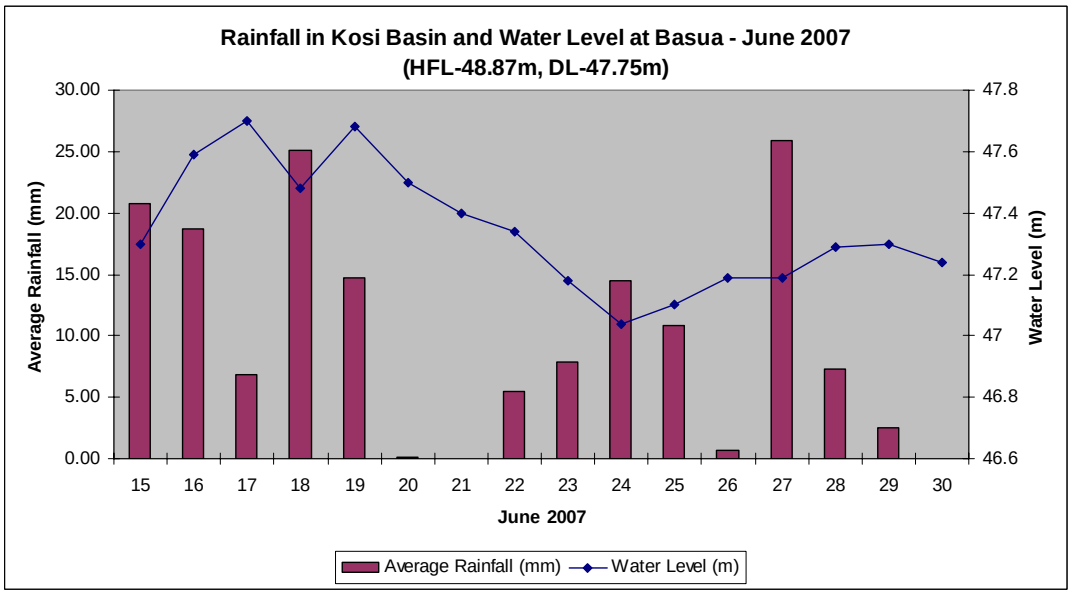


October received quite low rainfall. Steep rise in water level observed on 8-9th does not match with the rainfall occurred.



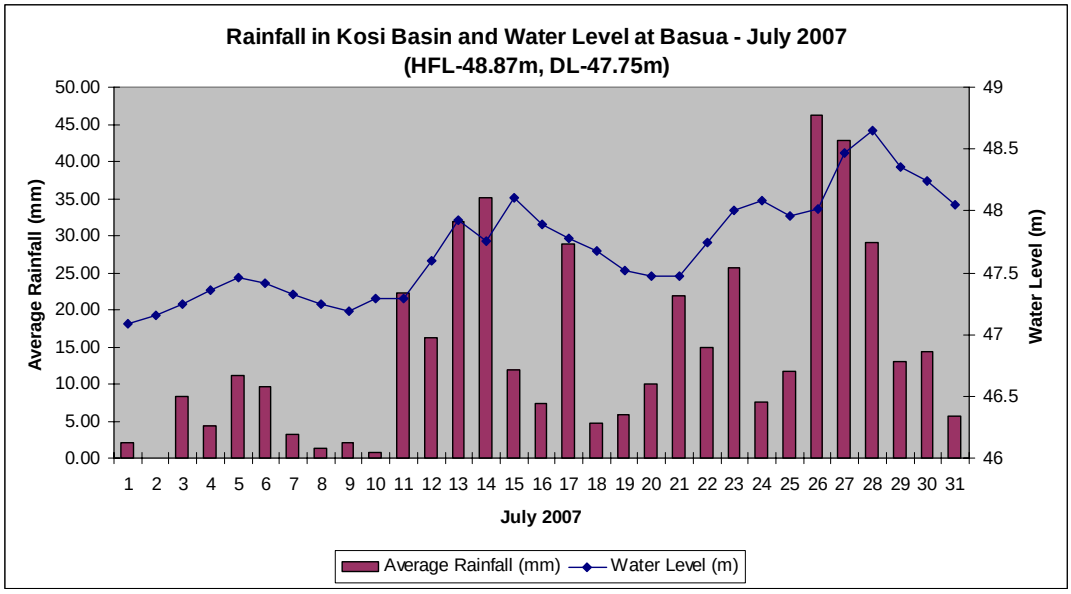
4.3.4 Kosi

From June 15th almost every day some rainfall has been observed. Early rise in water level was marked which followed a recession after 19th.

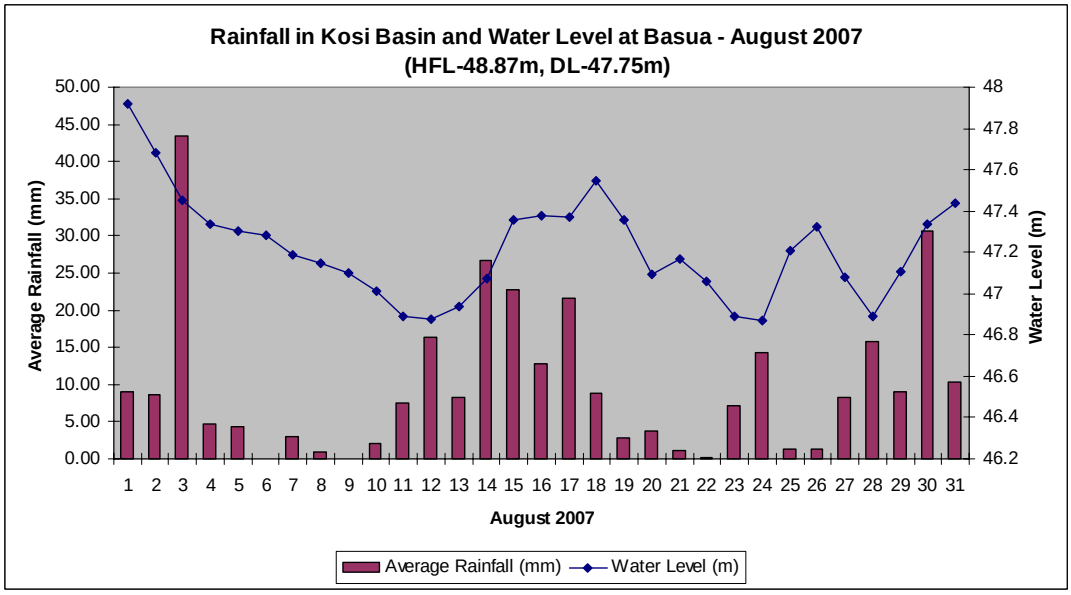


July has been a completely wet month observing 30 rainy days. Maximum average rainfall was observed on 26th. Water level appears rising and falling following the pattern

of rainfall except a few instances like drop in water level on 13-14th. Rainfall of 17th also does not get reflection in water level.

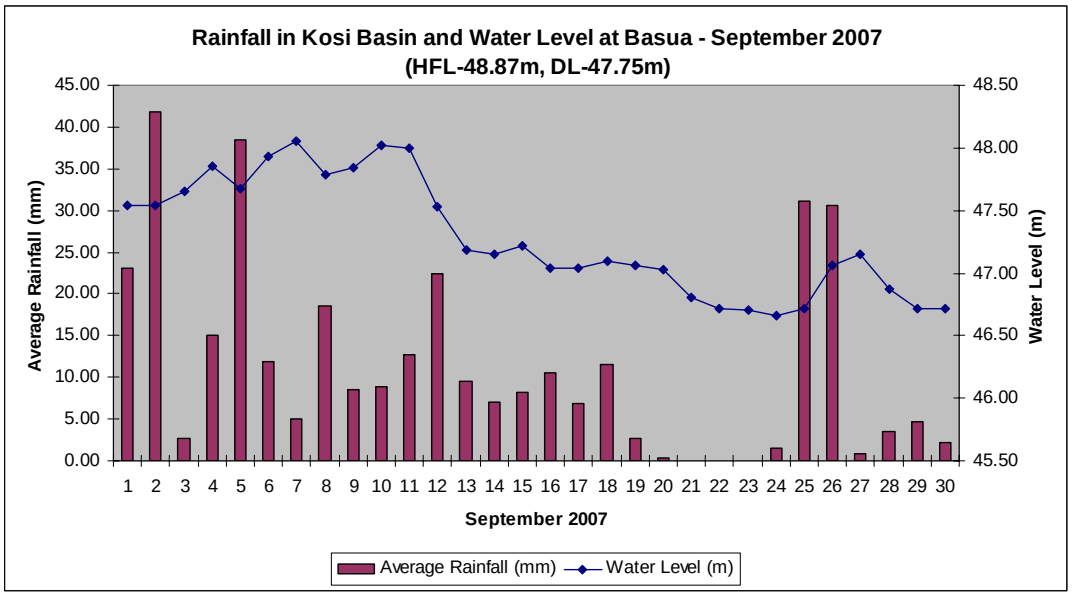


August rainfall pattern shows three different storms of low magnitude to have occurred. There was continuous drop in water level during the first 12 days, however, the rate of drop seems to have slowed down by the rainfall of 3rd August. Water level follows the rainfall but they don't appear in good correlation.

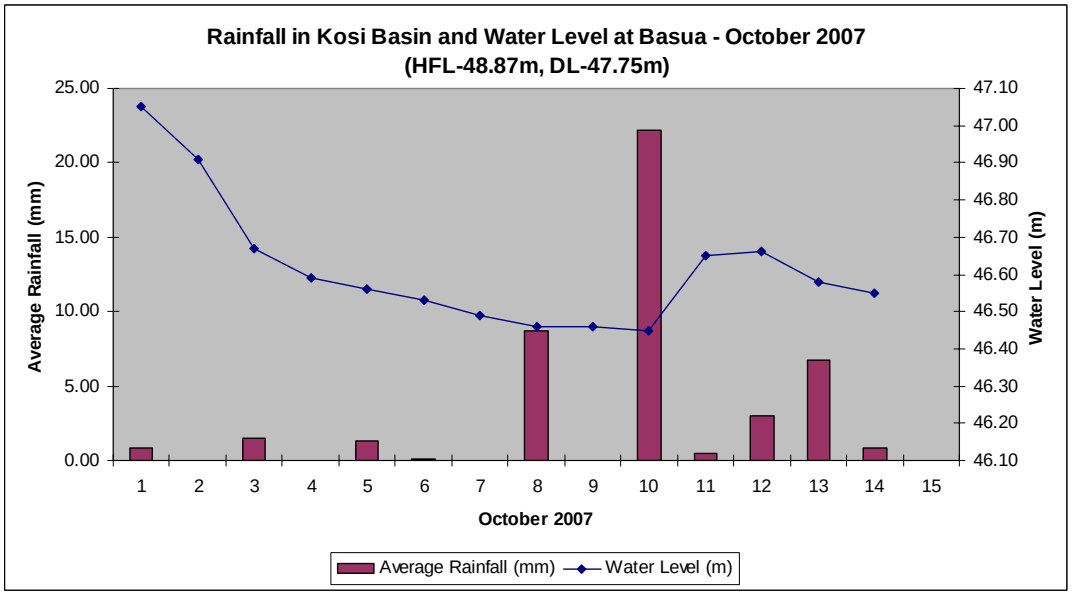


September observes continuous but low magnitude rainfall up to 20th. Thereafter, some considerable amount of rainfall occurred on 25th and 26th which caused rise in water level

making a peak on 27th. Steep drop in water level between 11-13th is not supported by the rainfall pattern.



Rainfall in October has been negligible. Only rainfall of about 22.00mm on 10th caused some rise in water level, otherwise it has been continuously decreasing with minimum on 10th.



4.3.5 Conclusions

1. Water level doesn't seem to have systematic relationship with average rainfall. The possible reason may be inadequacy of number of rain gauge stations used to compute average rainfall. The available rain gauge stations are too less in number to capture the spatial variability of rainfall. Secondly, arithmetic mean doesn't hold good in hilly terrain. Isohyetal method with adequate number of rain gauge stations may improve the result.

2. Rainfall - water-level relation is also bound to be affected by the control structures present up stream of the gauge site on the river Bagmati, Kamla and Kosi.

3. At Lalbegiaghat, Sonakhan, Jainagar and Basua lead time appears to be one day to two days. We can have more precise lead time if we use hourly or two-hourly data series in the analysis.

4.4 Rainfall Forecasts

Under a memorandum of understanding signed between FMISC, Bihar and IMD, New Delhi, the IMD has been providing rainfall forecast for an area between latitude 25.53^{o}N to 28.77^{o}N and longitude 83.24^{o}E to 88.50^{o}E. This area entirely covers the AOI, catchments area of all rivers lying in Nepal and some adjoining area in Bihar as well as Nepal. The forecasts were done using MM5 model for each 45km grids, total 140 numbers of grids covering the area. It was done every day for the next three consecutive days separately i.e. three 24-hr cumulative forecasts for day1, day2 and day3. Thus for each day 3 forecasts were available – 1st, 72 hrs in advance, 2nd, 48 hrs in advance and 3rd, 24 hrs in advance. The 3rd one was supposed to be based on more recent weather conditions hence, more accurate. With 24-hr cumulative forecasts 6-hr cumulative forecasts for the same three consecutive days were also made available.

Maximum value of forecasts for each four river basins of the AOI were extracted and provided in the Daily Flood Information Bulletin issued from the FMISC. These forecasts were used to enquire the availability of satellite images with NRSA, Hyderabad on the days likely to have critical rainfall.

Validity of the rainfall forecasts has been an issue. 45km grid size is too coarse to compare its forecast with any point observation within the grid. IMD also has a plan to provide forecasts for 5 km size grids in place of 45km from the next monsoon. It is hoped that with reduced size of the grid, improved forecasts will be available.

4.5 Satellite based analysis of Flood impact

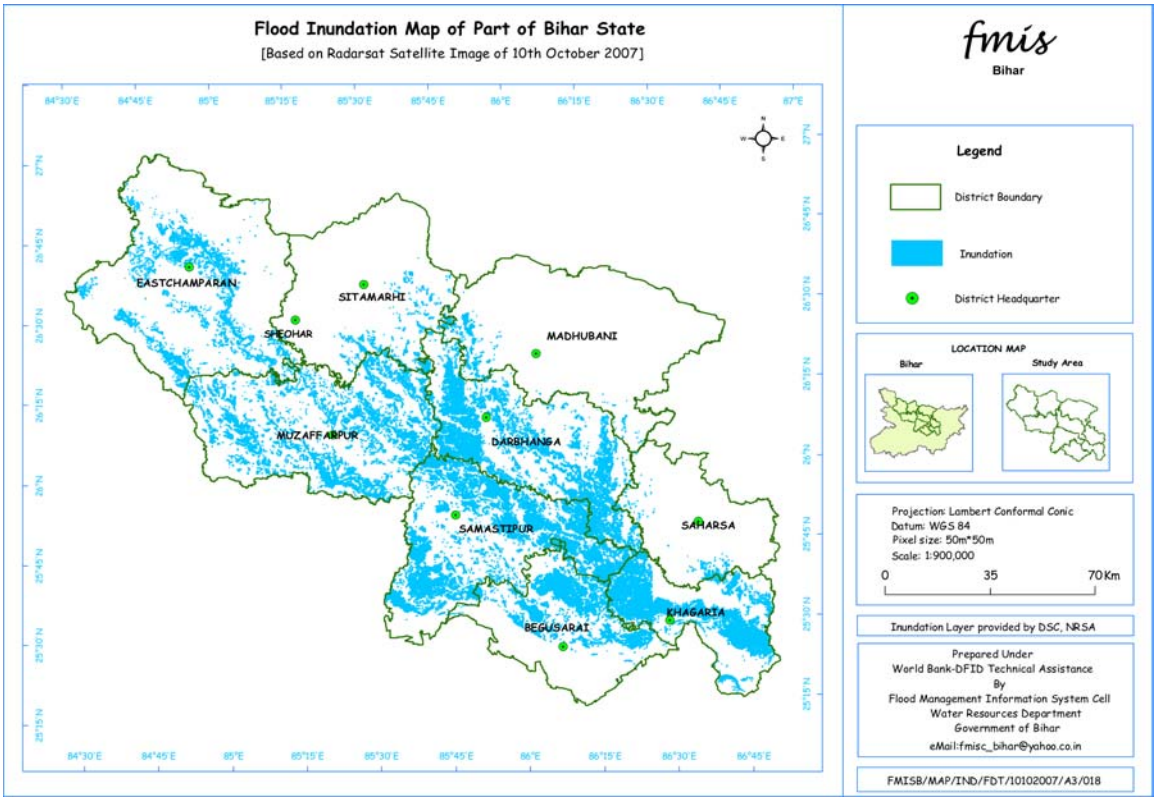
RADARSAT images covering the AOI were obtained during the flood season to view the flood impact. These images were procured and primarily processed under national disaster management support program (DMSP) by NRSA, Hyderabad, and then given to the Flood Management Information System Cell, Patna where value addition was done and disseminated to the user departments: Water Resources, Disaster Management, and Agriculture Departments. The maps depict the extent of flood inundation. The statistics elaborates the number of blocks / villages under inundation, population, and area affected etc. Details of the satellite data acquired are as follows

4.5.1 Satellite Data Acquired

Sl. No.	Date of Passing	Satellite / Sensors	Resolution (meter)	Focus Area Coverage
1	16/6/07	LISS III	23.5	Partial Covered
2	18/6/07	AWiFS	56	Partial Covered
3	20/6/07	Radarsat	50	Partial Covered
4	27/6/07	Radarsat	50	Partial Covered
5	06/7/07	Radarsat	50	Partial Covered
6	16/7/07	Radarsat	50	Partial Covered
7	18/7/07	Radarsat	50	Partial Covered
8	21/7/07	Radarsat	50	Full Covered
9	26/7/07	Radarsat	25	Not Covered
10	28/7/07	Radarsat	50	Full Covered
11	31/7/07	Radarsat	50	Partial Covered
12	04/8/07	Radarsat	50	Full Covered
13	06 & 07/8/07	Radarsat	50	Full Covered
14	09/8/07	Radarsat / WiFS	25	Partial Covered
15	16/8/07	Radarsat	25	Partial Covered
16	21/8/07	Radarsat	50	Full Covered
17	23/8/07	Radarsat	50	Full Covered
18	28/8/07	Radarsat	50	Full Covered
19	30 & 31/8/07	Radarsat	25	Full Covered
20	07/9/07	Radarsat	50	Full Covered
21	14 & 16/9/07	Radarsat	50	Full Covered
22	21 & 23/9/07	Radarsat	50	Partial Covered
23	23 & 24/9/07	Radarsat	50	Full Covered
24	26/9/07	Radarsat	50	Not Covered
25	01/10/07	Radarsat	50	Full Covered
26	03/10/07	Radarsat	50	Full Covered
27	08/10/07	Radarsat	50	Full Covered
28	10/10/07	Radarsat	50	Full Covered

Note: All inundation maps and statistics generated by FMISC for the 2007 flood season are based on the above satellite data provided by NRSA, Hyderabad.

A sample inundation map of 10th October 2007 is shown below.

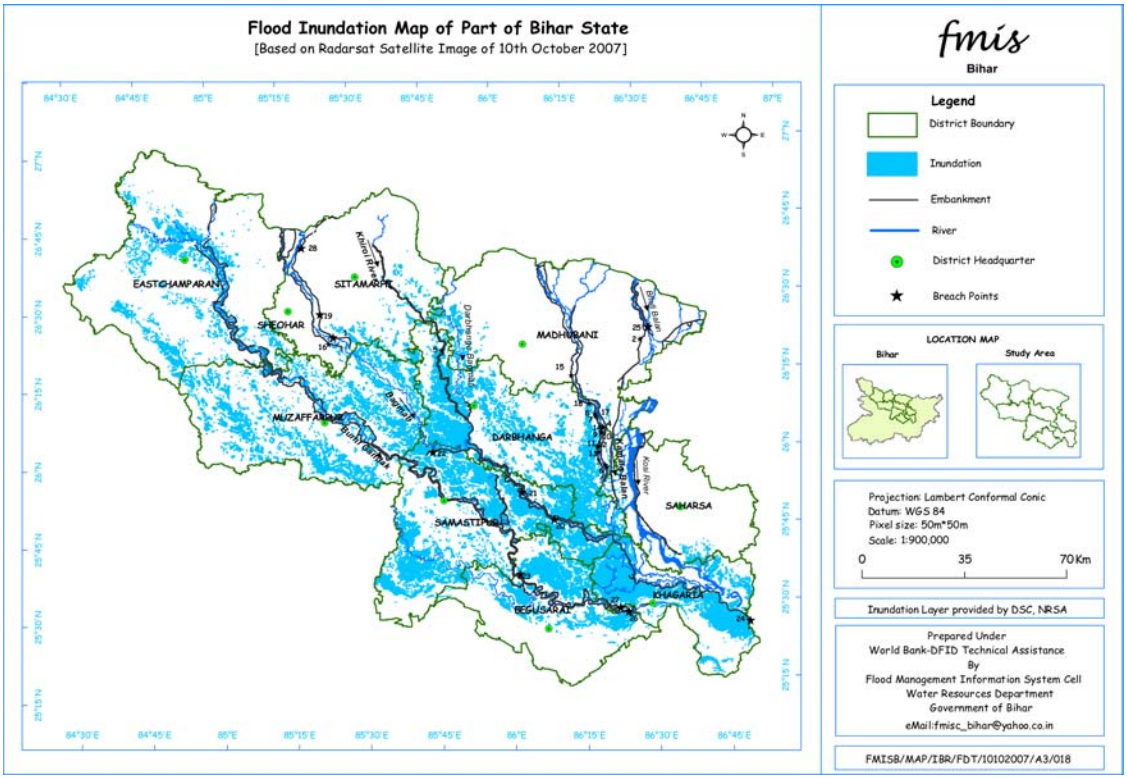


Map 4.8 Inundation Map of Part of Bihar State 10th October 2007.

Statistics of Inundated Geographic Area of Part of Bihar state on 10th October 2007:

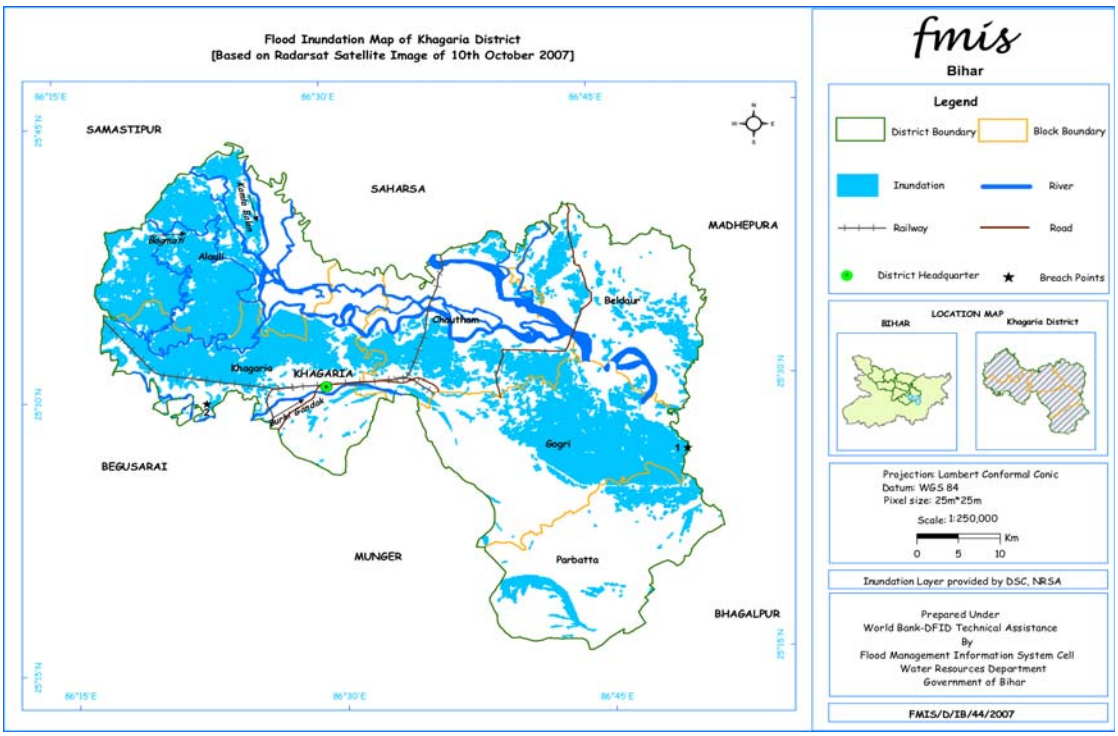
Sl. No.	District Name	Actual Area (Hectares)	Inundation (Hectares)	Inundation (%)
1	Khagaria	148600	51109	34
2	Darbhanga	227900	66207	29
3	Samastipur	290400	80614	28
4	Begusarai	191800	34152	18
5	Muzaffarpur	317200	51508	16
6	Eastchamparan	396800	26343	7
7	Sitamarhi + Sheohar	264300	6049	2
8	Saharsa	169200	2187	1
9	Madhubani	350100	4366	1
Affected Area		**2356300**	**322535**	**14**

Map prepared at the end of the season (2007) showing flood embankments, locations of reported breaches and cuts are shown below:



Map 4.9 Map showing flood embankments, locations of reported breaches and cuts

A sample customized inundation map for a district is shown below:



Map 4.10 Flood Inundation of Khagaria District and its Blocks

4.6 Breach Details-Flood 2007 in The FMIS Focus Area

SR. No.	Date of Breach	Name of River Embankment	Breach location	Name of village	District	Block	Latitude	Longitude
1	15-Jun-07	Bagmati left embankment	chain 418	Pachnaur Murahi	Sitamarhi	Belsand	26 24 1 N	85 25 18 E
2	26-Jul-07	Bhuti Balan right embankment	25 KM	Phulparas	Madhubani	Phulparas	26 21 18 N	86 29 37 E
3	26-Jul-07	Kamla Balan left embankment	89.9 KM	Jamalpur	Darbhanga	Ghansyampur/ Kiratpur	25 57 19 N	86 21 6 E
4	26-Jul-07	Kamla Balan western right embankment	70.50 KM	Kumbhraul	Darbhanga	Ghansyampur	26 4 37 N	85 20 55 E
5	26-Jul-07	Khirohi right embankment	12.5 KM	Belwara	Darbhanga	jale	26 20 38 N	85 40 0 E
6	26-Jul-07	Kamla Balan left embankment	91 KM	Chatra	Darbhanga	Ghanshyampur/ Tardih	25 56 52 N	86 21 22 E
7	27-Jul-07	Kamla Balan western right embankment	66.85 KM	Pardi	Darbhanga	Ghansyampur	26 6 47 N	86 19 34 E
8	27-Jul-07	Kamla Balan western right embankment	66.90 KM	Pardi	Darbhanga	Ghansyampur	26 6 42 N	86 19 34 E
9	27-Jul-07	Kamla Balan western right embankment	73.55 km	Baur	Darbhanga	Ghansyampur	26 3 38 N	86 20 38 E
10	27-Jul-07	Kamla Balan western right embankment	73.65 km	Baur	Darbhanga	Ghansyampur	26 3 35 N	86 20 37 E
11	27-Jul-07	Kamla Balan western right embankment	79.60 KM	Bath mansara	Darbhanga	Ghansyampur	25 0 56 N	86 19 43 E
12	27-Jul-07	Kamla Balan western right embankment	79.8 KM	Bath mansara	Darbhanga	Ghansyampur	26 0 49 N	86 19 41 E
13	27-Jul-07	Kamla Balan western right embankment	82.60 KM	Bath mansara	Darbhanga	Ghansyampur	25 59 50 N	86 19 50 E
14	27-Jul-07	Kamla Balan western right embankment	70.80 KM	Kumbhraul	Darbhanga	Ghansyampur	26 4 28 N	86 20 58 E
15	27-Jul-07	Kamla Balan western right embankment	47.80 KM	Naruar	Madhubani	Janjharpur	26 14 51 N	86 14 50 E
16	27-Jul-07	Bagmati right embankment	Chain 615	Balua Kharaua	Sitamarhi	Runnisaiadpur	26 22 45 N	85 24 26 E

17	27-Jul-07	Kamla Balan western right embankment	65.10 KM	jadupatti	Darbhanga	Ghanshyampur/ Tardih	26 7 9 N	86 19 25 E
18	27-Jul-07	Kamla Balan western right embankment	61 KM	Deona	Darbhanga	Manigachhi / Taradih	26 9 18 N	86 18 12 E
19	28-Jul-07	Bagmati left embankment	Chain 117,118	Ramni Tola	Sitamarhi	Belsand	26 28 32 N	85 22 46 E
20	1-Aug-07	Bagmati(kareh) right embankment	56.80 KM	Jaganathpur	Samastipur	Hasanpur / Rosara	25 47 13 N	86 9 56 E
21	1-Aug-07	Bagmati(kareh) right embankment	35.60 KM	Sitwahi	Samastipur	Rosara / Shivajinagar	25 52 42 N	86 3 24 E
22	2-Aug-07	Sormar Hayaghat (Bagmati(kareh) right embankment)	7 KM	Surmar/ malkaulli	Samastipur	Kalyanpur	26 1 8 N	85 45 11 E
23	2-Aug-07	Burhi Gandak left embankment	72-73 KM	Basahi	Begusarai	Cherria barairpur	25 36 54 N	86 2 18 E
24	10-Aug-07	Badalaghat nagarpara embankment (Kosi)	34.20 KM	Paikant	Khagaria	Gogari	25 26 5 N	86 49 41 E
25	14-Aug-07	Burhi Gandak left embankment	1km, 2km	Bishanpur Ahok	Begusarai	Sahebpur Kamal	25 28 51 N	86 24 38 E
26	15-Aug-07	Burhi Gandak left embankment	8.50 KM	Gangia	Khagaria	Khagaria	25 28 37 N	86 22 52 E
27	19-Aug-07	Bagmati left embankment	Chain 3.94 KM	Rampur kanth	Sitamarhi	Bairgania / Suppi	26 41 30 N	85 19 17 E
28	11-Sep-07	Bhuti Balan left embankment	18 KM	Hanuman nagar	Madhubani	Phulparas	26 23 32 N	86 31 21 E

4.7 Case Study: Inundated Area due to Breach in Burhi Gandak Left Embankment at 72-73 km near Basahi village in Begusarai District on August 03, 2007 at 1:45 am.

A breach occurred in Burhi Gandak left embankment (at 72-73 km) near Basahi Village in Begusarai District on August 03, 2007 at 1:45 am. It caused inundation in the adjoining areas. A case study was done in the FMISC to see the inundation effects of the breach on the adjoining blocks: Khudabandpur, Cheria-Bariarpur and Bakhri all, in Begusarai District.

Four RADARSAT images of 28th July, 4th, 6th /7th and 9th August, 2007 were used in the study. River water level observed at Samastipur and Rosera as well as rainfall observed in the basin up stream of the breach location from August 2 to 9 were also reviewed.

It is observed that an area of only 1896 Hectares (Ha) in the above mentioned three blocks was inundated on 28th July 07. After breach on August 3 the inundation increased rapidly and it became 6722 Ha on 4th, 9002 Ha on 6th and 9188 Ha on 9th August. The rate of increase of the area under inundation is fast during the first 2-3 days and slows thereafter. Block wise inundation on the above dates can be seen in the following Table.

Table No. 4.7.1 Inundated area on different dates due to breach in Burhi Gandak.

	Name of Block	Inundated Area (Hect.)			
		28/07/2007	4/08/2007	6/08/2007	9/08/2007
1	Khudabandpur	21	235	289	310
2	Bakhri	95	387	1202	1385
3	Cheria Bariarpur	1779	6100	7511	7492
Total Affected Area		1896	6722	9002	9188

Two river gauge stations of CWC are located at Rosera and Samastipur in the up stream of the breach location. Rosera is about 25 km and Samastipur 65 km from the breach location. It can be seen from the following Table that the breach has significant effect on the river water level at Rosera where it dropped by 0.44m from August 3 to 6 and by 1.09m from August 3 to 9. The drop is not of this extent at Samastipur. Water level on different dates can be seen in the following Table:

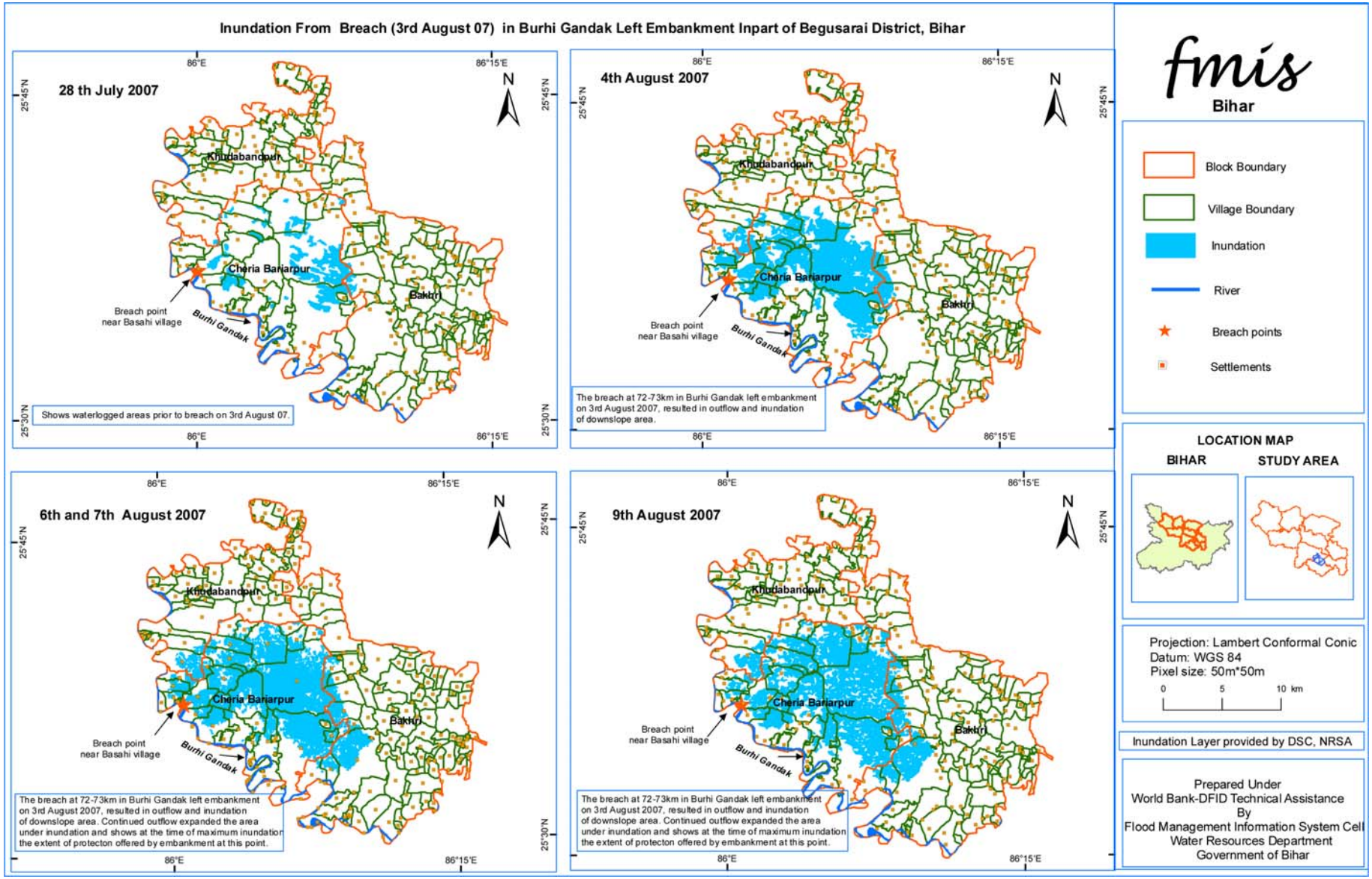
Table No. 4.7.2 Water level at Samastipur

Sr. No.	Date	Average[1] Rainfall (mm)	Water level (m) at Samastipur (HFL-49.38m, DL-46.02m)	Water level (m) at Rosera (HFL-46.35m, DL-42.63m)	Remarks
1	2/8/2007	29.28	48.87	45.80	
2	3/8/2007	10.36	49.23	46.03	
3	4/8/2007	2.6	49.23	45.74	
4	5/8/2007	0	49.22	45.68	
5	6/8/2007	0	49.11	45.59	
6	7/8/2007	7.28	48.99	45.41	
7	8/8/2007	7.72	48.75	45.17	
8	9/8/2007	0.8	48.51	44.94	

[1] Average of the rainfall at Simara, Lalbegiaghat, Sikandarpur, Samastipur and Rosera.

Average daily rainfall in the basin up stream of the breach location after the occurrence of the breach is observed less than 10 mm.

Map 4.11 Inundated Area On Different Dates Due To Breach In Burhi Gandak Left Embankment

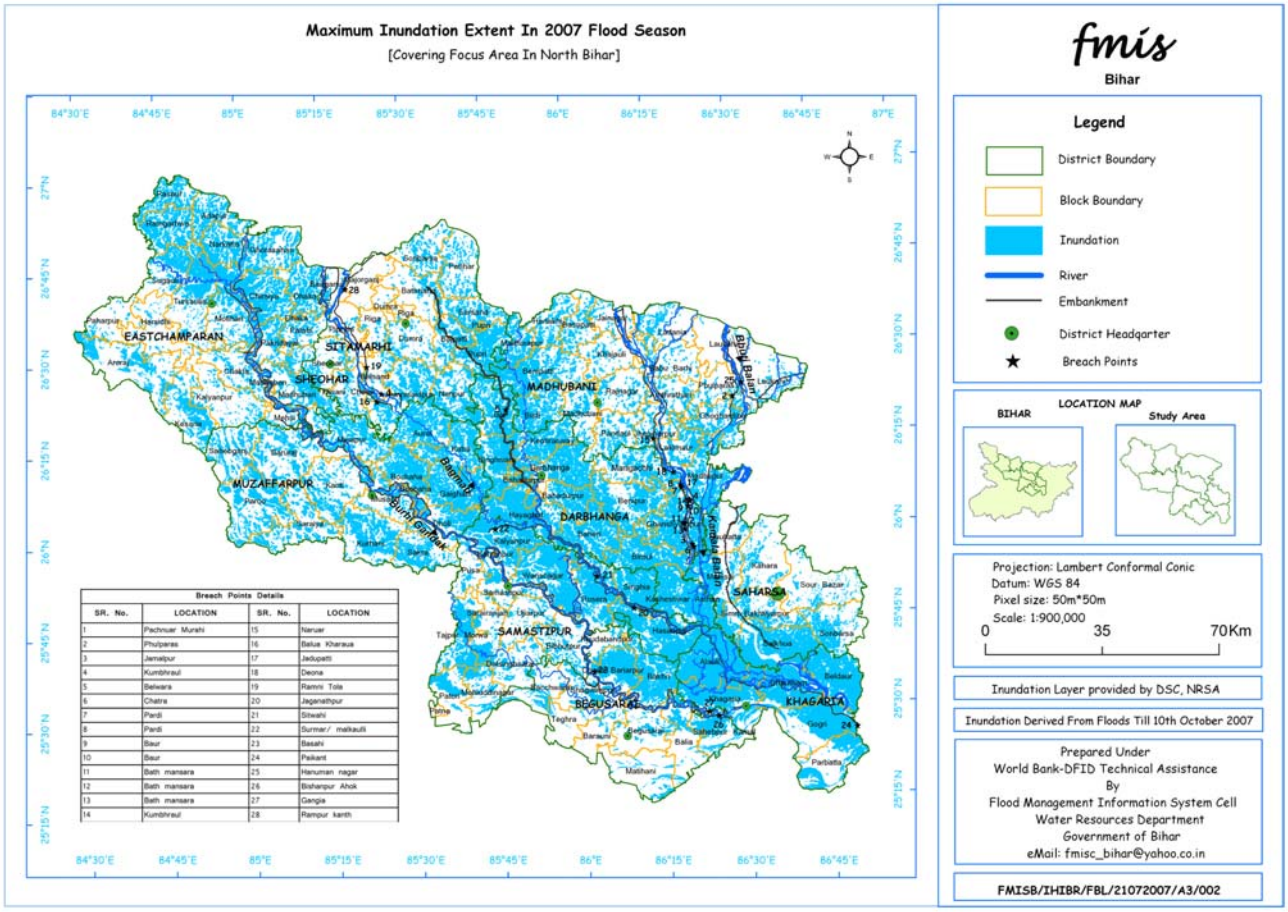


4.8 Value Added Product

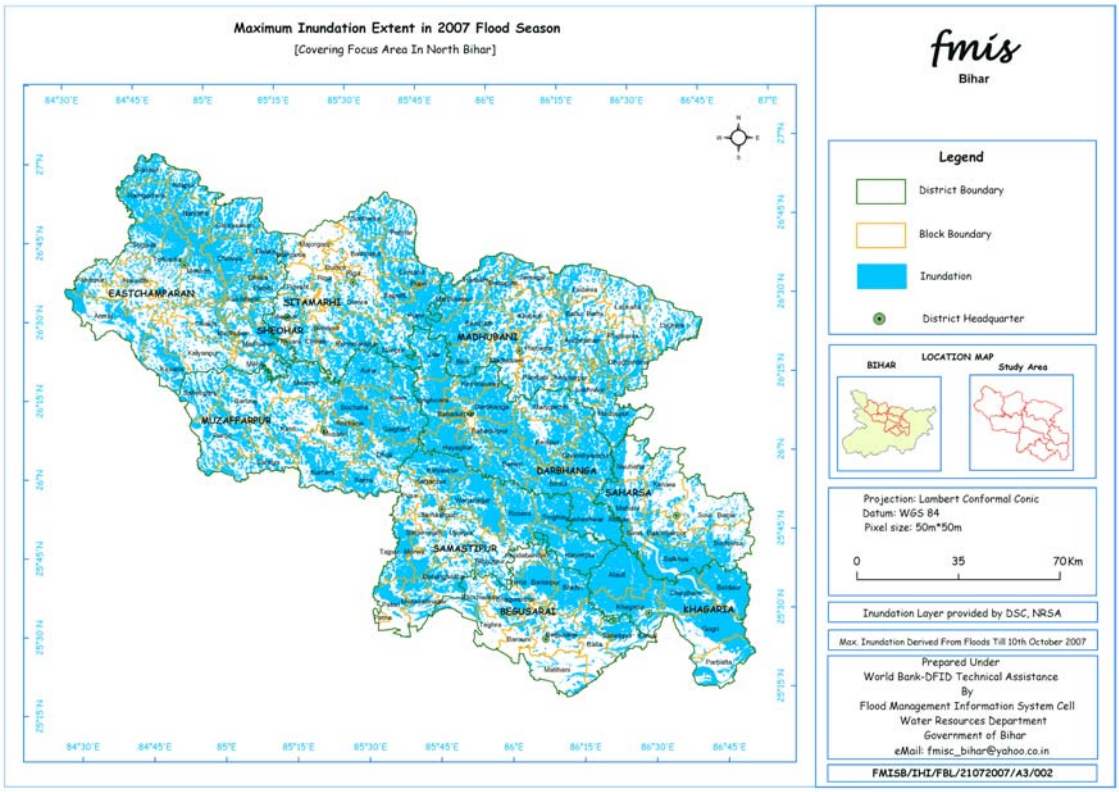
Flood frequency, flood duration, flood intensity maps were prepared at the end of the season. All maps prepared and disseminated during the season were compiled in two volumes (One for the Water Resources Department and other for the Disaster Management and Agriculture Department) and their hard and soft copy were released by the Principal Secretary, WRD in the workshop organized on 24th October, 2007 at Sinchai Bhawan, Patna. The analysis is based on database (census 1991) and inundation layer provided by NRSA, Hyderabad. The database is being updated for coming flood season.

4.8.1 Maximum Inundation Extent Map

Maximum Extent of Inundation map is derived from RADARSAT data from 21st July to 10th October. 15 numbers of scenes which fully covered the focus area were taken to prepare the layers of inundation maps. These 15 layers were used to generate the maximum extent of inundation during the flood season 2007. The map shows the area is flooded at least once in the given period (21st July to 10th October). The maps were prepared for Water Resources Department and Disaster Management Department. The locations of breaches as reported by WRD are marked as star in the map of WRD and are tabulated within the map for easy reference.



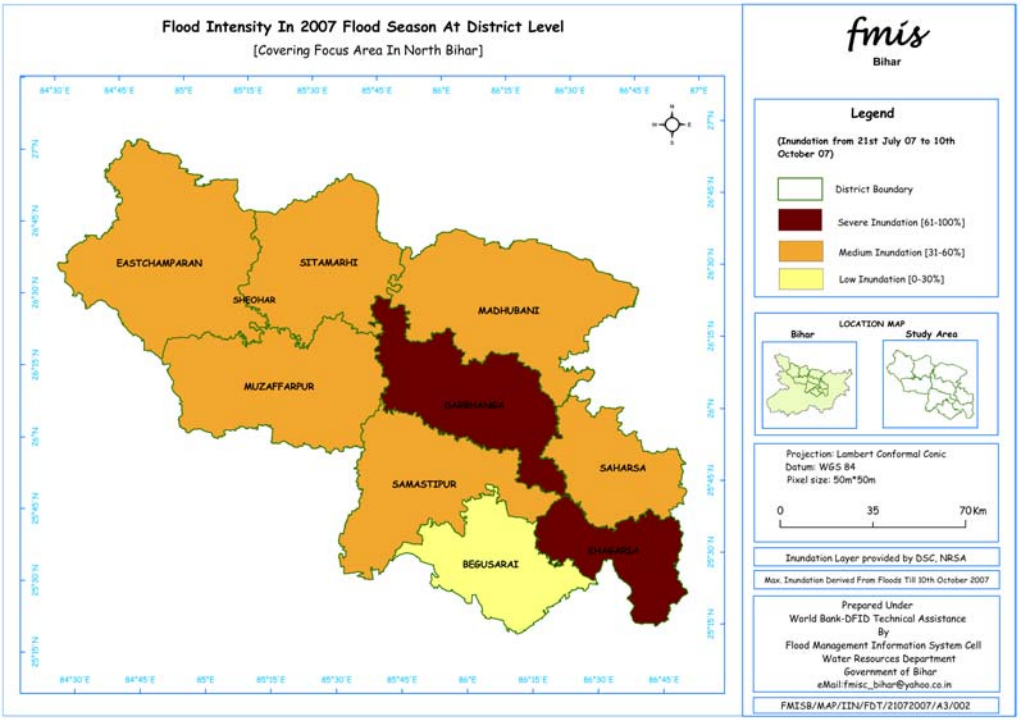
Map 4.12 Maximum Inundation Extent Map in flood season 2007 for WRD.



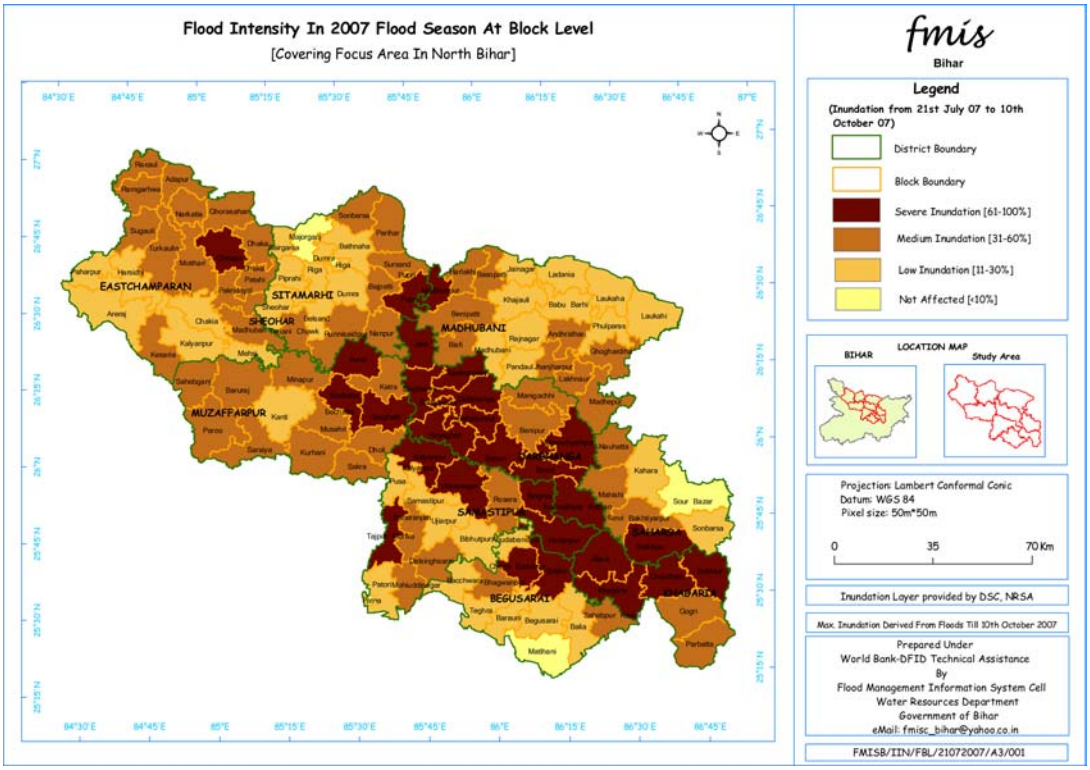
Map 4.13 Maximum Inundation Extent Map in flood season 2007 for DMD

4.8.2 Flood Intensity Map

The maps are prepared using the 15 numbers of Radarsat scenes as referred in above paragraph. This has been prepared for district level and block level at the end of season of monsoon 2007.



Map 4.14 Flood Intensity Map in flood season 2007 for DMD at District level.



Map 4.15 Flood Intensity Map in flood season 2007 for DMD at Block level.

The flood statistics below shows the district wise maximum inundation during the flood season 2007 and is a by product of above maps. The basis of making these maps are 15 numbers of scenes of different date from 21st July to 10th October which were the RADARSAT data and fully covered the focus area. The exact date can be referred from table at 4.5.1. The maximum inundation percentage indicates the percentage with respect to the inundation area to the geographical area of the district. It has been categorized in three distinct flood intensity group as severe, medium and low.

4.8.3 District Level Statistic of Maximum Inundated Area During Flood Season 2007, Part of North Bihar State Maximum Inundation derived from floods till 10th October 2007

District Name	Geographical Area (Hect.)	Maximum Inundation (Hect.)	Maximum Inundation Percentage	Flood Intensity
KHAGARIA	149021	101022	68	Severe
DARBHANGA	251425	160868	64	Severe
SAMASTIPUR	267397	125679	47	Medium
MUZAFFARPUR	317302	139218	44	Medium
EASTCHAMPARAN	396949	149987	38	Medium
MADHUBANI	349784	121921	35	Medium
SAHARSA	166556	56045	34	Medium
SITAMARHI	263569	82450	31	Medium
BEGUSARAI	192097	57093	30	Low

5.0 Lessons learned

5.1 Satellite data acquisition

- A protocol must be developed before next monsoon by lessons learned during the last monsoon
- Gauge and rainfall data received from CWC and Nepal website should be analyzed to perceive the ground situation as these are the key factor to cause flood.
- On identifying the critical flood based on above the satellite data acquisition process as per protocol is followed
- As the data received from Nepal Website is after a gap of 9 to 24 hrs, steps may be taken to reduce the time.
- Technical proposal for both RADARSAT and optical satellite should be procured from NRSA beforehand
- At times the browsed data from NRSA web site shows good quality but when asked for the Quality Control shows some problem
- The coordination with Decision Support Centre, NRSA may be reinforced
- IMD rainfall forecast should be well understood and validated to increase the lead time for data acquisition

5.2 Processing

- Multiple license of the Erdas Imagine 9.1 software and Arc Info workstation required so that more persons can work for customized map preparation
- The workstation becomes slow while geo-processing for union or intersection of various customized layers is carried so upgradation of workstation to at least 4 GB RAM can be done
- FMIS software implemented by Geo-informatics, NRSA needs improvement which will reduce many repetitive steps while adding value to the inundation layer.
- The engineers deputed in the cell should be trained in map preparation for coming seasons

5.3 Product Preparation

- WRD customized inundation maps must contains river layers and structures like embankments, canal layers and major and minors irrigation structures to better understand the ground situation
- The daily information bulletin containing the rainfall forecast for next three days incorporated in WRD daily flood bulletin.
- Agriculture department requires permanents water bodies that can be used for aquaculture and land use land cover details in their maps. Flood frequency and flood duration maps so that suggestion may be given to alternative crops
- Disaster Management department needs high land in the flooded area for air dropping and safe evacuation. Also the inundation maps excluding the rice field.

5.4 Dissemination

- Alternative internet connectivity.
- User department having problem in internet connectivity and computer facility

- Agencies ask for hard copy as they do not have printers

5.5 Utilization

- A workshop should be organized pre and post monsoon season for better coordination with stakeholders of FMIS
- High risk area needs to be identified, zoned and mapped
- Knowledge and experience of floods and the ability to forecast flood needs to be improved.
- Visualize scenario and develop effective solution
- The water level and hydrological information available may be used for assessment of flood both in geographical and temporal extent
- The tributaries need to be understood. The meteorological knowledge base may be used to provide linkage between regional storm and flood runoff.

5.6 Infrastructure

- Alternative phone and internet connection during flood season.
- For roster duty FMIS cell should be strengthened with officers, staff and security
- V Sat connectivity for high speed data transfer.

6.0 Plans for 2008 Flood Season

Database:	In the coming year upgraded database will be available. Hence more reliable customized maps and statistical report will be prepared for user agencies e.g. important air drops point may be identified during the flood.
Flood forecasting model:	With help of this we expect to forecast the flood in the coming flood season.
Web:	FMIS web will be hosted and current information will be upgraded and better coordination between user and the cell will be possible.
Telemetry network:	FMIS will be in better position to assess the current status of hydro meteorological stations in our focus area. Bagmati basin telemetry network should be completed before 2008 flood.
Validated rainfall forecast:	IMD will provide validated rainfall forecast data for the FMIS focus area with better resolution up to 5 km.
Upgraded flood manual:	This flood manual will be circulated to the user agencies for their feedback, comments and approval.
Workshops:	The planned workshop for stakeholders, user agencies and users will make them well acquainted, trained, and better
DEM:	Based on Shuttle Radar Topography Mission (SRTM) data Digital Elevation Model (DEM) for focus area available. This DEM will support the flood forecasting and inundation mapping. Also Airborne Laser Terrain Mapper (ALTM) by NRSA will improve the DEM from SRTM.
FMIS:	A prototype FMIS from NRSA is installed in the cell which will be improved and final version will be ready by next monsoon
Focus Area:	Focus area for FMIS should increase for whole North Bihar.

7.0 Fields Photos of 2007 Flood