

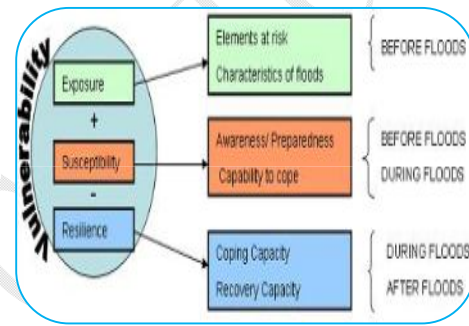


FLOOD VULNERABILITY AND ASSESSMENT OF FLOOD HAZARD IN NATIONAL CAPITAL TERRITORY OF DELHI

Dr. Naveen Chandra Singh
Associate Professor , Department of Geography,
M. M. H. College Ghaziabad, Uttar Pradesh, India.

ABSTRACT:

Frequent flood hazard in National Capital Territory (NCT) of Delhi has attracted major attention of town planners and policy makers. Delhi experiences floods almost every year mainly due to heavy rainfall in catchment area of the Yamuna River. Urban flooding, which is caused by increased runoff due to insufficient drainage system is more specific in metropolitan areas like Delhi. The loss of wetlands, mushrooming growth of slums, growth of unauthorised colonies, inappropriate disposal of solid waste, trespassing on storm water drains and encroachments on floodplain are some human activities, which have exacerbated the critical condition of flood in NCT Delhi but rapid urbanization marked with unprecedented growth in the population may be considered as the root cause, which has enhanced the vulnerability of the flood. Hydro-meteorological data reveals that floods in NCT Delhi occur more frequently in NCT Delhi and sometimes its intensity was so high that it was hazardous. In the past, some disastrous consequences of floods have been witnessed in Delhi, causing irreparable damage to life, property and infrastructure. In spite of some serious efforts by the government, such as construction of embankments, improvement of drainage efficiency, removal of unauthorized structures and promotion of rain water harvesting, NCT Delhi is still susceptible to severe flooding. This research article is an attempt to analyze the flood vulnerability and to assess flood hazard in NCT Delhi.



KEYWORDS: Flash flooding, Floodplain, Runoff, Urban flooding, Urbanization, Yamuna River.

INTRODUCTION :

Flood is often known as an overflow of excess water that submerges land. Several scholars, especially geographers have attempted to define flood. According to White, Renner and Warman (1968, p.418), 'a flood is a flow of water over a stream's banks.' They believe that flood is a feature of mature and old valleys, which is usually

caused by seasonal rainfall. In addition to submergence of land area, the definition of flood also incorporates the damages caused by the flood. Thus, flooding is regarded as an overflow of a water body, which inundates a portion of land that is usually not submerged and causes damage to property and life. The causes of flooding include both natural such as

heavy rainfall and artificial such as release of water from dams. Floods are usually classified on the basis of their duration, frequency and location. According to duration, floods are classified as flash flooding, rapid-onset flooding, slow-onset flooding etc. On the basis of location, floods are categorized as riverine flooding, coastal flooding, urban flooding etc.

Floods may also be classified according to the probability of their temporal occurrence. Riverine flooding is the result of heavy precipitation in the catchment area of a river. Flooding in urban areas are usually caused by flash floods, river floods etc., but there is also a specific flooding due to lack of adequate drainage system in urban area is known as urban flooding. Gleick and others (2006, p.104) describe urban flooding as 'flooding that occurs on relatively short time periods when insufficient drainage is available to remove precipitation.' Thus, floods are short-term discrete events, which occur when more water is produced than the soil can absorb and a stream can normally carry in its channel.

The National Capital Territory of Delhi has been prone to different types of flooding including flash flood, river flood and urban flooding, but high magnitudes floods are mainly caused by the Yamuna River, which is only perennial river in the territory. The Yamuna River has crossed its danger level several times. The highest flood level was recorded as 207.49 meter in 1978 against the danger level of 204.826 meter. Sahibi, a seasonal river aggravates the severe flood situation through Najafgarh drain in monsoon season. The city also experiences floods due to a network of several drains whose catchment area extends beyond its limits. Drains are also subject to backflow effects when water level in the Yamuna River rises above to danger mark. In almost every year, the successive flooding with varying intensity causes huge destruction and irreparable economic loss. In order to cope with the problem of flooding in NCT Delhi, Government has taken some necessary measures, but these are not sufficient to protect Delhi from flooding.

OBJECTIVES

The primary objective of this research paper is to study different aspects of flooding, which has a devastating effect on the lives of residents particularly on those who reside in slum areas and unauthorised colonies in NCT Delhi. The research paper aims to:

1. Find out causes and sources of flooding.
2. Identify the flood prone areas.
3. Assess the intensity of floods.
4. Analyse major flood hazards.
5. Evaluate the preventive measures.

METHODOLOGY

The research article is based on primary and secondary data. However, this research paper requires long-term flood data, but the actual data collected from different sources describes mainly the past five decades. Reports and publications of Irrigation and Flood Control Department, Planning Department and Delhi Disaster Management Authority (Government of NCT Delhi) are the main sources of data, but News Papers, Journals, Books and reports of other government agencies like National Capital Region Planning Board have also been consulted. Survey of India toposheets and satellite imageries of the study area have been collected and analysed. To assess the flood vulnerability, historical approach has been followed whereas field surveys have been conducted to collect the primary data during the floods of 2010, 2013 and 2018.

STUDY AREA

The study area selected to evaluate the vulnerability of flood is NCT Delhi, which includes New Delhi, the capital of India. NCT Delhi is in almost central geographical location in India between 28°23'17"N & 28°53'00"N latitudes and between 76°50'24"E & 77°20'37"E longitudes and surrounded by Haryana on the south, west and north sides and by Uttar Pradesh on the east side. India's two major landform systems, the Indo-Gangetic Plain and the Aravalli Range meet here. The terminal part of the Aravalli, which is known as Delhi Ridge extends about 35 kilometres in NCT Delhi. Most of the Delhi Ridge is covered with forest, hence it is popularly known as green lungs of this region. Besides the Delhi Ridge, the Yamuna River is another prominent geographical feature and NCT Delhi is located on the both sides of it. The flow of the river follows the general slope of the territory, which is north to south. At present, the Yamuna River appears like a seasonal river due to diversion of its water into canals in

Haryana. The water of the river is also regulated by the barrages in NCT Delhi. However the Yamuna is the most important source of raw water in Delhi but it is highly polluted due to a numbers of drains, which joins it during its journey in the capital territory.

The Yamuna flood plain, which consists of new alluvial deposits is a low-lying and sandy area adjacent to the river that are subject to recurring inundation. The North-western part of NCT Delhi, which consists of older alluvium, is upland beyond the reach of floodwater. The low-lying area in the southwest part of the territory which is locally known as Dabar gets flooded usually during monsoon season. The major part of NCT Delhi is plain whereas the southern part is hilly and mostly consists of rocks. The Delhi Ridge, which stretches in almost triangular in shape from Delhi-Haryana border in south to the western bank of the Yamuna River near Wazirabad forms a water divide between the Indus and Ganga river systems. The impact of geographical location is also reflected in the climatic conditions of NCT Delhi that signify an extreme continental climate. However, it is classified as semi-arid, but it also has characteristics of humid sub-tropical climate. January is the coldest month when the minimum temperature reaches below 5°C whereas May is considered as the hottest month during which maximum temperature has been recorded around 45°C. In NCT Delhi, the normal annual rainfall is 779 mm, of which 80 percent is received during the three monsoon months of July, August and September. Despite the horrible heat in summer and severe cold in winter, the population of NCT Delhi has increased rapidly and more than nine times increase is recorded in post independence period (1951-2011). As per the Government estimate, more than half of the population of NCT Delhi resides in slum areas, unauthorized colonies and resettlement colonies.

SOURCES OF FLOODING

NCT Delhi is affected by different sources of flooding, including Yamuna River, Sahibi River (through Najafgarh drain), drains and overland flows due to excessive rainfall. Flood occurrence in NCT Delhi is the result of one or combination of two or more sources.

1. The River Yamuna: The National Capital Territory of Delhi is prone to flooding mainly from the Yamuna River, which originates from the Yamunotri glacier of the lower Himalayas and is a major tributary of the Ganga River. The total length of the Yamuna River is about 1376 kilometres and total drainage area is about 366,220 square kilometer, which incorporates the areas of seven states, namely Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, NCT Delhi, Rajasthan and Madhya Pradesh. After traversing about 390 kilometers from the origin, the Yamuna River enters NCT Delhi near Palla village at the elevation of about 212 meters above mean sea level (msl) and leaves near Jaitpur village in south at the elevation of about 198 meters above msl. Keeping in view the topography, the Yamuna catchments up to Delhi are divided in two parts: (a) the upper catchment (from source to Kalanaur in Haryana) and (b) the lower catchment (from Kalanaur to old Delhi Bridge). Some barrages have been set up to regulate the flow of the water in the upper catchment of the river. Dakpathar is the first notable barrage in the way of the Yamuna River, which is built near Dehradun to generate electricity. The Asan Barrage is another important barrage, which is located at Uttarakhand-Himachal Pradesh border. The Hathni Kund barrage is constructed near Uttar Pradesh-Haryana border to replace Tajewala, where the water of the river is diverted into two important canals, the Western Yamuna Canal and the Eastern Yamuna Canal.

The stretch of the Yamuna River in NCT Delhi from Palla to Jaitpur is about 48 kilometers and has a catchment area of about 1485 square kilometres, which accounts 0.4 percent of its total catchment area. The flow of the river is controlled by three barrages viz, Wazirabad Barrage, ITO Barrage and Okhla Barrage in its Delhi segment. Despite these barrages and diversion of water in canals, abnormal rise in water level of the Yamuna River causes flooding in NCT Delhi. In the event of heavy rainfall in the catchment area, excess water, which is largely released from Tajewala barrage, causes serious flooding in NCT Delhi. By recurring deposit of the detritus and silt, brought down by the Yamuna from its catchment area, raises its bed, which is also liable to serious flooding. One of the

important causes of severe flooding in NCT Delhi is the construction of embankments on the river Yamuna in the state of Haryana, which has virtually eliminated the natural storage of the river valley.

2. The Sahibi River: The Sahibi River is an ephemeral stream which flows in Rajasthan and Haryana. A segment of the river in Haryana is known as Outfall Drain No. 8, which enters NCT Delhi through Najafgarh drain. The Sahibi River remains dry throughout the year except monsoon period. In earlier years, very little quantity of water used to enter NCT Delhi. Due to improvements in land development and drainage system in Haryana, it is found that the amount of water entering NCT Delhi every year is increasing rapidly. It has also been observed that the water level in Najafgarh Lake has risen and it is now submerged throughout the year. During monsoon period, the river caused serious flood problem in NCT Delhi in the past. Heavy floods due to the Sahibi River were experienced in the years of 1964, 1967 and 1977. Government has attempted to solve the problem of flood largely by increasing the capacity of Najafgarh drain. The problem of flood still remains due to lack of proper drainage system in Delhi-Gurugram border areas. The development of Najafgarh basin may resolve this problem.

3. Overland Flow: Floods in NCT Delhi are mainly caused by heavy rainfall during the monsoon period. Overland flow is the surface runoff, which is generated either by heavy rainfall or by prolonged rainfall in NCT Delhi. This surface runoff, depending on urban features is a major source of flooding in urban areas. NCT Delhi receives most of its rainfall in the months of July, August and September and the normal rainfall of these months is 210.60 mm, 247.70 mm and 125.40 mm respectively. Due to concentration of rainfall in three months, NCT Delhi experiences moderate to heavy flooding usually in these months. During the hazardous flooding in 2010, the rainfall was recorded as 239.60 mm, 455.10 mm and 332.90 mm in respective months. Excessive rainfall in monsoon months has produced the most disastrous floods in NCT Delhi in the past. Over the past few years, Delhi has witnessed mostly excessive rainfall. In the case of heavy rainfall, whenever it exceeds 50 millimetres (mm) per 24 hours, it becomes inevitable to take necessary steps in low-lying areas.

4. Drains: NCT Delhi has also a complex network of small drainage channels. Master Plan for Delhi 2021 has identified 22 main drains, which collect most of the surface water are finally discharged into the Yamuna River. On the basis of topographical characteristics, the existing drainage network may be divided into six drainage basins, namely Alipur (North Delhi), Khanjhwala (West Delhi), Najafgarh (South West Delhi), Khushk-Barapullah (Central-south & South-east), Trans-Yamuna (North East and East Delhi) and Mehrauli (South Delhi). By overtopping of banks, some of the drains cause flooding in Delhi. Drain No. 6, which runs in North Delhi is more significant in this regard. Mungeshpur drain, Ghazipur drain, Shahdara link drains are some others, which are notorious for serious flooding in surrounding areas, especially in Monsoon season. Significant increase in water level of the Yamuna also causes backflow effect in the drains having outfall in the river. As a result of the backflow, the direction of flow in the drains is reversed and drainage channels tend to overflow, causing floods in the surrounding areas.

FACTORS AFFECTING FLOOD VULNERABILITY

Apart from the physical factors, such as excessive rainfall, scarcity of vegetation and excessive sedimentation, human activities are also much significant thereby, the risk of floods in NCT Delhi has increased. Human activities include encroachment of riverine areas, establishment of unauthorized colonies, poor water and sewage management, enhanced built-up area, trespassing on water storm drains etc. The main factors affecting flood vulnerability in NCT Delhi are as follows:

1. Lack of wetlands: Wetlands act as natural reservoirs and store the excess water. Wetlands also regulate the flow of water in a basin and reduce the risk of flooding. The water bodies and wetlands of NCT Delhi have been targeted to fulfil the requirement of land for township development. The floodplain of the Yamuna River, which is the most productive wetland zone in NCT Delhi and spreads

out excess water of the river, has also been encroached. By storing and infiltrating water, wetlands reduce the risk of flood. When wetlands become smaller, their ability to regulate the flow becomes less and hence it causes flooding. A number of wetlands and water bodies have been gradually filled up in NCT Delhi. In addition to illegal filling and encroachment on wetland, dumping of solid waste and untreated sewage water has also destructed the wetlands, which acts as a buffer against flood occurrence.

2. Urbanization: Due to rapid urbanization during last six decades, NCT Delhi has witnessed a significant increase in paved area and corresponding reduction in agricultural land and open space, which used to act as a percolation zone. Increased impervious areas such as road, houses, and pavements cannot absorb the rainwater, consequently water flows quickly into river through paved areas. Hence, the increased surface runoff leads to flooding in NCT Delhi.

3. Trespassing on Storm Water Drains: Rain and flood water passes easily through storm water drains, which are developed naturally or constructed in NCT Delhi, but a significant part of these drains, have been trespassed especially by slum dwellers. The areas of storm water drains are also occupied for development purposes and garbage dumping. All these result in interruption of the flow of water and thus contribute to the outbreak of the flood.

4. Blockage of Drains: Drainage obstruction is a serious problem in NCT Delhi, where huge amount of solid waste is generated due to modernization of lifestyle. Apart from accumulation of dust, garbage, debris and solid waste materials in drains, several cables and pipes pass through drains, which reduce waterway. Blockage of drains and sewers causes severe flooding in adjacent localities.

5. Unplanned Development of Unauthorized Colonies: A number of slums and several unauthorized colonies have been developed by urban poor on the agricultural or open land without considering the city plans, drainage patterns and sewerage system. A significant number of slums and unplanned settlements may also be spotted on floodplains and the exposed riverbed. All these contribute significantly to flooding in NCT Delhi especially during heavy rainfall.

6. Poor Drainage and Sewerage Management: A considerable number of old drains and sewerage have not been renovated properly. Most of the old drains and sewer system in NCT Delhi has been damaged and a significant number of drain collapse cases is reported during monsoon period almost every year. A demolished drain or sewage line is usually the manifestation of poor management and neglected maintenance.

7. Lack of Planning: However, drainage plan for of Delhi was prepared in 1976 but drainage planning in NCT Delhi is not so satisfactory because it has many drawbacks. The Drainage Plan does not assume future urban expansions. It also does not consider the drainage problems of slum areas. A number of government agencies and civic bodies mainly Municipal Corporation, New Delhi Municipal Council, Delhi Jal Board, Delhi Development Authority and Public Work Department are involved in drainage planning but all these agencies work independently. An overall integrated drainage plan for NCT Delhi requires collaborative efforts of government agencies.

INTENSITY OF FLOOD

Intensity of flood is generally described as its damaging capacity and analysed by the rise of water or volume of inundation. For the study of flood situation in NCT Delhi, the reference to water level at old Railway Bridge is taken as the basis. The warning level and danger level of the Yamuna is fixed at 204.216 meter and 204.826 meter respectively at old Railway Bridge. The Yamuna River crossed its danger level thirty eight times during last fifty six years (Table 1). On the basis of intensity, floods of NCT Delhi may be divided into three categories viz., low, medium and high.

1. Low Intensity flood: During the dry season, the normal water level of the Yamuna is approximately 202 meter on the old railway bridge. When water level of the Yamuna remains below warning level i.e. 204.216 meter, floods are categorized as low intensity. During these floods, the water usually remains within its regime and no danger is found to life and property.

2. Medium Intensity Flood: When water level of the Yamuna crosses the warning level (204.216 meter) and remains under the danger level (204.826 meter), the floods may be called as medium intensity. In this situation, water spreads out of the regime and touches the embankments of both side of the Yamuna. At this stage, back flow starts in most of the drains out falling in the Yamuna and hence their regulators have to be brought in operation.

3. High Intensity Flood: When the water level of the Yamuna goes above the danger level (204.826 meter), the flood is termed as high intensity. As mentioned above, the Yamuna river has crossed its danger level thirty eight times during last fifty-six years. In recent past Delhi experienced high magnitude floods (above 206.00 meter) in 1978, 1988, 1995, 1998, 2008, 2010, 2013 and 2018.

Table 1
Water Level above Danger Level in Yamuna River at
Old Railway Bridge, Delhi: 1963-2018

S. No.	Date	Gauge (in meter)	S. No.	Date	Gauge (in meter)
1	25.03.1963	205.40	20	30.08.1989	205.67
2	28.09.1964	205.64	21	15.08.1990	205.02
3	15.08.1966	205.85	22	19.08.1992	205.40
4	29.07.1967	206.19	23	24.07.1993	205.06
5	09.08.1968	205.27	24	26.08.1994	205.36
6	16.08.1969	204.88	25	08.09.1995	206.93
7	10.08.1971	206.28	26	11.09.1996	205.55
8	18.07.1972	205.00	27	06.08.1997	205.88
9	29.07.1973	205.50	28	21.10.1998	206.18
10	07.08.1974	205.15	29	23.07.1999	205.28
11	12.09.1975	206.00	30	20.07.2000	205.60
12	22.08.1976	206.60	31	16.08.2001	205.12
13	07.08.1977	205.85	32	16.09.2002	205.16
14	06.09.1978	207.49	33	18.07.2005	204.86
15	16.07.1980	205.55	34	23.09.2008	206.00
16	05.08.1981	204.90	35	15.09.2009	205.33
17	30.08.1983	205.95	36	22.09.2010	207.11
18	12.10.1985	205.20	37	19.06.2013	207.32
19	27.09.1988	206.92	38	31.07.2018	206.05

Source: Data compiled from Irrigation and Flood Control Department, Government of NCT Delhi 2011, District Disaster Management Authority, East (n.d.) and Times of India Delhi, 2018.

Major Flood Hazards

Flood of 1977: In 1977, Najafgarh drain experienced heavy floods due to discharge from the Sahibi River. Two major floods occurred in 1977, first between 29th to 31st July and second between 4th to 6th August. As per Irrigation and Flood Department (Government of NCT Delhi), the water level of Dhansa bund started rising rapidly and reached 213.575 meter on 6th August 1977 whereas top of the bund was at a level of 214 meter. It is roughly estimated that the maximum discharge passed through Dhansa bund (Regulator as well as by pass channel) was of the magnitude of 36,000 cusses. On account of this heavy flow from Dhansa and also due to inflow from direct catchment of Najafgarh Lake, the Jhatikara

bund on the left bank of Najafgarh Drain in Delhi breached. Consequently, the entire Najafgarh Jheel and vast area of Delhi came under submersion. Najafgarh drain also breached at several places between Dhansa and Karkraula.

Flood of 1978: River Yamuna experienced a devastating flood in September 1978. The water level was recorded as 207.49 meter with discharge of 2.53 lakh cusec at old Railway Bridge (7.0 lakh cusec discharge was released from Tajewala). As mentioned above, it is the highest recorded water level in the available history of the Yamuna River. Many villages and some urban areas of NCT Delhi, which were unaffected in the past, were seriously affected in 1978 flood. Urban colonies like Adarsh Nagar, Model Town, Mukherjee Nagar etc., submerged under deep water, causing extensive damage to property.

Flood of 1988: In September 1988, the Yamuna River witnessed floods of very high magnitude. At this time water level of the Yamuna was recorded as 206.92 meter against danger mark of 204.83 meter. Several villages and urban localities like Mukherjee Nagar, Geeta Colony, Shastri Park, Yamuna Bazar, and Red Fort areas were affected. The flood water caused dampness to the buildings walls and sinking of foundations resulting into cracks of walls and collapse of several houses.

Floods of 1995 and 1998: Due to heavy rainfall in catchment area and release of huge volume of water from Tajewala barrage, the Yamuna River experienced high magnitude floods in 1995 and 1998. During September 1995, floods badly affected the villages and unplanned settlements situated within the riverbed. Approximately 15,000 families became homeless. In 1998, the highest water level of Yamuna was recorded as 206.18 meter in late October. It was an exceptional case when late October experienced high magnitude of flood in NCT Delhi.

Flood of 2010 and 2013: After 1978, NCT Delhi witnessed the highest flood level on 22 September 2010, when water level of the Yamuna reached at 207.11 meter at old Railway Bridge. For the second time in the available history of the Yamuna, river breached the water level of 207 meter. The flood water entered several localities, such as Batla House, Kashmiri Gate, Majnu ka Tila, Jaitpur etc. The low-lying areas of Usmanpur, Shastri Park, Bhajanpura, Yamuna Colony, Geeta Colony etc., were highly affected and thousands of flood victims were shifted to safer locations. Being low-lying area, Common Wealth Games Village was under the high risk of flood just before the starting of games. The old Yamuna Bridge, which connects east Delhi to the rest of Delhi, was closed for rail and road traffic. Delhi received record rainfall in September 2010 and most probably, it was the wettest month in Delhi since 1978. The heavy rainfall in upper catchment area of the Yamuna and resultant release of huge volume of water from Hathini Kund barrage led to serious flooding in NCT Delhi. Almost similar situation of floods has been observed in 2013, when the monsoon had arrived before its normal time and unprecedented rainfall was recorded in NCT Delhi in the month of June. The Yamuna River crossed the danger mark and touched 207.32 metres on 19th June 2013. Flood caused substantial damage to property and infrastructure including loss of human life.

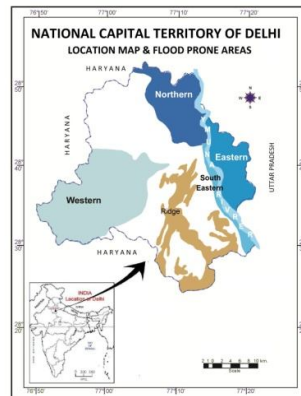


Figure 1

FLOOD PRONE AREAS

As per the Flood Atlas of India prepared by Central Water Commission, Delhi has been classified into thirteen zones based on the flood risk in relation to incremental rise in the water level of the Yamuna. This map covers part of north Delhi on the west bank of the Yamuna and almost the entire Trans-Yamuna area on the east bank. Besides this Irrigation and Flood Control Department of Delhi Government also identifies four flood sectors in NCT Delhi, namely Shahadra, Wazirabad-Babrapur, Alipur and Nangloi-Najafgarh sectors. As mentioned earlier, the Yamuna River enters NCT Delhi from northeast near Palla village and leaves the territory near Jaitpur in south. The total length of the river in NCT Delhi is about 48 kilometres with a total riverbed/flood plain area of about 97 sq. km. The low-lying flat surface on both the sides of the Yamuna River represents the floodplain, which occupies mainly north, northeast and eastern parts of NCT Delhi. The surface elevation of floodplain varies from 213 meter in northwest to 200 meter in southeast. The width of the plain varies from 17 km in north to 10 km in south. This plain is highly affected by floods. Apart from this, the low-lying area of south-west Delhi is liable to flooding by the Sahibi River through Najafgarh drain. Thus, the flood prone areas of NCT Delhi may be divided into four parts, which are as follows: (i) Northern Flood Prone Area, (ii) Eastern Flood Prone Area, (iii) South-eastern Flood Prone Area and (iv) Western Flood Prone Area

Northern and eastern flood prone areas experience extensive inundation during high magnitude flood in the Yamuna. Northern flood prone area includes highly developed urban colonies whereas whole of the trans-Yamuna zone comes under the eastern flood prone area. Apart from planned and developed colonies, a number of unplanned or poorly planned areas having high population density and sub-standard housing structure are identified as high risk flood zone. Some of the residential colonies, developed in flood prone areas are still three to four meter below the water level of 1978 flood; consequently these were badly affected during the flood of 2010. A number of temporary settlement erected between the Yamuna channel and embankment are subject to regular flooding. South-eastern flood prone area, which stretches along the western bank of the Yamuna in a narrow strip of land, is subject to recurring flooding. Being topographically low-lying, the western flood prone area is vulnerable to flooding due to heavy rainfall and widespread flooding in Rajasthan and Haryana. In this area, adverse functioning of Najafgarh drain is a peculiar factor, which intensifies the flood problem. This zone was badly affected by the floods due to Sahibi River in the years of 1964, 1967 and 1977. The effect of flooding and consequent damages may be seen particularly in rural areas however, the urban areas situated along the bank of Najafgarh drain are also affected.

Efforts of Flood Control and Prevention

Almost every year after flood, government attempts to curb floods in NCT Delhi. Various flood mitigating measures like raising and strengthening of marginal embankments of the Yamuna, remodelling of drains and construction of supplementary drains have been taken up. As per Central Water Commission only a small area about 25 sq. km. in south-east part of NCT Delhi is unprotected

flood prone area whereas rest about 74 sq. km. is protected by earthen embankments (NCR Planning Board, 2013, p.237). The preventive measures taken by the government are illustrated here.

1. Construction Work: To protect NCT Delhi from the Yamuna flood, marginal embankments on left and right banks of the Yamuna River have been constructed. After the flood of 1978, the bank of the Yamuna River has been raised and several spurs, bed bars, studs etc, have been constructed to protect the embankments. These embankments act as barriers for flooding. In the wake of Commonwealth Games in 2010, several embankments were raised and strengthened, such as embankment on right bank of the Yamuna River between Nizamuddin Railways Bridge and Road Bridge, Yamuna Bazaar wall, Left Forward Bund etc. To improve the flow of drainage in the exiting drains, supplementary drains and Regulators have been constructed in NCT Delhi. With these constructions, modifications and remodelling, the construction of Ajmeripura Dam on the Sahibi River in Rajasthan and the Masani Barrage in Haryana has considerably reduced the flood in NCT Delhi.

2. Improvement of Drainage Efficiency: Major drains of NCT Delhi need to be protected from garbage, silt, debris and solid waste materials. A coordination committee has been constituted including members from government and civic bodies to observe the cleanliness of all the drains. It has also been decided that all drains would be cleaned before monsoon every year. To protect the major drains from garbage and debris, it has been planned to build boundary wall with wire mesh along the major drains. Localities like Vasant Kunj, Mahipalpur and Dwarka suffer from flooding due to lack of proper drainage system. To solve this problem, government agencies have also worked out a comprehensive plan.

3. Rainwater Harvesting: Rainwater harvesting plays a significant role not only in controlling the floods but also in solving the problem of water scarcity in NCT Delhi. Government agencies have planned to store the rain water in storm drains and have identified certain areas as retention basins for detaining excess water. A number of constructions such as tanks in villages, artificial recharge trenches and Check Dams have been completed for rain water harvesting. After the court intervention, the government has made some serious efforts to revitalize and develop water bodies. The Government has also revised the Building Bye-laws to ensure that the new building has a roof area for rainwater harvesting.

4. Removal of Unauthorized Structure from Floodplain: A number of slums and unauthorized structures have come up on the floodplain along the banks of the Yamuna River. Attempts have been made to remove all encroachments up to 300 meter from water edge of the Yamuna River. In addition to all these measures, the recommendations of various committees and provisions of different action plans have contributed significantly to the management of flood in NCT Delhi.

CONCLUSION AND SUGGESTIONS

Despite the various flood mitigation measures, NCT Delhi is still suffering from routine flooding with misery and loss of property almost every year in monsoon season. Apart from heavy rainfall in catchment area of the Yamuna during monsoon period, blockage of drain channels by silt and solid waste, small discharge structure, inadequate pumping arrangement, small outfalls are among the important causes, which have enhanced the problem of flooding in NCT Delhi. Serious and sometimes dangerous flooding has affected urban structure, human lives and eco-system largely. In order to overcome the problem of flood in NCT Delhi, following suggestions may be made.

- Topographical consideration in flood control mechanism.
- Diversion of the Yamuna water into new canals in upper catchment area.
- Channel modification for increasing carrying capacity of the Yamuna River.
- Raising and strengthening the embankments of the Yamuna River.
- Desilting and removal of solid waste materials from all drains.

- Construction of supplementary drains.
- Removal of encroachment from storm water drain areas.
- Removal of structures from flood plain, riverbed and embankments.
- Installation of flood forecasting system.
- Establishment of well developed flood control machinery with the coordination of all the government departments and civic agencies.
- Interstate coordination.

The changes in land use caused by rapid urbanization have affected flooding in various ways. Over the past century, rapid urban sprawl has reduced the permeability of land. Approximately half of the population in NCT Delhi is living in informal settlements with inadequate housing, drainage, water and sanitation facilities. Moreover, population has occupied the flood vulnerable areas including active floodplain and exposed riverbed which not only increases the magnitude of flood but also leads to serious damages. Apparently, NCT Delhi requires planning of informal settlements, which will be a consequential action towards flood mitigation.

REFERENCES

1. Central Ground Water Board (2008), *Success Stories of Rainwater Harvesting and Artificial Recharge of Ground water in NCT, Delhi*, New Delhi: Central Ground Water Board, Ministry of Water Resources.
2. Centre for Civil Society (2006), *State of Governance: Delhi Citizen Handbook 2006*, New Delhi: Centre for Civil Society.
3. Delhi Development Authority (2010), *Master Plan for Delhi- 2021*, New Delhi: Delhi Development Authority.
4. District Disaster Management Authority, East (n.d.), *A Report on Management of Yamuna Flood-2013*, Delhi: District Disaster Management Authority (East).
5. Gleick, Peter H. et al. (2006), *The World's Water 2006-2007: The Biennial Report on Freshwater Resources*, Washington DC: Island Press.
6. Irrigation & Flood Control Department (2011), *Flood Control Order 2011*, Delhi: Irrigation & Flood Control Department, Government of NCT Delhi.
7. Narain, Sunita (2012), *State of India's Environment, a Citizen Report, Excreta Matters: How Urban India is Soaking up Water, Polluting Rivers and Drowning in its own Waste*, New Delhi: Centre for Science and Environment.
8. National Capital Region Planning Board (2013), *Draft Revised Regional Plan 2021 National Capital Region*, New Delhi: National Capital Region Planning Board.
9. Planning Department (2018), *Economic Survey of Delhi, 2017-18*, New Delhi: Planning Department, Government of NCT Delhi.
10. Times of India (2018), 'Yamuna Water Level Recedes', *Times of India*, Delhi, Dated 01 August 2018.
11. White, C. Langdon, George T. Renner and Henry J. Warman (1968), *Geography: Factors and Concepts*, New York: Meredith Corporation.



Dr. Naveen Chandra Singh
Associate Professor, Department of Geography, M. M. H. College Ghaziabad,
Uttar Pradesh, India.