URBAN INFRASTRUCTURE RESILIENCE

A Case Study of Gurugram City Water Systems

Study Report

Integrated Centre for Adaptation, Disaster Risk Resilience and Sustainability (ICARS)
IIT Roorkee – Greater Noida Campus (NCR), India

Urban Infrastructure Resilience: A Case Study of Gurugram City Water Systems

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Prof. K. K. Pant
Director

सत्यमेव जयते

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Foreword

With a legacy of 178 years, IIT Roorkee has always been at the forefront of advancing scientific knowledge and technological innovation in the areas of disaster management, climate, water, and related research. In line with India's national vision for sustainable and climate-resilient growth, the Institute continues to play a pivotal role in developing solutions that integrate science, engineering, and societal needs.

The Centre of Excellence on "Integrated Centre for Adaptation to Climate Change, Disaster Risk Resilience and Sustainability (ICARS)" is supported by the Department of Science and Technology (DST)-Govt. of India, and is established at IIT Roorkee's Greater Noida campus. It focuses on policy-linked research, action research, research to support capacity-building and knowledge integration into policy-strategies, makes it a unique institution of its kind. The report titled "Urban Infrastructure Resilience: A Case Study of Gurugram City Water System", represents a timely and important contribution to this effort. The study exemplifies how interdisciplinary research—spanning engineering, environment, planning, and governance—can generate actionable insights for improving the resilience of urban systems against climate-induced stresses. This initiative reflects the power of collaboration between academic institutions, policymakers, and field agencies.

I congratulate the Principal Investigator and the ICARS team for their dedicated efforts and commend the Department of Science & Technology for its continued support in strengthening research and innovation for national development. I am confident that this study will serve as a valuable reference for scientists, practitioners, and policymakers working towards a resilient and sustainable urban future.

K. K. Pant

Preface

The study on “Urban Infrastructure Resilience: A Case Study of Gurugram City Water System” has been undertaken as part of the analytical studies under the mandates of the Integrated Centre for Adaptation to Climate Change, Disaster Risk Resilience and Sustainability (ICARS) at IIT Roorkee, a Centre of Excellence by the Department of Science & Technology (DST), Government of India. The initiative aims to strengthen research, capacity, and policy linkages in the field of climate adaptation and disaster resilience through integrated and interdisciplinary approaches.

This report focuses on understanding the resilience of Gurugram’s urban water, wastewater, and drainage systems in the face of growing environmental and climatic stresses. Through extensive stakeholder consultations, field visits, and institutional assessments, the study seeks to identify critical vulnerabilities and opportunities for enhancing systemic resilience across multiple dimensions — technical, institutional, environmental, and social.

The findings presented here reflect not only the scientific inquiry and field-based learning but also the importance of collaboration between academia, government institutions, and local authorities. The insights derived from this study are intended to inform resilient planning and policymaking for urban infrastructure systems across India.

It is my earnest hope that this study contributes meaningfully to the national efforts toward achieving climate-resilient, sustainable, and inclusive urban development.

Prof. Anil K Gupta
Professor- WRDM & Principal Investigator,
ICARS, IIT Roorkee-Greater Noida Campus

Acknowledgement

The analytical study on Urban Infrastructure Resilience: A Case Study of Gurugram City Water Systems is brought out under the project Integrated Centre for Adaptation, Disaster Risk Resilience and Sustainability (ICARS) at IIT Roorkee, supported by the Department of Science & Technology (DST), Government of India. We are thankful to Prof. Abhay Karandikar (Secretary, DST-GoI) for entrusting IIT Roorkee with the opportunity to undertake and work on the ICARS-CoE. A special note of thanks to Dr. Anita Gupta (Advisor & Head, CEST, DST-GoI), Dr. Vandana Singh (Scientist-F, CEST, DST-GoI) and Dr. Swati Jain (Scientist-D, CEST, DST-GoI) for the support extended to ICARS.

The project team is thankful to Prof. K.K.Pant (Director, IIT Roorkee), Dr. Akhilesh Gupta (Distinguished Professor, CDMM, IIT Roorkee), and Dr. Thanga Raj Chelliah (HoD, WRD&M, IIT Roorkee) for their constant support and encouragement for undertaking the various strategic endeavours and ensuring the smooth functioning of ICARS. From the ICARS team, a special thanks to the Co-PIs (Prof. Ashish Pandey, Prof. Akshay Dvivedi, Dr. Komal Tripathi), and expert collaborators (Prof. Manish Goyal, IIT Indore, Dr. Mohit Mohanty and Dr. Rajarshi Dasgupta, IIT Delhi) for their collaborative efforts and valuable contributions to ICARS.

The team is grateful to the officials of Municipal Corporation of Gurugram (MCG) and Gurugram Metropolitan Development Authority (GMDA) for sharing data and insights over meetings during 2024 into drainage, water supply and, wastewater infrastructure network in the Gurugram-Manesar Urban Complex (GMUC)-2031 that also includes the area under the jurisdiction of MCG. Specifically, Shri. Vishal Bansal, Chief Engineer, MCG, Subhas Yadav, Addl. CEO, Urban Environment Division, GMDA, Shri. Rajesh Bansal, Chief Engineer, GMDA, Shri. Abhinav Verma, Executive Engineer, GMDA, and Shri. Vikram Singh, Executive Engineer, GMDA.

Further, we acknowledge the authors Mr. Shashikant Chopde (Sr. Advisor, Tarutium Global Consulting) and Ms. Pritha Acharya (Project Scientist-II, ICARS) for taking up this study and drafting the report. Thanks are also due to Mr. Vishes Kanaujia (Project Assistant II, ICARS) for supporting in data collection.

We believe this study will set the course for further learning, as well as scaling up resilient infrastructure in the urban water infrastructure sectors in India and globally, in the context of triad of issues of climate change, urbanisation and poverty.

Prof. Anil K Gupta

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Abbreviations

1. AMRUT: Atal Mission for Rejuvenation and Urban Transformation mission
2. ASP: Activated Sludge Process
3. CCIP: Climate Change Information Portal
4. CDRI: Coalition for Disaster Resilient Infrastructure
5. CSCAF 2.0: Climate Smart Cities Assessment Framework 2.0
6. DBFOMT: Design, Build, Finance, Operate, Maintain and Transfer
7. DTCP: Department of Town and Country Planning, Haryana
8. GDP: Gross Domestic Product
9. GHG: Greenhouse Gas
10. GIZ: Deutsche Gesellschaft fur Internationale Zusammeenarbeit GmbH
11. GMDA: Gurugram Metropolitan Development Authority
12. GMUC: Gurugram-Manesar Urban Complex– 2031
13. GoI: Government of India
14. GWS Canal: Gurugram Water Supply canal
15. HSIIDC: Haryana State Industrial and Infrastructure Development Corporation
16. ICCC: Incident Command and Control Centre
17. IPCC: Intergovernmental Panel on Climate Change
18. MoEFCC: Ministry of Environment, Forests and Climate Change, (Government of India)
19. MCG: Municipal Corporation of Gurugram
20. MLD: Million Litres per Day
21. NCR Canal: National Capital Region canal
22. NCTD: National Capital Territory of Delhi
23. NDMP: National Disaster Management Plan 2019
24. NbS: Nature-based Solution

25. NIP: National Infrastructure Pipeline
26. NIST: National Institute of Standards and Technology (NIST), US Department of Commerce
27. NPDM: National Policy on Disaster Management 2009
28. PPP: Public-Private Partnership
29. RCP: Representative Concentration Pathway
30. SCADA: Supervisory Control and Data Acquisition
31. SBM: Swachh Bharat Mission
32. SBR: Sequencing Batch Reactor
33. SDG: Sustainable Development Goals
34. SFDRR: Sendai Framework for Disaster Risk Reduction
35. STP: Sewage Treatment Plant
36. UNDRR: United Nations Office for Disaster Risk Reduction
37. WSDI: Warm Spell Duration Indicator
38. WTP: Water Treatment Plant
39. WWTP: Wastewater Treatment Plant
40. TOD: Transit-Oriented Development

1. Introduction

The National Capital Territory of Delhi (NCTD) is the second largest urban agglomeration with population of 34.6 million in 2025 (World Population Review, 2025) after Tokyo in the world and it is poised to become the largest urban agglomeration in the world by 2030 with a population of 39 million (UN, 2024). Gurugram is one of the key cities in the NCT (location map of Gurugram Figure 1) and is dotted with swanky corporate houses, high rises, and is a significant contributor to Gross Domestic Product (GDP) of NCTD after Delhi. However, the pace of infrastructure development has been outpaced by urbanisation (Tiwari & Kashyap, 2024) leading to citizens facing several challenges (KPMG, 2017).

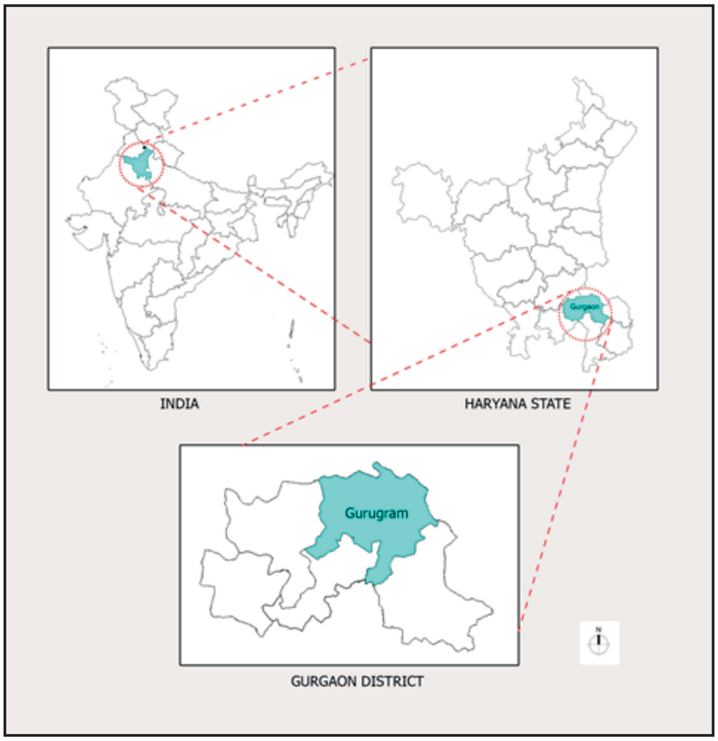


Figure 1: Location map of Gurugram.

Source: Authors Representation

The Government of India has put in place several policies/ missions/ programmes that enable development of resilient infrastructure in the urban water sectors—drainage, water supply and wastewater. The key ones include Smart Cities Mission, Swachh Bharat Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) mission Urban, (NIUA, 2023) Swachh Bharat Mission (SBM)-Urban, National Infrastructure Pipeline (NIP) (MoF, 2020), India Infrastructure Report (Morris, 2023), Climate Smart Cities Assessment Framework (CSCAF) 2.0 (NIUA, 2020) apart from policy development in digital technologies that, together with other missions, comprehensively can enable making infrastructure in urban water sectors disaster/ climate resilient. The lessons from this Gurugram case study can foster development of resilient (urban water) infrastructure sectors in various cities in India specifically in drainage, water supply and wastewater management (Gupta, Madan, & Acharya, 2022).

Gurugram is privileged to have a steep gradient from south to north, generally (Figure 2). The steep gradient enables storm runoff to flow into the Najafgarh drain situated at the northernmost edge. However, rapid urbanization, increase in impervious areas, and reduction in drainage capacity are key factors in Gurugram that cause flooding with flooding/ waterlogging becoming almost an annual feature. In the recent past, it experienced major flooding/ waterlogging in 2016, 2018, 2019, 2021, 2022, and even in the monsoon of 2023 (Aparna & Piyush , 2025). Flooding/ waterlogging can impact water supply and wastewater infrastructure networks. In addition, the city is also exposed to high heat hazard and water scarcity that are induced by climate change and anthropogenic factors (Rao, 2025).

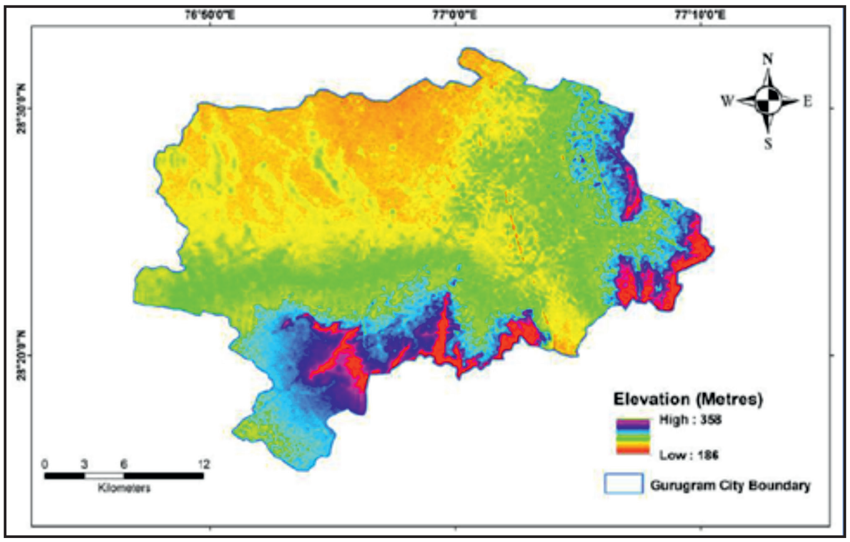


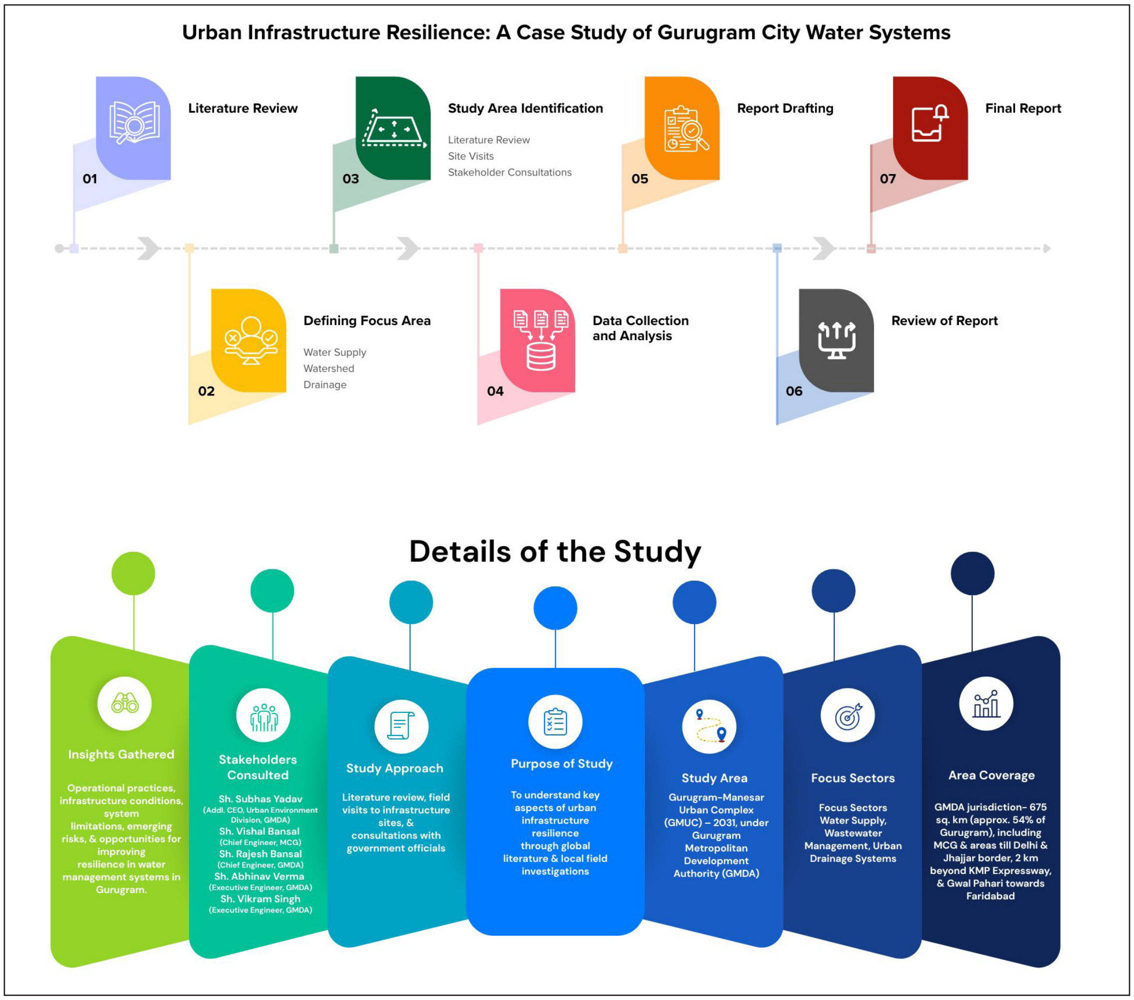
Figure 2: Natural elevation/ slope of Gurugram

Source: Climate Action Plan for Net Zero for Gurugram by 2050, The Celestial Earth, 2023

2. Methodology

About the Study

The current study on climate resilience of infrastructure is being undertaken as part of Analytical Studies as part of the objective 5 on "to develop knowledge base through collection and undertaking of the case studies, compilation/organization and analysis, to support policies and capacity building processes". This study is developed under the Integrated Centre for Adaptation, Disaster Risk Resilience and Sustainability (ICARS) project of the Indian Institute of Technology (IIT) Roorkee. The study is undertaken for Gurugram city and investigates the barriers and opportunities for resilience in water supply, wastewater, and drainage sectors/ infrastructure. It comes up with strategic insights on the overall approach and elements to consider for resilient infrastructure in urban water sectors that could be adapted to cities in India and globally.



3. Key Principles of Resilient Infrastructure from Global Literature

The United Nations office for Disaster Risk Reduction (UNDRR) defines resilience as :

"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNDRR, 2017)."

In the climate change context, resilience is defined by the Intergovernmental Panel on Climate Change as:

"The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbances, responding or re-organising in ways that maintain their essential functions, identity, and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/ or transformation (IPCC, 2021)*".*

Climate risks on infrastructure affect design and construction costs of project as well as various costs during the operation phase, resultantly affecting multiple costs during the lifecycle of infrastructure (design and construction, and operations). While the impacts can increase design and construction costs, during the operation phase, it can reduce revenues and increase asset losses, and operation and maintenance costs (ADB & GCA, 2021). Infusing resilience in infrastructure reduces these costs while enhancing revenues. Infact, a World Bank report highlighted that investing in more resilient infrastructure can save around $4.2 Trillion (Hallegatte, Rentschler, & Rozenberg, 2019).

The policy perspectives (OECD, 2024) that are important for infrastructure resilience include, inter alia, considering inter-dependencies across various infrastructure sectors and integration of Nature-based Solutions (NbS). The former necessitates considering cascading impacts/ failures of one infrastructure on other--such as failure of power supply on water supply etc., while the later (NbS) lends cost-effectiveness and other larger co-benefits to the society, overall (Saxena, Sonwani, Gupta, Ratnoo, & Acharya, 2025).

The key qualities of resilience as per Arup's City Resilience Framework (ARUP, 2024) include Reflective, Robustness, Redundancy, Flexibility, Resourceful, Inclusive, and Integrated. Likewise, the Institute for Social and Environmental Transition-International's (ISET-International) Urban Resilience Framework (Stephen Tyler & Marcus, 2012) categorises key elements of resilience into three interconnected aspects-- Systems, Agents, and Institution. While the elements in Systems include flexibility and diversity, redundancy and modularity, safe failure, the elements under Agents category include responsiveness, resourcefulness, and capacity to learn. And, Institutions cover elements of rights and entitlements linked to system access (inclusiveness), decision-making processes (good governance), information flows, and (generation and) application of new knowledge.

Risk-based performance goals need to be set for various sectors including for water supply and wastewater. For example, the performance goals could consider "smart grid" for water distribution or planned replacement of aging water systems (McAllister, 2013).

At core resilience depends on the capacity of a system to maintain acceptable levels of functionality during and post-disaster event and to recover to full functionality within minimum/ stipulated/ accepted period (Gupta, A.K, Acharya, & Gupta , 2024). The time of full recovery depends on actions taken to improve performance on prevention and mitigation, preparedness, and response, and post-disaster reconstruction and recovery (Mentges, Halekotte, Schneider, Demmer, & Lichte, 2023).

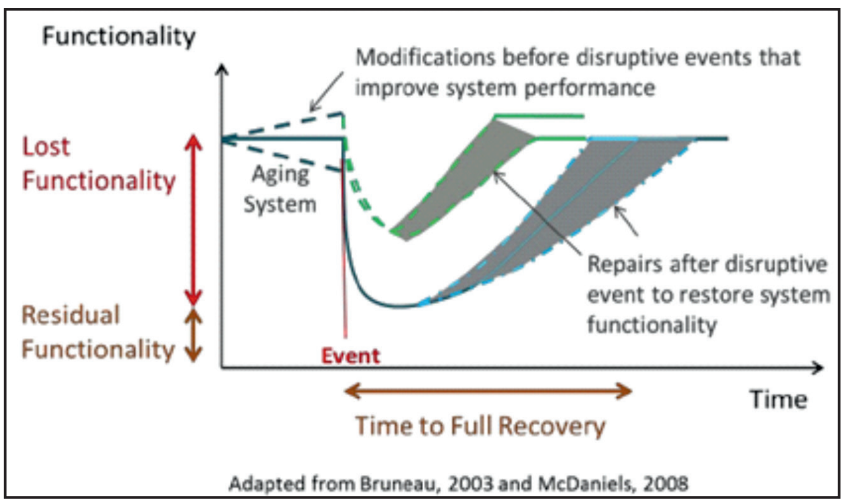


Figure 3: Resilience Concept vs. Recovery Time from a Disruptive Event.
Source: MacAllister, 2013

There is need to strengthen governance for resilient infrastructure (Sharma & Gupta , 2024). This can be achieved by considering: a) whole systems perspectives (interconnected systems); b) increasing adaptive capacity (reflexive governance and capacity to learn); c) prioritizing infrastructure needs (project prioritization, evaluation and selection; decision-making and coordination for incorporating resilience); d) infrastructure finance (lack of finance for resilience projects; financing project's pre-development activities); e) regulations, codes and standards (guidance on standards and creating regulations); f) capacity and resourcing (lack of skills and capacity); and, g) data, information and technology (generating evidence-base for infrastructure decision-making) (Akshaya Kannan, 2021).

From the foregoing it can be deduced that at core urban infrastructure resilience is the state/ capacity of an infrastructure to deliver uninterrupted/ minimally disrupted service throughout its life in the context where the risks from changing climate are compounded by inappropriate urban planning/ development.

Considering the various perspectives/ frameworks/ definitions of resilience as above, infrastructure resilience can be assessed through following indicators/ aspects:

i. Infrastructure system related: Robustness, Flexibility, Redundancy, and interconnectedness with other systems (/sectors including natural environment).

ii. Organisation/ Agent related: Responsiveness, resourcefulness, capacity to learn

iii. And the third most important aspect that governs/ enables the above two aspects is the policy and institutions: Policies, Acts, Rules, and Regulations, plans, codes, norms, guidelines, manuals etc.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4. Climate Hazards of Gurugram: Current and Future

The key climate hazards for Gurugram include floods/ waterlogging, heat and water scarcity. For understanding the current and future scenarios of the climate hazards we consider climate indices from the Ministry of Environment, Forests and Climate Change (MOEFCC)-GIZ Climate Change Information Portal (CCIP)[1] for Gurugram district in absence of Gurugram city level climate projections. The values for each of the indices are presented for the baseline period (1981-2010), mid-term (2021-2050) and end-century (2071-2100) for each of the two scenarios, i.e., Representative Concentration Pathways (RCP) 4.5 and RCP 8.5. While RCP 4.5 is a stabilisation (intermediate) scenario in which radiative forcing stabilises at 4.5 W/m2 before 2100 through deployment of strategies and actions to reduce Greenhouse Gas (GHG) emissions, RCP 8.5 is a worst case scenario in which GHG emissions are assumed to continue to rise throughout the 21st century. Its noteworthy, that the world has very low chances to be on the RCP 4.5 path unless concerted and stringent emission reduction strategies are implemented. All the indices are averages of annual values for the time periods specified. So, for example, Very wet day precipitation (mm) for the mid-term period would indicate average of annual values over 2021-2050.

4.1 Seasonal Variation of Rainfall

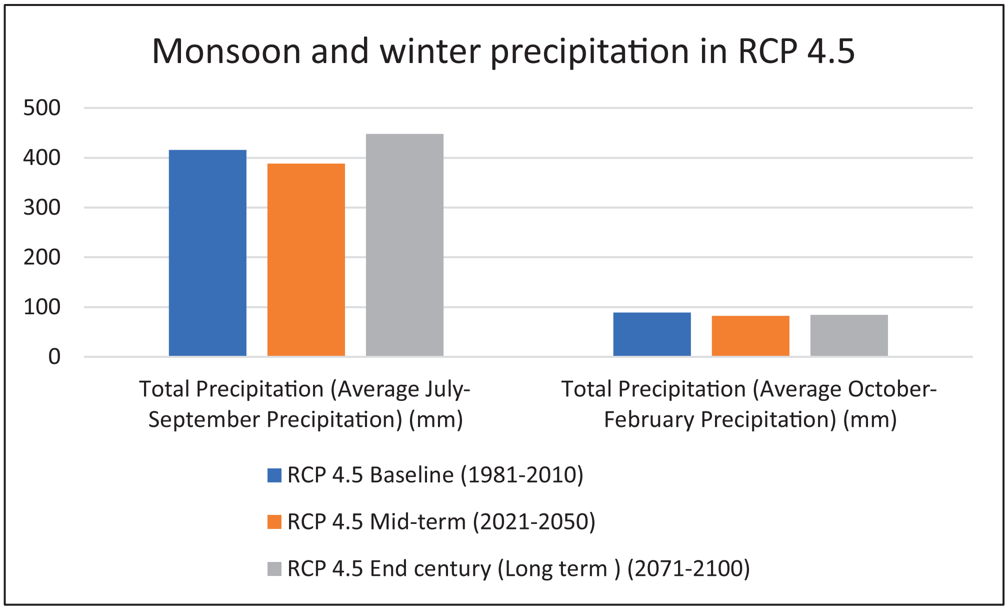

Figure 4: Monsoon and winter precipitation changes in RCP 4.5 scenario

1 *Ministry of Environment, Forests and Climate Change (MOEFCC)- GIZ Climate change vulnerability portal (http://climatevulnerability.in/)*

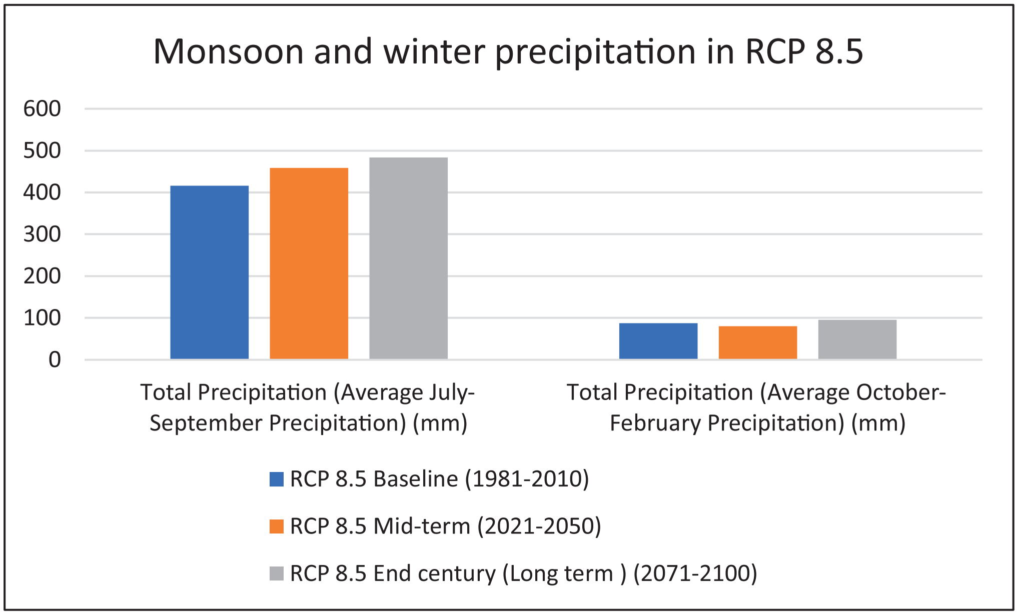

Figure 5: Monsoon and winter precipitation changes in RCP 8.5 scenario

While the monsoon precipitation (June-September) in RCP 4.5 scenario decreases slightly in mid-term) and increases in end-term as compared to the baseline, it increases consistently in the RCP 8.5 scenario in both the mid-term and end-term. The winter precipitation decreases slightly in the mid-term and end-term in the RCP 4.5 scenario. Further in the RCP 8.5 scenario it decreases in mid-term and increases in the end-term as compared to the baseline period (Figure 4 and Figure 5).

4.2 Flooding/ Water-logging

The relevant indices for flooding/ waterlogging include intensity and duration related. Intensity related include: Very wet day precipitation (mm), Extremely wet day precipitation (mm), Max 1-day precipitation (mm), Max 5-day precipitation while duration related indices include Number of Heavy Precipitation Days and Number of Very Precipitation Days. Specifically, very wet day and extremely wet day precipitation, both expressed in mm, denotes annual total precipitation due to events with precipitation higher than 95th and 99th percentile, respectively, for the reference period.

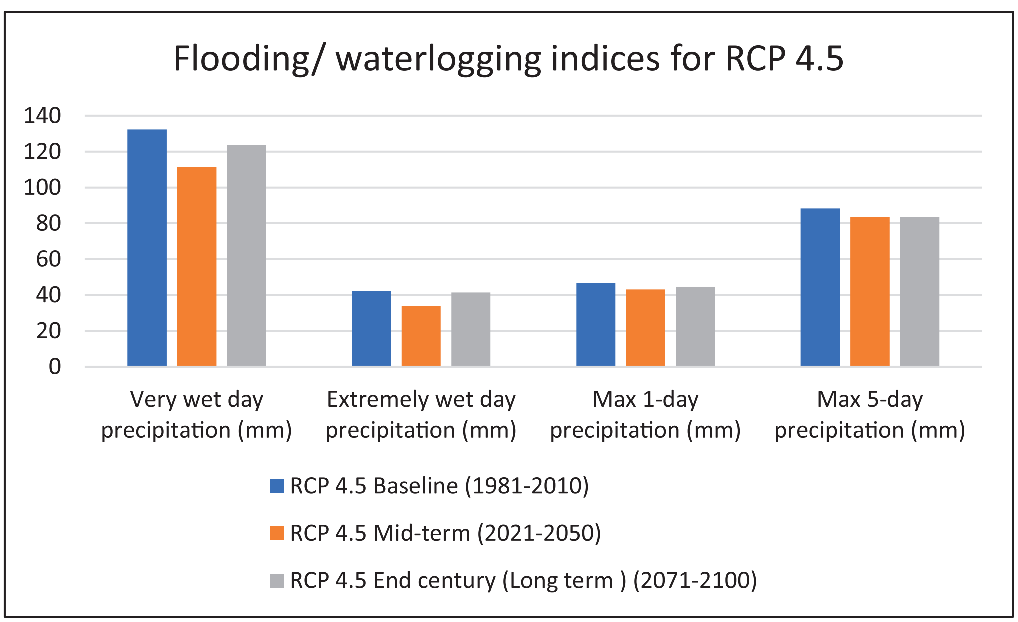

Figure 6: Flooding/ waterlogging intensity related climate indices for RCP 4.5 scenario

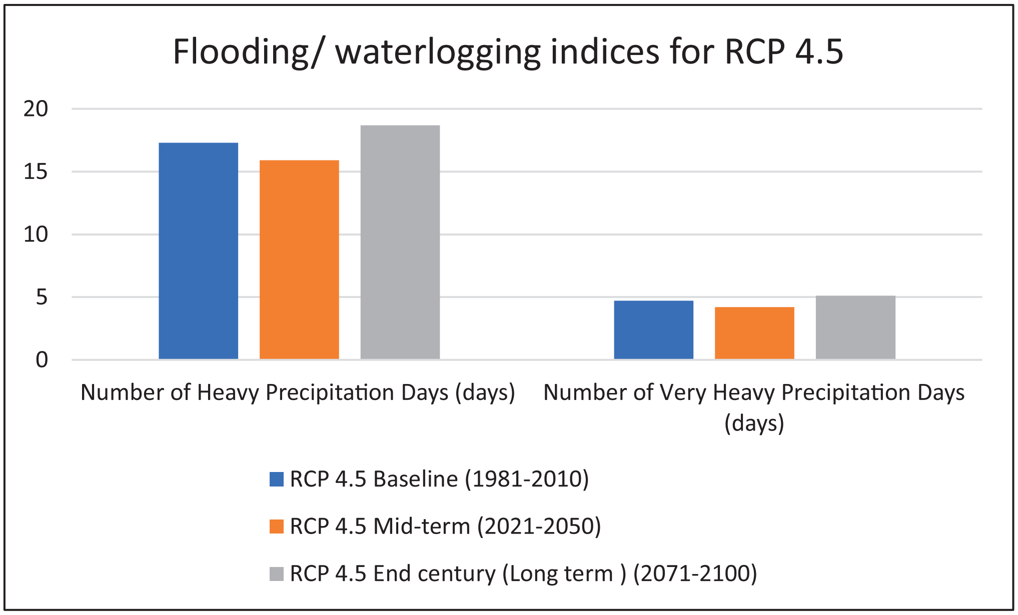

Figure 7: Flooding/ waterlogging duration related climate indices for RCP 4.5

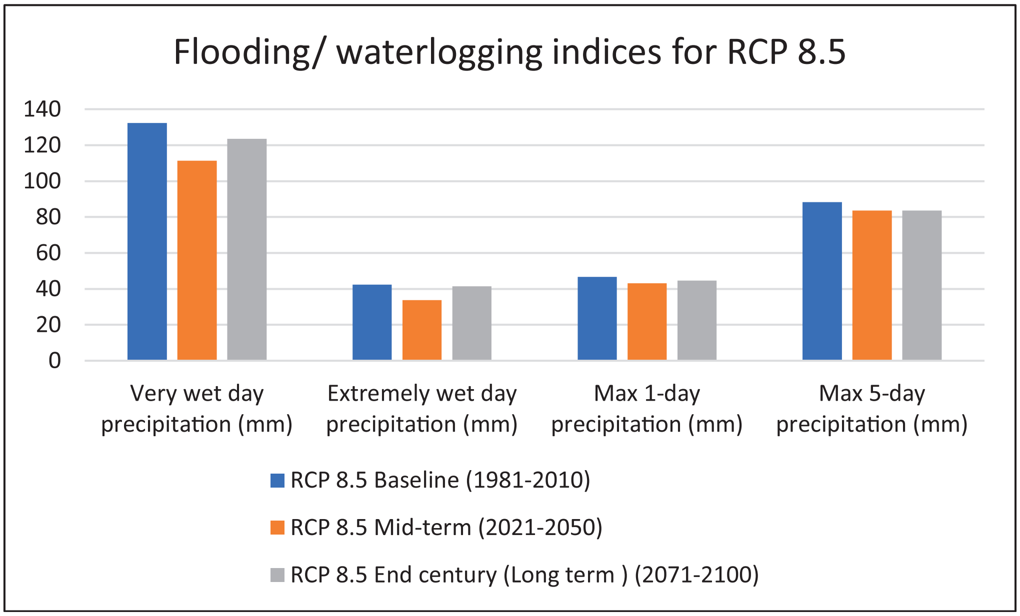

Figure 8: Flooding/ waterlogging intensity related climate indices for RCP 8.5

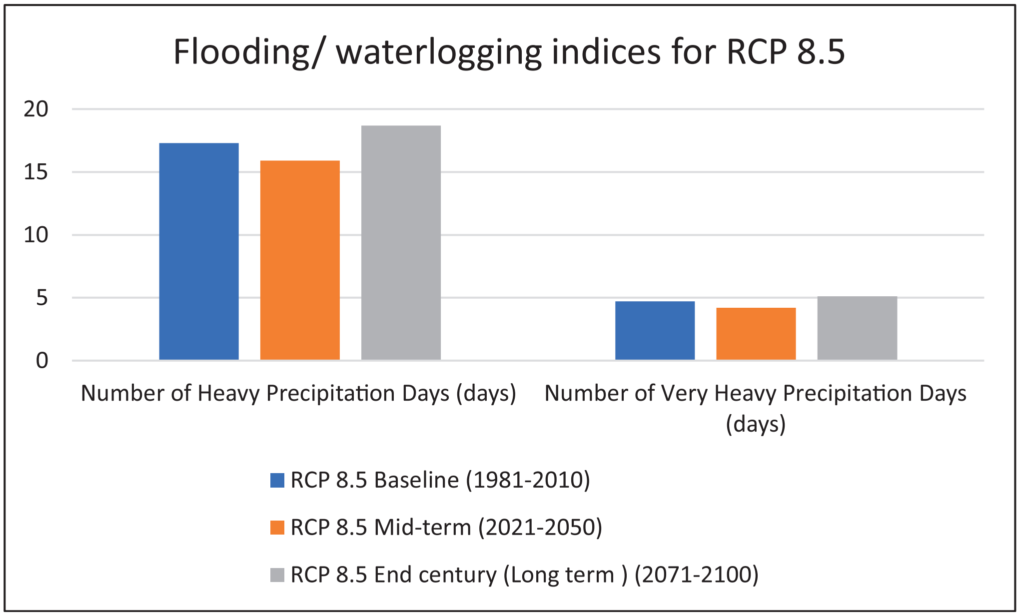

Figure 9: Flooding/ waterlogging duration related climate indices for RCP 8.5

While all the intensity (Figure 6) and duration (Figure 7) related climate indices for RCP 4.5 scenario show slight decrease over mid-term and then slight increase over long-term as compared to the baseline period, they show consistent and slight increase over both the mid-term and long-term periods (Figure 8 and Figure 9).

4.3 Heat Hazard

The scenario of heat hazard in future is contrastingly very different to flooding/ waterlogging. While the relevant intensity indicator considered is Maximum Day time Temperature, for duration indices we consider Warm Spell Duration Indicator (WSDI in days) and Warm days (% days). Specifically, the WSDI is number of days with at least 6 consecutive days with maximum temperature above 90th percentile, calculated for a 5-day window centered on each calendar day for the reference period.

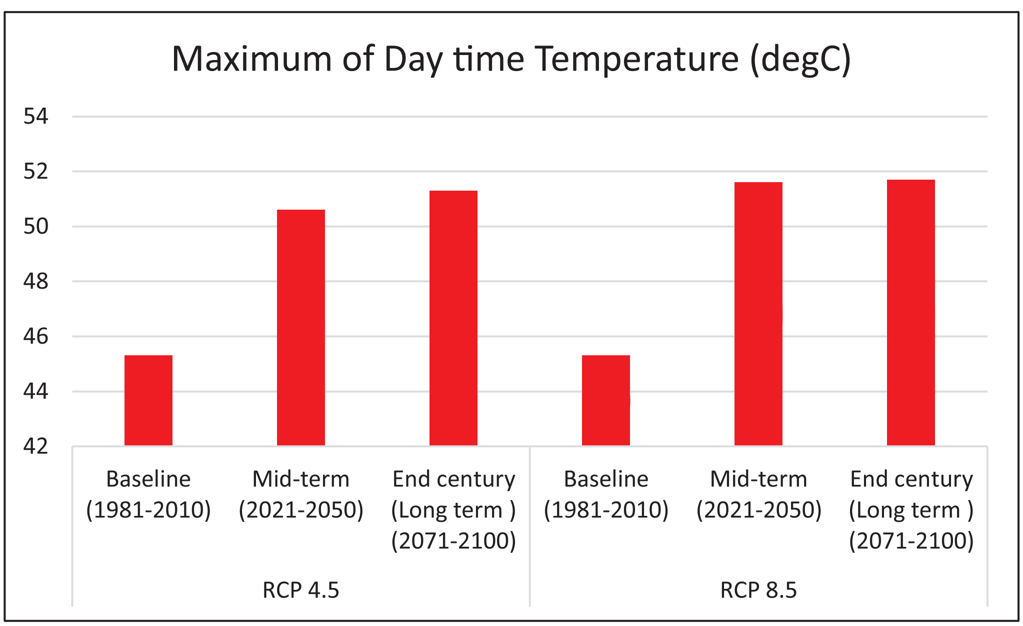

Figure 10: Maximum Day time Temperature in RCP 4.5 and RCP 8.5 scenarios

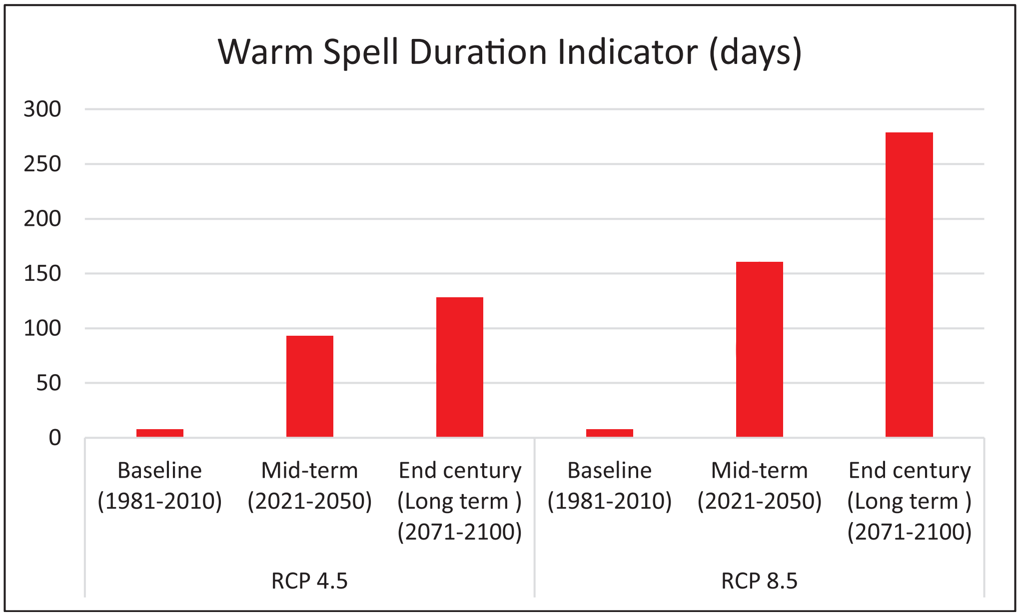

Figure 11: Warm Spell Duration Indicator (days) in RCP 4.5 and RCP 8.5 scenarios

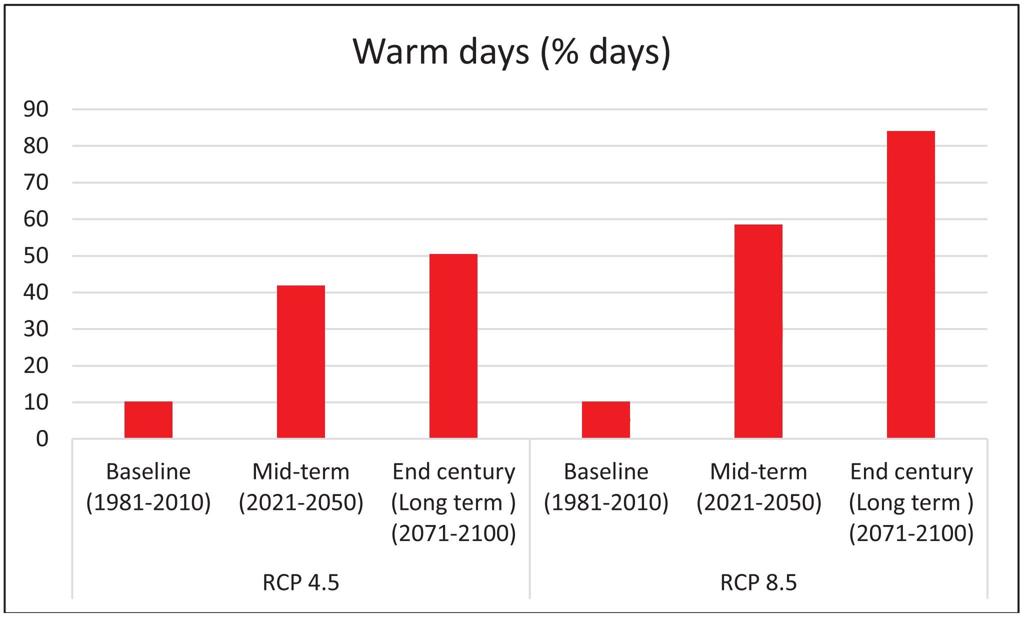

Figure 12: Percentage Warm days in RCP 4.5 and RCP 8.5 scenarios

All the heat related climate indices show a consistently and large-scale increase during both mid- and end-term as compared to the baseline period (Figure 10, Figure 11, and Figure 12).

4.4 Drought/ Water Scarcity

It is evident from the changes in flooding/ waterlogging and heat indices that drought/ water scarcity is likely to exacerbate in future. With similar heavy precipitation days and high heat hazard as compared to the baseline period (1981-2010) there is likely to be increased water demand and decrease in local water supplies (groundwater) in future triggered by climate change.

5. Storm Water Drainage Infrastructure

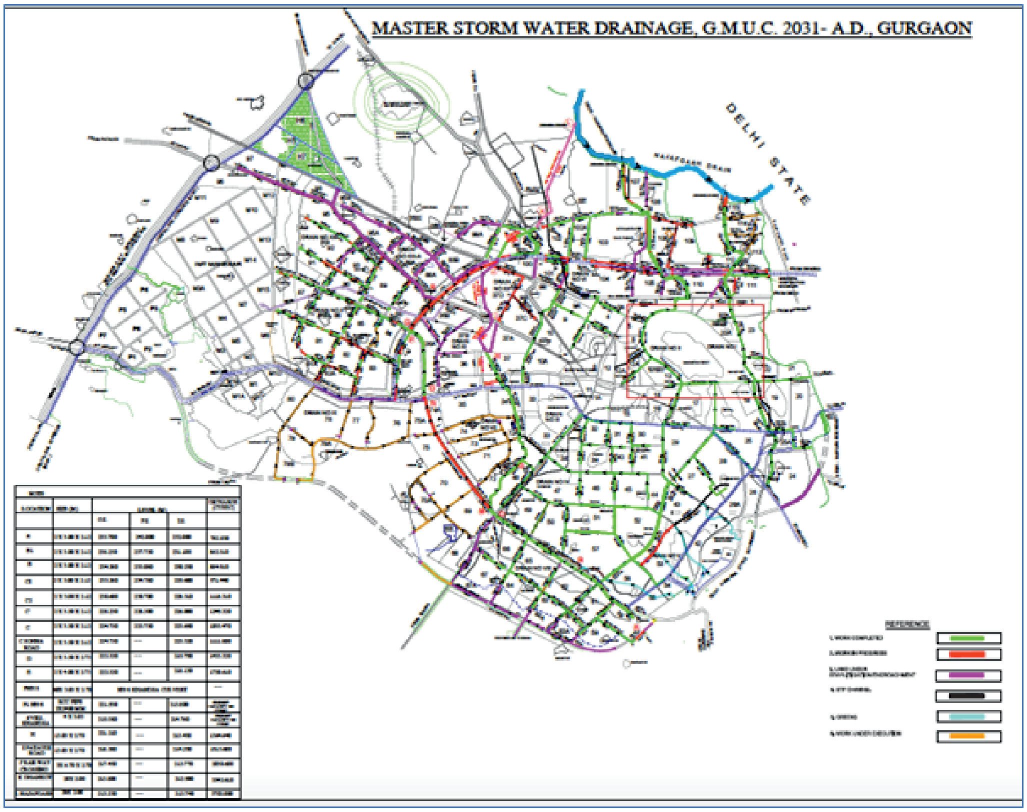

Figure 13: Master Storm Water Drainage Network in GMUC-2031 area

Source: GMDA

5.1 Features

As can been from Figure 13 the storm water system of GMUC-2031 encompass network of interconnected RCC pipes, RCC box drains, and natural drainage network. The Badshapur and Najafgarh drains are the two major natural drains that are connected with man-made and natural drainage systems. Gurugram has the privilege of higher slope gradient from south to north with Najafgarh drain located along the northern boundary of the GMUC-2031 area.

5.2 Issues

- Till around five years ago there were 78 waterlogging points with all being critical points. These have been reduced to around seven a year ago with concerted efforts of GMDA (please see Annexure I—source GMDA, for specific locations that get waterlogged).
- Laying of storm water drainage network in some critical stretches (on tail end) especially in the vicinity/ along the National Highway/ Railway line has been stalled due to stay/ litigation/ encroachment in the old and new town areas.
- The drainage system through primary drains in various sectors are in poor state that causes overwhelming the inlet points of the master storm water drain network even during low intensity storms.
- Waste dumping in drains hinders performance of drainage system. There is need for penalties and awareness campaigns to stop dumping waste in drains.

5.3 Status of Resilience

We assess the resilience of drainage infrastructure based on the indicators/ aspects as mentioned in the foregoing (Chapter/ Section 3). In doing so, we assume the third aspect (policy and institutions) or the enabling environment as available for the features we observe on the ground—without which the features on the first two indicators/ aspects we noted would not have been possible/ implemented by the authority/ local body/ department. The information for assessing resilience is based on meetings with officials of GMDA in 2024:

Table 1: Resilience of Drainage Infrastructure

RESILIENCE INDICATOR/ ASPECT	ILLUSTRATION
EXPOSURE	
Exposure to flooding/ water logging	-
Exposure to heat	• All the infrastructure assets are exposed to high level of heat hazard currently, and likely to be exposed to a much higher level of heat hazard in future due to climate change. (for details refer to Chapter/ Section 5)
SYSTEM RELATED	
Robustness	-
Flexibility/ dynamicity of capacity of system	• The drainage infrastructure when laid fully can provide the additional capacity to address the waterlogging issues faced by Gurugram.
Redundancy	-
Interconnectedness with other systems/ sectors including environment sector (Nature-based Solutions)	• As mentioned in the foregoing waste is being dumped by the city residents in the drainage system. The performance of drainage sector is linked quantum of waste dumped in it. Higher waste dumping can hamper efficient working of drainage system.

	• The capacity of man-made drainage system (usually referred to as grey infrastructure) is very dependent on capacity of natural (pond/ waterbody) retention/ (stream) drainage systems (usually referred to as green infrastructure) to absorb the stormwater runoff. Currently Gurugram (GMDA) has implemented a lot of interventions to revive the natural retention systems in a manner that integrates grey-green infrastructure to reduce instances of flooding/ waterlogging.
ORGANISATIONAL/ AGENT RELATED	
Responsiveness	• Mock drills are conducted regularly during normal times for addressing waterlogging in underpasses. • GMDA monitors the waterlogging levels in various underpasses with assistance of other departments/ authorities. • There is an Incident Command and Control Centre (ICCC) centre put in place. • Emergency response plan exists. • In instances of waterlogging in underpasses mobile dewatering pumps are commissioned. These pumps have diesel gensets for electricity supply. In addition, speed breakers have been constructed in the approach road of underpasses to divert the excess runoffs.
Resourcefulness	• The user charges adequately cover the O & M expenses. The user charges are fixed on a no-profit no-loss basis with the user charges being able to meet O & M costs of water supply, wastewater, recycle/ reuse (treated) wastewater, and drainage system.
Capacity to learn	• GMDA monitors instances of waterlogging closely.

6. Water Supply Infrastructure

6.1 Features

The water supply distribution network in the Gurugram-Manesar Urban Complex (GMUC)-2031 is as shown in Figure 14.

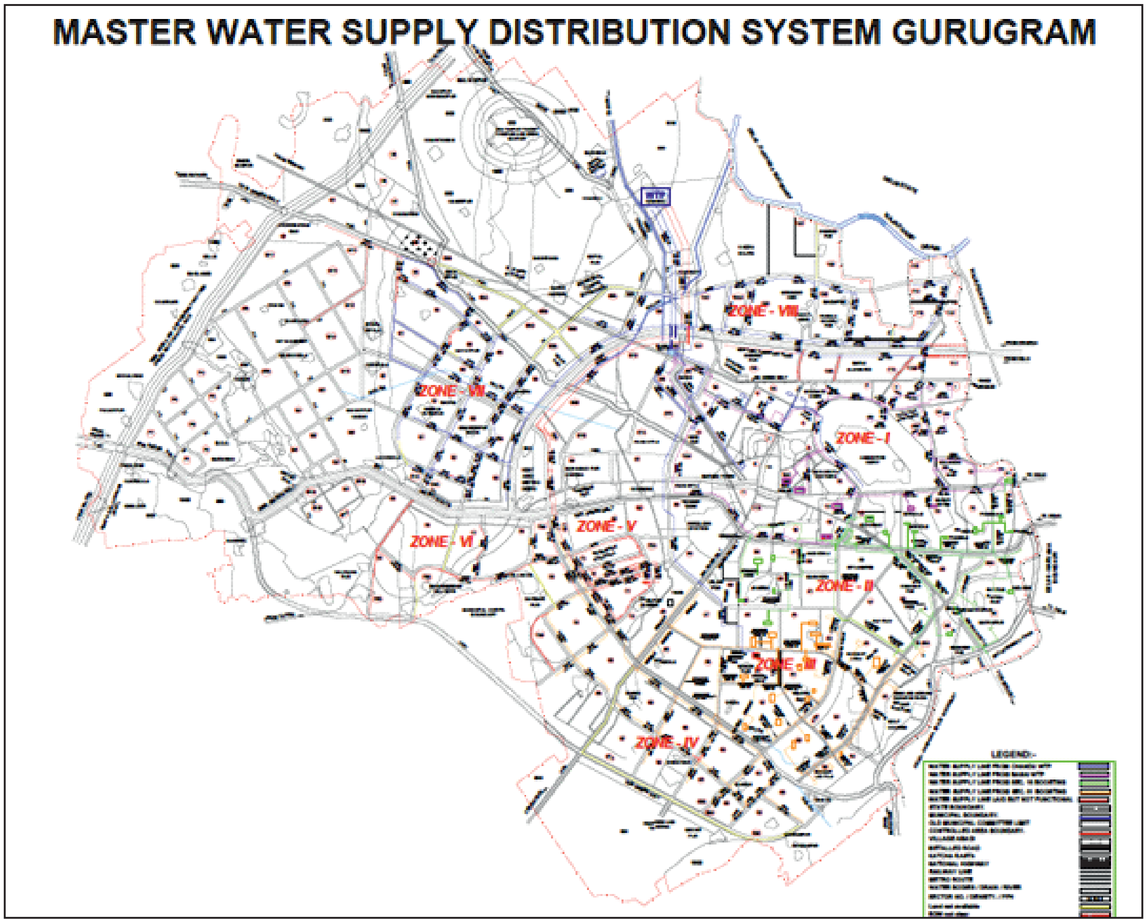

Figure 14: Master Water Supply Network in GMUC-2031 area

Source: GMDA

GMDA manages the Water Treatment Plants, and main lines (master distribution network) and supplies to boosting stations of local authority/ agency (such as MCG and Haryana State Industrial and Infrastructure Development Corporation—HSIIDC, Department of Town and Country Planning—DTCP license holder and approved CLU unit). From the boosting stations, the MCG supplies water to residents/ consumers. MCG is responsible for maintenance of its internal lines in various sectors of Gurugram.

The key features of the Master Water Supply Network include as of 2024 :

- 270 MLD[2] Water Treatment Plant (WTP) in Basai that is fed by Gurugram Water Supply (GWS) canal with capacity of 140 cusecs (which depletes to 110 cusecs during dry seasons). The GWS canal brings Yamuna water from upstream: Three units of 90 MLD capacity each; six numbers of S & S Tanks having approximate 3.5 days storage capacity. The supply from this plant caters to the old town area of Sectors 1-46.
    - o Boosting station at Sector 16.
- 300 MLD of WTP plant at Chandu Budhera that is fed by the National Capital Region (NCR) canal with capacity of 500 cusecs of which Gurugram's share is 280 cusecs: Three units of 100 MLD capacity each. The supply from this plant caters to new and developed area—Sectors 47-115.
    - o Boosting station at Sector 51.
- Master distribution pipeline: DI and MS pipes. The MS pipes are cement lined from inside and have 3 LPE coating on outside.
- Water supply system is divided into eight zones—Zone I to VIII.

6.2 Issues

- The water supply system of Gurugram is marred by issues like other cities in India. The rapid and unplanned urbanization has led to development of Unauthorized Colonies (UACs) that tap water from the distribution system of GMDA during 2024.

6.3 Status of Resilience.

We assess the resilience of water supply infrastructure based on the indicators/ aspects as mentioned in the foregoing (Chapter/ Section 4). In doing so, we assume the third aspect (policy and institutions) or the enabling environment as available for the features we observe on the ground—without which the features on the first two indicators/ aspects we noted would not have been possible/ implemented by the authority/ local body/ department. The information for assessing resilience is based on meetings with officials of GMDA:

Table 2: Resilience of Water Supply Infrastructure

RESILIENCE INDICATOR/ ASPECT	ILLUSTRATION
EXPOSURE	
Exposure to flooding/ water logging	• Minimal to none despite some of the infrastructure assets located in areas that could have been waterlogged.
Exposure to heat	• All the infrastructure assets are exposed to high level of heat hazard currently, and likely to be exposed to a much higher level of heat hazard in future due to climate change. (for details refer to Chapter/ Section 5)

[2] *Million Litres per Day*

SYSTEM RELATED	
Robustness	• The supply is sourced from Gurgaon Water Supply (GWS) and National Capital Region (NCR) canals. The flow in them is regulated and they are maintained by Irrigation and Water Resources Department. So, the raw water inlet is unaffected during monsoon from debris/ vegetation/ tree logs carted from upstream as can be seen in case where water is tapped from rivers. • The Basai WTP is located close to Railway line and could have been exposed to high levels of waterlogging but it is not because of a protection bund. • The MS pipes used in distribution system are lined with cement from inside and triple LPE coating from outside, so can withstand any pH decrease (acidic) of water in the canals even at high temperatures experienced in future due to climate change (see Chapter/ Section 5 for details). • Regular preventive maintenance is taken-up through detection and fixation of leakages in the system. • The water supply system has been upgraded by GMDA as regard placement and number of air valves as per design norms that enhances flow and efficiency. • The Non-Revenue Water (NRW) has been brought down to 24 percent. • The motors/ pumps have capacity to remain functional even at 65oC temperature against the max projected daily temperature due to climate change around 52oC (for details please refer to Chapter/ Section 5 on Climate hazards.
Flexibility/ dynamicity of capacity of system	• The GWS canal flow is 140 cusecs which depletes to around 110 cusecs in summers. However, Gurugram has the option of augmenting water supply from the NCR canal given that it currently draws only 140 cusecs of the 280 cusecs of its share. • At least for now Gurugram has option/ capacity to augment capacity by using existing/ new water sources. Apart from the 570 MLD

	treatment plants, two treatment plants of 100 MLD each are under construction/ tendering with DPR being prepared for the third 100 MLD plant that has been approved.
Redundancy	• DG sets exist at the two WTPs. • There exists a three-day (backup) storage of water to be supplied at the WTPs in the eventuality that the GWS or NCR canal, in extremely low probability, do not have any flows. • In one case, a tail end of bulk water supply location, GMDA Water Supply Master Network system has planned an additional supply main distribution line directly from the treatment plant to enable the tail-end to receive adequate supply.
Interconnectedness with other systems/ sectors including environment sector (Nature-based Solutions)	• Power supply is critical to functioning of WTPs While a dedicated 66 KV power substation is already functional at Chandu Budhera WTP to provide the needed power supply, a 66 KV substation is being installed/ constructed at Basai WTP. Both these substations will ensure that power supply does not get disrupted especially during high heat stress days in future. • Gurugram has severe groundwater degradation that can impact local water supplies. There are efforts to recharge the groundwater by GMDA through filling/ rejuvenating water bodies/ green belts through treated wastewater. Also, the treated wastewater is used for industrial, agriculture and landscaping uses reducing the supply to meet the demand to meet the abovementioned needs. (please refer to Chapter/ Section 7 for more details)
ORGANISATIONAL/ AGENT RELATED	
Responsiveness	• GMDA has an Emergency Response Plan • GMDA has entered into 4 years Public-Private Partnership (PPP) contract (item based competitive contracting) with private agencies for managing O & M (Operations and Management) of WTP and distribution system. • The above PPP (procurement) contract has

	provision for cure period and penalties that provides “carrots and sticks” to the private agencies to maintain/ keep running various motors in the WTP plants despite any challenges faced either due to ageing of asset or changing landscape of hazard due to climate change. • The MCG provides water supply through tankers for un-serviced areas.
Resourcefulness	• The user charges adequately cover the O & M expenses. The user charges are fixed on a no-profit no-loss basis with the user charges being able to meet O & M costs of water supply, wastewater, recycle/ reuse (treated) wastewater, and drainage system. • The PPP contracting enables GMDA to put the onus of effective O & M to private agencies over the four years duration of contracting at a very efficient cost.
Capacity to learn	• GMDA has established SCADA (very partially) for the distribution system to especially monitor the distribution of water supply. GMDA is developing the Data Acquisition system (DA of SCADA) to cover all nodes that will enable the Supervisory Control (SC of SCADA). It has plans to cover the entire system with SCADA under the Smart Cities Mission support. And, the whole system is linked to the ICCCC.

7. Wastewater Infrastructure

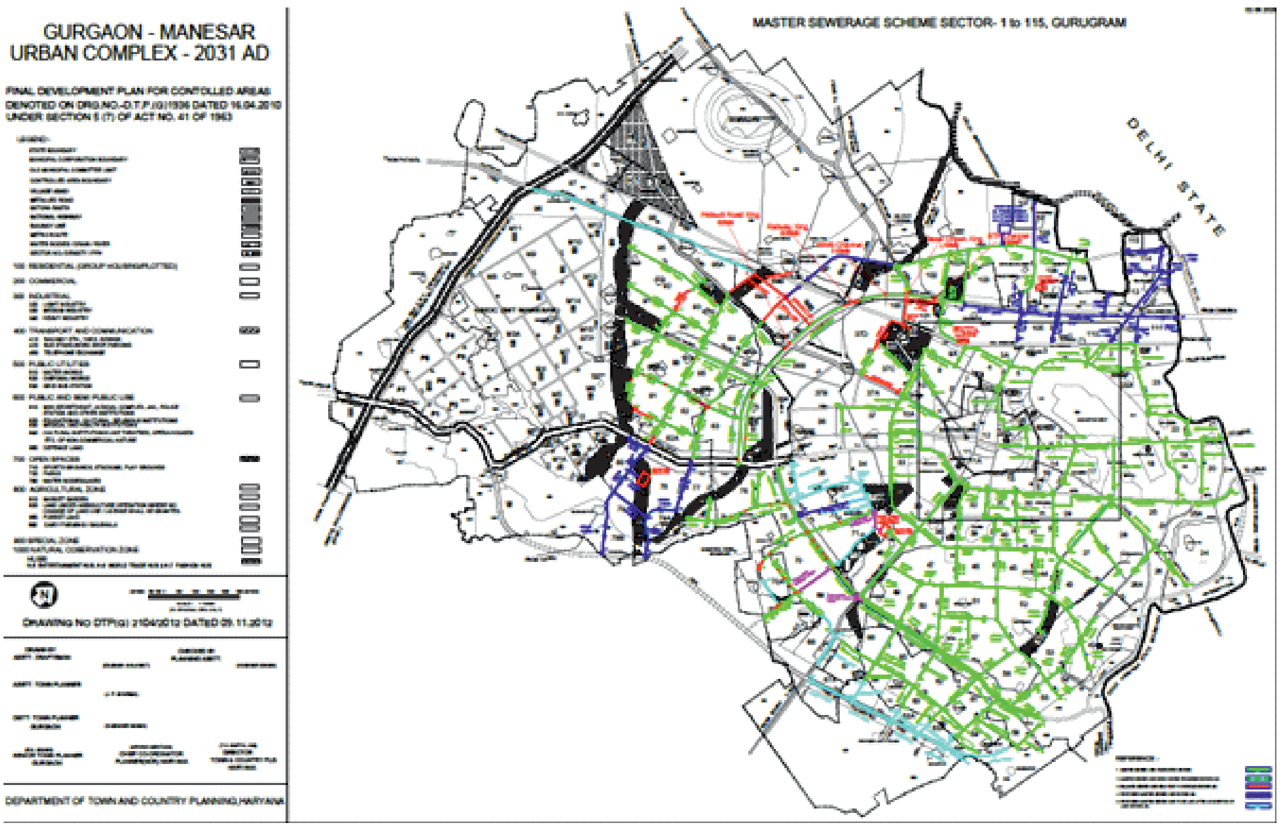

***Figure 15: R**ecycled Water Network*

Source: GMDA

7.1 Features

As can be seen from Figure 15, there are two Sewage Treatment Plant (STP) units at Behrampur and Dhanwapur:

Table 3: Sewage Treatment Plants in Gurugram

STP capacity	Technology	Capacity of various levels of treatment till 2024
BEHRAMPUR		
50 MLD	Activated Sludge Process (ASP)	10 MLD Tertiary on ASP 40 MLD Tertiary on Rapid Sand Gravity Filter
120 MLD	Sequencing Batch Reactor (SBR)	30 MLD Tertiary treated. 90 MLD Secondary treated.
DHANWAPUR		
68 MLD	ASP	68 MLD to Tertiary through Rapid Sand Gravity Filter
100 MLD	ASP	25 MLD Tertiary through Rapid Sand Gravity Filter 75 MLD to Secondary level
50 MLD	SBR	Tertiary treated through Disc filters.

7.2 Issues

- Laying of wastewater network for short stretches on downstream end/ northern part have been stalled due to hurdles in the new town area (Sectors 47-115).
- In the new town area laying of wastewater network for short stretches both in the upstream and downstream end of network has been proposed. Also, some short stretches in the upstream and middle-stretches the wastewater network is waiting for land acquisition to be installed.
- The wastewater system gets overwhelmed during monsoons due to inflow of rainwater.

7.3 Status of Resilience

We assess the resilience of wastewater infrastructure based on the indicators/ aspects as mentioned in the foregoing (Chapter/ Section 4). In doing so, we assume the third aspect (policy and institutions) or the enabling environment as available for the features we observe on the ground—without which the features on the first two indicators/ aspects we noted would not have been possible/ implemented by the authority/ local body/ department. The information for assessing resilience is based on meetings with officials of GMDA during 2024:

Table 4: Resilience of Wastewater Infrastructure

RESILIENCE INDICATOR/ ASPECT	ILLUSTRATION
EXPOSURE	
Exposure to flooding/ water logging	• None, as all the assets are located in areas that are not prone to flooding/ waterlogging.
Exposure to heat	• All the infrastructure assets are exposed to high level of heat hazard currently, and likely to be exposed to a much higher level of heat hazard in future due to climate change. (for details refer to Chapter/ Section 5)
SYSTEM related Robustness Flexibility/ dynamicity of capacity of system	- • Additional 20 MLD treatment plant has been commissioned on trial run at Jehazgarh
Redundancy	• Backup standby pump sets installed at STPs
Interconnectedness with other systems/ sectors including environment sector (Nature-based Solutions)	• Power supply is critical to functioning of Wastewater Treatment Plants (WWTPs). While a dedicated 33 KV power substation is under construction at Behrampur, similar station is being planned at Dhanwapur. Both these substations will ensure that power supply does not get disrupted especially during high heat stress days in future.
	• In addition, DG backup is being installed at all the five WWTP units.
ORGANISATIONAL/ Agents related	
Responsiveness	• All the STP pumps, Generator Sets, Transformers, and Panels are repaired and serviced before every monsoon. This includes also the standby pump sets.
Resourcefulness	• The user charges adequately cover the O & M expenses. The user charges are fixed on a no-profit no-loss basis with the user charges being able to meet O & M costs of water supply, wastewater, recycle/ reuse (treated) wastewater, and drainage system.
Capacity to learn	• SCADA is proposed on the STP Behrampur that will be integrated with the ICCC.

8. Recycled Treated Wastewater

In fact, this section should not be a separate section as it can be integrated with wastewater, drainage, or water supply sections, in the foregoing. An ideal urban system would integrate all the above three networks to leverage greater efficiency and effectiveness to deal with climate change issues that get compounded by inappropriate urban planning/ development. However, for the purpose of clarity, we provide a separate treatment to this section.

Overall 25 percent of the projected total water demand as of 2024 (potable and non-potable uses) that amounts to 330 MLD is proposed to be met from recycled treated wastewater in the GMUC-2031 area. Table 5 and Figure 16 provides the details of the recycle pipeline network[3] :

Table 5: Recycled Treated Wastewater Pipeline Network in GMUC-2031 area

Sectors	Total length of recycle network pipeline as per approved proposals	Length of recycled network pipeline laid out of approved proposals
Sectors 1-57	56.40 kms	55 kms
Sectors 58-80	67.20 kms	20 kms
Sectors 81-115	96.70 kms	35 kms

Source: GMDA

[3] *Presentation by IIT-Roorkee "Infrastructure Development Plan for GMUC-2031 and Gwal Pahari-2021 dated 2023 as shared by Addl CEO, GMDA.*

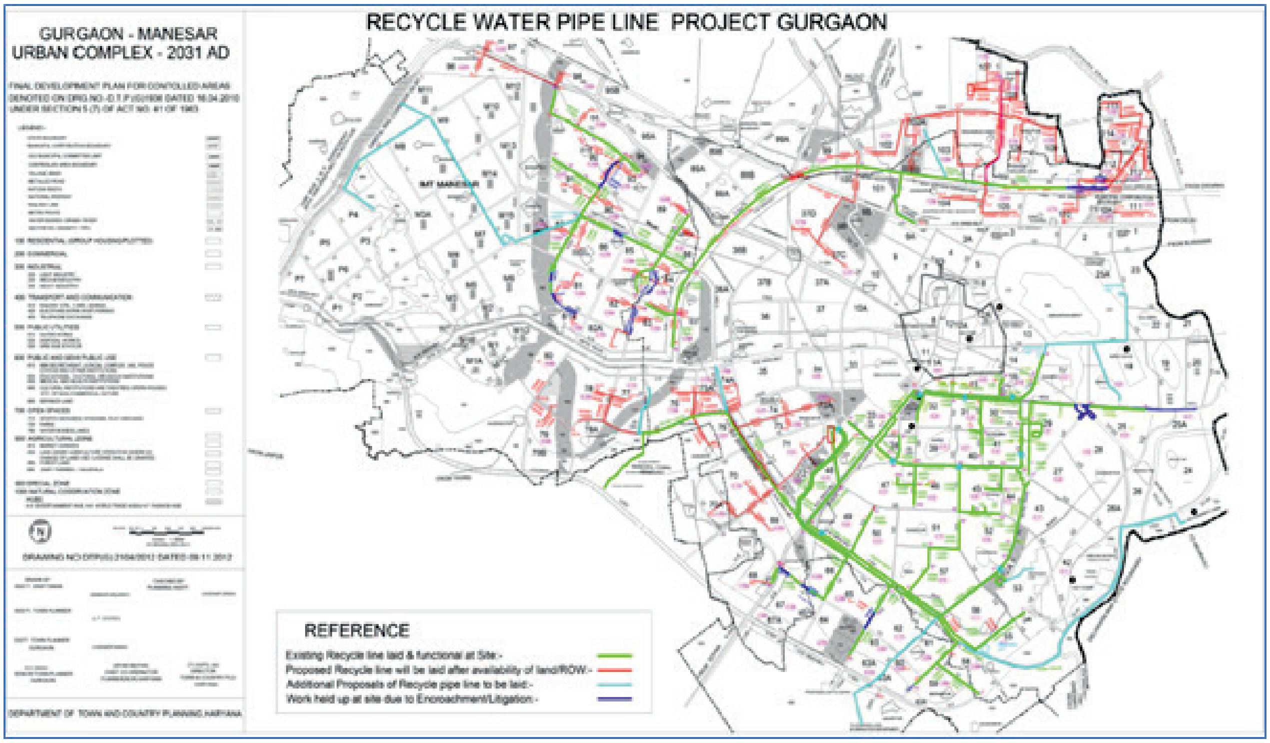

Figure 16: *The Six Critical Waterlogging Points Currently in Gurugram*
Source: GMDA

In addition to the master network there is lateral network for recycled treated wastewater laid by GMDA and MCG.

GMDA plan to lay the remaining master network of recycled pipeline after land/ ROW is available and obtaining clearance from encroachment/ litigation.

It is noteworthy that Gurugram's Policy on use of treated wastewater (2019) aims to achieve 50 percent and 80 percent of treated wastewater reuse by 2025 and 2030, respectively, for non-domestic uses—residential dual water supply system, construction, agriculture, green belts, parks etc.

As against the volume of treated wastewater (Table 3), the existing utilization is around 25 percent of it[4] . GMDA plans to recycle the entire treated water in the GMUC-2031 area for non-potable uses (as detailed in the next section below) in coming few years[5].

8.1 Integration of Nature-based Solutions (NbS) in Gurugram

As mentioned in the foregoing, integration of NbS with the infrastructure in water sectors (drainage, water supply, and wastewater) in a city is one of the key components to build resilience (Section/ Chapter 4); this integration fosters resilience against each of the, specifically, three climate hazards Gurugram faces (Section/ Chapter 5)—flooding/ waterlogging, heat, and drought/ water scarcity:

- It sustains green belts and parks through irrigation support to mitigate the heat stress;
- It helps recharge the already stressed/ degraded groundwater resource with provisioning water supply to water bodies and green belts to mitigate drought/ water scarcity stress by augmenting local (groundwater) supplies; and,

4 *Ibid.*
5 *Water Action Plan Gurugram, GMDA and MCG*

- It helps absorb surge in overland run-off in waterbodies and parks especially during intense rainfall that can cause flooding/ waterlogging.

Interestingly, Gurugram has initiated PPP models for enhancing efficiency and effectiveness of maintenance of green belts[6].

6 *https://timesofindia.indiatimes.com/city/gurgaon/now-upkeep-of-gurugrams-green-belts-gets-corporate-push/articleshow/97673384.cms*

9 Conclusions and Way Forward

9.1 Opportunities and Barriers to Strengthen Resilience in Gurugram

Here we look at ways to further develop resilience of water sector infrastructure in Gurugram across the various resilience parameters/ aspects identified in the foregoing:

i. **Robustness:** An infrastructure system is robust to climate impacts/ risks if it can absorb the hazard/ shock, adequately. There are several aspects that can be considered to develop resilience on this parameter such as: building a robust Operation and Management (O & M) system to maintain health of the infrastructure; deploying hazard prevention infrastructure (bunds/ dykes); strengthening risk mitigation techniques—preventive maintenance, using robust/ higher resistant (to climate risks) materials. As can been seen from various status of resilience tables (Table 1, Table 2, and Table 4) Gurugram demonstrates deploying all the above three techniques in various water infrastructure systems. In addition, Gurugram has/ plans to harness power of nature by integrating NbS in all the three infrastructure systems.

ii. **Flexibility:** This parameter indicates the degree of flexibility/ dynamicity an infrastructure has that enables to be adjusted to changing landscape of climate risks without getting locked-in in a maladapted infrastructure investment given the uncertainties of climate change risks. At core, this parameter refers to ability to expand/ change the infrastructure system at optimal costs to cater to the need to effectively provide service in the changing climate context—such as increasing/ decreasing waterlogging risks. Gurugram is leveraging planned augmentation of infrastructure capacity through the available opportunities in all the three water sectors through additional investments. Simultaneously it is ensuring that it promotes environment conservation through integration of NbS in various infrastructure system—popularly referred to as integration of grey-green infrastructure.

iii. **Redundancy:** Redundancy in elements of a system, for example additional/ redundant pipelines, acts as a backup to keep the system running in the event of failure in one element. While DG sets have been installed or proposed to be installed in the WTPs and WWTPs to keep them functional in the event of power disruption, additional redundancies can be thought of especially for critical/ vulnerable elements of network, be it water supply or wastewater network. For example, the boosting stations of MCG/ GMDA can be interconnected along critical/ vulnerable elements of networks.

iv. **Interconnectedness with other sectors:** Failure in one system, such as power, can impact water supply/ wastewater/ drainage system. Gurugram is/ has plans to become resilient in the three sectors by, for example, having a dedicated 66 KV power substation for its various infrastructure assets/ systems.

v. **Responsiveness:** This feature of resilient system has more to do with organizational capacities. Being responsive during pre-, during-, and post- disaster contexts through set of actions that maintain functionality of system in the event of failure/ disruption. As can be seen from above, inter alia, Gurugram (/GMDA): has Emergency Response Plans; conducts mock drills; has an ICCC; and has put in place innovative maintenance regimes through forging PPPs. These features demonstrate the agility of organisation(s) to deal with disasters. However, there is scope for strengthening PPP procurement through DBFOMT (Design, Build, Finance, Operate, Maintain and Transfer) system that will enable leveraging technical know-how of private sector for even designing and building the infrastructure, as well as through optimal sharing of risks across the public and private entities.

vi. **Resourcefulness:** This feature of resilient infrastructure is another organizational feature. It refers to capacities of an organisation to respond during pre-, during-, and post-disaster contexts through skilled personnel and financial resources. The GMDA, for example as evident from the foregoing, covers all its expenditures in the three water infrastructure sectors (drainage, water supply and wastewater) adequately through fees/ user charges. However, to build the resourcefulness further, exposure visits to key staff from GMDA and MCG could be organized.

vii. **Capacity to learn:** Given that resilience of an infrastructure system, at core, refers to maintaining functionality with minimal disruption in its services especially in, during and post disasters contexts, it becomes imperative to develop systems to monitor and track the performance of infrastructure systems, continually. In this context, there is need to expand installation and use of ICT-enabled monitoring systems through smart sensors in various infrastructure systems. The SCADA system needs to be expanded to cover monitoring of performance of all assets across the water supply and wastewater infrastructure systems. In addition, smart sensors can be used to monitor extent of waterlogging, urban heat island effect, and quality of water in canals/ nallahs/ streams/ rivers that are used to source/ discharge water/ wastewater. In addition, exposure visits for officials needs to be organized especially for the management, operational and field staff levels.

viii. **Barriers:** We note a couple of barriers in promoting resilient infrastructure in the case of Gurugram. The issue of land acquisition and litigation related to making land available for laying of infrastructure needs to be addressed. A way to deal it with it, for example, is thinking about multistoried WTPs/ WWTP that could make efficient use of land parcel. However, other land availability related barriers will need to be resolved. In fact even for promoting PPP effectively (/DBFOMT models) land can become an hurdle.

9.2 Lessons from Gurugram case study: Scope of Replication in India's Policy Environment

The Gurugram case study provides insights into resilience issues on infrastructure systems in drainage, water supply, and wastewater sectors. In the context of building resilience of water infrastructure, the Government of India (GoI) has put in place several policies, strategies, and plans in the arena of urban and infrastructure development that support various international frameworks/ strategies/ agreements such as Paris Agreement, Sendai Framework for Disaster Risk Reduction (SFDRR), and Sustainable Development Goals (SDGs). These policies/ strategies/ plans provide an enabling environment to replicate/ adapt lessons from the Gurugram case study:

- The Smart Cities mission aims to provide the needed core infrastructure and, a clean and sustainable environment for citizens to improve quality of life through "smart" solutions.
- The Atal Mission for Urban Rejuvenation and Transformation (AMRUT) primarily focuses on water supply, wastewater, and rejuvenation of water bodies and green spaces that enhance sustainability

of water supply, clean and sustainable environment, that would lead to improving quality of life for citizens.

- The Swachh Bharat Mission (Urban) 2.0 emphasises on improving access and sustained use of sanitation, waste management, and promote a circular economy.

- Climate Smart Cities Assessment Framework (CSCAF) 2.0 that provides clear guidance on areas for improvement for a city through a set of carefully and well-designed indicators across themes that include: Energy and Green Buildings; Urban Planning, Green Cover and Biodiversity; Water Management; Waste Management; and Mobility and Air Quality. The framework guides cities to become climate-smart by efforts aimed at climate mitigation, resilience, clean and sustainable environment, and sustainability.

- The National Infrastructure Pipeline for providing quality infrastructure in all the sectors. It emphasizes on Public-Private Partnerships (PPPs) for sustainable development/ delivery of infrastructure/ services.

- The recently launched (in December 2023) India Infrastructure Report focuses on compact and Transit-Oriented Development (TOD), financing, Public-Private Partnerships (PPPs), service delivery, and integration of infrastructure development with urban re-development.

- In the Disaster Risk Reduction area, National Disaster Management Plan (2019), National Policy on Disaster Management (NPDM) 2009, and the (International) Coalition for Disaster Resilient Infrastructure (CDRI), apart from several guidelines/ codes that support disaster resilience.

In addition to above and on the targeted financing systems apart from insurance, there is special emphasis on Disaster Management in the Fifteenth Finance Commission Report. While insurance in agriculture sector has been supporting farmers to cope with financial loss and damages due to climatic disasters, there is a need to develop financial resilience models including insurance and PPP models in infrastructure sectors--especially in the sectors where the PPP models are underdeveloped/ absent, through sharing risks optimally between the public and private entities.

The Gurugram case study presents insights into building resilient infrastructure in the urban water sectors—drainage, water supply and wastewater, with clean and sustainable environment as a cross-cutting issue in the wake of climate change. While we observe varying levels of climate hazards and exposure to flooding/ waterlogging, heat, and water scarcity in Gurugram that are emerging as typical urban phenomena in Indian cities, the lessons can be adapted to other cities in India and globally.

9.3 Way forward

- Gurugram case has been used only as a demonstration case though it may not be impacted severely due to all climatic disasters; floods, waterlogging, heat, water scarcity, cyclones, storm surge and sea level rise, that various cities/ urban areas face in India. Further work will be required to understand the ways to build resilience to the remaining climate hazards.

- The case study presents status of resilience of the three urban water infrastructure sectors—drainage, water supply and wastewater through illustration in form of text against each of the seven features of resilient infrastructure. Further work will be required to develop an objective scoring and ranking framework that can foster comparison across cities/ urban areas in India/ globally.

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11. Annexure

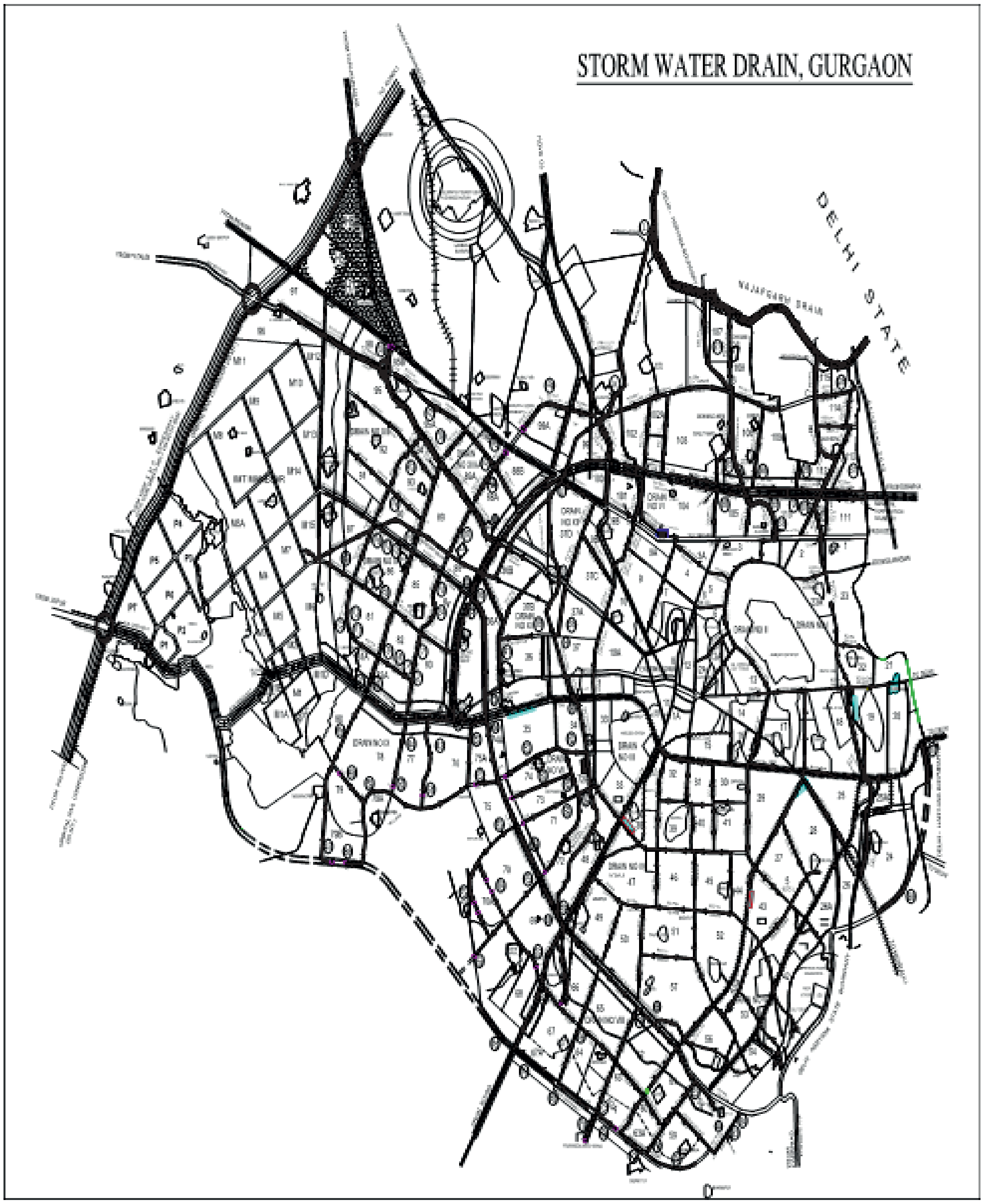

Figure 16: The Six Critical Waterlogging Points Currently in Gurugram
Source: GMDA

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