Mahindra - TERI
Centre of Excellence for
Sustainable Habitats

WATER SUSTAINABILITY ASSESSMENT OF GURUGRAM CITY

Mahindra-TERI Centre of Excellence for Sustainable Habitats

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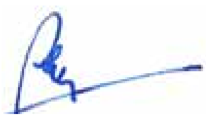
MESSAGE

The Mahindra-TERI Centre of Excellence (MTCoE) is a joint research initiative of Mahindra Lifespace Developers Limited (MLDL) and The Energy and Resources Institute (TERI). MTCoE has been established to develop science-based solutions for India's future built environment with emphasis on enhanced occupant comfort, resource efficiency and sustainable construction. The CoE aims to create a repository of innovative materials and technologies and provide an array of strategies for achieving sustainable habitats.

Overutilization of water resources and contamination of river systems along with lack of water treatment facilities has aggravated the already existing water crisis in India. Climate change impact has led to alteration in rainfall patterns across the country, thus creating an imbalance between water demand and supply. The future of India consists of rapid urbanization and an increasing population which will excessively multiply the water demand across sectors energy, industry, domestic, irrigation etc. Hence, it is crucial to spread awareness and adopt sustainable practices to replenish and conserve water.

The Mahindra-TERI CoE is pleased to present a report on "Water Sustainability Assessment of Gurugram' as a part of our 3-report series for the cities of Chennai, Gurugram and Pune. This report has been prepared to help building professionals, researchers, real estate developers, policy makers, administrative agencies and end users to generate awareness on the aspects of water sustainability and provide potential solutions to overcome the challenges.

I gratefully acknowledge the support of all those associated with the development of this report and look forward to their continued guidance for its enhancement.



Sanjay Seth
Senior Director
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TERI

PREFACE

Literature describes urban areas as open systems with porous boundaries and highlights the importance of a system's perspective to understand ecological sustainability of human settlements. Similarly, a socio-ecological framework helps to understand the nexus between social equity, environmental sustainability, and economic efficiency. India is urbanizing rapidly with characteristic inequality and conflicts across the social, economic, and locational axes. Following the global pattern, Indian cities use social and natural resources of the rural hinterland and their own resources for survival and growth. And, in the process, they generate a large amount of waste. Besides, water is the most important 'resource flow' in an urban area, driven by a complex set of intersecting socio-economic, political, infrastructural, hydrological, and other factors. These drivers vary a great deal within a city and have a significant impact on the water flow and its management. Thus, to address the issue of water flow and its management in a city, both micro- and macro-level studies are required.

With this background, water sustainability assessments of Chennai, Gurugram, and Pune were conducted to enhance the water flow and its management in the cities. The aim was to undertake an assessment of potential risks associated with the water sources and demand and supply at the city level to provide recommendations to mitigate the same. This report shows the analysis of Gurugram city.

Approach

A number of studies have been conducted with respect to urban water management across the country. Most of these studies focus on certain aspects of water such as storm water management, wastewater treatment systems, water supply systems, etc. But in these studies, planning for water is oversimplified by governments as the assessments were conducted in isolated entities. Therefore, drifting from the age-old approach, this study takes up 'One Water' approach, which basically defies the segregation of water in various categories such as storm water, wastewater, etc. Secondly, it follows a metabolism approach. It is an emerging field and, since 2013, there have been a number of international studies on this. For the first time, the metabolism approach was adopted for this kind of study. Also, the past and existing data on water management were studied, based on which potential risks were computed for 2025. This was followed by recommendations for mitigating these risks.

Outcome

The metabolism approach provides disaggregated understanding about the areas where water could be secured without creating negative hydrological footprint to the surrounding regions. Thus, it was envisaged that the output of this approach would inform about (a) the new sources of water (b) amount of wasted water, which could help in addressing the issue of inefficiency in per capita water storage and availability, (c) seasonal problems such as flooding and inefficient storm water management and required balance for an equitable water distribution over time, (d) water-related infrastructure and, (e) water recycling potential.

Audience

As the world faces the challenges of water scarcity, there is a growing realization that citizens have to contribute in the efforts towards achieving water sustainability. With this background, it is expected that this report would not only help urban planners, policymakers, and administrative agencies but also every stakeholder in the water sector including citizens to understand the present and the future challenges and the means by which these challenges could be addressed.

Challenges

It has to be mentioned here that data gathering for this report was a challenging exercise. The data elements were fed into the model to calculate the output metrics/indicators by extrapolations from the available historical data. In this context, the researchers succeeded in tiding over the obstacles to access data.

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ABBREVIATIONS

AMC	–	Annual Maintenance Contract
CGWB	–	Central Ground Water Board
CPCB	–	Central Pollution Control Board
CPHEEO	–	Central Public Health and Environmental Engineering Organisation
CWC	–	Central Water Commission
GDP	–	Gross Domestic Product
GHG	–	Greenhouse Gas
GMDA	–	Gurugram Metropolitan Development Authority
GSDA	–	Groundwater Survey and Development Agency
HSIIDC	–	Haryana State Industrial and Infrastructure Development Corporation
HSPC	–	Haryana State Pollution Control Board
HSVP	–	Haryana Shahari Vikas Pradhikaran
HUDA	–	Haryana Urban Development Authority
HWRA	–	Haryana Water Resources (Conservation, Regulation and Management) Authority
ICT	–	Information and Communications Technology
IT	–	Information Technology
IUWM	–	Integrated Urban Water Management
KPI	–	Key Performance Indicator
lpcd	–	Litres per Capita per Day
MCG	–	Municipal Corporation of Gurugram
MCM	–	Million Cubic Meters
MLD	–	Million Litres per Day
MoEFCC	–	Ministry of Environment, Forest and Climate Change
MoWR	–	Ministry of Water Resources
RWA	–	Resident Welfare Association
RWH	–	Rainwater Harvesting
SPCB	–	State Pollution Control Board
STP	–	Sewage Treatment Plant
ULB	–	Urban Local Body
WTP	–	Water Treatment Plant

EXECUTIVE SUMMARY

The urban population in India was estimated to be 34.5% in 2019, as per the World Bank.[1] There has been an increase in urbanization by almost 4% in the last decade due to more number of people migrating from rural areas to cities in search of better job opportunities. It is estimated that at this rate by 2030 and further in 2050, population in Indian cities will go beyond 40% and 50%, respectively.[2]

With the growing population, expanding economies, urbanization, and changing lifestyles there has been a significant impact on our economic, social, and environmental well-being due to increasing pressure on already strained water resources. The rapid population growth along with rising consumption levels and pollution contributes in spiralling water insecurities in urban India. The depleting water resources together with rising water demand limits the possibilities to augment water supply in future. Rising effects of climate change may further aggravate the situation by generating higher magnitude and frequency of extreme weather events and by altering precipitation volume and pattern. This shall have adverse effects on the available sources of freshwater supply.

Water stress has specifically magnified for metropolitan cities including Bengaluru, Chennai, Delhi, Kolkata, Pune, etc., with depleting groundwater levels, widening of water demand and supply gap, and rising pollution in waterbodies, to name a few. Thus, to combat these issues, there is a need to enhance the sustainable water flow management in cities. In this context, Mahindra-TERI Centre of Excellence (MTCoE) carried out a study to assess water sustainability in Chennai, Gurugram, and Pune. This report presents the water sustainability assessment of Gurugram city.

To achieve the aforementioned objective, a desk-based research was carried out by exploring different types of literature. A number of official reports and documents, Acts, etc., by the state government (Haryana), urban local bodies, municipalities, and other concerned institutions including research by private organizations were studied.

1 Details available at https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?end=2019&locations=IN&start=1960, last accessed on September 13, 2021

2 Details available at https://www.thestatesman.com/business/urban-population-india-may-go-beyond-50-2050-mohua-secretary-1502757868.html, last accessed on September 13, 2021

Various parameters were analysed including city growth, land use, demographics, social and economic character, water policies and institutional set-up at central, state, and city levels, and water sources and the related infrastructure. The parameters were essential to find avenues for water sustainability, quantify anthropogenic and natural flows into and out of a town, and develop a metaphorical framework of water metabolism of an area to analyse water flows within it and to select dominant indicators that impact urban hydrology.

The study of these parameters led to the identification of potential risks associated with urban hydrology and water management in Gurugram, especially focusing on the aspects related to stakeholder engagement and flood risk. To overcome these threats, a list of recommendations was prepared. The study also goes a step further to identify the reasons for weak implementation of the proposed recommendations and suggests measures to strengthen them.

1
INTRODUCTION

This report presents a study of metabolic flow of water within urban system of Gurugram city for water planning and illustrates the nexus between various urban goals. The central objectives of the study are (a) to account for inflows and outflows of water (including wastewater) and to construct a well-defined water mass balance, (b) to illustrate how the metabolic flow of water is shaped by economic, policy, social, and other variables and how it alters the background water hydrology of the city, and (c) to demonstrate the spatial diversity and variation among the drivers of water flow in the city.

Chapter II: City Growth and Environment discusses about geographic characteristics, city growth and land use, demographics, and social and economic character of the city. These are important drivers for urbanization and were used to analyse the urbanization rate and its impact on water systems of the city.

Chapter III: Water Governance and Administration includes water policies and institutional set-up at central, state, and city levels. Water use and its management is influenced governance over water, that is, who gets what water, when and how and who has the right to water and related services, and their benefits. Water governance determines the equity and efficiency in water resources, services allocation and distribution, and balances water use between socio-economic activities and ecosystems. This chapter also presents the identified gaps pertaining to water governance in the city.

Chapter IV: Water Source Management and Infrastructure discusses about various water sources available for the city and their related infrastructure including water treatment plants, sewage treatment plants, water meters, etc., and also discusses water quality of waterways carrying wastewater. The study helps in the analysis of existing water sources in CMA and deficiencies in the existing water-related infrastructure.

Note: Water quality analysis of rivers was not conducted in detail as it is out of the scope of this study and would require a separate assessment. Moreover, the objective of the study was to focus on the quantity aspect with a brief touch upon on quality.

Chapter V: Potential Risks in Water Management highlights the possible threats to the urban water cycle and water demand and supply of the city. This chapter is significant as it identifies the issues interconnected with each other on the projections for 2025, starting from water availability, its allocation, to capacities of water and sewage treatment plants.

Chapter VI: Recommendations on Sustainable Water Management lays down a list of suggestions to combat the identified risks and improve the existing water management. The chapter lists recommendations through an upgraded urban water cycle for the city and covers all the topics/drivers discussed in the previous chapters that impact urban water management.

System Definitions

The system boundary is defined as Gurugram city (municipal area), which includes both urban and some rural parts of the city. To analyse water hydrology, water mass balance, and water demand of the city, the study is confined to urban areas due to inaccessibility of data for rural areas.

2
CITY GROWTH AND ENVIRONMENT

2.1 Geographic Characteristics

The geographic characteristics section consists of parameters such as location, physiography and landforms, climate, forest, and biodiversity.

2.1.1 Location

Gurugram is located in the Indian State of Haryana having latitude and longitude coordinates as 28.3606° N and 76.8721° E, respectively. It is located 30 kms south of the New Delhi, the National Capital of India. The district is one of Delhi's major satellite cities and is part of the National Capital Region. Gurugram is the industrial and financial centre of Haryana.

The district is located in the south-eastern bulge of the State and shares a common

border with Delhi in the north. Jhajjar district lies in its north-west direction, Rewari district in its south west, Mewat district in its south, Palwal district in its south east, and Faridabad district shares its eastern boundary. Gurugram contains many small hill ranges which are part of the Aravali and Mangar Bani ranges.

Gurugram district is one of the 22 districts located in Haryana, which covers an area of 1257 km^2 including 976 km^2 of rural area and 281 km^2 of urban area.

The district is divided into four sub-divisions – Gurugram (West), Gurugram (South), Badshahpur, and Pataudi. They are further divided into five revenue tehsils, namely Gurugram, Sohna, Pataudi, Farrukh Nagar, and Manesar and four sub-tehsils, namely Wazirabad, Badshahpur, Kadipur, and Harsaru. It also comprises four rural development blocks – Gurugram, Sohna, Farrukhnagar, and Pataudi.

Gurugram tehsil covers an area of 333 km2 out of which 131.8 km^2 is rural area and 201.3 km^2 is urban area.[3] Gurugram city, that is, municipal area covers an area of 250 km^2.[4] For the purpose of this study, Gurugram city (municipal area) of Gurugram tehsil in Gurugram district was considered.

[3] Details available at https://villageinfo.in/haryana/gurgaon/gurgaon.html, last accessed on October 14, 2021

[4] Details available at https://en.wikipedia.org/wiki/Gurgaon#cite_note-Gurgaon_Info-38, last accessed on October 14, 2021

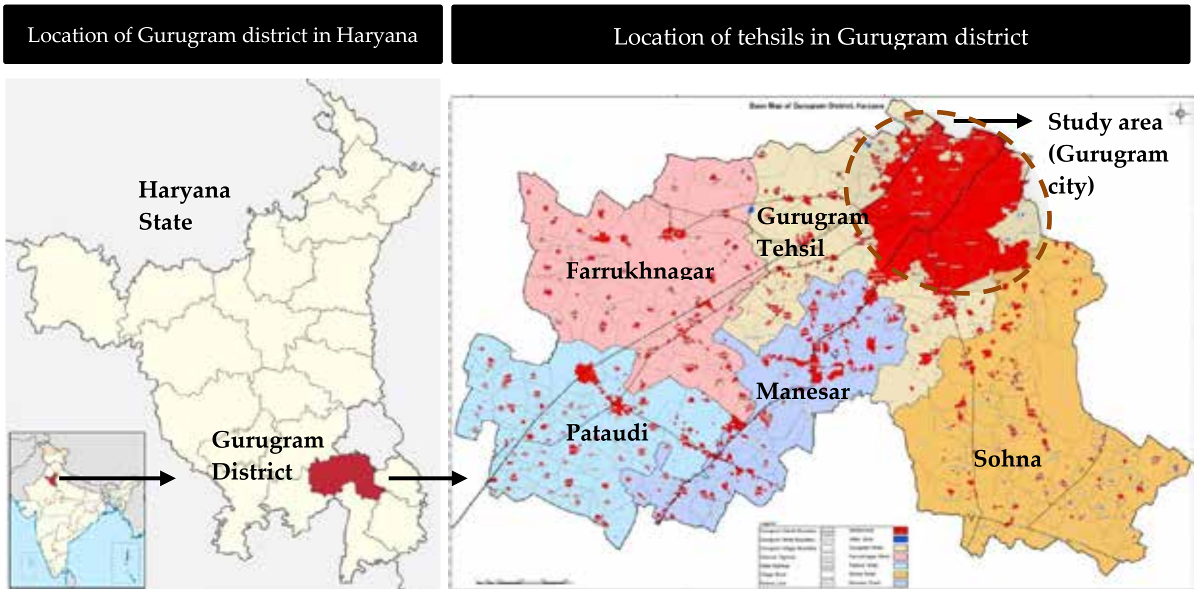


Figure 1 : Geographical location of Gurugram city in Gurugram district[5]

2.1.2 Physiography and landform

Gurugram district comprises hills on the one hand and depressions on the other, forming irregular and diverse nature of topography. Two ridges: Delhi ridge and Firojpur Jhirka-Delhi ridge form the eastern and the western boundaries, respectively, of the district. These hills are northern extension of the Aravalli hills. These rocks are one of the oldest mountain systems in the country. The hillocks are dissected by rainfed torrents. The north-western part of the district is covered with sand dunes lying in the westerly direction due to south-western winds. The extension of the Aravalli hills and the presence of sand dunes collectively form a diverse physiography of the district.

Physiographically, the district can be divided into two sub-parts – Gurugram plain and Sohna undulating plain with Aravalli offshoots. The Gurugram plain spreads over northern and north-western parts of Gurugram tehsil and whole of Pataudi tehsil. The region as a whole is a plain area. On the other hand, Sohna undulating plain with Aravalli offshoots extends over some parts of Sohna and Gurugram tehsils. The entire region is covered with rocky surfaces of Aravalli offshoots. Only some patches of the land are under cultivation owing to rocky areas, poor soil cover, and roughness of surface. Due to offshoots of Aravalli ranges, the region is undulating.

There is no perennial river in the district. Seasonal streams are only a few, smaller in size, and are inland. The drainage of the district is typical of the arid and semi-arid areas. Because of topographic diversity, streams in the region do no flow in any uniform direction. Important depressions of the district are Khalilpur Lake, Chandani Lake, Sangel – Ujhina Lake, Kotla Dhar Lake, and Najafgarh Lake. Sahibi and Indrani are two important seasonal streams of the district.

The Sahibi Nadi, which originates in the Sewar hills of Jaipur, makes its presence in Gurugram tehsil before losing itself in the topographic depression of Jhajjar district after flowing in northern direction through Rajasthan and Rewari district. The Indori Nadi originates from Aravalli hills in Rajasthan near village Indauri. After passing through many villages of the district it joins Sahibi Nadi near Pataudi.

[5] Details available at https://gurugram.gov.in/about-district/map-of-district/, last accessed on October 14, 2021

Apart from the aforementioned streams, Badshahpur, Mehndwari, Kasan, Manesar and Landoha nallahs play havoc during heavy rains. The district has light soils as sandy loam, medium soil, particularly light loam (Seoti) and loam (Bhangar and Nardak), coarse loam (Dahar and choeknote), and rocky surfaces. The soils in Gurugram sub-division range between sandy and sandy loam.

Various streams flowing across the Gurugram district and its watershed region are shown in Figure 2.

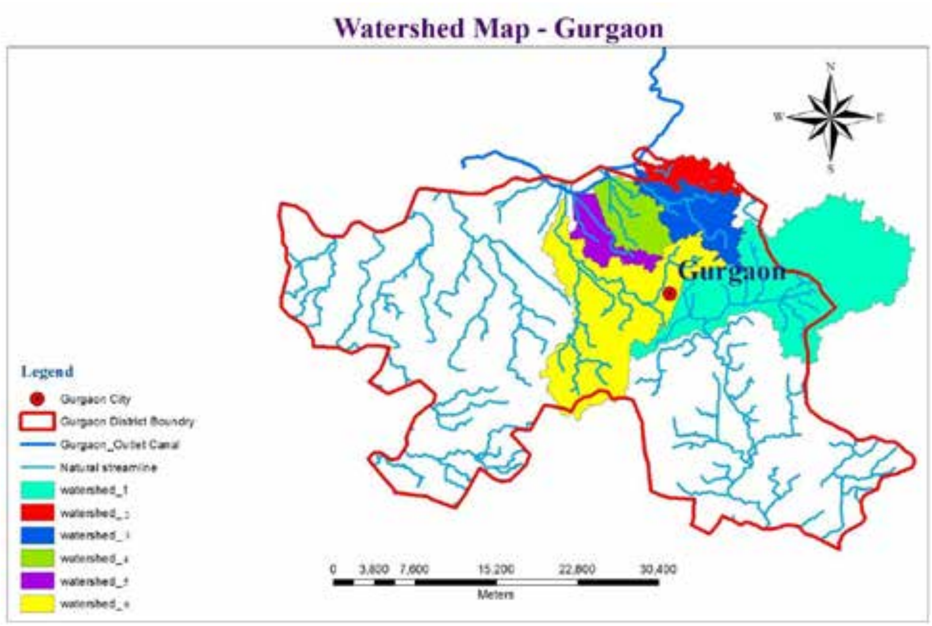


Figure 2 : Hydrological map of Gurugram district.[6]

2.1.3 Climate

The climate of the district is characterized by dry and extreme temperature and scanty rainfall. The district has a sub-tropical continental monsoon climate where seasonal rhythm, hot summer, cool winter, unreliable rainfall, and great variation in temperature are found. During the greater part of the year, scorching dust-laden winds that blow during hot season render the weather very tiring. Dense fog sometimes occurs during winter months.

Four seasons are observed in a year in this region, which are as follows: (i) Summer – from mid-March to end of June, (ii) followed by a rainy season from July to mid-September, (iii) after which a transition period of two months follows, and (iv) then the cold season starts from mid-November to mid-March. January is the coldest month when mean daily maximum temperature is about 21.4°C and mean daily minimum temperature remains at 5.4°C. On the other hand, May and June are the hottest months. The mean daily maximum temperature in May is around 40.2°C. Occasionally, the day temperature may exceed to 45°C in the region. The highest maximum temperature recorded at Gurugram was 49°C on May 10, 1966 and the lowest minimum temperature was 0.4° C on December 5, 1966.[7]

The district receives 72% of the normal annual rainfall during June–September, wherein July and September are the rainiest months. The average annual rainfall in Gurugram district is 505.4 mm.[8]

6 T E R I. 2015. Water Energy Food Nexus in Urban Ecosystem New Delhi: The Energy and Resources Institute.
7 District Census Handbook Gurgaon 2011
8 District Census Handbook Gurgaon 2011

2.14 Forest and biodiversity

The district covers Gurugram, Sohna, and Pataudi forest ranges. The area under forests is classified according to ownership, viz. Private and State. Forests owned by corporate bodies and private individuals are included under private forests. The State forests are categorized as reserved, protected, and unclassed.

These natural forests contain species including Khairi (*Acacia Senegal*), Dhouk (*Anogeissus pendula Edgew.*), Dhak (*Butea monosperma*), Papri (*Holoptelea integrifolia planch*), Rounj (*Acacia leucophloea*) Inderjo (*Wrightia tinctoria*), Chamror (*Ehretia laevis*), phalsa (*Grewia populifolia*), etc. Shisham and Neem are found in foothills and plains in the region. Kikar grows in the plains. Shisham, Neem, and Kikar are valuable as timber, firewoods, and for making agricultural implements. Plantation of eucalyptus trees in the plains, along roads, canals, and boundaries of agricultural fields are the latest phenomenon in the region's forestry development. Kit is used as firewood and pulp wood for paper industry.

Furthermore, the district is inhabited by various groups of mammals. Primates are represented by rhesus macaque or monkey and langur in the region. Tigers and leopards once abundant in the district are now almost extinct. Panthers and wolves have also seen the same fate. The carnivorous animals found in forested areas of the district include jungle cats (banbilla), foxes, jackals, mongoose (neola), and hare. Rats and mice are very common. A large number of migratory water birds visit the district during winter. Various types of ducks and geese such as Eastern greylag goose, Bar headed goose, Brahminy duck, Common teal, Mallard, Gadwall, Wigeon, Blue winged teal, Shoveler, Common pochard, Ferruginous duck, Tufted duck, etc., can be seen at tanks and lakes in the district during winter. Colourful birds add beauty to the varied wild life. Most common colourful birds are Flamingo, Large Indian Parakeet, Rose-ringed Parakeet, Kingfishers Woodpecker, Bulbul, etc. The national bird of India, the common peafowl, is quite common and is seen in orchards, fields, and gardens in the region.

2.2 Urban Growth and Land Use

This section discusses about spatial growth pattern, land utilization, and land cover of the region.

2.2.1 Spatial growth pattern

The existence of Gurugram dates back to the mythological period of Mahabharata. From ancient to medieval to modern history period, the region (Gurugram and Manesar tehsils) had witnessed immense changes and transformation. Gurugram became prominent only around 1970s, when one of the leading automobile manufacturing companies, that is, Maruti Suzuki India Limited established a manufacturing plant in Manesar tehsil.9 Since then Gurugram has been constantly expanding vertically as well as horizontally. It has grown organically due to economic imperatives and incentives.[10] However, considering the chaos created yearly due to floods during monsoon in the city, it is also a warning of what would happen if the state abandons its role of shaping and enabling that growth. With the city's inception, the state-level Haryana Urban Development Authority (HUDA) was expected to build the connective infrastructure, when there was no municipal body. This meant the lack of any semblance of planning—not helped by malfeasance where private developers were able to push projects through without adequate development plans.

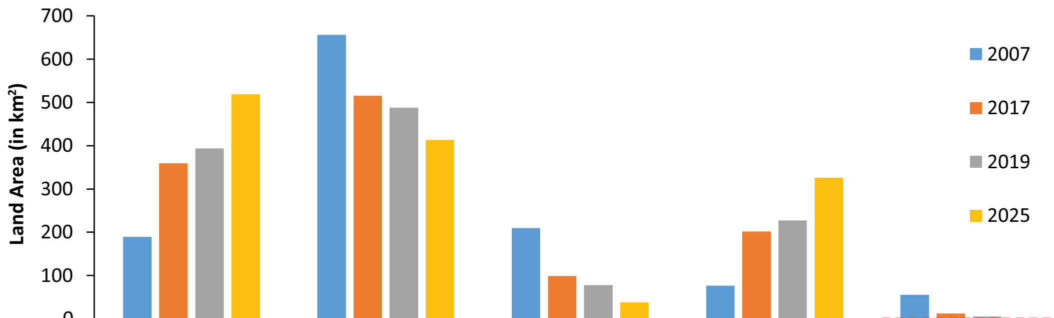
[9] Kumar, K P Narayana. 2012. Gurgaon: How not to build a city. Forbesindia.com. Details available at https://www.forbesindia.com/article/real-issue/gurgaon-how-not-to-build-a-city/33444/1, last accessed on October 14, 2021

[10] Details available at http://www.ijesrr.org/publication/51/IJESRR%20V-5-1-8.pdf

[11] Goyal, A, M Sharma, and D D Singh. 2019. Land use/land cover change detection using geoinformatics in Gurugram district, Haryana, India. International Journal of Recent Technology and Engineering 8(2): 2277–3878

2.2.2 Land utilization and land cover

The study of land use classification of Gurugram district has been shown in Figure 3 (land use classification of Gurugram city is not available). The statistics of Gurugram district can be taken as a representation of the city (part of Gurugram tehsil) as it has witnessed the maximum land use change with 9 times more population than in other 4 tehsils. The district has witnessed significant changes in land-use pattern from 2007 to 2017.



	Built Up	Agriculture	Vegetation	Barren	Water Body
2007	189.67	656.23	209.64	76.61	55.25
2017	358.9	515.59	98.92	201.56	12.43
2019	393.54	487.85	78.02	227.32	5.34
2025	518.86	413.25	38.27	326.12	0.42

Types of land use

Figure 3 : Land use land cover change in Gurugram district (2007–2017) and estimated change in 2019 and 2025[12]

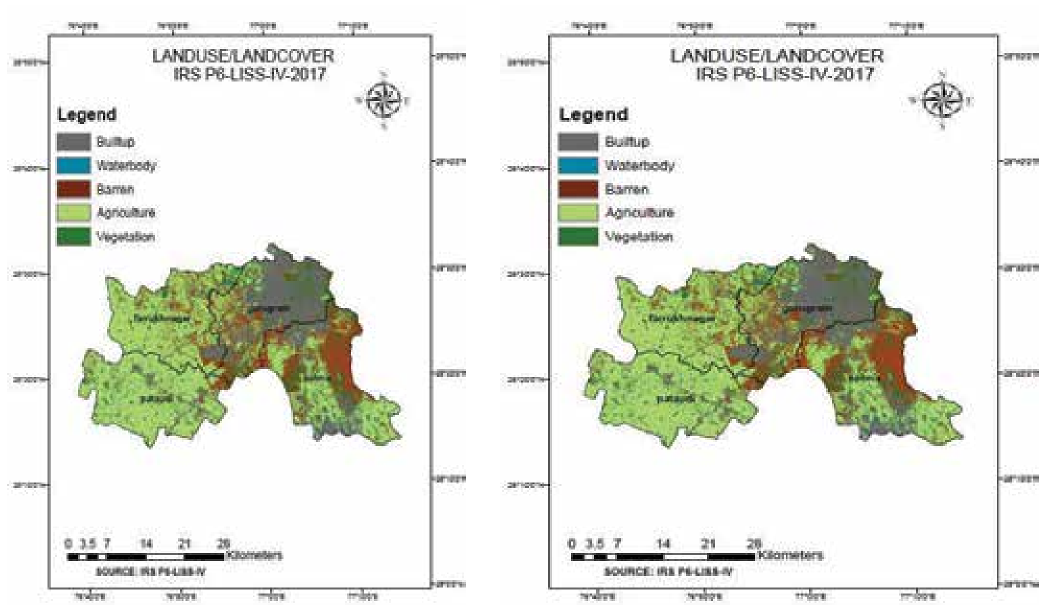


Figure 4 : Graphical representation of land use land cover change in Gurugram district (2007–2017)[13]

[12] Author's analysis

[13] Goyal, A, M Sharma, and D D Singh. 2019. Land use/land cover change detection using geoinformatics in Gurugram district, Haryana, India. International Journal of Recent Technology and Engineering 8(2): 2277–3878

Gurugram is one of the fastest growing urban regions due to industrial growth and population influx. As seen in Figures 3 and 4, the following land use land cover changes have been experienced in the Gurugram district:

1. The built-up area in Gurugram has grown almost two-times from 189.67 km2 in 2007 to 358.90 km2 in 2017. This can be attributed to its emergence as a major industrial hub in the last two decades. It was done through large-scale acquisitions of agricultural lands by the government along with the development of residential townships and infrastructure for multinational companies (MNCs). It is estimated that if this urban growth trend continues, then the built-up area will be increased to 518.86 km2 by 2025. As seen in Figure 4, most of the built-up expansion is witnessed in the Gurugram tehsil followed by Manesar tehsil.

2. Due to the development and expansion of industries and settlements, vast agricultural lands decreased from 2007 to 2017 due to their conversion to built-up areas. The agriculture land covering an area of about 656.23 km2 in 2007 reduced to 515.59 km2 in 2017 in the region. Thus, it is estimated that if this urban growth trend continues, the agricultural land will be decreased to 413.25 km2 by 2025. The agricultural land is mostly concentrated in Patudi, Farrukh Nagar, and Sohna tehsils.

3. Due to continuous built-up expansion and encroachments from 2007 to 2017, water bodies and the vegetation area decreased from 55.25 km^2 to 12.43 km^2 and from 209.64 km^2 to 98.92 km^2, respectively, in the region. It is estimated that if this trend continues, then the overall area of these two types of land use, which is already less, will be dropped to 38.27 km^2 in case of vegetation area and to 0.42 km^2 for water bodies by 2025. Thus, necessary interventions are required from the concerned authorities to conserve the water bodies. The increase in annual monsoon floods in the city is a testament of the impact of shrinking water bodies and green cover.

In 1950s, Gurugram was replete with water bodies that merrily captured both rainwater and water flowing downhill from the Aravallis slopes. As per a first-of-its-kind study done by the Gurugram Metropolitan Development Authority (GMDA), the district had some 644 small and large water bodies. This was inferred by collating data from three main sources – the revenue record of 1956, the Survey of India Map 1976 and the world view satellite imagery of 2012.[14] Out of the 644 water bodies:

- 153 were found to be vanished beyond recovery.
- Another 53 bodies face severe threat due to intentional landfilling, garbage and construction waste dumping, and encroachment.
- 132 water bodies face contamination due to discharge of industrial affluent and wastewater.
- The remaining 44 cannot be called water bodies as they experience only seasonal waterlogging.

4. Barren land in the region appears to be expanding due to rising influence of human activities on the area's natural resources. Increasing use of pesticides, fertilizers, herbicides, and insecticides are polluting the agricultural soil and making it unproductive. From 2007 to 2017, the barren land area increased from 76.61 km^2 to 201.56 km^2, respectively.

[14] Details available at https://www.hindustantimes.com/cities/all-stakeholders-need-to-work-together-to-revive-water-bodies/story-71yd5P0hH4cXZy6sZ7UWWL.html, last accessed on October 14, 2021

2.3 Demographic Description

The demographic description discusses about the population growth trend in Gurugram district and Gurugram city (tehsil).

2.3.1 Population growth trend

Gurugram District

In 2011, Gurugram district was the fourth most populated city in Haryana with 15,14,085 population. There has been a rapid increase in population of the district due to magnificent growth with latest industrialization and infrastructure development. The population growth of the district till 2011 is shown in Figure 5. The population is estimated to increase in future, considering the existing rate of growth in population.

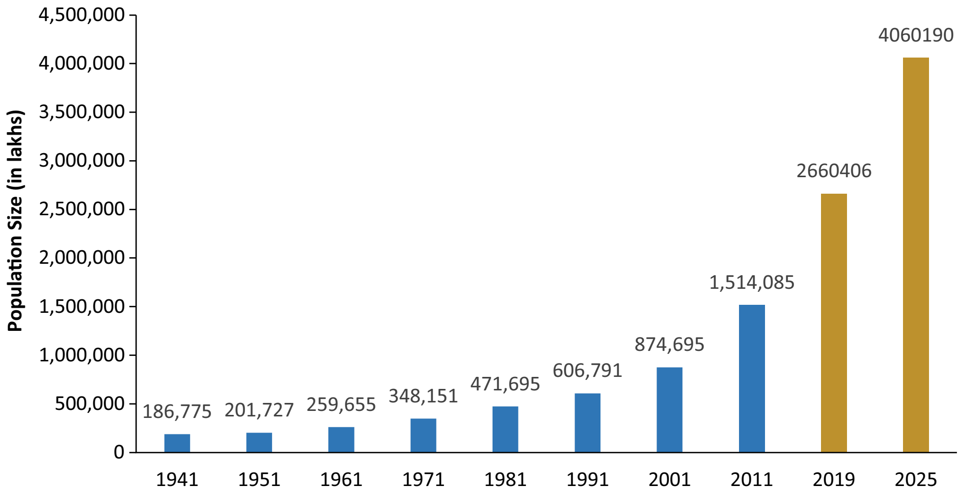


Figure 5 : Population increase in Gurugram district (1941–2011)[15] and estimated population change from 2019 to 2025

With the initiation of economic reforms in 1991, Gurugram saw a massive expansion in its population and economy after the real estate major, the DLF Group, started buying farmlands owned by the local people. It acquired the land to develop housing societies for the upper middle-class residents of Delhi. Moreover, the government removed bottlenecks in obtaining permits and provided special incentives to information technology (IT)-enabled services and the business process outsourcing sectors, which attracted foreign investment. Due to this the decadal variation in population jumped from 28.6% to 44.1% from 1991 to 2001, respectively, as shown in Figure 6.

[15] A - 2 DECADAL VARIATION IN POPULATION SINCE 1901, Census of India and Census of India 2001 and Provisional figures of Census India, 2011 and Development Plan of Gurgaon

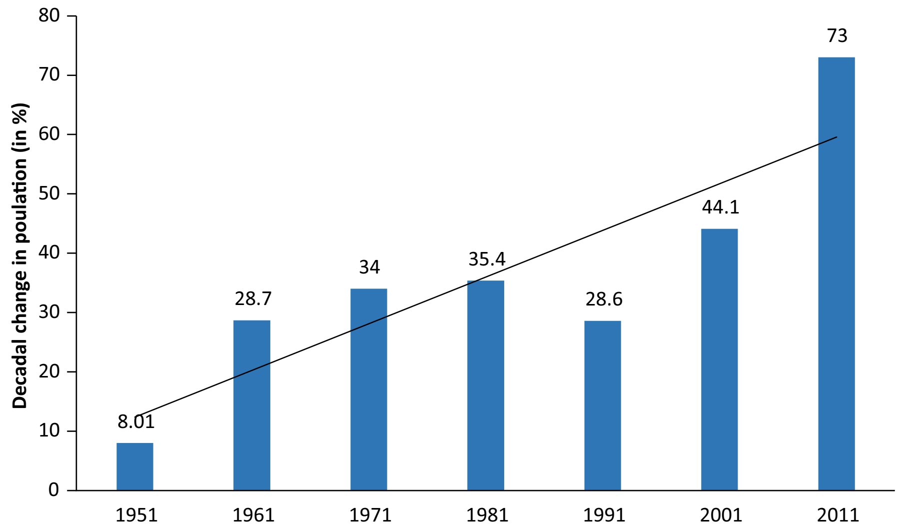


Figure 6 : Percentage decadal variation in population of Gurugram district (1951–2011)[16]

Population density in the Gurugram district continued to increase from 716 persons/km^2 in 2001 to 1241 persons/km^2 in 2011 due to rapid expansion of IT industry. The industry generated more employment opportunities resulting in influx of migrant population, giving push to the development of residential spaces. Considering the rate of change from 2001 to 2011, the population density is expected to further increase to 3341 persons/km^2 by 2025.

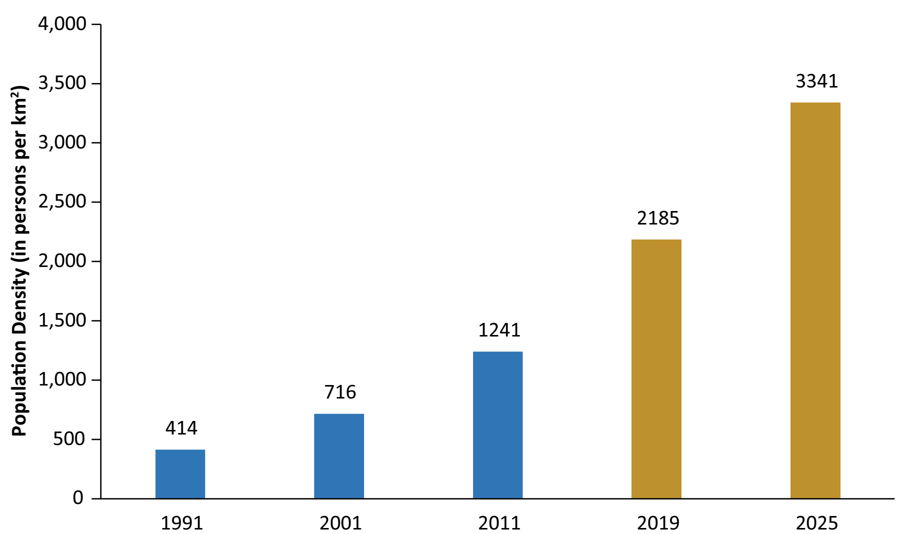


Figure 7 : Change in population density in Gurugram district from 1991 to 2011[17] and the estimated change in 2019 and 2015

[16] A - 2 DECADAL VARIATION IN POPULATION SINCE 1901, Census of India and Census of India 2001 and Provisional figures of Census India, 2011 and Development Plan of Gurgaon

[17] A - 2 DECADAL VARIATION IN POPULATION SINCE 1901, Census of India and Census of India 2001 and Provisional figures of Census India, 2011 and Development Plan of Gurgaon

Gurugram City (Tehsil)

Out of all the five tehsils, Gurugram tehsil has witnessed the maximum urbanization and population growth due to following reasons:

- Job opportunities are available in large numbers in Gurugram in almost all the trades.
- Better infrastructure development and a decent standard of living.
- Major IT companies have their main or branch office in Gurugram.
- Connectivity of Delhi Metro to Gurugram with Delhi and Noida offers better transport facilities at low cost.
- Universities and colleges are available in large number in Gurugram.
- Better road connectivity with Delhi and NCR region plays another major role as traveling becomes easy and affordable.

The maximum increase in population has occurred in central Gurugram city, which forms the industrial region, contiguous to Delhi and is therefore the hub of multinational corporations' expansion.

Considering the current rate of population growth, the population in Gurugram tehsil is expected to reach 4.3 million by 2025.

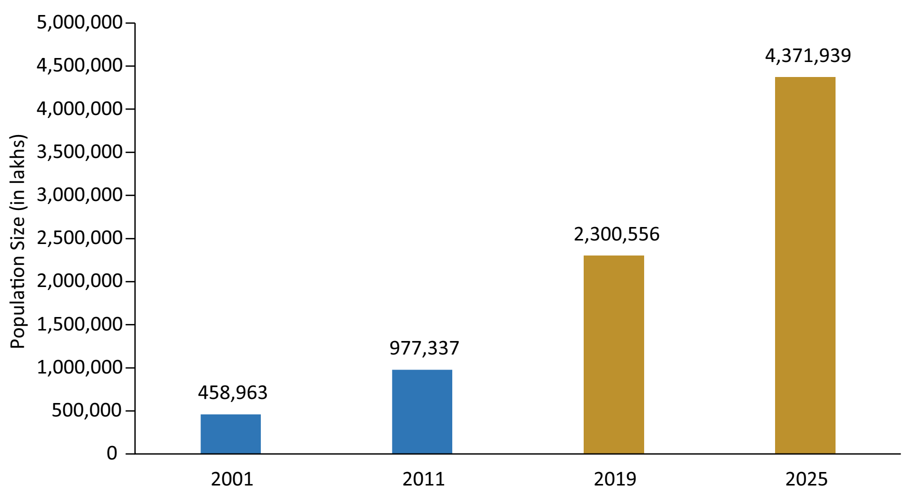


Figure 8 : Population increase in Gurugram tehsil from 2001 to 2011[18] and estimated population change in 2019 and 2025

2.4 Social and economic character

2.4.1 Economy

Gurugram has become a hub of MNCs, industries giants, call centres, software companies, shopping malls, and skyscrapers. With the collaboration of Suzuki Motors of Japan and Maruti Udyog Limited in early 80s, a new area of rapid industrialization in Gurugram started. Consequently, the district came on the international map. The automobile industry in Gurugram has been producing passenger cars, motor cycles, scooters and their components. The Gurugram-Manesar-Bawal belt has emerged as the auto hub

[18] District Census Handbook Gurgaon, Village and Town Directory, Census of India 2011, Haryana

of the country, thereby offering ample opportunities to the entrepreneurs. There are many prominent and prestigious units involved in the manufacturing of telecommunication equipment, electrical goods, sports goods, rubber products, and readymade garments, and in software development. Other industries include light engineering goods, pharmaceuticals, agro based and foods processing, leather, terry towels, air conditioners, shoes, pesticides, insecticides, etc.

The gross domestic product (GDP) of Gurugram district had the highest share of 25.3% in the Haryana's income (2011-12).[19] Gurugram recorded the highest GDP of INR 2,699,055 lakh in the sub-region in 2009-10 followed by Faridabad district.[20]

In 2009-10, the district-wise per capita income in the state was the highest in Gurugram with INR 229,208 lakh.[21] Also, it continued to remain the highest in 2011-12 with INR 316,512 in 2011-12, making it the richest district of Haryana.[22]

The workforce participation in the primary, secondary, and tertiary sectors was 52.9%, 20.03%, and 27% in 2001, respectively.[23] But, the workforce engagement changed over the years and Gurugram district transformed its economy from 'agriculturally dominant' to 'developing' economy. The proportion of main workers engaged in agricultural activities (cultivators and agricultural labourers) came down from 53.9% in 1991 Census to 12.3% in 2011 Census. Tertiary activities such as IT, software, service, and sales, with 81.4% of the main worker force, now rapidly dominate the economy of the district.[24]

2.4.2 Agriculture

Rural population forms a major portion of the city's total population and agriculture is the predominant occupation of the majority of the people in Gurugram district. The main source of irrigation is tube well, which irrigates about 96.8% of the total irrigated area in the district.

As can be seen from Figure 3, agriculture area in Gurugram district has decreased over the last two decades. The agriculture area decreased from 656.23 km^2 in 2007 to 515.59 km^2 in 2017. Taking this as the declining rate, the agriculture area might be roughly decreased to 487.85 km^2 in 2019. The urban growth of the Gurugram and Manesar tehsils has transformed most of the agricultural and barren lands into residential, commercial, and office areas. Currently, the agricultural land is mostly concentrated in Pataudi, Farrukh Nagar, and Sohna tehsils.

The agriculture water demand in the area is met through groundwater supplied by canal systems and tube wells. Monsoon and non-monsoon rainfall, irrigation return flow, recharge from canals, lakes, ponds, and floods contribute to groundwater resources. This annual recharge of the aquifer contributes towards dynamic groundwater resources, a significant quantity of which is stored in the aquifer and part of it contributes to the rivers as base flow.

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19 Inter-Regional Disparities in Haryana, Institute for Development and Communication, 2014

20 Sub-Regional Plan for Haryana Sub-Region of NCR-2021, Chapter 5, Economic Scenario

21 Sub-Regional Plan for Haryana Sub-Region of NCR-2021, Chapter 5, Economic Scenario

22 Inter-Regional Disparities in Haryana, Institute for Development and Communication, 2014

23 Sub-Regional Plan for Haryana Sub-Region of NCR-2021, Chapter 5, Economic Scenario

24 District Census Handbook Gurgaon, Village and Town Directory, Census of India 2011, Haryana

Artificial irrigation systems such as canals, wells, tanks, and tube wells provide water for irrigating a vast expanse of agricultural land. As previously mentioned, the district has a considerable topographic diversity. As drains tend to flow towards inland depressions instead of some river, here irrigation is possible only by storing water by making bunds. Though underground water level is relatively high in the district, water level is quite deep below rocky surfaces. Irrigation facilities are coming up in the district, giving a hope of prosperity to the farmers whose mainstay is agriculture.

Recent data on agriculture output are not available for Gurugram district. Therefore, agriculture water demand was not considered in the final calculations for Gurugram's water demand and supply.

2.4.3 Industry

Gurugram was envisioned as one of the four major satellite cities of Delhi to ease the pressure of industrial and economic growth in the national capital. Consequently, in late 1970s, the sleepy hamlet transitioned into an industrial hub with the establishment of one of the largest automobile manufacturing units by Maruti Suzuki. The growth of ancillary industries such as auto components, along with textile and chemical industries, transformed Gurugram into an industrial hub. After liberalization of the Indian economy in 1990, the city developed rapidly into an information technology/business process outsourcing (IT/BPO) taking advantage of its proximity to Indira Gandhi International Airport, New Delhi.

Currently, Gurugram district has the largest number of large and medium units among all the districts of the State. Till 2010, there were 425 large and medium industrial units in Gurugram district. Having about 27.5% of the large and medium industrial units, it was the top-ranking district of the State.[25]

As per Statistical Abstract of Haryana for 2012, there were 1825 registered working factories in the district, which employed 250,202 workers. Major fields of concentration of industries included textile products, other manufacturing industries, transport equipment and parts, chemical and chemical products, electrical machinery, apparatus and appliances, machinery and machine tools, non-metallic mineral products, rubber, plastic, and petroleum products, metal products and parts, and basic metal and alloys. Minor areas of concentration included food products, cotton textile, repair services, wool, silk, and synthetic fibres, beverages, tobacco and products, gas and steam, water works and supply, and wholesale and retail trade. The State government has set up a Software Technology Park in Electronic City, Gurugram, which has been functioning since 2002. Furthermore, the district, alone in the State, exported software of over INR 1500 crore during 2000-01. Prominent IT units in the district are Huge Software Systems Ltd, Tata Consultancy Senses Centre, G.E. Credit International, IBM, HCL Technology, Motorola Ltd, Polaris Ltd, Alcatel Modi Systems Ltd, etc.

Data on industrial water consumption are not available for Gurugram district. Therefore, industrial water demand was not considered in the final calculations for Gurugram's water demand and supply.

2.4.4 Housing

Gurugram city (tehsil) is divided into 36 wards, with each ward further divided into blocks. The housing type in the city consists largely of attached housing and also attached multi-dwelling units, including apartments, condominiums and high-rise residential towers. The city has an estimated 1100 residential high-rises.

[26] District Census Handbook Gurgaon, Village and Town Directory, Census of India 2011, Haryana

The Gurugram city landscape presents a very contrasting picture where hundreds of jhuggis located in the slums can be seen with high-rise buildings and residential complexes in the backdrop. These slums are occupied with thousands of people who provide cheap workforce for the residences and offices in the nearby vicinity.

One of the major stresses for Gurugram is massive migration of rural population in its periphery. There have been illegal encroachments by immigrants who have occupied several locations, and are living in disdainful conditions. According to the 2011 Census, in 2015, Gurugram had 30,888 slums with 144,805 population.[26] Thus, the city had 10.2% of Haryana's slum population with a large population of 169,549 slum dwellers in 2015.

The distribution of piped water to Gurugram began in 1990, when the city started drawing water from the Yamuna canal in Sonepat. Prior to this, the area was entirely dependent on groundwater as there was no other major source of surface water. The launch of the city's first water treatment plant in Basai, in 1995, helped in augmenting water supply for the then developing sectors (sector 1 to sector 57), which have since come to rely almost entirely on the canal water. With the city's continued urban boom, currently, the demand for piped water comes mainly from sectors 58 to 115.[27]

Data on households with access to tap water are not available for Gurugram city and thus was not analysed.

2.5 Inferences

- Gurugram city is going to experience a continuous exponential built-up expansion in coming years due to the rapid economic development. This shall lead to an unprecedented growth of the city in terms of population, which in turn shall increase the demand for housing and other civic amenities such as water supply. A major chunk of the migrated population shall be constituted of lower strata group, which would be forced to live in slums due to demand–supply gap of housing in the city. Providing water connections to growing population in slums could pose a challenge for the authorities, as it furthers the burden on water resources, which are already under pressure and an overall urban infrastructure.
- Haphazard and uncontrolled growth in and around the city has led to severe repercussions on local ecological systems, wetland and natural vegetation loss, and interruption of natural drainage channels. Gurugram has experienced continuous rapid depletion of water bodies due to alteration in the land topography in the process of maximizing real estate development in the city. Buildings have come up right upon low-lying places that once had *johads* (traditional name for ponds and lakes). Rapid built-up expansion in coming years could put an enormous pressure on land and water resources, which could further alter resources availability and ecology of the area. Ponds and lakes could continue to shrink due to encroachments, unauthorized constructions, and poor disposal of municipal waste and construction debris into them. The flood intensity during monsoons will keep

[26] Singh, V, R S Sangwan, and S Sangwan. 2018. Social conditions of urban slum dwellers in Municipal Corporation Gurugram (MCG). International Journal of Research and Analytical Reviews 5(4): 858u–862u

[27] Details available at https://www.hindustantimes.com/gurgaon/haryana-chief-minister-okays-state-slum-in-situ-rehabilitation-policy/story-d164gg7p0qaZjzr9Kx9I0J.html#:~:text=%2C%E2%80%9D%20Jain%20said.-,According%20to%20the%202011%20Census%2C%20Gurgaon%20has%20a%20total%20of,city%E2%80%948%2C86%2C519%20people, last accessed on October 18, 2021

on increasing in Gurugram city due to reduction in catchment area, shrinking water bodies and green cover, and expansion in built-up land.

- Gurugram's rapid expansion due to IT revolution and leveraging its proximity to the airport in the last two decades has resulted in a rapid increase in population of the city. Due to unplanned growth model, the city may continue facing issues related to meeting water demand for residential, commercial, and industrial projects, as Gurugram nears its urbanization potential.
- Farmland in the region is on a decline due to its conversion into built-up area, which would almost become negligible in near future. Thus, the major water consumption sectors in the city in coming years would be residential housing and commercial and institutional establishments. Currently, the agricultural land in the region is mostly concentrated in Pataudi, Farrukh Nagar, and Sohna tehsils.

3
WATER GOVERNANCE AND ADMINISTRATION

3.1 Water Laws and Policy in India

In India, water-related legal provisions can be seen in the constitution, court decisions, central and state laws, and various irrigation acts. However, India does not have any exclusive or comprehensive water law. Water was included in the State List of the 7th Schedule of the Constitution of India. Hence, all activities related to planning, development, and management of water resources are undertaken by the respective States through their water resources or irrigation departments. In many cases, state governments have established autonomous bodies and corporations for the development and management of water resources.

India does not have any specific law that defines the ownership of and rights over water sources. The laws are derived from court rulings and customs. Several court judgments in post-independent India have affirmed that all natural resources that are by nature meant for public use and enjoyment are held by the State in public trust. For example, the legal position on whether groundwater is a resource meant for public use is fuzzy, and India has no law that explicitly defines groundwater ownership. It is customarily accepted across India that a well on a piece of land belongs to the owner of that land, and others have no right to extract water from the well or to restrict the landowner's right to use the water. This belief and practice is indirectly supported by various laws such as Land Acts and Irrigation Acts that list all the things to which the government has a right, but groundwater is not mentioned in any such list.

As yet, no law or policy has been formulated that asserts water is a fundamental and inviolable right enjoyed by every citizen of the country. The 'right to water' can, therefore, be obtained in India on a case-by-case basis, by appealing to the court. At the same time, it has been implicitly accepted that the central and the state governments have a primary responsibility to provide drinking water and, subsequently, water for other purposes. Accordingly, a host of programmes and policies have been framed and implemented at the central and the state levels including the National Water Policy (National Water Policy 2002 and National Water Policy 2012).

3.1.1 Institutional Setup at Central Level

At the central level, the Ministry of Water Resources (MoWR), set up in 1985, is the nodal ministry responsible for developing, conserving, and managing water as a national resource.

In May 2019, MoWR, River Development and Ganga Rejuvenation, and the Ministry of Drinking Water and Sanitation were merged to form the Ministry of Jal Shakti to streamline their functions, that is, to maintain the quality of drinking water and natural water bodies, ensure efficient use of water resources to meet the growing demand, and sensitize citizens for water conservation, thus contributing towards the enhancement of sustainable development. The ministry's remit covers areas as diverse as irrigation, multipurpose groundwater exploitation, command area development, drainage, and flood control. It also tackles issues related to waterlogging, soil erosion, dam safety, and creation of structures for navigation and hydropower, and oversees the development and regulation of interstate rivers.

The following three principal technical organizations are part of the ministry: Central Water Commission is responsible for developing and quality measurement of surface water in the basins of major and medium-sized rivers; Central Ground Water Board (CGWB) monitors, develops, and regulates groundwater resources, and the National Water Development Agency was set up to assess the possibilities of inter-basin water transfers.

The Central Pollution Control Board, in collaboration with the State Pollution Control Boards in several states, has been separately monitoring aquatic resources at selected locations since 1977.

Water quality and environmental matters come largely under the Ministry of Environment, Forest and Climate Change (MoEFCC), which coordinates India's Environmental Action Plan. The Ministry of Housing and Urban Affairs coordinates projects in urban water supply and sanitation. The Rajiv Gandhi National Drinking Water Mission, which is part of the Ministry of Rural Areas and Employment, handles rural water supply and sanitation. The Ministry of Power and the Central Electricity Authority handle water for power generation. Water is also a subject of several other ministries and departments, such as the Ministry of Agriculture (irrigation), the Ministry of Health and Family Welfare, the Ministry of Surface Transport, the Inland Waterways Authority of India, and, for planning and financing, Niti Ayog, the Ministry of Finance, and the Finance Commission.

3.1.2 Institutional Set-Up at State Level

Haryana Water Resources (Conservation, Regulation and Management) Authority: It was constituted in 2020 under The Haryana Water Resources (Conservation, Management and Regulation) Bill, 2020. The authority is established to ensure conservation, management, and regulation of water resources, that is, groundwater and surface water in the State. It is responsible for ensuring judicious, equitable, and sustainable utilization, management, and regulation of water.

Haryana State Pollution Control Board: It was constituted in 1974 after the enactment of Water (Prevention & Control of Pollution) Act, 1974. It was established to preserve the wholesomeness of water in the State. Later on, with the enactment of other environmental laws, the responsibility to implement provisions of such laws was also entrusted to the Haryana State Pollution Control Board in Haryana. The objectives of the board pertaining to water are as follows:

i. Control pollution at the source with due regard to techno-economic feasibility for liquid effluents.

ii. Ensure that natural waters are not polluted by discharge of untreated city sewage.

iii. Maximize reuse/recycling of sewage and trade effluents and use the treated effluent on land for irrigation and for industrial purpose after appropriate treatment.

Haryana Shahari Vikas Pradhikaran: Haryana Shahari Vikas Pradhikaran (HSVP), formerly known as Haryana Urban Development Authority (HUDA) was established in 1977. It is the urban planning agency of Haryana. Until the formation of Gurugram Metropolitan Development Authority (GMDA) in 2017, Gurugram was governed by HSVP.

Irrigation and Water Resources Department, Government of Haryana: It looks after the water resources management, irrigation, and flood works across the State.

Haryana State Industrial and Infrastructure Development Corporation (HSIIDC): Haryana State Industrial and Infrastructure Development Corporation (HSIIDC) is the nodal agency for development of industrial infrastructure in Haryana. Its functions are to provide water supply, drainage and sewerage services, and industrial wastewater treatment services in the industrial designated areas.

3.1.3 Administrative Set-Up of Gurugram City (Tehsil)

The 74th Amendment to the Constitution mandates state governments to transfer the responsibility of water supply services to urban local bodies. Local bodies and development authorities in Gurugram are governed by the important pieces of legislation, namely, The Haryana Municipal Corporation Act 1994 and The Gurugram Metropolitan Development Authority Ordinance, 2017, respectively.

GMDA was constituted in 2017 to improve the overall governance, land acquisition for implementation of infrastructure development plans, and sustainable management of the urban environment, and to look after water infrastructure related maintenance issues in the city. It is responsible for improving coordination among different government bodies in Gurugram and cutting down multiplicity of authorities in this respect. It provides treated raw water to area under its jurisdiction (municipal area).

Furthermore, Public Health Engineering Department, Haryana (PHED) provides piped drinking water supply in villages and towns, sewerage facilities, and storm water disposal in towns. It is also responsible for construction of sewage treatment plants in the State.

Municipal Corporation of Gurugram (MCG) was formed in 2008 to look after the water supply and drainage system of the city (covering sectors 1 to 57). Contrary to popular perception, MCG does not have the responsibility of managing all areas of the city. There are a lot of areas especially in New Gurugram that are managed by RWAs and HUDA.

Various agencies working in the water sector of Gurugram City and their functions are as follows:

- Water supply, sewerage services, rainwater harvesting, and storm water drain management are partially under MCG, HUDA, GMDA, and PHED. Post formation of GMDA in 2017, services including water supply network and sewage infrastructure were handed over to them from HUDA except for two sectors, that is, Sector 29, which is purely commercial, and Sector 53, where plots are yet to be given out. GMDA controls the master water supply and sewerage network while MCG looks after internal lines.
- Water quality monitoring of water bodies is done by Haryana State Pollution Control Board (MPCB).
- Groundwater use forms an important part of water usage in the city. The onus of groundwater control, its regulation, abstractions, and transportation is on CGWB.

- Irrigation and Water Resources Department, Government of Haryana looks after the irrigation and flood control works in Gurugram.

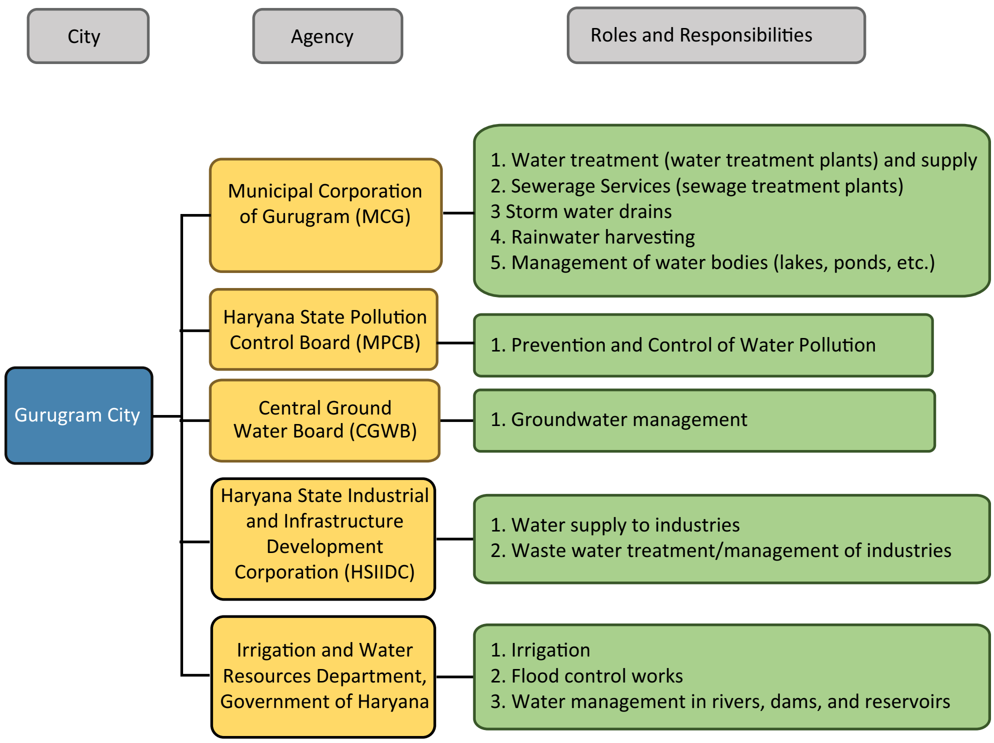

Figure 9 : Institutional framework of the water sector in Gurugram city

3.2 Inferences

- The governance in the Gurugram city has always been fragmented. HUDA, PWD of the Haryana State government, MCG, GMDA, and private developers have been responsible for service provisioning in different parts of the city depending on their respective jurisdictions. Consequently, this has created infrastructure problems in certain areas of the city. Gurugram was relatively a small urban area and did not acquire the status of a city till 2001. It was governed by a municipal council and was directly controlled by the Chief Minister's Office, making it easy to get requisite clearances for changes in land-use plans. The city landed its first Municipal Corporation in 2008. In 2017, GMDA was created by an Act of the State Legislature. These multiple urban governance bodies in the city function within a tangle of overlapping jurisdictions and poor coordination. This leads to weak accountability and delay in finding and implementing solutions to the problems being addressed. For example, a newly demarcated function depicts that MCG does the frontend work and GMDA takes care of the backend, but this process is yet to percolate entirely.
- The model of development adopted by the Haryana government is characterized by a random nature of growth in the city. For example, in 1975, the state government passed the Haryana Development and Regulation of Urban Areas Act, augmenting the private sector's role in the real estate development. This resulted in acquisition of a vast expanse of agricultural land by the private sector. A number of

water bodies in the city have said to be filled up to facilitate construction, resulting in the brazen destruction of the ecology. This, coupled with the rampant flouting of planning and construction norms, has spelt disaster for the waterscape in the city. Due to this, the city sprung up in a haphazard manner rapidly leading to several parts of the city deprived of basic amenities such as water supply and sewerage lines.

4

WATER SOURCE MANAGEMENT AND INFRASTRUCTURE

4.1 Water Sources

Gurugram does not have any major lake or river that flows across the city. Most of the seasonal streams and ponds have dried up due to rampant concretization and ill maintenance. However, it was not always like this. The Najafgarh *jheel* (lake) used to be an immense wetland lying across Gurugram and Delhi. It was fed by the Sahibi River and floodwaters from Gurugram, Rewari, Jhajjar, and north-west Delhi.

Old records indicate that the *jheel* was spread over 300 km^2 before its unfortunate draining. Its existence was recorded as far back as 1807. It played a vital role in the agrarian economy by supporting irrigation, animal husbandry, and fishing. The Najafgarh *jheel's* wetlands hosted innumerable migratory and resident birds, including the endangered Siberian crane, pink-headed ducks, and greater flamingos. To date, wild animals and reptiles endemic to the region and several species of birds are sighted here. In addition, the *jheel* was a recharge source for the surrounding aquifers.

In 1960, the Flood Control Department of Delhi kept widening the Najafgarh drain in the pretext of saving Delhi from floods and eventually quickly drained the once huge and ecologically rich Najafgarh Lake completely. It was converted into farmland first and, by now, various large-scale housing projects occupy the former lake basin. However, in case the Najafgarh Drain ever breaches its human-made and fortified embankments during the monsoon season, large swaths of these housing colonies could be flooded, causing a major disaster.

Gurugram gets its water from the nearby flowing river Yamuna through human-made canals. Large-scale extraction of groundwater by private tube wells is also seen.

To fulfil the increasing demand of water in Gurugram city, a number of sources are being tapped to source and distribute water to the region. The area receives its water from three main sources: rainwater, surface water, and groundwater.

4.1.1 Rainwater

The monsoon period in Gurugram starts from late June and lasts till September. As shown in Table 1, Gurugram city receives maximum rainfall from June to September with an average annual rainfall of 795.4

mm and with August being the wettest month (as per average data from 1956 to 2000).[28] Water from monsoon rains fills the streams and ponds and replenishes the groundwater periodically. This water is then distributed to meet the requirements of the city.

Table 1: Average month-wise rainfall and evapotranspiration statistics of Gurugram city[29]

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Average rainfall (mm) (1956-2000)	18.9	16.6	10.8	30.4	29	54.3	216.8	247.6	133.8	15.4	6.6	15.2	795.4

Table 2: Month-wise rainfall and rainy days statistics of Gurugram city from 2010 to 2020[30]

Months/ Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
January	Rain (mm)	5.95	1.17	0.58	7.18	11.96	0.9	0.01	11.05	1.91	48.3	44.1
	Days	2	1	3	2	5	2	1	3	1	6	9
February	Rain (mm)	2.55	18.17	0.03	26.49	7.84	6.91	1.69	0.06	3.72	61.1	34.5
	Days	3	7	0	7	4	2	1	0	1	10	3
March	Rain (mm)	0.88	0.93	1.06	2.44	11.15	31.41	6.48	4.87	4.51	16.9	95.7
	Days	1	3	1	2	8	11	4	3	3	5	12
April	Rain (mm)	0.41	11	9.81	6.7	3.02	21.08	1.23	2.7	4.67	129.5	13.8
	Days	1	4	8	5	3	7	7	1	10	4	11
May	Rain (mm)	0.06	22.61	3.1	0.24	7.87	1.11	11.38	2.8	2.56	12.9	19.7
	Days	0	9	0	0	5	1	6	3	2	10	13
June	Rain (mm)	1.16	68.99	4.49	30.91	12.07	61.67	24.2	22.36	43.18	15.7	29.4
	Days	2	19	2	11	9	7	9	10	9	6	15
July	Rain (mm)	131.79	174.26	**68.98**	**45.27**	17.64	**121.7**	**96.24**	38.9	**153**	**240.8**	156.7
	Days	20	28	**20**	**16**	9	**12**	**28**	15	**20**	**23**	25
August	Rain (mm)	157.65	**311.17**	64.93	40.63	13.23	55.01	60.49	**57.56**	66.52	155.3	**229.4**
	Days	29	**27**	21	22	12	18	17	**11**	20	28	**26**
September	Rain (mm)	**212.46**	136.69	50.16	14.65	**30.86**	26.75	3.23	32.33	94.25	74.5	12.5
	Days	**22**	18	11	5	**8**	9	3	7	13	16	9
October	Rain (mm)	2.65	0	0.03	1.49	0.62	1.11	0	0	0	3	0
	Days	3	0	0	2	1	1	0	0	0	3	0

[28] Details available at http://www.imd.gov.in/pages/services_climate.php?adta=PDF&adtb=&adtc=../section/climate/climateimp, last accessed on October 18, 2021
[29] Details available at http://www.imd.gov.in/pages/services_climate.php?adta=PDF&adtb=&adtc=../section/climate/climateimp, last accessed on October 18, 2021
[30] Details available at https://www.worldweatheronline.com/gurgaon-weather-averages/haryana/in.aspx, last accessed on October 18, 2021

Months/ Year		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
November	Rain (mm)	6.5	0	0	0.23	0	0.17	0	0.07	0.31	22.2	15.2
	Days	4	0	0	0	0	0	0	0	1	5	2
December	Rain (mm)	4.41	0	0.57	2.07	1.5	0.12	0	0.51	5.19	23.7	0.3
	Days	2	0	1	2	2	0	0	1	2	4	1
Total annual rainfall (mm)		526.4	744.9	203.7	178.3	117.7	327.9	204.9	173.2	379.8	803.9	651.3
Total number of rainy days in a year		89	116	67	74	66	70	76	54	82	120	126

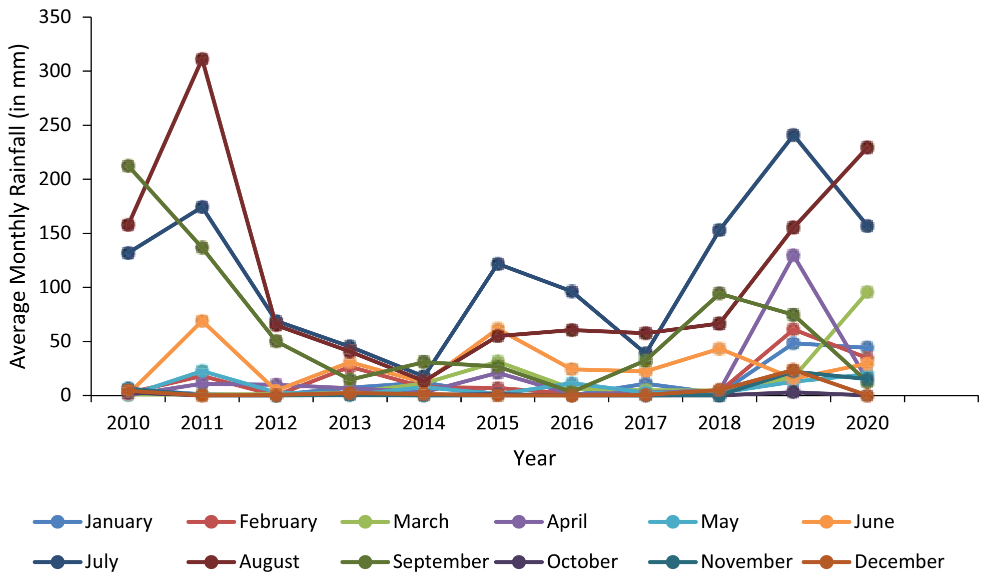

Figure 10 : Month-wise rainfall and rainy days statistics of Gurugram city from 2010 to 2020

As seen in Table 2, the rainfall pattern in Gurugram from 2010 to 2020 was analysed as follows:

- Firstly, it can be seen that in the non-monsoon months, that is, from January to May, of last 10 years, there has been an extremely inconsistent rainfall pattern. Especially in 2019, there was a drastic increase in the average rainfall intensity in January, February, and April as compared to the previous years.
- Secondly, in the last 10 years, July became the wettest month in Gurugram as compared to the data from 1956 to 2000 in which August used to be the wettest month, indicating preponement of heavy spell of rain.
- The total annual rainfall decreased six-times from 2011 (744.9 mm) to 2014 (117.7 mm). In 2015, it shot up thrice to 327.9 mm. Then, it continued to decrease again till 2017 to 173.2 mm. Further, in 2019, the annual rainfall intensity jumped to 803.9 mm. That year, Gurugram saw one of the worst floods in the region, which affected lives and property and lead the city come to a standstill.

The major factor for such an unpredicted rain spell can be attributed to the changing climate across the world due to global warming of which GHG emissions is the most prominent reason. Earlier, the city used to witness continuous light rain over 2-3 days and was spread evenly across monsoon months. But in the last decade, the same quantum of rainfall occurs in just 2-3 hours showing an irregular downpour even in the monsoon months. These extreme events have been taking place across the entire tropical region for quite some time now.

4.1.2 Surface Water

The Western Yamuna Canal (WYC) command area is located between the northern latitudes 28°20' and 30 29' and the eastern longitudes 75°48' and 77°35'. It comprises the eastern, central, and southern parts of Haryana. It has a geographical area of about 13,543 km^2 spread over 49 blocks in the districts of Karnal, Panipat, Sonepat, Rohtak, and Jhajjar and partly in the districts of Hisar, Bhiwani, Jind, Yamunnagar, Gurugram, and Rewari.[31]

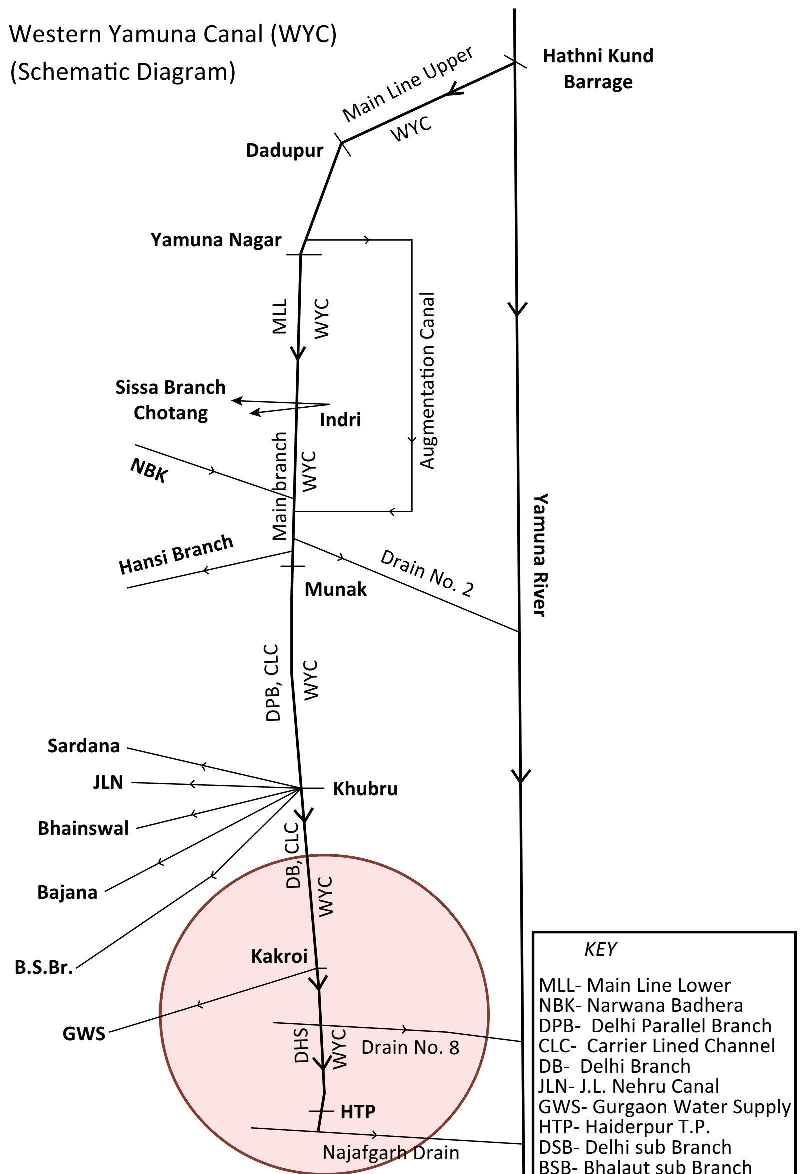

Figure 11 : Schematic diagram of Western Yamuna Canal highlighting the Gurugram Wastewater Supply channel

31 Amita Bhaduri, B. H. (2010, August). On the Brink. Water Governance in the Yamuna River Basin in Haryana. New Delhi: PEACE Institute Charitable Trust

The total length of the WYC with all its branches is 325 km. The Delhi Branch section (Khubru head till Kakroi head) is 45 km long, which discharges 2000 cusec of water. The off-take of raw water from this section is done by two channels that supply water to the city, namely:[32]

- **Gurugram Water Supply (GWS) Channel:** Gurugram gets water that comes through the Western Yamuna Canal near Sonepat and then through the 70-km GWS channels from Kakaroi village to water treatment plant (WTP) in Basai, Gurugram. It is under the jurisdiction of the Delhi Water Services Division of the Irrigation Department. The channel was constructed in 1994-95 with a capacity of 135 cusecs, which has since been increased to 200 cusecs. The remaining requirement of 800 cusecs of water, out of the ultimate projected demand of 1000 cusecs, is expected to be met through the new National Capital Region (NCR) Water Supply Channel.
- **National Capital Region Water Supply Channel**: It was built to supply water to the fast growing Gurugram city and other proposed townships of HSIIDC and SEZs by corporate developers in the area. NCR channel runs parallel to GWC. Initially, the channel had water carrying capacity of 500 cusecs, with a provision to increase it to 800 cusecs. The channel has been obliged to meet the requirement of drinking water in the embryonic metropolitan city of Gurugram and also for other areas including Bahadurgarh, Sampla, Badli, rural areas of Jhajjar district, SEZs, and industrial townships at Manesar, Bahadurgarh, and Kharkhoda. Finally, now the NCR channel is being constructed for a length of 75.536 km to meet the ultimate demand of 800 cusec discharge up to the year 2021 for meeting drinking, industrial, and tourism water requirements.

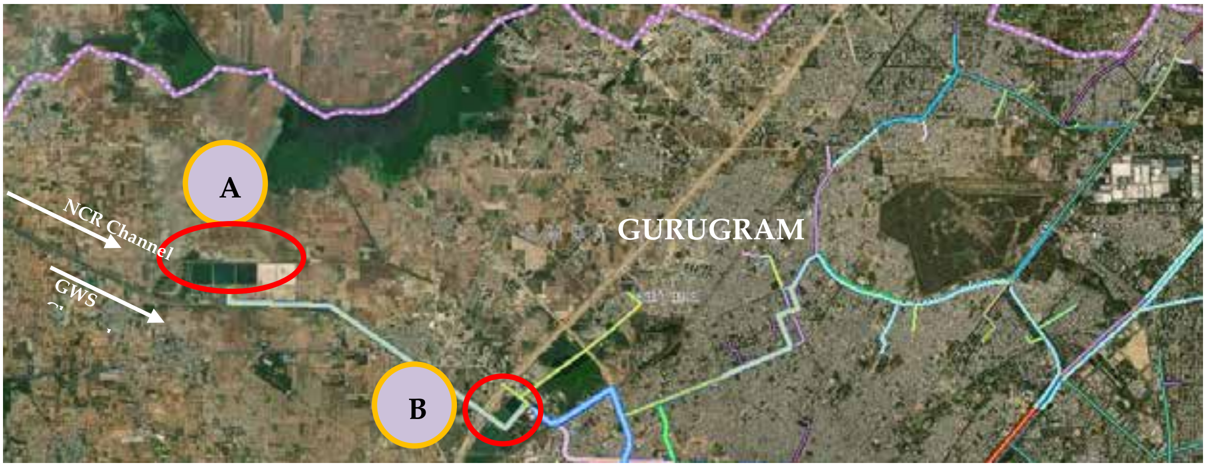

Figure 12 : Water supply network in Gurugram tehsil getting water from Chandu Budhera (A) and Basai water treatment plants (B)[33]

[32] Narain, V. &. (2017). Flowing against the current: The socio-technical mediation of water (in)security in periurban Gurgaon, India. Geoforum. 81, 66-75. 10.1016/j.geoforum.2017.02.010.

[33] Details available at https://onemapggm.gmda.gov.in/GIS/Auth/OneMap2D/, last accessed on October 18, 2021

Figure 13 : Surface water sources for Gurugram tehsil

4.1.3 Groundwater

Gurugram ever since it came into being has been drawing groundwater at an alarming rate. The withdrawals accelerated after the Haryana government invited private enterprises to set up their base in the city. Residential and office complexes came up at a dizzying speed, and went on guzzling even larger amounts of groundwater – all free of cost. The inevitable result being with the city's expansion in the 1980s, Gurugram's water table has fallen by over a metre each year.[34]

The average depth of water in Gurugram district is critical and continuously increasing. The average water level depth in 1974 was 6.64 m, which increased to 22.62 m in 2014.[35]

[34] CSE India. (2012). Excreta Matters Vol. 2. Gurgaon The Water Waste Portrait. Retrieved from CSE India Web site: https://www.cseindia.org/excreta-matters-media-briefing-and-workshop-on-gurgaons-water-and-sewage-4035

[35] Aneja, D. R. (2017). Ground Water Level in Haryana: A Challenge for Sustainability. IJRAR- International Journal of Research and Analytical Reviews , 43-48.

Table 3 shows the groundwater development in Gurugram district. The statistics given below reflect that groundwater development is too high, more than 200%, in Gurugram. This stage of development comes under the overexploited category.[36]

Table 3: Details of groundwater development in Gurugram district in 2015

District	Groundwater Availability (Hectare Meter)	Groundwater Consumption for Irrigation (Hectare Meter)	Domestic and Industrial Consumption of Groundwater (Hectare Meter)	Total Consumption of Groundwater (Hectare Meter)	Groundwater Development (%)
Gurugram	23,261	35,777	18,150	53,927	231.83

The average depth of water in Gurugram block (tehsil) is also extremely critical and is continuously increasing as shown in Figure 14. The water table fell to 36.21 m below ground level in 2016. In 2006, this was 19.85 m, showing an alarming decline of about 17 m over the decade.[37]

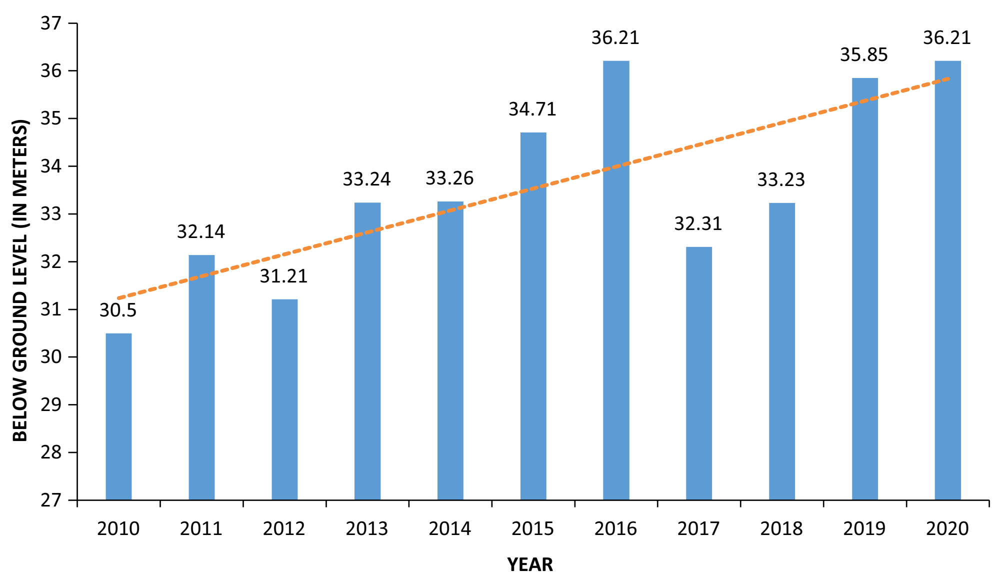

Figure 14 : Groundwater level in Gurugram city (2010-2020)

Rapid real estate development has outpaced both city planning and public infrastructure related to water supply, wastewater treatment, and recharge in the region. This rapid development is also impacting water bodies, green spaces, nullas as well as air quality and the overall quality of life in Gurugram. Rapid population growth in Gurugram has led to an imbalance between annual groundwater extraction and recharge levels.

Rainfall variability has a potential impact on the groundwater resources. More rain means higher groundwater levels. But if we observe the annual rainfall statistics in Table 2, the change in groundwater levels are found to be abrupt as far as its dependence on rainfall intensity is concerned. For example,

36 Gangurde, K. (2015). GROUND WATER QUALITY AND LEVEL IN HARYANA, INDIA: A REVIEW. Scholarly Research Journals for Interdisciplinary Studies, 4806-4814.

37 Pati, I. (2020, September 24). Gurugram's groundwater level down by 3m in two years, says report. The Timesof India.

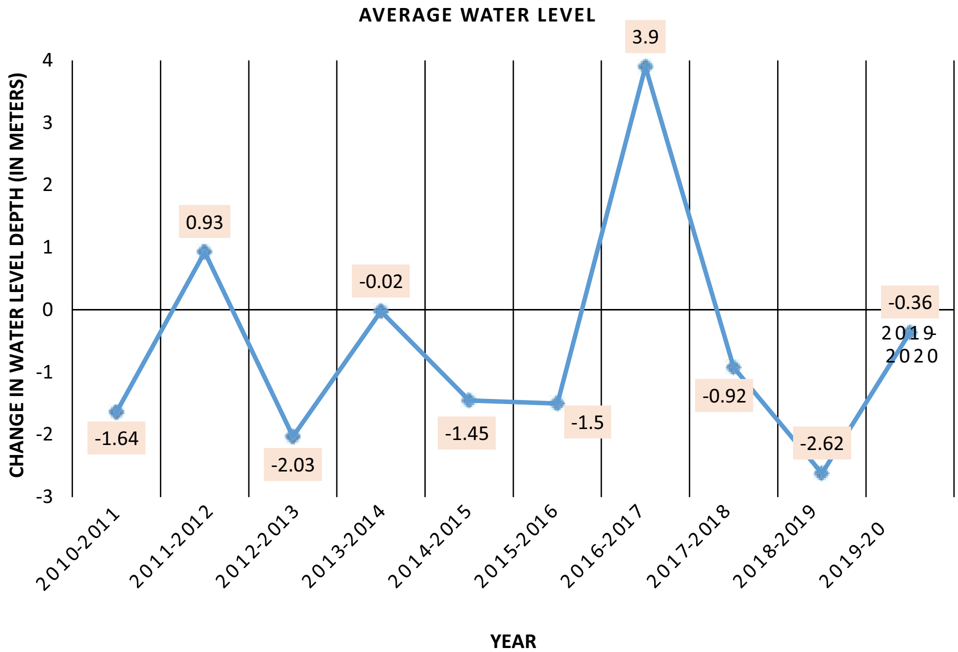

Figure 15 : Change in water level depth in Gurugram city (2010-2020)

groundwater level in 2020 was 36.2 m (lowest in 2010-2020), while the annual rainfall was 803.9 mm (which was highest as compared to other years). This recurring anomaly can be due to the following reasons as follows:

- Raid population increase has led to higher levels of groundwater extraction than recharge. Due to this, there has been a decline in the city's groundwater table by 1.5-2 m on an average each year over the last decade. This is faster than the rate of depletion of groundwater table in Delhi. It has more than 40% area which does not have water connections provided by civic agencies, and thus are dependent on groundwater.[38]
- In 2008, Central Ground Water Agency (CGWA)declared Gurugram as a dark zone where illegal groundwater extraction is being carried out openly.[39]
- There are about 9140 bore wells that are officially registered in Gurugram city, and more than 15,000 that are operating without permission.[40] However, the actual number of illegal bore wells is unknown, making it difficult for monitoring the illegal extraction and control it.
- The Aravalli hills in the city have high level of cracks and fissures that make it a superior zone for groundwater recharge. But due to dilution of protective laws, illegal felling of trees and encroachment are wiping out the hills, affecting the groundwater levels.
- Excessive concretization due to infrastructure development has led to shrinking of catchment areas**,** thus resulting in flooding. Due to which the downpour is either evaporated or lost as storm water runoff and is unable to seep inside the ground.

[38] Pati, I. (2020, September 24). Gurugram's groundwater level down by 3m in two years, says report. The Timesof India.
[39] Pati, I. (2020, September 24). Gurugram's groundwater level down by 3m in two years, says report. The Timesof India.
[40] Jha, B. (2020, January 22). In one month, 15 illegal borewells sealed in Gurugram. The Times of India.

4.2 Water and Wastewater Treatment Infrastructure

To meet various types of city's water demand, an infrastructure is required for a safe and continuous supply of water to the end user. Thus, to meet the minimum water quality standards, WTPs are installed in the city where water tapped from reservoirs/rivers/canals is treated and further supplied to the city. Also, waste water from cities is collected and treated in waste WTPs to remove as much of the suspended solids as possible before the remaining water is discharged back to the rivers.

4.2.1 Water treatment plants

Gurugram gets its water from the Yamuna River's Tajewala headworks near Yamunanagar. The ever-increasing freshwater demand of the growing city has been met by WTPs and two canals, built on acquired lands from the peripheral villages, namely, Basai, Chandu, and Budhera. The two raw water canals, cutting through the periurban villages that lost both land and water sources located within their periphery in this process are GWS and NCR channels.

The GWS and NCR channels feed the Basai WTP and the Chandu Budhera WTP, respectively. Then, the treated water from these WTPs is distributed to different parts of the city and supplied for different end uses for domestic and industrial purposes. At a WTP, the raw water is made potable up to the standards of safe drinking water by pre-chlorination, primary treatment, and filtration. Quality control is assured through laboratory testing at the WTPs.

Table 4 : Water treatment plants serving Gurugram city (existing and proposed)

S. No.	Name of Water Treatment Plant	Treatment Capacity (MLD)	Status/Targeted Year of Completion	Source of Water
1	Basai Water Treatment Plant	272	Existing	GWS Canal
		90	2024	GWS Canal
2	Chandu Budhera Water Treatment Plant	300	Existing	NCR Canal (Yamuna)
		300	2024	NCR Canal (Yamuna)
Total Augmentation		962		

4.2.2 Sewage Treatment Plants

The city has five major sewage treatment plants (STPs), of which three are in Dhanwapur and two in Behrampur as shown in Table 5.[41]

[41] GMDA. (2020, July 5). Comments on Final report of the Yamuna Monitoring Committee dt 29.6.2020. Retrieved from National Green Tribunal: https://greentribunal.gov.in/sites/default/files/news_updates/Comments%20on%20final%20report%20submitted%20by%20YMC%20in%20OA%206%20of%202012%20%20titled%20Manoj%20Mishra%20Vs.%20Union%20of%20India.pdf

Table 5: Sewage treatment plants in Gurugram city as of 2019

S. No.	Name of Sewage Treatment Plants	Capacity (MLD)	Department
1	Dhanwapur- STP I	68	Haryana Shahari Vikas Pradhikaran
2	Dhanwapur- STP II	50	Municipal Corporation of Gurugram
3	Dhanwapur- STP III	100	
4	Behrampur- STP I	120	Haryana Shahari Vikas Pradhikaran
5	Behrampur- STP II	50	
Total Capacity		**388**	

As of now, sewage from Sectors 1–57 goes to both Dhanwapur STPs and Behrampur STPs, while waste from Sectors 58–80 goes to Behrampur STP. In Dhanwapur, Haryana Shahari Vikas Pradhikaran (HSVP) runs one STP and the other is managed by Municipal Corporation of Gurugram (MCG). Also, HSVP runs another STP in Sector 48. Besides, there are 24 more small STPs installed at different places in the city. The Sectors between 99 and 115 do not have an STP for their waste and are not connected to the master sewage line either.

Furthermore, private developers can install separate STPs in their respective premises by taking construction licenses from the town and country planning department. However, random checks by officials found that a number of such developed sites have not installed STPs or are not using it and directly throwing sewerage water in the drain thus polluting it.

The treated effluents from STPs are disposed of into an unlined drain which travels about 8 km to meet the Najafgarh drain in Delhi. Here, they get mixed with untreated sewage discharged from the Khost drain, the Badshahpur Nullah, drain nos 1 and 2 from Gurugram, and several other drains falling in from Delhi, before meeting the river Yamuna.[42]

4.2.3 Water meters

Water metering is the process of measuring water use. It helps in cutting losses due to theft and ageing infrastructure and also makes the end user to use water judiciously. More the coverage of metered water connections, more efficient is the revenue collection by the municipality. Due to its numerous benefits, water meter installation is increasing in Indian cities both by municipalities and private entities.

As of 2007, there were 27,758 connections in the Gurugram city, of which about 10,729 (about 38%) were metered as shown in Table 6.[43] In other words, about 61% of the connections were paying water charges on flat rates basis. Due to inadequate metered connections, resulted revenue collection for the water supply department was very low. Also, the high number of unmetered water connections further led to non-judicious use of water.

[42] CSE India. (2012). Excreta Matters Vol. 2. Gurgaon The Water Waste Portrait. Retrieved from CSE India Web site: https://www.cseindia.org/excreta-matters-media-briefing-and-workshop-on-gurgaons-water-and-sewage-4035

[43] CSE India. (2012). Excreta Matters Vol. 2. Gurgaon The Water Waste Portrait. Retrieved from CSE India Web site: https://www.cseindia.org/excreta-matters-media-briefing-and-workshop-on-gurgaons-water-and-sewage-4035

Recently in 2019, MCG expanded their water connections to 36,000. In 2020, the number increased to 76,000. In order to overcome the shortage of water meters in the city, MCG had started a drive to install water meters in all zones of the city, however, only about 20% have been installed till November, 2020. This investment in installing smart water meters was done to monitor, measure, and manage activities across its network covering both commercial and residential sites. The objective is to encourage customers to reduce consumption levels and ensure continuous water supply.

Table 6 : Water meter connections in the Municipal Corporation of Gurugram's limits

S. No.	Year	No. of Connections	No. of Metered Connections	No. of Unmetered Connections	Ratio of Metered to Total No. of Connections (in %)
1	2007[44]	27,758	10,729	17,029	38.6
2	2019[45]	36,000	-	-	-
3	November 2020[46]	76000	15,200	60,800	0.2

4.2.4 Water quality of waterways carrying waste water

Gurugram comprises Najafgarh *jheel* along with other small streams. Najafgarh *jheel* is the biggest natural water reservoir, rainwater catchment area, and groundwater recharger for both Delhi and Gurugram. It has been slowly destroyed over the years due to poor policies and planning. Once fed by the Sahibi *nadi* and storm water runoff from surrounding areas, the Najafgarh *jheel* was vastly spread across 300 m^2. But now it is fed primarily by waste water from the Badshahpur drain, Outfall drain No. 8, and rainwater in monsoons.

The water of the Najafgarh *jheel* now comprises largely sewage from the drains of surrounding urban sprawl with the bulk of it being disgorged by the Badshahpur drain flowing through Gurugram. The major factors for its pollution are untreated domestic waste water discharge into the *jheel* due to inadequate sewerage system (including pumping stations) and sewage treatment capacity. The Sahibi canal on the other hand has now transmogrified into the Najafgarh *nala*, which receives its own share of waste water from a multitude of drains on Delhi's side. The pollutants from the *jheel* are leaching into the soil and also contaminating the aquifers. Furthermore, the *jheel*'s ability to recharge aquifers has been severely compromised. As a result, water woes of residents of south-west Delhi and Gurugram have intensified as they have limited access to piped water and are heavily dependent on groundwater. To add to this, Delhi had constructed an embankment on its side of the *jheel* after the floods of 1964, depriving its arable lands of the regular inundation and recharge cycle.

As it can be seen, the water quality of the *jheel* in Gurugram has degraded and is in need of immediate interventions. This would require a detailed study to fill in the gaps and generate solutions to improve the quality of these water bodies.

44 CSE India. (2012). Excreta Matters Vol. 2. Gurgaon The Water Waste Portrait. Retrieved from CSE India Web site: https://www.cseindia.org/excreta-matters-media-briefing-and-workshop-on-gurgaons-water-and-sewage-4035

45 Kachhwaha, R. (2020, November 18). Gurgaon News: Bill coming with penalty, get water meter installed soon. Retrieved from The Indian Paper: https://www.theindianpaper.com/gurgaon-news-bill-coming-with-penalty-get-water-meter-installed-soon/

46 Kachhwaha, R. (2020, November 18). Gurgaon News: Bill coming with penalty, get water meter installed soon. Retrieved from The Indian Paper: https://www.theindianpaper.com/gurgaon-news-bill-coming-with-penalty-get-water-meter-installed-soon/

4.3 Inferences

Surface water source

- Looking at the last decade's data, it can be concluded that the region is going to experience an unpredicted pattern of rain spell over the coming years due to rapidly changing climate. Thus, it would be difficult to predict the rainfall intensity and period. Further, due to poor rainwater management by authorities accompanied by intense concretization and groundwater contamination, this shall lead to continuous loss of water levels in streams and ponds, making them disappear soon. Therefore, the authorities would have to emphasize on tapping alternative sources of water. This includes treated STP water and adoption of water-efficient technologies to cope up with the challenges of water scarcity that could be faced in the future. Adaptation strategies would also be required to avert the rising flood risk due to excessive rainfall.

Groundwater source

- Over exploitation of groundwater sources to meet the growing water demand has resulted in depleting water table in Gurugram. It is analysed that if the built-up expansion is not controlled and water flow is not properly managed, the groundwater levels and water quality will keep on decreasing in near future. In addition, cultivation of water hungry crops like paddy and sugarcane in certain regions of the district is also responsible for a continuous decline in groundwater level. All these factors have resulted in declining water table in Gurugram, which has now become a serious threat in the regions' socio-economic development. In future, if precautions are not taken to reduce the use of groundwater, then the city is going to face the problem of water scarcity.

Water metering

- It was analysed that the expansion of water connections by MCG in Gurugram had been extremely slow until 2019. This resulted in poor coverage of water metre connections. Further, to overcome this issue, in 2019, authorities proposed to install water meters across the city. Currently, they are in the process of installing the meters. This shall help in efficient monitoring of water use and losses, thus making a significant step towards building a water-secure future.

Water Quality of Waterways Carrying Wastewater

- The quality of Najafgarh *jheel* in Gurugram is in deteriorating state due to discharge of untreated domestic sewage into it and encroachment of catchment area for developing housing infrastructure.

5

POTENTIAL RISKS IN WATER MANAGEMENT

5.1 Urban Water Cycle

Water is continuously cycling around, through and above the Earth in a natural water cycle that has existed for billions of years. As water moves between the land, ocean, rivers, and atmosphere, it changes from solid to liquid to gas. This natural water cycle is our planet's way of recycling water, and is essential for life on Earth. It can be defined as a conceptual model describing the storage and circulation of water between the biosphere, the atmosphere, the lithosphere, and the hydrosphere. The stages of natural water cycle include environmental evaporation, condensation, precipitation, infiltration, runoff, and transpiration. Water can be stored in the atmosphere, oceans, lakes, rivers, streams, soils, glaciers, snowfields, and groundwater aquifers. Circulation of water among these storage compartments is caused by processes such as evapotranspiration, condensation, precipitation, infiltration, percolation, snowmelt, and runoff, which are also referred as the water cycle components.

The combined effects of urbanization, industrialization, and population growth affect natural landscapes and hydrological response of watersheds. Although many elements of the natural environment are affected by the anthropogenic factors with respect to pathways and hydrologic abstractions (or sources of water), the principal structure of the hydrological cycle remains intact in urban areas. However, the

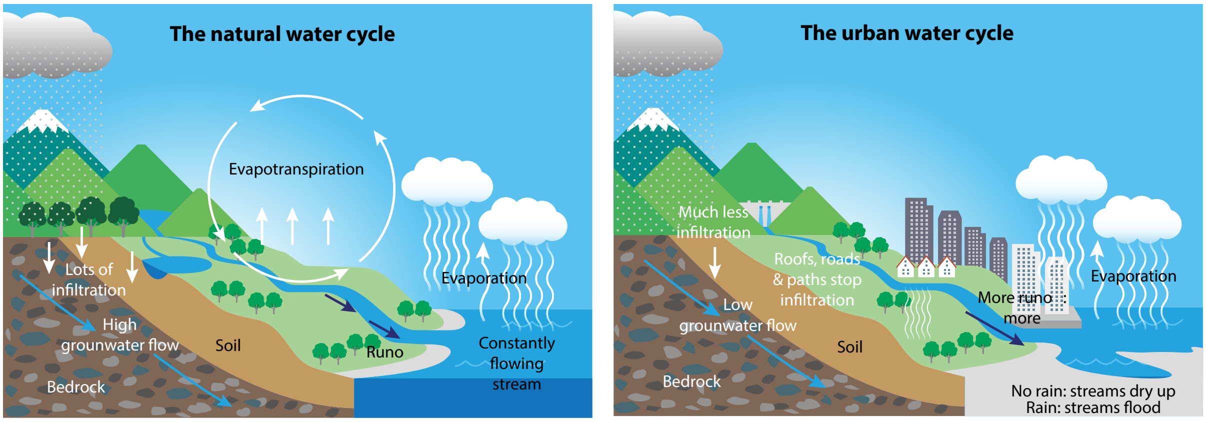

Figure 16 : Natural and urban water cycles

hydrologic cycle is greatly modified by urbanization impacts on the environment and the need to provide water services to the urban population. This includes water supply, drainage, wastewater collection and management, and beneficial uses of receiving waters. Consequently, the hydrological cycle has become more complex in urban areas with many anthropogenic influences and interventions. Thus, the resulting 'urban' hydrological cycle is termed as urban water cycle.

The main stages of urban water cycle for Gurugram city are as follows:

1. **Source:** The major source of water supply in Gurugram city is surface water, which is used to meet the domestic and non-domestic water requirements of residential, commercial, industrial, agricultural, and vegetation spaces. The major sources of water supply in the city are Gurugram Water Supply (GWS) and the National Capital Region (NCR) water supply channels that extract water from the Yamuna River.

   Groundwater is another important source for meeting the water supply demand of Gurugram. However, it is unregulated, resulting in its exploitation. The groundwater extraction is found to be carried out by private entities (housing societies, individual houses, etc.). Tankers are also found to be used during months of water scarcity.

   The Najafgarh *jheel*, which is located on the Delhi–Gurugram border, is shrunk and heavily polluted due to waste discharge.

2. **Treatment, storage, and distribution**: Water tapped from GWS and NCR water supply channels is transferred to the Basai and Chandu Budhera WTPs, respectively, which are built across the city for treatment. The treated water is then distributed and stored in several large water storage tanks. This treated water is then supplied from these water service reservoirs to the respective zones through a network of pipes of different diameters. There are eight water supply zones in Gurugram as shown in Table 7.[47]

Table 7 : Sectors in Gurugram district covered under different water supply zones

S. No.	Zone	Sectors Covered
1	I-III	1–57 (covers Gurugram city under MCG jurisdiction)
2	IV	58–67, 63A, 67A
3	V	71, 72, 72A, 73, 74, 74A, 37C, 37D
4	VI	68, 69,70, 70A, 75, 75A, 76–80
5	VII	81–98, ISBT/METRO
6	VIII	99–115

3. **Use:** The supplied treated water from water service reservoirs is then used for residential, commercial, public, agriculture and landscape purposes in the city. There are no heavy automobile industries inside the Gurugram city; therefore, industrial waste water has not been included in the water cycle of the city.

[47] GMDA. (2018, August 3). MINUTES OF THE FIRST MEETING OF THE EXECUTIVE COMMITTEE. Retrieved from GURUGRAM METROPOLITAN DEVELOPMENT AUTHORITY: https://gmda.gov.in/download.html?fid=50e75030-4e18-4d85-82d5-8da9abaea859&code=generalResource&key=attachment&identifier=1574941148059

4. **Collection**: The waste water from residential, commercial, and public spaces is then collected and conveyed by sewer systems to waste water treatment plants. Waste water from vegetation and agriculture land is collected and conveyed through storm water drains into nearby water bodies.

5. **Wastewater treatment and discharge:** The storm water drainage of Gurugram is divided into six zones having outfalls into the Najafgarh *jheel*, falling on the western part of the town and further amalgamating into the river Yamuna through the Najafgarh drain.

Waste water generated from the city goes into various public STPs for treatment through sewer drains, after which the treated waste water is discharged into drains carrying waste water. As STPs of the city run below their existing capacities, a significant amount of domestic and industrial effluents are being discharged into the natural drains and ultimately to the Yamuna River, making them heavily polluted. Furthermore, a number of sites developed by private developers have been found flouting the rules by not installing STPs or are not using the installed ones and directly throwing sewerage water into the drains.

6. Urban floods

In the last few years, The 'Millennium city – Gurugram' has been bearing the brunt of annual floods, disrupting lives and damaging property and infrastructure, as shown in Figure 17. A few hours of rainfall floods the streets of the city with the master drainage lines getting choked at critical points or burst at their seams during monsoon. Most of the rainwater flows back into Gurugram due to lack of outlet for it to release.

Figure 17 : (a) Submerged DLF Phase 1 underpass on Golf Course Road with rainwater collected almost till its roof; (b) a portion of caved in road near Gurugram's IFFCO Chowk; (c) a waterlogged four-way roundabout intersection on Golf Course Road and; (d) vehicles wading through rainwater, following heavy rainfall in the region in August 2020

The broken natural water body linkage and obstructions in the water flow in the city due to frantic construction in the last decade has resulted in increased frequency of urban floods coupled with inadequate flood preparedness. The identified reasons for the recurring floods in the Gurugram city are as follows:

a. **Disrespecting the natural topography:** The main cause of floods in the city can be attributed to avoiding the heterogeneous topography of the region while designing the city's drainage. On the one hand, there is no perennial river in the district and on the other, a number of barsati nallahs and hills can be found here, which cross the entire region and are blamed for floods during rainy season. However, the truth is that undulations, natural drainage systems, etc., have not been considered while planning the city. The city's topography has been continuously flattened to maximize the area of land for development. With no natural drainage, even a moderate rainfall causes flooding.

b. **Poor development and planning:** Gurugram has been time and again regarded as the ultimate planning disaster. City planners despite being aware of that Gurugram was the natural drainage for rainwater from Delhi and nearby areas, they constructed buildings and roads on water bodies, natural drains, and flood plains by filling them up with mud.

c. **Rapid urbanization and population boom:** There has been a population boom in recent years in Gurugram due to development of the IT sector and its proximity to the national capital. Figure 18 shows the drastic expansion of the built-up area in the city from 1986 to 2016 occupying the green cover and water bodies. This lead to the rampant construction of built infrastructure in Gurugram followed by rapid urbanization to meet the demands of the people flocking to the city in search of work from all over the country. This unplanned increase in the built infrastructure reduced the permeable surfaces in the city.

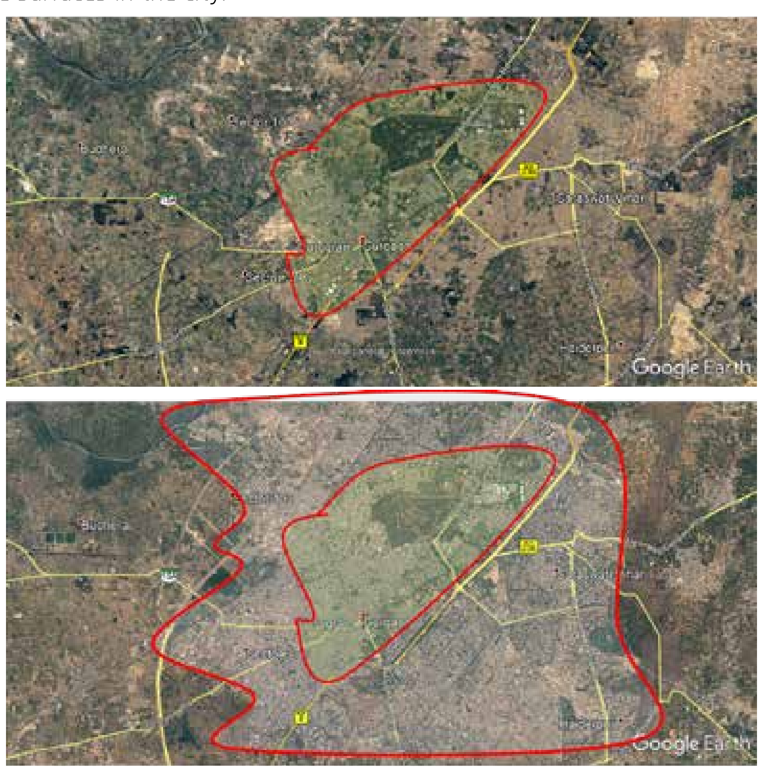

Figure 18 : Drastic expansion of built-up area over green cover and water bodies in Gurugram city from 1986 to 2016

d. **Blocked natural drains, encroached water bodies, and destruction of traditional water control infrastructure:** Gurugram of the 1980s was a pristine landscape, dotted with '*jheels*', or water bodies in the low-lying areas. Now the city has morphed into a millennium city with its distinctive skyline of glitzy skyscrapers and glass-fronted offices and trendy shopping malls. The water bodies in the Aravallis were ideal to drain rainwater. Rapid urbanization through the 1990s and the turn of the new millennium led to blockage of natural drains in the region due to encroachment by builders and dumping of sewage, silt, and construction waste. A land revenue record from 1956 showed that Gurugram had around 640 water bodies, which has since whittled down to 251 in 2018-19. A 2014 report by the Delhi Parks and Gardens Society indicates that at least 200 water bodies out of 251 that existed in the city in the 20th Century have been encroached.

A few documented lakes, drains, and other structures that were instrumental in preventing water-logging in Gurugram and that have been slowly disappearing over the years are as follows:

- **Shrinking lakes and vanishing natural drains:** Mentioned in the Gazette of India (1883), Ghata Lake is a seasonal water body that covered almost 370 acres until the early 2000s. The natural lake could hold some 50 feet of water until a few years ago. But unfortunately, it has been converted into a dumping ground. This is even more shocking since the Ghata Lake bed serves as a floodplain for storm water drains – especially those that enter Gurugram from Delhi. Located in the Ghata village, this network, known as the Badshahpur drain (the most important drain in Gurugram city), aids the drainage around the city, especially during monsoon. However, with the lake reducing to less than 50 acres and poor maintenance of the drain, flooding is almost inevitable.

Figure 19 : Plan of Badshahpur drain starting at Ghata Lake and ending at Najafgarh drain

The Ghata Lake also recharges groundwater, something Gurugram is quickly growing short of. At the same time, the Najafgarh *jheel*, which is another prominent water body for the region, has been continuous shrinking due to over concretization (covered in Chapter 4, Section 4.2.4).

Figure 20 : Dried Ghata lake (left) and shrunked Najafgarh lake (right) in Gurugram

- **Bundhs (traditional dams):** Gurugram's old survey maps that date back to the 1970s show that the area had several natural drainage lines and channels. Also, there were small dams in Gurugram. Most of them existed in areas such as Nuthupur, Wazirabad, Ghata, Manesar, and Jharsa. But with increased urbanization and construction of roads, these seem to have disappeared over time resulting in flooding of the Golf Course Road and its neighbouring areas. Reports state that there were at least 118 bundhs in Gurugram-Faridabad area. But much information about them has ceased to exist over time. These small channels are helpful because they break the flow of water into smaller rivulets. Traditionally, they were also used to irrigate agricultural fields and recharge groundwater levels.

Figure 21 : Dilapidated traditional dams (bundhs) in Aravallis

e. Climate change: Due to climate change and rising temperature, the number of rainy days has decreased but the intensity of rainfall has increased. It has become evident that short bursts of intense rainfall are expected to be more common across India and will continue to result in extreme weather events in coming years.

The urban water cycle of Gurugram city is shown in Figure 22.

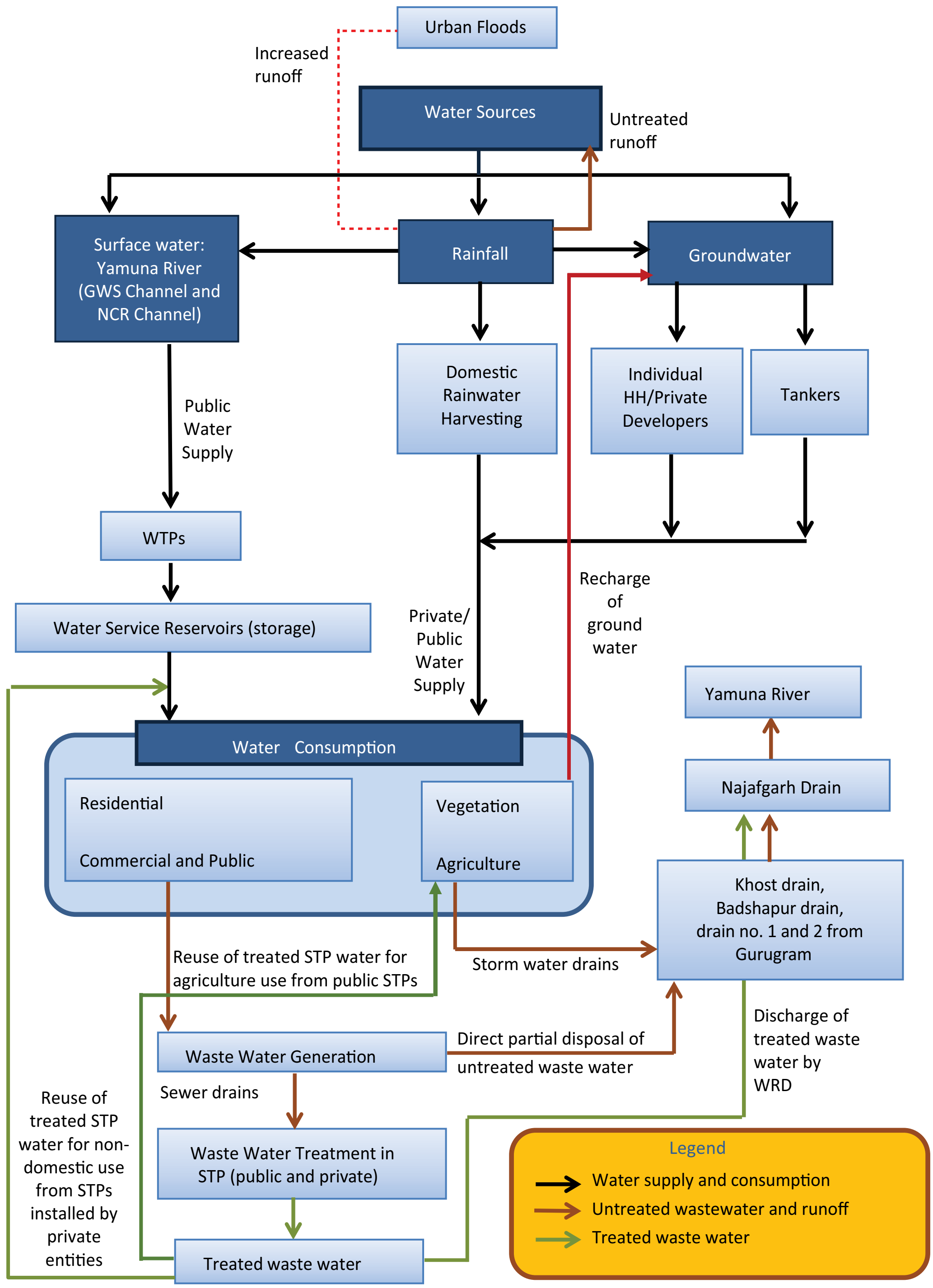

Figure 22 : Urban water cycle of Gurugram city

5.2 Water Demand and Supply

The sustainability and quality of water in any city is closely linked to the quantity and quality of the basic infrastructure facilities that support it.

Water demand is generally classified as domestic water demand and non-domestic water demand. Domestic water demand covers the use of water for drinking, washing, bathing, flushing, etc. Non-domestic water demand includes the water demand for industries and other uses.

In the study, the researchers considered only the domestic water demand (for residential, commercial, institutional, and other public spaces) of Gurugram city for computation.

Table 8 shows the water demand and supply statistics for 2011 and 2019. Quantities were listed considering the water supply for 2011 and water demand for 2019. Some of the attributes for 2019 such as population and total water demand were computed by the author due to unavailability of data. Taking this as reference, water demand estimation for 2025 was computed.

Table 8 : Water supply and demand statistics for 2011, 2019, and projections for 2025.

Parameters	2011	2019
City population	977,337[48]	2,300,556[49]
Per capita average water supply (lpcd)	136[50]	200 lpcd[51]
Total water supply (MLD)	132.9[52]	450[53]
Actual water demand of city (MLD)	195.4[54]	460.1[55]
WTP installed capacity (MLD)	273[56]	572[57]
Waste water generation (MLD)	(80% of 195.4) = 156.3	(80% of 460.1) = 368
STP installed capacity (MLD)	148[58]	388[59]

[48] District Census Handbook Gurugram, Village and Town Directory, Census of India 2011, Haryana

[49] Computed by author by considering exponential growth in population

[50] Sub-regional Plan for Haryana Sub-Region of NCR-2021, Chapter 9 – Sewerage, Solid Waste Management, Drainage and Irrigation

[51] National Building Code (NBC) 2016, IS1172 (1993). Code of basic requirements for water supply, drainage and sanitation, for communities with more than 1 lakh population and full flushing systems

[52] Computed by author by considering exponential growth in population

[53] Kumar, A. 2019. Is the Millenium City fast running out of water? The Hindu, June 24, 2019

[54] Computed by taking 200 lpcd water demand from National Building Code (NBC) 2016, IS1172 (1993). Code of basic requirements for water supply, drainage and sanitation, for communities with more than 1 lakh population and full flushing systems

[55] Computed by taking 200 lpcd water demand from National Building Code (NBC) 2016, IS1172 (1993). Code of basic requirements for water supply, drainage and sanitation, for communities with more than 1 lakh population and full flushing systems

[56] CSE India. 2012. Gurugram: The Water Waste Portrait. Excreta Matters Vol. 2

[57] Jha, D. 2019. Work to double treatment capacity of Chandu Budhera plant to start March 10. Gurugram News, March 4, 2019

[58] Sub-regional Plan for Haryana Sub-Region of NCR-2021, Chapter 9 – Sewerage, Solid Waste Management, Drainage and Irrigation

[59] Comments on final report of the Yamuna Monitoring Committee dt 29.6.2020, NGT

Parameters	2011	2019
Parameters	**2025**	
City population[60]	43,71,939	
Total domestic water demand (MLD)[61]	874.3	
Per capita average water demand (in lpcd)[62]	200	
WTP installed capacity (MLD)[63]	962	
Waste water generation (MLD)	(80% of 874.3) = 699.4	
Required STP installed capacity (MLD)[64]	Increase to 734.37 MLD	

Past scenario in 2011

1. In 2011, the average per capita water supply in the city was 136 lpcd, which is less than the suggested standard of National Building Code of 150–200 lpcd.
2. The total water supply to the city was 132.9 MLD, which was lower than the total water demand which was 195.4 MLD (considering average water demand of 200 lpcd).
3. The water treatment plants were found to have adequate capacity (273 MLD) according to the water demand by the population.
4. The quantity of waste water generated in CMA was around 156.3 MLD. Out of this, approximately around 148 MLD was treated in the treatment plants. Remaining wastewater was being let into the streams, thereby contaminating them. This reflected the scarcity of STPs in the city.

Existing scenario in 2019

1. Due to significant increase in population, the total domestic water demand of the city increased to 460.1 MLD from 195.4 MLD in 2011.
2. The total water supply to the city was 450 MLD, which was lower than the total water demand, which was 460.1 MLD (considering average water demand of 200 lpcd).
3. To meet the increasing water demand, the installed capacity of WTPs was increased to 572 MLD. This treatment capacity was found to be adequate for the population, having total domestic water demand of 460.1 MLD.
4. The quantity of waste water generated in Gurugram city increased to 368 MLD. The installed STP capacity was also increased to 388 MLD. This was found to be sufficient to treat the total sewage generated in the city.

Expected scenario in 2025

1. Gurugram city is going to experience a rapid rise in population by 2025 to stand at around 4,371,939. Thus, the water demand of the city would increase to 874.3 MLD.

[60] Computed by author by considering exponential growth in population
[61] Computed by author by considering exponential growth in population
[62] National Building Code (NBC) 2016, IS1172 (1993). Code of basic requirements for water supply, drainage and sanitation, for communities with more than 1 lakh population and full flushing systems
[63] Jha, D. 2019. Work to double treatment capacity of Chandu Budhera plant to start March 10. Gurugram News, March 4, 2019
[64] Computed by author, required capacity is 5% (peak load) of waste water generation in addition to waste water generation capacity

2. The installed capacity of WTPs is proposed to increase to 962 MLD by 2025, which is found to be adequate for the population, having total domestic water demand of 874.3 MLD in 2025.
3. The quantity of waste water generated in Gurugram city is estimated to increase to 699.4 MLD in 2025. The current STP infrastructure (388 MLD installed capacity) would fail to treat the waste water to be generated, thus would pollute the natural water ways. The installed capacity would have to increase to 734.37 MLD.

5.3 Inferences

Groundwater

Rapid real estate development in Gurugram has outpaced both city planning and public infrastructure related to water supply, with rampant increase in groundwater extraction. Along with this, rapid population growth in the city has led to an imbalance between annual groundwater extraction and recharge levels, which if not controlled is going to worsen the situation in near future.

The actual number of illegal bore wells is unknown which makes it difficult to monitor the illegal extraction and control it.

Water treatment plants

The installed capacity of WTPs is proposed to increase to 962 MLD, which is estimated to be sufficient for the population that would have total domestic water demand of 874.3 MLD in 2025.

Sewage treatment plants

As of 2019, the current number of STPs in the city and there capacities were found to be sufficient to treat the total sewage generated in the city. However, the quantity of wastewater generated is estimated to increase to 699.4 MLD in 2025. Thus, the current STP infrastructure (388 MLD installed capacity) would fail to treat the wastewater that would be generated, thus polluting the natural water ways. Hence, the installed capacity would have to increase to 734.37 MLD.

6 RECOMMENDATIONS FOR SUSTAINABLE WATER MANAGEMENT

To achieve sustainability in water management in cities, it becomes imperative to study and analyse all the aspects related to it. It should cover both micro-scale green development measures such as rainwater harvesting, macro-scale water source management, water/wastewater/storm water infrastructure, and landscape preservation. This is known as integrated urban water management (IUWM), a water management approach that has become quite popular in the last decade. IUWM is based on designing solutions that are not isolated in nature but are interconnected water management clusters. The approach has been followed in this study to recommend the most appropriate and practical measures to the identified potential risks, as discussed in the previous chapter, for water management in Gurugram city.

6.1 Upgradation in Urban Water Cycle

A suggestive upgradation model of the water cycle for the Gurugram city is shown in Figure 23, where the lacunas of existing water management of the city has been tried to fill. This is based on the projections computed for 2025 in the last chapter.

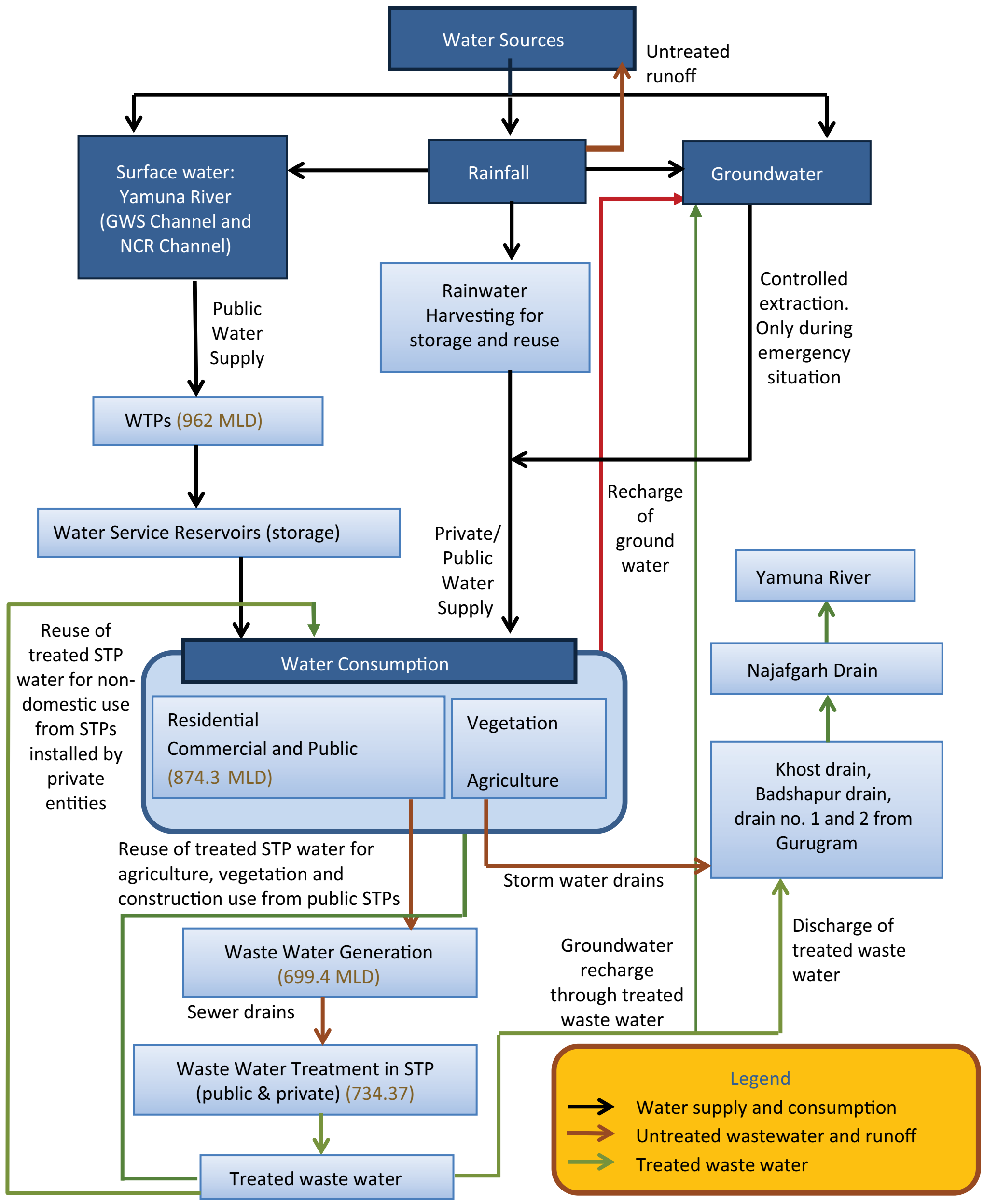

Figure 23 : Upgraded urban water cycle of Gurugram city for 2025[65]

1. Identification and filling up of data gaps

While finding the best solutions for poor water management in Gurugram city, the study encountered various hindrances due to non-availability of data. Thus, research should be conducted to collect appropriate data to fill the missing gaps. For example, there is a dearth of data on groundwater availability and its extraction for Gurugram city, thus, challenging the regulation of groundwater and resulting in its exploitation. Therefore, identification of such gaps related to water data in the city should be carried out and required measures should be taken for data generation.

[65] Projected values in the upgraded water cycle have been computed and shown in Table 8

2. **Modifications in existing water infrastructure**

- **Water transmission and distribution**
  - Minimizing the distribution and transmission losses of water by refurbishing the old water supply network and covering the newly added areas.
  - Ensuring equitable distribution of water supply in all areas of the city with 24X7 pressurized water supply.
- **Water treatment plants**

There is no need to enhance the treatment capacity of the existing WTPs till 2025. The proposed increase in the capacity of WTPs is 962 MLD from 572 MLD (as of today) would be sufficient for the population that would have total domestic water demand of 874.3 MLD in 2025.

- **Sewage treatment plants**

Increase the capacity of public STPs (~734.3 MLD) to treat the entire sewage generation of the city in 2025. The quantity of waste water generated is estimated to increase to 699.4 MLD in 2025, which the current STP infrastructure (388 MLD installed capacity) would fail to treat.

The provision of a city-wide sewerage network (including slums and suburbs) covering each and every household is required, which shall ensure complete sewage collection.

- **Water metering**

Hundred per cent coverage of metered connections across the city is required to ensure fair revenue collection and controlled water usage.

- **Water quality of waterways carrying wastewater**

Zero discharge of untreated waste water from the city into the natural drains, local ponds, and lakes should be ensured to protect them from polluting and to maintain their natural good quality. Complete waste water from Gurugram city should be treated in STPs, ensuring there is no direct untreated waste water discharge into the water bodies.

3. **Potential water sources for use in future**

Gurugram city is located in a semi-arid region with no major lake or river in its vicinity. The ones that existed such as Najafgarh Lake and Ghata Lake are on the verge of drying up due to its poor management amidst rapid urban sprawl in the city. The only stream found in the city is Sahibi River. It is a tributary of Yamuna, which originates from the Aravalli range in Rajasthan and flows through west and south Haryana into Delhi, known as Najafgarh drain. The tributary is heavily polluted due to excess sewage and other waste discharge. Nearly 50% of the city's water requirement is met by Yamuna's water that comes via canals through water treatment plants. While the remaining water requirement is met by groundwater, which due to rampant exploitation has been bearing a deteriorated quality and lowered levels. This has increased the water availability concerns in the city that faces frequent water shortage periods. Therefore, it is more essential to identify and assess the potential water sources in the region. There are potential alternative water sources which if tapped efficiently could help in overcoming the water scarcity issue of Gurugram.

- **Restoration of degraded water bodies in Gurugram**

Revival of water bodies can help in adding potential freshwater sources for the region. Over the years due to rapid urbanization these lakes and ponds were degraded and lie in a pathetic condition due to which the groundwater availability has gone down.

Recently, a positive step towards this was taken in 2019, when the Haryana Government formed 'GuruJal' – an integrated water management initiative, which aims to address the issues of water scarcity, groundwater depletion, flooding, and stagnation in the Gurugram district. The project started with restoration of water bodies in the region with an ambitious target of reviving 250 water bodies such as Ghata lake, Kasan and Khaintawas ponds, etc., by 2022. At present, revival of 25 ponds is ongoing. In these 25 ponds, 13 are in the possession of MCG and 12 are owned by the Panchayati lands.[66] The initiative would require a study of all the documented water bodies to check their revival potential and use as a drinking water source.

Encroachment of agricultural/vacant land around these water bodies should be stopped as these areas play a crucial role in providing water for irrigation and recharge structures.

Artificial water bodies/reservoirs could also be constructed which shall not only increase the freshwater availability but also enhance the groundwater table in the region.

Figure 24 : Encroached catchment areas of ponds in Ghata, Jharsa, and Sukhrali by infrastructure projects and illegal settlements, dumped with municipal sewage

[66] Ohrie, P. (2020, January 7). Gurujal set to revive three water bodies by February in Gurugram. Retrieved from Millenium Post: http://www.millenniumpost.in/delhi/farmers-debate-govts-option-cops-discussincreased-surveillance-and-alternate-routes-429799?infinitescroll=1

- **Groundwater sources**

The concerned authorities should ensure controlled groundwater extraction in the region to keep a check on its level and quality by studying it on regular intervals. In fact, groundwater use should be completely restricted citing its decreasing levels and should only be used during emergency times when the water availability falls short.

- **Treated waste water source**

The treated water from STPs can be a potential resource for saving groundwater and water fetched from the Yamuna River. Thus, treated water from STPs, which is being discharged into drains, could be reused for non-domestic purposes. This shall also help in reviving the heavily polluted Najafgarh drain and its subsidiaries.

To carry out its successful implementation, installation of STPs and reuse of treated sewage for flushing, gardening, construction, etc., in upcoming residential housing and commercial projects should be promoted.

To ensure that 100% no direct untreated waste water discharge gets into the water bodies in Gurugram, the capacities or number of STPs should be increased, if required.

- **Rainwater harvesting systems:**

The use of rainwater harvesting systems for storage and reuse of water should be promoted. This could be done by promoting the installation of localized rainwater storage systems at an individual level in new buildings for domestic purposes. As this will help in reducing the potable water supply and runoff, this shall also contribute in the reduction of water-related infrastructure cost and water bills.

Localized tapping of rainwater by developing human-made water bodies should be done. Channelizing of storm water through drains before merging with the main drain takes a considerable amount of time. As a result, the water gets evaporated or contaminated along the way. Instead, this rainwater could be fully utilized by these local human-made water bodies to improve the groundwater recharge. Also, this reduces groundwater contamination due to natural percolation of rainwater. Treated waste water from STPs could be discharged into these local water bodies to enhance the groundwater levels.

4. Implementation of flood resilience measures

As explained in Section 5.1, the frequency of floods has increased in Gurugram over the last decade, which leads to havoc during monsoon. Thus, there is a need for designing and implementing flood resilience measures to reduce damage caused by recurrent floods in the region especially during monsoons, which are as follows:

- **Accounting natural topography in city planning**

The proposed and upcoming development plans, housing schemes, etc., in Gurugram must consider the natural drainage profile of the city. Also, any project that blocks the natural drainage should not be approved, unless there is an alternate drainage plan. Topographical conditions of the area and the natural drainage should be respected and preserved in all development projects of any city.

- **Reducing concretization and increasing permeable spaces**

The city has been concretized right from the roads to drains and from public spaces to playgrounds. For most of the people living in urban areas, the solution to most problems lies in more construction, which means using building materials such as bitumen, steel, and cement. In most of the cases, it aggravates the problem instead of solving it. Consequently, water stays on impermeable surfaces and with encroached and blocked drains, it remains stagnant for hours and days in the city. Waterlogging was not an issue in Gurugram till this millennium. The city had enough porous spaces for water to seep through. Hence, the city needs to have permeable spaces which can easily be done by turfing, using interlocking tiles, etc.

- **Developing resilient infrastructure and built environment**

There is growing evidence that changes in atmospheric conditions have resulted in and will continue to result in extreme weather events. While climate change is a complex subject that is being debated and addressed at international levels, many resulting issues, such as downpour and deluge, are crippling our cities. Therefore, cities need to plan for resilient infrastructure and the built environment.

For example, in Gurugram, a slight downpour causes a failure of traffic signals; however, the city can overcome this by investing in all-weather signals. Though they are costly, their impact will also be very high. Similarly, innovations such as porous bitumen should also be tested, especially in parking areas.

Unnecessary concretizing of the city's elements, such as footpaths, drains, etc., should be stopped. The city should invest in green and resilient infrastructure and projects such as bio-diversity parks should not only be preserved and protected, but also scaled-up.

5. Capacity building and training

Capacity building and training of existing and new recruits of government staff, municipalities, boards and other parastatal working in water supply and its management in the city should be done to strengthen work practices and thereby improving their overall performance.

6.2 Stakeholder Engagement for Sustainable Water Management

An effective implementation of the measures discussed in the last section to enhance water sustainability in the city requires a robust stakeholders' involvement. This is important as it ensures that the water management plans for the city takes into consideration the local requirements, interests, and experiences of all the stakeholders. It bridges the gap between experts, implementers, and policymakers. Also, to make a sustainable change with respect to water management, it is essential that all the stakeholders cooperate and collaborate with each other while carrying out their responsibilities towards water management efficiently. Table 9 comprises the ways by which the stakeholders' participation could be enhanced to ensure sustainable water management in the city.

Table 9 : Stakeholders and their responsibilities to ensure sustainable water management

S. No.	Stakeholders	Roles and Responsibilities
International Level		
1.	International, regional and multilateral organizations	◆ Provide funds for city water management projects and conduct promotion programmes ◆ Provide technical assistance and documentation ◆ Create knowledge exchange platforms
National and State Level		
2.	National and state governments	◆ Develop policies and legal frameworks that enable and strengthen sustainable water management in cities
3.	Standardization bodies such as Bureau of Indian Standards, CPHEEO, etc.	◆ Develope new standards related to water consumption and management w.r.t to changes in technology of the water infrastructure ◆ Identify gaps and renew the standards

S. No.	Stakeholders	Roles and Responsibilities
City Level		
4.	Urban local bodies, municipalities, city administration, and state water regulatory authorities	• Promote and design a roadmap to follow sustainable water management initiatives and specific solutions for its implementation • Enhance citizen engagement and sensitize them with the benefits of sustainable water management practices • Strengthen monitoring and tracking of city services by defining key performance indicators (KPIs) and evaluating them
5.	City services companies	• Provide expertise to collaborate with municipalities and information and communication technology (ICT) companies to develop integrated collaborative models for smart water management • Develop smart and KPI-based city service models
6.	Utility providers	• Deploy sustainable water management practices such as smart water management services
7.	ICT companies (start-ups and software companies)	• Provide the ICT infrastructure to support and integrate smart water management services • Provide technical solutions through research and innovation • Develop financially sustainable business models to enable smart water management implementation
8.	Urban planners	• Inclusion of water management plan in studies and city planning processes as a part of a broader approach • Give guidance to concerned stakeholders on city planning needs
9.	Non-government organizations	• Raise awareness regarding citizen concerns related to water availability • Increase public awareness on urban water issues
10.	Academia, research organizations and specialized bodies	• Conduct research and advice and assist city managers and policymakers on the measures to achieve sustainable urban water management in the city • Drive research and innovation in the city's water management field
Building/Site Level		
11.	Citizens and citizen related organizations like RWAs	• Participate actively in the city's urban water management projects • RWAs and end users should take necessary documents from the facility manager, such as plumbing, WTP drawings, AMC, etc., during handing over the property • Practice water-saving measures at an individual level
12.	Construction sector	• Refer section 6.2.1
13.	Industries	• Adopt Integrated Water Management Framework (Refer Section 6.2.2)

Disclaimer: This is an indicative list and not an exhaustive list.

6.2.1 Role of construction sector in ensuring sustainable water management

Scarcity of water has hampered various industries including the construction industry in North India in some way or the other. Water is needed in large quantities in the construction industry for various purposes. Reducing water consumption and improving water efficiency in buildings is a major step towards sustainable water management. Key opportunities to reduce water use on-site are as follows:

- Use of gunny bags, ponding technique, or curing compound.
- Use water-reducing admixture in concrete mix.
- Meter and monitor water consumption during construction. Tracking of water usage over time provides information of where it is being used and helps in identifying leaks or inefficiencies.
- Use of treated wastewater and/or captured storm water, to offset main supplies or tanker water supplies. Abstracted water would incur lower cost and reduce the need to treat water that does not have to be of a potable standard.
- Using water-efficient taps and fixtures in site offices delivers quick savings with high returns on investment.
- Finalize a water-efficient plant and equipment when discussing options with suppliers/subcontractors to ensure water efficiency is construction projects. Some key considerations are shown in Table 10.

Table 10 : Water-efficient plant and equipment

S. No.	Plant	Saving	Considerations
1	Dust suppression (general)	~90%	◆ Avoid high capacity 'rain guns' and hoses ◆ Choose misting/atomizing systems, which use less water and are more effective ◆ Consider using non-potable water (ideally rainwater harvested on-site)
2	Dust suppression (vehicles)	~90%	◆ Avoid using high-pressure water jets diffused by a splash plate ◆ Choose misting/atomising systems, which use less water and are more effective
3	Road sweeping	~30%	◆ Avoid using an open hose ◆ Ensure that operators are trained in water-efficient practices, vehicles have adjustable spray bars/nozzles, and any stand-alone washers are of high pressure (low flow) with trigger controls ◆ Consider water recirculation systems
4	Wheel washing	~40%	◆ Avoid manual wheel washing (except when the need is very limited) ◆ Choose drive-on recirculating systems with a sensor-controlled shut off (where demand is on-going) ◆ Ensure that water top-up to settlement tank is controlled (e.g., a float valve), supply pressure reflects site conditions, and the filter in the settlement tank is kept clean to avoid overflows

6.2.2 Role of industries in ensuring sustainable water management through integrated water management framework

Given the state of resource availability, use, and competing demand, the critical challenge lies in foresight of the issues and preparedness to respond to them for sustainable business operations. The management of water resources need a multifarious approach for not only improving the in-plant water-use efficiency, but also to look beyond the paradigm of *in situ* water management. This involves critical extrinsic factors such as source vulnerability, climate, allocation, access, competing use (irrigation, domestic, and industrial), regional water quality and availability, regional policies and regulations, socio-economic setup, and importantly, the stakeholders (government agencies, local community, etc.) including the industrial value chain. With growing demand, competing use, and scarcity scenarios in the region, there may not be enough water to meet societal, environmental, agricultural, or industrial needs. Besides, with the growing awareness, industries have a reputational stake if perceived as mismanaging their water resources or impacting on others directly or indirectly. Thus, there is a need of a holistic approach to manage water resources. As a first step, an integrated water management framework is required along with responsive corporate water policies and programmes to respond to potential water-related challenges within and outside a plant's boundaries.

The following generic framework was developed for industries and businesses across the board who want to better manage their water footprint and ensure efficient water management.[67]

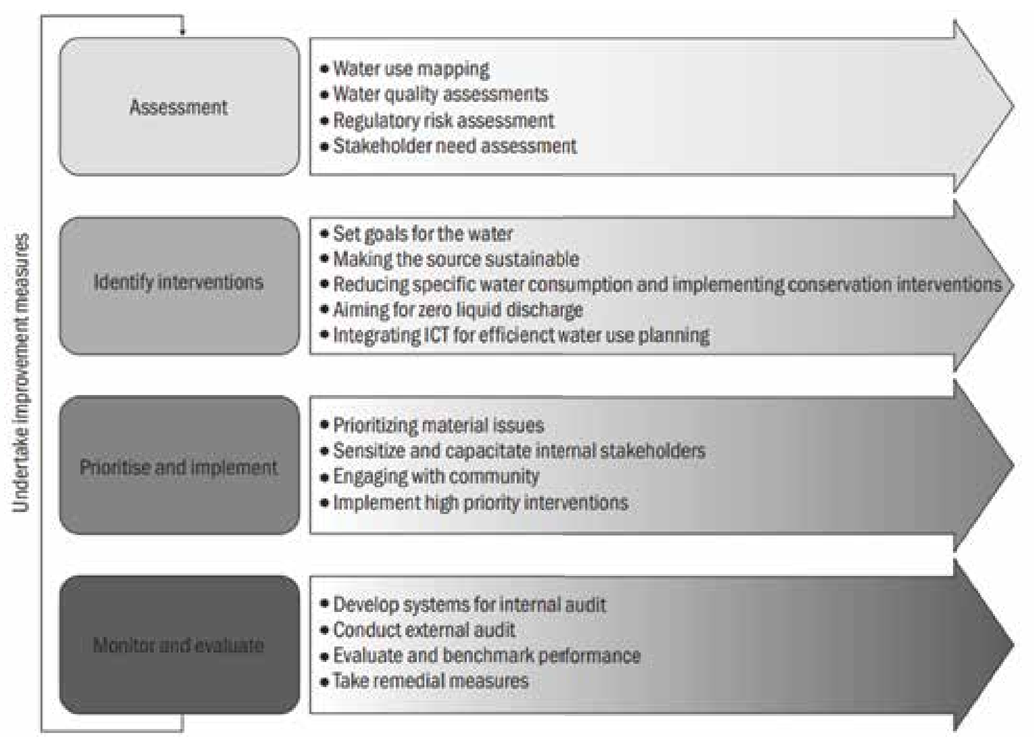

Figure 25 : Approach for institutionalizing an integrated water management framework

[67] Details available at http://cbs.teriin.org/pdf/researchreports/Integrated_water_management.pdf, last accessed on October 20, 2021

1. **Assessment**

- **Water use mapping**

To begin with, industries should map their water use, starting from the source to the end point, which is generally the discharge point. This should include all possible information related to the capacity, source, infrastructure type, age, leakage if any, and storage structures. Along with this, information related to water and effluent treatment plants of the industry, including the type of treatment options, capacity, O&M (Operations and Management) schedule, etc., should also be documented.

Identification of alternate sources of water for the industry and all the pertinent information related to the available sources of water should be done.

- **Water quantity and quality assessment**

Industries should document the overall water consumption in the industry, based on the inflow and outflow from the industry. Similarly, water quality of the inflow and outflow should be assessed and documented by the industries.

For a detail assessment, specific water use for various processes or product manufacturing should be assessed to understand the water cycle of the industries. Based on this, a baseline for water consumption should be established for the year of assessment and recorded properly. This would help in assessing the future water needs of the industry.

The water availability should be considered at the watershed level. The surface and groundwater availability in the watershed should be assessed. Also, future water availability should be considered while taking in to account the effects of climate change.

Besides, it is important to assess the water footprint of the industry. A water footprint is a way of assessing potential environmental impacts related to water. It also helps in identifying opportunities to reduce water-related potential impacts of products at various life-cycle stages, and with processes and organizations.

- **Regulatory risk assessments**

Industry should list down all the applicable regional regulatory and policy framework and programmes. Besides the applicable standards and norms specific to the industry, they should consider the applicable regional regulations, restrictions, notifications, as well as government policies and programmes cross-cutting various sectors such as water, land use, agriculture, urban/ rural development, industrial development, sensitive zones, environment and ecosystem, etc. Also, the effectiveness of the policies on groundwater extraction, wastewater disposal, and capacity building should be assessed.

- **Stakeholder need assessment**

Industry should assess their relationship with the following important stakeholders to understand their water related concerns:

Local communities: There are several areas of concern for a community when an industry is set up in their vicinity. Issues such as adequate availability of clean water for drinking, sanitation, and cooking are very important to be considered for the communities operating around the facility. Communities become non-cooperative if the industry operating in the region depletes or pollutes the groundwater table. Therefore, it is critical to gauge the needs of the local communities while engaging them for smooth operations of the organization.

Regulators: The regulators are also important stakeholders; therefore, it is quintessential for organizations to engage with regulatory bodies while staying abreast with the latest regulatory and compliance-related developments for the industry.

Other competing industries: It is important to build a rapport with the other competing industries operating in the same watershed and drawing water from a common source. The competition for water increases many-folds if all the industries are water-intensive units. Thus, there can be a decrease in the availability of water share. Also, due to the existence of industries in a region, the common source of water gets contaminated with untreated effluent from these establishments. If the source of water is groundwater for all industries in a watershed then the situation becomes more serious, as it is a limited source, and as per the hydro-geological set-up of the area, its yield can be a limiting factor.

Therefore, it is important to know the water demand, use, and discharge practises of the competing users in a common watershed, and accordingly, adopt sustainable practices.

2. **Identify interventions**

- **Source sustainability**

The most important aspect for a plant's operation is sustainability of the water source. The source should be able to provide good quality and quantity of water to sustain the plant's operation. Depending on the source type, a plant can take necessary actions to enhance its sustainability. Also it is important to know if the source is shared with some other user or not. If the source is shared by many stakeholders, then it is a common responsibility of all to protect the source and to enhance its sustainability. In this, industries can take a lead.

Industries should ensure that the source of water for them is well-maintained and all the important aspects including its level, quality, etc., are recorded regularly. An alternate source of water for the industries should also be identified and characterized as a contingency measure. An important exercise in this regard is to conduct a Source Vulnerability Assessment (SVA).

SVA is a systematic examination process to assess a water system's sensitivity to potential threats (un-checked exploitation, pollution, etc.). The assessment helps in identifying the crucial challenges to the system in managing risks that arise as a consequence of such threats. Usually, an assessment of this sort takes into account the water balance of the system at the watershed scale (water supply/allocation and demands), policies and legal frameworks to support water resources conservation and management, and the hydrological variations due to changing climate and other environmental factors.

3. **Reducing specific water consumption and implementing water conservation interventions**

Reduction of specific water consumption is very important to reduce the water footprint. This can be done by adopting various water conservation measures by following the priority order of potential options at the industry level. Eventually, this helps in reducing water stress at the watershed level as it reduces freshwater intake of industries. Specific water consumption level should be brought down using various techniques to a level that can be set as a benchmark for future reference of the industry.

Water audit is one of the key processes to be taken up by the industries to identify leaks, water flows, and then take necessary measures to reduce losses and increase efficiency. Regular water audits should be done by industries to ensure prevention and mitigation of leakages and unnecessary water loss.

Apart from reducing water loss, it is important to focus on the aspects of water conservation. Below are some of the interventions that can enable *in situ* and *ex situ* water conservation.

a. *In situ* conservation

Rooftop rainwater harvesting: It is both an economical and eco-friendly technique of collecting rainwater and utilizing it for immediate and future use. Thus, it helps in reducing stress on public water supply and other sources. The implementation of this intervention involves site assessment, estimation of rainwater harvesting potential, designing a rainwater harvesting system, implementation and operation and maintenance.

Wastewater recycling: This involves setting up of a system for recycling of wastewater generated in the industry through appropriate treatment methods. This water can be reused for different purposes in the industry. Wastewater recycling can be planned in a centralized or decentralized manner depending on site conditions. Recycling provides an opportunity for zero discharge or even positive water balance for the plant. Wastewater should be recycled at source to reduce pollution load at the effluent treatment plant (ETP), ensure material recovery and reduce treatment costs, besides reducing the overall water demand of the plant.

Reduction in leakages/losses and process optimization: Often a significant scope for potential water savings lies in optimization of water use in various processes such as cooling towers, boilers, etc. Besides, in many cases, leak detection coupled with, metering and regular water audits helps in reducing leakages/ losses in the network or process, thus, saving water and reducing freshwater intake.

a. *Ex situ* conservation

Watershed-level rainwater harvesting: This involves setting up of surface water harvesting interventions or watershed structures such as check dams, gabions, bunds, percolation tanks, storage ponds, etc. In addition to storing rainwater during monsoons, it helps in groundwater recharge.

Artificial recharge of groundwater: Water from surrounding streams and drains are collected through constructed streams, which further run through a human-made filtration system from where it flows into a shallow aquifer, thus, recharging the groundwater. There are several groundwater recharge technologies such as shafts, etc., that can be adopted.

- Zero liquid discharge

The effluent discharged from industries is equally or even more important factor than inflow to industries as it can be a challenge or an opportunity for water security. If discharged untreated, it can lead to pollution of water and land bodies, but if treated and reused it can decrease pressure on the existing water sources in a watershed. Therefore, it is important to ensure that a multi-stage ETP is installed in the industrial facility for treating the industrial waste so that rivers/water bodies remain contamination-free.

- Efficient water use planning

For effective water use, it is important to integrate ICT tools in planning, which includes Management Information System, Decision Support System, etc. An ICT system can be used for controls and monitoring. They can be simply put to use for avoiding water wastage and providing regular information for better management of the resource, automation of systems, etc. In addition, ICT is the driving force behind innovation, as its is helpful in transforming business models and value chains. With the growing technological advancements, economically feasible options are available. All the industries should include ICT tools for management of water resources in their plant.

2. Prioritize and Implement

- **Prioritizing material issues**

It is important for organizations to earmark and identify specific issues within the ambit of water management that are of higher relevance to them. After identification, organizations must be able to assign them priority levels according to their impact on the business. In this way, it becomes easier for organizations to identify higher priority tasks first, while being able to mitigate the risks associated with them.

- **Sensitize and capacitate internal stakeholders**

Engagement and involvement of employees is critical for the successful implementation of effective water management and conservation interventions. Employees must be sensitized and trained for the implementation of the measures.

- **Engaging with community**

One of the foremost elements of efficient water management planning involves engaging communities and other stakeholders regularly. All the water-positive actions taken up by industries should be showcased to locals and the responsibility of ensuring water security at the watershed level should be shouldered with them. It is important to return back to nature what is taken from, thus, the efficient use of water by avoiding losses and conserving water through different methods not only benefit the plant, but also the surrounding watershed.

- **Implementing high-priority interventions**

Once all the aforementioned issues are addressed, the highest priority interventions should be with the internal stakeholders and the community at large.

3. Monitor and Evaluate

After taking the necessary actions, it is important to monitor and evaluate the implemented actions regularly to learn from their benefits and weaknesses and to fix the issues, if any, on time. This helps in strengthening the system and understanding the overall benefits accrued by the industry.

It is suggested that industries can hold internal audits to evaluate the implemented plans twice a year as well as hold an external third-party assessment once a year. Evaluating and benchmarking the water performance on a regular basis is the key to a successful and integrated water management plan. Remedial measures from the evaluation and monitoring must then be undertaken to sustain continual improvements in the system while the organization tries to optimize its water use and management performance.

6.3 Effective Implementation of Recommendations

Many recommendations suggested in Sections 6.1 and 6.2 to achieve sustainable water management against the identified potential risks as given in Chapter 5 are an extension to the already existing proposed measures by the concerned authorities. However, their implementation was found to be missing on ground. In fact, despite having an extensive National Water Policy in place and existence of various state and centre-level institutions, water resource development and management has not been very satisfactory in the region. Thus, a few questions arise such as whether the policy recommendations and institutions till now really been effective in providing safe and sufficient water to all for all types of purposes, be it domestic, industrial, and irrigation? Has it been instrumental in improving water management, protecting natural water resources, and maintaining the water quality?

To answer these pertinent questions, a list of areas that need immediate interventions to strengthen the implementation of these suggested recommendations are given in Table 11.

Table 11 : Suggested interventions to strengthen the implementation of the recommendations

S. No.	Identified Issue	Required Intervention
1	**Governance and institutional challenges** The water resources management and formulations of projects and plans are fragmented, uncoordinated, and follow a top-down approach, which results in weak implementation. This is primarily due to two main reasons, which are as follows: First, the presence of multiplicity of institutions sharing the responsibility leads to non-accountability in performance. Second, in the top-down approach, the decision-makers are not well-versed with the local settings and micro-level ground realities, which often results in poor decision-making	**Development of an Integrated Water Resource Management (IWRM) along with bottom-up approach** IWRM is a process that promotes the coordinated development and management of water, land, and other related resources to maximize economic and social welfare in an equitable manner without compromising the sustainability of the vital ecosystems and the environment. It is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach towards water resource management. As the local nature and needs of water-related services, resources, and management vary, it is ideal that the task of managing them is handed over to institutions in a decentralized manner. A bottom-up approach for an institutional framework with the active involvement of local stakeholders is essential for effective planning and execution of any programme aimed at water management in the region
2	**Lack of high level political commitment** Most attempts at building political commitment are targeted at national governments because the budgets, laws, policies, and regulations that can sustain a water management programme in the long run often flow from governments. However, even if it appears that the political commitment established by the national government is sufficient to sustain a programme, the commitment may still evaporate with elections and a new leadership or simply because of shifting priorities and policy concerns.	**Decentralization of water governance structure** Firstly, there should be a sustained political will and a strong commitment for the implementation of the designed water-related plans and policies, which can translate into prioritization through different layers of government and effective course correction. However, due to change in the leadership, the commitment may change. Therefore, it becomes important to decentralize and delegate the decision-making powers to local levels of governance, which largely would remain unaffected by the election results. The political devolution is also required because it is unlikely that political commitment can be effectively built or sustained by focusing on any single type of stakeholder. Rather, there is a need to consider all the actors involved in the policy space, for example, urban local bodies, urban planners, utility providers, industries, citizens, nongovernmental organizations, etc., who are needed to support the programme and its transition.

S. No.	Identified Issue	Required Intervention
3	**Inefficiency in creating water-related databases** Databases of the quantity and quality of water and the consumption patterns of various sectoral users are necessary to take effective decisions. One of the biggest challenges in the water management sector in India is the lack of adequate scientific data needed for water budgeting, allocation planning, and water management decision-making. Adequate information flows are not available because the bodies administering the water resources seldom have the financial and technical capacity necessary for undertaking the exercise of collection and analysis of a large amount of data. This is because the process of urbanization is dynamic and cities are spiralling and becoming more complex. Hence, any capacity enhancement is prone to quick depletion. Processes, technologies, and innovations take their toll on knowledge and skills based on older models.	There are two possible processes by which the databases can be strengthened, which are as follows: Firstly, there is a constant need to update and convert capacity building into an on-going process for the water-administering bodies. It is time to reimagine capacity building by creating a municipal capacity building management system for all stakeholders, including municipal employees, councillors, and citizens. This system could be involved in conducting a training-need analysis, creating quality training materials, and arranging for field training. The system could assess the need for lateral hiring of professionals and engaging private institutions, research agencies, and corporates for capacity enhancement. Also, to conduct training, an urban local body needs funds. The system could create blocks that would work towards collaboration with national and international funding agencies and tapping into CSR. The other alternative can be to engage external stakeholders including NGOs, research institutes, private entities, etc., who have expertise in water-related areas and can play an important role in populating data and its management, research and analysis, and infuse new ideas.

Conversely, India's effort in initiating adoption of water-related technologies and innovation in the country especially on the digital water management is noteworthy. This creation of innovation and implementation cycles is expected to reduce gaps between research and practice in various fields. India is a rising economic power and an increasingly important locus of innovation. Spurred by competition unleashed by liberalization of once stifling regulations, India's private sector firms are fast improving the quality of their products and services and rapidly expanding their global presence. Efforts are on to use digital technologies, drones, radar and satellite technologies, artificial intelligence solutions, and many more, which shall play a critical role in water resources and their management in the country.

Indeed, there is a long list of technological trends and advances that are likely to benefit rapid and effective adaptation of the water sector, as follows:

- Cybernetics, artificial intelligence and instantaneous information technology (smarter internet)
- Nanotechnology
- Cost-effective energy technology (solar, space-based energy, algae as fuel)

- Biotechnology (genetic engineering) to help feed the populace and save endangered species
- Space-based environmental monitoring systems and instantaneous feedback to predictive models even to remote areas
- Geoengineering to reverse global warming (e.g., giant reflectors in orbit; greening deserts; iron fertilization of the sea; aerosols in the stratosphere)
- Effective and reliable prediction of most weather and climate events
- Renewable energy replacing fossil fuels entirely – low-carbon societies
- Desalinization (in conjunction with cheap fusion energy) becoming cost-effective and providing water for most large coastal urban areas and megacities
- Vastly improved sanitation and wastewater treatment technologies and recycling
- Biotech approaches to pest control for improved agricultural yields
- Ecological engineering to preserve habitats, reverse species extinctions, and combat invasive species
- Mapping groundwater resources and sustainable extraction levels

Computer-based optimization and simulation models incorporated with interactive graphics, audio-based decision support systems will continue to help us in identifying plans, designs, and policies that maximize the desired impacts and minimize the undesired ones as well as making clearer the trade-offs between the two.

Science, technology, and innovation strategies are the integral parts of sustainable development strategies. Many innovations in sustainable water management are high risk and with uncertain returns. Government financing and policies for innovation, supported by public–private partnerships, can be designed and implemented to reduce risks and promote research and development and diffusion and transfer of technologies.

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