ISSN 2229-5518

Urban Floods in India

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Abstract: Flooding is an accumulation of water in an area either by direct rainfall irresistible to the volume of drainage systems or a spill of huge amount of water from water bodies beyond normal limits. It could be localized, impacting a small area or could be vast or massive, impacting very large area. Urban flooding is caused by heavy rainfall overwhelming drainage capacity. It already has large economic and social impacts. These are very likely to increase if no changes are made to the unplanned development of buildings and infrastructure and poor management of urban drainage. Urban floods are a great disturbance of daily life in the city. Urbanization in developing countries doubled from less than 25% in 1970 to more than 50% in 2006. By 2020, seven of the world's ten largest economies will be from Asia. At the same time, Asia in one of the fastest urbanization regions in the world. In 2000, 37% of its population lived in cities and the proportion is projected to reach more than 50% by 2025.Across India, in the recent times, city after city has experienced floods. Through this paper, the author reviews urban flood events within India in recent past. This paper describes why it is important to study urban floods scenarios and what the need for this study is. It highlights the types and causes of the localized flooding as well as its impact and consequences. The study concludes the infrastructure and economic losses due to these urban events.

1 Urban Flood

FLOOD is in itself abbreviates - Finally Loss Occurred after Opportunities Denied

The definition of flood in engineering term - Flood is such a high stage in a water coarse i.e. river, drain or their tributary or in a water retaining body i.e. lake, pond, reservoir , seas, ocean or other low lying areas- the level at which water over flows over its banks and inundates the adjoining areas.

Flood is influenced by various factors - rainfall, river-flow and tidal-surge, topography, measure of flood-control, and alterations due to infrastructural. Some floods grow and discharge gradually, while others can develop in just a few minutes and recede quickly such as flash flood. Flood events are happening for the last many years and centuries but urban floods are getting studied moderately of late (Brown, 2011).

Urban flooding is caused by heavy rainfall overwhelming drainage capacity. It already has large economic and social impacts. These are very likely to increase if no changes are made to the management of urban drainage. Urban floods are a great disturbance of daily life in the city. Roads can be blocked; people can't go to work or to schools. The economic damages are high but the number of casualties is usually very limited, because of the nature of the flood. The water slowly rises on the city streets. When the city is on flat terrain the flow speed is low and you can still see people driving through it. The water rises relatively slow and the water level usually does not reach life endangering heights (Aggarwal, 2014). Then, if an intense rainfall burst occurs, causing a large amount of rain within a brief period, flash flooding may occur with little or no warning.

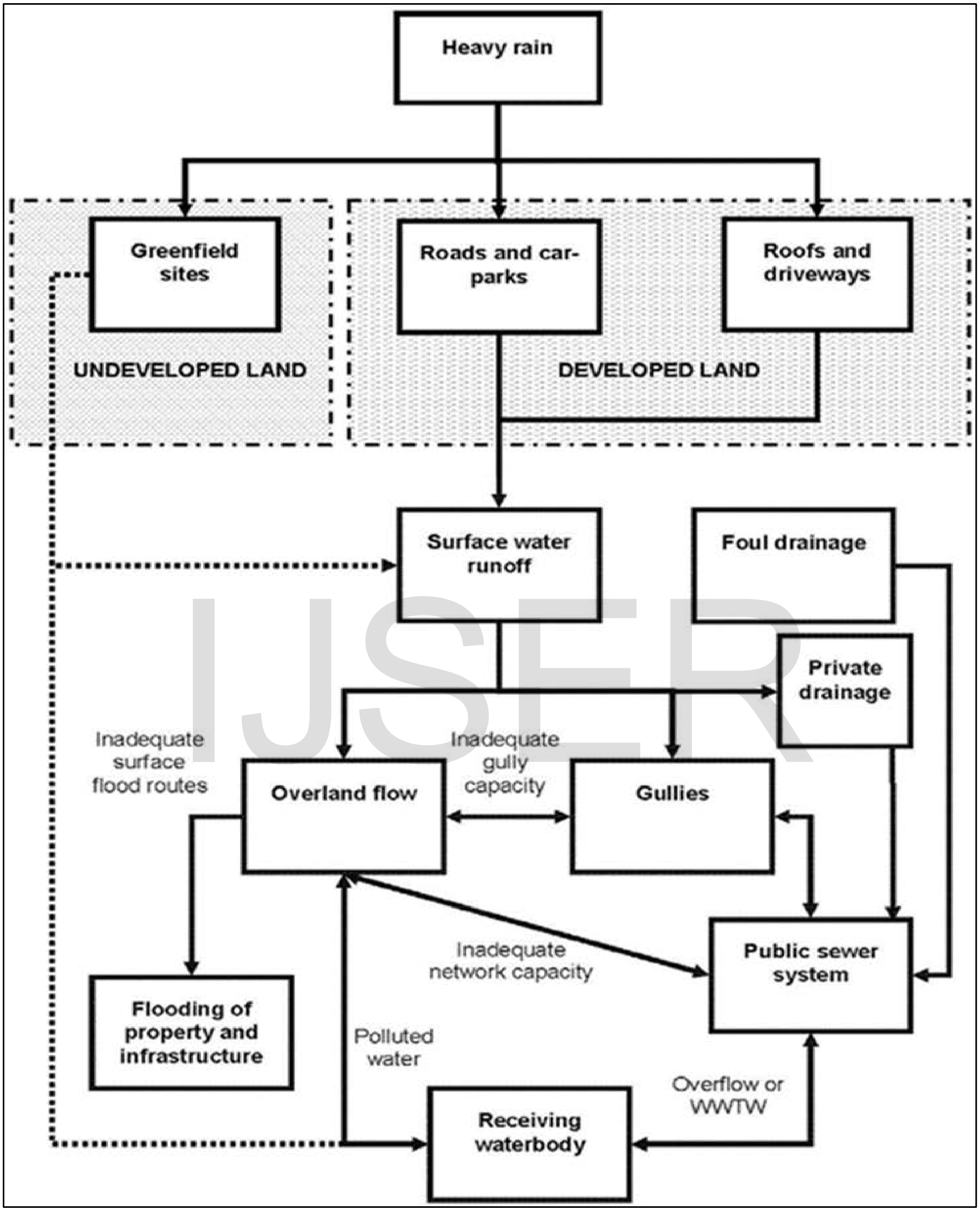

Figure 2-1: Systematic Diagram of Urban Flooding

The urban areas have been constructed upon and now it is too late to plan and tackle the problem of flooding for such centers. Yet if the people want to save themselves from the wrath of the floods and the government wants to avoid paying recurrent compensations to the people one of the way out is to construct large tanks where rain water could be stored and also to puncture the ground at several places like it is done for rain water harvesting. This would augment the seepage capacity of the ground. In addition a holistic drainage system for every urban complex would save many a lives, economic losses and inconvenience due to floods. Seepage holes will prevent water-logging and the menace of the mosquitoes.

These floodplains, often under the control of built infrastructure (i.e., levees or dams), have been exploited worldwide for food production, reducing these benefits and making agricultural production and associated human settlements vulnerable to flood damage. Knowledge of the spatial and temporal patterns of flooding, as influenced by the combination of natural flood regimes and human-built controls, is critical in maintaining the ecological functioning of floodplains (Townsend and Walsh, 1998).

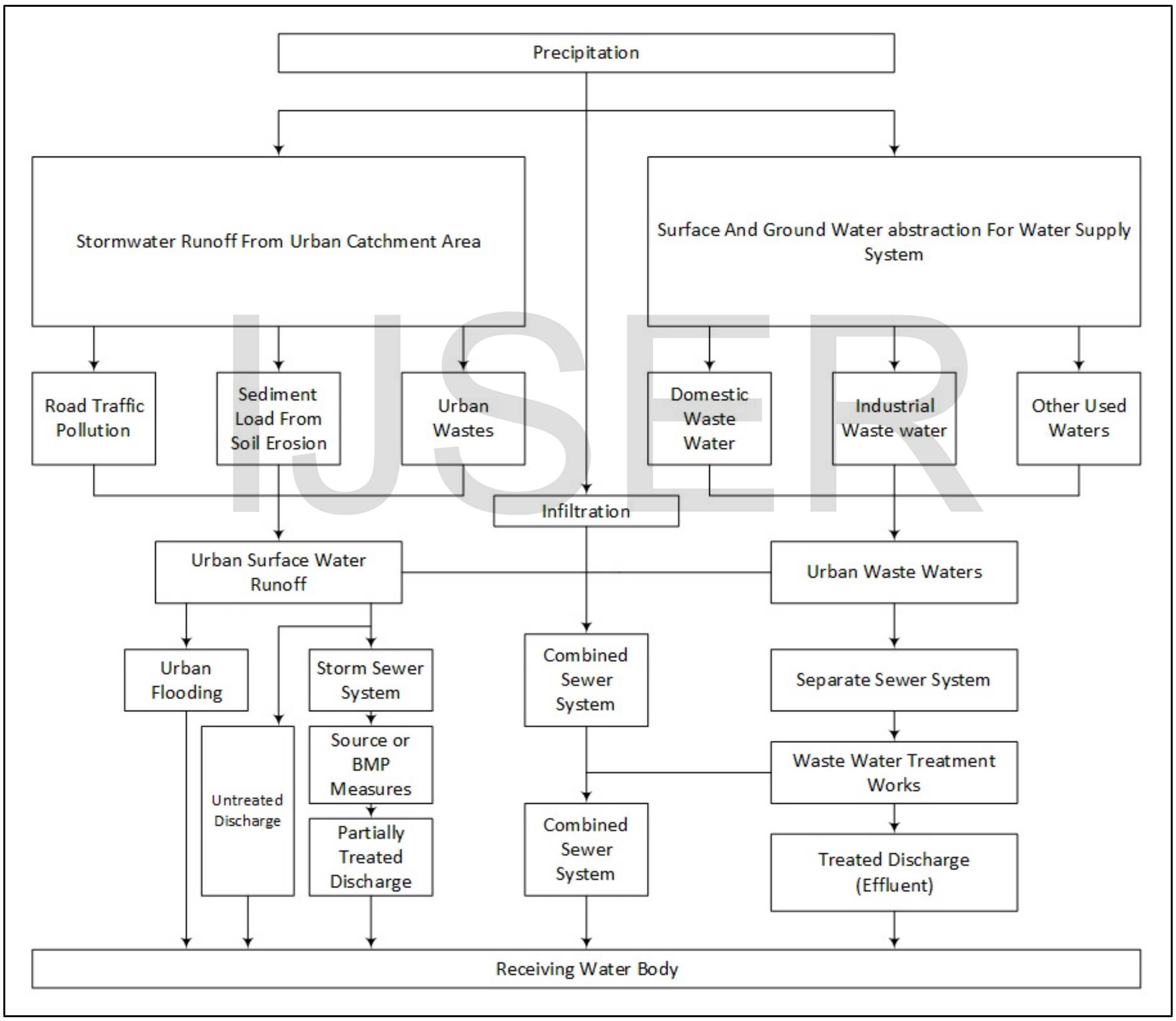

Figure 2-2: Urban Water Courses

1.1 Need of Urban Flood Study

Urban flooding is significantly different from rural flooding, as urbanization increases flood risk by up to 3 times, peak flows result in flooding very quickly due to faster flow times (in a matter of minutes), large number of people are affected in dense population clusters and severe economic and infrastructure loss to industry and commerce. Urban flooding can be reduced with measures like: maintaining existing drainage channels, providing alternative drainage paths (may be underground), control of solid waste entering the drainage systems, providing porous pavements to allow infiltration of rainwater, etc. (Ranger, 2011)

Climate models predict that winter rainfall will increase by 20-30% by the 2080s. Such an increase could lead to a much larger (up to 200%) increase in flood risk. Poor natural drainage, chocking of drainage system, extreme climate events and development in river flood plain are the main causes of the urban flooding.

Primary Losses	Loss of life & physical injury
	Damage to buildings, contents & infrastructures
	Disruptions to industrial production
	Loss of, or disruptions to utility supplies
	Loss of heritage or archaeological site
Secondary Losses	Increased stress; physical & psychological trauma
	Enhanced rate of property deterioration & decay
	Lost value added to IND
	Increased traffic congestion; disruption of flow of employees to work
	Contamination of water supplies; food and other shortages
	Loss of exports; Reduced national gross domestic product

1.2 Reasons of Urban Flooding

A series of storms moving over the same area can cause areal flash flooding. A muddy flood is produced by an accumulation of runoff generated on cropland. Sediments are then detached by runoff and carried as suspended matter or bed load. Muddy runoff is more likely detected when it reaches inhabited areas.

A lot of the sewerage and drainage network is old and its condition is unknown. They cannot cope with the volume of water or are blocked by rubbish and by non-biodegradable plastic bags. Sewers overflow because of illegal connections and the sewer system cannot cope with the increased volumes. As new developments cover previously permeable ground, the amount of rainwater running off the surface into drains and sewers increases dramatically. Developments encroach floodplains, obstructing floodways and causing loss of natural flood storage. Continued development and redevelopment to higher density land uses by high land costs. The proportion of impermeable ground in existing developments is increasing as people build patios and pave over front gardens. Increased impervious areas such as roads, roofs and paving, due to increasing development densities means more run-offs (Singh and Singh, 2011). Some of the major hydrological effects of urbanization are: (1) increased water demand, often exceeding the available natural resources; (2) increased wastewater, burdening rivers and lakes and endangering the ecology; (3) increased peak flow; (4) reduced infiltration and (5) reduced groundwater recharge, increased use of groundwater, and diminishing base flow of streams. According to natural hydrological phenomena, due to increased impervious area precipitation responds quickly reducing the time to peak and producing higher peak flows in the drainage channels.

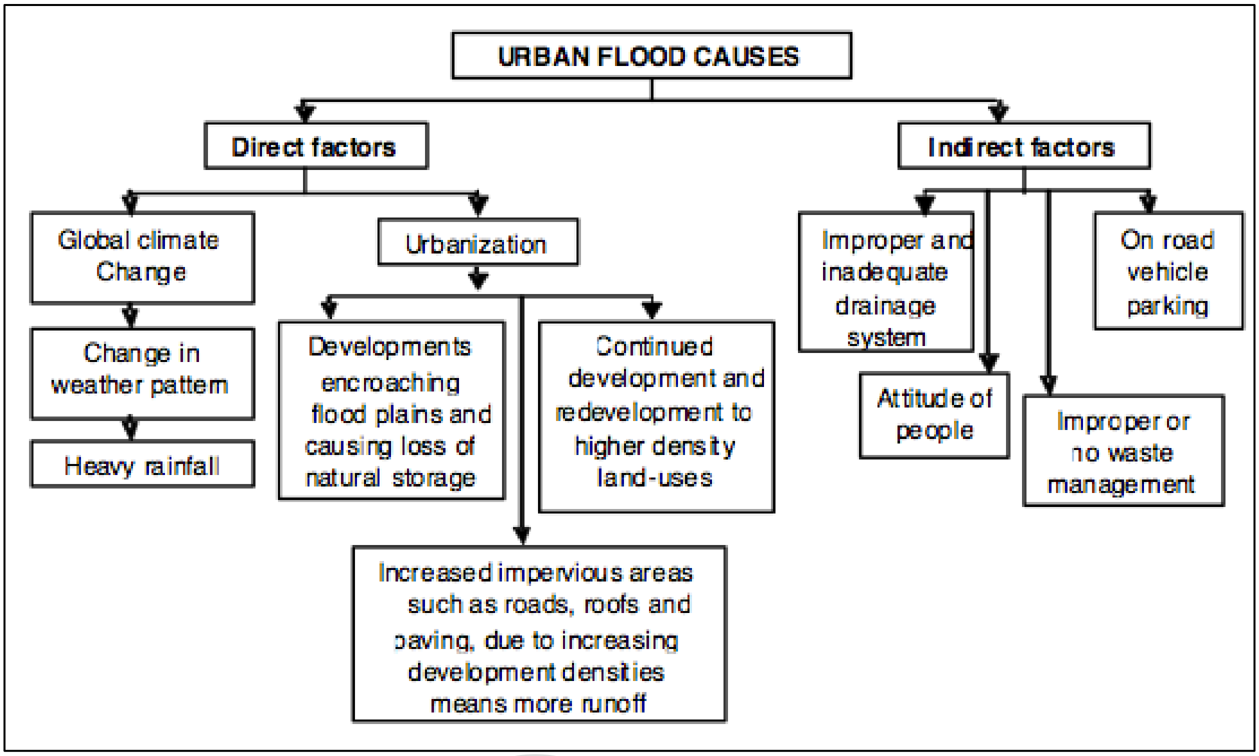

Figure 2-3: Causes of Urban Floods

1.3 Consequences of Urban Flooding

Urban Floods results in stagnation of water on roads, railway tracks and in few cases even at airports because of the inadequate storm water drainage capacity. This results in traffic jams and traffic diversions resulting in loss of man hours. In the events of heavy rainstorms air traffic gets diverted. Telecommunication gets disturbed and maintenance of supply of essential commodities becomes challenge. As communications is disrupted industrial production gets hampered. Prices of essential commodities shoot up. During and after urban floods the immediate task is restoration of damaged roads, railway tracks, damaged buildings (which is very common for over lived buildings) and other structures and rehabilitation of residents from low lying areas and collapsed buildings. Damages of assets are significant in warehouses and buildings due to flooding by storm and sewage water. Perishable articles add to economical loss. Accidents and fire due to short circuit are also common. Hence there are a lot of financial burdens on relief measures. There is a psychological stress as safe returns of family members is not sure. Schools and colleges get closed. Displacement of population in low lying areas and collapsed structures generally meets stiff resistance. Disruption in supply of essential commodities including power supply results in unrest. Water bodies get polluted (Ganaie et al., 2013). Waste disposal gets hampered due to traffic disruption. The stagnation of water, pollution of potable water and accumulation of waste at dustbins result in epidemics. Accidents due to open pits, manholes hidden under accumulated water adds to problem. As traffic gets disrupted it is challenging to assist medical assistance.

2 Mumbai's Meteorological Event of 26th July, 2005

The 26 July 2005 event has been classified as 'very heavy' (>200 mm/day as per the criteria for rainfall classification of IMD). The strongest rain ever recorded in India. Severe urban floods were reported from 10 cities and Mumbai was worst affected. The Santa Cruz observatory at Mumbai airport recorded 944 mm during the 24 hours ending 08:30 h on 27 July 2006 while the Colaba observatory recorded only 74 mm of rain.

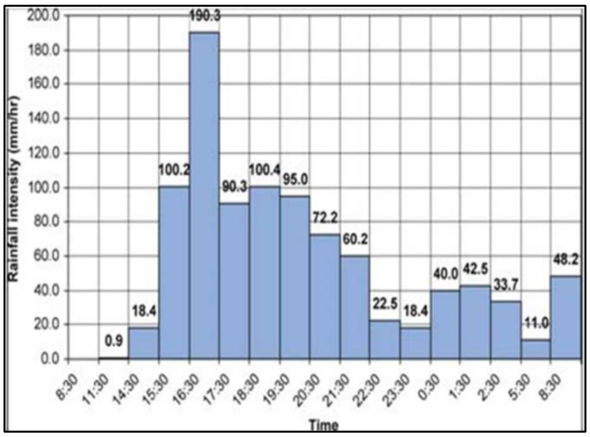

Figure 3-1: Hyetograph of 26 July 2005 Rainfall- 24 H Ending 08:30 on 27 July 2005

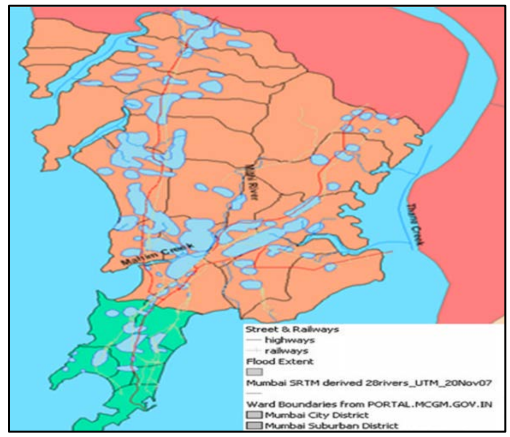

Figure 3-2: Inundated Areas in Mumbai City Area

The Santa Cruz, heavy rainfall started at 14:30 with 481.2 mm falling in just 4 h between 14:30 and 18:30 and hourly rainfall exceeding 190 mm/h during 14:30 to 15:30. This has exceeded the rainfall record of Cherrapunji, which has been considered the world's wettest place. The extremely high rainfall resulted in overflows from the already inadequate e drainage system and it was unable to drain out to the sea because of the maximum high tide level of 4.48 m at 15:50 during the month of July 2005.

Over 60% of Mumbai was inundated to various degrees on 26 July 2005 as shown in Figure 4-2. The IMD was unable to issue advance warnings of this event. Even when there was heavy rainfall in the northern suburbs, the IMD was unable to monitor the rainfall and issue warnings in real time. This has been attributed to the lack of state-of-the-art equipment like tipping bucket rain gauges with the IMD. IMD has only two rain gauges in Mumbai and both are of the symphonic type which record data on graph paper attached to clockwork driven drums. These are read only at 08:30 daily. The main causes of flooding in Mumbai were .low ground levels Low ground levels, low Level of outfalls, silt of drains/nallas, dilapidated drains, obstructions of utilities, encroachment along nallas, slums along outfalls, urbanization, loss of holding ponds, garbage dumping in SWDs/nallas mainly in slums and increase in runoff coefficient (Gupta, 2007.

The extreme rainfall event of 994 mm on 26 July 2005 has been a lesson for Mumbai and it has indicated the perils of rapid development in highly concentrated urban areas. This event has resulted in Mumbai setting up a much better response mechanism based on real-time monitoring of rainfall at 27 locations in the city to handle recurrences of similar events in the future. The Central Water Power Research Station, Pune is currently (2007 – 2008) in the process of preparing a detailed scale model for carrying out the hydraulic model studies for the Mithi River. This model is intended to provide a basis for long-term planning of Mumbai taking into account the impacts of climate change and sea-level rise. It would also help in identifying the tidal impact on the flooding and estimate the extent of inundation of low lying areas through the progression of low and high tides.

Concurrently, another study (BRIMSTOWAD-II) with design rainfall intensity of 100 mm/h has been commissioned by the MCGM to revise the earlier BRIMSTOWAD study (1993) which was based on design rainfall intensity of 50 mm/h. The results of this study are intended to recommend various structural, non-structural and pumping options for Mumbai city for the long-term and an amount of 200 m. Euros has been allocated for implementing these measures. Under the present global economy, where major call centers and other BPO institutions are located in major cities of the developing world, disruption in one city has roll-over effects for worldwide business; hence, we cannot ignore flooding in any city as being just a local phenomenon (Ranger et al., 2010).

However, the present rate of urban development is likely to continue in most of the cities. If all the resources and infrastructure are concentrated in a very small area, the cities must have a monitoring and response mechanism to handle extreme rainfall events and other disasters. Also developments in any major city need to be accompanied by an adequate water supply, wastewater and storm water disposal system based on analysis of extreme rainfall events. The Mumbai experience would be helpful for planning response strategies for other large cities to cope with similar events in the future.

3 Chennai Urban Flood of Nov – Dec 2015

Chennai is crisscrossed by sluggish tributaries namely Cooum and Adhyar. Cooum flows over the core of the city. Between the buildings of the University of Madras and Fort St. George, it drains in the ocean. It accumulates excess from 75 tanks in its catchments within Chennai Metropolitan Area. The Adhyar river collects surplus from about 450 tanks in its catchments, apart from overflows from the Chembarambakkam tank. Chennai and its suburbs once boasted of over 150 small and big waterbodies. Today the numbers of waterbodies in Chennai have been reduced to a mere 46 due to onslaught of development. Geographically Chennai is a flat topography and absences of natural slope cease unrestricted run off. This is a major reason for development an active scheme for storm water drainage. The Corporation of Chennai has developed and maintains a storm water drain network of 855 km in the city. The storm water drainage system is divided into Micro Drainage and Marco Drainage System. Past records have shown that there were several catastrophic flooding in Chennai in 1943, 1976, 1985, 2002, 2004, 2005, 2006, 2007 and 2015 (Gupta and Nair, 2010).

Haphazard town planning, chocked drains, poor garbage management, and the rampant destruction of mangroves, forests, and pastures have been identified as contributory factor to flood risk in Chennai. The unprecedented rain from northeast monsoon from November to December 2015 left vast portion of Chennai submerged. Most of the flood in Chennai are credited to depression over Bay of Bengal. However, 2015 Chennai flood has been attributes to El Nino phenomenon (The Indian Express, 2015). Low pressure area was amalgamated and gradually strengthened into a deep depression on 8th of November 2015. As a result of which, there was very substantial downpour over Chennai and northern districts of Tamil Nadu starting from 9th of Nov. (The Hindu, 2015). There was 370 mm rainfall in 24 hours. Several low lying areas were inundated by 13th Nov. In continuation, 15 to 16th of Nov, Chennai city and neighboring areas got 246.5 mm of rain precipitation. It inundated most of the parts of the city. In total Chennai drenched with 1049 mm of rainfall touching a return period of almost 100 years.

Second system developed and bring heavy rainfall on 28th to 29th of November. It precipitates 490 mm of heavy rainfall in 24 hours. It was recorded as an official disaster (zeenews.india.com, 2015).

4 Delhi Urban Floods

Delhi has a long past of flooding in Yamuna river and the Najafgarh Drain system. A steady monitoring of floods in Delhi due to in Yamuna River was started in 1958. The danger level was fixed at 204.83m. During the past 33 years, Yamuna River has crossed its maximum level 25 times. Since 1990, Delhi has witnessed 6 massive floods in different years. The peak level of Yamuna was above danger level of 204.49 m in the years 1924, 1947, 1976, 1978, 1988 and 1995. The highest recorded peak of 206.92 m was on September 27, 1988.

One of the most populous area of Delhi is to the eastern side of Delhi ridge. It includes Connaught Place, the hub of commercial activity. Unfortunately, during storm showers, it is the site for heavy water impounding. This may be attributed to providing concrete surface over the entire available surface on the pretext of beautifying the area. The non-availability of sufficient recharge surface has compounded the problem of water impounding. The drains in the Delhi were initially designed to transport excess storm water and sewerage flow. However, due to improper layout and improper maintenance and unsuitable geomorphological conditions, these now form pool of stagnant water in north-west and northern parts of Delhi. As a part of solution, check dams and small lakes or ponds may be designed for increasing ground water table and as storm water holding points. The design shall preserve the natural.

5 Noida Urban Flood Event of Flood of Sep 2010

Event of Flood of September 2010 is chosen for the testing. On Sep 9, 2010 Yamuna Rivers continues to flow above the danger mark at 204.83 meters. Five villages of Noida was submerged on 5th Nov 2010 due to the water in Yamuna went up. One village was worst impacted. Villagers have been shifted to community center situated on elevated ground (The Times of India, 2010).

Table 3-1: Location of Localized Flooding in Noida Due to Rainfall

1	Sector 6, Block B	It is the location where Noida Authority is located and very prone of water logging due to rainfall. To overcome Noida Authority has set up a permanent pump. It can be seen clearly seen just before the entrance street of Noida Authority. There is a cabin at the permanent pump location along with an engine setup.
2	Sector 6, Park	There is also one setup at the park of Sector 6. The engine is moveable.
3	Sector 12, Bock A & H	
4	Sector 11	Dhavalgiri flats near Nehru Yuva Kendra. The street of the blocks are at lower elevation of 1m than the main road. Thus Dhavalgiri flat are always inundated due to rainfall. It is a classic case of poor designing. The storm water drains are also poorly designed, the slope of storm network is also poor and do not transports water to main drain.
5	Sector 19, Block B	
6	Sector 27, Block C	This location is also supported by a permanent pump with engine same as the Noida Authority set up at block B of Sector 6.
7	Sector 34	Overall sector and its arterial streets are at lower elevation of 1mwith respect to

		the main road.

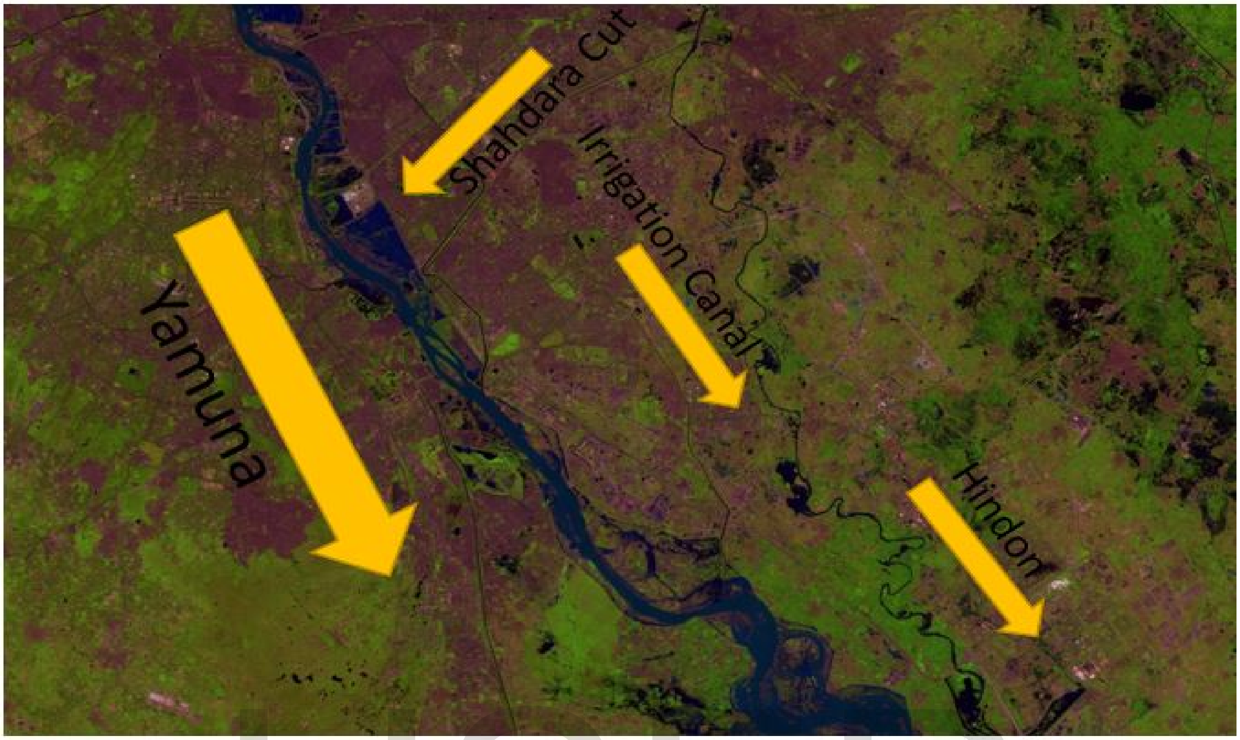

Figure 3-1: Drainage of Noida

6 Kolkata Urban Flood of 30th June, 2007

Heavy monsoon rains have caused a second wave of floods that have swept across a vast and densely populated area of the Indian state of West Bengal. To date, it is estimated that over 15 million people have been affected. More than 800 people are now feared dead and eight districts have been declared flood-affected. In addition, large areas of Calcutta were flooded several times over the last two days as a result of a high tide in the Bay of Bengal, leading to a counter flow of water upstream, with subsequent flooding of the Hoogli River.

Although there has been a slight improvement in the northern districts of West Bengal as flood waters start to recede, the situation in the south-east remains critical with many areas still completely cut off. Rescue efforts continue day and night, but resources are too limited and millions of flood victims remain stranded. The West Bengal government has started to take urgent steps to bring drinking water to the flood-hit people in the districts. According to the local media, arrangements are being made to take water by tanker and poly packs to remote flood-affected areas. Army helicopters continue to airdrop food to marooned communities. Meanwhile, reports of cholera, dehydration and water borne diseases are starting to emerge.

This second wave of floods came at a time when West Bengal was just starting to recover from the previous wave of flooding in July and August which also struck other states including Assam, Bihar, Arunachal Pradesh, Uttar Pradesh and Himachal Pradesh. During this period, torrential monsoon rains and flash floods affected more than 10 million people.

7 Bharauch, Gujarat Urban Flood of 3rd August, 2004

Bharuch district faces a number of hazards every year, which pose the threat of disaster. However, this disaster was very new to the district. On the day of 3rd August 2004, there is a news of four person's death due to flash flood in Karjan River. This incidence was reported to Gandhinagar. In evening at 7:00 O'clock, rain started. That rain did not stop until mid-night. Entire south Gujarat was badly affected by the calamity of heavy rainfall. Fourth and fifth August was very painful days for Bharuch district. Water was overflowing at the Sardar Sarovar dam on 2nd august. However, with the increasing rain activities in the Narmada Catchment area the water level at the dam had been increased which is at 113.62 meter. Similarly, at Garudeswar the water level was 18.62 and at the Golden Bridge 5.00 meter on 3rd August.

Bharuch City, Ankleshwar City and surrounding rural areas were affected badly because of the rainfall. Traditional drainage in this area got blocked due to encroachment. Intensity of rainfall was very high. Therefore, the area was unable to hold the water. This created a situation like flash floods. In short, human obstructions to natural water flow and heavy rainfall were two prime reasons for this disaster in Bharuch.

The heavy rainfall situation was well handled in Bharuch District. There were some problems like lack of resources etc. District Administration tackled the situation in coordinated approach. Limitations observed to analyze it constructively. Many new things about disaster management have been learnt. However, the most important thing is managing the disaster in really is very difficult task for any administrator. Hard work and devotions of disaster managers saves many lives during such disasters.

8 Conclusion

The risk of urban flooding increases during the progress of urbanization. It cause severe consequences as they happen. A total of six urban flood cases have been reviewed and summarizes in table 2.

Table 4-1: Recent urban floods and economic losses caused

Events	Consequences of the Event & Economic Losses
Chennai Urban Flood of Nov – Dec, 2015	The losses are accumulating from Rupees 50,000 crores to 100,000 crores. The automobile sector's losses alone were estimated between 8,000 crore. Maximum people died in Cuddalore locality. In Saidapet area, 2,000 huts were submerged. 540 people dead on 10 Dec during the event. 400 people were killed 18 lakhs were displaced. Several suburban trains' services were crippled. Several flights were cancelled and many were diverted since runway was flooded.
Srinagar Event of Sep, 2014	Srinagar received more than 550 mm of rainfall in one week. Entire city of Srinagar was inundation by 7 – 8 m of flooded water. 215 people who lost their lives in the deluge. 2,600 villages were reported affected out of which 390 villages were submerged. The infrastructural damage is likely to cross Rs. 6,000 crore. Hectares of ripe crop and orchards have been lost.
2008 Localized Floods in Jamshedpur, Mumbai and Bihar	
2008 Urban Flood of Hyderabad in	Hyderabad received over 15 cm of rainfall in less than 14 hours within a span of two days. It is second highest in four decades. Normal life came to a grinding halt in the affected areas. With some roads under water, vehicular

ISSN 2229-5518

Aug	traffic between twin cities remained paralyzed. Hyderabad bore the brunt of the natural calamity with 14 people losing their lives, mostly in house collapses. As many as 52 residential areas in and around the state capital were inundated as twenty tanks and several major storm water drains overflowed. Even after rains, hundreds of houses under water.
2007 Kolkata Flood	Number of affected cities rose to 35. Kolkata was worst affected. It is estimated that over 15 million people have been affected. More than 800 people are now feared dead and eight districts have been declared flood-affected. USD 680 million, including damage to infrastructure and housing and crops and livestock losses.
2006 Surat	Uninsured loss is $2 bn. It has a diamond turnover of around Rs.130 crore ($28 million) daily, has been forced to a standstill due to heavy rainfall and high floods. The devastating floods push Surat backwards by 25yrs. Number of affected cities rose to 22. Surat was worst affected. 95% of Surat under 10 to 15 feet of water for days together. Nearly 90 per cent of the households were affected; six of the seven wards of the city had water standing for days.
2006 Vishakhapatnam	Vishakhapatnam airport was inundated for more than 10 days.
2006 Bhopal Event of Aug	Most of the low lying localities were inundated as water entered up to 2 – 3 feet in houses. Estimated loss of more than Rs. 85 crores.
Mumbai's Meteorological Event of 26th July 2005	Rs. 450 crores loss. At least 87 people were killed in two days of crippling rains and another 130 were feared buried in landslides. At least 419 people lost their lives including 65 killed in the several landslides. Also, 216 people died owing to the various deluge-related epidemics. A substantial number of buildings were damaged. 2000 residential buildings were fully damaged. Total collapse of the transport and communication system. Both the Mumbai Santa Cruz airport used for commercial flights and Juhu airport used mainly for helicopter operations had to be closed down for two days on 26 – 27 July, 2005. The runways were waterlogged, the terminal buildings were flooded and crucial navigation and landing aids damaged, thus forcing over 750 flights to be either diverted or cancelled. Both the major roads linking the northern suburbs to the city, namely the western expressway and the eastern expressway were submerged. Most arterial roads and highways in the suburbs were severely affected due to water logging and traffic jams resulting from breakdown of vehicles in deep waters. Intercity train services had to be cancelled for over a week, while suburban trains, which are the lifeline of the city, could not operate from 16:30 onwards for the next 36 h.
Bharauch, Gujarat Urban Flood of 3rd August, 2004	Preliminary eye estimate suggested damage to 350 kms of Panchayat Roads, costing some Rs. 9.44 Crores, necessitating roughly Rs 1 crore on immediate repairs and Rs. 8.44 Crores on permanent repairs. Six state highways in the district were totally blocked for traffic due to heavy water logging and flooding in the roads. 2 bridges and 22 culverts were damaged.

	Ahmedabad-Mumbai rail and road links were disturbed due to heavy rain. Therefore, railway traffic was disrupted in major way and many trains were cancelled. Communication and electricity were also affected in rural areas of Bharuch district. Power supply was badly affected due to damage to supply lines.

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