सत्यमेव जयते

YAMUNA URBAN FLOODS IN DELHI WITH FOCUS ON JULY 2023 EVENT

Flood Monitoring Cell
Geo-Meteorological Risks Management Division

nidm

Resilient India - Disaster Free India

National Institute of Disaster Management
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कार्यकारी निदेशक

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Executive Director

सत्यमेव जयते

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FOREWORD

Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management. The developing countries like India suffer the greatest costs when a disaster hits. More deaths are caused by hazards that occur in developing countries, and losses due to natural hazards are much greater in developing countries than in industrialized countries. Since urban flooding has become a prominent disaster affecting various cities across the globe, increasing trend of urban flooding is a universal phenomenon and poses a great challenge to urban planners the world over.

While the factors like lack of adequate drainage system, large scale urbanization, reduction in holding capacity of the catchment, the confining of river spread by construction of embankments coupled with climate change phenomenon are the major causes of flood in Delhi. Challenges and complexities of governance and multiple organizations for flood control and drainage exacerbate the flood problem of Delhi.

It is in the context of Yamuna urban floods problems of Delhi with focus on flood during July 2023, this publication is being brought out. The documentation is based on research, first hand experiences of the stakeholders, knowledge and experiences of many resource persons, Data and information received from relevant departments in Delhi. Not only the genesis causes, impacts of flood of July 2023 have been addressed but also flood scenario of Delhi is seen with a retrospective viewpoint by delving upon the history of floods in Delhi in its essence. The challenges faced in evacuation, response relief and rescue have also been highlighted.

It is hoped that the publication of this documentation will stimulate improved data collection and research, which can enable the gaps so identified in the management of disasters, to be addressed in future.

(Madhup Vyas)

PREFACE

This publication is focused not only on Yamuna urban flood of Delhi that occurred in July 2023 but also encompasses the past recurrent floods in Delhi with a retrospective view point. Based on the lessons drawn and challenges faced in the past, a way forward is suggested. It needs to be realized that the issue of flooding of Delhi is complex and its solution is not simple and straightforward but presents a daunting task. The reasons for floods in Delhi are manifold and more or less known but its high time that an implementable action plan is drawn. However, in order to conceive the solution to the flooding in Delhi, a micro level analysis along with a holistic approach is required to be dwelled upon at the same time. The instant documentation is, therefore, intended to be an intermediate step in right direction towards a feasible and practical solution to the problem. In order to draw an actionable strategy, this publication reflects upon the complexities in all dimensions with respect to reasons, multitude of stakeholders, widespread impacts, mitigation strategies and challenges in response relief and recovery.

Rapid and haphazard urbanization, encroachment into flood plain and drainage channels, reclamation of wetlands and flood plain, inadequacies and lacuna in drainage system results in pronounced urban flooding and it's the poor who have built shelters on illegal, unsafe land in high risk zones are the worst affected. Besides, flood in Delhi also renders infrastructural damages and disruption in economic activities, vital services and means of transport.

On account of precarious nature of flood in Delhi, this publication is intended to be an eye opener to all associated with the flood in Delhi including administration, all stakeholders, line departments and the ministries who were brought onto one forum by holding a consultative workshop during the process of documentation. The issue has been thoroughly researched from the existing literature review including published papers and reports, newspaper reports, various website and the internet, updated data and information obtained from concerned organizations and many resource persons. All perspectives have been taken care of as far as possible from viewpoint of basin states to town planners and academicians, professionals and policy makers alike.

It is hoped that the publication, which is an attempt to synthesize and synergize the myriad perspectives, will serve to appreciate the differential viewpoints of one stakeholder by another and will serve as a reference document and guide for the way forward of future endeavors in respect of flood risk reduction and resilience in Delhi.

(Surya Parkash)

ACKNOWLEDGEMENT

The eventful flood of July 2023 of Delhi when the High Flood Level of Yamuna recorded highest ever in the history has pointed how much vulnerable to floods is the city of Delhi. Though, there has been no human casualty but life, however many vital services like water supply and transport were badly affected. It was worthwhile, therefore, not only to document this flood event and its related causes, effects, relief and response activities along with the past floods and to delve into depth of the issue in order to consolidate the lessons learnt and the way forward.

The publication is the result of much handholding and team effort. First of all I would like to thank Shri Madhup Vyas, IAS, Executive Director, NIDM for his visionary guidance and immense support during the process of documentation. The documentation would not have been possible without the contribution of many departments through the data and information provided to NIDM in time and as and when required. In particular IMD, DDMA, I&FC Delhi, CWC and many other stakeholders and line departments who contributed by giving worthwhile suggestions due to their first hand experience in dealing with Delhi Floods in general and July 2023 event in particular.

Thanks are due to Shri Santosh Kumar Tiwari, Librarian, NIDM, and Ms Karanpreet Kaur Sodhi, Jr. Consultant, publication cell for extending the necessary cooperation in printing of the document. Time to time suggestions and feedback provided by the GMRD team of NIDM primarily, Shri M. S. Dhillon, Sandeep Kumar Singh, Dr. Ravinder Singh, Vimal Tiwari, Dr. Shubham Badola, Karishma Choudhary, Stanzin Tsela, Dr. Kundan Deval for providing review assistance and Ms. Pallavi, for their assistance in completing this task, heartfelt thanks are due to them. All the faculty and staff members of NIDM, who have directly and indirectly supported in preparing the document, are also acknowledged

It is hoped this documentation on "**Yamuna Urban Floods in Delhi with Focus on July 2023 Event"** will go a long way in helping those who are committed to building a disaster-resilient society

(Surya Parkash)

CONTENTS

LIST OF FIGURES

List of Tables

ABBREVIATIONS AND ACRONYMS

ADAG	: Anil Dhirubhai Ambani Group
API	: Antecedent Precipitation Index
ATI	: Administrative Training Institute
BIS	: Bureau of Indian Standards
BMTPC	: Building Materials and Technology Promotion Council
BRPS	: BSES Rajdhani Power Supply Ltd.
BSES	: Bombay Suburban Electric Supply
BYPL	: BSES Yamuna Power Limited
CAPF	: Central Armed Police Forces
CBRI	: Central Buildings Research Institute
CBRN	: Chemical, Biological, Radiological, and Nuclear
CBSE	: Central Board of Secondary Education
CDEF	: Cultural Development and Exchange Fund
CPHEEO	: Central Public Health and Environmental Engineering Organization
CrPC	: Criminal Penal Code
CRRI	: Central Road Research Institute
CSIR	: Council of Scientific & Industrial Research
Cumec	: Cubic meters per second
Cusec	: Cubic feet per second
d/s	: Downstream
DC	: District Collector
DCB	: Delhi Cantonment Board
DDA	: Delhi Development Authority
DDMA	: Delhi Disaster Management Authority

Degrees C	: Degrees Celsius
DERC	: Delhi Electric Regulatory Commission
DESU	: Delhi Electric Supply Undertaking
DG	: Director General
DHS	: Directorate of Health Services
DIAL	: Delhi International Airport Limited (DIAL)
DL	: Danger Level
DPCL	: Delhi Power Supply Corporation Limited
DTC	: Delhi Transport Corporation
DUSIB	: Delhi Urban Shelter Improvement Board
DVB	: Delhi Vidyut Board
EOC	: Emergency Operations Center
F&ES	: Fire and Emergency Services
FSO	: Food Security Officer
GNCTD	: Government of National Capital Territory of Delhi
GOI	: Government of India
GSDP	: Gross State Domestic Product
HFL	: High Flood Level
Hrs	: Hours
I&FCD	: Irrigation and Flood Control Department, Delhi
IAS	: Indian Administrative Service
IE(I)	: Institution of Engineers (India)
IMD	: India Meteorological Department
IRC	: Indian Roads Congress
Kms	: Kilometers
L/B	: Left Bank
LG	: Lieutenant Governor
lpm	: Liters per minute
m. bgl	: meters below ground level
MAFW	: Ministry of Agriculture and Farmers Welfare
MCA	: Ministry of Corporate Affairs

MCD	: Municipal Corporation of Delhi
MEITY	: Ministry of Electronics and Information Technology
MFIN	: Ministry of Finance
MoHFW	: Ministry of Health and Family Welfare
MHRD	: Ministry of Human Resource Development
MLA	: Member of Legislative Assembly
MoCI	: Ministry of Commerce and Industry
MoEFCC	: Ministry of Environment, Forest and Climate Change
MoES	: Ministry of Earth Sciences
MoHA	: Ministry of Home Affairs
MoHUA	: Ministry of Housing and Urban Affairs
MoJS	: Ministry of Jal Shakti
MoRD	: Ministry of Rural Development
MoSPI	: Ministry of Statistics & Programme Implementation
MoWR	: Ministry of Water Resources
MP	: Member of Parliament
MS	: Mild Steel
MSJE	: Ministry of Social Justice and Empowerment
MWCD	: Ministry of Women Child Development
MYAS	: Ministry of Youth Affairs and Sports
NBCC	: National Buildings Construction Corporation
NDMA	: National Disaster Management Authority
NDMC	: New Delhi Municipal Council
NDRF	: National Disaster Response Force
NE	: North East
NGO	: Non-Governmental Organization
ORB	: Old Railway Bridge

ORS	:	Oral Rehydration Solution
PRIS	:	Panchayati Raj Institutes
PS	:	Police Station
R/B	:	Right Bank
RWA	:	Resident Welfare Association
SDM	:	Sub Divisional Magistrate
SDMA	:	State Disaster Management Authority
SE	:	Superintending Engineer
SERC	:	Structural Engineering Research Center
SIDM	:	Society of Indian Defense Manufacturers
SOP	:	Standard Operating Procedure
SQ	:	Square
STP	:	Sewage Treatment Plant
SW	:	South West
TPDDL	:	Tata Power Delhi Distribution Limited
u/s	:	Upstream
UDD	:	Urban Development Department
ULB	:	Urban Local Body
UN	:	United Nations
USD	:	United States Dollars
WD	:	Withdrawal
WL	:	Warning Level
WTP	:	Water Treatment Plant

About the Organisation

National Institute of Disaster Management (NIDM)

The National Institute of Disaster Management (NIDM) was established under an Act of Parliament to serve as a premier institute for capacity development in disaster management in India and the region. Initially formed as the National Centre for Disaster Management (NCDM) in 1995, it was later redesigned as NIDM in 2003, focusing on training and capacity building. Under the Disaster Management Act of 2005, NIDM was tasked with responsibilities such as human resource development, capacity building, training, research, documentation, and policy advocacy in disaster management.

NIDM has played a vital role in bringing disaster risk reduction to the national forefront by promoting a "Culture of Prevention" involving all stakeholders. The Institute collaborates with various ministries, central, state, and local governments, academic, research, and technical organizations, both within India and internationally, as well as with bilateral and multilateral agencies.

The Institute boasts a multi-disciplinary team of professionals dedicated to various aspects of disaster management. It offers state-of-the-art facilities, including classrooms, seminar halls, and video-conferencing capabilities. NIDM also has a specialized library focused on disaster management and mitigation. Training is provided through face-to-face sessions, online platforms, self-learning modes, and satellite-based training. Free in-house and off-campus training is available to state government officials, including modest boarding and lodging.

NIDM supports national and state agencies in Disaster Management and Disaster Risk Reduction by building capacity and preparedness at all levels. Its vision is to create a Disaster Resilient India through comprehensive capacity building for disaster prevention and preparedness.

Delhi Disaster Management Authority (DDMA)

Delhi Disaster Management Authority (DDMA) was established on 19 March 2008, under the chairmanship of the Hon'ble Lt. Governor of Delhi. The Secretary (DDMA)/Divisional Commissioner of Delhi heads the nodal department for disaster management and serves as the Convenor of DDMA. This framework aims to provide institutional structures for unified command, control, and coordination, with legal authority to address Delhi's disaster management needs, including defining roles and

responsibilities, creating a techno-legal regime, generating awareness, building capacity, and developing disaster management plans at all levels.

The Disaster Risk Management (DRM) programme, in collaboration with GoI-UNDP from 2003-2008, emphasized awareness, education, training, and capacity development for better disaster preparedness and risk management at community, district, and state levels. It also focused on strengthening Emergency Operation Centers. Key elements of the disaster management strategy include generating awareness, developing preparedness and response plans, fostering collaboration between government and civil society, and building the capacity of government institutions in disaster mitigation and recovery. Efforts have been made to develop a database on hazards, vulnerabilities, and risks in Delhi. The establishment of Emergency Operation Centers at state and district levels ensures coordinated relief and rescue during emergencies. Partnerships with academic institutions and the private sector support the development of disaster risk management plans and projects. Both structural and non-structural measures are being implemented to reduce disaster impacts, enhance management skills, and improve the preparedness and response capacities of communities, local authorities, urban bodies, and state authorities.

Irrigation & Flood Control Department (I&FC)

Irrigation & Flood Control Department is headed by Principal Secretary (I & FC) along with two Chief Engineers. As per sanctioned strength there are Six Superintending Engineers/ SSW (Civil),Twenty-Five Executive Engineers/ SW (Civil), Four Executive Engineers (Mech.), Eighty-Two Assistant Engineers (Civil), Eighteen Assistant Engineers (Mech.), One Hundred Fifty Junior Engineer (Civil), Twenty-Six Junior Engineers (Mech.), Six Drafts Man Grade-I, 24 Drafts Man Grade-II and Seven Drafts Man Grade-III and Four Surveyor. The total sanctioned strength of Technical Staff is 352. Two zones are assisted by one Administrative Officer and Financial Advisor-cum Accounts Officer and 19 AAO. The total sanctioned staff strength of Ministerial staff and Administrative Staff is 265. Thus, the overall sanctioned strength of Technical + Ministerial & Accounts Cadre is 617.

The Irrigation and Flood Control Department of Delhi is responsible for managing water resources in the region, including irrigation systems, flood management, and infrastructure related to water supply. They implement various projects to prevent flooding and ensure efficient water usage within the city.

Chapter 1: Introduction to Floods

1.1 Background

Disaster means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence, which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area (DM Act 2005).

Hazards are often divided into natural hazard and anthropogenic hazards depending upon their genesis and source. Examples of natural hazards include avalanches, flooding, cold waves and heat waves, droughts, earthquakes, cyclones, landslides, lightning, tsunamis, volcanic activity, wildfires, and winter precipitation (hazards.fema.gov). Examples of anthropogenic hazards include stampede, terrorism, war, industrial hazards, engineering hazards, fire and transportation hazards. However, in modern times, the divide between natural, human-made and human-accelerated disasters is difficult to draw (Gould et. al. 2016).

Developing countries like India suffer the greatest costs when a disaster hits. More than 65% of all deaths caused by hazards occur in developing countries, and losses due to natural hazards are 20 times greater (as a percentage of gross domestic product) in developing countries than in industrialized countries (Ballesteros Luis Flores, 2008).

Urban flooding has become a prominent disaster affecting various cities across the globe. Urban flooding is the inundation of land or property in a built environment, particularly in more densely populated areas, caused by rainfall over the city itself overwhelming the capacity of drainage systems, such as storm sewers or additionally due to river or a water body near or passing through the city, causing inundation of the low lying urban areas. Although, sometimes triggered by events such as flash flooding or snowmelt, urban flooding is a condition, characterized by its repetitive and systemic impacts on communities that can happen regardless of whether or not affected communities are located within designated floodplains or near any body of water. Aside from potential overflow of rivers and lakes, snowmelt, storm water or water released from damaged water mains may accumulate on property and in public rights-of-way, seep through building walls and floors, or backup into buildings through drains, sewer pipes, toilets and sinks.

Urban Floods typically result from the confluence of meteorological, hydrological and physiographic factors such as rainfall frequency and intensity, storms, temperature, land use, land forms and other physiographic conditions further exacerbated by human actions and built environment. The replacement

of earth's natural land cover and vegetation by impervious surfaces such as built-up structures and roads has raised the issues of inundation of urban areas over the last few decades. This is diminishing the natural storage capacity of the soil and alters the existing hydrological cycle often increasing the surface runoffs. According to the National Disaster Management Authority (NDMA), the volumes in case of urban floods can increase by up to 6 times while the peaks from 1.8 to 8 times in comparison to that of a rural flood. As a result, urban flooding can occur within a very short duration, sometimes even within a couple of minutes, due to high-speed flow. The artificial drainage channels that are constructed also fail to deal with the excess runoff creating inundation and flooding. Several issues like encroachment of river plains, land reclamation below flood level, disposal of wastes in water bodies, loss of natural drains and ponds, etc. also arise due to the increasing urban population. These urban challenges further get aggravated by impacts of climate change. Global climate change is resulting in changed weather patterns and increased episodes of high intensity rainfall events occurring in shorter periods of time. Then the threat of sea level rise is also looming large, threatening all the coastal cities. Cities/towns located on the coast, on river banks, upstream / downstream of dams, inland cities and in hilly areas can all be affected

Increasing trend of urban flooding is a universal phenomenon and poses a great challenge to urban planners the world over. Problems associated with urban floods range from relatively localized incidents to major incidents, resulting in cities being inundated from hours to several days. Therefore, the impact can also be widespread, including temporary relocation of people, damage to civic amenities, loss of lives, property damage, and deterioration of water quality and risk of epidemics.

Urban flooding also impacts critical public services, including public transportation systems (Suraez et. al. 2005, Chang et. al. 2010). Traffic congestion can be worsened by urban flood events, impacting ease of access to transportation, as well as the ability of emergency services to operate effectively. Urban flooding can also create far-reaching supply chain issues, which can create significant interruptions in the availability of goods and services, as well as financial losses for businesses.

1.2 Urban Flooding: Global Scenario

Some of the most obvious impacts of urban flooding are those to human life and to property damage. In 2020, floods caused an estimated 6,000 deaths and caused US$51.3B in damages globally (source: Centre for Research on the Epidemiology; UN Office for Disaster Risk Reduction, 2021). Flood and its related disasters are caused by excessive volumes of runoff, which are not absorbed by the ground. Residents at low-elevated regions are often at risk of inundation, financial loss, and even the loss of lives. As the pace of urbanization accelerates around the world, flash flood damage takes place more frequently. Between 1961 and 2020, nearly 10,000 cases were reported with 1.3 million deaths and a minimum of USD 3.3 trillion of financial losses at an equivalent loss rate of almost USD 1800 per second. On an average, the total reported deaths worldwide were around 23,000/year for the past 6 decades at an equivalent rate of one death every 24 min. (Ling et. al. 2022)

The Los Angeles flood of 1938, which witnessed high runoff leading to floods and the Rapid City Flood of 1972 that resulted due to the clogging of water channels and drains, were some of the early instances of urban flooding. The major issues of urban floods, however, started arising in the 21st century and gradually amplified with urbanization. The frequency of urban floods across the world started increasing, resulting in heavy loss and damage. There have been 3,600 cases of urban flooding in the United States

as reported by the National Weather Service between 1993 and 2017 (Poon, 2018). Illinois alone has suffered a loss of 2.3 billion USD between 2007 and 2014 (Grabar, 2019). The Hull Flood of 2007, Newcastle Flood of 2012, Ireland Flood of 2012-13 and Cumbria Floods of 2017 are a few of the catastrophic urban flooding in Europe. The Queensland Flooding of 2011 and Townsville Floods of 2019 have been the major events of urban flooding in Australia in the previous decade.

In Asia, urban flooding is a frequent phenomenon. In urban environments, farmland, vegetation cover, and bare soil have been converted into built-up areas. In urban areas, with rapid increase in impermeable surfaces and urban development, the likelihood of flooding has increased. Similarly, the intensity of urban floods becomes higher with prolonged rainfall. The probability of urban flooding is expected to further increase with changing climate (Carmin et al., 2013). In Asia, numerous coastal cities are exposed to both urban and coastal floods, whereas inland cities are vulnerable to flash floods, river floods, or urban floods. In developing countries, human encroachments onto the active flood channel, poor flood management strategies, lack of flood early warning systems, and disposal of solid waste in drainage lines are the major causes of urban flooding.

In Asian cities, populations grow gradually, and these new residents/immigrants need shelter to accommodate their needs. As urban populations grow, the pressure on existing resources and infrastructure intensifies. At the same time, land values increase, and higher buildings are constructed to fulfill the housing demand. Finally, the most pronounced aspect of cities in the developing world is haphazard urban expansion over valuable natural resources. In all these cases, poor people are the ones who have no choice but to build shelter on illegal, unsafe land in high-risk zones. This situation, where people consistently encroaching onto the flood prone areas narrow the channel and in turn reduce the channel carrying capacity, is very common in almost every megacity.

In Asia, almost every city of the continent is prone to urban floods because of their climatic conditions and topographical characteristics. Asian megacities like Bangkok, Manila, Guangzhou, Dhaka, Ho Chi Minh City, Jakarta and Mumbai are extremely vulnerable to frequent flooding.

Top 20 cities vulnerable to urban flooding in the world are as follows:-

1. Guangzhou, China
2. Mumbai, India
3. Kolkata, India
4. Guayaquil, Ecuador
5. Shenzen, China
6. Miami, Florida, USA
7. Tianjin, China
8. New York — Newark, New Jersey, USA
9. Ho Chi Minh City, Vietnam
10. New Orleans, Louisiana
11. Jakarta, Indonesia
12. Abidjan, Ivory Coast
13. Chennai, India
14. Surat, India
15. Zhanjiang, China

16. Tampa—St. Petersburg, Florida, USA
17. Boston, Massachusetts, USA
18. Bangkok, Thailand
19. Xiamen, China
20. Nagoya, Japan

(Source- https://www.archdaily.com/429767/the-20-cities-most-vulnerable-to-flooding)

1.3 Urban Flooding: Indian Scenario

A special feature in India is that it has heavy rainfall during monsoons. There are other weather systems also that bring in a lot of rain. Storm surges can also affect coastal cities/ towns. Sudden release or failure to release water from dams can also have severe impact.

There has been an increasing trend of flooding in Indian towns and cities over the last few decades due to the increase in the average annual rainfall in many parts of India over the years. Most of the major cities of India at present are vulnerable to urban flooding and have witnessed repeated instances of flooding. The most notable amongst them are Hyderabad in 2000 and 2020, Ahmedabad in 2001, Delhi in 2002, 2003, 2009, 2010, 2013 and 2019 Chennai in 2004 and 2015, Mumbai in 2005 and 2017, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, and Guwahati in 2010, Bengaluru in 2022 and now the most recent flood in Delhi during July 2023.

The heavy rainfall received in India during southwest monsoons makes its towns and cities extremely vulnerable to urban floods. The average annual rainfall received in the country varies from 2813 mm in Panaji on the higher side to 609 mm in Jaipur on the lower side. Many Indian cities like Cherrapunji (11,777 mm); Port Blair (2872 mm); Panaji (2813 mm); Dibrugarh (2569 mm); Dehradun (2220 mm); Shillong (2207 mm); Mumbai (2186 mm); Agartala (2149); Kohima (1831 mm) Kolkata (1800 mm) , and Guwahati (1722 mm) receive high rainfall compared to that of flood- vulnerable cities of other countries like Guangzhou (1720 mm) ; Miami (1570 mm) and Jakarta (1755 mm). The coastal cities are also vulnerable to flooding because of storm surges and cyclones. The exponential increase in urban populations and the expansion of urbanized areas (Fig 1.1 and Fig 1.2) further worsen these conditions. The rapid urbanization is leading to the reclamation of wet lands and flood plains, encroachment on drainage channels, clogging of channels due to improper waste disposal, poor maintenance of storm water drains, etc. It also leads to urban heat island effect increasing the rainfall received in urban areas. The issue of over-concretization has been a serious problem for all the flood-prone towns and cities. The impacts of changing climate and seasonal unpredictability also add to the gravity of the situation.

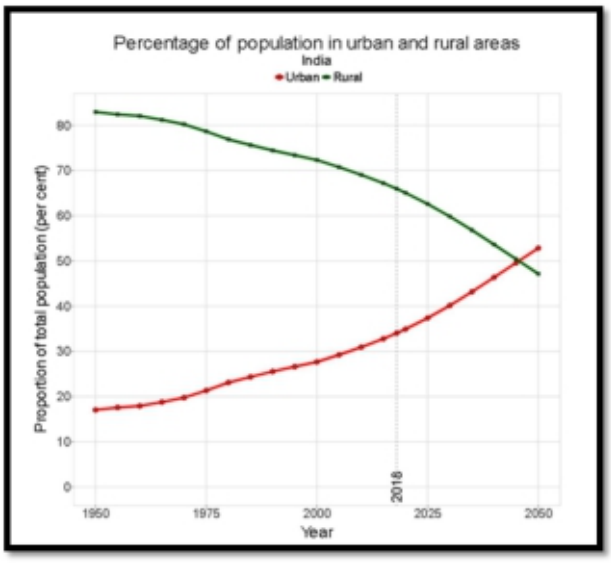


Fig 1.1: Exponential Increase in Urban Population
(Source: https://population.un.org/wup/country-profiles/)

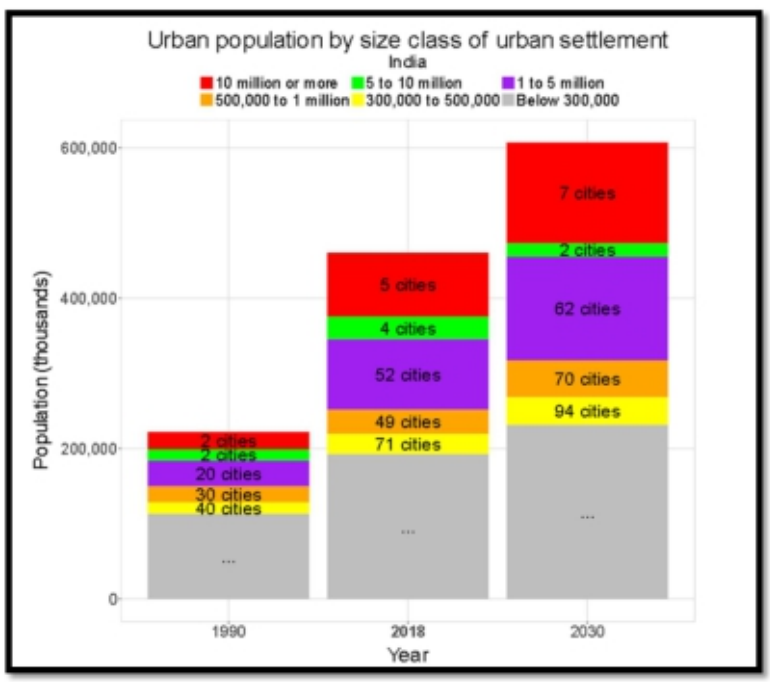


Fig 1.2: Urban population by size class of urban settlement
(Source: https://population.un.org/wup/country-profiles/)

India suffers huge infrastructural damages, destruction of properties, disruption of economic services and activities and loss of lives with the increasing occurrences of urban flooding. It has been projected that by 2030, infrastructure of approximately 150 billion USD would be exposed to disaster risks because of urban flooding in India. Urban areas are also centers of economic activities with vital infrastructure which needs to be protected 24x7. In most of the cities, damage to vital infrastructure has a bearing not only for the state and the country but it could even have global implications. Major cities in India have witnessed loss of life and property, disruption in transport and power and incidence of epidemics. Therefore, management of urban flooding has to be accorded top priority.

1.4 Urban Flood Management Guidelines

Urban Flooding has become a nightmare for urban planners, designers, engineers and Disaster Risk Reduction (DRR) professionals. The characteristics of urban floods being different from flash floods is a major challenge for the authorities. The July 2005 urban flood of Mumbai was an eye-opener for the entire nation and urban flooding was introduced as a separate disaster by NDMA, delinking it from riverine and coastal floods. The flooding in Surat in 2006 and the flooding of Kolkata in 2007 brought to the fore the need for comprehensive interventions for urban flood mitigation. The NDMA set up a committee in 2008 to formulate the "National Guidelines on Management of Urban Floods", which was published in the year of 2010. The National Guidelines have been prepared with an objective to guide the ministries and departments for the management of urban flooding risks and call for a proactive , participatory, well-structured, multi-disciplinary and multi-sectoral Urban Local Bodies (ULBs) to implement catchment-based planning and designing for storm water drainage systems. A mandate for detailed contour mapping with 0.2-0.5 meters interval has been issued for planning drainage systems of urban areas as per the National Guidelines. The "Manual on Sewerage" published in 1993 by the Central Public Health and Environmental Engineering Organization (CPHEEO) has a specific section for the storm drainage basin. Guidelines on urban drainage which provide for drainage design for roads (SP-50-1999, IRC) was brought out by the Indian Roads Congress (IRC) in 1999. Both of these guidelines do not take into account the spatial distribution of rainfall over India or within cities. However, an exclusive and detailed "Manual on Storm Water Drainage Systems" has been published in May 2019 by CPHEEO under the MoHUA.

1.5 Institutional Frame work for Management of Urban Floods

The institutional framework for the whole of India, in general, is such that the nodal ministry for providing coordination, technical inputs, and support for the management of urban flooding is the Ministry of Housing and Urban Affairs (MoHUA). The ministry also acts as the nodal ministry for central assistance. The dissemination of warning and information is coordinated by the Ministry of Jal Shakti (MoJS) and Ministry of Earth Sciences (MoES) at the national level and State Disaster Management Authority (SDMA) and Revenue Department at the state level. The District Disaster Management Authority (DDMA) and ULBs coordinate preparedness and response at the district and local level. Table 1.1 shows Responsibilities of Departments and Authorities for Urban Flood Management.

Table 1.1: Responsibilities of Departments and Authorities for Urban Flood Management

Authorities	Responsibilities	National Authorities	State
Understanding Urban Flood Risks	Mapping/Zoning, Estimation of Possible Inundation Levels, Monitoring Networks	MoHUA, MoES, MoJS, DoS	DMD, SDMA, RD, SRSAC, DDMA, PRIs (for peri-urban areas), ULBs
	Information Systems, Monitoring, Forecasting, Early Warning	MoES, MoJS	
	Hazard, Risk Vulnerability and Capacity Assessment (HRVCA)	NDMA, NIDM, MSJE	
	Disaster Data Collection and Management	MHA (Nodal Body), MoSPI, all ministries /departments	DMD, SDMA, all departments
Inter-Agency Coordination	Overall Disaster Governance	MoHUA	DMD, SDMA, RD, DDMA,ULBs, PRIs (for peri-urban areas)
	Response	MoHUA	DMD, SDMA, RD, DDMA,ULBs, PRIs (for peri-urban areas)
	Warnings, Information, Data	MoES (IMD)-Nodal Body, MoJS, MoES, NDMA, MEITY	DMD, SDMA, RD, DDMA,ULBs, PRIs (for peri-urban areas)
	Non-Structural Measures	MoHUA, BIS, NDMA	DMD, SDMA, RD, DDMA,ULBs, PRIs (for peri-urban areas)
Structural DRR Measures	Civil Works	MoHUA(Nodal Body), NBCC, BMTPC, CBRI, SERC, IE(I), CRRI	DMD, UDD, ULBS, PRIs (for peri-urban areas)
	Establishment/ Strengthening of Emergency Operation Centers	Relevant Central Ministries, MHA	DMD, SDMA, ULBs, PRIs (for peri urban areas)
	Hazard resistant construction, strengthening and retrofitting of all lifeline structures and critical infrastructure	NDMA, NBCC, BMTPC, CBRI, SERC, IE(I)	SDMA, DDMA, ULBs, PRIs (for peri-urban areas)
	Preparation of	MoHUA	DMD, SDMA,

Authorities	Responsibilities	National Authorities	State
Non-Structural DRR measures	comprehensive Urban Storm Drainage Design Manual		DDMA,UDD
	Preparation of Storm Water Drainage System Inventory	MoHUA	DMD, SDMA, ULBs, PRIs (for peri urban areas)
	Operation and Maintenance of Drainage System	MoHUA	DMD, SDMA, ULBs, PRIs (for peri urban areas)
	Environmental Impact Assessment	MoEFCC (Nodal Body), MoHUA	DMD, SDMA, ULBs, EFD, PRIs (for peri urban areas
	Techno-Legal Regime Land use planning City/Town planning	MoHUA, MFIN	DMD, SDMA, ULBs, EFD, PRIs (for peri urban areas
	Constitution of Urban Flooding Cell for Integrated UFDM	MoHUA	DMD, SDMA, UDD
	Public- Private Partnerships	NDMA, MoHUA, MCA (Nodal Body), MCF, MoCI, MPFI, MHIPE, MFIN	UDD, SDMA, DDMA
Capacity Development	Risk Transfer	MFIN (Nodal Body), NDMA, MHA, MoAFW	DFIN (Nodal Body), DMD, SDMA, State Department of Agriculture
	Education and Training	MoHUA(Nodal Body), MHRD, MoHFW, NDRF, NIDM, CBSE, MYAS	ULB, PRIs (For peri-urban areas), SDRF
	Awareness Generation	MoHUA (Nodal Body), NDMA, NDRF, CAPF, NIDM	DMD, SDMA, RD, DDMA, SDRF, F&ES, CDEF, Police, ULB, PRIs (for peri-urban areas)
	Documentation	NIDM	DMD, SDMA, RD, DDMA, ULB, State ATI
	Empowering Women, marginalized and persons with disabilities	MWCD (Nodal Body), MSJE, NDMA, NIDM	DMD, SDMA, DDMA, RD, SIDM, ATI and other State- level institutions
	Community- Based Disaster Management	MoHUA (Nodal body), MoRD (Nodal Agency), NDMA,	DMD, SDMA, SDRF, RD, DDMA, ULB, SIDM

Authorities	Responsibilities	National Authorities	State
	Mock Drills/Exercises	NIDM MoHUA, NDMA, All Govt Ministries/Agencies, NDRF, Armed Forces CAPF	DMD, SDMA, RD, DDMA, ULB, SDRF, F&ES, CDEF, Police
Climate Change Risk Management	Research, Forecasting/Early Warning, Data Management, Zoning, Mapping	MoES, MoJS (Nodal Body), MoST, CSIR, DoS, NLRTI	DMD, SDMA, RD, IRD, WRD, SLRTI
	Climate Change Adaptation (CCA)	MoES & MoEFCC (Nodal Body), MoST, DoS, MoJS	DMD, SDMA, IRD, WSD (Nodal Body), EFD, DRD, DDMA, ULBs, PRIs (for peri urban areas)

Chapter 2: Salient Characteristics of Delhi

The flood vulnerability of Delhi is required to be perceived in the backdrop of its salient characteristics. Delhi is surrounded by four states viz Haryana, Uttar Pradesh and Rajasthan makes its situation peculiar in the Yamuna Basin for their influence with respect to floods. Additionally the upstream states like Himachal Pradesh and Uttarakhand affect the flooding in Delhi. Similarly weather and climate, geomorphology, hydrogeology, demographic profile, economic profile, and land use pattern have influence on the urban flooding risk in Delhi. The complex administration of Delhi and multiple agencies looking after floods exacerbate the urban flooding in Delhi. Following paragraphs dwell on the salient characteristics of Delhi.

2.1 Location and General Characteristics

Delhi is the capital of India. It is located in northern part of the country between the latitudes of 28°-24'-17" and 28°-53'-00" North and longitudes of 76°-50'-24" and 77°-20'-37" East. Delhi shares border with the States of Uttar Pradesh and Haryana (Fig 2.1) It has an area of 1,484 sq. kms. Its maximum length is 51.90 kms and maximum width is 48.48 kms. Its geography divides the state into three parts- the Delhi ridge, the Yamuna flood plain and the plains. The Yamuna flood plains are very fertile as they are flooded by the river and are rich in alluvial soil. The Delhi ridge is the most important characteristic of the state and is a part of the Aravalli range that passes through Delhi.

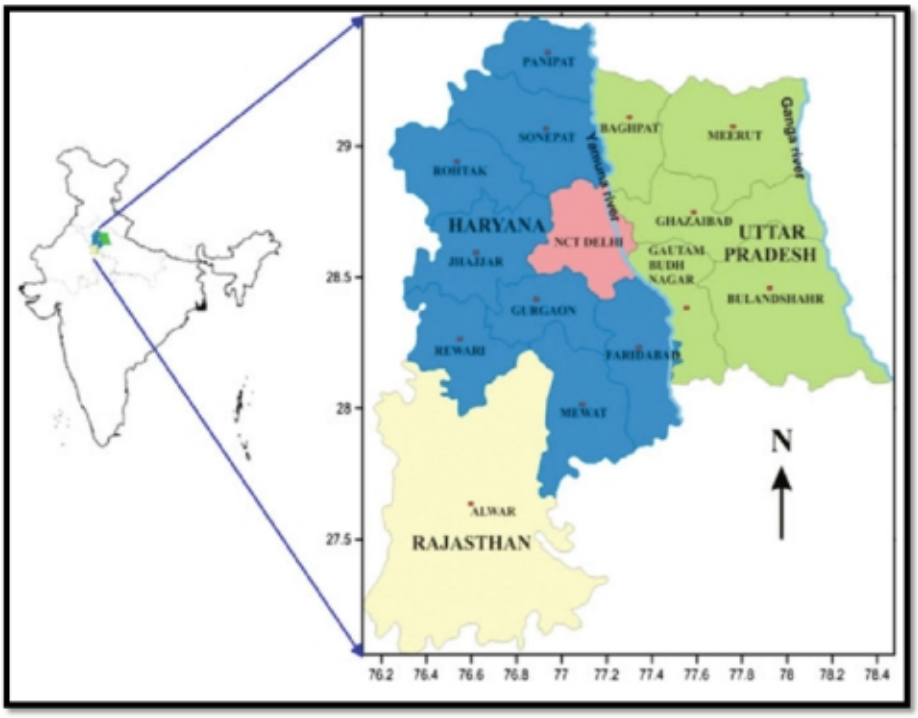


Fig 2.1: Location of Delhi

2.2 Weather and Climate

Delhi weather varies with the different climatic conditions that are faced by this city. It is a city characterized by weather extremes. The geographical location of this city influences the weather conditions. Delhi experiences tropical steppe type of climate and hence, its seasons are marked with extreme temperatures. The summer season commences in the month of April and continues till July. During this season, continental air blows over the city and makes the weather in Delhi very dry and hot. Summer weather condition is characterized by scorching heat and unbearable temperature. Temperature reaches almost 45 degrees C in the summer months. On the contrary, winter, which lasts from December to January, is extremely cold. Temperature falls to almost 5 degrees C during the winter months in Delhi. The rainy season in Delhi begins in June and continues almost till October. Delhi receives most of its rain during this period of Delhi remains pleasant during the rainy season, but humidity level remains

2.3 Geomorphology

Delhi is bounded by the Indo-Gangetic alluvial plains in the North and East, by Thar Desert in the West and by Aravalli hill ranges in the South. The terrain of Delhi is flat in general except for a low NNE-SSW trending ridge that is considered as an extension of the Aravalli hills of Rajasthan.The ridge may be said to enter Delhi from the SW.The eastern part of the ridge extends up to Okhla in the South and disappears below Yamuna alluvium in the NE on the right bank of the river. Fig 2.2 shows Geomorphological map of Delhi.

Fig 2.2: Geomorphological Map of Delhi
(Source: http://www.rainwaterharvesting.org/index_files/geology.html)

2.4 Hydrogeology

In terms of hydrogeology, fresh water is available up to 60 meters depth below ground level for over 90 per cent of the city, and the quality of water is also potable. For the 10 per cent of city limits comprising the Ridge, that is not suitable for water recharge or aquifer; the remainder has saline and brackish waters. A map showing January 2018 ground water levels in NCT of Delhi is given in Figure 2.3 and areas under various depth zones presented in Figure 2.4. Around 16% of NCT Delhi areas, in parts of North, North West and some small pockets of Central & Southwest districts have shallow water level up to 5 m bgl. Deep water levels of 20 to 60 m observed in around 30% of NCT Delhi, in South, South East, New Delhi, West & South West districts. In rest of NCT Delhi, 54% areas have water level in range of 5 to 20 m bgl. In terms of groundwater potential (as indicated in Fig. 2.5) of the city, area covered by younger alluvium has the potential to yield 800 litres per minute (lpm) to 3200 lpm. For areas under older alluvium, the yield is 400 lpm to 500 lpm. While for fringe areas, yield is low at 150 lpm to 300 lpm and for the Delhi quartzite or the area under Delhi ridge, the yield of groundwater is limited at 100 lpm to 150 lpm.

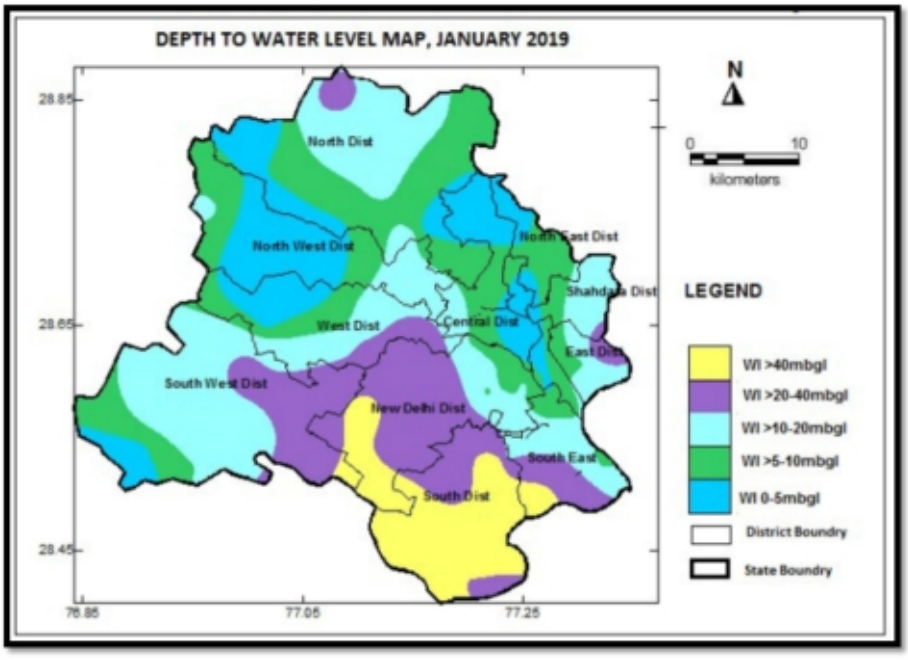


Fig 2.3: Depth to Water Level Map of Delhi
(Source: Ground Water Year Book National Capital Territory, Delhi 2018-19)

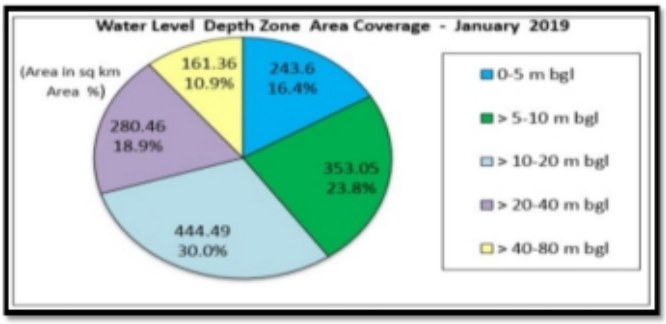


Fig 2.4: Water Level Depth Zone Area Coverage-January 2019
(Source: Ground Water Year Book National Capital Territory, Delhi 2018-19)

Fig 2.5: Groundwater Potential of Delhi
(Source: http://www.indiaenvironmentportal.org.in/files/Kaushik.pdf)

2.5 Demographic Profile of Delhi

Delhi is one of the fastest growing cities in the country. Due to rapid pace of urbanization,the landscape of Delhi has undergone a change from a rural majority to urban. The rural to urban area change during the last three censuses in Delhi is depicted in Table 2.1. The population in Delhi during 1951-2011 is depicted in Fig 2.6.

Table 2.1: Area – Rural and Urban (Source : Population Census of India)

S. No.	Classification of Area	1991		2001		2011	
		Km²	%	Km²	%	Km²	%
1.	Rural	797.66	53.79	558.32	37.65	369.35	24.90
2.	Urban	685.34	46.21	924.68	62.35	1113.5	75.1
3.	Total	1483	100	1483	100	1483	100

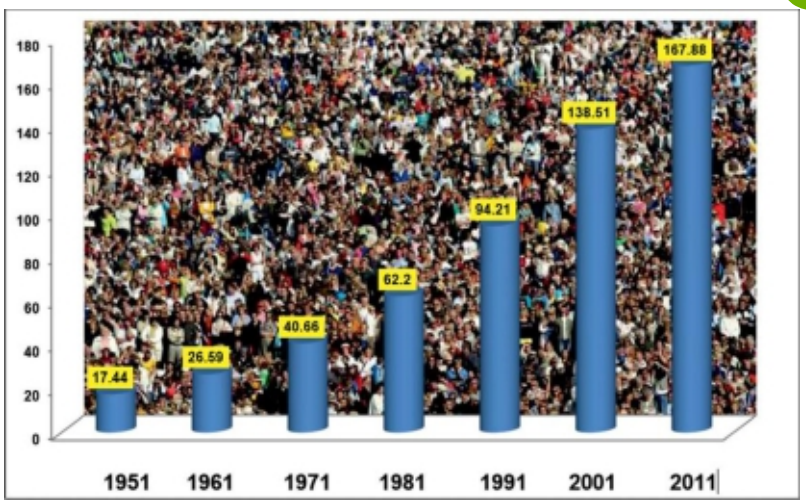


Fig 2.6: Population of Delhi from 1951 to 2011
(Source : Population Census of India)

2.6 Economic Profile of Delhi

Main Highlights of Delhi Economic Survey 2022-23 are:

(i) The Advance Estimate of Gross State Domestic Product (GSDP) of Delhi at current prices during 2022-23 is likely to attain a level of ₹1043759 crore which is at a growth of 15.38% over 2021-22.

(ii) Overall economic activity in Delhi has recovered more faster compared to national, past the pre-pandemic levels. In the years 2021-22 & 2022-23, a sharp recovery of real GSDP of Delhi with growth of 9.14% & 9.18% respectively is based on a low base effect and inherent strengths of the economy.

(iii) Its economy was a predominant Service Sector with its share of contribution to Gross State Value Added (at current prices) at 84.84% during 2022-23 followed by contribution of Secondary Sector (12.53%) and Primary Sector (2.63%).

(iv) Its Per Capita Income during 2022-23 at current prices, has been worked out to ₹444768 as against ₹389529 during 2021-22 showing a growth of 14.18 percent.

(v) Its Per Capita Income has always been around 2.6 times higher when compared to national average, both at current and constant prices.

(vi) It has maintained its consistent Revenue Surplus; it increased to ₹3270 crore during 2021-22 (Provisional) as compared to ₹1450 crore in 2020-21. Its revenue surplus was 0.36% of GSDP during 2021-22 and 0.73% during 2022-23 (BE).

(vii) Tax Collection of Delhi Government registered a tremendous growth of 36% during 2021-22 (Provisional) as compared to the negative growth of 19.53% in 2020-21 (due to COVID Pandemic).

(viii) Govt. of NCT of Delhi has been working with an aim to transform Delhi to a world class city and to fulfill the aspiration of its citizen by making it an inclusive, equitable and livable global city.

(ix) During 2022-23, Transport Sector has been allocated the major share of about 20% of total Budget allocation of Schemes/ Programmes/ Projects, followed by Education (17%), Water Supply & Sanitation (15%) and Medical & Public Health (13%).

2.7 Land Use Pattern of Delhi

The demographic structure has brought with it the areal growth and spatial transformation of the city. As there has been a sharp spurt in the population of the city in the last 20 to 30 years, there has been a parallel increase and growth in its built up area. The need to accommodate the growing population has caused this increase in area. The growth in its area has brought with the change in the nature of land use with the growing limits of the city. This has brought the encroachment of the peripheral villages. Consequently, there has been landscape change in the city. A considerable change in land use has occurred during the last few decades. The change may be in a specific area or the entire region. The change from rural to urban land use is so fast that the resultant need and complex uses coupled with the shortage of land have led to speculation and increase in land values.

With reference to Table 2.2 and Figures 2.7 to 2.10, it may be interpreted that in 1985, Built-up land covered 298 km^2 areas which are almost 20% of the total area, where agricultural land 49.12% or 729 km^2, 209 km^2 area covered by forest, 215.98 km^2 area under scrub, waste and barren land, and water bodies stand with 32 km^2 or 2.16% of the area.

In 1998, after 13 years there is a massive change observed in this area and built-up land rapidly increased to reach 31.88% or 473 km^2, where the major impact of this expansion shown in agricultural land which shrinks from 729 km^2 to 572 km^2 almost 38%, and forest slightly increased 209 to 211 km^2 or 14 per cent to 14.25%, waste-barren and scrub land are least effected and it stands 13.23% (earier 14.56%) of the area, where water bodies have no major changes and it still stands on 2.16 to 2.10% respectively

In 2008, after 10 years of gap, there is a major change seen in built-up land, and it covered 46.67% or 692.50 km^2, where 372 km^2 or 25.07% high density, 160.57 km^2 or 10.82% medium, and 126.17 km^2 or 8.50% low-density area, and this expansion is in the cost of agricultural land; which shrink from 38.54 to 32.74%, forest; 14.25 to 10.38% and waste-barren-scrub land; 13.23 to 8.19%, respectively

In 2018, the rate of growth was slow, and the urban built-up area reached at 773.59 km^2 or 52.13% in which high density built-up increased from 372 to 461 or 25 to 31.45%, medium-density built-up area from 160.57 to 181 km^2 or 10.82 to 12.19% and low density continue in decreasing trend and is almost 2% area. In the other side, the agricultural area shrinks from 485.91 to 412.41 km^2. During this period, the massive positive changes observed in the forest area, which has extended from 153.96 km^2 to 197.34 km^2 area, which is almost 13.29% of the total area.

Table 2.2: Land Use Land Cover Area Statistics of 1985-2018
(Source: Rupesh Kumar Gupta, 2021)

Year/LULC Category Delhi	1985		1998		2008		2018		1985-1998	1998-2008	2008-2018
	km^2	%	Area	%	km^2	%	km^2	%	Growth km^2 per annum		
Built Up Land	298	20.08	472.98	31.88	692.50	46.67	773.59	52.13	13.46	21.95	8.10
Agricultural Land	729	49.12	572	38.54	485.91	32.74	412.41	27.79	12.07	8.60	7.35
Forest	209.02	14.08	211.42	14.25	153.96	10.38	197.34	13.29	0.18	5.75	4.34
Barren & Scrub Land	215.98	14.56	196.31	13.23	121.55	8.19	74.23	5.01	1.51	7.47	4.73
Water Bodies	32	2.16	31.29	2.10	30.08	2.02	26.43	1.78	0.05	0.12	0.36
Total Area	1484	100	1484	100	1484	100	1484	100			

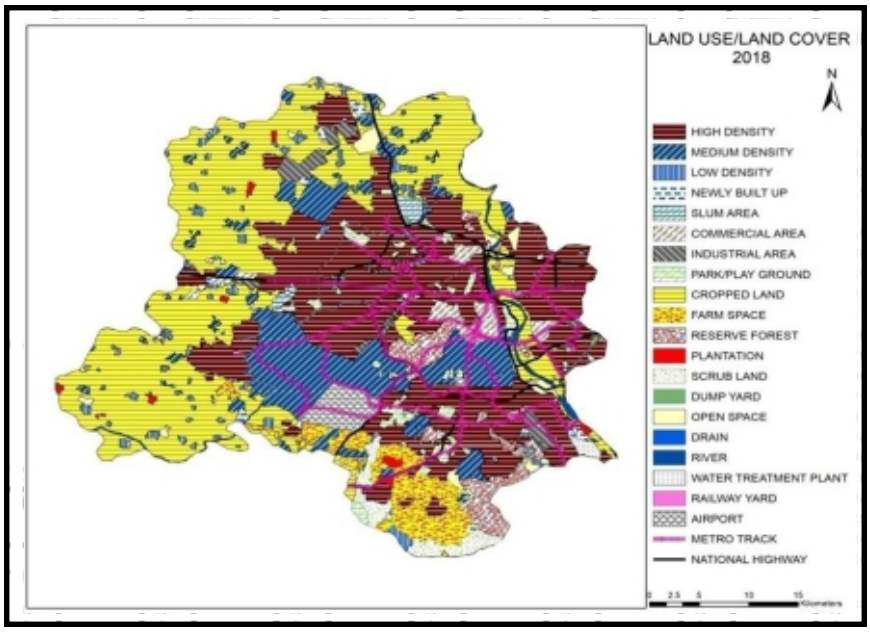


Fig 2.7: Land Use and Land Cover Map of Delhi 2018

(Source: Rupesh Kumar Gupta, 2021)

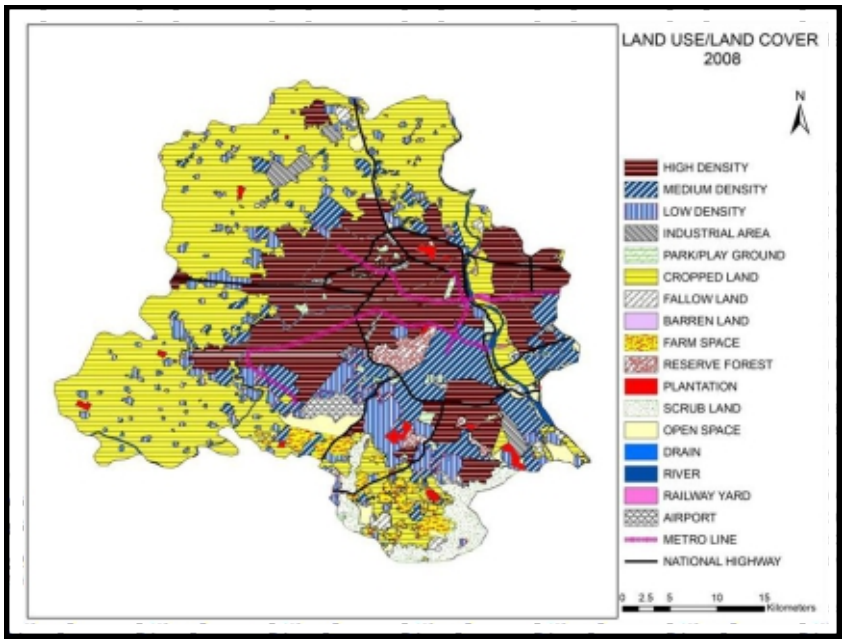


Fig 2.8: Land Use Land Cover Map of Delhi, 2008

(Source: Rupesh Kumar Gupta, 2021)

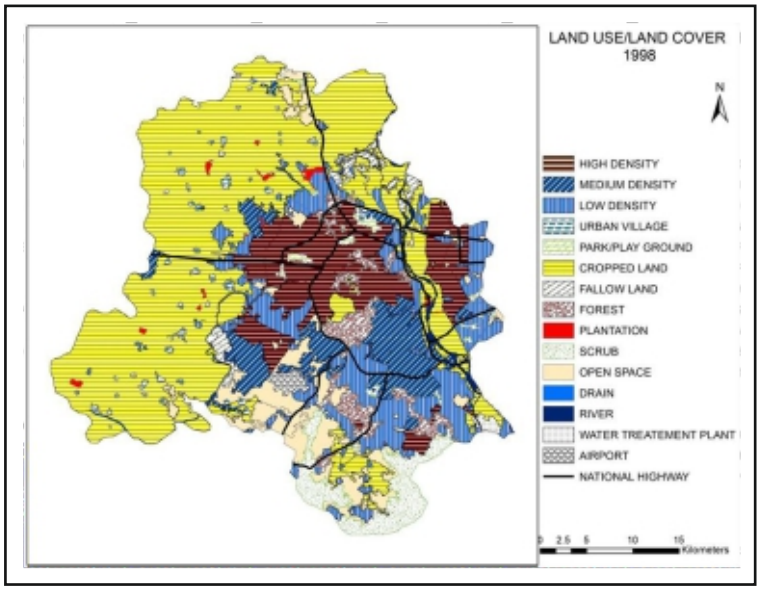


Fig 2.9: Land Use Land Cover Map of Delhi, 1998
(Source: Rupesh Kumar Gupta, 2021)

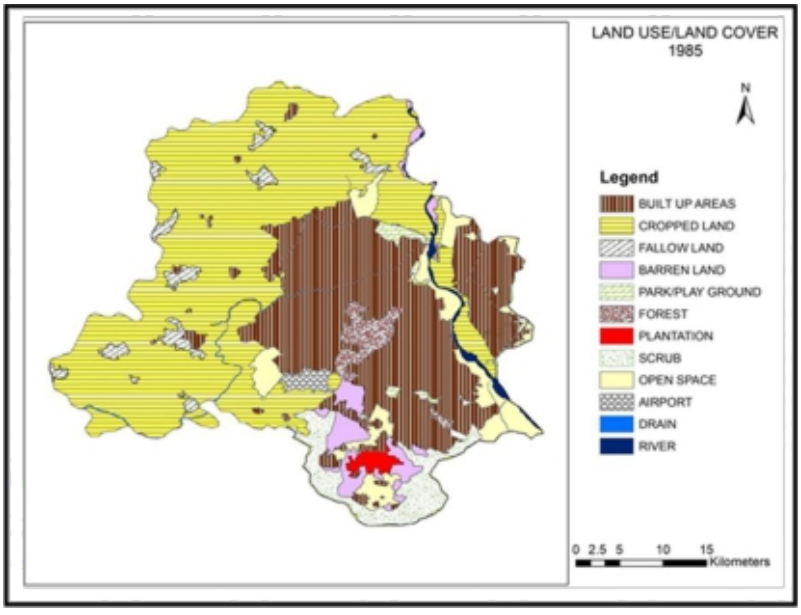


Fig 2.10: Land Use Land Cover Map of Delhi, 1985
(Source: Rupesh Kumar Gupta, 2021)

2.8 Administrative Setup

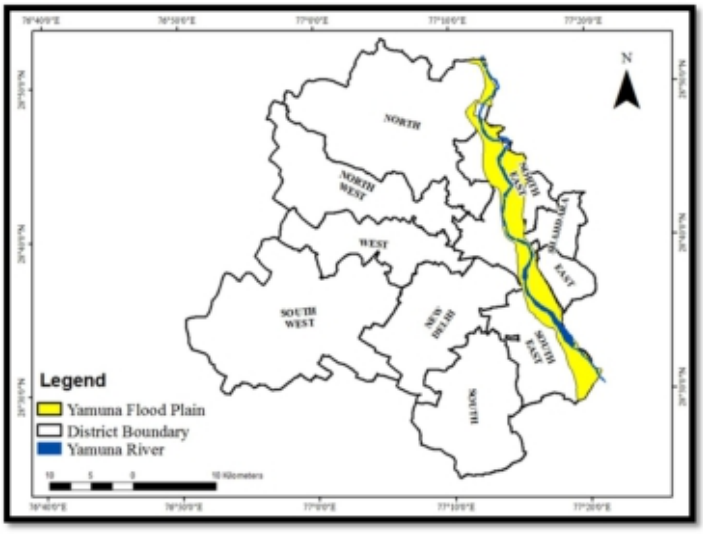


Fig 2.11: The eleven administrative districts of Delhi
(Source: https://nriol.com/india-statistics/delhi/districts.asp)

Delhi enjoys a unique ('sui generis') status compared to other States and Union Territories. Under Article 239AA, Delhi remains a Union Territory but possesses certain State-like features. As a Union Territory, the NCT of Delhi is an extension of the Union of India. Union Territories are directly governed by a Union-appointed Administrator (for Delhi, this is the Lieutenant Governor). However, since Delhi also has a democratically elected Legislative Assembly and Council of Ministers, the Lieutenant Governor's powers are severely limited compared to the Administrators of other Union Territories.

Government of the National Capital Territory of Delhi (GNCTD) is the governing body of the Union Territory of Delhi, whose urban area is the seat of the Government of India. It also governs the city or local governments in the area as per the 74th Constitutional Amendment Act.

Union Territories are governed by the Union Government. There are a few exceptions, such as Delhi and Puducherry, which also have their own elected governments with some limitation

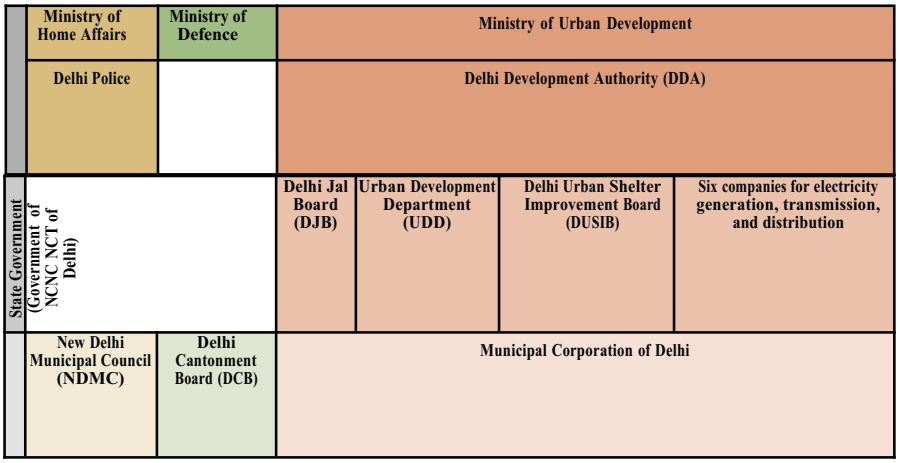


Fig 2.12: Union, State, and Local Agencies Involved in the Governance of Delhi
(Source: https://cprindia.org/wp-content/uploads/2021/12/The-Intersection-of-Governments-in-Delhi.pdf)

Many of the challenges and complexities of governance in Delhi arise from its place at the intersection of local, state, and national jurisdictions

2.8.1 Local

Delhi's local government is made up of three urban local bodies: the New Delhi Municipal Council (NDMC), the Delhi Cantonment Board (DCB), Delhi Municipal Corporation (MCD). New Delhi Municipal Council (NDMC) was established through the NDMC Act, 1994, amended in 2011, and includes about three per cent of Delhi's area under its jurisdiction. According to Census of India 2011, 249,998 people live within the area governed by the NDMC. The Council is a nominated body, and is headed by a chairperson who is appointed by the Ministry of Home Affairs of the Government of India. The Council, in turn, is directly accountable to this Ministry.

The Delhi Cantonment Board is also a municipality that has jurisdiction in the city, since cantonment boards are municipalities as per the Cantonment Board Act 2006 and are under control of the Ministry of Defence. The Delhi Cantonment Board (DCB), established in 1914, also has about three per cent of Delhi's area under its jurisdiction, housing a population of 116,352 (Census 2011). The DCB is legislated by The Cantonments Act, 1924, amended in 2006, and is made up of eight elected members. The executive head of the Board is appointed by the Ministry of Defence, and, just as the NDMC answers directly to the Ministry of Home Affairs, the DCB is accountable to Ministry of Defence.

Municipal Corporation of Delhi is one of the largest municipal bodies in the world providing civic services to approximately 20 million citizens of Delhi. It occupies an area of 1397.3 Sq. kms. which is sub- divided into 12 Zones i.e. Centre, South, West, Najafgarh, Rohini, Civil Lines, Karol Bagh, SP-City, Keshavpuram, Narela, Shahdara North & Shahdara South.The MHA appoints a commissioner to lead Municipal Corporation of Delhi.

2.8.2 State - Government of NCT of Delhi

Although it briefly had a legislature after Independence, between 1956 and 1992 Delhi was a union territory, governed by the union government with no state-level legislative power. In 1992 the Government of National Capital Territory of Delhi Act, 1991 came into force, creating Delhi as a state with a new state-level representative government to be called the Government of the National Capital Territory of Delhi (GNCTD). At present, the GNCTD oversees nearly 1500 square kilometres.

In many ways, the GNCTD is similar to any other state level government: it manages transport, industrial development, revenue administration, power generation, food and civil supplies, and health and family welfare. The GNCTD's legislative body—the Legislative Assembly of the National Capital Territory of Delhi—is made up of 70 members (MLAs), each representing an assembly constituency averaging 200,000 voters, delimited based on data from the Census of India 2001. Each constituency contains four municipal wards.

Due to certain special provisions inserted into the Constitution of India by the GNCTD Act, 1991, the legislature is more limited than other state governments. While the Legislative Assembly has the power to make laws for the whole or any part of the NCT of Delhi with respect to matters set out in the State List or in the Concurrent List of the Constitution, it does not have the power to make laws relating to police, public order, or land; these areas remain the purview of the Parliament of India. This limitation extends to executive power: according to the Constitution of India, executive power is 'co-extensive' with the legislative power of the Parliament of India.

In other words, the GNCTD is not responsible for physical planning, development of land, or law and order. These functions are overseen by bodies that are directly accountable to the Government of India, leading to a governance structure that is often described as "limited statehood". For administrative purposes, the GNCTD area is divided into 11 districts (Fig 2.11).

Presently, basic service provision in Delhi is largely the purview of the GNCTD, which has absorbed and reconfigured several local-level bodies since its creation in 1992.

2.8.3 Water

The Delhi Jal Board (DJB), formed in 1998, is directly accountable to the GNCTD and is responsible for water and sewage-related infrastructure in Delhi. The DJB oversees bulk water supply for all of Delhi and distribution of water in the MCD areas; the NDMC and DCB are responsible for distribution of water in the areas under their control. The DJB was preceded by the Delhi Water Supply and Sewage Disposal Undertaking (DWS&SDU), part of the MCD from 1958 until 1996, when it was transferred to the GNCTD.

2.8.4 Electricity

Like water, electricity generation, transmission, and distribution was overseen by an MCD body for many years i.e. the Delhi Electric Supply Undertaking (DESU). In 1997, the state-level Delhi Vidyut Board (DVB) replaced the DESU, shifting responsibility for electricity to the GNCTD. In 2002, the DVB was split into six companies. Three of these have remained pure government undertakings: the Delhi Power Supply Company Limited (DPCL), a holding company; Indraprastha Power Generation Company Limited (referred to as Genco), the power generation company; and the Delhi Transco Limited (referred to as Transco), the power transmission company.

The remaining three companies, which have become known as "discoms", are responsible for distribution. Fifty per cent of each of these was auctioned to private players, resulting in three joint venture distribution companies: Tata Power Delhi Distribution Limited (TPDDL) for North Delhi, BSES Rajdhani Power Limited (BRPL) for South Delhi, and BSES Yamuna Power Limited (BYPL) for East Delhi. The private partner in Tata Power Delhi Distribution Limited (TPDDL) is the Tata Group, and the private partner in both BSES Rajdhani Power Limited (BRPL) and BSES Yamuna Power Limited (BYPL) is the Reliance Anil Dhirubhai Ambani Group (ADAG). The remaining fifty per cent of each of these distribution companies is still owned by the GNCTD. A sixth body, the Delhi Electricity Regulatory Commission (DERC), regulates electricity tariffs.

2.8.5 Union - Government of India

According to the 2011 Census of India, Delhi's seven Members of Parliament (MPs) each represent an average of 2,500,000 voters, distributed across ten assembly constituencies. This means that for every 2.5 million voters, there is one national-level representative, ten state-level representatives, and approximately forty local representatives.

The constitutional head of Delhi is the Lieutenant Governor (or LG) of Delhi, who is appointed by the President of India. Delhi is the only state with an LG, a post otherwise reserved for union territories. The LG of Delhi heads governance functions in Delhi vested with the union government, and he or she leads the executive bodies that carry out the functions of land, police, and public order.

The Delhi Development Authority (DDA) is responsible for all physical planning and development of land and housing in Delhi. The DDA was established through the Delhi Development Act, 1957, passed by the Parliament of India. It is important to note that the DDA was created at a time when Delhi was a union territory, with no state level government. The DDA has remained a union government body since Delhi became a state in 1992 and continues to be accountable to the Ministry of Urban Development of the Government of India.

In addition to its planning, Delhi's law and order are also managed by the union government: the Delhi Police is directly accountable to the Ministry of Home Affairs at the Government of India.

2.9 Multiple Institutions for flood control and drainage

The urban flood problem of Delhi is exasperated due to multitude organizations for flood control and drainage in Delhi. With regard to the management of the storm water drainage system within NCT of Delhi, there is, conspicuously, no single institution that bears an overall responsibility of the total system. To the contrary, the administrative authority of the capital's drainage system is quixotically distributed amongst numerous civic bodies and various constituent departments of Government of NCT of Delhi as well as Government of India. These include

(i) Irrigation & Flood Control, Delhi
(ii) Delhi Jal Board
(iii) Municipal Corporation of Delhi
(iv) Urban Development Department, Delhi
(v) Ministry of Housing and Urban Affairs, GoI
(vi) New Delhi Municipal Council
(vii) Delhi Development Authority
(viii) Delhi Cantonment Board
(ix) Delhi State Industrial Development Corporation
(x) Public Works Department, Delhi
(xi) Delhi Disaster Management Authority

Other departments of the Government and civic bodies whose jurisdiction does not entail any direct responsibility pertaining to the state of the capital's drainage system but nevertheless their effectiveness is indeed a matter of interest includes

a) Irrigation & Flood Control, Government of Haryana
b) Traffic Police, Delhi
c) Geo Spatial Delhi Ltd.
d) Central Water Commission, GoI
e) Indian Meteorological Department
f) Various Resident Welfare Associations (RWAs)
g) Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change, Govt. of India
h) National Green Tribunal
i) National Highway Authority of India
j) Delhi International Airport Limited
k) Civil society activist groups

Chapter 3: Multi-hazard scenario in Delhi

Delhi, the capital of India, is vulnerable to natural disasters like earthquakes and urban flooding as well as human induced disasters such as bomb-blasts, acts of terrorism, industrial and CBRN hazards, road accidents etc. Some of these disasters have crosscutting issues with floods.

3.1 Earthquake

Earthquake disaster in Delhi has the potential to go well beyond the statistics of deaths and injuries. Such a disaster in the country's capital, which also happens to be a major commercial and industrial center, will have huge economic and political implications which will affect the entire country and not just the population of Delhi. This adds an extra dimension to the earthquakes problem for Delhi. Considering the potential for a mega disaster, we cannot afford to ignore the earthquake problem.

3.1.1 Geological Setting of Delhi

Delhi is bound by the Indo-Gangetic alluvial plains in the north and east, the Thar Desert and Aravalli Hill range in the west and south, respectively. The city has a flat terrain except for a low NNE-SSW trending ridge, an extension of Aravalli hills of Rajasthan.

Delhi being one of the fastest-growing old cities, in terms of both built ambiences and population, and one of the seismically vulnerable areas of India, could be under high seismic risk. Delhi lies in the closer vicinity of Himalayan Belt, and many previous studies mentioned about the movement of the Indian plate and Eurasian plate along the Himalayan Belt that causes deformations in the Himalayan region including northern parts of Delhi. Seismicity in North India, including the Himalayas, is due to collision of the Indian plate with Eurasian plate. This is a continuous process happening for the last 50 million years. These colliding plates flex, storing energy like a spring, and when the plate's margin finally slip to release energy, an earthquake results.

Delhi the capital of India, is a metropolitan city having a population of over 16 million people. It has an area of 1484 km^2 of which 784 km^2 is designated as rural area and 700 km^2 as urban area. The major reason behind Delhi's seismic vulnerability is its location. The faults closer to Delhi with potential to generate moderate to large earthquakes are Mahendragarh fault line, Moradabad fault line, Delhi–Haridwar ridge zone, and the Sohna fault. The city also lies in the vicinity to the Himalayan active tectonic plate.

3.1.2 Seismic Zoning

The latest seismic zonation code of India (BIS 1893:2002, Part I) divides the country into four zones of different seismicity based on historical earthquake data rather than a scientific seismic hazard analysis. Currently, the seismic hazard zone map available for India as per Bureau of Indian Standards (IS1893-2002) broadly classifies India into four hazard zones based on past earthquake data (Fig.3.1) These maps are based on subjective estimates of intensity from available information on earthquake occurrence, geology and tectonics of the country. The zoning of a country is a continuous process which keeps undergoing changes as more and more data on occurrence of earthquakes in the country becomes available. Delhi lies in Seismic Zone IV. Some studies, however, indicate the inappropriateness of the seismic zone map since it renders amorphous regions of lower hazards as lumps of landmasses, lacking substantial data of past earthquakes (Raghu Kanth and Iyengar 2006; Menon et al. 2010); which implies the necessity for a state-of-the-art seismic hazard analysis.

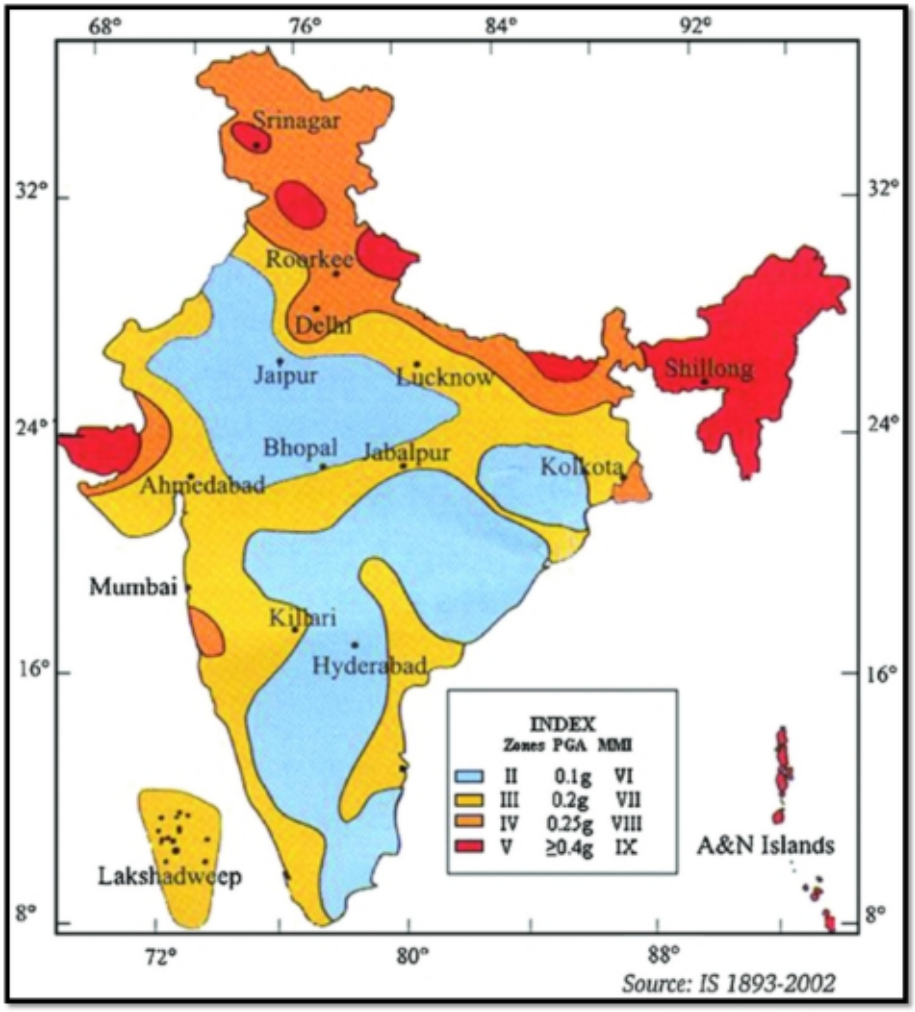


Fig 3.1: Seismic Zoning Map of India

(Source IS 1893-2002)

3.1.3 History of Earthquakes in Delhi

In the last 100 years, 25 to 30 earthquakes have happened in Delhi without significant damage. But, the capital is in such a position where it is not only affected by quakes in the Himalayan region but also has fault lines closer to it. National Capital's proximity to the Himalaya is one of the main reasons for frequent earthquakes in the Delhi-NCR, and adjoining parts of north India. The Himalaya range, which is roughly around 300 kilometers from Delhi, were formed due to collision between Indian and Eurasian tectonic plates. Table 3.1 shows history of some major earthquakes in Delhi.

Table 3.1: History of Earthquakes in Delhi

Date	Intensity on Richter Scale
27 July 1960	5.6
28 July 1994	4.0
28 February 2001	4.0
28 April 2001	3.8
25 November 2007	4.1
7 September 2011	4.2
5 March 2012	4.9
24 April 2018	3.5
20 December 2019	6.3
12 April 2020	3.5
13 April 2020	2.7
12 November 2022	5.4
23 January 2023	5.8
21 March 2023	6.6
28 May 2023	5.2
13 June 2023	5.4
5 August 2023	5.8

(Source:https://www.timesnownews.com/india/article/timeline-of-earthquakes-that-struck-delhi-in-recent-history/603923)

3.2 Floods

Delhi is the capital of India. The city has been experiencing floods of various magnitudes in the past due to floods in the Yamuna and the Najafgarh Drain system. The Yamuna crossed its danger level (fixed at 205.33m) twenty five times during the last 33 years. Since 1900, Delhi has experienced 9 major floods in the years 1924, 1947, 1977, 1978, 1988, 1995, 2010, 2013, 2019 when peak level of Yamuna River was one meter or more above danger level of 205.33 m at old rail bridge. Until July 2023, a High Flood Level of 2.66m above the danger level had occurred on sixth September 1978. The second record peak of 206.92m has been on twenty seventh September 1988. Urban flooding in Delhi has assumed importance particularly in view of the recent flood of July 2023 when an unprecedented flood hit the city and brought the life in many areas to standstill. During this flood the Highest Flood Level reached a record level of 208.66 m on the 13th July 2023. Table 3.2 lists major floods inn Delhi along with Gauge at Old Railway Bridge.

Table 3.2: Major Flood events in Yamuna River in Delhi

Year	Gauge at ORB (m)
1976	206.70
1978	207.49
1988	206.92
1995	206.93
1998	206.36
2010	207
2013	207.32
2019	206.60
2023	208.66

(Source: Irrigation and Flood Control Department, Delhi)

3.3 Fire

In Delhi, there has been a substantial increase in population and industrialization, since Independence. Well over 1,50,000 small scale industrial units in identified industrial units in identified industrial pockets (in addition to industries running illegally), over 1200 J.J. Clusters providing shelter to nearly one third of the population and over 3.5 million automotive vehicles have choked infrastructural services. The fast increase has not been planned for.

Master Plan for Delhi, had been created as an instrument to control the use of land in urban area and protect the welfare of people. The concept of zoning has not yielded desirable results over and above allowing for mixed use and occupancy, authorized as well as unauthorized. Banquet halls in residential areas, cottage industries in congested areas, trade of hazardous chemicals from the highly congested residential/commercial areas, hazardous and non-hazardous industries in close vicinity are few to mention which have further deteriorated environmental services. This has certainly added to the fire risk already inherited by a particular occupancy. As a result losses due to fire are increasing to both the life and property. This is developing a dangerous trend. Man-made disasters are likely in these areas.

Zoning and mixed use planning is a vital part of urban design. However, it can fail through abuse, misuse, and resistance to changes in urban pattern essential for the general welfare of the population. The price, which is being paid, is high. It needs to be understood, appreciated and accepted that the solution to complex problems is not always simple and widely acknowledged. Many a times they are complex, hard and unpopular in a democratic setup.

Major fire incidents in Delhi:-

(i) **June 13, 1997:** A fire broke out at the Uphaar theatre during the screening of Bollywood film 'Border', killing 59 people and injuring over 100.
(ii) **November 20, 2011:** Fourteen people died and over 30 were injured when a fire broke out at a community function of eunuchs in Nandnagari in east Delhi.
(iii) **January 20, 2018:** At least 10 women and seven men were charred to death in a fire that broke out in a firecracker unit in northwest Delhi's Bawana industrial area.
(iv) **April 13, 2018:** Four members of a family, including two minor children, were killed in a major fire in Delhi's Kohat Enclave.
(v) **April 23, 2018:** At least 300 shanties were gutted after a major fire broke out in Shahdara's MS Park. A girl was killed in the fire
(vi) **May 29, 2018:** A massive blaze, which fire officials said was of "highest magnitude", broke out at a godown in south Delhi's Malviya Nagar. No casualty was reported.
(vii) **Nov 19, 2018**: Four people were killed and one person was injured after a fire broke out at a factory in central Delhi's Karol Bagh.
(viii) **January 30, 2019:** Four people were injured in a fire at a chemical factory in Okhla Phase-I in southeastern Delhi.
(ix) **February 7, 2019:** Scores of patients and staff at Noida's Metro Hospital and Heart Institute had to be evacuated after a major fire.

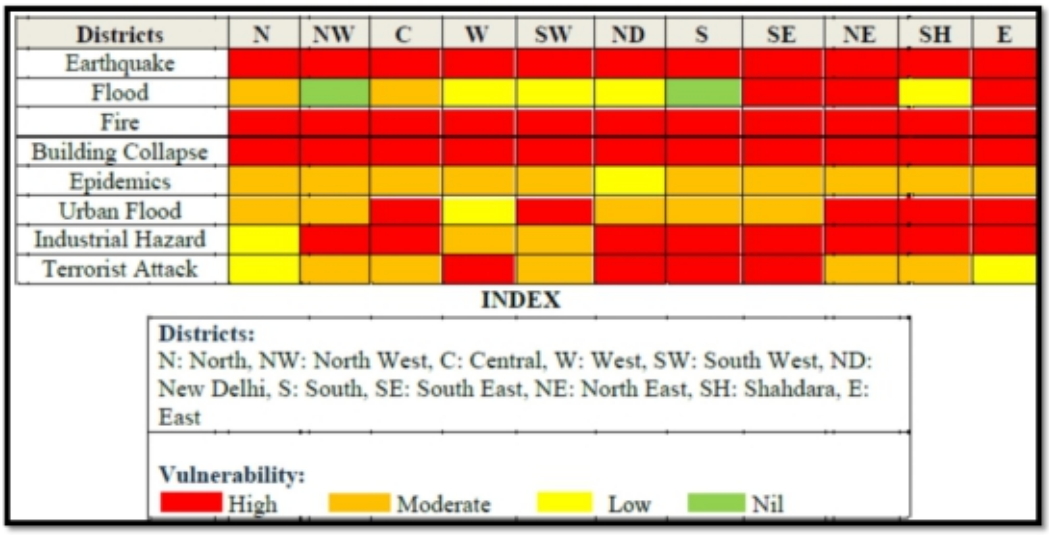
3.4 Other Hazards

Other than Earthquake, Floods and Fire, Delhi is subject to many other hazards as follows:

1. Cold Wave and Heat Wave
2. Cloud Burst
3. Thunderstorm & Squall
4. Epidemics Hazard
5. Drinking Water Shortage
6. Road accidents
7. Industrial Hazards
8. CBRN Disaster
9. Building Collapse
10. Terrorist Attacks and Bomb Blast
11. Environment Pollution
12. Societal Vulnerability

Table 3.2 explains (on the basis of hazard analysis) district-wise degree of risk and vulnerability involved in Delhi for some of the main hazards

Table 3.2: Vulnerability Matrix of Delhi



(Source: DDMA Plan 2016-17)

Chapter 4:Floods Hazard, Vulnerability and Risks in Delhi

4.1 Major Flood Hazard Events in Delhi

Delhi has been experiencing floods of various magnitudes in the past due to floods in the Yamuna and the Najafgarh Drain system. The Yamuna crossed its danger level (fixed at 204.83m) twenty five times during the last 33 years. Since 1900, Delhi has experienced 9 major floods in the years 1924, 1947, 1977, 1978, 1988, 1995, 2010, 2013 and 2019 when peak level of Yamuna river was one meter or more above danger level of 204.49m at old rail bridge (2.66m above the danger level) occurred on 6th September 1978. The second record peak of 206.92m was on 27th September 1988. During July 2023 flood, however, the Highest Flood Level reached a record level of 208.66 m on the 13th July 2023.

4.1.1 The 1924 flood

During the 1924 flood, Tajewala Head Works was severely damaged, resulting in loss of life and property along the eastern bank of the river. Water flowed through breaches in embankments and eroded the Eastern Yamuna canal at several locations. Delhi-Shahdara railway line was damaged and it took a month to restore it. Shahdara and neighboring villages were submerged. In 1924 upper reach of the Yamuna was not embanked. The embankments were constructed after 1955. The trans-Yamuna area of Delhi did not have proper drainage network in 1924, thereby exacerbating the problem caused by the flood.

4.1.2 The 1977 flood

Delhi is at the tail end of Aravalli, due to which the major portion of the rainfall is absorbed in the semi-arid region of Sahibi catchment, and the remaining water is discharged into Jahajgarh and Najafgarh lakes in Haryana and Delhi, respectively. The flood havoc in 1977 was due to the excess flow in Sahibi River, which originates from Rajasthan and enters Delhi at Dhansa after traversing a distance of 222 km. The Sahibi finally outfalls into Yamuna through Najafgarh drain. Due to heavy rainfall in Sahibi River catchment, an unprecedented flood occurred in Rajasthan, Haryana and Delhi.

4.1.3 The 1978 flood

On the 11th of July, a 15 m wide breach occurred in drain number 6, which was connected to Bawana Escape. The breach resulted in the flooding of Jindpur, Hiranki and Mukhmailpur in Alipur block, due to back flow of Yamuna water On the 4th of August, 30 m portion of Bawana Escape at Qadirpur breached due to back flow when the water level in Yamuna at the Old Railway Bridge (ORB) was 206.2 m. Due to this breach, a large area in Alipur block was flooded, forcing the administration to seek the help of Indian army in relief and rescue operations. The most severe flood in the history of Yamuna occurred on 3rd September, when release of more than 19,841 cumec (7 lakh cusec) was made from Tajewala barrage. Model town, Mukharjee Nagar and Nirankari Colony were amongst the several colonies that were submerged under water.

4.1.4 The 1995 flood

During the 1995 flood, the maximum water level recorded at the ORB was 206.93 m due to the release of 15,193 cumec (5.36 lakh Cusec) from Tajewala barrage. The gauge at the ORB depends upon the operation of barrages at ITO and Okhla. People residing in the colonies in the vicinity of ORB such as Gautampuri near Raj Ghat, Nanglamachi near drain number 14, Shriram colony, Sonia Vihar, Geeta Colony, Shamsan Ghat, Shastri Park, Chandgi Ram Akhara and Nigam Bodh Ghat were evacuated to safer places. The entire zoo area was flooded due to blockage in storm water and sewage, endangering the animals.

4.1.5 The 2010 flood

The new barrage at Hathnikund replaced the old barrage at Tajewala in Haryana, and became operational in 2002. During the flood of 2010, a discharge of 21,090 cumec (7.44 lakh Cusec) was released from Hathnikund Barrage. It resulted in maximum water lever of 207.11 m at the ORB. The river flowed above danger level from 20 to 27 September. Several areas in Lalita Park, Sakarpur, Laxmi Nagar experienced seepage flow for almost one month when the Yamuna was flowing above the danger mark at the ORB.

4.1.6 The 2013 flood

Due to sudden heavy rainfall in the upper catchment of Yamuna, huge amount of water was released from the Hathnikund Barrage. Consequently, the level of river Yamuna rose to 207.32 m at ORB on 19th June. Several areas in the vicinity of the ORB were affected. The ring road, which is a peripheral road in Delhi was flooded at several places. Around 10000 people were shifted to safer places. Both the road and the rail traffic were not allowed on the ORB for three days.

4.1.7 The 2019 Flood

In 2019, on August 18-19, water was released in the river with a flow of (23464 cumec) 8.28 lakh cusecs and the water level rose to 206.6 meters More than 10,000 people living in low-lying areas along the Yamuna in Delhi were evacuated by government agencies as the river breached the danger mark.

4.1.8 The 2023 Flood

During 8-11 July 2023, Delhi experienced widespread rainfall with isolated Heavy to very heavy rainfall. As a result, Hathnikund Barrage in Haryana, the discharge from which is around 10 Cumec (352 Cusec) in the non-monsoon months hit a peak of 10173 Cumec (3.59 Lakh Cusec) on 11th July. The Highest Flood Level at the old railway bridge reached a record level of 208.66 m on the 13th of July 2023. Many areas in North, North East, East and South East were in deluge for weeks. The flood water submerged parts of the capital-including parts of the arterial Ring Road, the busy ITO intersection, Rajghat, and even reached the periphery of the Supreme Court.

4.2 Flood Vulnerability and Risks in Delhi

Delhi, a mega city with a population of 16.78 million, is situated on the bank of River Yamuna. During the last three decades, the hydrological characteristics of the Yamuna River basin (Fig 4.1) have significantly changed. Due to rapid urbanization in the basin, the runoff has considerably increased. Consequently, the flooding events are now occurring more frequently and with higher magnitudes. Large scale urbanization, reduction in holding capacity of the catchment, the confining of the river spread by construction of embankments coupled with the climate change phenomenon are the major contributors for increase in peak flow magnitude. Increase in impermeable surface during urbanization increases the peak flow, reduce the time of concentration and thus make the area more flood prone.

Fig 4.1: The Yamuna River Basin
(Source- Delhi Development Authority, DDA)

Fig 4.2 shows the vulnerable areas along Yamuna in Delhi.The rate of urbanization is relatively high in the regions of Upper Yamuna just upstream of Delhi compared to regions further up in the basin. There is clearly evident from the 2011 census of India (Chandramouli et al. 2011) which indicated an increase of more than 40% in the urban population of three states in the Upper Yamuna region. A majority of these settlements is in the low-lying areas, which make them highly vulnerableto flooding events of even moderate intensity.

Fig 4.2: Vulnerable Areas along Yamuna.

(Source: Sharif et al. 2016)

4.2.1 Local Flooding

A significant phenomenon which has been increasing during recent years is that of local flooding. Urban areas are characterized by an impervious high area under surfaces (Roads, pavements, houses etc.). High rates of development along with the resultant loss of soft landscape has led to high surface water run-off rates. This results in flash floods in the low lying areas even after moderate precipitation. Another factor adding to this effect is that of river because the river is already flowing at a higher level within its embankments. Thus, the water gets logged in the city areas and it takes several days to mechanically pump it out and bring the situation under control. Similarly, during the past few years, flooding due to the city's 18 major drains has also become a common phenomenon. Already under the pressure of the city's effluent discharge, these drains experience reverse flow from the Yamuna, which is in spate, and as a result they tip their banks, flooding the neighboring colonies.

4.2.2 Settlement Pattern in Flood Plain

A close analysis of the flood zoning pattern reveals that the high risk zones are the areas that have earlier been identified as unplanned or poorly planned areas having high population densities and substandard housing structures. These include areas of North Delhi, and Trans Yamuna Area. Some of the colonies that have come up in these areas are at levels 3 to 4 meters below the 1978 flood level.

The community exposed to the highest risk from floods comprises the families living in the villages and unauthorized colonies within the river-bed. There are over 15,000 such families, having over 75,000 persons. Situated on the wrong side of the embankments, these people live on the edge of the floods, and are the first ones to find their homes washed away.

Direct effect of floods is due to the river Yamuna and the city's network of drains. These affect the population living in the Yamuna River-bed and on the banks of the river and drains.

Local flash floods and water logging increased surface run-off due to high ratio of hard surfaces leading to flash floods. This in turn badly affects the low lying areas, particularly the unplanned colonies which get water logged.

4.2.3 Risk of breach in embankments

Protection from the river by embankments lead to a false sense of safety and development starts taking place in the shadow of these embankments. In the event of failure of these protective works, as has been seen in the form of breaches during past floods, the effect is devastating because the pressure of the entire embanked stretch is released at one point, and it takes the people by surprise.

4.2.4 Risk to Population, Infrastructure, Critical Facilities, Services and Utilities

District North-East, East, Central, and South East of Delhi are most affected by floods in the city. Most settlements situated along the Yamuna River are prone to the flood hazard. The extent of the vulnerability of the poor within the city is captured in the statistics offered by the Yamuna Action Plan, a river revitalization effort of the Government of India. They observe that about 45 percent of the city's population live in a combination of unregulated settlements, including unauthorized colonies, villages, slums, and the like. Further, three million people live along the Yamuna River, which is prone to flooding, where 600,000 dwellings are classified as slums. Further, they observe that nearly 62,000 units are estimated to be located in the river bed of Yamuna on both sides of its stretch along Delhi and on the embankments of a few major storm water drains such as Najafgarh drain, Barapulla drain etc. Moreover, the low quality of housing in slums and their proximity to environmentally degraded land and flood-prone areas further exacerbate the vulnerability of the poor. Within the slums, climate-induced stress is likely to affect certain social groups more than others, particularly the elderly, women, and children.

Delhi’s physical infrastructure, social services, and slum populations make the city highly vulnerable. Demand for basic infrastructure services like water, electricity, and public transport far exceeds supply (Delhi Development Authority, 2005). To add to the existing conditions, climate change- induced variability in rains and temperatures could worsen the severe shortage of drinking water in summers and aggravate the floods in the monsoon season, thus making the existing energy shortage more challenging to address.

With regard to transportation, Delhi has the highest per capita vehicular population in India—5.4 million automobiles for 15 million people. This poses a challenge for a city with mixed land use and varying urban densities within the metropolitan region to introduce effective modes of public transport. Carbon emissions from vehicles, traffic congestion, and increasing

particulate matter all pose challenges. During the floods in Delhi roads are flooded which render transportation as highly vulnerable.

Main vulnerable areas along the river Yamuna are shown in Figure 4.2 Many critical facilities, utilities and services like Police Training Camp, Metro Operational Office, Rajghat Power Plant, Indira Gandhi Indoor Stadium, Delhi Secretariat, CWG Village, Akshardham Temple, Millenium Depot, Rajiv Smriti Van and Indian Oil Bottling Plant are situated in flood prone area.

4.3 Standard Operating Procedure for Flood Risk Reduction

Floods are among the most common and destructive natural hazards causing extensive damage to infrastructure, public and private services, environment and economy. Though NCT of Delhi does not have a record of devastating flood of mass causalities, the flood risk still holds its place. Keeping this in the realm the immediate action plan has been incorporated to aid the management operation at its best efficient level.

The Flood Action Plan consists of the following activities:

- Declaration of Flood disaster
- Flood Forecasting and Warning
- Trigger mechanism
- Response mechanism of the concerned line departments along with the roles and responsibilities Flood Action Plan
- Relief

4.3.1 Declaration

The immediate response is to demarcate the areas affected by the severity of flood by declaring the situation a disaster at macro or micro level. The Delhi Govt. through Delhi Disaster Management Authority‘s network declares the graveness of the calamity as per the occurrence. The Relief Commissioner immediately propels all the District Collectors to act on the plan in relevance to their districts.

4.3.2 Flood Forecasting and Warning

Flood forecasting is the process whereby the impending risks to the livelihoods may be imparted at the earliest. It includes the meteorological interpretation to the occurrences in the atmosphere and thus warning the people of any grave occurrence. Since the forecasting is very important, it has to be done by the experts in this field. This is at present being done by the Meteorological Department of India and Central Water Commission. The main components of a national flood forecasting and warning system are as follows:

- Collection of real-time data and prediction of flood severity and time of onset of monsoon
- Particular levels of flooding
- Preparation of warning messages, describing what is happening, predictions of what will happen and expected impact. Messages can also include what action should be taken.

- The communication and dissemination of such messages.
- Interpretation of the predictions and other flood information to determine flood impacts on communities
- Response to the warnings by the agencies involved and communities.
- Review of the warning system and improvement in the system after flood event.
- If predictions fail, the reasons of prediction failure should be communicated to communities in order to establish trust. For a flood warning system to work effectively, all these components must be present and they must be integrated with each other rather than operating in isolation.

Central Flood Forecasting Division of Central Water Commission, R.K. Puram, New Delhi monitors the flood discharges in River Yamuna right from the upper catchment and issues flood forecasting bulletins for various stage of floods. The forecasts based on the discharge from the Hathnikund Barrage (3 km. u/s of Tajewala) are relevant to Delhi as the travel time required for the flood water from Hathni Kund Barrage to Delhi varies between 36 to 72 hours depending upon the prevailing flow conditions in the river. First, second and third warning shall be issued from central flood control room situated at the office of D.C. (East) as per the discharge volume at Hathnikund Barrage, as laid down in flood control order of Delhi. Procedure for disseminating warnings to remote areas:

- Local radio, which should be supplied with clear and accurate information for Local means of raising alarms, for example, sirens, loud hailers, loudspeakers etc.
- 'Sky Shout' from emergency service helicopters.
- Doordarshan and the local cable channels (TV channels & radio Channels including FM radio)
- Bulletins in the Press
- Satellite Based disaster Warning Systems
- Fax
- Telephone
- Media warnings (print and electronic)
- General warning indicators, for example sirens warnings delivered to areas by community leaders or emergency services
- A community-based warning system to pass any information about an approaching flood to every family

4.3.3 Trigger Mechanism

Plan Activation: - The flood response system will be activated on the occurrence of a heavy rain. The Divisional Commissioner through (Central Flood Control Room) will activate all the Departments for emergency response. He will issue instructions to include the following details:

- Specify exact resources required
- The type of assistance to be provided
- The time limit within which assistance is needed
- The state, district or other contact persons/agencies for the provision of the assistance
- Other Task Forces with which coordination should take place
- The EOC (HQ) and other control rooms at the district level as well as sub-district control rooms should be activated with full strength. Once the situation is totally controlled and normalcy is restored, the Divisional Commissioner declares End of Emergency Response and issues instructions to demobilize the staff deployed in emergency duties.

4.3.4 The duties, roles and responsibilities of the various departments have been clearly outlined in Table 4.1 below

Table 4.1: Response Action and Concerned Departments

SI.No.	Response Action	Concerned Department
1	• Report the occurrence of flood to Divisional Commissioner, concerned DCs, Heads of line departments, Chief Secretary and Chief Minister's office and NEOC, MHA & NDMA • Establish communication links by alternate communication equipment's like HAM radio etc. in district EOC and flood watch locations. • Verifying authenticity of flood from agencies like CWC, andalso from District EOCs • Remain in constant touch with IMD and CWC for earlywarning information	In-Charge, Central Flood Control Room
2	• Hold first meeting with Duty Officers • Dispatch of Search & Rescue teams, medical aid teams to theaffected areas. • Make arrangements for the aerial survey of affected areas • Instruct local administration to evacuate victims to safer sites	Divisional Commissioner
3	Hold meeting of SEC of DDMA within 12 hours of flood, if situation demands and assess the initial situation reports.	Chief Secretary
4	The sector committees affected districts shall conduct regular coordination meetings during the flood to monitor & evaluate the situation and plan for response and relief activities.	DCs of concerned districts

5	Assess the situation from initial survey reports and call for Army and NDRF, if situation demands.	Divisional Commissioner
6	Although adequate Wireless sets are available in irrigation and flood control deptt., yet in case of emergency Civil Defence Volunteers / Home Guards will be responsible for setting up wireless stations at the Flood Control Room, L.M .Bund Office of the Dist. Magistrate (East) and various sectors as per requirements of the Divisional Commissioner Delhi. All these wireless stations will be manned by the Civil Defence Volunteers.	Divisional Commissioner & DG (Home Guards)
7	Home guards/CDVs will be deployed for patrolling duties on bunds and regulators when required to guard against any sabotage and for initiating rescue operations of marooned villages. Civil Defence volunteers will be deployed for camp management, distribution of rations etc as per the requirements of the Divisional Commissioner	Concerned DC (Revenue) and DG (Home Guards)
8	On receipt of requisition from Divisional Commissioner, Delhi, Secretary (Health), Govt. of Delhi would make arrangements for setting up first aid posts/ mobile dispensaries at relief camps and arrange visits of medical teams to the flood affected area. In case of need, Secretary (Health) may seek the assistance from the chief Medical Officer, NDMC/MCD.	Secretary (Health)
9	Provision of temporary latrines, urinals and street lighting atcamp site. Providing safe drinking water to the victims would be arranged by Delhi Jal Board and other line departments in floodaffected areas and relief camps.	Concerned Supdt. Engineer DJB, MCDs, NDMC, DUSIB & PWD
10	A medical team of veterinary staff will be deployed in the flood affected areas and the cattle camps.	Director (Animal Husbandry)
11	Assess the condition of road and rail network for quick mobilization of Emergency teams and resources to affected areas and take follow up steps. Adequate no. of trucks and other category vehicles as may be needed would be arranged when notified by the Divisional Commissioner for providing transport services to shelter sites.	Secretary (Transport) and Dy. Commissioner (Traffic)
12	• Establish Relief Camps in designated areas • Providing temporary shelters to evacuated persons • Providing food materials to the victims	Revenue Department (Concerned DCs and SDMs)
13	Arrangements to be made for quick identification and maintenance of the records of disposal of dead bodies in the affected areas	Secretary (Home), Secretary (Health), Commissioner of Police

14	• Arrangements to be made to record the complaints of all persons reported missing • Follow up action in terms of verification of the report alsoneeds to be made	Secretary (Home), Divisional Commissioner
15	• District Magistrates and sub-divisional magistrates to be empowered to exempt the requirement of identification and post-mortem in case of mass casualties. • Separate Cell to be established district level to coordinate with the NGOs and outside do nor/aid agencies	Concerned DCs and SDMs of Revenue Deptt.
16	Directorate of Information & Publicity to coordinate with the media to play a positive role in disseminating appropriate information to public and the government in order to facilitate the speedy recovery. Issue daily press releases	Director (DIP) and Divisional Commissioner
17	Assess the requirements of deployment of rescue boats on dailybasis and also strategically position them.	Secretary (I & FC)
18	Ensure that local health workers and veterinary officers survey the affected area on regular basis for disease surveillance and prevention. Carry out Immunization and prevention of disease due to worms in domestic animals in water logged areas	Director (DHS), Concerned Municipal HealthOfficers, Director (AH)
19	Establish mobile veterinary health care posts and ensure supply of adequateanimal food in affected areas.	Director (AH)
20	Health Post/Van with essential medicines and health kits anddistribution of chlorine, halogen and ORS packets at camps	Concerned CDMO & Municipal Health Officers
21	Sanitary Survey and water disinfection, Water supply restoration and purification. Demarcation of bore wells/ tube wells unsafe for drinking water purposes.	Concerned Supdt. Engineer (DJB)
22	Ensure maintenance of registers at the relief centres fordamaged houses, stock of relief materials, visitors, suggestions, victims, etc.	Concerned SDM
23	Ensure daily reporting of situation of flood and relief centers toState EOC and Central Flood Control Room.	In-Charge of affected district's EOC
24	Mass feeding shall be only for initial period; if possible dry ration shall be given for home cooking. Food distribution shall be discontinued as soon as possible. NGOs and CBOs shall be involved in supplementing effort of Govt.	Divisional Commissioner, Secretary (F&S)

25	Arrangement of Tents, Clothing, Bedding, Stoves, Fuel, Lighting, Water, sanitary facilities and hygiene (temporary latrine & bathing, utensils, soaps, toothpastes, etc.), health care, electricity, solid waste disposal at relief camps. At least 1 mobile toilet/20 persons at relief camps.	DC (Revenue), DC (MCD), SE (DUSIB)
26	Arrange for education at alternate locations for children at relief camps and affected areas.	Director (Education)

4.3.5 Assessment of Damage/Loss and Needs

- The Divisional Commissioner to issue instructions to the district magistrates to provide the 'Need Assessment Report', 'Damage and Loss Assessment Report'.
- The relief need assessment report should be provided by each District Magistrate.
- Arrangements for distribution of gratuitous relief and cash doles to be made by Revenue Department.

Chapter 5:Yamuna Flood of Delhi- The July 2023 Event

Delhi experienced an unprecedented flood during July 2023. Thousands of people abandoned their homes on the Yamuna floodplains as the water level in the river rose to a 45-year high of 208.05 meters on Wednesday ie 12th of July. The water level of the Yamuna touched an all-time high 208.66 m on Thursday, the 13th of July. Bringing with it multiplicity of woes like water logging , disruption in vital lifelines of Delhi including water supply, rail and road transport, metro, hospitals, siltation of roads and residential areas, flooding of fields, embankment breaches and threat of vector borne diseases. Many areas in North, North East, East and South East were in deluge for weeks. Even as the water level of the Yamuna began to recede slowly, the Army and the National Disaster Response Force (NDRF) were pressed into service on 14th July , as the flood water submerged parts of the capital-including parts of the arterial Ring Road, the busy ITO intersection, Rajghat, and even reached the periphery of the Supreme Court-following a breach caused by a malfunctioning drain regulator. The following paragraphs trace the events of rainfall causing outfow from the Hathnikund barrage and the consequent observed levels at the Old Railway bridge (ORB) as well as the after effects in the city.

Fig 5.1: The Old Railway Bridge (ORB) –A witness to many floods beared the brunt of rising Yamuna, popularly known as Lohe ka pul, has seen several chapters of history unfold in the capital in its 150 years of existance.

The course of Yamuna river passing through Delhi between Palla on the upstream and Jaitpur on the downstream is shown in Fig 5.3 alongwith location of Wazirabad barrage, Old Railway bridge, ITO barrage, Nizammudin bridge and Okhla barrage. Pictorial views of Hathnikund barrage, Wazirabad barrage, ITO barrage, and Okhla Barrage are shown in Fig 5.4, Fig 5.5, Fig 5.6 and Fig 5.7 respectively. Fig 5.2 shows location of Hathnikund barrage.

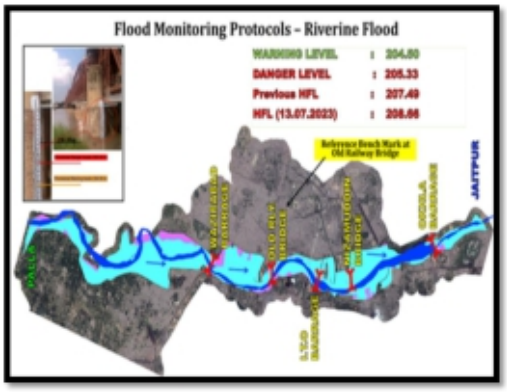


Fig 5.2: Yamuna River Course through Delhi

Fig 5.3: Hathnikund Barrage

Fig 5.4: Wazirabad Barrage

Fig 5.5: ITO Barrage

Fig 5.6: Location of Hathnikund Barrage

Fig 5.7: Okhla Barrage

5.1 Heavy Rain fall over Delhi

During 8-11 July 2023, Delhi experienced widespread rainfall with isolated Heavy to very heavy rainfall. Annexure 1 shows significant rainfall reported over various stations at Delhi during 8-11 July (24 hours cumulative heavy rainfall in cm (≥ 1 cm) at time ending at 0830 hours IST of the date). The state has around a total of 20 numbers of rainfall monitoring stations reporting daily rainfall (refer Fig 5.8). Rainfall data for the period shows during the period, heavy rainfall event was observed during 8-10 July, and the main city observatory Safderjung received 15cm for 24-h of 0830 hrs IST of 8th July till 0830 hours IST of 9th July 2023 (reported at 0830 hrs IST of 9th July), which is the highest value among all stations for the state of Delhi in the period, followed by 12cm at Lodi Road, Delhi University, 10cm at the President house and 9cm at Mayur Vihar during the same date. It then continued on 2nd day on 9th July, but with some reduction in intensity with 12cm over Delhi Lodi Road, 11cm over Safdarjung, 8cm over Delhi University and 8cm over the President house. On 10th July, it was further reduced to moderate rainfall with only one station Delhi Pusa reported as 7cm while other stations were light to moderate rainfall (6.4cm). Historical IMD past data shows (Refer Table 1) the rainfall of 15cm reported on 9th July over Safaderjung is the highest 24-h rainfall observed over Safderjung after 25th July 1983, when 17cm rainfall was observed.

Fig 5.9 shows date-wise rainfall realized at different stations as reported on dates of 8th July to 11th July (4 days) while Fig 5.10 shows their cumulative values for the 3 days when rainfall was significant covering the period of 8-11 July 2023. It shows the heavy rainfall event spell was a 2-days spell and it mainly occurred on 8th and 9th July covering areas mainly for the districts of New Delhi, Central Delhi, and North Delhi with New Delhi areas received the highest rainfall. Fig 5.9 also shows none of the stations located in areas of West Delhi, Southwest Delhi and South Delhi (like Palam, IGI Airport, Nazafgarh and Aya Nagar etc), reported any rainfall >64mm for any date during the period and hence these areas had lower impacts.

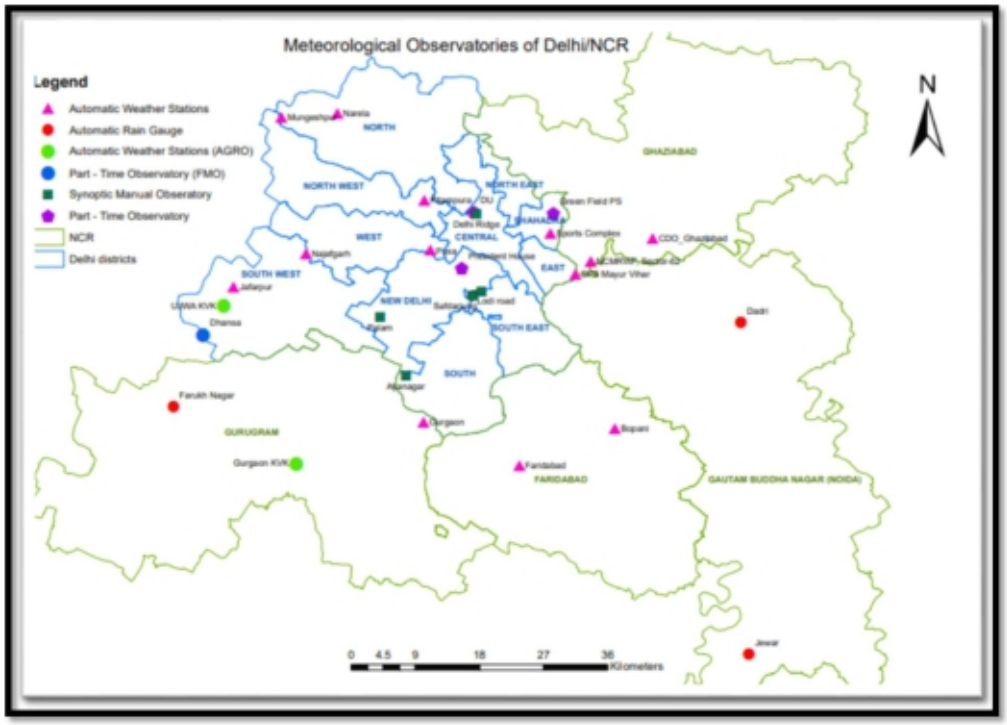


Fig 5.8 : IMD Rainfall Monitoring Stations in Delhi

(Source: IMD)

5.1.1 08th July 2023

Delhi Jafarpur AWS 5, Delhi University OBS 3, Delhi Pitampura AWS 1, Delhi University AWS 1

5.1.2 09th July 2023

Delhi Safdarjung 15, Lodi Road 12, Delhi University AWS 12, Delhi Unniversity OBS 11, Delhi President House 10, Delhi SPS Mayur Vihar 9, Delhi Jafarpur AWS 9, Delhi Pitampura AWS 9, Delhi Pusa AWS 7, Gurgaon Rev 7, Faridabad 7, Delhi Sports Complex AWS 5, Delhi Mungeshpur AWS 5, Delhi Aya Nagar 4, Delhi Palam 4, Delhi Narela AWS 2, Delhi Green Field PS 1.

5.1.3 10th July 2023

Delhi Lodi Road 12, Delhi Safdarjung 11, Delhii University OBS 8, Delhi President House 8, Gurgaon Rev 7, Delhi Ridge 7, Rai Rev 7, Delhi Pusa AWS 5, Panipat 5, Delhi Dhansa 5, Delhi SPS Mayur Vihar 5, Delhi Aya Nagar 4, Delhi Jafarpur AWS 4, Delhi Sports Complex AWS 4, Pataudi 4, Delhi University AWS 4, Delhi Pitampura AWS 3, Delhi Palam 3, Delhi Greenfield PS 2, Delhi Nazafgarh AWS 2, Delhi Narela AWS 1

5.1.4 11th July 2023

Delhi Pusa AWS 7, Delhi SPS Mayur Vihar 4, Delhi University OBS 3, Delhi Dhansa 3, Delhi Ridge 3, Delhi President House 2, Delhi Pitampura AWS 2, Delhi Sports Complex AWS 1, Delhi University AWS 1, Delhi Lodi Road 1, Delhi Narela AWS 1, Delhi Safdarjung 1.

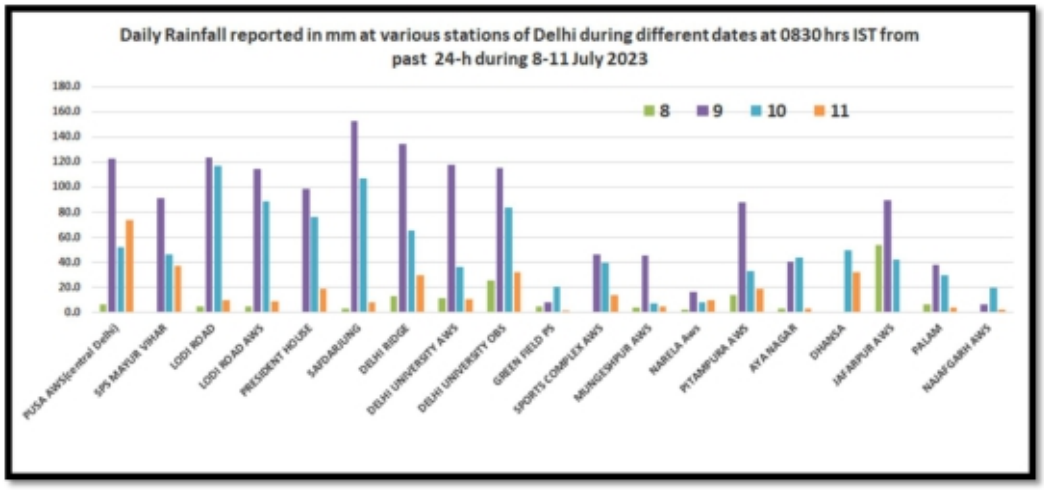


Fig 5.9: Daily Rainfall reported in mm at various stations of Delhi during different dates at 0830 hrs IST from past 24-h during 8-11 July 2023 (Source: IMD)

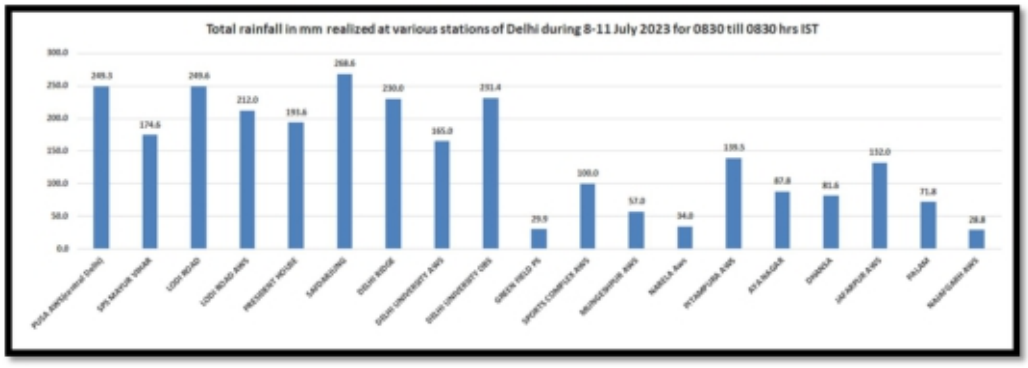


Fig 5.10: Total rainfall in mm realized at various stations of Delhi during 8-11 July 2023 for 0830 till 0830 hrs

(Source: IMD)

Table 5.1: Highest Rainfall Records

Five Highest Rainfall Records of 24-hour rainfall in the month of July for New Delhi (Safdarjung) during 1958-2023			
Year	Date	Rain (in mm)	Rank
1958	20th-21st July	266.2	1st
1982	25th-26th July	169.9	2nd
2023	08th-09th July	153	3rd
2003	09th-10th July	133.4	4th
2009	27th-28th July	126	5th

5.2 Meteorological Conditions

As per IMD, this unique heavy rainfall event occurrences was mainly due to confluence of two systems over the region mainly during 8-10 July such as i) active monsoon trough located at south of the normal position with moisture laden easterly/southeasterly and extended upto 3000 feet from surface and lay at lower levels and mainly confined to north Rajasthan-south Haryan-Delhi-south Uttar Pradesh belt and interacted persistently during the period with ii) a very slowly moved active Wind Direction which lay as a north-south intense convergence line from extreme northeast Pakistan to northeast Arabian Sea across Gujarat - Rajasthan areas during the same period and then with an induce cycir/Lows during 8-11 July. A high moisture incursion was also observed by southerly winds from Arabian Sea at middle level when WD was highly intense with its longer amplitude north-south trough/convergence line was dipped to north Arabian Sea during 8-10 July.

5.3 Flood Forecasting

The Central Water Commission (CWC) set up by Government of India under the earstwhile MoWR in 1945 performs flood forecasting activities on major rivers and their tributaries in the country and issues flood forecast at 175 stations. The forecasts issued by CWC are utilized by local administration in taking suitable administrative measures including evacuation of people from flood affected areas to safer locations during floods. The inflow forecasts issued by CWC are utilized by the project authorities in proper operation of reservoirs in order to mitigate flood impact in the downstream areas.

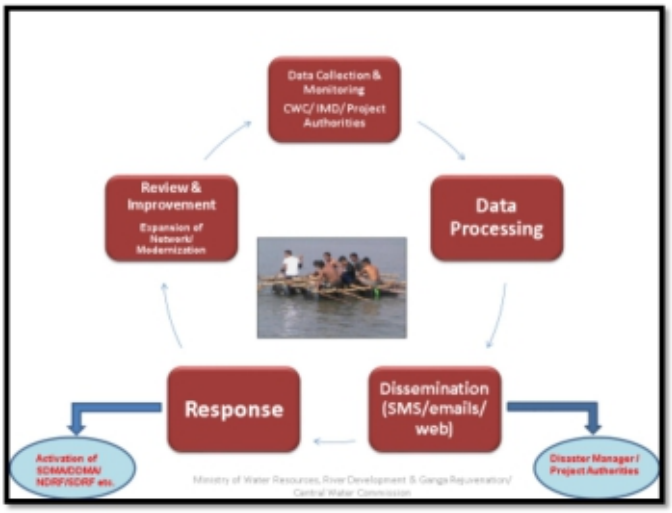


Fig 5.11: CWC Flood Forecasting process for Disaster Risk Reduction

Data Collection is done both Manually as through Sensors and Transmission through Wireless, Telephone, Mobiles, Telemetry, Vsat.

While forecast Formulation or Data processing is done by both Statistical Correlations using gauge to gauge, Gauge – discharge data – Multiple coaxial correlations using gauge, rainfall, Antecedent Precipitation Index (API) Data as well as using Mathematical Models like MIKE - II– Rainfall Runoff module, Hydrodynamic module, Flood forecast module.

Mode of communication now a days adopted widely-Email, SMS, Website (http://india-water.gov.in/ffs), Google Public Alert.

Frequency: Once in day in case of normal flood, updated 12 hourly in case of High Flood and 3 hourly in case of unprecedented Flood preferably by SMS.

Mailing list / Beneficiaries

Commonly – civil / engineering authorities of concerned State, defence, railways / highways authorities, industrial and other important establishments located in the flood prone areas through telephone / fax / e-mail / special messenger for taking advance action for flood fighting & evacuating population to safer places.

Also Media, Press for the benefit of the likely flood affected population.

Fig 5.11 shows CWC Flood Category and Alert Colour used by CWC fig 5.13 Red Bulletin issued by CWC on 13th July 2023 and fig 5.14 Level Forecast issued by CWC for ORB on 13th July 2023

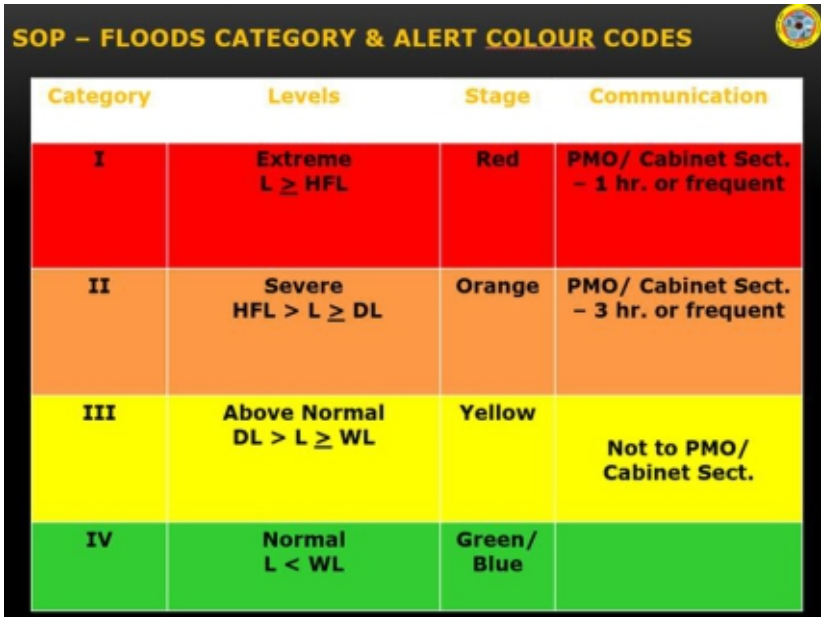


Fig 5.12: Flood Category and Alert Colour Codes used by CWC

Central Water Commission

Date	13/07/23
Bulletin No :	74

Tele No 011-29583666
Email : fmdte@nic.in

Government of India
Central Water Commission
Flood Forecast Monitoring Directorate
Central Flood Control Room

West Block 2, Ground Floor, Wing No 7, R.K. Puram Sector -1 , New Delhi 110066

FLOOD SITUATION SUMMARY

PART – I:LEVEL FORECAST **Total Sites=199**

S No	Flood Situations	State-wise Flood Situation	Number of Forecasting Sites
A	Extreme Flood Situation (Site (s) where the previous Highest Flood Level (HFL) is exceeded or equaled)	Delhi (1)	1
B	Severe Flood Situation (Site (s) where water level is touching or exceeding the Danger Level but below the Highest Flood Level (HFL))	Assam (5), Bihar (2), Uttar Pradesh (2), West Bengal (2)	11
C	Above Normal Flood Situation (Site (s) where water level is touching or exceeding the Warning Level but below the Danger Level))	Assam (8), Bihar (5), Uttar Pradesh (5), West Bengal (5)	23
Total number of sites above Warning Level (A+B+C)			35
PART – II : INFLOW FORECAST	(Total Sites = 134)		
Number of sites for which inflow forecast issued (Where inflows are equal or exceed the specified Threshold Limit for a particular reservoir / barrage)		Tamil Nadu (2), Uttar Pradesh (3)	5

URL FOR FLOOD FORECASTING WEBSITE : https://ffs.india.water.gov.in/

URL FOR FIVE DAYS ADVISORY FLOOD FORECAST (AFF) : https://aff.india.water.gov.in/

Name Duty Officer

Designation Central Flood Control Room

Fig 5.13: Red Bulletin issued by CWC on 13th July 2023

(Source: CWC WhatsApp Group "Flood Messages")

Central Water Commission Date : 13/07/2023

PART – I : DAILY WATER LEVEL AND FORECASTS FOR LEVEL FORECAST SITES

A : Extreme Flood Situations :							
Sites where the previous Highest Flood Level (HFL) is equaled or exceeded							
Sl. No.	River	DIstrict	Warning Level (m)	Danger Level (m)	Highest Flood Level (m)	Actual Level	Forecasted Level
						Trend	Trend
	Station	State			Date (dd-mm-yyyy)	Trend Magnitude (mm/hr)	Date (dd-mm-yyyy)
						Time	Time
1	Yamuna	NORTH	204.5	205.33	207.49	208.62	208.75
	Delhi Railway Bridge	Delhi			06-09-1978	Steady	Steady
						0.0	13-07-2023
						14 : 00	16:00:00

Fig 5.14: Level Forecast issued by CWC for ORB on 13th July 2023

(Source CWC WhatsApp Group "Flood Messages")

5.4 Flood Events from 9th to 31st July 2023

The discharge from the Hathnikund barrage and the consequent water levels at the ORB from July 10th to July 31st are plotted and shown in Fig 5.14 and Fig 5.15. Two distinct peaks in the levels at ORB can be distinguished shown as first peak of 208.66 m on 13th July at around 6 PM and a much lower second peak of 206.56 m on the 23rd July at 6 PM corrresponding to peak discharge of 10173 Cumec (3.59 Lakh Cusec) and 7084 cumec (2.52 Lakh cusec) form Hathnikund barrage respectively. There has been some surges in between the two waves due to incessant rainfall over the basin. The peek level in the first flood wave is reflected in approximately 42 hours after the first peak discharge while the peak level in the second wave is reflected in approximately 36 hours after second peak discharge from the Hathnikund barrage. The lesser time duration for the second could be ascribed to the the reason that water had already spread and basin area become more saturated during the first wave. The day to day account of the flood is recorded in the following paragraphs.

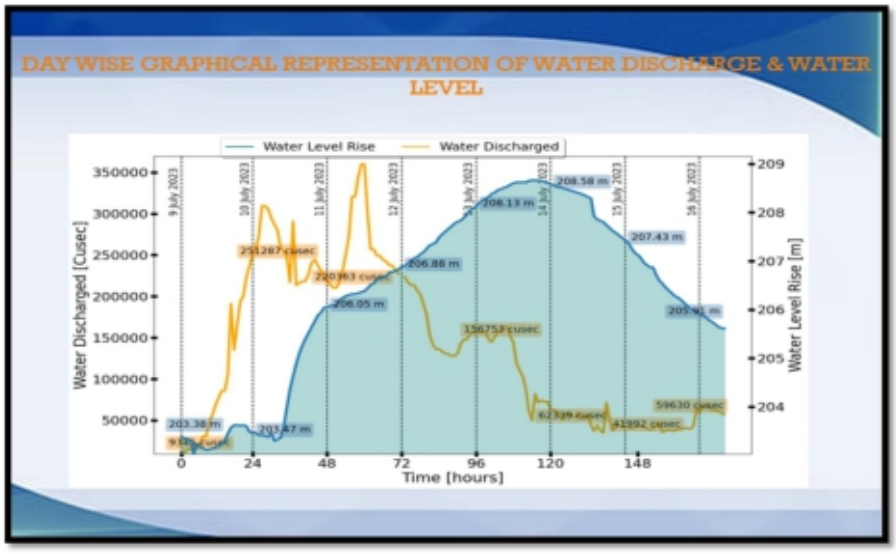


Fig 5.15: Discharge at Hathikund Barrage and Water Level at ORB July 9th to July 16th (First Peak)

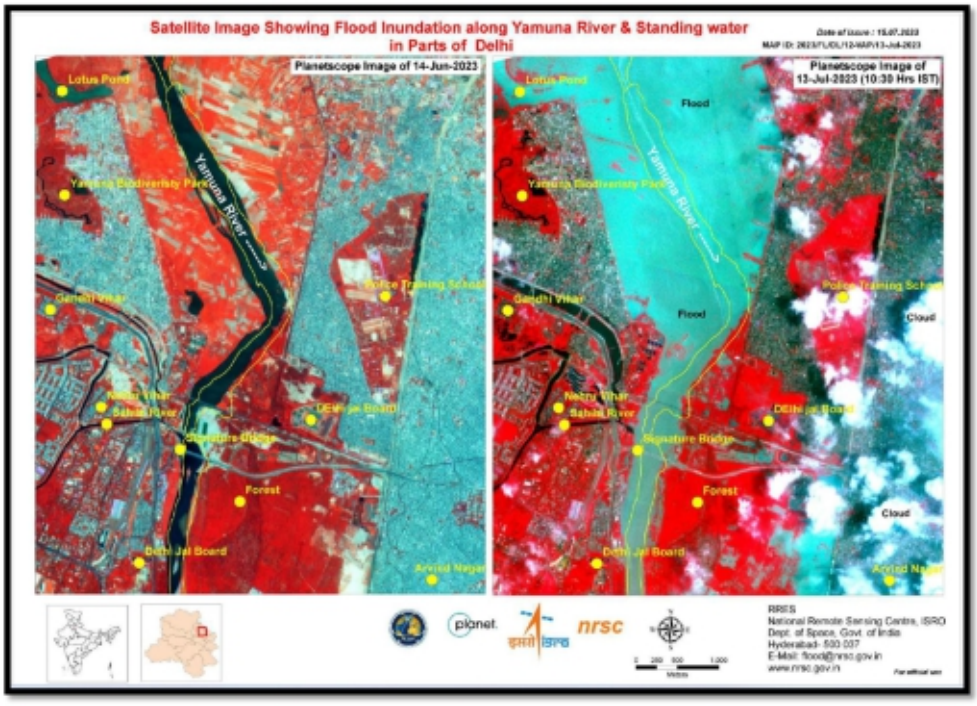


Fig 5.16: Satellite Images Before and during flood (Source: NRSC-ISRO)

5.4.1 Monday, 10th July 2023

There was heavy Rainfall in the Northwest India from Saturday the 8th of July to Tuesday the 11th of July, including in the basin states of river Yamuna, while Delhi also recorded heavy rainfall over the weekend. As a consequence of this heavy rainfall, water level which was nearly steady around 203.00 meters began to rise suddenly at around 09-30 hours on July 10th and crossed warning level of 204.22 meters at 13.30 hours and the danger level of 205.33 meters at 17-30 hours and continued to rise further.

5.4.2 Tuesday, 11th July 2023

The water level in the Yamuna is related to the discharge of water upstream from the Hathnikund Barrage in Haryana. The release, which is around 10 Cumec (352 Cusec) in the non-monsoon months hit a peak of 10173 Cumec. (3.59 Lakh Cusec) on Tuesday ie July 11th, on account of heavy rainfall over Northwest India. It remained at this level for two hours from 11 AM to around 1 PM. Meanwhile the water level at ORB continued the rising trend on the 11th of July.

Fig 5.17: The submergence starts at Monastry Market in Kashmere Gate
(Source: The Indian Express)

5.4.3 Wednesday, 12th July 2023

By 12th of July, parts of Ring Road were submerged, waist-deep water collected at the Monastry Market near Kashmere Gate (Fig 5.18) and thousands of people abandoned their homes on the Yamuna floodplains as the water level in the river touched the previous H.F.L. of 207.49 m attained in 1978. At around 11-00 hrs, it further rose to a 45-year high of 208.05 meters and predicted to rise further.

With the river's water level breaching the 208 meter mark late on 12th night, parts of the Ring Road, and areas abutting the river, including parts of Kashmere Gate, Civil Lines, the areas near ITO and some parts of East Delhi were inundated on the 13th of July.

Over 20000 people who live along the flood plains of the river moved to higher ground either to temporary sheds set up by the administration or set up their own makeshift tents on pavements close to the floodplains.

5.4.4 Thursday, 13th July 2023

The water level of the Yamuna touched an all- time high 208.66 m on Thursday the 13th of July at 1900 hours which over a meter more than the previous record of 207.49 meters reported in 1978. It was predicted to recede marginally by Friday the 14th morning after submerging the floodplains and leaving a few roads and low lying areas in the national capital inundated. According Central Water Commission (CWC) forecast marginal improvement was expected by 3 AM with the levels expected to fall to 208.45 meters at the old railway bridge. This would be well above the river's danger mark of 205.33 meters.

5.4.5 Problems Faced as on 13th July 2023

- **Leakage / Overtopping of regulator gates** – At Matcalf House, Tonga Stand, Ali Drain, Suppl. Drain – 08 nos. and Nazafgarh Drain 04 nos.,
- **Overtopping of banks** – At Neeli Chhatri, Boat Club, DMRC store, Tibbati colony, Monastery Market, Aarti Sthal, Geeta Ghat, Najafgarh Drain (L/B 30 mtr. portion, d/s of Mall Road Bridge).
- **Submergence of settlement within flood plain** – At Garhi Mandu, Usmanpur, Badarpur Khadar, Vishwakarma Colony (Jaitpur), Dhobhi Ghat Jhuggies (Okhla).
- **Backflow of Pipeline** – U.P. Jal Nigam treated water Pipeline near Sonia Vihar WTP.
- **Settlement of bank and seepage** – At Jahangirpuri Drain, Supplementary Drain, Najafgarh Drain.
- **Silted up Closed gates at ITO Barrage.**
- **Yamuna Bazar** – Despite protection wall, inundation reached 8-10 ft. evacuation arranged.
- **Drain No.12 regulator** – The MS gate at the regulator dislocated from the slots due to breach in the embankment.
- **Sonia Vihar L.F. Bund** – Breach – The embankment breach under the water pipelines and heavy discharge started flowing through the breach endangered large populated area of Sonia Vihar, Shri Ram Colony.

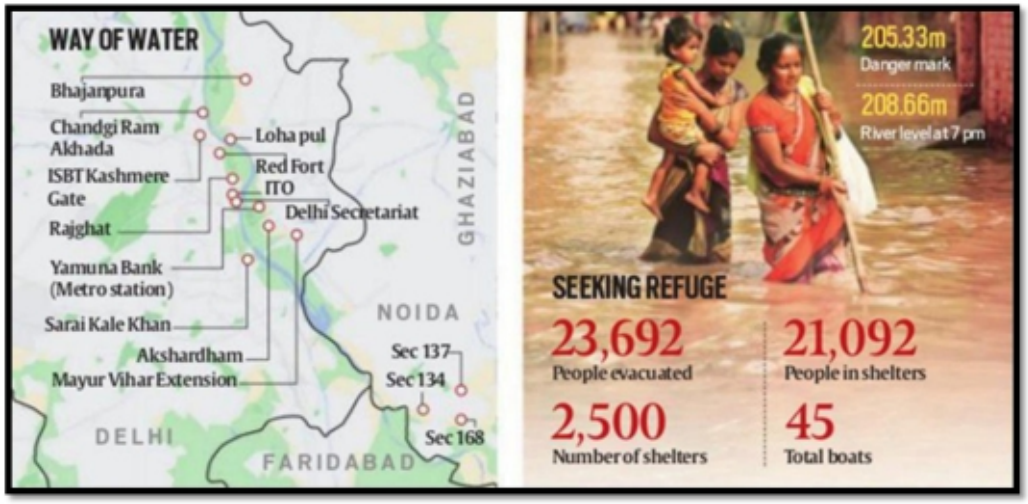


Fig 5.18 : Major Inundated areas and the after effects
(Source: The Indian Express)

Fig 5.19 : Innudation near ISBT
(Source: The Indian Express)

Fig 5.20: Inundation at the Nigambodh Ghat
(Source: The Indian Express)

Fig 5.21 : Inundation at Civil Lines
(Source: The Indian Express)

Fig 5.22: Inundation at Red Fort
(Source: The Indian Express)

5.4.6 Friday, 14th July 2023

Water level maintained a gradual though slow decline throughout on the 14th of July touching 208.12 meters at 8 PM, still well above the river's danger mark of 205.33 meters. The peak discharge from the Hathnikund barrage which was 10173 Cumec (3.59 Lakh Cusec) on the 10th of July fell to 1643 cumec (58000 cusec) on the 14th of July.

5.4.7 Saturday, 15th July 2023

On the 15th of July, the water level at the ORB had receded to 206.54 m at 11 P.M. and the discharge from Hathnikund had fallen to 1105 Cumec (39000 cusec) at 1 PM.

5.4.8 Sunday, 16th July and Monday, 17th July 2023

The wave receded to its lowest and near to warning level on the 17th of July morning at around 6 PM. Though after 17th of July, there were few surges due to continuing rainfall over the basin, the worst flood wave was over.

Meanwhile, the water level in Yamuna river at the Okhla barrage in Noida reached well below the danger level of 200.60 meters at 4 P.M. on the 16th of July. Levels of the Hindon Barrage at Ghaziabad at 4PM was 198.95 meters well below the danger mark of 205.80 meters.

5.4.9 18th to 31st July 2023

A much lower second peak of 206.56 m was observed on the 23rd July at 6 PM corrresponding to peak discharge of 7084 cumec (2.52 Lakh cusec) form Hathnikund barrage. There has been some surges in between the two waves due to incessant rainfall over the basin.

Fig 5.23: Deluge in NOIDA

(Source: The Indian Express)

5.5 Flood Impacts

5.5.1 Life Disruptions

Several areas in the city including Red fort, Kashmere Gate, Civil Lines, Rajghat and ITO were inundated. Archeological Survey of India (ASI) which manages Red Fort shut the 17th century monument to visitors on Friday the 14th July. After heavy rainfall over the weekend in Delhi and other parts of Northwest India, the Yamuna's water level in Delhi crossed the "danger" mark of 205.33 meters on Monday the 10th of July evening, and kept rising since then. In view of the situation, the Delhi Disaster Management Authority directed schools and colleges, and non-essential government offices to remain shut till Sunday, the 16th of July. Interstate buses from Haryana, Chandigarh, Himachal, Jammu and Kashmir and Uttrakhand which usually terminate at ISBT Kashmere Gate were ordered to terminate at Singhu Border. Trucks except those carrying essentials like milk, poultry and vegetables not allowed to enter city. An advisory issued to government and private offices asking them to get their employees to work from home. Entry/Exit at Yamuna Bank Metro Station stopped and metro trains to run slow at four bridges on Yamuna. Meanwhile, movement of around 400 passenger trains were affected between July 7 and July 13 in addition to 600 mail/express trains being affected during the same period. Northern Railway has had to divert 101 mail/express trains and 26 passenger trains to avoid the Yamuna bridge. Owing to flooding hearings in many of Delhi's District courts shifted to virtual mode.

Water from the overflowing Yamuna river gushed into the premises of Delhi Government's Sushruta Trauma Center and St Stephen's Hospital in North Delhi viz Delhi on July 13th prompting the evacuation of patients at Sushruta Trauma Cente.

Water supply to several areas of the national capital including North, Central, East and South Delhi were affected for two days after three water treatment plants (WTP's) at Wazirabad, Chandrawal and Okhla were shut down on Thursday the 13th July because of the raging waters of the Yamuna. In addition to three WTP's production at Sonia Vihar WTP was reduced by 25%. Further, drawing water from ranney wells and tube wells in the Palla floodplain were also stopped hitting production of around 32 MGD of water. Thus water production in the city fell by a total amount of 330 MGD according to Delhi Jal Board (DJB).

5.5.2 Record of Rainfall of 16th July, 2023

The water level of the Yamuna was set to dip to 206.4 meters by 10 AM on Sunday the 16th of July. Meanwhile, the Safdarjung weather station in Southeast Delhi that serves as a marker for the city, recorded 10.8 mm of rainfall between 5:30 PM and 8:30 PM, the observatory in Pusa in West Delhi recorded 29.5 mm and Mayur Vihar in East Delhi recorded 6 mm. The India Meteorological Department (IMD) forecast light to moderate rainfall on the 16th and 17th of July.

5.5.3 Disruption in water supply

Water supply was disrupted in several parts of the city as the two water treatment plants at Wazirabad and Chandrawal remained shut. Several parts of North and Central Delhi which receive supply from these two plants were affected including Narela, Burari, Timarpur, Adarsh Nagar, Badli, Model Town, Sadar Bazar, Chandni Chowk, Matia Mahal, Ballimaran, Karol Bagh, Patel Nagar and Rajender Nagar.

5.5.4 Vector-borne diseases

On July 16th, the Delhi Government directed its officials to determine the serotype of the prevailing Dengue virus in identified laboratories. This step facilitated crucial information for developing targeted interventions and enhancing the effectiveness of disease management efforts. MCD Commissioner was directed to deploy drones for mosquito surveillance and control particularly in vulnerable areas such as construction sites, nurseries and abandoned houses to identify breeding sites and implement targeted interventions to prevent disease transmission. Representatives from DMRC were directed to display precautionary messages provided by DGHS at metro stations and trains. At Government and private schools children were to be provided with Dengue homework cards.

5.5.5 Silt Accumulation

Since 16th of July, the city staring at a long-drawn clean-process as silt had to be removed from drains and roads. On 15th and 16th of July, the Municipal Corporation of Delhi lifted carcasses of more than 500 animals. It also cleaned 300 metric tons of silt from the Tamoor Nagar drain.

5.5.6 Flooding of fields

Flood waters started receding in several places across Haryana even as relief work continued in affected areas. At least 13 districts including Ambala, Fatehabad, Faridabad, Jhajjar and Kaithal continued to be heavily affected with flood waters. Thousands of hectares of farmland continued to remain waterlogged in several districts including Ambala, Yamuna Nagar, Karnal, Palwal, Kurukshetra, Kaithal, Panipat, Sonipat, Sirsa and Jhajjar.

5.5.7 Embankment Breach at Alipur

On the 13th of July, the Alipur embankment of the Yamuna river broke. A day after on the 14th of July, the residents of five villages in Ghaziabad's Loni area continued to find their homes in water even as the teams of police and NDRF sped up rescue efforts. The embankment breaks when there is excessive erosion. Water released form Hathnikund barrage is one of the reasons for this. The second reason is that this time, there had been a lot of rain in Saharanpur which accumulated in the area. Apart from this, illegal construction in the Yamuna floodplains in the Delhi-NCR is another reason.

5.5.8 Malfunctioning and Repair of Regulator and Barrage at ITO

Even as the water level of the Yamuna began to recede slowly, the Army and the National Disaster Response Force (NDRF) were pressed into service on 14th July as the flood water submerged parts of the capital-including parts of the arterial Ring Road, the busy ITO intersection, Rajghat, and even reached the periphery of the Supreme Court following a breach caused by a malfunctioning drain regulator. According to Delhi Disaster Management Authority, a regulator at Indraprastha metro station, which has not been used or maintained for several years collapsed because of its poor condition as well as strong water pressure and inundated the Ring Road also five gates of Barrage at ITO were reported to be jammed.

Fig 5.24: The Ring Road Submergence due to broken Regulator
(Source: The Indian Express)

Fig 5.25: Inundation at the Rajghat and Fixation of Regulator
(Source: The Indian Express)

Fig 5.26: Submergence of Yamuna Bank Metro Station
(Source: The Indian Express)

Chapter 6: Causes of Floods in Delhi

Due to rapid urbanization in the basin, the runoff has considerably increased. Consequently, the flooding events are now occurring more frequently and with higher magnitudes. A sizeable population of the city of Delhi resides in settlements that have mushroomed in the flood plains of Yamuna River. Large scale urbanization, reduction in holding capacity of the catchment, the confining of the river spread by construction of embankments coupled with the climate change phenomenon are the major contributors for increase in peak flow magnitude. The impacts of which are far and wide. Though, there has been much more water flow from Hathnikund barrage in the past as compared July 2023 (Fig 6.1) and much higher water levels observed at the various CWC sites on the upstream in the past (Fig 6.2), yet the extent of flood has been much more in July 2023 as compared to the earlier events in the past.

6.1 Causes of the July 2023 Event

Due to heavy to very heavy rainfall from 8th July to 11th July, starting from July 10th, the water level in the Yamuna in Delhi maintained its upward trend on 12th July, it reclaimed the flood plains, which cushioned the blow of the flood waters. Though, the river crossed its highest flood level till 12th of July and continued to rise thereafter, even as the peak discharge of water from the Hathnikund barrage upstream in Haryana was not the highest that has been recorded so far. A higher peak discharge of 22670 Cumec (8 Lakh Cusec) was recorded even in 2019 from Hathnikund barrage higher than the peak of 10173 Cumec (3.59 Lakh cusec) that was recorded on 12th of July, 2023. However, the highest flood level so attained in 1978 was not breached in 2019, but this time it was breached. This could be due to the reason that there was heavy rainfall downstream of Hathnikund and also due to multiple cross-sectional and longitudinal structures along the Delhi stretch of river due to which there is silt accumulated and trapped in Delhi stretch of the river. Furthermore, the time of concentration is shorter, that the same amount of rainfall has fallen in a shorter period and has moved downstream quickly.

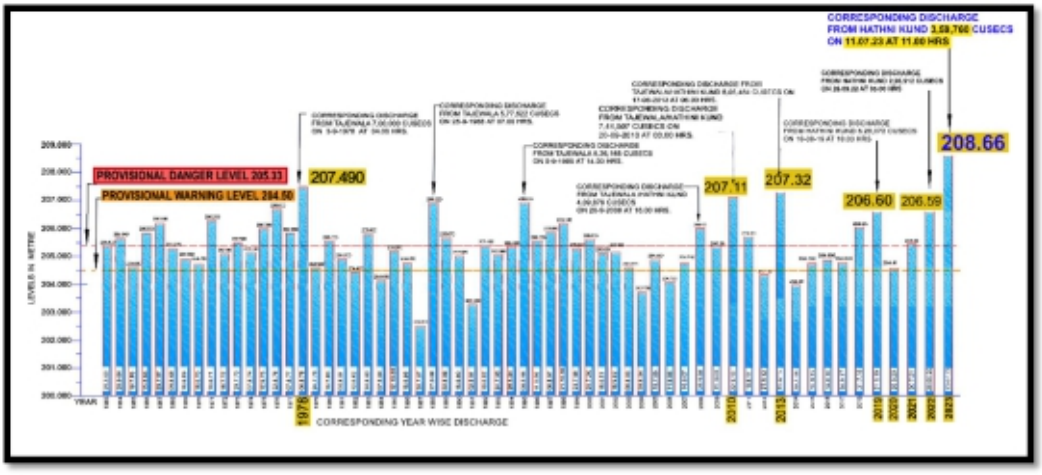


Fig 6.1: **Yearly Highest Flood Level of Yamuna River Observed at Old Railway Bridge**
(Source: I &FC D, Delhi)

CWC monitoring stations upstream of the old Railway Bridge along the Yamuna from Hathnikund barrage to Delhi had not breached the highest levels they had recorded in previous years. These were the stations of Kalanaur and Karnal in Haryana, Mawi and Baghpat in Uttar Pradesh and Palla which is near the point where the river enters Delhi. There could be many reasons for this – flood plain encroachments, multiple structures, concretization, the gates of ITO Barrage being closed would have also blocked the free flowing water.

Flooding at this scale is unusual in Delhi. Usually it will first hit areas that lies upstream in Haryana. This time however, the water rose quickly and breach in the regulator near ITO made the matters worse. Simply put no one was ready for this. The Irrigation and Flood Control Department of Delhi Government is small and not the most well prepared since such a situation is rare. One of the answers may lie in the way the Yamuna flows through the region. In upstream Haryana, the floodplains are mostly unencumbered. Even when it enters Delhi near Palla, a wide floodplain is available for the Yamuna to spread across. It is near Wazirabad that the river becomes jacketed between the embankments and can only rise vertically.

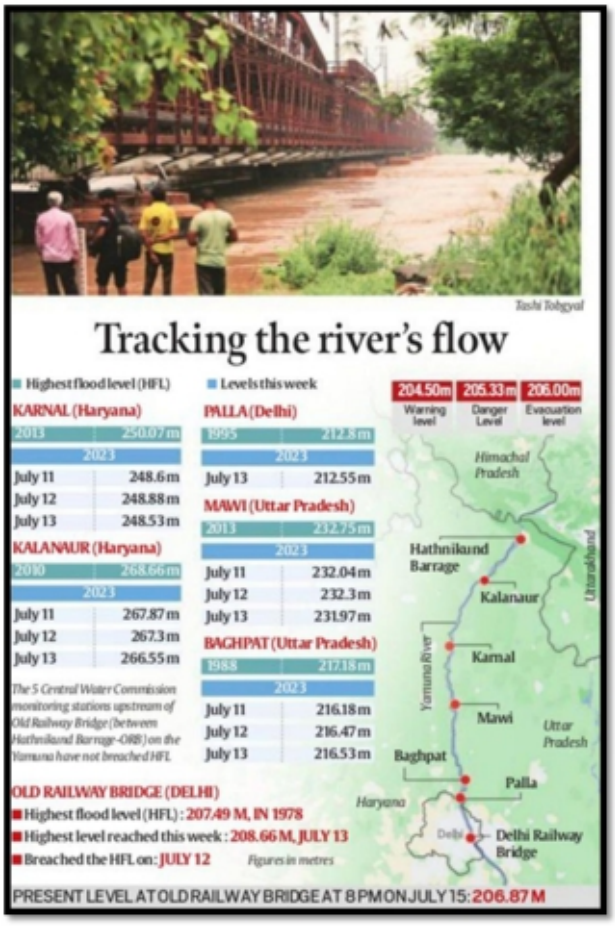


Fig 6.2: The Central Water Commission Flood Monitoring Stations and Comparative Study
(Source: The Indian Express)

In the wake of the peculiar situation arising in the July 2023 Floods, Central Water Commission has set up a committee of various stakeholders under the Chairman, CWC to examine and arrive at the particular reasons for the peculiar situation of flood and give its recommendations for mitigation. The report of the committee is awaited.

6.2 Causes of current Floods in Delhi

There have been several broad reasons of floods which have occurred in Delhi in the past as well as in July 2023, which are enumerated in the following paragraphs:

- The total surface water available in Yamuna Basin is estimated as 90 billion cubic metre (bcm), of which 80% is generated in the monsoon season. The present storage capacity of major and medium water storage projects in the basin is 17 bcm, and 85% of this capacity is in basin area down-stream of Delhi (Narula et al. 2001). There are two major barrages on River Yamuna, namely Dak Pather and Hathnikund u/s of Delhi. There are no dams on river Yamuna, and therefore most of the monsoon flow remains unutilized, resulting in floods in the monsoon season. Due to absence of dams, there is a shortage of water during the dry season.
- In nineteenth century, the flow in Yamuna was just on the eastern side of Narela and Wazirabad. During 1955–1956, embankments were made to avoid frequent flooding of adjoining areas. It resulted in rapid urbanization in protected areas. The encroachment on flood plain from 1807 to 1980 was slow in comparison to period from 1980 to 2014, when the flood plain was utilized for settlements, civic structures, roads, bridges, flyovers, metros etc. (Khan and Bajpai 2014). Decrease in flood plain from 1807 to 2014 is shown in Figure 6.3.

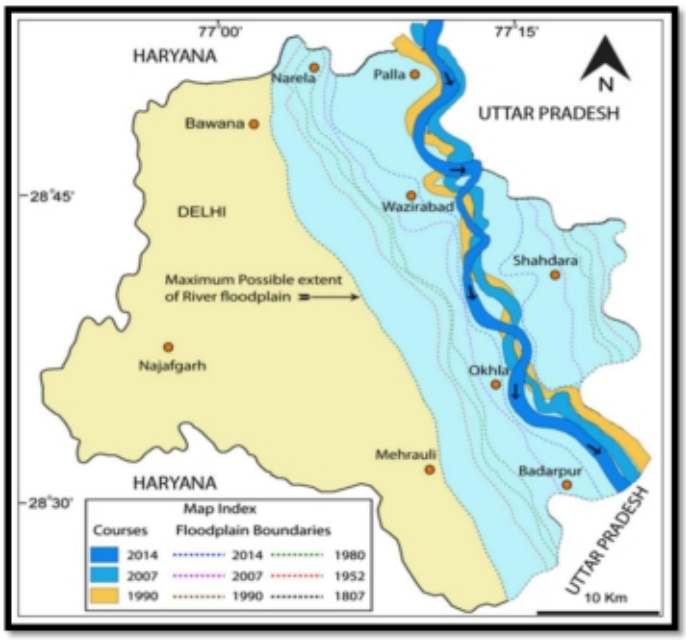


Fig 6.3: Reduction in Yamuna flood plains boundaries in Delhi
(Source: Khan and Bajpai 2014)

- There are some locations where the active course of the river is close to embankment making it vulnerable to breaching. Therefore, a constant vigil is to be maintained during high flood and a huge stock of flood fighting materials is to be kept to prevent any erosion.

- Some of the drains do not have regulators while some others have temporary arrangements for back flow prevention. The major cause of the 1978 flood was a breach of embankments of drain number 6 and Bawana Escape in Alipur block.

- After closure of regulator gates, pumping of city side water into Yamuna is required. Many of out-falling drains do not have a permanent pumping station due to which water from the drains starts flowing back in low lying areas.

- Service lines like, water pipe, sewer pipe, telephone and electricity cables are laid in drains or on banks, which reduce the carrying capacity and adversely affects maintenance operations.

- Sewage network in a large number of unauthorized colonies, rural villages and other regularized areas is yet to be laid. It results in huge quantity of sewage finding its way into the drainage system, resulting in additional siltation load, for which drainage system is not designed. Interconnected sewage and drainage network is one of the major causes of flooding in low-lying colonies due to backflow.

- Although several drainage related works have been carried out in Delhi, but no comprehensive planning was undertaken. Therefore, the old drainage system needs to be reviewed to carry the increased runoff. Large scale covering of storm water drains has been carried out either to construct roads, parking space or to prevent foul smell from drains. Consequently, desilting of drains has become difficult.

- In Delhi, the lack of flood plain development policy has led to a growth of unauthorized colonies. Several government projects such as Metro Head Quarter, Shastri Park and Yamuna Bank Metro stations, CWG village and Millennium depot have come up in the Yamuna flood plain.

Chapter 7: Response, Relief and Recovery-2023 flood

Yamuna levels rise to a record high, 208.53 metres and broke the 45 years old record. Several key areas in Delhi were flooded on 13th July 2023, Thursday, impairing normal life and traffic movement, as authorities scrambled to lead rescue and relief efforts. Delhi Disaster Management Authority (DDMA) along with Delhi Government and different emergency support functionaries discussed the flood situation in the city.

7.1 Preparedness for Flood Response

All concerned District Magistrates (District North, North-East, Shahdara, Central, East, and South-East) and their district Sector Committees, I&FC Department, Delhi Disaster Management Authority, Delhi Police and other stakeholders were kept on alert mode to deal with the flood situation in coordination with each other. Areas like Boat Club, Pandav Nagar, some parts of Gandhi Nagar, Bhajanpura, Delhi Secretariat, Rajghat, were inundated with floodwaters. The road from Rajghat to Delhi Secretariat was also flooded, Ring Road stretch between Kashmere Gate and Purana Lohe Ka Pul was flooded and closed for traffic movement.

According to officials, locals in some areas showed reluctance in moving out even as water reached their homes.

The water level at the Old Railway Bridge crossed the 208-metre mark on 11th July Wednesday night and rose to 208.48 metres by 8:00 am on Thursday. According to the Central Water Commission, this was "extreme situation".

With the situation deteriorating every passing hour, government urged the Centre to intervene, and the city police imposed Section 144 of the CrPC in flood-prone areas to prevent unlawful assembly of four or more people and public movement in groups.

7.1.1 Delhi Disaster Management Authority and Delhi Police

- All required action to be taken for the people living in the low lying areas, flood prone areas, to make aware of the rising water level of river Yamuna by doing munadi/ other mode of communication and it was ensured that no person goes near the river water in view of the rising water level and high water current.
- Some police personnel/ other officials were stationed round the clock at the vulnerable points/ low lying areas, where people living in those areas go inside the river water for doing their daily chores like bathing, washing clothes etc., to ensure that no such activity takes place so as to prevent any untoward incident.
- Delhi police was directed to evacuate people living in low lying areas and shift them to higher altitudes. It was monitored at DCP levels.
- District Magistrate asked the SDM & Tehsildar to be in alert mode and evacuate all people living in low lying areas and shift them to safer places and provide them food, water, medicine etc.

7.1.2 Traffic Police

The traffic police on Thursday i.e. 13th July issued an advisory about the restrictions and regulation of vehicular movement due to the rise in water level of the Yamuna. According to the advisory, due to the rise in water level of the Yamuna and consequent inundation of low-lying areas, traffic movement was impaired on Mahatma Gandhi Marg between IP Flyover and Chandgi Ram Akhara, Mahatma Gandhi Marg between Kalighat Mandir and Delhi Secretariat and Outer Ring Road between Wazirabad Bridge and Chandgi Ram Akhara.

Non-destined commercial vehicles were not allowed to enter Delhi and diverted to Eastern and Western Peripheral Expressway. The commercial vehicles were diverted from Mukarba Chowk. No commercial vehicles were to be allowed between Mukarba Chowk and Wazirabad Bridge, as per the advisory.

Commercial vehicles were diverted from Sarai Kale Khan. No such vehicles were allowed between Sarai Kale Khan and IP flyover. Commercial vehicles were diverted from Ghazipur border as well as from Akshardham towards DND. No such vehicles were allowed between Akshardham and Sarai Kale Khan.

7.1.3 Education Dept (Delhi Government, Private & EDMC Schools)

- Some of the schools were identified as relief centers for the flood affected people, representative of Education Department were directed to inform the school administration and keep them ready in the event of requirement of schools, building as shelter homes in case of requirement.
- Education Department was asked to carry out the inspection of all the schools to check the dangerous part of any school building including trees.

7.1.4 Instructor Civil Defense

District Magistrate directed Instructor Civil Defence (ICD) to ensure deployment Civil Defence Volunteers (CDVs) on Nishkam seva basis in the flood affected area with the number of CDV deployed to be provided to DM office and ICD to continuously monitor the effective use of CDVs.

7.1.5 Delhi Urban Shelter Improvement Board

DUSIB was asked to make arrangements for mobile toilets at designated locations.

7.1.6 Delhi Health Services

- CDMO was directed to provide round the clock deployment of medical camp with team of doctors, medicines, and other required equipment at each of the relief camp.
- LBS Hospital were on an alert mode for any kind of emergency for the people, and CNBC hospital to be on alert mode for kids. Since there may be cases of snakebites, anti -venom vials were made available in the emergency.
- CDMO was asked to provide the details of mobile health workers along with vehicle who will visit relief shelters for health checkup during the time of flood.

Fig 7.1: Flood Relief Camps of North East District

7.1.7 Municipal Corporation of Delhi

- MCD to ensure cleanliness in the relief camp, proper fogging in these areas, cleaning of MTVs.
- Some community centers were identified as relief camp site, MCD to make them available in case of requirement of these relief camps.
- MCD was entrusted to ensure that there is no water logging on the roads and drains under their supervision.

7.1.8 Public Works Department

PWD was asked to identify the vulnerable areas of water logging points of East Delhi and to install extra functional pump in those vulnerable points.

7.1.9 Delhi Development Authority

- Some community centers were identified as relief camp site. DDA to make them available in case of requirement of these relief camps.
- DDA to ensure cleanliness of roads and desilting of drains to avoid water logging and installation of pumps in the areas where water logging is high.

7.1.10 Boat Club Incharge

Boat Club In-charge was asked to station boats at vulnerable points of Yamuna river in case of emergency and to provide the list of locations, where the boats are deployed to flood control room/DDMA.

7.1.11 Delhi Transport Corporation

DTC was required to ensure availability to buses in case of requirement of shifting the evacuated people, in case the water level reaches the evacuation level for their concerned areas and oversee the activities like pitching of tents, deployment of CDVs, availability of power, food, medical facilities, water, sanitation and all other required amenities.

7.2 Evacuation, Rescue and Relief

People living in low-lying areas and who were required to be evacuated at this stage, were evacuated and shifted to safer places at higher altitude. Regular 'Munadi' was done to make people aware of the flood situation by deploying Police personnel and CDVs at each such location and advisories issued to people to keep away from the river water.

A Special meeting of the Delhi Disaster Management Authority (DDMA) chaired by Hon'ble Lt Governor, Delhi was held on 13th July 2023. The agenda of the meeting was to review the prevailing flooding situation in Delhi. Hon'ble Chief Minister, Delhi/Vice Chairperson, DDMA, Revenue Minister, Minister of Water, Irrigation & Flood Control, along with Chief Secretary, Commissioner of Police and senior officers of Departments concerned, apart from DG (NDRF) and representative from NDMA, CWC, and IMD etc. were present in the meeting. Following decisions were taken in the meeting:-

- People who have been evacuated out of the flooded areas to be shifted to neighboring Government school buildings/community Halls/govt. buildings.
- Sufficient food, drinking water, medical aid and toilets/mobile toilets to be ensured at relief camps.
- Schools and colleges / universities across Delhi to remain closed till Sunday, 16th July, 2023.
- Non-essential government offices (i.e. those not involved in monitoring, relief, rehabilitation of flood work) to remain closed till Sunday, 16th July, 2023.
- Private establishments / offices to be advised to work from home.
- Inter-state buses coming to ISBT, Kashmere Gate to be stopped at Singhu Border - DTC buses to be provided to ferry passengers from there.
- Additional provisioning of personnel to be done for traffic management in affected areas.
- Borders at Chilla, Loni and Badarpur to be restricted for entry of only those heavy vehicles carrying essential goods.
- Business / commercial establishments in and around Kashmere Gate to be asked to close till the situation improves.
- Precautionary and proactive relief and preventive measures to be undertaken in areas like Sonia Vihar, Mukherjee Nagar, Haqeeqat Nagar, etc., susceptible to flooding.
- Apart from the 12 NDRF teams operational in the city, additional teams already in place, to help in the relief and rescue measures at sites prone to flooding. Concerned DMs / DCPs to ensure action accordingly.
- All control rooms to work in total coordination to address any emergent situation.
- Crematoriums in the vicinity of those closed down due to rising water levels, to remain in state of preparedness.
- Rationalization of water supply in the city, in light of closing down of WTPs at Wazirabad, Chandrawal and Okhla to ensure drinking water supply.
- Health infrastructure in the city to remain on alert mode to deal with any eventuality and ensure preparedness to handle the situation once the water recedes.
- General appeal to the residents of the city to avoid unnecessary travel and commute.

7.3 Decisions made with increasing water level

- Wazirabad, Chandrawal and Okhla water treatment plants were shut down, which could affect the water supply in the national capital.
- All officials to reach relief camps and provide all possible support to people who stayed there.
- 45 boats (17 pertaining to Boat Club and 28 pertaining to I&FC Department) were put on duty for 'Munadi' / awareness, evacuation & rescue work.
- Road Traffic at Old Railway Bridge was closed since Morning of 13th July.
- All gates at Okhla Barrage were kept open to release excess water; so as to ensure that water level in River Yamuna does not remain at high level for long.
- All concerned DMs and their sector committees were put on alert mode and they worked in coordination with I&FC Department, Police, DJB, DUSIB and other stakeholders to deal with flood situation and relief / rescue work.
- I&FC Department of Delhi also worked in close coordination with its counterparts in UP and Haryana for smooth passage of water through Delhi.

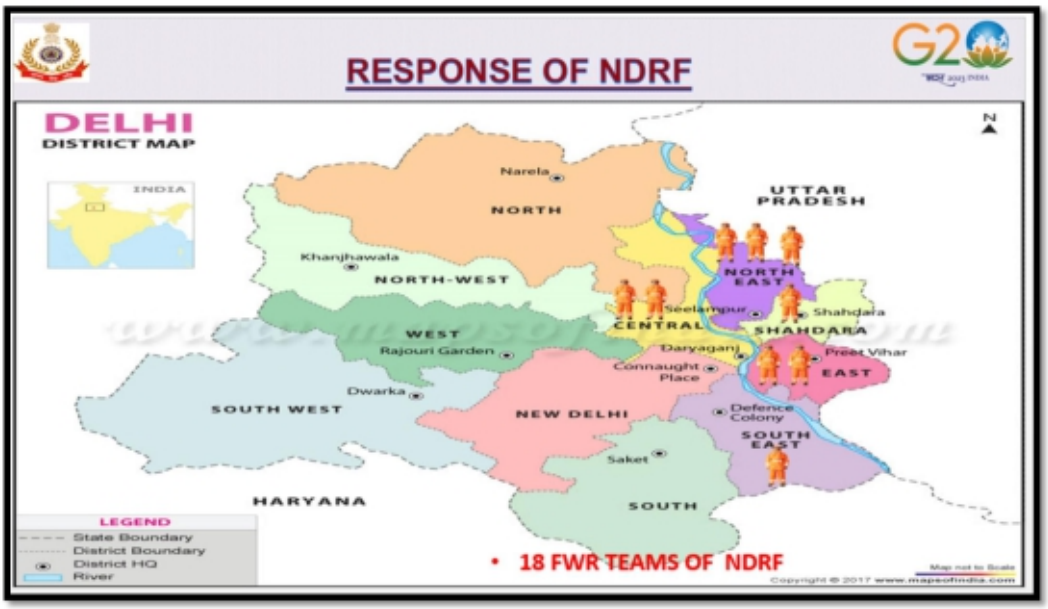


Fig 7.2: Response of NDRF

Fig 7.3: Relief Material Distributed with photographs

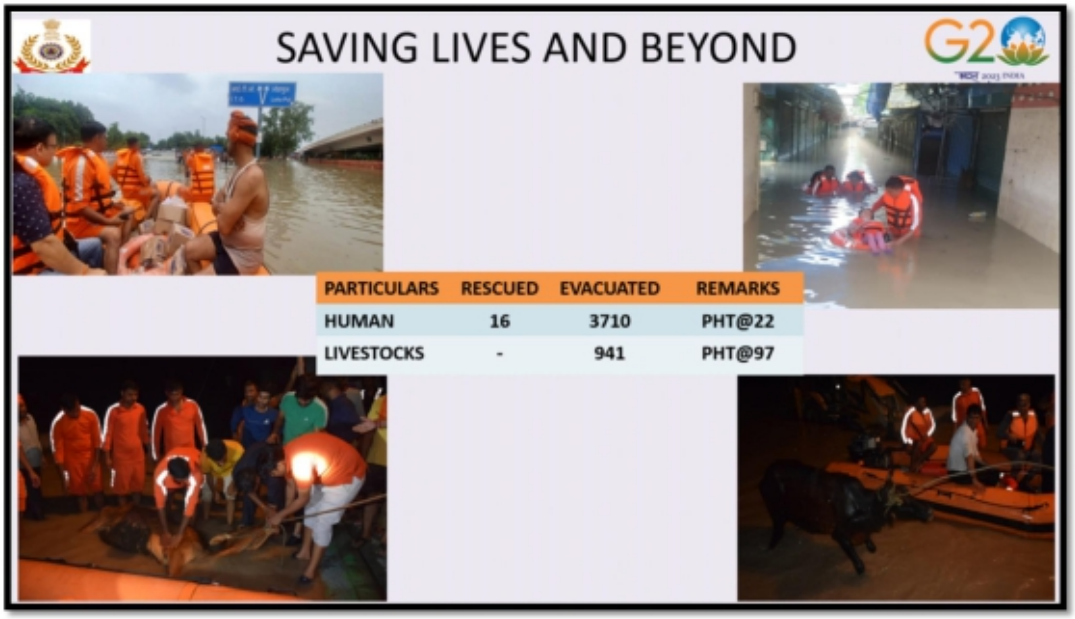


Fig 7.4: Saving Lives and Beyond

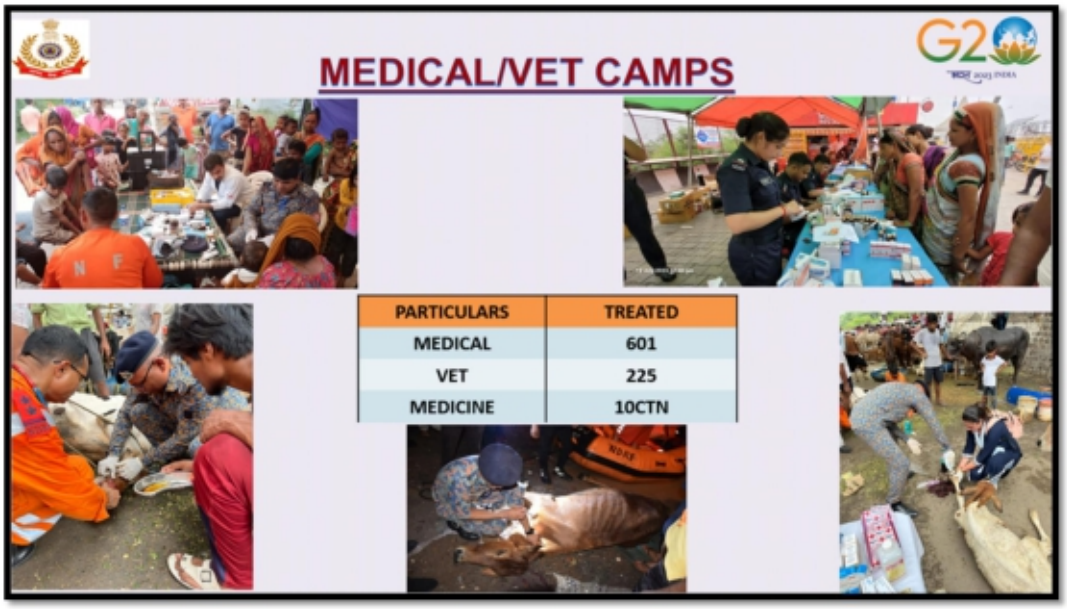


Fig 7.5: Medical / Vet Camps

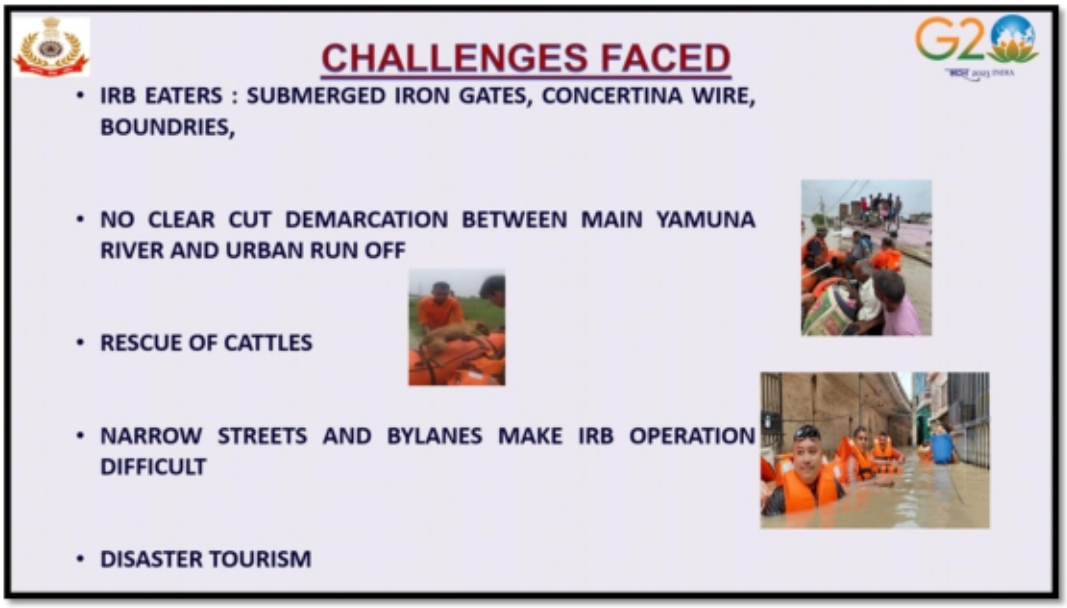


Fig 7.6: Challenges faced

- Facilities of food, drinking water, medical teams, ambulances, electricity, mobile toilets, sanitation, etc. were provided to the evacuated people staying in relief camps.
- Approximately, 26401 people were evacuated from flood-affected low- areas of these six districts, out of which approximately 21,504 people stayed in 44 camps (including temporary relief camps as well as Pucca Buildings i.e. schools, community centers etc.). Rest of the evacuated people were shifted to the places of their choice i.e. at their relatives' houses, rented accommodation, etc.
- 17 teams of NDRF were deployed in flood affected districts in rescue work. 1606 people were rescued & also 7241 people & 956 livestock were evacuated by these NDRF teams. Further, pre -hospital treatment were given to 908 rescued persons.
- NGOs were engaged for providing relief (Food, Shelter Kit, Medicines, etc.) to the evacuated persons.
- Anti-viral spray was done by MCD, safai karmcharis deployed and bleaching powder sprinkled every 12 hours.
- Fans, Mattresses, Mobile toilet, female bathing enclosure etc. placed and adequate food and water arrangement was done.
- Adequate number of medical teams and ambulances were deployed by the Health Department at all the relief camp sites.
- Munadi was done to ensure that they stay in relief camp as there was possibility that water level can rise again. Sufficient arrangement to continue in relief camp for all the person.
- All concerned DMs and their sector committees were kept at alert mode and worked in coordination with I&FC Department, Police, DJB, DUSIB and other stakeholders to deal with flood situation and relief / rescue work.
- Decisions taken in the Delhi Disaster Management Authority (DDMA) meeting, held on 13th July, 2023, under the chairmanship of Hon'ble Lt. Governor, Delhi were implemented.
- FSOs and FSIs of the Food & Civil Supplies department were deployed at all the relief camps on 24 X 7 basis for coordination purpose with the Revenue Department.
- Senior IAS and DANICS officers were deployed for monitoring and assistance of all the flood-affected districts /sub-divisions.
- Hon'ble Chief Minister and other Hon'ble Minsters, Govt. of NCT of Delhi also inspected some of the relief camps installed across flood-affected districts of Delhi.
- Govt. of NCT of Delhi decided to make Ex-Gratia relief payment of Rs.10000 to flood affected families residing in relief camps.
- Flood Situation Bulletins were issued.

Fig 7.7: Cattle being rescued

Chapter 8: Flood Disaster Risk Management Strategies for Delhi

Rapid urbanization of Delhi combined with unplanned development, encroachments of flood plains, multiple bridges, further confinement of the Yamuna River and accumulation of silt has complicated the problems and associated flood risk management strategies for Delhi. The solutions call for an integrated approach by multiple stake holders combined with appropriate model studies and formulation and implementation of an action plan. Following measures are however broadly suggested for flood risk management for the NCT of Delhi.

8.1 Structural Measures

- Storage reservoirs can help in peak attenuation and thus reduce the magnitude of flood in the downstream. Storage of around 400 mm^3 is required to be carried upstream of Hathnikund barrage at Sambar Khera in Dehradun district of Uttrakhand on Tons River, which is a tributary of Yamuna river (Mukesh Kumar et al 2017).

- Barrages can be utilized for flood protection through the attenuation of flood peak. Construction of the barrage at Palla will provide Delhi the additional storage facility. An 8 m high barrage at the end of pondage of Wazirabad near Jagatpur might create storage capacity of around 120 MCM. During the flood season, barrage can moderate the peak of the flood. Thus, it has the potential to reduce the stress on embankments downstream of Palla. (Mukesh Kumar et al 2017).

- To avoid back flow of water from Yamuna into the drains, it is suggested that all out falling drains should have permanent pumping stations. Power supply failure is a common feature during heavy storms. Hence, generators should be deployed as a standby arrangement at all regulators in addition to local power supply for ensuring smooth pumping even in case of power failure.

- The capacity of the water bodies needs to be increased through dredging. Adequate number of retention basins should be constructed in the reach upstream of Wazirabad Barrage when the flood level exceeds a pre-defined critical stage. Providing retention basins will facilitate conservation of flood water as well as attenuate flood peaks.

- All vulnerable portions of the embankments may be identified and be strengthened to avoid any imminent breach in future.

- Due to recent large scale urbanization in the upper Yamuna catchment, the flood risk in downstream areas has exacerbated. Therefore, sustainable drainage systems should be created to prevent the impact of urbanization on receiving water courses.

- After delinking of the sewerage system of drains, the network of drains can be beautified and utilized for water conservation by forming control structures in drains. This will control the surface runoff and increase the infiltration.

- Delhi water and sewer (Tariff and Metering) regulation stipulates that Rain Water Harvesting (RWH) is mandatory for property/floor size of 500 m^2 or more, failing which, the consumer is liable to be charged 1.5 times the normal tariff. Ministry of Urban Development and Poverty Alleviation of the government of India vide notification dated 28.07.2001 made RWH mandatory in all new buildings with area of 100 m^2 and above. Strict implementation of both these regulations is urgently required.

- A significant portion of the urbanized area is in the form of footpaths and paved parking. To reduce runoff, the use of permeable concrete, perforated tiles, tiles with gravel filled joints, pavers with grass joints should be made mandatory.

- Delhi has 12 bridges in the urbanized stretch from Wazirabad to Okhla, which have almost jacketed the river. These constraints obstruct the free flow during peak discharge and create afflux in up-stream areas. These bridges are pseudo-bridges and have varying openings of less than 800 m. Pseudo bridges or elevated road cum embankment should not be allowed. In case a new bridge is required, it should be supported on pillars throughout between embankments, so that further jacketing of river and resulting afflux can be avoided.

8.2 Non-structural Measures

- It is widely acknowledged that afforestation reduces soil erosion. Afforestation along the river will help in controlling agricultural run off having pesticides and fertilizers, oxygenate riverwater, and reduce evaporation losses.

- Stringent regulations must be put in place by the government of NCT of Delhi to prevent encroachment on flood plains

- A database of all water bodies in catchment needs to be prepared followed by an action plan for development, maintenance and preservation. Use of a water body for the decentralized water supply, bio diversity and recreational purpose will generate revenue as well. Desilting, landscaping, greening and regular weed removal activity should be carried out to improve aesthetics. These measures will likely augment ground water, provide habitat for aquatic and avian bio diversity, moderate micro climate, reduce runoff from the catchment area, thus reducing the magnitude of floods down stream

- Data analysis of various floods has shown that during floods the discharge released from barrages varies significantly. A coordinate release policy must be formulated in order to ensure safe disposal of flood water through different barrages.
- In the absence of legislation on flood plain zoning there in indiscriminate occupation of flood plain resulting in thickly populated settlements in flood plains. There is, therefore, an urgent need of legislation for reducing loss of life and property in the flood plains. Apart from flood safety, flood plain which consists of wide and deep aquifers also serves as an enormous natural storage of water.
- Flood risk maps for various return period floods should be prepared and made available to the general public to create awareness about the potential flood risk involved under different scenarios. Identification of flash flood prone areas and susceptible flood plains will help in planning strategies for mitigation and emergency preparedness.
- Buildings located in risk areas should be relocated in areas away from the embankment. If relocation is not possible, then new structures must not be allowed and existing structures should be flood resilient. Some of the measures that should be undertaken in making the properties flood resilient include the use of resilient fittings and fixtures. In vulnerable areas, the electric supply, water supply, sewage, communication, sanitation, schools, police stations, and public buildings should also be flood resilient.
- Urbanization, deforestation, encroachment on a flood plain, embanking of the river or its tributaries in one state can have consequential effects on other states, particularly those on the downstream side. The risk of flood in Delhi is generally not from heavy rainfall over its geographical area, but due to high discharge from either Masani barrage on Sahibi River or from Hathni kund barrage on the Yamuna. Hence, it is suggested that the Yamuna river Basin Authority may be formed with flood risk management as one of its objectives.
- One of the major constraint in developing a sustainable flood prevention and control mechanism is non-availability of data of a sufficiently long period. Collection of hydrological data for the analysis and study of catchment behavior of river Yamuna adopting sub-basin approach is necessary to evaluate the changes and their consequential impact, for creating a robust system for flood prevention. A greater number of flow monitoring stations should be set up on the Yamuna.

- Regular inspection and maintenance of flood embankments, regulators, sluice gates, storm water and sewage pumping stations, mobile pump sets, and DG sets should be carried out to ensure their smooth functioning. Round the clock vigil should be maintained on spurs, studs and bed bars to ensure their safety during the flood season.

8.3 Beyond Structural and Non-structural Measures

A One Day Stakeholders' Workshop was conducted with resource persons and participants form various Stakeholders, line departments and the administration on 12th December 2023, wherein, it was brought out that besides judicious combination of both structural and non- structural methods for the flood problem of Delhi, it is also important to look beyond in the context of risk assessment, early warning systems, response and recovery needs relief operations, policy change, administrative revamping and so on. The lessons, challenges and the way forward which emanated from this workshop in this respect are listed in Chapter 9

8.4 Proposed Strategies for Urban Floods in Other Cities and Metros

Though in general causes of flooding in various cities and metros could be stated to be high rainfall, increase in population resulting haphazard development, encroachment of flood plains and water bodies and poor drainage system yet the many characteristics of each city and metro demand a unique approach and different strategies of flood mitigation.

8.4.1 Chennai

A devastating flood hit Chennai city during November-December 2015 and claimed more than 400 lives (including other parts of Tamil Nadu) and caused enormous economic damages. Chennai received 539 mm of rain in December as against monthly average of 191 mm which was almost 3 times more than the normal rainfall in December. Chennai had already received high amount of rainfall in November itself, which made soil in the catchment highly saturated. As high amount of rainfall happened in 2-3 December, the catchment generated huge amount of runoff creating massive floods. Chennai city's drinking water supply is managed by small reservoirs like Poondi, Chembarambakkam, and Puzhal. The capacities of these reservoirs is very small compared to normal reservoirs. The flooding was caused by release of water from the reservoirs. Besides this, Chennai city has big and small ponds, the capacity and the connectivity of these ponds has been either reduced or lost. Due to reduced capacities, the storage of flood waters in the ponds which moderate flood water did not happen effectively and the missing connectivity of the lakes also hindered the efficient transfer of flood water from one pond to another. A plan needs to be to be devised to revive these systems of ponds and their connectivity.

8.4.2 Mumbai

The primary reason for flooding in Mumbai is that Mumbai City was built through the reclamation of separate islands. The reclaimed space between the islands was below the high water level. When there is heavy rainfall, it can only drain slowly. The heavy rainfall resulting from the monsoon combined with the tide can lead to poor drainage and compound flooding. Poor drainage, decrease in number of forests and wetland and poor living conditions and lack of assistance to the poor are the other causes of flooding in Mumbai. Mitigation measures like improvement of poor drainage system, participatory flood risk mapping and adopting nature based solutions like restoration and construction of bioretention areas and wetlands.

8.4.3 Kolkata

The city of Kolkata located on the river Hoogly is the third most populous urban agglomerate in India and is ranked 20th most populous city in the world. Heavy rainfall, overtopping of the river Hoogly due to water rise in Monsoon as well as increased inflow from catchment and storm effects are the major contributors to urban flooding in Kolkata. The solution to flooding in Kolkata lies in preparation and implementation of a comprehensive city drainage plan to cope with the ongoing pace of urbanization and increasing events of heavy rainfall and tropical cyclones.

8.4.3 Surat

The floods of 1968, 2004 and 2006 occurred due to heavy discharges from the Ukai dam which brought to the fore growing vulnerability of rapidly expanding population in Surat city. The 2006 flood was most devastating of all floods since the construction of Ukai dam in 1971. Over 15 Lakh people were affected and 135 persons died during flood of 2006. Besides other flood mitigation measures, the solution to flooding in Surat lies in management of Ukai dam under competing demands of water supply versus flood control

Chapter 9: Key Suggestions from Stakeholders Consultative Workshop

It is in the context of the Yamuna urban floods of Delhi with focus on July 2023 event that a stakeholders' workshop was conducted on 12th December 2023, so as to bring into limelight the experiences and lessons learnt and visualize strategies and actions for a way forward. Various stakeholders viz. India Meteorological Department (IMD), Irrigation and Flood Control Department (I&FCD) of Delhi, I&FCD, of UP, I& FCD of Haryana, Central Water Commission (CWC), Delhi Disaster Management Authority (DDMA), Municipal Corporation of Dlehi (MCD), Delhi Development Authority (DDA), Health and Revenue Departments of National Capital Territory of Delhi, Delhi Jal Board (DJB), National Disaster Relief Force (NDRF), Public Works Department (PWD), BSES, Delhi Urban Shelter Improvement Board (DUSIB), Boat Club and Centralized Accident and Trauma Services (CATS) Ambulance demonstrated enthusiasm in sending delegates and participants to this workshop. Actions taken and proposed solutions and road ahead were showcased by various resource persons.

9.1 Objectives

The workshop was conducted with following objectives:

- To disseminate the experiences of stakeholders, Administration and Line Departments about urban flooding in Delhi.
- To bring forth all issues and concerns of all stakeholders, Administration and Line Department for a more coordinated response to the floods in Delhi in future.
- To equip participants with the necessary knowledge, skills, and abilities to respond effectively to floods in Delhi in future.
- To draw a future roadmap for flood mitigation in Delhi.

9.2 Contents of the Workshop

Contents of the workshop touched upon following aspects in order to achieve the objectives:

- Problems faced
- Actions taken
- Urban flood vulnerability of Delhi
- Urban Flood Risk Management
- Flood Forecasting
- Early Warning System
- Flood impacts
- Response and Recovery Needs

- Relief Operations
- Building System Resilience
- Institutional framework
- Causes of floods in Delhi
- Mitigation and management strategies

9.3 Summary and Over all Key Suggestions

This concise summary encapsulates the key discussions, presentations, and outcomes of the workshop, providing valuable insights for future flood mitigation strategies in Delhi. The workshop served as a platform for stakeholders to share experiences, challenges, and solutions related to flood mitigation and disaster management in Delhi. Insights from experts, government officials, and frontline responders highlighted the need for improved coordination, early warning systems, infrastructure development, and community engagement in flood preparedness and response efforts. Discussions were held on the economic, social, and infrastructural repercussions of the flood. Insights were shared by experts on the existing flood monitoring systems and early warning mechanisms in Delhi. Discussions were also held on the effectiveness and challenges of the current systems and suggestions for improvement. Presentation were given by representatives from various departments and agencies on flood preparedness measures and response planning along with emphasis on coordination, resource allocation, and community engagement in flood response efforts. Along with acknowledgment of achievements, identification of areas for improvement, and commitment to continuous collaboration, emphasis was laid upon coordination, communication, safety measures, and infrastructure development. Following are the overall key suggestions that emanated from the workshop:-

- India Meteorological Department provides Hydro meteorological Support for Flood Forecasting by providing observed rainfall and Quantitative Precipitation Forecast (QPF) for 156 river sub basins. Based on which Joint advisories on Flood Status are issued by IMD, CWC and NDRF.
- Even though IMD has made several achievements like increase in lead time from 5 to 7 days, increase of rain gauge network to 5896 and use of high resolution dynamical model yet IMD needs to improve upon coordination and exchange of information among stakeholders.
- According to the study presented by Dr Gosain Professor emeritus IIT Delhi, a model is simulated for the two scenarios, first with the natural terrain and second by incorporating the constant thickness of silt by raising the bed level by 1.8 meters (6 feet) from downstream of Palla to ITO barrage, showed that the actual observed level matched with the simulated water level which points to dredging the entire channel from downstream of Palla to ITO barrage as a possible solution to the problem. However, dredging the entire channel is not recommended as per extant CWC guidelines.
- In the wake of July 2023 Yamuna urban floods, a committee has been set up

consisting of various stakeholders under the Chairmanship of Chairman, (CWC), to examine and arrive at reasons for the peculiar situation of flood of July 2023 and give its recommendations for flood mitigation in Delhi. The report of the committee is awaited.

- As per DDMA and other resource persons, major problems faced during the flood event of July 2023 have been leakage or overtopping of regulator gates, over topping of banks due to rise in river water level, submergence of settlements on the flood plains, jamming of some gates due to silting up, breach of embankment and regulator gates, lack of effective storm water drainage system and shut down of three water treatment plants.
- Even as the peak discharge of water from the Hathnikund barrage upstream in Haryana was not the highest that has been recorded so far. A higher peak discharge of 8 Lakh Cusecs was recorded even in 2019 from Hathnikund Barrage which is larger than the peak of 3.59 Lakh cusecs that was recorded on 12th of July 2023. However, the highest flood level so attained in 1978 (207.49m) at ORB was not exceeded in 2019, but during the July 2023 event it was exceeded by 1.17m (208.66m) at ORB.
- As per DDMA and other resource persons, the peculiar situation mentioned above could likely be due to the heavy rainfall downstream of Hathnikund and also due to multiple cross-sectional and longitudinal structures along the Delhi stretch of river due to which, there is silt accumulated and trapped in Delhi stretch of the river. Furthermore, the time of concentration is shorter such that the same amount of rainfall has fallen in a shorter period and has moved downstream quickly. Flood plain encroachments, constrictions due to various bridges in the course of the river, concretization are the other reasons. The gates of ITO Barrage being closed would have also blocked the free flowing water.
- More effective drainage system, better management of Water Treatment Plants and Sewerage system is called for by improving coordination among different agencies.
- Standard Operating Procedures for pumping operations, WTPs, STPs and SPSs should be formulated to mitigate the effect of flooding.
- DJB highlighted that storm water drains and sewerage system should not be interconnected as sewerage system is not designed to take load of storm water.

- PWD representative highlighted major causes and remedial measures for road flooding during heavy rainfall. He suggested proper drainage management, sewer line maintenance and rain water harvesting to reduce its impact.
- Floodplain restoration and rejuvenation initiatives by DDA and discussion on projects aimed at restoring wetlands, creating green spaces, and enhancing floodplain ecosystems were highlighted by representatives from DDA.
- Insights were shared by NDRF representatives on the role of NDRF in flood response, including rescue operations and humanitarian aid and discussion on challenges faced and proposed solutions for effective flood response. Discussion also took place on evacuation, rescue operations, and relief measures implemented during the flood.
- Case presentation was made by SDM, Sarita Vihar, Delhi on the flood situation in Vishwakarma Colony, Jaitpur, and the response efforts undertaken by the District Administration.
- There was active participation from representatives of Districts and line departments, including DUSIB, BSES, Health Department, CATS Ambulance, Boat Club, and MCD with discussion on challenges faced during flood relief operations and suggestions for improvement in the open forum discussion.

Chapter 10: The lessons, challenges and the way forward

The lessons, challenges and the way forward are synthesized based on the research from various sources including published journals and reports, newspapers, internet, various websites, analysis of data and information supplied by the concerned departments, resource persons and suggestions made by stakeholders and line departments in the stakeholders' consultative workshop of 12th December 2023.

10.1 Lessons

- The flood in Delhi has been a case of human accelerated natural disaster as it has been not only due to peculiar meteorological conditions, heavy rainfall over a short period but also exacerbated due to anthropogenic reasons of increase in urbanization, growth of population and human encroachments.

- The reasons for the flooding in Delhi in July 2023 were threefold
  (i) Due to heavy to very heavy rainfall over Delhi.
  (ii) Due to river Yamuna being in spate resulting in backflow in the drains and inundation of the low lying areas.
  (iii) Due to congestion in the drainage system.

- A two pronged approach with both riverine and urban flooding combined may have to be adopted by the various stakeholders for mitigation of floods in Delhi.

- The river Yamuna crosses several states viz. Uttrakhand, Himachal Pradesh, Haryana and Uttar Pradesh besides flowing through Delhi and urbanization and industrialization has taken place in the basin in last couple of decades. It appears that all stakeholders including the states of Yamuna Basin i.e. Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana and Delhi may have to collaborate with an integrated and holistic approach.

- Besides judicious combination of structural and non- structural methods for the flood problem of Delhi, it is also important to look beyond in the context of risk assessment, modernizing and improving early warning systems, response and recovery needs, relief operations, policy change and revamping institutional mechanisms.

10.2 Challenges

10.2.1 Flood Management

- Major problems faced during the flood event of July 2023 have been leakage or overtopping of regulator gates, over topping of banks due to rise in river water level, submergence of settlements on the flood plains, jamming of some gates due to silting up, breach of embankment and regulator gates, lack of effective storm water drainage system and shut down of three water treatment plants.

- The urban flood problem of Delhi is exacerbated due to multitude organizations for flood control in Delhi. The administrative authority of the capital's flood control and drainage system is quixotically distributed amongst numerous civic bodies and various constituent departments of Government of NCT of Delhi as well as Government of India.

10.2.2 Drainage

- Multiple agencies /departments like I&FC, PWD,DJB, MCD are maintaining different stretches of drains/sewers which results in flooding related issues due to lack of coordination.
- Inadequate pumping capacity and low formation level of pump houses, NDMC area getting flooded due to improper outfall of MCD drains and inadequate desilting of drains are another set of problems so no overarching agency is there to take care of this.

10.2.3 Evacuation, Response, Relief and Rescue during July 2023 event

- Unwillingness and reluctance of people living in flooded areas to leave their habitations in spite of munadis and warning given to them. Even after the water had entered the houses, people were waiting for police and administration to rescue them, their cattles/animals and other belongings rather than moving out on their own after initial warnings.

- Few relief camps were erected on the road side which obstructed smooth flow of traffic and could have led to accident or any other mishap especially in areas where people moved with their cattle and animals.

- Shortage of boats was felt by Delhi Police in the initial phase of rescue/ evacuation operation before arrival of NDRF. Uneven topography coupled with barbed wire fencing at some places led to obstruction in free movement of boats. NDRF inflatable boats even got punctured due to barbed wire. These aspects need to be taken care of in future.

- Evacuation of cattle to be done in advance. In case animals are surrounded by flood water, then it is very difficult to evacuate them as the animals like cow, buffalo cannot be accommodated on boat (IRB). Thus its rescue becomes very risky in flood water. Therefore people may have to be advised to evacuate cattle well in advance if there is forecast of flood water in their area.

- It was experienced during Delhi flood that media persons were approaching to NDRF team for carrying them in boat to cover the news. Since the prime task of NDRF is to rescue the victims on priority and providing humanitarian aids to the victims and their early evacuation to safer place. But such intervention of media people creates chaos in rescue operation. It is felt that administration may declare where the newspersons can go and beyond which they can't go. Administration may also use the media effectively by giving official bulletins to the media from time to time.

10.2.4 Administration

- Delhi is case wherein many of the challenges and complexities of Governance arise from its place at the intersection of local, state and national jurisdictions and the urban flood problem of Delhi is exacerbated due to multiple organizations for flood control and drainage consequently leading to an unclear accountability.

- As a result the drainage issues of the city which arise generally during the ongoing event of flood disaster and remains unresolved after the disaster, though time to act upon is intervening period between two monsoons when identification of bottlenecks, formulating and implementing integrated long term and medium term action plans is required to be done to enhance/augment the drainage system.

10.3 Way Forward

10.3.1 Flood Management

- In the wake of July 2023 Yamuna urban floods, a committee has been set up consisting of various stakeholders under the Chairmanship of Chairman, (CWC), to examine and arrive at reasons for the peculiar situation of flood of July 2023 and give its recommendations for flood mitigation in Delhi. The report of the committee is published. The committee recommends enhancing flood management by improving drainage systems, restoring encroached floodplains, and assessing the feasibility of underground reservoirs for floodwater storage. It also emphasizes better coordination among stakeholders, effective use of flood forecasting data, and implementation of flood protection measures along the Yamuna River's critical sections (Source-Ministry of Jal Shakti and CWC, 2024).

- It was deliberated in the workshop that apparently, since river bed has silted up, selective dredging of the river bed near mouths of Nallahs, outlets and intakes etc. could be undertaken after detailed studies and investigations. Formation of island/silt deposition in course of Yamuna as well as rise of river bed over the years, in different stretches needs to be studied properly for its due remedial measures. Also, the Warning level, Danger Level and High Flood Levels of Yamuna need a review in view of rise in bed level of the river.

- It is emphasized that the solution to the flood problem requires a huge effort. Since the problems are already identified, what now required is to formulate a scientific action plan with participation of all stakeholders. The Government could consider the formation of Yamuna Basin Authority under River Basin Organization Act as per entry 56 of the constitution.

- It is also desirable that no further construction within embankment should be allowed and flood plains should be declared as no construction zones.

- Proper Flood Plain Zoning may be done in scientific way. No new structures in the prohibited zone as per zoning policy be allowed. All old structures hindering the desired flow conditions in different zones need to be retrofitted for streamlining the flood and may need shifting outside the prohibited zone, if required.

- There should be reassessment of waterways in the Yamuna including over 25 bridges so as to mitigate the afflux effect due to reduction in water ways. Afflux due to bridges from Wazirabad to Okhla stretch, where there are 17 Nos. (14 Nos. exist + 3 Nos. under construction) bridges. Due to the guide bunds embanked approach, roads water way is reduced upto 500 meter. (approx.). It is recommended to develop mathematical model with existing bridges in position to study the effect.

- The Central Water Commission is a line department for flood forecasting and collects data. Processes data and does dissemination to various stake holders and for response activation. However, it still relies primarily on gauge to gauge correlation and able to achieve a lead time of up to 24 hours in flood forecasting. In this connection, it is desirable that the lead time be improved by CWC with simultaneous increase in accuracy of its forecast. There is need to improve flood forecasting by adopting better techniques for improvement in lead time of the forecast. Besides detailed modeling at the basin level may be undertaken for inundation forecast for an advance action for evacuation by NDRF and SDRF.

- Requirement of proper storage in Yamuna for moderating floods. Projects like Renuka Kishau and Lakhwar Vyasi may be expedited.
- Flood fighting equipment to be stock piled at easily accessible locations for prompt transportation and supply to the intended sites. Immediate flood fighting measures such as repairs, closing of inlets, plugging of leakages/ breaches etc. should be taken at site by I&FC Department.

10.3.2 Drainage

- Every year before onset of monsoon, Delhi Traffic Police shares list of locations where frequent water logging happened in the previous year. Civic bodies and concerned departments can identify these locations and place mobile dewatering pumps to avert water logging.
- There is need to take proactive steps by the Government of NCT of Delhi with respect to updating and drainage plan of Delhi at the right earnest with effective implementation. There should be a statutorily mandatory pre-monsoon inspection of entire drainage system just like in dam safety inspection, so that it functions well during flood and is not found choked. In fact a Drainage Act for the capital city may be need of the hour.
- Larger drains falling in river Yamuna should be with one agency as far as possible. ULBs can look at colony drains and the rest should be with one Department to avoid issues of multiplicity. Smaller drains can be rerouted to join these larger drains instead of falling directly in Yamuna thereby giving way to backwaters. These larger drains falling in Yamuna can be controlled with proper gate operations and channelizing for a reasonable length.
- Procurement of latest technology emergency response equipment like mobile dewatering pumps of different capacities, quick response vehicles equipped with repairing tools by all agencies i.e. MCD, I&FC, PWD & NDMC is also required.

- Development of water supply scheme with GIS mapping of all networks.
- Desilting of sewer lines to be more systematic and it should be monitored with the help of latest technology, like cameras and sensors.
- Follow up National Guidelines on Management on Urban Floods published by NDMA in 2010 which call for a proactive, participatory, well structured, multi-disciplinary and multi sectoral Urban Local Bodies (ULB's) to implement catchment based planning and designing for storm water drainage system.
- Standard Operating Procedures (SOP's) for handling the breakdowns of pumping equipment/regulators/ breaches in drains needs to be in place.
- All the unauthorized pipes laid for disposal of sewerage from the colonies out falling into major drains should be removed and connected to sewer manholes of DJB.
- All the service / utility lines i.e. water line, sewer line, electric / telephone cables, gas pipeline, transformers should be outside/below DBL or above embankment level of drain and well designed to stand scour during flood.
- Strengthening of pumping infrastructure by replacing old pumps with those having higher capacity and improved energy efficiency. Installation of high capacity pumping systems at flood gates of I&FC Department to control rise of water level inside city during closure of gates.
- Existing drainage system needs to be redesigned to account for discharge of unauthorized colonies. Slopes of existing drains of all agencies needs analysis and correction as per present scenario in Delhi. Major dredging exercise to be undertaken for all major drains.
- Development of Green Infrastructure and to design Delhi as Sponge City with artificial recharge using rain water harvesting, constructions of permeable pavements to capture maximum rain water to stop its contribution in flooding. Rejuvenation of water bodies, and implementation of BIOSWALES by road owning agencies (PWD, MCD) etc. Bioswales are channels designed to concentrate and convey storm water runoff while removing debris and pollution and beneficial in recharging ground water.

10.3.3 Evacuation, Response, Relief and Rescue

- Need for formulation of Emergency Response Teams for operation and maintenance of STP/SPS/WTPs and other installations.

- Mock Drills involving situation related to relief and rescue during flooding should also be conducted on regular basis to improve co-ordination among line department.

- **Role of NGOs:** Although NDRF is mandated to respond in any kind of level-3 disasters except fire incident, but in wide area flooding situation in which large number of people are trapped, there may be shortage of NDRF teams as per requirement then in such condition NGOs and Civil Defence Volunteers (CDVs) may play vital role in evacuating trapped people and also they may help in providing food and distribution of relief materials. The list of NGOs may be kept ready and they may briefed well in advance about their key role during such disasters.

- Raising of State Disaster Response Force for Delhi to support in undertaking prompt response and immediate relief measures in the wake of any disaster.

10.3.4 Administration

- Timely Dissemination of information across the agencies in a seamless manner by getting all nodal officers/ Senior officers of stake holders/ departments in a single platforms, thereby facilitating coordination among the nodal officers of all agencies and even with the departments of neighboring states .

- Use of IDRN Portal: District administration and all other stake holders should update information on IDRN Portal so that people can gain information about all resources and the prevailing situations around them. This portal has been developed by NIDM to consolidate all relevant information on single dashboard.

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About the Institute

National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity developmentin India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its redesignation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

NIDM is proud to have a multi-disciplinary core team of professionals working in various aspects of disaster management. In its endeavour to facilitate training and capacity development, the Institute has state-of-the-art facilities like class rooms, seminar hall and video-conferencing facilities etc. The Institute has a well-stocked library exclusively on the theme of disaster management and mitigation. The Institute provides training in face-to-face, on-line and self-learning mode as well as satellite based training. In-house and off-campus face-to-face training to the officials of the state governments is provided free of charge including modest boarding and lodging facilities.

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