Chapter 2
Mechanics of Floods in Ganga and Brahmaputra Basins and Long Term Solutions

N. N. Rai, J. Chandrashekhar Iyer and T. S. Mehra

Abstract The Ganga River basin is one of the largest and complex river network traversing eleven States of India, revered and regarded as lifeline of the region. Brahmaputra water is the prime resource endowed to the NE region and it has the potential to bring all the desired growth and prosperity to the region. Flood is a major concern in Ganga and Brahmaputra basins and it becomes the biggest bottleneck against development due to recurring floods. River Governance is a multi-dimensional and multi-disciplinary task and poses a formidable challenge for administrators, decision makers and water sector professionals, both in Central and State Government. This paper focuses itself on one such river governance dimension i.e. integrated approach in tackling the recurrent floods. The primary responsibility for flood control lies with the States. The Union Government renders assistance to States which is technical, advisory, catalytic and promotional in nature. We need to remind ourselves that floods per se do not understand State boundaries. Further, for large basins like Ganga and Brahmaputra, the cooperation and synergy among the riparian States on the issue of tackling flood is very vital. In this context, the significance of integrated development and operation of storages in the major sub-basins of Ganga and Brahmaputra river systems to mitigate the flood damages is emphasized in this paper presenting outcome of a study.

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2.1 Brief Description of Ganga River Basin

The Ganga River basin is one of the largest and complex river network traversing eleven States of India viz. Uttarakhand, Himachal Pradesh, Haryana, Rajasthan, Delhi, Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand, Chattisgarh and West Bengal. River Bhagirathi rises from the Gangotri glacier in the Himalayas at an elevation of about 4000 m above mean sea level (MSL) in Uttarkashi district of Uttarakhand. River Alaknanda rises from the confluence of Satopath and Bhagirathi Kharak glaciers at an elevation of about 5000 m, in Chamoli district of Uttarakhand. The Alaknanda and the Bhagirathi rivers unite near Devprayag and form river Ganga which traverses its course of 2525 km (1450 km in Uttarakhand and Uttar Pradesh, 110 km along Uttar Pradesh-Bihar border, 445 km in Bihar and Jharkhand and 520 km in West Bengal) before its outfall into the Bay of Bengal. Ganga River is joined by a number of tributaries in its course, such as Ramganga, Yamuna, Tauns, Gomti, Ghaghara, Sone, Gandak, Kosi, Damodar and other small streams.

The total drainage area of Ganga river at Farakka barrage, including the drainage area in Nepal and China as estimated works out to be about 9,31,000 km^2. The drainage area map of Ganga basin up to Farakka barrage is presented in Fig. 2.1. The drainage area of some of the rivers of Ganga river system is presented in Table 2.1.

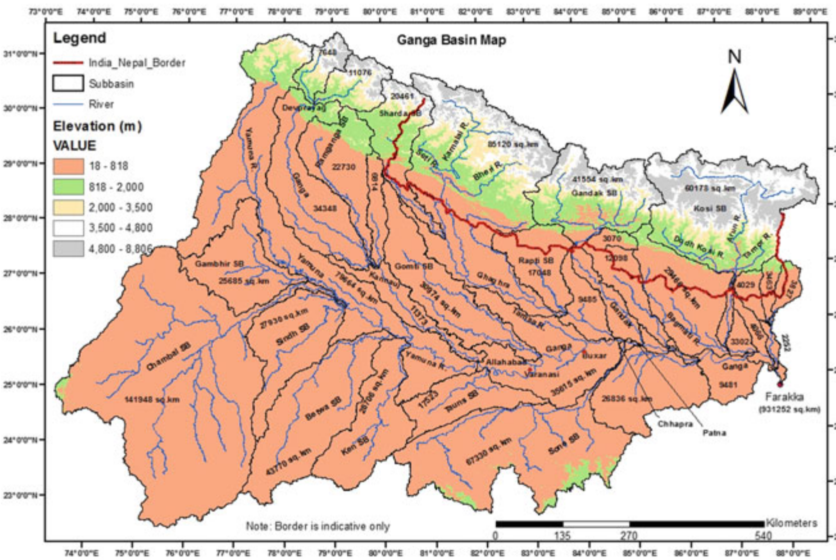

Fig. 2.1 Drainage area map of river Ganga at Farakka barrage

Table 2.1 Drainage area of some of the rivers of Ganga basin

River	Drainage area (km^2)
Ganga at Allahabad	93,989
Yamuna at Allahabad	347,703
Tauns	17,523
Ghaghra	132,114
Gandak	41,554
Sone	67,330
Kosi	60,178
Bagmati	29,466
Tributaries of Yamuna	
Gambhir	25,685
Chambal	141,948
Sind	27,930
Betwa	43,770
Ken	28,706

2.2 Meteorological Scenario of Ganga Basin

The southwest monsoon makes landfall at the mouth of the Ganga around the first week of June and advances upstream. By the end of July, the monsoon reaches the western end of the basin. The mean annual rainfall in the basin is about 1,170 mm. About 88% of the annual rainfall is received during the period of June to October. The bulk of the remaining 12% occurs mostly in the periods of March to May and November to December. During monsoon, cyclonic disturbances cause heavy spells of rainfall in the Ganga River Basin. On an average seven cyclonic disturbances (mainly depressions) form in the Bay of Bengal during the 4 months from June to September. These disturbances generally move in a west-northwest direction after their formation at the head of the Bay of Bengal up to the central parts of the country before weakening. It is well known that heavy rainfall occurs in the south western sector of the monsoon depressions due to strong convergence in that sector. The part of basin comes in the southwest of monsoon depressions tracks and as such heavy to very heavy rainfall occurs over different parts of the Basin.

The topography of the basin including Himalayas also plays an important role in causing heavy rainfall in the parts of the basin during the southwest monsoon season. The main synoptic situations of the southwest monsoon system that produce heavy rainfall over the Ganga River Basin are formation and subsequent movement of monsoon depressions, low-pressure systems from the head Bay of Bengal and well marked seasonal trough. Some of the severe rainstorm producing tracks of cyclonic disturbances are presented in Fig. 2.2.

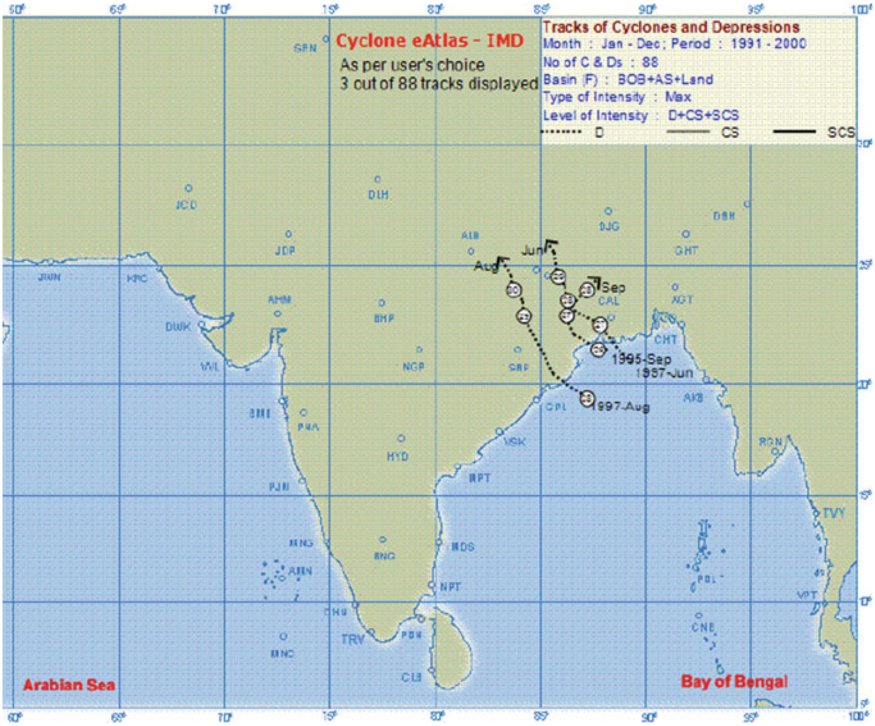

Fig. 2.2 Ganga river basin severe rainstorm producing tracks of cyclonic disturbances (1991–00) (*Source* Cyclone eAtlas—IMD)

The August 2016 floods in the Gangetic plains was also due to low pressure depression formations. As per IMD two low pressure systems were active during the period 1st to 10th August which affected the areas of Gangetic West Bengal, Jharkhand, Madhya Pradesh and East Rajasthan. Consequent to these two low pressure systems heavy to very heavy rainfall occurred in the sub-catchments of Koel, Rihand, Sone, Tauns, Ken, Betwa, Urmil, Lower Chambal, Kalisindh, Gambhir, Yamuna and Ganga downstream of Dalmau sub-catchments.

Meanwhile a slow moving deep depression also formed in Gangetic West Bengal and adjoining Bangladesh on 16th August 2016 and moved very slowly west wards after intensifying from 16th to 21st August 2016. It finally weakened in East Rajasthan. Rainfall of heavy to very heavy intensity at a few places with extremely heavy rainfall at isolated places were witnessed in the basins of Koel, Rihand, Sone, Tons, Ken, Betwa, Urmil, Lower Chambal, Kalisindh, Gambhir, Yamuna and Ganga downstream of Dalmau sub-catchments.

2.3 Floods in Ganga Basin

The management of the recurrent floods in Ganga River is a formidable challenge for the Central and State Governments. The flood control and management schemes are planned, investigated, formulated and implemented by the State Government. The Union Government renders assistance to States which is technical, advisory, catalytic and promotional in nature. The flood prone area in this basin as reported by States to the 12th Plan Working group is around 242 lakh hectare.

The country is witness to several flood events in the recent past when the wrath of the river in spate has left behind a trail of destruction spread across many States. *There are several structural and non-structural measures in flood management.* Nevertheless, reservoirs along the river basin are central to the issue of flood management as they can moderate the intensity and timing of the incoming flood. They are more effective for flood management if, apart from the incidental moderation available, specific flood volume is earmarked as in the case of DVC dams. At present, of the 80 odd large dams having height more than 100 m and capacity above 1 km^3, dedicated flood cushion has been provided only in 10 dams.

The August 2016 floods in the Gangetic plains is fresh in our minds that brings to the fore several intricate issues pertaining to management of a river basin reeling under floods. A study initiated recently post August—2016 floods in Bihar at the instance of Ministry of Water Resources, River Development and Ganga Rejuvenation by Central Water Commission to holistically understand the flood peak formation phenomenon in river Ganga and to estimate the flood storage requirements in the Ganga basin has interesting revelations that is briefly discussed here. The other structural and non-structural possibilities in flood management, sediment issues etc. are not dealt in this paper to ensure focus on the significance of flood storages in the basin and surrounding issues.

2.4 Flood Peak Pattern Analysis of Ganga River System

The vast historical data available on Ganga river system has been examined and an attempt has been made to understand the flood peak formation phenomenon in the main stem of river Ganga between Allahabad and Patna for which the annual flood peak patterns of different contributing rivers have been plotted in Fig. 2.3. The flood peak data of river Ganga and its tributaries for more than 50 years has been used. From the flood peak pattern plot and date of occurrence of flood peak at respective locations, the study concludes that the flood peaks in main stem of river Ganga i.e. at Varanasi and Gandhighat, Patna is being governed by the flood peaks in river Yamuna at Partappur. Further, the second most important contributor in flood peak of river Ganga at Patna is Sone river system.

It is seen that in Ghaghra river system, most of the flows gets spread out in vast territory of UP and Bihar creating huge floods. Thus Ghagra's contribution in flood

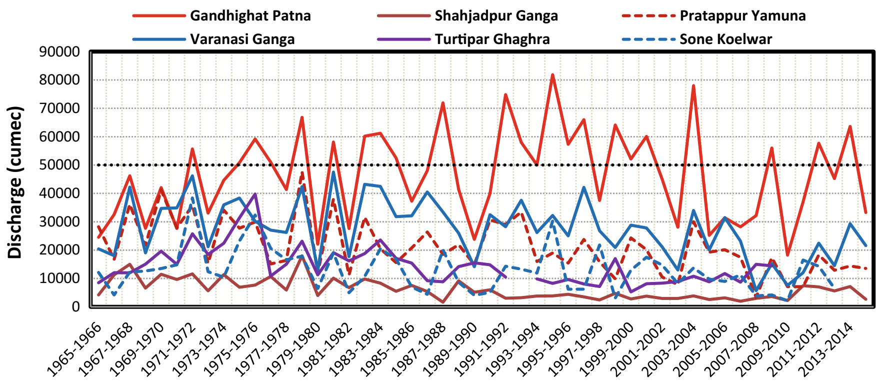

Fig. 2.3 Annual flood peak pattern in river Ganga and its tributaries

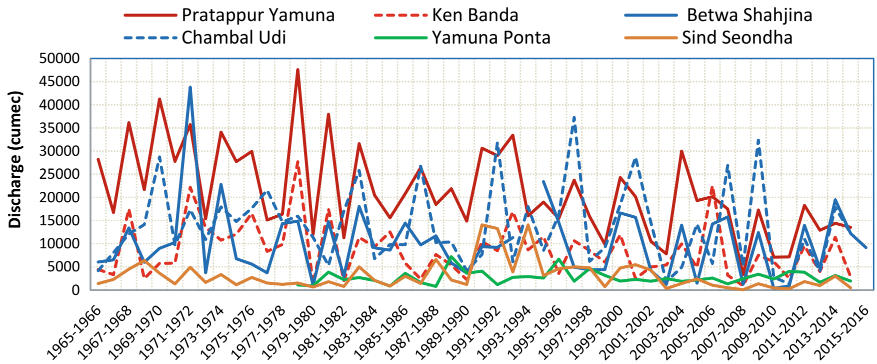

Fig. 2.4 Annual flood peak pattern in river Yamuna and its tributaries

peaks in the main stem of river Ganga is of the order of about 8000 to 10,000 cumec. One of the important revelations is that the concurrent occurrence of Kosi flood peak with Ganga flood peaks is very rare. However, the huge discharge in Kosi river results in flooding within its drainage area in Bihar.

The flood peak pattern analysis carried out for the Yamuna river system as presented in Fig. 2.4 reveals that majority of the flood peaks occurrences in Yamuna are due to significant contributions from its tributaries viz. Chambal, Betwa and Ken.

In Chambal river, the major storage projects viz Gandhi Sagar and Ranapratap Sagar were commissioned way back in the year 1970. As can be seen from the annual flood peak pattern, number of flood peaks with a significant discharge of more than 20,000 cumec have continued even after the year 1970. As per the study, some significant additional flood storage is essential on river Chambal and some dedicated flood cushion in existing projects coupled with inflow forecast may help further mitigation of flood peaks.

As on date, there is no storage project on the river Ken, and contribution of river Ken during the major flood events is more than 10,000 cumec, the study concludes that significant flood storage is essential on river Ken. Similarly, provision of dedicated flood cushion coupled with inflow forecast in the existing projects on river Betwa and additional storage will help in mitigating the flood peaks of river Betwa.

2.5 Flood Storage Estimate for Ganga Basin

As a sequel to the flood peak pattern analysis, flood storage estimate study for the entire Ganga basin too has valuable findings. It is worth mentioning here that the drainage area of river Ganga at Gandhighat Patna is about 7,25,000 km^2. Considering the possibilities of storage on Yamuna river system viz Ken, Betwa, Sind, Chambal etc. and Himalayan part of Yamuna, Tauns, Sone, Ghaghra, the total drainage area which can be tapped is about 2,70,000 km^2 only. About 4,55,000 km^2 (i.e. about 63% of the drainage area) shall remain untapped due to topographical constraints. This contribution from untapped catchment may vary from 30,000 cumec to 40,000 cumec in a flood scenario of above 65,000 cumec.

From the data of flood peaks at Gandhighat, Patna, Hathidah and Farakka on main stem of river Ganga, it has been found that the magnitude of flood peak at Gandhighat Patna is maximum in almost all the flood events that have occurred so far. The lesser flood peak at Hathidah and Farakka in comparison to Patna due to attenuation of flood peak by Mokama Taal and spillage of water in flood plains. To illustrate, daily discharge pattern of four worst flood events of years 1987, 1991, 1994, 2003 and 2016 each of them having peak discharge of more than 70,000 cumec has been picked up and analysed to estimate flood storage requirement. In the analysis the flood volume has been estimated considering a target to curtail the flood peak at Patna by about 20,000–25,000 cumec. Accordingly, for the flood events with peak flow below 75,000 cumec, volume has been estimated above 50,000 cumec discharge. For the flood events with peak flow above 75,000 cumec, volume has been estimated above 55,000 cumec discharge. The study reveals that:

- For September 1987 flood, maximum recorded peak was 71,900 cumec and flood volume above 50,000 cumec was about 4.8 BCM.
- For September 1991 flood, maximum recorded peak was 72,608 cumec and flood volume above 50,000 cumec was about 11.9 BCM.
- For August 1994 flood, maximum recorded peak was 81,839 cumec and flood volume above 55,000 cumec was about 10.9 BCM.
- For September 2003 flood, maximum recorded peak was 78,000 cumec and flood volume above 55,000 cumec was about 16.8 BCM.
- For August-September, 2016 flood the flood volume at Patna above 55,000 cumec was about 12 BCM.

As stated above, the maximum influence on Ganga flood is mainly from Yamuna and Sone river systems. Considering that, a total flood storage of about 12 BCM in

Yamuna, Sone and Ghaghra sub basins may be beneficial in moderating the floods in the main stem of river Ganga between Allahabad, Patna and downstream of Patna. In order to mitigate the flood peaks at Patna by 20,000 cumec to 25,000 cumec, flood storage estimates for Chambal, Betwa and Ken river systems as per the study works out to 3.0 BCM, 2.5 BCM and 2.0 BCM respectively. The estimate for Sone river system is projected as 2.5 BCM. In the drainage area of Ghaghra, Gandak and Kosi river systems, flood storage of 3.0 BCM, 2.3 BCM and 3.25 BCM respectively has been estimated.

As per the study, efforts should be made to ensure some dynamic flood cushion supported with inflow forecast in existing projects viz Gandhisagar in Chambal sub basin, Bansagar, Rihand in Sone sub basin, Rajghat, Matatila in Betwa basin. The major projects being considered on Ghaghra river system are Pancheshwar multipurpose project on Sharda, Karnali (Chisapani) multipurpose project on Karnali (Ghaghra), Namure multipurpose project on River West Rapti which are at different stages of preparation in association with Government of Nepal. Similarly, on the Kosi river system, Saptakosi & Sunkosi multipurpose projects, Bagmati multipurpose project and Kamla Dam project are being investigated jointly with Government of Nepal. Substantial moderation of floods in Uttar Pradesh and Bihar can be expected from these projects.

2.6 Brief Description of Brahmaputra River Basin

Brahmaputra River originates as Yarlung Tsangpo river from Mansarovar near Mt. Kailash in the Himalayas, flows via Tibet, China, India and Bangladesh into Bay of Bengal. The total length of the river is about 2900 km. The drainage basin of the Brahmaputra extends to an area of about 580,000 km^2, from 82°E to 97° 50′ E longitudes and 25° 10′ to 31° 30′ N latitudes. The basin spans over an area of 293,000 km^2 (50.51%) in Tibet (China), 45,000 km^2 (7.75%) in Bhutan, 194,413 km^2 (33.52%) in India and 47,000 km^2 (8.1%) in Bangladesh. Its basin in India is shared by six states namely, Arunachal Pradesh (41.88%), Assam (36.33%), Nagaland (5.57%), Meghalaya (6.10%), Sikkim (3.75%) and West Bengal (6.47%). The mighty Brahmaputra and its tributaries flows above the danger level across Assam almost every year and affects more than one lakh people inundating human habitations and farm land in several districts of Assam and Arunachal Pradesh of North Eastern region of India.

Brahmaputra water is the prime resource endowed to this region, which has the potential to bring all the desired growth and prosperity to the region. If left unmanaged, it will become the biggest bottleneck against development due to recurring floods as this also gives sense of insecurity for sustainability of infrastructure. Accordingly, flood is a major concern for the overall development of North Eastern Region. Besides, Assam suffers an average loss of more than Rs. 200 crore every year due to floods, it loses large swathes of land to river bank erosion and recovering such lost land has become a challenging task for the state. The above problem can be solved effectively to a great extent through a flood management approach, where flood peaks of Brahmaputra are curtailed through storage of flood water in different sub basins of Brahmaputra. About 6 to 7 judiciously located storage projects leading to about 14 BCM of storage can turn around the biggest bottleneck of recurrent floods into a great opportunity of cheap and reliable non-polluting power with an efficient navigation round the year approaching all the way across the region.

2.7 Formation of Flood Waves in Brahmaputra Basin

In order to understand the flooding scenario in Brahmaputra river, it is essential to visualize the rainfall scenario in Brahmaputra basin. The same is shown in Fig. 2.5, where it can be seen that the average annual rainfall in Siang river upstream of great bend is less than 500 mm. The same scenario is also in Lohit basin where the rainfall in Chinese catchment of Lohit river is less than 500 mm. The average annual rainfall in Siang valley downstream of great bend and up to Passighat is of the order of 3500 mm. The rainfall in lower region of Dibang and Lohit basins is more than 4000 mm. There are certain pockets in Siang, Dibang and Lohit basins where annual rainfall is even of the order of 5500 mm. Similarly in some pockets of Subansiri basin the annual rainfall is more than 3000 mm. In the catchment of Brahmaputra plain the average annual rainfall is of the order of 2400 mm.

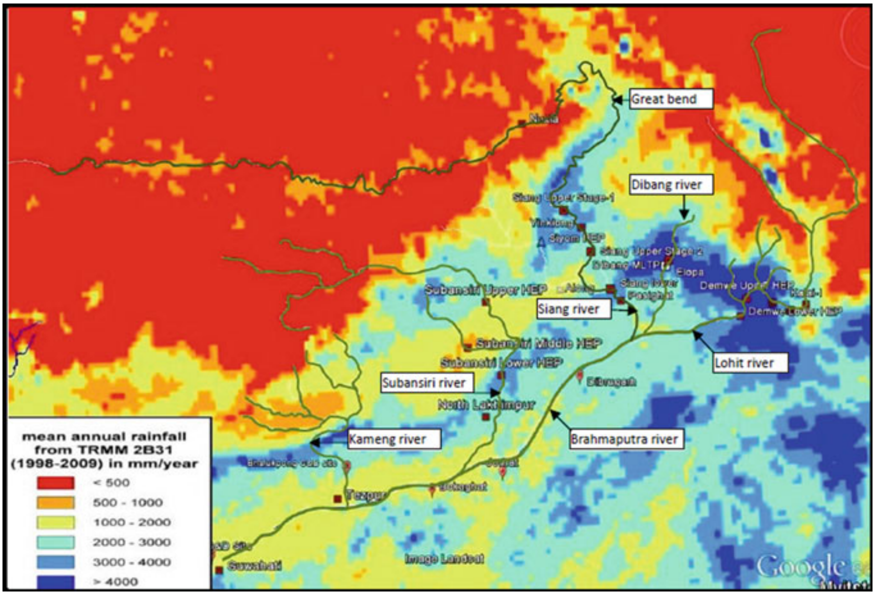

Fig. 2.5 Rainfall scenario in Brahmaputra basin

Apart from the rainfall scenario a comparison of flood peaks observed in Siang river at Tuting and Brahmaputra river at Guwahati is given below:

Siang at Tuting (About 25 km d/s of India-China Border)		Brahmaputra at Guwahati	
Date	Observed flood Peak (cumec)	Date	Observed flood Peak (cumec)
08/09/2007	12,180	12/9/2007	44,508
01/09/2008	13,485	4/9/2008	49,659
01/07/2009	9230	24/08/2009	36,138
05/09/2010	11,300	19/09/2010	39,469

From the above rainfall scenario and flood peak data of Tuting and Guwahati, it can be said that the flood or high discharge in Brahmaputra basin is basically due to very high rainfall in the Indian catchment of the basin. This may further get worsen due to climate change leading to more erratic and intense rainfall pattern, resulting in increase in the intensity of floods.

2.8 Flood Storage Requirement in Brahmaputra Basin

In addition to all non structural measures, it is essential to adopt all possible and effective structural measures for flood management so as to tackle the problem of floods in Brahmaputra basin. The catchment area of Brahmaputra at Guwahati is about 417,000 km^2 in which the catchment area of Siang alone is about 251,521 km^2. The Catchment area of Lohit near Parsuramkund is about 21,000 km^2, while Subansiri at Gerukamukh is about 26,000 km^2. Due to natural topography and availability of limited storage sites, it is possible to construct storage projects on Siang, Dibang, Lohit and Subansiri rivers at those sites only. Further, a large catchment area of about 108,669 km^2 up to Guwahati lies in plain, where no storage project is possible. It has been estimated that from the unregulated catchment of Brahmaputra plain a flood discharge of about 22,000 to 25,000 cumec is expected during the flood events of 100 year return period. However with judicious storage of flood waters in Siang, Dibang, Lohit and Subansiri rivers at identified locations, the flood peak of Brahmaputra can be mitigated to safer levels. The adequate flood storages can be provided in Upper Siang storage project in Siang sub basin, Dibang multipurpose project in Dibang sub basin, Subansiri lower, Kamla and Subansiri upper projects in Subansiri sub basin. In Lohit sub basin the storage available between operating level during monsoon and Full Reservoir Level (FRL) of Demwe lower, Demwe upper, Hutong-II, Kalai-II and Kalai-I can be used to meet the flood storage requirements. The location of above projects is shown in Fig. 2.6.

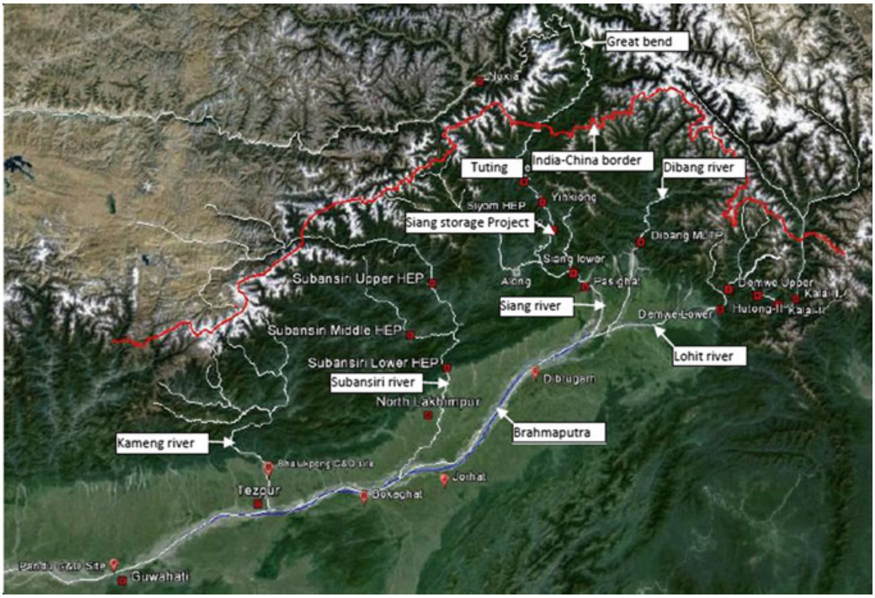

Fig. 2.6 Major River Valley Projects in Brahmaputra basin

In order to estimate the flood storage requirement in Brahmaputra basin, a Committee under Chairmanship of Member (D&R), CWC with experts from NHPC, CEA, Brahmaputra Board, Govt of Arunachal Pradesh and Govt of Assam was constituted by MoWR in July, 2013. The Committee after detailed analysis and several deliberations identified that the major contributor of flood in Brahmaputra is Siang. The other rivers which contribute significantly in Brahmaputra flood peak formation are Dibang, Lohit and Subansiri. In order to mitigate the Brahmaputra flood fury, the Committee estimated a flood storage requirement of 9.2 BCM in Siang, 0.6 BCM in Dibang, 1.61 BCM in Lohit and 1.91 BCM in Subansiri sub basins.

2.9 Benefits of Storage Projects

Flood management in Brahmaputra basin may be achieved by ensuring the availability of the required quantity of water at the required point of time. This may be made possible through storing flood water during flood season by moderating the flood peaks and releasing it at an appropriate time of requirement. With aforesaid proposed flood storage projects, it will be possible to reduce the 100 year flood peak at Guwahati from 62,000 cumec to about 42,000 cumec. The 25 year return period flood of about 55,000 cumec will be possible to reduce below 40,000 cumec. Depending upon the contribution from the unregulated catchment, the proposed flood storage scenario will result into reduction in water level at Guwahati by about 1.1–1.5 m. This will bring a major relief from floods and recurrent flood damages. Apart from the floods on account of rainfall occurrences, floods from Glacial Lake Outburst, breaching of land slide dams will also be effectively attenuated by proposed reservoirs, thus effectively mitigating their downstream impact. The benefits of flood moderation besides water security and better navigability during lean period would also be available up to Bangladesh which is a lower riparian country.

Through these storage projects in upper reaches of the Brahmaputra basin the flood levels in the main stem of Brahmaputra river will be reduced considerably. This will also facilitate removal of flood congestion and consequent reduction in flooding in the drainage area of the tributaries joining Brahmaputra river in downstream areas. One of such prominent area besides other areas where relief due removal of flood congestion would be available is Bodoland Territorial Council area in Assam.

The maximum flood storage is essential in Siang sub basin where the proposed Upper Siang Storage Project with installed capacity of 10,000 MW shall generate about 48,000 million unit of electricity annually even during the dry years.

Apart from the flood mitigation, the storage projects will help in overall development of NE region's economy through hydropower generation, major employment generation, industrialization, education, better medical facilities etc. Large reservoirs will also provide the huge employment generation through Tourism and fisheries for the local people. Other benefits are better navigability of Brahmaputra, water sports and enhanced river flows during lean period resulting in better river ecosystem besides adding the effectiveness to anti erosion/flood management and infrastructural works in Brahmaputra basin.

2.10 Water Security Aspects of Brahmaputra

Being a snow fed, Siang river is the major contributor of non-monsoon(November to April) flow of river Brahmaputra. The contribution of non-monsoon flow in Brahmaputra by Siang during November to April is about 22 BCM, out of which about 18 BCM is contributed from the drainage area in China. The possibility of diversion of Siang water by China has been raised by media from time to time. Also, as apprehended, the climatic change is reducing the size of glaciers which may also result in reduction of availability of water during non-monsoon period. Considering the possibility of reduction of Siang water in future, the upper Siang storage project will also ensure the non-monsoon water security in Brahmaputra basin besides becoming a safeguard to power projects and providing protection to ecology and environment.

2.11 Regulatory Framework for Brahmaputra Basin

Integrated water resources management (IWRM) of any basin for its overall development including integrated flood management may be achieved if there exists a well-structured and appropriately empowered regulatory authority at basin level. In Brahmaputra basin there exists a statutory body namely Brahmaputra Board at Guwahati, Assam since 1982, with certain limitations on its mandate. Presently Board is certainly not a regulatory authority. However, Brahmaputra Board may be revamped appropriately as a basin authority and may be made responsible for Brahmaputra basin's water resources management with the mandate of all activities of water resources including management of floods and regulation of reservoirs etc. As the effectiveness of flood storage can only be ensured by integrated operation of the proposed reservoirs in Brahmaputra basin hence, whenever projects come into existence, a Reservoir Regulation Committee comprising of all stakeholders for coordinated operation of reservoirs during monsoon shall be essential to ensure optimum flood moderation benefits through integrated flood management. The advice given by the Committee should be binding to all the project owners of the basin.

Further, policy for operation of multipurpose reservoirs is needed for reducing the impact of flood cushion requirement vis-à-vis power generation from the project. For coordinating large reservoirs in real time, comprehensive data collection and Decision Support System will be required to be set up. Land use planning, flood plain zoning in unregulated catchment of Brahmaputra will further enhance the effectiveness of integrated flood management approach.

2.12 Flood Management—A State Subject

The subject of flood control, unlike irrigation, does not figure as such in any of the three legislative lists included in the Constitution of India. However, Drainage and Embankments, are two of the measures specifically mentioned in Entry 17 of List II (State List), reproduced below:

> Water, that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power subject to the provision of entry 56 of List I (Union List).

Entry 56 of List I (Union List) reads as follows:

> Regulation and development of inter-State rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest.

It may be seen that the primary responsibility for flood control lies with the States. A number of States have already enacted laws with provisions to deal with the matters connected with flood control works. However, there exists a significant provision that the powers to be exercised are subject to Entry 56 of Union List.

2.13 Conclusion

The paper focuses on appreciation of two key aspects relating to flood moderation in Ganga and Brahmaputra river basins. One is the flood peak pattern analysis and the other is the estimate of flood storage requirement in different sub basins of Ganga river system. All over the world including India, the storage projects are playing key role to moderate the flood peaks and are bringing relief from devastation and fury of floods. In India, Bhakra Nangal dam in Sutlej basin, Bargi dam in Narmada basin, number of storage projects in Damodar valley, Tehri Dam in Ganga basin are some live examples, which are efficiently controlling the floods in their region. Similarly, in Murray Darling basin (Australia), Yellow river basin (China), Brantas river basin (Indonesia) and many other basins in all over the world, basin authorities are relying on flood management mainly with the help of large storage projects. Most of the basin authorities all over the world are relying on integrated flood management mainly with the help of large storage projects.

There is no doubt that the flood flows have to be managed effectively by the State and Central Government to mitigate the adverse flood impacts. We need to remind ourselves that floods per se do not understand man-made State boundaries. Floods have been inflicting damages to almost all the States in Ganga basin and Arunachal and Assam in Brahmaputra basin. While tackling floods in a large basins like Ganga and Brahmaputra, the cooperation and synergy among the riparian States on the issue of tackling flood is very vital in the interest of all. Integrated development and operation of the reservoirs in a river basin world over has significantly helped in efficient flood moderation.

Ganga and Brahmaputra basins are also not exception to that and strategic storage projects in the basin are essentially required for Integrated flood management. From the analysis of flood scenarios in Ganga basin it can be concluded that efforts should be made to ensure some dynamic flood cushion supported with inflow forecast in existing projects viz Gandhisagar in Chambal sub basin, Bansagar, Rihand in Sone sub basin, Rajghat, Matatila in Betwa basin. Further, on the rivers Ghaghra, Sharda, West Rapti, Kosi and Bagmati etc. in Ganga basin, construction of storage projects in association with Government of Nepal with adequate flood cushion may provide substantial moderation of floods in Uttar Pradesh and Bihar, apart from providing clean energy as hydropower for India and Nepal.

Similarly, flood storage projects can be provided only in North Brahmaputra where storage sites are available in Subansiri, Siang, Dibang and Lohit sub basins. The major contribution of flood in Brahmaputra is from the Siang river. With the proposed flood storage provisions it will be possible to mitigate the Brahmaputra floods substantially. The proposed storage will provide a major relief to frequently affected flood areas in the basin with average annual saving of more than Rs. 200 crore from flood damages in Assam apart from hydropower in the region and India. These projects will also provide effective relief from flooding in Arunachal Pradesh. Apart from the flood mitigation benefits, Government of Arunachal Pradesh will get huge free power and other benefits from all these projects. Hence, management of

Brahmaputra waters through construction of strategic storage projects with stakeholder's active participation and integrated management of floods could be a key to overall development of NE region.

As already stated above, water is mentioned in the State List of the Constitution and the primary responsibility for flood control lies with the States. The flood control and management schemes are planned, investigated, formulated and implemented by the State Government. The Union Government renders assistance to States which is technical, advisory, catalytic and promotional in nature. From State to State, the priority of projects normally differ and therefore all States may not necessarily agree to the integrated planning approach.

From the study outcome above, it is seen that large storage volumes are needed supported with reliable inflow forecast network for moderating floods in a large basin like Ganga and Brahmaputra implying huge financial implications. Some of these reservoirs in all likelihood would be inter-state projects requiring consensus among the party States and hence agreement on cost-benefit sharing would be vital. Difference of opinion between two States is enough to jeopardize the entire project. Above all, the proposed projects have to be environmentally sound and socially acceptable. River Ganga and Brahmaputra are holy rivers, worshipped, revered and regarded as lifeline of the region. Any interference in the river environment and its regime will not be taken lightly by the people and therefore building storages would require serious consideration and consultation of all stakeholders on all issues at the planning and developmental stage itself.

On the operational front, the best practices calls for all the major reservoirs (from storage volume consideration) to ideally come under integrated operation to ensure that the flood waters are efficiently routed and regulated. Further, for real time integrated operation, a robust state-of-art data acquisition, storage, retrieval and transmission system to and from the centralised control and command centre is paramount. However, with water being in State domain, the control over releases from reservoirs remain with the State Governments. Further, with increasing water conflicts among stakeholders in the basin, integrated operation would have to negotiate many hurdles. The issues on trans-boundary rivers too pose multiplicity of challenges. Confidence and Consensus building through participatory approach is therefore important and sincere efforts should continue diligently.

Disclaimer The views expressed in the paper are purely personal and not necessarily the views of the organisation.

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