ROADMAP FOR IMPLEMENTATION OF WATER-SENSITIVE URBAN DESIGN AND PLANNING IN DELHI

STORMWATER HARVESTING IN PUBLIC PARKS AND OPEN SPACES

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Maps used in this report are not to scale.

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1. Introduction

Urban water systems are confronted with significantly changing conditions. The impact of climate change, rapid urbanization, and deteriorating and outdated infrastructure are aggravating current water challenges of flooding, water scarcity and rehabilitation costs on a scale that will overwhelm the capacities of cities.[1] In this respect, stormwater management and water supply of cities serve as the vanguard and will take the brunt of the impact. This holds true for India's capital city. Urban flooding in Delhi during monsoon has become an annual affair, posing social and economic constraints.

The National Capital Territory (NCT) of Delhi has always had a difficult relationship with the water resources at its disposal. The city, one of the largest urban agglomerations in the world, is faced with a complex water crisis. The groundwater table is 40 m below ground level (b.g.l.) in as much as 30 per cent of the city. River Yamuna is at its most polluted within the urban limits of Delhi. Numerous water bodies have been encroached upon and are vanishing. Water supply in the city is dwindling. Every monsoon, even during moderate rainfall, the city faces urban flooding. Urban water cycle of Delhi is broken and in dire need of a paradigm shift in order to address vital issues related to urban water management. Centre for Science and Environment (CSE) research demonstrates the need for cities to adopt Water-sensitive Urban Design and Planning (WSUDP) approach, including sustainable urban drainage interventions. WSUDP approach realigns urban water infrastructure towards a circular economy, aiming to mimic the natural water cycle in order to fix the water systems in a city. Further, it integrates and optimizes the use of available water resources, and completes the urban water cycle through measures like protection of local water bodies, stormwater harvesting in public places, wastewater recycling and reuse, and improving water efficiency at household, neighbourhood and city–regional scale.

WSUDP in parks and open spaces has been successfully implemented in many parts of the world. It is seen as a critical component of efforts to mitigate urban flooding and managing high run-off volumes generated from urban catchments. Some of these approaches combine the best of traditional practices with the latest scientific insights. CSE has detailed some of them in *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems*, considered a seminal work in the field and *Making Water Everybody's Business: Practice and Policy of Water Harvesting*, another essential read on the subject.

As per the Final Report submitted by the National Green Tribunal (NGT)-appointed Yamuna Monitoring Committee, there are more than 16,000 parks and gardens in Delhi.[2] The city is considered one of the greenest metropolis in the global South. It is important to analyse the potential of implementing WSUDP in these parks and open spaces, with a focus on moderating urban run-off during the monsoon.

1.1 Research aim, objectives and methodology

This report aims to assess the potential of harvesting and moderating urban run-off generated during monsoon within the open spaces of Delhi for sustainable stormwater management with the following objectives:

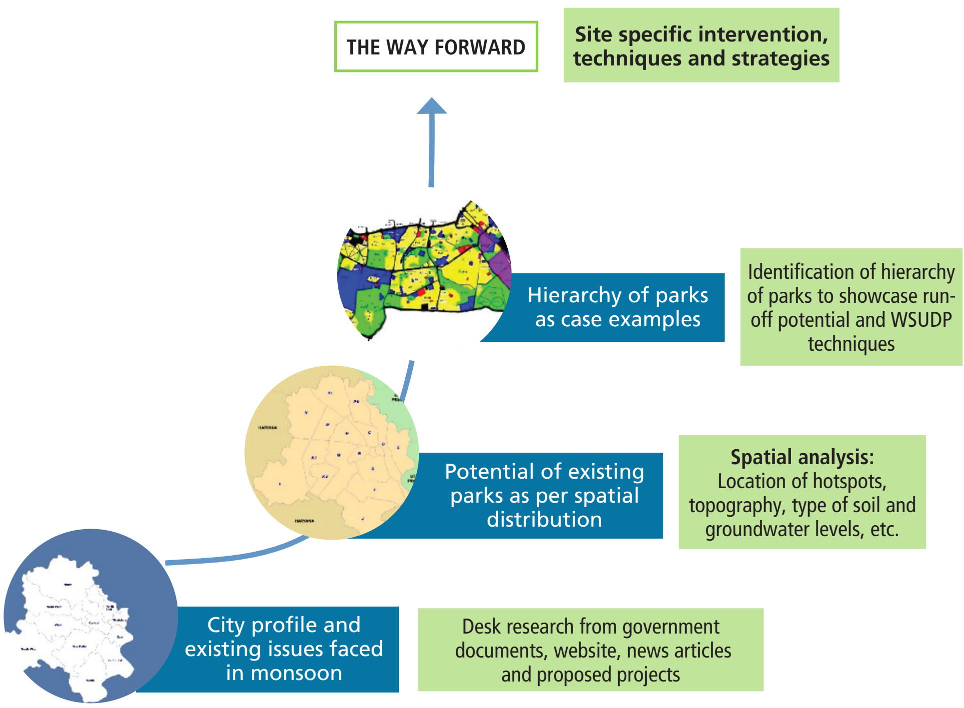
First, to assess the existing condition of Delhi in terms of stormwater management using factors like land use cover, open spaces, groundwater level, soil condition, slope and elevation and flood hotspots.

Second, to evaluate the potential and scope of stormwater management as per different natural profiles of the city. A field visit to pilot study areas was also conducted.

Third, to provide strategies for capturing and retaining stormwater run-off according to hierarchy of green open spaces as outlined in the Master Plan for Delhi, 2021 (MPD 2021).

The research methodology is secondary desk research supported by Geographic Information Systems (G.I.S.)-based spatial mapping of the study area—planning zones to identify the untapped potential of stormwater harvesting and recommending site-specific interventions, techniques and strategies as presented.

Figure 1: Methodology



Source: CSE

Stage 1: Desk research and G.I.S. analysis

Desk research has been conducted to collect data at the city level to assess the profile of Delhi in terms of natural factors like climate, topography, drainage, groundwater and land cover. This was supported by data on issues of waterlogging and pluvial flooding faced by the city. A review of the draft State Water Policy, MPD, 2021, Drainage Masterplan and projects related to WSUDP and rainwater harvesting (RWH) was also undertaken to explore the opportunities for and deficiencies in implementing WSUDP in parks and open spaces.

Municipal zones of Delhi have been analysed to assess the potential of WSUDP in parks and open spaces. Indicators like 'area under parks', 'groundwater level', 'geology', 'flood hotspots' have been taken into account to identify areas for WSUDP strategies based on retention, infiltration and moderation of urban run-off. These indicators have been assessed with respect to land use and the urban fabric.

Stage 2: Identification of site-specific interventions and next steps
In order to understand the potential and scope of interventions, stormwater harvesting potential of select parks in Delhi has been calculated. Pilot case examples of different hierarchies have been selected in South and North Delhi Municipal Corporations.

Challenges and opportunities, in terms of legal, social and environmental sustainability of any such intervention in open green spaces, have been identified. From these findings, park-specific interventions and strategies have been extracted, covering all the measures undertaken to improve the way in which the flow of run-off or water generated by rainfall in urban areas is managed and its volume stored or otherwise retained.

1.2 Need for the report

Delhi, the capital city of India, is growing rapidly. The geographic size of Delhi has almost doubled between 1991 and 2011. Delhi is a megalopolis offering development opportunities across countless urban sectors. The number of urban households has also doubled, while the number of rural households has declined by half (see *Figure 2: Increase in built-up area in Delhi-NCR, 1989 to 2018*).

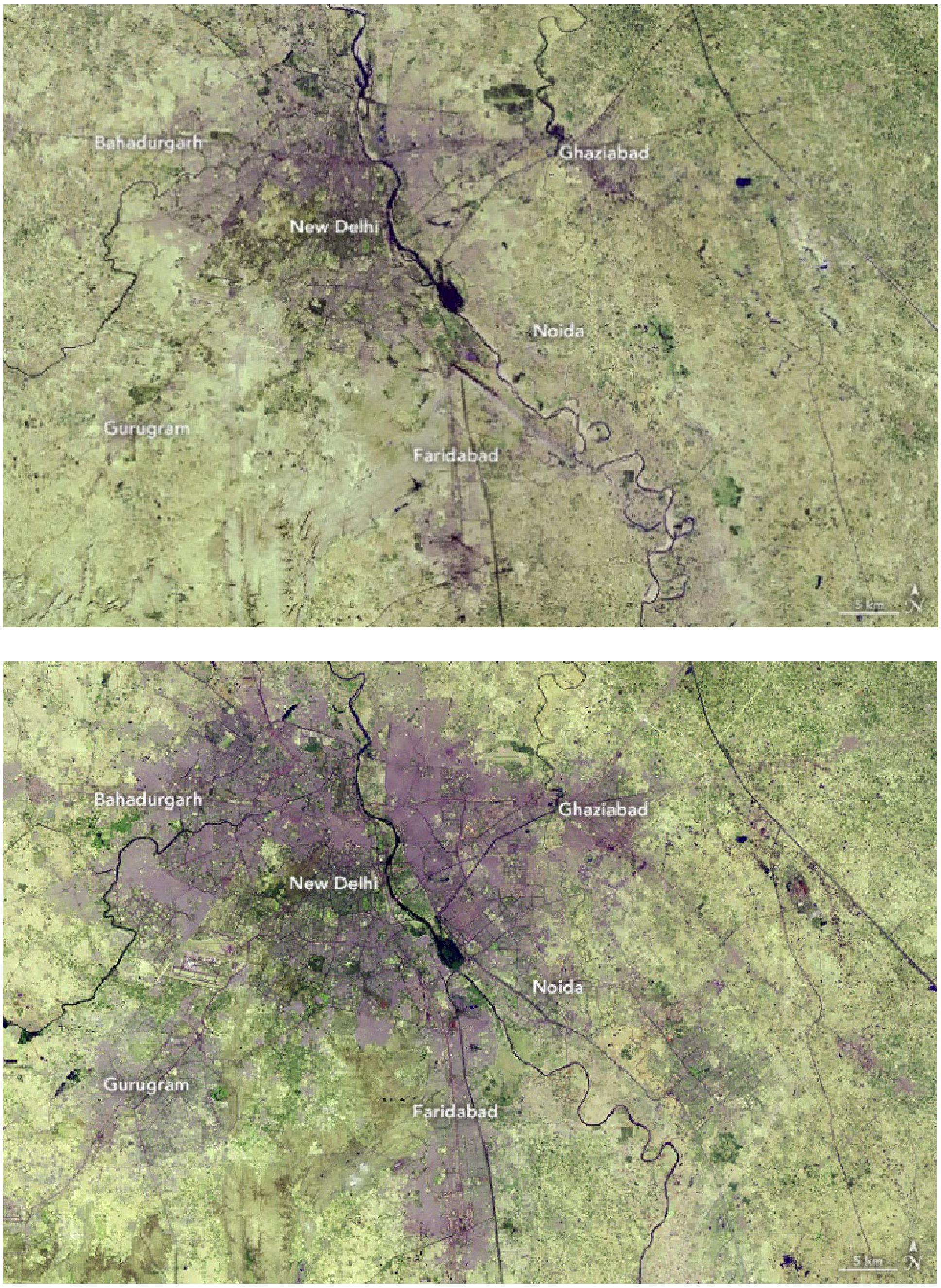
This, along with a consequent expansion of the city's surface, are weighing down the existing infrastructure, which has proved insufficient to accommodate such growth. The city's stormwater management and water supply services act as a vanguard in this respect. Urban flooding in Delhi during monsoon has become an annual affair. It inevitably leads to loss of life and property, and has an adverse impact on economic activities as well as the natural ecosystem.

As per the Intergovernmental Panel on Climate Change (IPCC), the rainfall pattern in India has been significantly altered during the past few decades. Though the average rainfall remains the same, we now witness fewer rainy days with more intense rainfall. This means that we are more likely to have 10-year, 15-year and 20-year rainfall events more frequently. At present, the design of stormwater infrastructure in Delhi is not adequate to deal with run-off generated because of such high-intensity rainfall events. Central Public Health and Environmental Engineering Organization (CPHEEO) reccomends designs for drains for one-year or two-year rainfall events. Although urban stormwater infrastructure covers 75 per cent of the city's road length, most of these drains are clogged due to siltation and disposal of solid waste.

Considering the urban issues, there is a need to push for alternative stormwater management techniques which can lead to sustainable groundwater infiltration while preventing urban flooding in the long-run in Delhi. This report provides an option to overcome pluvial flooding issues (caused in monsoon due to excess run-off). It provides information to identify the potential of stormwater harvesting within the existing urban fabric and planning standards.

It is high time we realize that urban stormwater management is not just dealing with the problem of excess water (in the form of rainfall), but to convert it into a resource and conserve it.

Figure 2: Increase in built-up area in Delhi-NCR, 1989 to 2018



Source: Images retrieved from NASA Earth Observatory (URL: www.earthobservatory.nasa.gov)

2. WSUDP in parks and open spaces

Parks and open spaces are a major contributor to both the quality of the environment and to human well-being. Integrating the urban water cycle with the planning and development of parks and open spaces is instrumental in developing sustainable cities, which provide nature-based solutions to issues related to urban water management.

Conventionally, stormwater management has been focused on drainage systems via underground pipes. This conventional approach has been found inadequate in many cases, particularly in dealing with moderate to extreme rainfall. In the context of climate change and rapid urbanization, it is important to augment stormwater management systems in urban areas with sustainable nature-based solutions in order to build urban water resilience. WSUDP for parks and open spaces provides an opportunity to address these concerns.

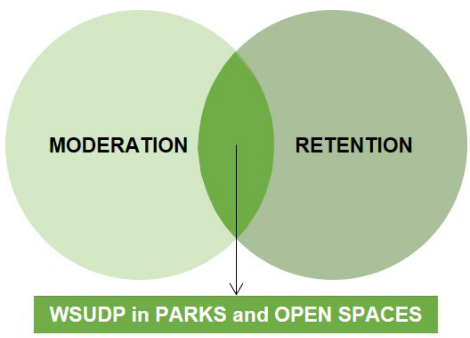
WSUDP for urban green spaces is considered to be an effective approach to reduce the adverse impact of urbanization on the hydrological cycle. Green spaces improve the natural hydrological systems in urban areas and dampen peak flows from storms that can otherwise lead to flooding. Expansion of urban green spaces is not only an economical and environment-friendly approach to deal with stormwater run-off and urban flooding, but it can also improve the resilience and sustainability of cities.

WSUDP interventions in public parks and open spaces provides critical green infrastructure linkages, which provide multi-dimensional benefits for the urban hydrological regime. WSUDP in parks and open spaces can be implemented at various scales.

Planning and designing of parks and open spaces in line with the urban hydrological regime provides opportunities for addressing urban flooding and augmenting groundwater resources.

The process follows the principles of 'moderation' of run-off during rainfall, via 'retention' for a particular time, allowing water to infiltrate, and the drainage system to gain the capacity to accommodate the extreme run-off (see *Figure 3: Principles of WSUDP in parks and open spaces*).

Figure 3: Principles of WSUDP in parks and open spaces

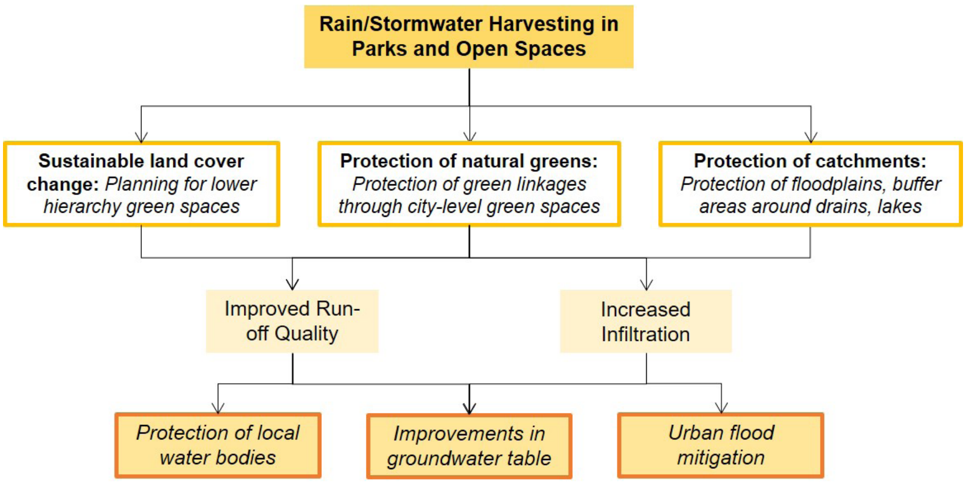


Source: CSE, 2020

While lower hierarchy parks and open spaces contribute to localized benefits, WSUDP interventions at city-level green spaces provide multiple large-scale benefits like protection of urban water bodies and their buffer areas.

WSUDP interventions in parks and open spaces at various scales lead to improved run-off quality and increased infiltration, which eventually leads to protection of local waterbodies, groundwater recharge and urban flood mitigation (see *Figure 4: WSUDP approach—integrating the urban water cycle*). Additionally, these interventions also enhance the biodiversity of the area and improve the micro-climate.

Figure 4: WSUDP approach—integrating the urban water cycle



Source: CSE, 2020

Stormwater harvesting in parks and open spaces can be undertaken at different scales, depending on the hierarchy of parks. While lower hierarchy parks are developed in residential and institutional areas, parks higher in the hierarchy are developed at the city or regional scale. Lower hierarchy interventions are localized and are successful in addressing local flooding. It must be noted that a majority of parks and open spaces in cities are planned at the neighbourhood level. WSUDP interventions in these areas can have a cumulative positive impact in addressing urban flooding in the city as a whole.

Higher hierarchy spaces provide essential green infrastructure linkages. WSUDP interventions in these spaces allows for large-scale interventions and can provide various regional benefits. Interventions in parks and open spaces at various scales are illustrated in *Table 1: WSUDP options and benefits for parks and open spaces* along with their estimated benefits in terms of run-off volume reduction and peak flow reduction. The values are based on globally implemented solutions.

Interventions like rain-gardens, rainwater harvesting solutions and swales can be implemented in lower hierarchy parks and open spaces. These interventions can reduce run-off and peak flow, improve water quality, and increase local biodiversity. Associated benefits include improved aesthetics and recreational benefits, which eventually lead to increased property values.

Detention ponds and bio-retention areas are more suitable for higher hierarchy parks and open spaces as they require more area and are able to handle higher

Table 1: WSUDP options and benefits for parks and open spaces

Measure	City	Area (sqm) / volume (cum)	Per cent reduction in		Co-benefits
			Run-off	Peak flow	
Rain-garden	Japan	Area: 1.862	36 to 100		· Increased biodiversity · Increased property value · Aesthetics
Vegetated swale	Beijing, China	Volume: 157	0.3 to 3	2.2	· Increased biodiversity · Reduced concentration of pollutants
	Hai He, China	Volume: 1,500	9.6	23.56	
Rainwater harvesting	Melbourne, Australia	Volume: 1 to 5	57.8 to 78.7		Improved water quality: · Total nitrogen reduced by 72–80 per cent
Dry-detention pond	Selangor, Malaysia	Area: 65,000		33 to 46	Recreational benefits
Detention pond	Texas, USA	Volume: 73,372		20	· Increased biodiversity · Recreational benefits
	Joinville, Brazil	Volume: 9,700	55.7	43.3	
Bio-retention	Beijing, China	Volume: 946	10.2 to 12.1		Improved water quality: · Reduced total suspended solids · Reduced total phosphorus
	Hai He, China	Volume: 1,708	9.10	41.65	
	Calgary, Canada	Volume: 48	90		
Infiltration trench	Hai He, China	Volume: 3,576	30.8	19.44	· Reduction in pollutants · Improved surfacewater quality
	Joinville, Brazil	Volume: 34,139	55.9	53.4	
Detention pond and rain-garden	Joinville, Brazil	Area: 18,327	70.8	60	Aesthetics
Detention pond and infiltration trench	Joinville, Brazil	Area: 18,327	75.1	67.8	Improved surfacewater quality

Source: L. Ruangpan et al.: Nature-based solutions for hydro-meteorological risk reduction

volumes of run-off. These interventions have a higher percentage reduction in peak flows and run-off, and also augment the quality of water. In addition to this, protection (and creation) of local waterbodies can also be done using these interventions. It is to be noted that various combinations of these interventions can be made in parks of various sizes. WSUDP interventions are most efficient if designed as a network of solutions within a particular park, and also solutions in a network of parks of various scales.

While these interventions provide a range of ecological, social and economic benefits, it is to be noted that these interventions are nature-based, they are not resource-intensive, and are easy to maintain and monitor, and they require only 1–5 per cent of the total park area.

2.1 Planning and management of WSUDP in parks and open spaces

For successful implementation and operation of WSUDP interventions, it is imperative to identify the actors and their roles and responsibilities with respect to WSUDP. It is crucial to link WSUDP interventions with provision of civic amenities, urban planning and local community participation.

Policy and planning

Planning strategies for parks and open spaces are usually defined in the city masterplan or development plan. These documents provide development control norms and standards regarding the area, which includes the number of parks required to support a population. It is imperative to define the norms and standards for preparing rainwater harvesting layout of these parks. These norms and standards should provide guidelines for allocation of area for WSUDP interventions in parks and preparation of local drainage plans in this regard.

In addition to the routine masterplan norms for parks, a city's drainage plan (or the masterplan) should identify areas that are more vulnerable to flooding. Adequate parks and open spaces must be allocated and designed in these areas as priority flood-retention measures.

Implementation, operation and maintenance

In Indian cities, 'parks' and 'open spaces' are part of civic amenities planned, implemented and maintained by urban local bodies (ULBs). In case of areas developed by development authorities, parks and open spaces are handed over to the ULB for maintenance.

The financial and human resources of ULBs in India is limited and not capable of maintaining the large number of lower hierarchy parks. ULBs entrust resident welfare associations (RWAs) to provide day-to-day maintenance of these spaces. For parks outside the jurisdiction of RWAs, ULBs are obligated to perform maintenance activities.

In terms of implementation of WSUDP interventions in parks, in case of pre-development stage, designs should be incorporated and planning authority or ULB should implement it. In case of retrofitting existing parks with WSUDP features, the jurisdictional organization (planning authority or ULB) is responsible for implementation.

Maintenance of WSUDP interventions can be undertaken along with regular maintenance activities in the parks. For parks in residential areas, RWAs can be tasked with managing the maintenance of these interventions. For institutional areas, estate managers can be tasked with the maintenance. For higher hierarchy open spaces, ULBs are responsible.

The institutional responsibilities for various activities with respect to WSUDP interventions in parks and open spaces are mentioned in *Table 2: Institutional set-up for WSUDP in parks and open spaces*.

Table 2: Institutional set-up for WSUDP in parks and open spaces

WSUDP intervention	Plan, project, operation and maintenance	Organization
Planning norms for parks	City masterplan	Development authority
Identification of vulnerable parks	City drainage plan	Flood control department
Implementation and operation	WSUDP projects	Urban local body (ULB)
Maintenance and monitoring	Operation and maintenance schedule and activities	ULB or RWAs

Source: CSE, 2020

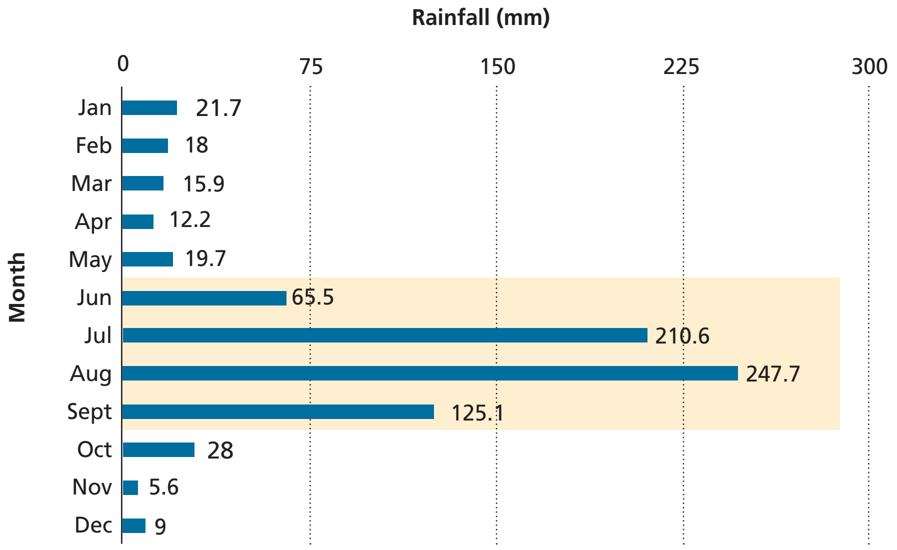
3. Profile—National Capital Territory of Delhi

The National Capital Territory (NCT) of Delhi is the second largest city in India, having a population of 1.67 crores (16.7 million), as per Census of India, 2011. It is spread across an area of 1,483 sq km and is one of the most densely populated cities in the world, with a population density of 11,320 persons per sq km. This chapter draws a city profile of Delhi in terms of natural resources, land cover, administration related to urban planning and civic amenities, and policies and recommendations related to rainwater harvesting. The chapter concludes with a short note on incidents of urban flooding in Delhi over the past decade.

3.1 Climate and rainfall

Delhi has a monsoon-influenced, humid and subtropical climate with significant variation between summer and winter, in terms of both temperatures and rainfall. The peak summer temperature can reach up to 45°C (May–June) while the peak winter temperature can be as low as 4°C (December–January). The average rainfall in Delhi is 779 mm, about 80 per cent of which occurs in the monsoon season, from July to September (see *Figure 5: Rainfall pattern in Delhi*). Maximum rainfall is recorded in the central, southern and eastern parts of Delhi (see *Figure 6: Isohyetal map of Delhi*).

Figure 5: Rainfall pattern in Delhi



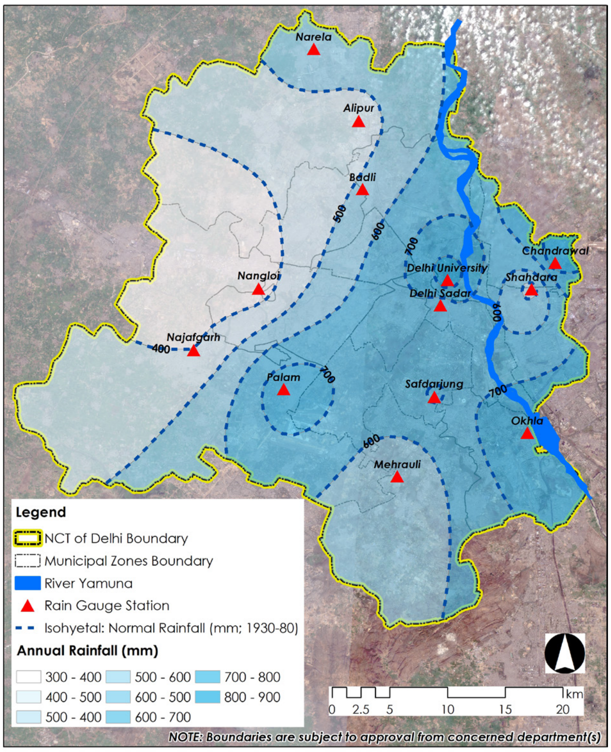
Source: CSE, 2020 (Compiled from IMD Data)

3.2 Land

Topography

The maximum elevation in the city is 332 m above mean sea level, observed in the Delhi Ridge, whereas the minimum elevation has been observed in the River Yamuna at 32 m above mean sea level. The floodplains of Yamuna are at an average elevation of 198 m above mean sea level.

Figure 6: Isohyetal map of Delhi



Source: Groundwater Year Book for NCT of Delhi, 2017-18

Slope

The city slopes outwards from the Ridge, towards the River Yamuna on the eastern side, and towards the agricultural areas on the western outskirts (see *Figure 7: Elevation profile of Delhi*).

Geology

Delhi can be divided into four categories of geological regimes: The Young Alluvium, which are areas in the floodplains of River Yamuna, the Delhi Super Group of the Aravallis, the Aeolian Soil in the southern parts of Delhi, and the Old Yamuna Alluvium (see *Figure 8: Geology of Delhi*).

3.3 Drainage and water resources

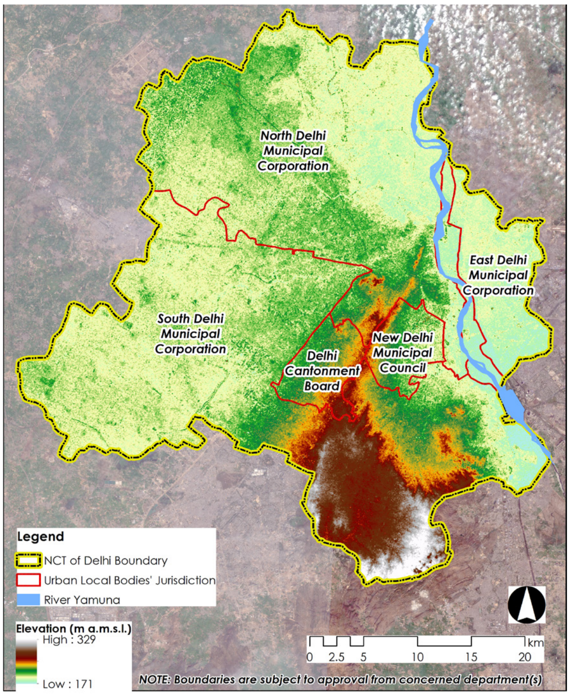
Yamuna and major drains

River Yamuna is the only perennial river in the area. A number of micro-watersheds also originate in the Delhi Super Group Quartzite area. The river flows from North to South, traversing 48 km in the NCT of Delhi (22 km in urban areas).

A total of 22 major drains empty into Yamuna, the three largest of which are the Najafgarh drain, Barapullah drain and the Shahdara Drain. These form the three major drainage basins within Delhi, in addition to two smaller catchments (see *Figure 9: River Yamuna and drainage basins in Delhi*).

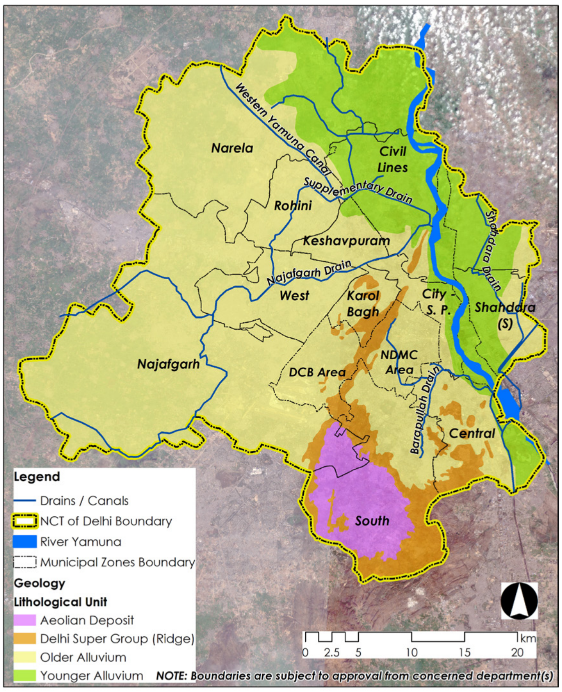
A total of 201 natural drains flow in the city, spread across a network totalling 456.5 km.

Figure 7: Elevation profile of Delhi



Source: CSE, 2020 (Prepared from DEM: SRTM)

Figure 8: Geology of Delhi



Source: Groundwater Year Book for NCT of Delhi, 2017-18

Urban lakes and ponds

As per the Delhi Parks and Gardens Society, 629 water bodies exist in Delhi.

Groundwater

The pre-monsoon groundwater table in the city varies from 2–5 m b.g.l. near the River Yamuna (see *Figure 10: Pre-monsoon groundwater table in Delhi, 2017*), to more than 40 m b.g.l. in the southern parts of Delhi (see *Figure 11: Post-monsoon groundwater table in Delhi, 2017*).

While a major portion of the city witnesses a 2 m rise in pre–post monsoon fluctuation, areas in southern Delhi witness a rise of more than 4 m during the same period (see *Figure 12: Fluctuations in groundwater table due to monsoon in Delhi, 2017*). This is due to the higher infiltration potential in areas in the older alluvial plains.

Various parts in central, northern and south-western Delhi witness up to 4 m fall due to lower infiltration rates, arising out of local geological conditions.

3.4 Land cover pattern and land use

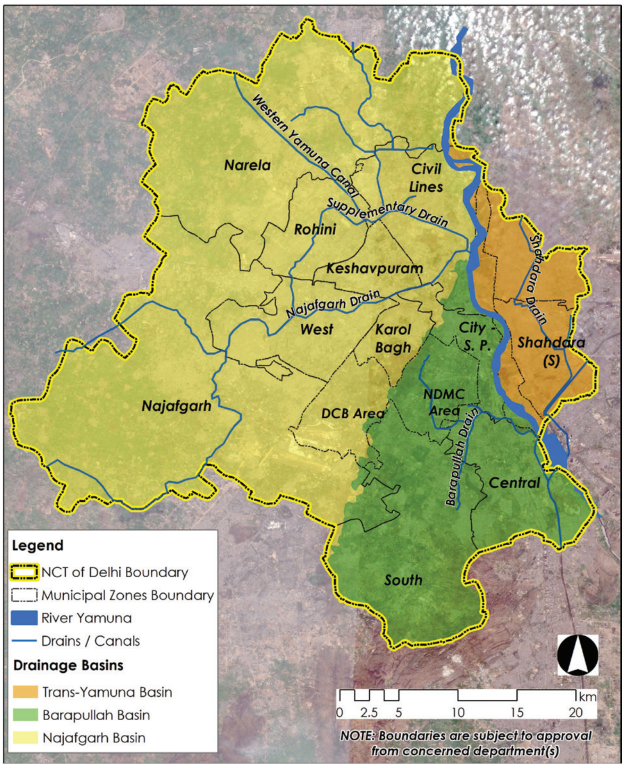
Land cover

Being the economic and political centre of the country, Delhi is facing rapid, unsustainable urbanization, which has resulted in severe environmental consequences on the natural resources of the city.

Over the past three decades, the city has witnessed a vast increase in built-up area (see *Figure 13: Land cover map of Delhi, 1989 to 2011*).

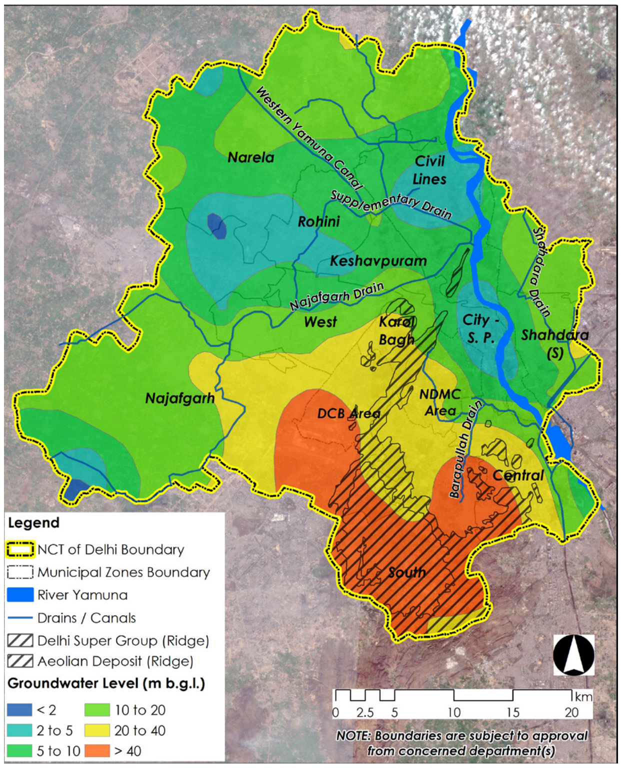
The change in land cover is taking place at the expense of open spaces, water bodies, forest areas and agricultural land (see *Figure 14: Land cover change in Delhi, 1999 to 2015*).

Figure 9: River Yamuna and drainage basins in Delhi



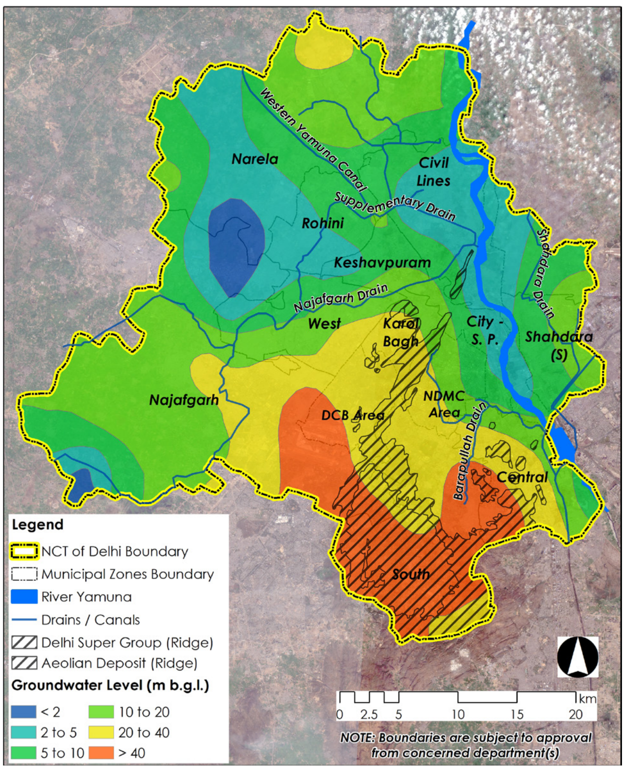
Source: Drainage Masterplan for NCT of Delhi

Figure 10: Pre-monsoon groundwater table in Delhi, 2017



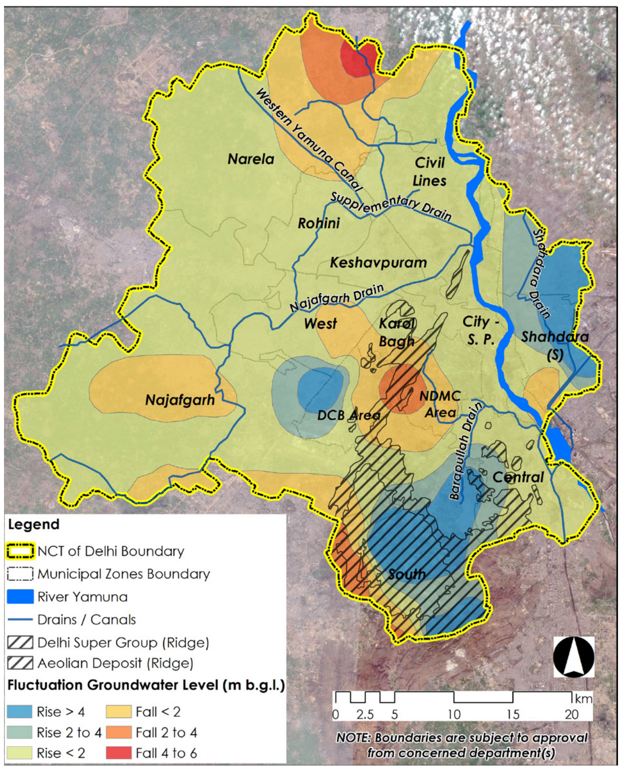
Source: Groundwater Year Book for NCT of Delhi, 2017-18

Figure 11: Post-monsoon groundwater table in Delhi, 2017



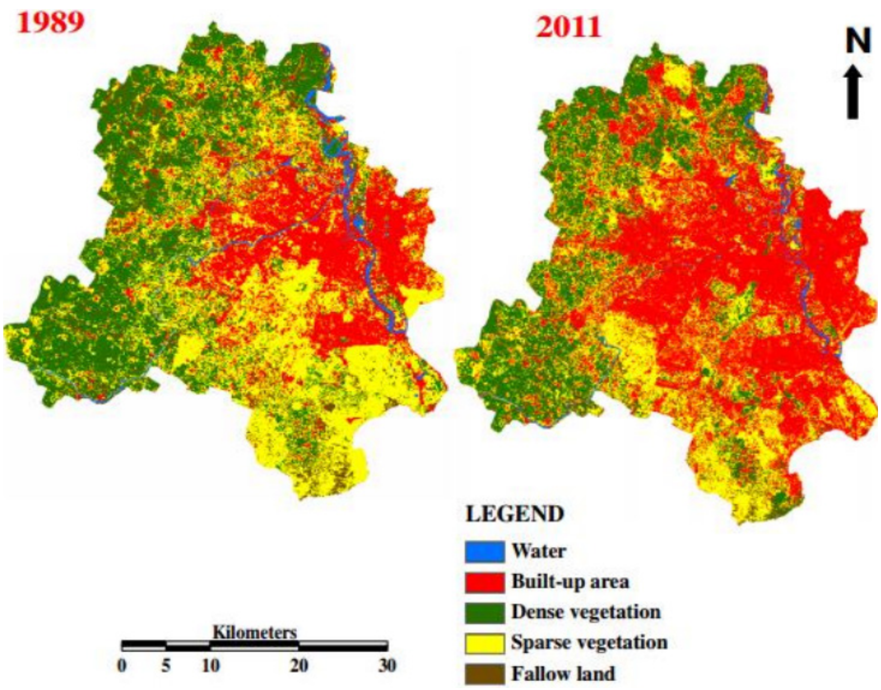
Source: Groundwater Year Book for NCT of Delhi, 2017-18

Figure 12: Fluctuations in groundwater table due to monsoon in Delhi, 2017



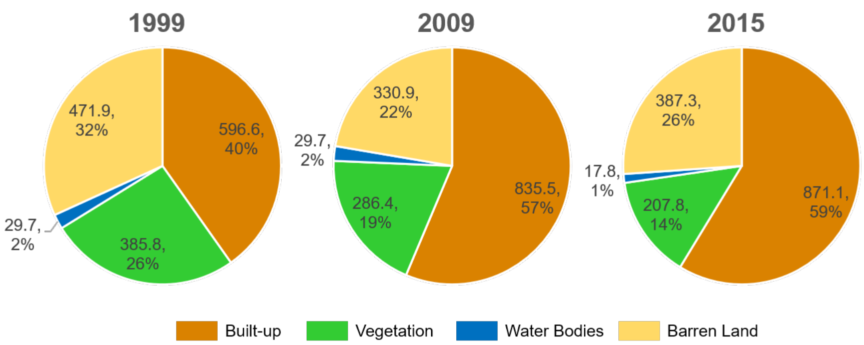
Source: Groundwater Year Book for NCT of Delhi, 2017-18

Figure 13: Land cover map of Delhi, 1989 to 2011



Source: Mukopadhyay, et al., 2013

Figure 14: Change in land cover in Delhi, 1999 to 2015



Source: TERI (n.d.). Floods in Delhi: Causes and Challenges.TERI: New Delhi

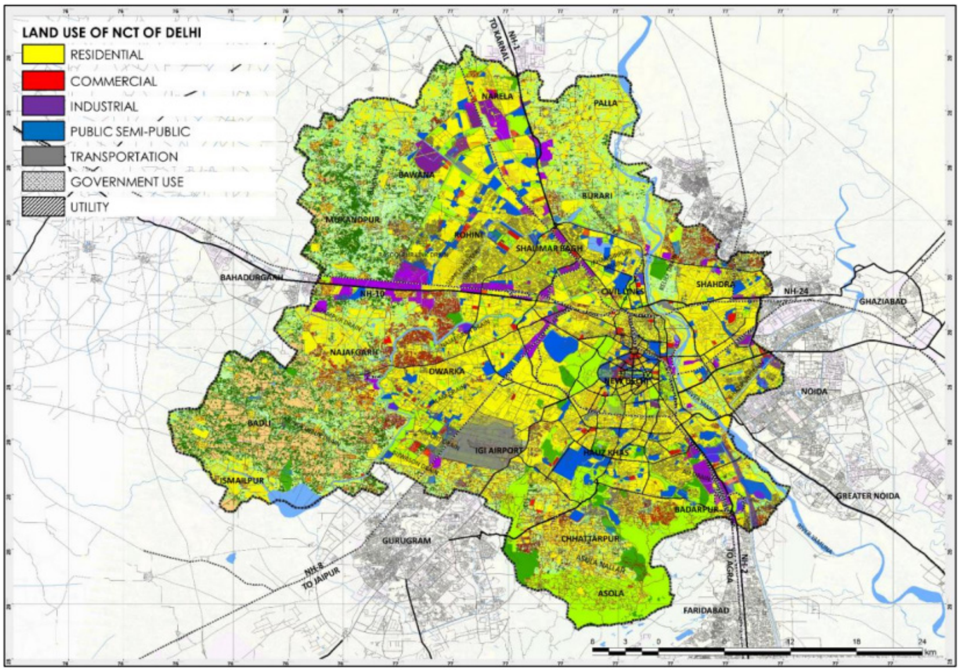
Land use

The city's land use is dominated by the residential sector *(see Figure 15: Land use map of Delhi, 2016*), occupying an area of 549 sq km (63 per cent of the built up area). Area under public, semi-public and government uses stands at 103 sq km (6.9 per cent of the total area of NCT of Delhi) and 55 sq km (3.7 per cent of the total area) respectively.

Area under commercial uses is 53 sq km (3.6 per cent of total area) while the area under industrial use is 46 sq km (3.1 per cent of the total area).[3] Transportation use occupies 148 sq km (10 per cent of the total area) and area under utilities is 36 sq km (2.4 per cent of the total area).

Planned recreation area in the city is 182 sq km (12.3 per cent of the total area).[4] In addition to this, 195 sq km of Delhi is considered as 'natural use',[5] which includes the river Yamuna, its floodplains, forests, biodiversity parks, etc.

Figure 15: Land use map of Delhi, 2016



Source: SPA (2017) Report on Impact of Floods on Delhi (Prepared under ClimTrans Project), SPA Delhi

Delhi comprises of 24,840 hectares of floodplains, of which 68 per cent forms a part of the Yamuna floodplains. In 2014, the Supreme Court passed an order delineating the floodplains (at 300 m on either side of the Yamuna, 100 meters on either side of drains feeding Yamuna and 50 m for tertiary drains and waterbodies like lakes and ponds).

The flood plains have been reduced in width, from an average of 800 m in 1986 to an average of 300 m in 2016, a result of urbanization leading to loss of the fragile ecosystem.Waterbodies in the city had a total area of 58.26 sq km in 1997. It decreased to 27.43 sq km by 2008 (a 52.9 per cent decrease). Shallow waterbodies shrank by 10.27 sq km, with only 2.82 sq km left.

3.5 Planning and management of parks

Administration of parks

Parks and open spaces fall under the jurisdiction ULBs in Delhi. At present, there are five ULBs in Delhi (see *Figure 16: Municipal jurisdictions in Delhi*). The New Delhi Municipal Council (NDMC) governs the Central Delhi area, while the Delhi Cantonment Board has jurisdiction over the cantonment areas of Delhi. The erstwhile Municipal Corporation of Delhi was trifurcated in 2014 into South, East and North Delhi Municipal Corporations (DMCs). These are further divided into 12 municipal zones, which are subdivided into 272 wards. The NDMC area also includes the Lutyens' Bungalow Zone, the Central Secretariat and other Central government offices. It has a mix of institutional and high-income residential areas, and is the greenest part of Delhi.

Municipal zones Civil Lines, Keshavpuram, City-S.P. and Karol Bagh were developed largely before independence, and they have a mix of planned and organic development.

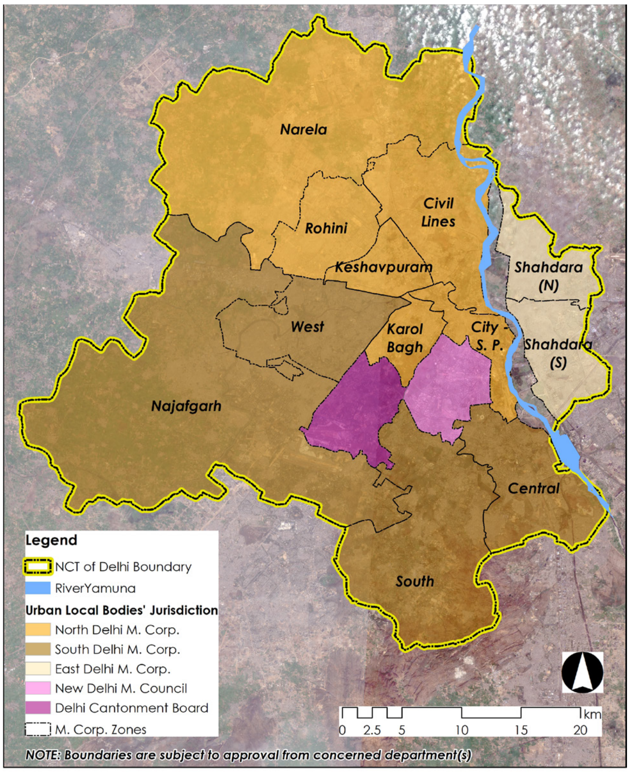
Rohini, West Delhi and parts of Central and South Delhi are mostly planned areas developed by the Delhi Development Authority (DDA).

Trans-Yamuna zones are Shahdara (North) and Shahdara (South), where most planned development took place after late 1970s.

The Najafgarh, Narela and southern areas of the South Zone are fairly rural in nature, with little planned development.

The Department of Horticulture of these ULBs are responsible for the maintenance of parks and gardens within their jurisdiction.

Figure 16: Municipal jurisdictions in Delhi



Source: CSE, 2020

Planning norms for parks and open spaces

DDA has been tasked with the planning and development of the NCT of Delhi under the Delhi Development (DD) Act, 1957. Under the Act, DDA has powers to acquire land, prepare masterplans and zonal development plans, and undertake development projects for areas under its jurisdiction. In addition to these functions, DDA also coordinates with other organizations of the Government of National Capital Territory of Delhi (GNCTD) (Delhi Jal Board, Delhi Parks and Gardens Society, etc.) and ULBs of Delhi, to discharge various civic functions including planning, designing and operation and maintenance of parks and open spaces.

MPD, 2021 has defined parks, open spaces and recreational areas at various scales, depending on the population they serve. The plan has defined parks at neighbourhood level and at the sub-city level. In addition to these, the plan also defines ‘multipurpose grounds’ as a separate category of open spaces (see

Table 3: Norms and standards for parks and recreational areas). These are over and above the various regional and national level green areas like forest, Ridge, floodplains, Green Belt, etc.

Table 3: Norms and standards for parks and recreational areas

Category	Population per unit	Area (hectare)	Category	Population per unit	Area (hectare)
City park	10 lakh	100	Tot lot	250	0.0125
District park	5 lakh	25	**Multi-purpose grounds**		
Community park	1 lakh	5	City level	10 lakh	8
Neighbourhood park	10,000	1	District level	5 lakh	4
Housing area park	5,000	0.5	Community level	1 lakh	2

Source: Master Plan for Delhi, 2021

Existing park infrastructure in NCT of Delhi

As per the *Final Report* submitted by the NGT-appointed Yamuna Monitoring Committee, there are more than 16,000 parks and gardens in Delhi.[6] These cover an area in excess of 8,000 hectares spread across the city.[7] The various authorities that have jurisdiction over these parks are mentioned in *Table 4: Jurisdiction-wise number of parks in NCT of Delhi*.

Table 4: Jurisdiction-wise number of parks in NCT of Delhi

Authority	Number of parks under jurisdiction
South Delhi Municipal Corporation	6,812
East Delhi Municipal Corporation	2,098
North Delhi Municipal Corporation	6,109
New Delhi Municipal Council	35
Delhi Cantonment Board (DCB)	18
Central Public Works Department (CPWD)	136
Delhi Development Authority (DDA)	810
Delhi Urban Shelter Improvement Board (DUSIB)	226
Archaeological Survey of India (ASI)	55
Total	**16,299**

Source: Chandra, S., Bajwan, B.S. (2020). Final Report: Rejuvenation of the River Yamuna and Abatement of Pollution. Yamuna Monitoring Committee: New Delhi.

Parks under the ULBs generally fall in the residential areas of the city. More than 96 per cent of parks under the ULBs are neighbourhood parks (with an area of less than one hectare). Community-level parks (with areas between one and five hectares) are also under the jurisdiction of the ULBs, but only a few such parks exist. Parks under Central Public Works Department (CPWD) are in areas with Central government housing and offices, whereas parks under Delhi Urban Shelter Improvement Board (DUSIB) are located in the DUSIB residential areas. Parks under CPWD and DUSIB are also of neighbourhood scale.

Parks under Archealogical Survey of India (ASI) are open areas within the archaeological complexes of Delhi, like Mehrauli and Tughlaqabad Archaeological Complexes. These are city-level open spaces spread across areas greater than five hectares.

Parks under DDA are of neighbourhood, community and city scale. Residential areas and sub-cities developed by DDA with neighbourhood and community parks, which have not been handed over to the respective ULBs, are under DDA. In addition to this, DDA has also developed various city-level parks and urban forests, e.g., Jahapannah City Forest, Sanjay Van, etc. These city-level parks are under the jurisdiction of DDA.

As is clear from *Table 4: Jurisdiction-wise number of parks in NCT of Delhi*, of the 16,299 parks in Delhi, 15,019 parks are under the jurisdiction of East DMC, South DMC and North DMC. The distribution of these parks of different scales as per municipal zones under these ULBs is laid down in *Table 5: Classification of parks under the North, South and East DMCs*.

Table 5: Classification of parks under the North, South and East DMCs

South DMC Zones	Neighbourhood park		Community park		Regional park	
	Number	Area (hectare)	Number	Area (hectare)	Number	Area (hectare)
Central	1,418	289.3	84	139.2	2	12.8
South	2,191	234.5	34	49.5	0	0.0
West	1,765	380.0	115	224.6	7	62.6
Najafgarh	1,177	110.7	18	22.4	1	11.3
South DMC	**6551**	**1,014.5**	**251**	**435.7**	**10**	**86.7**
Total number of parks under SDMC: 6,812			**Total area under SDMC parks: 1,536.9 hectare**			
North DMC Zones	**Neighbourhood park**		**Community park**		**Regional park**	
	Number	**Area (hectare)**	**Number**	**Area (hectare)**	**Number**	**Area (hectare)**
City S.P.	235	29.3	11	23.1	1	10
Civil Lines	605	69.2	12	21.6	3	19.5
Karol Bagh	750	83.9	7	11.1	1	7.3
Keshavpuram	1,672	206.0	41	63.3	1	23.2
Narela	738	67.5	12	15.1	0	0
Rohini	1,987	147.6	31	48.9	0	0
North DMC	**5,987**	**603.5**	**114**	**183.1**	**6**	**60**
Total number of parks under NDMC: 6,109			**Total area under NDMC parks: 846.6 hectare**			
East DMC Zones	**Neighbourhood park**		**Community park**		**Regional park**	
	Number	**Area (hectare)**	**Number**	**Area (hectare)**	**Number**	**Area (hectare)**
Shahdara (N)	587	99.6	6	7.9	1	18
Shahdara (S)	1,492	144.9	12	20.4	0	0
East DMC	**2,079**	**244.5**	**18**	**28.3**	**1**	**18**
Total number of parks under EDMC: 2,098			**Total area under EDMC parks: 290.8 hectare**			

Source: Information provided from North DMC,South DMC and East DMC

Maintenance of parks and open spaces

Parks and open spaces are civic amenities, and the responsibility of their upkeep and maintenance lies with the ULBs or any other organization in charge of these spaces— like DDA, ASI, CPWD or DUSIB. As the majority of parks in the city are of neighbourhood scale, they fall under the jurisdiction of ULBs. The role of ULBs in the maintenance of these spaces is, therefore, very important.

It is to be noted that ULBs lack the human and financial resources needed to maintain all parks in the city. In many cases, therefore, ULBs work out arrangements with RWAs for the day-to-day upkeep and maintenance of these parks. Ward councillors also provide financial assistance to RWAs for development and maintenance of parks under the local area development fund.

The Delhi Parks and Gardens Society (DPGS) is a registered society formed by the GNCTD in order to provide assistance in the management of various parks and gardens in Delhi. As many parks and gardens are maintained by RWAs, DPGS has been implementing a financial assistance scheme under which it provides Rs 2–3 lakh annually to RWAs and NGOs to develop and maintain these parks and gardens.

As of September 2020, a total of 435 entities have been provided financial assistance, amounting to Rs 6.59 crore (Rs 65 million). A total of 1,797 parks (with a combined area of 234 hectare) are being maintained under this scheme.[8] While this fund is aimed at providing maintenance material in terms of equipment, manure, fertilizers, etc., the scheme has the potential to expand and implement WSUDP in select parks.

3.6 WSUDP—policies, programmes and projects

Delhi has an annual monsoon affair with urban flooding and waterlogging (see *Section 3.7: Urban flooding*). This is coupled with depleting groundwater resources in many parts of Delhi, and diminishing waterbodies due to rapid and unsustainable urbanization. In response to these factors, numerous measures for rainwater harvesting have been put in place in different parts of Delhi. This section highlights the policies, plans, programmes, schemes and projects related to WSUDP in Delhi.

Policy-level interventions

Draft Delhi State Water Policy[9]

The draft Delhi State Water Policy was released by DJB in 2016, but is yet to be notified by GNCTD. The draft policy calls for installation of RWH structures in all new constructions. It recommends buildings of institutional land uses to install RWH structures. The policy suggests aggressive pursuit of RWH at micro- and macro-scale, and strategizing incentives for implementation.

DJB has also released the *Rainwater Harvesting Guidelines*[10] which provide schematic designs for RWH structures. The Delhi Water and Sewer (Tariff and Metering) Regulations, 2012, have made the following provisions in this regard:

- RWH for recharge is compulsory in all buildings having area greater than 100 sq m and discharge of more than 10 kilolitre per day
- Water permission shall be granted only after relevant certificate of installation of a functional RWH system is produced
- In areas where post-monsoon groundwater table is shallower than 5 m b.g.l., buildings need to install storage structures, and recharge structures are not recommended
- Failure to install RWH as per the regulations will attract a penalty 1.5 times the water bill. In terms of incentives, a 10 per cent rebate on the water bill will be granted to properties installing a functional RWH system. In case of RWH systems being installed in group housing, each individual member will be eligible for a 10 per cent rebate

Key takeaways

- Provision of RWH in buildings have been clearly defined, with various incentives and penalties put in place. The RWH guidelines provide a general overview and schematics for designing of RWH systems. However, the policy and guidelines do not mention the modalities of operation and maintenance of RWH structures
- The policy and guidelines are silent on institutional arrangements with respect to monitoring the functionality of implemented structures
- RWH initiatives are only limited to roof-top or building level. The policy and guidelines do not mention implementation of RWH in public parks and open spaces. Stormwater harvesting in areas such as floodplains and water bodies is vaguely mentioned in the draft policy

National-level guidelines

Manual on Stormwater Drainage Systems[11]

The Manual on Stormwater Drainage Systems, 2019 was prepared by Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Housing and Urban Affairs, Government of India as a three-volume guideline, providing details on engineering, operation and maintenance, and management of drainage systems in urban areas. The objective of the manual is to aid government functionaries in the better planning, design, operation and maintenance, and management of stormwater infrastructure in urban areas.

While the manual provides detailed design, operation and maintenance, and management techniques for grey infrastructure in detail, it also mentions WSUDP as ‘Innovative Stormwater Management Practices’. The key highlights of the draft Manual are:

- Design of roadside drains is limited to rainfall events of one–five year floods (based on land uses), with detailed analysis of calculation of rainfall intensities
- Innovative stormwater practices showcase best practices from Australia (WSUD), USA (LID) and France (SuDS), which provide broad objectives and methodology of these models
- A separate section on integration of RWH in stormwater drainage design includes use of parks, open spaces and low-lying areas for retention and groundwater recharge, as a measure to reduce run-off load in stormwater drains

Key takeaways

- Guidelines on WSUDP in the form of best practices are inadequately mentioned, without any details on planning, design, operation and maintenance, and management. These are introduced as concepts and approaches, providing a general methodology. Further contextualization and techniques are required
- Design of stormwater drains does not take into account higher rainfall intensities, and misses out on moderate and extreme rainfall events, which need to be taken into account due to changing climate
- Integration of roadside stormwater drains with natural drains has to be detailed in the manual

Planning interventions

Master Plan for Delhi, 2021[12]

DDA is the authority in-charge of preparation of the Master Plans for Delhi (MPDs). Rainwater harvesting provisions for buildings were first recommended in the MPD, 2001. MPD, 2021 has estimated the annual rainwater harvesting potential of Delhi at 2,500 million litres per day. This is in addition to the rooftop rainwater harvesting potential of 27 million litres per day. The plan estimates that 25 per cent of the annual potential would cover the projected water deficit of the city. MPD 2021 has incorporated the following rainwater and stormwater harvesting recommendations:

- Layout plans of all residential areas, industrial clusters, motels, hotels, institutional buildings, etc. are required to have rainwater harvesting as an integral part of their stormwater drainage plans
- Development of parks and green corridors along nallahs shall incorporate rainwater and stormwater harvesting features
- Zonal Development Plan for Zone 'O' recommends floodwater harvesting in the floodplains of River Yamuna
- Multi-purpose grounds of community scale (with a minimum area of two hectares) and above are required to reserve 5–10 per cent of their area for rainwater harvesting or a waterbody
- Development of features like sub-wells under flyovers for rainwater harvesting has to be promoted
- Features classified as 'waterbodies' and listed in the Plan and waterbodies with a minimum size and surface area greater than one hectare should be preserved by concerned authorities

Key takeaways

- The provisions highlighted in MPD, 2021 clearly state that apart from buildings and various land uses, public parks and gardens need to reserve area for rainwater and stormwater harvesting or for a waterbody
- Provisions for RWH is limited to multipurpose grounds of community scale. Similar interventions need to be recommended for parks at neighbourhood level

NCR Regional Plan, 2021

The NCR Planning Board (NCRPB) is the authority in-charge of preparation of the Regional Plans for the NCR. Part of the regional plans are 'Functional Plans', prepared to elaborate one or more aspects of the regional plan. Rainwater harvesting provisions are made under the following functional plans for NCR:

- Functional Plan on Drainage for NCR[13] recommends harvesting of surface run-off by increasing recharge from the basins through various methods, including natural as well as induced techniques, such as placing recharge structures in the drains, recharge trenches, wells, harvesting by means of reviving or recharging lakes and ponds, and rooftop harvesting
- Functional Plan on Groundwater Recharge for NCR[14] recommends RWH techniques for recharge from rooftop catchments and public parks and open spaces, through recharge wells and sustainable urban development system (SuDS) structures

Key takeaways

- NCR Regional Plan focuses on various aspects of rainwater and stormwater harvesting to address issues related to urban flooding and groundwater recharge in the NCR. It recommends multi-scale strategies for rainwater and stormwater harvesting for *nallahs*, open areas, buildings, floodplains, and buffer areas, etc.

Drainage Master Plan for NCT of Delhi[15]

The Drainage Master Plan for NCT of Delhi was prepared by the Department of Irrigation and Flood Control (I&FC), GNCTD in 1976. The latest version has been prepared by IIT Delhi on behalf of the Department of I&FC and is aimed at mitigation and elimination of issues related to urban flooding and waterlogging. The document provides the following provisions for rainwater and stormwater harvesting at various scales:

- Adoption of low-impact development (LID) options to manage stormwater run-off, wherever feasible. These options include SuDS techniques
- Rejuvenation of water bodies which are in a poor state, and have been encroached upon. These bodies act as natural detention and recharge basins

Key takeaways

- The plan strongly recommends use of SuDS techniques to handle stormwater run-off, and address issues of waterlogging and urban flooding. Simulations illustrated in the plan showcase options for using parks and open spaces for stormwater harvesting using SuDS features
- Rejuvenation of waterbodies has been stressed upon, in order to repair broken linkages of smaller catchments, which can act as critical green infrastructure

Project-level interventions

Urban development missions: AMRUT and Smart Cities Mission

Delhi is one of the 500 Atal Mission for Rejuvenation and Urban Transformation (AMRUT) cities, and receives funds for implementing urban infrastructure projects as per key thrust areas. Projects under AMRUT are aimed at achieving service-level benchmarks (SLBs). SLBs for the thrust area 'Storm Water Drainage to Reduce Flooding' are:

- Per cent length of roads with stormwater drains
- Incidences of sewage mixing in drains
- Incidences of waterlogging

The NDMC area of NCT of Delhi is one of the 100 Smart Cities, which implement projects under area-based development and pan-city strategies. There are varied thrust areas for these projects

Key takeaways

- Projects under AMRUT are implemented by the GNCTD and the ULBs in Delhi. While information on progress of various projects is limited, there are no projects related to rainwater harvesting in public parks and open spaces
- RWH projects in parks and open spaces are not implemented under the Smart Cities Mission

Waterbodies revival and floodplain management by DJB and Department of I&FC

DJB and the Department of I&FC are working on two projects related to revival of waterbodies in Delhi, and floodwater harvesting in the Yamuna floodplains. DJB has identified 159 waterbodies in Delhi for the Waterbodies Revival Project. They have also identified areas for groundwater recharge in Yamuna floodplains. The status of these projects is:

- Only one functional project, Rajokari Lake Revival Project, has been completed, and the model project is still under the testing phase. The lake precinct, however, is designed to accommodate excess surface run-off and direct it to the lake
- The initial project for floodplain harvesting has been identified in the Palla region in northern Delhi, and is in the planning and design stage

Key takeaways

- The performance of the model project at Rajokari has given mixed results in terms of lake revival with respect to water quality. The stormwater harvesting system implemented at Rajokari is a replicable design, for managing run-off within the lake precinct. However, it needs to take into account other aspects like community participation, etc. The site may or may not address flooding and waterlogging issues in the neighbouring settlements.

In addition to these projects by the GNCTD, various other projects related to rainwater and stormwater harvesting in open parks and public places have been implemented by community groups, and other non-state actors like NGOs, RWAs, etc. Some of them include RWH in parks of Nizamuddin East Colony, revival of Pochanpur Lake, and stormwater harvesting in Garden of Five Senses and parks of Vasant Kunj.

A brief summary of rainwater and stormwater harvesting recommendations at various levels is shown in *Table 6: Rainwater and stormwater harvesting components in policies, plans and projects*. The summary illustrates whether a particular policy, plan or project addresses the various dimensions related to rainwater and stormwater harvesting: rooftop RWH, RWH in parks and open spaces, water body rejuvenation and floodwater harvesting and similar measures.

Table 6: Rainwater and stormwater harvesting components in policies, plans and projects

Policy, plan or project	Rooftop RWH	WSUDP for parks and gardens	Waterbody rejuvenation	Floodwater harvesting
Draft State Water Policy				
CPHEEO Manual, 2019				
MPD, 2021				
Drainage Masterplan, 2018				
NCR Regional Plan, 2021				
AMRUT and Smart Cities				
DJB projects				

Source: CSE, 2020

Planning interventions recommend rainwater and stormwater harvesting across multiple dimensions. The drainage masterplan focuses on drainage issues beyond individual buildings. However, the implementation of projects related to WSUDP in parks, waterbody rejuvenation and floodwater harvesting is the responsibility of the local authority and DJB.

WSUDP in public parks and open spaces is still in the planning stage in Delhi, and has not witnessed implementation and impetus from GNCTD authorities (DJB, Delhi Parks and Gardens Society, Department of I&FC, etc.) and the ULBs in Delhi.

In order to mainstream WSUDP in urban areas of India, Delhi-based Centre for Science and Environment (CSE), as a Centre for Excellence under the erstwhile Ministry of Housing and Urban Development, prepared the *Green Infrastructure: A Practitioner's Guide* and *Water-Sensitive Urban Design and Planning: A Practitioner's Guide, 2017.* The guides are aimed to mainstream reforms and help scale-up implementation of WSUDP at building, neighbourhood and city scale.

The guides provide various tools and techniques for planning, design, operation and maintenance, and management of WSUDP projects for parks and open spaces in urban areas. They provide cost-effective nature-based solutions for issues related to urban flooding and stormwater management. They also provide practitioners with planning parameters and best practices regarding suitable locations and WSUDP techniques for various urban settings.

3.7 Urban flooding

It is noteworthy that pluvial flooding in Delhi is an annual affair with various stretches of the city getting waterlogged. Over the past decade, every two years, an extreme rainfall event is recorded, which results in severe flooding in the city, as major roads are waterlogged, resulting in chaos.

Citizens of Delhi face high economic and social losses like impacts on housing and infrastructure, family dynamics and impacts on health during the flooding every monsoon and also for a while after the floods. Vulnerability of different resident groups varies to these events, as certain groups affected by floods suffer more pronounced effects than others.

For instance, slum dwellers and low-income groups residing on floodplains face potentially large-scale damage to property, some are also evacuated from their homes. Over a 10,000 people were evacuated from low-lying areas in the national capital during heavy rains in the month of August 2019.[16] These groups are also vulnerable to certain health impacts and water-borne diseases as children and women are exposed to these waterlogged stretches, resulting in direct contamination and ingestion of pathogens.

One such example can often be observed in the informal settlement of Sangam Vihar in Delhi. Stormwater drains in the area are inadequate, cramped within the 3 m-wide internal roads to cater to high peak run-off. Roadside drains in the local streets have to carry greywater from households, effluents from household industrial units and stormwater from streets and houses. It eventually results in flooded roads, sometimes about three–four feet deep.[17]

For the rest of the income groups, too, urban flooding causes widespread disruption in the city life, essential public services and transport systems, not least through the loss of income. People commuting to work and other purposes have to swim against the tide of the urban flood, literally and metaphorically.

For example, the rains of August 2019 in Delhi made commuters battle through knee-deep waters and cars and buses were submerged as torrential rains added to the traffic woes in the city of 20 million.

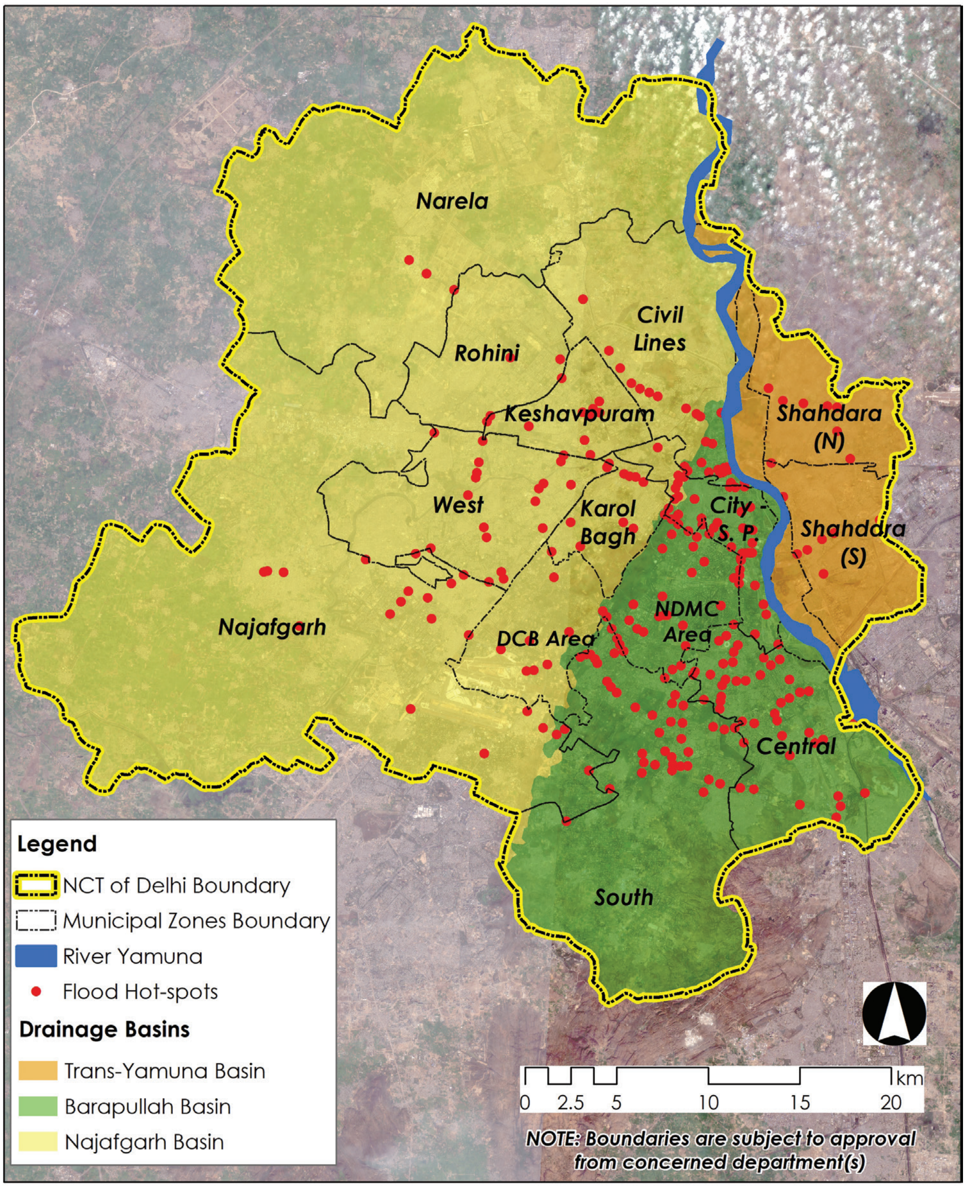
With 30 August 2016 receiving 63 mm rainfall in three hours, it resulted in severe flooding of roads in the capital city.

A waterlogged carriageway in Delhi during the August 2016 monsoon

Source: Saxena, V. (2 Sept, 2016). Delhi waterlogging: Same old story in same old problem spots. India Today.

Delhi Traffic Police has identified as many as 160 chronic waterlogging stretches, in both planned and unplanned areas (see *Figure 17: Flood and waterlogging hotspots in Delhi*). Delhi and Gurgaon witness flooded roads and chaos every monsoon, as they receive more than 20–25 mm in a day very often (see *Figure 18: Incidents of flooding in Delhi-NCR*).

Figure 17: Flood and waterlogging hotspots in Delhi



Source: Drainage Masterplan for NCT of Delhi

Increase in flood frequency due to Delhi sub-basin's urbanization leading to increase in impervious areas and enhanced surface run-off is one of the major reasons leading to frequent flooding. Rapid urbanization with low level of outfalls, dilapidated drains, obstruction of utilities, encroachment along nallahs, failure to hold on to and maintain natural lakes and ponds, cropping up of garbage dumps or solid waste disposal in stormwater drains are other factors that exacerbate the situation.[18]

Urban drainage has been given low priority in the city, much behind water supply and sewerage, so most plans were never implemented or completed. In September 2018, while pulling up authorities for poor stormwater management, the Delhi High Court described Delhi as the waterlogged capital of India.[19] Overall, the city lacks the systematic approach to plan, formulate and implement a stormwater drainage system with a holistic approach.

Figure 18: Incidents of flooding in Delhi-NCR

Source: Compiled by CSE, 2020

4. Potential of WSUDP in NCT of Delhi

The NCT of Delhi has more than 16,000 parks and open spaces, spread across the city, of many different hierarchies (see *Section 3.5: Planning and management of parks*). MPD, 2021 provides various norms and standards for development of parks and open spaces at multiple scales (see *Table 3: Norms and standards for parks and recreational areas*). The norms also recommend allocation of 1–5 per cent area for WSUDP intervention in neighbourhood parks and 5–10 per cent for multi-purpose parks of higher hierarchies (see *Section 3.6: WSUDP—policies, programmes and projects*).

In addition to this, norms and standards for maximum allowable ground coverage for each land use and use zones in Delhi have also been also defined. According to the Guidelines, the average built-up area for a group housing must be 33 per cent, while the remaining 67 per cent has to be available open space. Realizing the potential for these open spaces, MPD, 2021 has recommended implementing WSUDP interventions as a part of the drainage plan for layouts prepared in these land uses. Per capita green space availability in Delhi is 20 sq m (approximately) and per capita public open space is 30 sq m (approximately).

It is high time that public open spaces in Delhi are analysed and designed to give space for run-off to avoid flooding. Interventions can take the shape of waterbodies such as ponds, parks and other green areas. They can be used for recreational activities for the rest of the year. There is a need to include public open spaces within the urban fabric in the form of storm management infrastructure that could help transform Delhi into a water-sensitive city.

4.1 WSUDP potential in parks and open spaces

Planning and designing for WSUDP interventions in parks and open spaces is dependent on a variety of factors. Depending on the natural resource profile, land cover and flood vulnerability, different parts of the city have different potential for WSUDP. In order to analyse these parameters, indicators for assessment of WSUDP potential have been prepared (see *Table 7: Indicators for determining potential of WSUDP in parks and open* spaces). A zonal level analysis of Delhi has been conducted in order to identify the potential areas for implementing WSUDP in parks and open spaces, based on principles of moderation of run-off, retention and infiltration.

Table 7: Indicators for determining potential of WSUDP in parks and open spaces

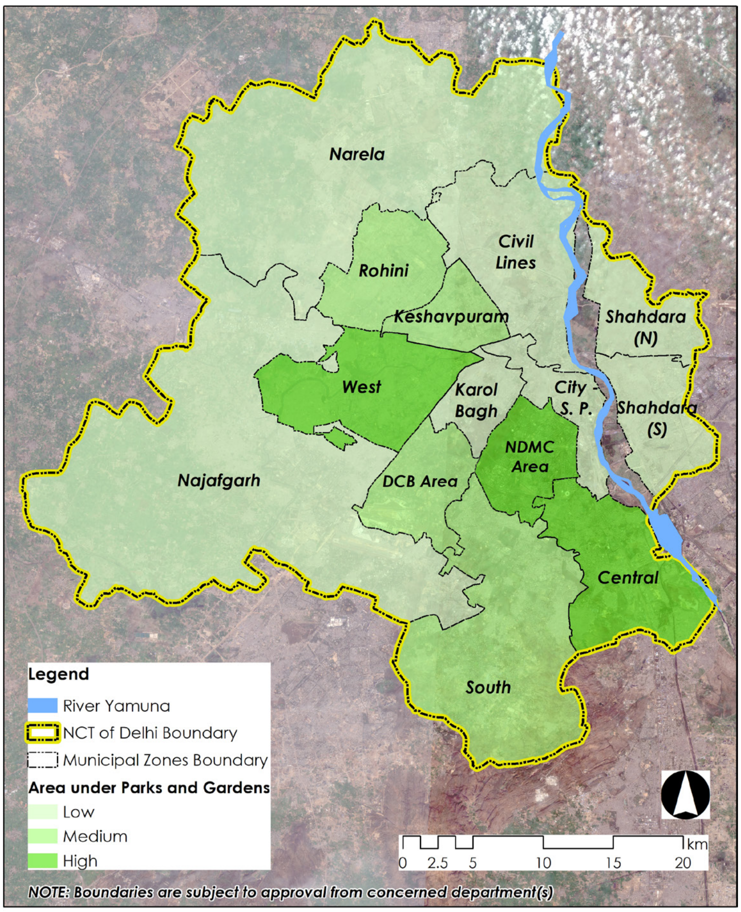
Indicator	Potential of WSUDP
Area under parks, open spaces and recreational area	• Municipal zones having higher number of parks provide more opportunities for implementing WSUDP • Areas under regional-level parks have higher potential for large-scale interventions
Post-monsoon groundwater level	• WSUDP designs for areas having shallow groundwater table are based on principles of retention and moderation of excess run-off • Areas with steeper groundwater levels are better suited for WSUDP interventions based on the principles of infiltration
Geology and soil type	• WSUDP designs for areas having a rocky terrain are limited to small-scale retention areas • For areas having higher content of clayey soil, retention strategies are more suitable, whereas areas with sandy–loamy soil are better suited for infiltration-based WSUDP interventions
Flood or waterlogging hotspots	WSUDP interventions based on retention and moderation of run-off in parks and open spaces in the vicinity of flood and water-logging hotspots can address flooding issues
Low-lying areas	WSUDP interventions in parks and open spaces in low-lying areas vulnerable to flooding are essential for flood mitigation

Source: CSE, 2020

Area under parks, open spaces and recreation areas

The city has approximately 8,000 hectares under parks, gardens, open spaces and recreation areas. However, they are not uniformly distributed across Delhi (see *Figure 19: Geographical distribution of area under parks in Delhi).*

Figure 19: Geographical distribution of area under parks in Delhi



Source: CSE, 2020

Outskirts of Delhi in the Najafgarh, Narela and South zones are categorized as urban extension areas under the MPD, 2021. These areas are yet to be urbanized. Municipal zones West and Central and NDMC area have the highest area under parks and gardens. A majority of these areas are planned and developed keeping in mind the provision of different hierarchies of parks and open spaces.

Area under Delhi Cantonment Board (DCB), and South, Rohini and Keshavpuram zones have considerable area under parks and open spaces, and have a mix of formal and informal developments. Karol Bagh, City S.P., Civil Lines and Shahdara are organic settlements of the city, and these also contain informal settlements. Compared to other zones, these zones have lower areas under parks and gardens.

Post-monsoon groundwater table

Post-monsoon groundwater levels are less than 5 m b.g.l. along the Yamuna floodplains, in Shahdara, Civil Lines, City-S.P. zones and parts of the central zone (see *Figure 11: Post-monsoon groundwater table in Delhi, 2017*). Moreover, Rohini, Keshavpuram and West zones also exhibit shallow groundwater levels post-monsoon. For these areas, WSUDP strategies in parks and open spaces are suited for retention and moderation of excess run-off.

South, Central and Najafgarh municipal zones exhibit a deep groundwater table post monsoon, and WSUDP strategies suited for infiltration are recommended in these zones. Furthermore, these zones (except areas under the Delhi Ridge) have a positive GW fluctuation, with rise in the water table from pre- to post-monsoon. Therefore, infiltration strategies are recommended for parks in these zones.

Geology

The majority of the city consists of old Yamuna alluvium (see *Figure 8: Geology of Delhi*), for which WSUDP interventions for both retention and infiltration are recommended. For areas having young alluvium, in floodplains of Yamuna and plains of other natural streams, WSUDP interventions for retention and moderation of excess run-off are recommended. WSUDP strategies based on retention and small-scale infiltration (wherever possible) for areas under the Aravalli outcrops in South Zone are recommended.

Flood and waterlogging hotspots

WSUDP in public parks and open spaces provide a unique opportunity to address issues related to urban flooding and waterlogging. Waterlogging on impervious surfaces like roads, streets, parking areas, etc. can be conveyed into parks and open spaces, where part of it percolates into the soil, while the remaining flood waters can be temporarily held for 6–18 hours (depending upon run-off generated), while the drainage system is overwhelmed during a flood event.

As per the Drainage Masterplan for Delhi, the majority of flood hotspots are located in South, Central, and City S.P. zones, and the NDMC area. Hotspots have also been identified in West, Rohini, Keshavpuram and Karol Bagh zones (see *Figure 17: Flood and waterlogging hotspots in Delhi*).

Low-lying areas in Delhi

While flood hotspots provide the areas reported to be flooding as per the Delhi Traffic Police, it is to be noted that the enumeration of these areas is not an exhaustive list. It is important to identify areas vulnerable to floods, mostly low-lying areas in the city. These areas are prone to flooding, and WSUDP in parks and open spaces in the vicinity of these areas can address issues of waterlogging.

Conclusion

The NCT of Delhi provides various opportunities for WSUDP in parks and open spaces of various scales. Based on the indicators, municipal zones South and Central and the NDMC area are ideal for providing a range of WSUDP strategies for retention and moderation of excess run-off, as well as for infiltration strategies. As these zones also witness higher number of incidents of waterlogging and flooding, they provide an ideal scenario for selection of pilot examples.

Further, West, Rohini and Keshavpuram zones also provide a wide range of opportunities for WSUDP interventions based on retention and moderation of excess run-off. These areas, and parts of the Najafgarh zone, also contain large number of regional parks, which can be used for conserving and reviving local waterbodies through large-scale WSUDP interventions. The overall potential of WSUDP in parks and gardens of different scales in Delhi are summarized in *Table 8: Summary of WSUDP potential in parks of Delhi*.

Table 8: Summary of WSUDP potential in parks of Delhi

WSUDP potential	South DMC	North DMC	East DMC	Total
Neighbourhood parks				
Total park area (hectare)	1,015	604	245	
Annual potential run-off (million litres)	1,299	772	313	2,384
Area of WSUDP interventions (hectare)	10 to 15	6 to 9	2 to 4	
Community parks				
Total park area (hectare)	436	183	28	
Annual potential run-off (million litres)	558	234	36	828
Area of WSUDP interventions (hectare)	4 to 7	2 to 3	0.2 to 0.4	
Regional parks				
Total park area (hectare)	87	60	18	
Annual potential run-off (million litres)	111	77	23	211
Area of WSUDP interventions (hectare)	1 to 1.5	1 to 1.5	0.1 to 0.3	
Total WSUDP potential (million litres)	**1,968**	**1,083**	**372**	**3,423**
• Annual rainfall of Delhi: 800 mm (approximate) • Assumed peak rainfall: 100 to 150 mm • Depth of infiltration structures: 2 m • Area of infiltration structures: 1.5–3 per cent of total area of parks (to cater to peak rainfall over 15 minutes)		**3,424 million litres run-off quantity is the missed potential which sometimes become a liability in the city. If managed efficiently, the run-off can be stored, recharged and moderated during peak rainfall**		

Source: CSE, 2020

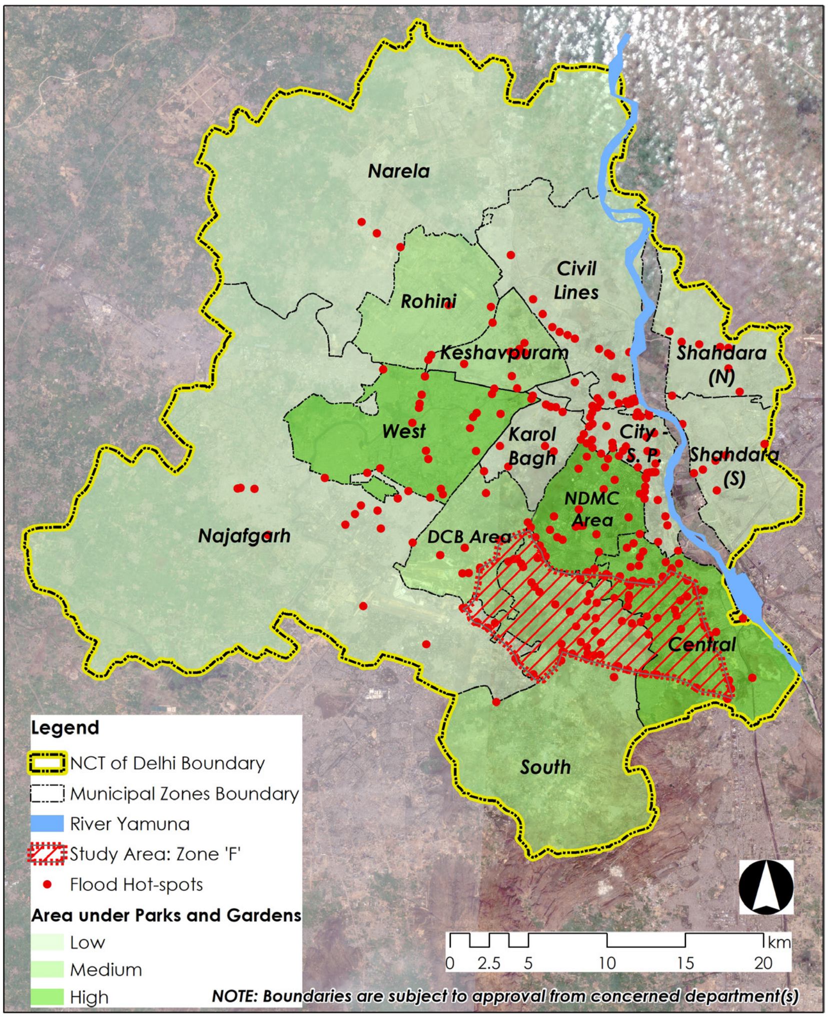
5. Pilot sites for WSUDP in parks and open spaces

The NCT of Delhi provides various opportunities for WSUDP interventions in parks and open spaces. South and Central municipal zones (under South DMC) provide an ideal scenario for exploring potential WSUDP interventions in parks and open spaces of different hierarchies.

In addition to parks, these areas also contain a network of green spaces along the city forests like Jahanpanah City Forest, Sanjay Van, etc., which can be harnessed to reap cumulative benefits.

Under these municipal zones, the South Delhi area (DDA Zone 'F') is selected to further explore these linkages, and identify pilot parks for the WSUDP concept plan. Zone 'F' is one of the greenest areas in Delhi, contaning a large number of open spaces of various scales.

Figure 20: Study area for the WSUDP pilot cases



Source: CSE, 2020

It has a mix of informal and formal residential development, with a wide variety of institutional land uses. The area also contains a large number of flooding hotspots (see *Figure 20: Study area for the WSUDP pilot cases*). A brief profile of the study area has been explored, followed by selection of pilot case studies.

5.1 Study area profile

Zone 'F' is bound by the Inner Ring Road to the north, Mehrauli–Badarpur Road to the south, Mathura Road to the east and NH-8 to the west. Movement Corridors aim to link tracts of scattered metropolitan greens along with the network of nullahs. Other areas of opportunity within Zone 'F' include links to city greens, nullah systems, arterial roads, connecting neighbouring precincts and amenities. The general characteristics of the zone are mentioned in *Table 8: General parameters of the study area*.

Table 9: General parameters of the study area

Area (hectare)	11,958
Recreational area (hectare)	3,105
Per capita open space (sq m)	16.1
Category of greens	• Regional scale: South Delhi Ridge • City scale: Mehrauli Archaeological Park, Tughlaqabad Archaeological Park, Hauz Khas Forest, Sanjay Van and Jahanpanah Forest • Neighbourhood scale: Various parks in residential areas
Major waterbodies	Jheel Park, Hauz Khas and Satpula

Source: Zonal Development Plan for Zone 'F', 2021

Geological cross-sections across South Delhi expose quarzatic ridges that rise to about 300 m a.s.l. in some locations and drop to 100 m b.g.l. in certain other areas (CGWB, 2006 a). They also reveal that the Chhattarpur Basin is filled with clay, silt, and kankar nodules and intercalated granular zones of sand.

Drainage basin

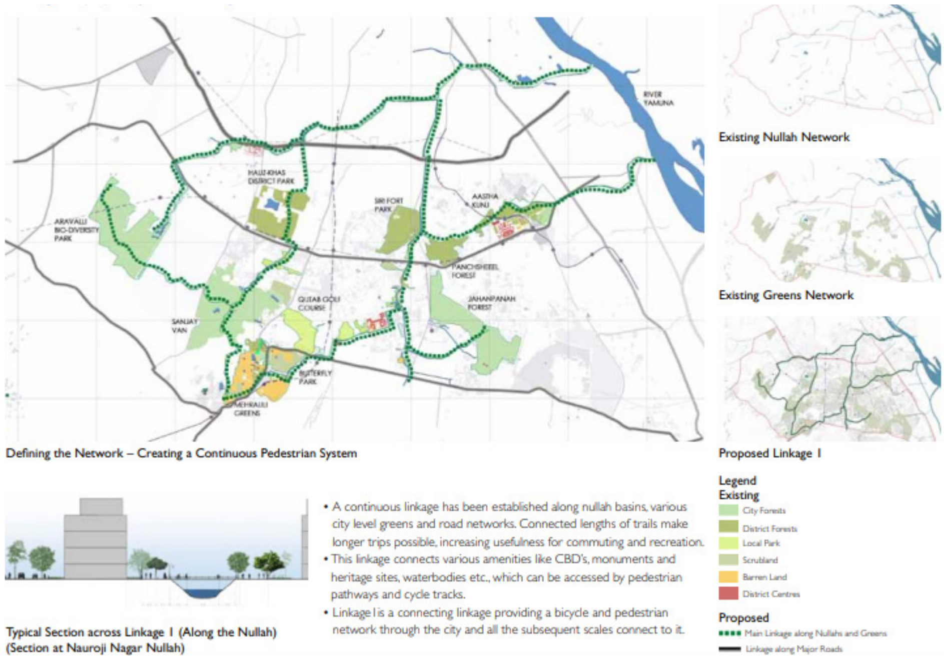
Zone 'F' lies in the drainage basin of the Kushak sub-basin, which includes drains such as a part of the Barapullah *nallah*, Kushak Drain and Palam Drain. It also includes the Sarita Vihar Drain, Maharani Bagh Drain and Kalkaji Drain. It is part of the larger Barapullah Basin. The system of *nallahs* distributed across the city follows its natural topographic features (see *Figure 21: Blue–green linkages in Zone 'F'*). In Zone 'F', it connects the Aravalli in the south to the Yamuna River Basin.

Stormwater resource management in public open spaces

Zone 'F' includes numerous city-level forests such as Sanjay Van, Aravalli Biodiversity Park, Jahanpanah Forest, etc. (refer *Figure 21: Blue–green linkages in Zone 'F'*). These form parts of metropolitan green expanses like forests, district parks, planned greens and avenue plantations.

Continuous stretches of green and vacant pockets could be transformed into unobstructed and alternative paths for the movement of water between important destinations in Zone 'F'. The zone contains large pockets of various levels of greens, which form a natural continuous organic pattern. These green and open pockets have the potential to be connected via internal trails and form a network for movement of rainwater and stormwater within the zone.[20]

Figure 21: Blue–green linkages in Zone 'F'



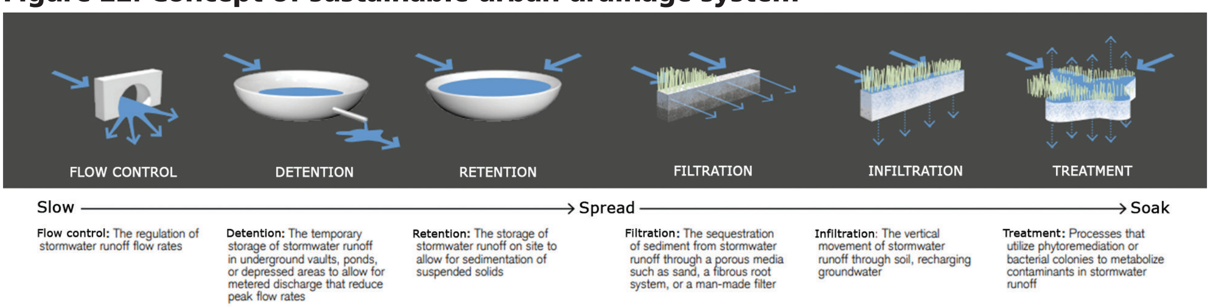
Source: DUAC (2014), 'Movement Corridors: Vision for Delhi (South Zone)'

These connected public open spaces in Delhi could also be used to follow the SuDS train (see *Figure 22: Concept of sustainable urban drainage system*). Stormwater retention structures could be placed in these connected open spaces to prevent and reduce stormwater run-off quality and quantity (preventing run-off by reducing impermeable areas).

These practices are characterized by being located within green spaces or other clearly defined public areas that can manage the storage and conveyance of surfacewater run-off.

The main objective of stormwater retention areas is to integrate stormwater management into the landscape, creating multiple-use corridors that maximize the visual and recreational amenity of urban development. Environmental benefits such as reducing artificially increased volumes of stormwater run-off as a result of urban development and protection of groundwater resources can be achieved with stormwater management and aquifer recharge schemes.

Figure 22: Concept of sustainable urban drainage system



Source: Adopted fromHuber, J. (2010). Low-Impact Development: a design manual for urban areas. University of Arkansas Community Design Center: Fayetteville, AR, USA.

5.2 WSUDP concept plans for pilot areas in Delhi

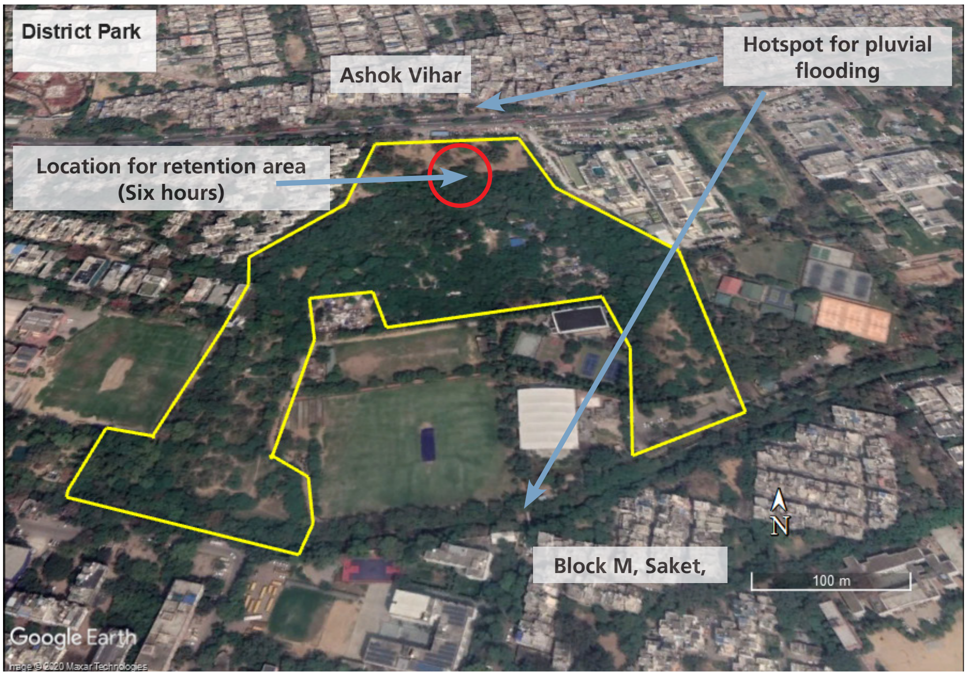
In view of the discussion on existing green open spaces in Delhi to retain and infiltrate stormwater in monsoon, three parks (of different scales) in Zone 'F' have been taken into consideration for calculating WSUDP potential. The criteria for selection include vicinity of flooding hotspots, which can be effectively addressed by WSUDP.

The three parks selected for pilot projects are:

1. Saket District Park
2. Park along Ring Road
3. Neighbourhood park, Greater Kailash

Saket District Park

Coordinates: 28.525802°N, 77.209875°E; | Area: 71,150 sq m (approximately).



Source: CSE, 2020

Potential run-off generated: 56,921 kilo-litre annually with an annual rainfall of 800 mm. Assuming peak rainfall to be within the range of 100–150 mm:

- Depth of structure to be 2 m
- Area required for infiltration structures will be within the range of 890–1,134 sq m.

Hence, the percentage of land required to be dedicated for infiltration structures is in the range 1.5–2 of the total area of the park to cater to peak rainfall of over 15 minutes.

Potential infiltration systems (see *Annexure*):

- Swale along the footpath or desired path
- Bio-retention areas surrounded by vegetation at nodes
- Detention basin in the centre
- Infiltration basin

District Park, Saket: Play area

Inflow points for excess run-off from neighbouring Panchsheel Colony

Source: CSE, 2020

Park along Ring Road

Coordinates: 28.542494°N, 77.214938°E | Area: 7,000 sq m (approximately)

Figure 24: WSUDP structures for the park along the Ring Road

Source: CSE, 2020

- Potential run-off generated: 1,120 litres annually with annual rainfall of 800 mm
- Assuming peak rainfall to be within a range of 100–150 mm
- Depth of structure to be 2 m
- Area required for infiltration structures will be in the range of 88–131sq m

Hence, the percentage of land required to be dedicated for the infiltration structure is in the range of 1.5–3 of the total area of the park to cater to peak rainfall of over 15 minutes.

Potential infiltration systems (see *Annexure*):
- Bio-retention areas can be located after identifying low-lying areas within the park
- Trench with filter strips and swales can be located along the footpath.

Neighbourhood park, Panchsheel Enclave

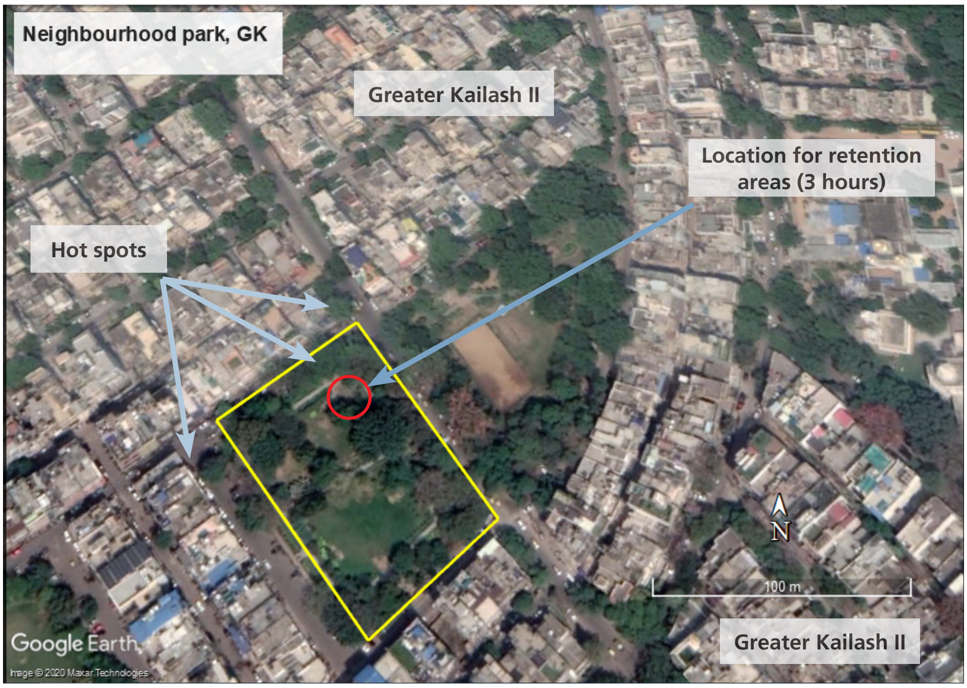
Divided catchments in the park

Source: CSE, 2020

Neighbourhood park, Greater Kailash

Coordinates: 28.534163°N, 77.243980°E; | Area: 5,940 sq m (approximately)

Figure 25: Neighbourhood park, Greater Kailash



Source: CSE, 2020

- Potential run-off generated: 950 litres annually with a rainfall of 800 mm
- Assuming peak rainfall to be in the range of 100–150 mm
- Depth of structure to be 2 m
- Area required for infiltration structures will be in the range of 74–100 sq m

Hence, the percentage of land required to be dedicated for infiltration structures is in the ranges of 1.5–3 of the total area of the park to cater to peak rainfall of over 15 minutes.

Potential infiltration systems (see *Annexure*):
- A small rain-garden can be proposed with provisions of overflow
- Trench with filter strips and swales can be located along the footpath

Neighbourhood park, Greater Kailash

Potential area of capturing run-off from the road into the park

Public amenities in the park: Bio-toilet

Source: CSE, 2020

6. WSUDP approach to develop parks and open spaces

Multi-functionality of an open green space is essential in urban areas. Green spaces provide critical health and social benefits like recreation and relaxation, leisure and sports as well as environmental benefits like thermal comfort, absorption and filtration of pollutants. They also work as a buffer against noise pollution and provide habitats for maintaining biodiversity.

Furthermore, green open spaces play a major role in water management, as they help mitigate urban flooding by collecting water from heavy rainfall and allowing it to percolate into the soil rather than losing it to open waters and overburdening the existing drainage system or sewer systems of cities.[21]

Sustainable landscape focuses on creating environments that are beneficial for both human uses and natural resource conservation in both the short- and long-terms. To minimize the consequences of urban flooding caused by local heavy rainfall, a system of well-designed green open spaces with infrastructure can significantly contribute to urban neighbourhoods and maximize the benefits in managing urban stormwater. Open green spaces can be a great space if they are sensitively designed, properly maintained and appropriately programmed.[22]

There is a great variability in the sustainability of an open green space or parks in how they are designed and their response to particular landforms, geology and climate. These spaces function best when they are in their original geography and natural history of the site, minimally developed and blend seamlessly into the existing topography. Naturalistic parks and gardens tend to leave the terrain of their sites unaltered, or sculpt it in collinear shapes, use more native plant species and their water features closely resemble natural forms (see *Figure 26: Levels of naturalistic and structured gardens*). They must be adapted to meet the physical constraints of the site, including soil conditions, natural flow pathways, space availability and the location of sewer, stormwater, water and other utilities.[23]

The levels of topographic variations, small hills, ditches with the use of slopes or steps provides different perceptions and dimensions to a park or garden space and enables it to be used for different purposes.[24] In contrast, most commonly seen green open spaces and parks transform the natural topography of their sites into flat or inclined planes that challenge the natural drainage of rainwater run-off.

The following suggestions emphasize the various principles to consider while designing and landscaping open green spaces in a sustainable manner that protects and enhances all of their natural resources while making provisions for human use:[25]

- Retain as much as possible of pre-existing landscape and follow the natural flow pathways
- Think through the terrain and slope of the site
- Maintain high quality soils and native vegetation
- Minimize non-porous surfaces
- Maintain natural stormwater management and green infrastructure systems
- Structures and furnishings must be congruent with the naturalistic environment

Figure 26: Levels of naturalistic and structured gardens

Source:Twedt, E., Rainey, R. M. (2016). Designed natural spaces: informal gardens are perceived to be more restorative than formal gardens. Frontiers in psychology, 7, 88.

Some examples of successfully implemented parks and open spaces based on the above principles are as follows:

Retain as much as possible of pre-existing landscape and follow the natural flow pathways

Retain as much as possible of pre-existing landscape during development of open spaces including the contour of sites, soil, rocks, native vegetation and wetlands, if any. A site should follow natural flow pathways of rainwater to help manage site run-off, which can be determined by examining the topography and historic flood courses. These flow pathways can be attractively integrated with the site's landscaping, reducing irrigation demands and providing valuable site amenities that require minimal maintenance.[26]

Case example: Regis Park, Auckland, New Zealand

A wide-ranging baseline analysis was carried out before the design of the Regis Park was finalized, which includes a detailed understanding of geology; hydrology; topography; biodiversity; urban form; access and movement; archaeological, historic and cultural resources; current structures of public and private open spaces; and landscape character.

Areas with rainwater and stormwater harvesting potential have been managed in a sustainable way using opportunites provided by the natural system. In 2004, earthwork on the site was carried out along ridgelines, followed by the plantation of native trees and wetland seedlings on 60 per cent of the site. This vegetation is now several meters tall. Stormwater is managed at-site.

Regis Park demonstrates that the merging of urban design, urban planning, integrated catchment management, and catchment revegetation can bring about enhancement of aquatic and terrestrial ecology, thereby optimizing the sustainability, aesthetics and liveability of low-density residential neighbourhoods. This is brought about by a combination of urban layout (clustering of buildings to optimize creation of communal open spaces) and at-source stormwater management.

Regis Park low-density development, New Zealand (Photo source: Marjorie van Roon)

Source: Sharma, A., Gardner, T., & Begbie, D. (Eds.). (2018). Approaches to Water Sensitive Urban Design: Potential, Design, Ecological Health, Urban Greening, Economics, Policies, and Community Perceptions. Woodhead Publishing.

Think through the terrain and slope of the site

Wherever possible, shape the terrain of parks in a way that larger areas are at a higher elevation than the surroundings so that cooler air can flow down. Smaller areas with groups of trees should be designed as basins providing space for the retention of large quantities of precipitation. Percolation zones for water precipitation should be set lower as collection of basins for the surrounding terrain.[27] Areas of landscape with a slope of 5 per cent or less are preferred. This absorbed water may be stored below ground, or it may move horizontally through sloping soil patterns.

Case example: Railroad Park, Birmingham, US

This 7.6 hectare park has been developed over 11 abandoned rail line tracks. The site's low elevation makes a logical place to store water from the immediate watershed and to provide flood protection.

The lake creates a major reservoir on site for summer irrigation needs. The fringes of the parks are planted with large bio-filtration wetlands.

The lake and stream system organizes district storm drainage, detaining, infilterating, and bio-filtering water as it passes through the park to a flood storage low point at the west end.

Views of the Railroad Park

Source: Hi-design International Publishing (HK) Co. Ltd.

Maintain high quality soils and native vegetation

Maintain high quality soils that will hold water and supply plants with proper nutrients. Maximum amount of possible existing topsoil should be left on the site during construction.[28] Replace non-native turf grasses with native warm season grasses which have lower maintenance needs. Non-native turf offers little habitat benefit and is not as effective as many native plants in pollution filtration, flood prevention and erosion control. Use native plants as much as possible, especially trees in buffers around any stream, lake or wetland. The roots from these riparian buffers prevent erosion of soils and minimize flooding events. Significantly larger tree base areas and planting pits with higher capacity can be created for water absorption.[29]

Case example: Henry C. Palmisano (Stearns Quarry) Park, Chicago, US

Henry Palmisano Park is designed for the exploration and discovery of natural processes by providing several native ecosystems including prairie plant communities, simulated wetlands, and a large 8,094 sq m pond. All stormwater on the site is directed towards the pond and wetlands instead of the city's sewers. A variety of nature trails wind up and down hills, through native plantings and wildlife habitats.

Views of Henry C. Palmisano (Stearns Quarry) Park

Source: Hi-design International Publishing (HK) Co. Ltd.

Minimization of non-porous surfaces

Minimization of non-porous surfaces like roads and paved trails should be considered. Replacing asphalt and concrete with porous pavement, mulch paths, gravel lots and native vegetation can help recharge groundwater, reduce erosion, lessen flooding events and also filter out pollutants.[30]

Brookside Gardens: Permeable Pavements

Source: LID Centre Inc.

Herron Park pre- and post-GI Elements

Source: Langan Engineering

Case example: Historic Fourth Ward Park, Atlanta, US

Completed in 2011, the Historic Fourth Ward Park is a 17-acre urban park located along Atlanta's Belt Line. It is situated in a lowland area that used experience flooding and sewer overflows during storms. The site of the park was originally a mix of industrial and commercial properties, including areas that had become vacant or blighted. City planners wanted to provide the surrounding neighbourhood with a multipurpose green space in which residents could gather, while at the same time improving stormwater management.The park includes:

- A two-acre stormwater retention pond bordered by plantings and a walkway that can capture run-off from a 100-year storm
- An underground cistern that allows for the reuse of non-potable water, and rain-gardens with constructed wetlands
- An increase in pervious groundcover
- Recreational amenities including open meadows and lawns

Historic Fourth Ward Park: Pre- and post-interventions (Photo source: Steve Carrol, HDR)

Source: U.S. Environmental Protection Agency, Office of Water, June 2017

Natural stormwater management and green infrastructure systems

Natural stormwater management systems and other green infrastructure such as rain gardens and swales with native grasses can be created. Emergency waterways can be devised for redirecting large rainwater masses to temporary retention areas (playgrounds and sports fields) and they should be lowered accordingly. Where space availability for retention areas is not feasible, construction of trenches and cisterns can be considered.

Case example: Trabrennbahn Farmsen Park, Hamburg, Germany

The stormwater management concept of Trabrennbahn Farmsen considers all aspects of the local conditions and the water system was designed to complement the spatial planning scheme. Stormwater being the major element, the visibility of water, in swales, channels, and ponds defines the character of the settlement. Given that infiltration is limited in the area and stormwater is retained, only surplus water is discharged to the receiving water body Hopfengraben.

For this to be possible, the system had to take the naturally existing site grade into account. Various water-sensitive features have been incorporated in the park.

Water elements in Trabrennbahn Farmsen Park

Water quality is ensured by oil-separators and the prohibition of cars in the inner area. In addition, plants are chosen carefully for their water purification qualities.

Open drainage system follows the track of the former harness racetrack; existing ponds in the centre of the quarter are a relic of the former brickyard and now used for retention of stormwater.

Green infrastructure elements in Trabrennbahn Farmsen Park (Germany)

Source: Losco, S. (2014). Water Sensitive Urban Design-WSUD-Principles and Inspiration for Sustainable Stormwater Management in the City of the Future-AA. VV. CSE-City Safety Energy, (1)

Detention Pond at Fourth Ward Park, Atlanta (US)

Constructed Wetland at community park in Chattanoonga (US)

Source: NRPA (National Recreation and Park Association). (2019). Green infrastructure in Parks. Resource guide for planning, designing and implementing

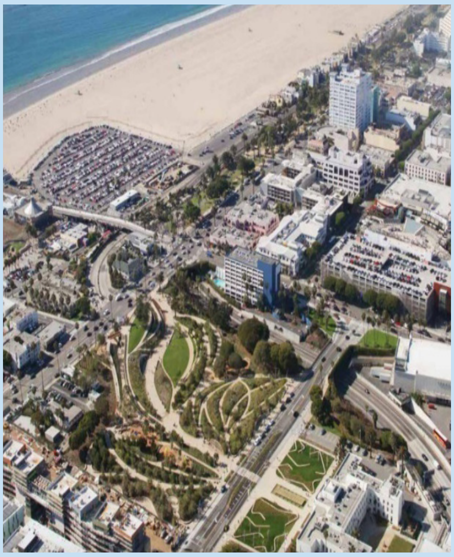
Structures and furnishings must be congruent with naturalistic environment

The different materials used to create structures and furnishings must be congruent with the naturalistic environment of the park.[31] If sloping or irregular earth work is necessary to conform the new construction with the design plan, to provide adequate drainage, or in order to relate properly to neighbouring topography and views, then levelling can be considered.[32]

Case example: Tongva Park and Ken Genser Square, Santa Monica, US

Transformed from a flat parking lot into a series of topographically dynamic meadows and gardens, the most dramatic aspect of the site has been its ecosystem

Materials for the park and square consist of non-tropical hardwoods that have been sustainably forested, local aggregates and stone, numerous products with recycled content, low VOC paints, sealants and adhesives and soy-based anti-graffiti coatings.



Tongva Park and Ken Genser Square View

7. The way forward

The NCT of Delhi has more than 16,000 parks and open spaces, spread across an area in excess of 8,000 hectares, where stormwater harvesting can be implemented. Therefore, a total of 12,800 million litres of rainwater can be harvested in Delhi annually.

Monsoons can be a great asset for Delhi. They certainly have been in the past. However, today, most of the city suffers from problems of urban flooding during the monsoon season. This eventually leads to loss of life and property, and affects economic activities as well as natural ecosystems within the city-state.

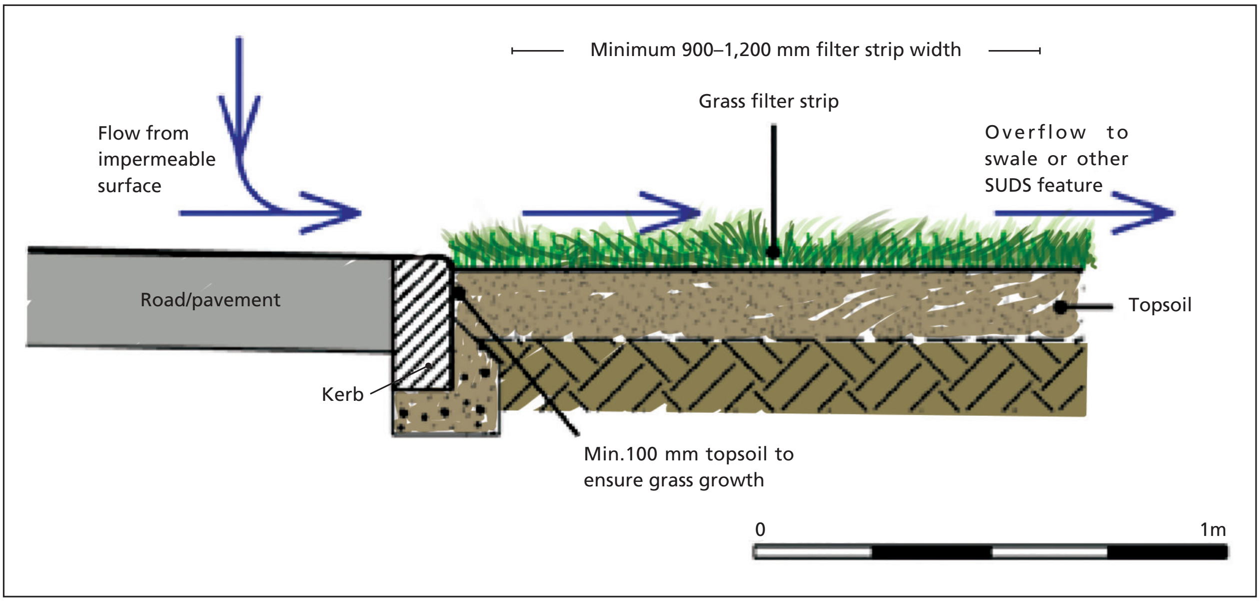
Over the years, it has become clear that directing more and more run-off into surface water drainage systems is not the solution. It will eventually overload them, causing major floods. The need of the hour is to recognize the importance of urban green spaces in creating a naturally-oriented watercycle while contributing to the amenity of the city.

A start could be made with the adoption of water-sensitive approaches to lower hydrological impact of urbanization and increase the hydrological carrying capacity of the urban areas. Promoting rainfall infiltration into the soil at public places, through integration of elements and principles of retention areas into landscape design, could be the immediate initiative that can be taken up by city officials.

8. Annexure: Options and techniques of stormwater management in public open spaces

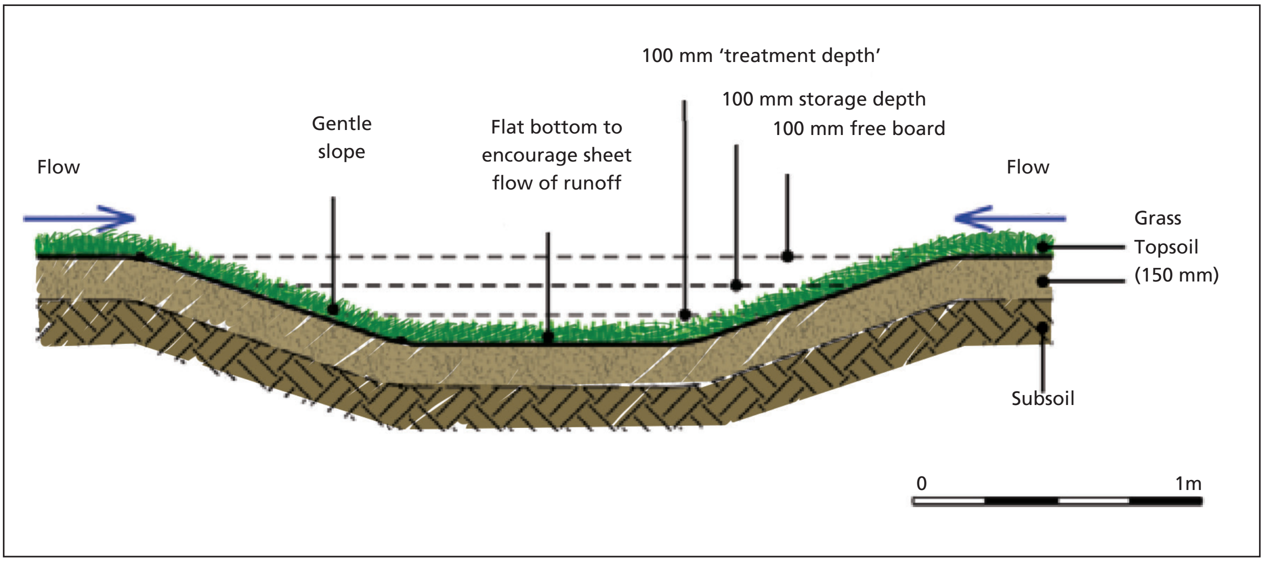
The following are SUDS measures for public open spaces:

Filter strips: Filter strips are grassy or other densely vegetated strips of land that collect surface water runoff as sheet flow from impermeable surfaces.



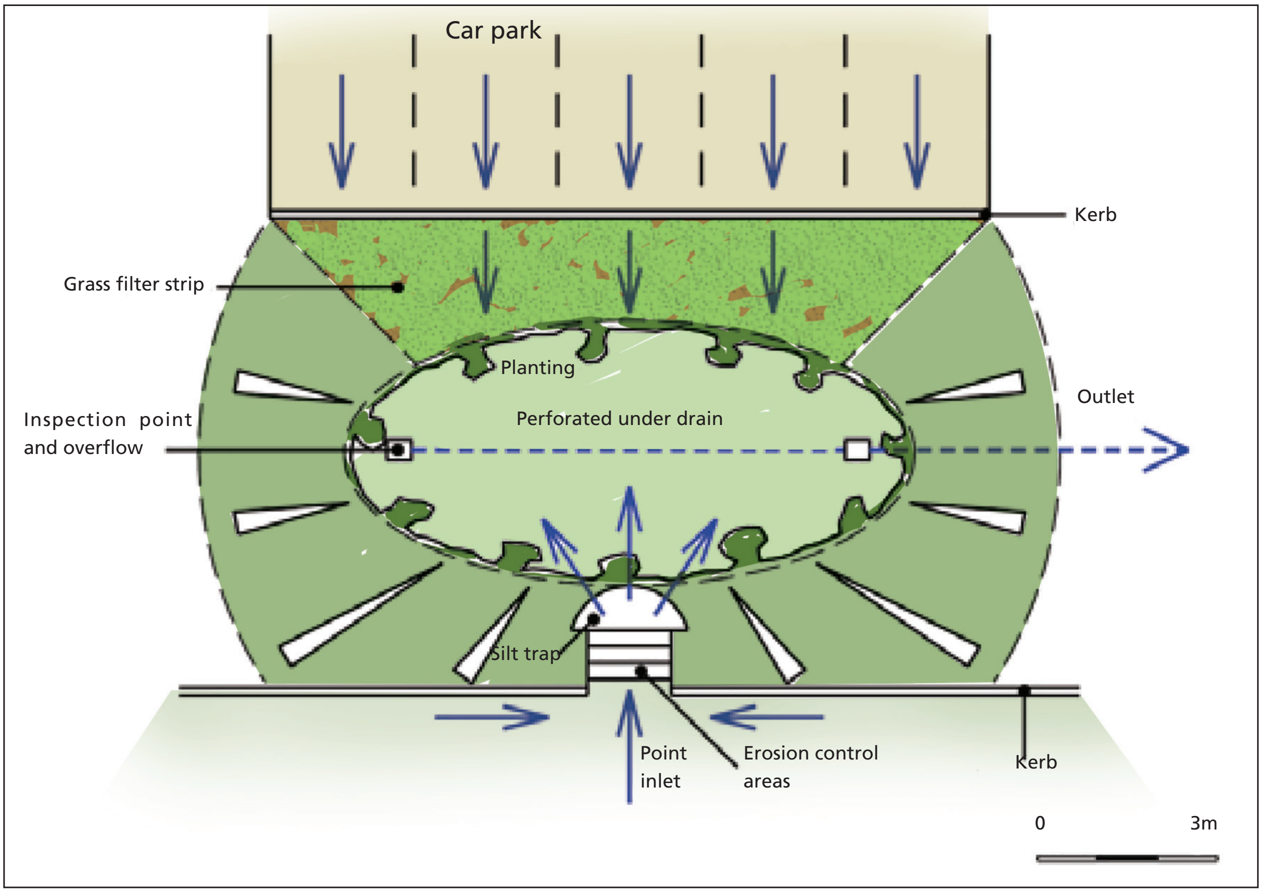
Source: CSE, 2016

Swales: Swales are linear vegetated channels with a flat base that encourage sheet flow of water through grass or other robust vegetation. They collect, convey and sometimes store surface water runoff allowing water to soak into the ground where soil conditions are suitable.



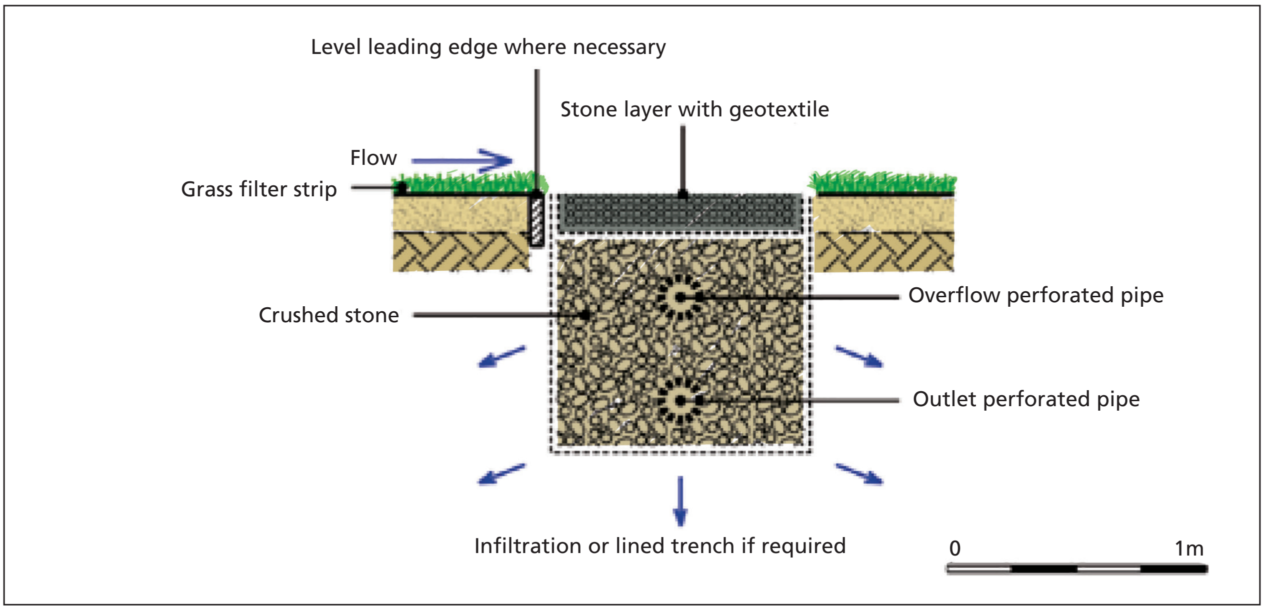
Source: CSE, 2016

Bio-retention areas and rain gardens: Bio-retention areas and rain gardens are planted areas designed to provide a drainage function as well as contribute to the soft landscape.



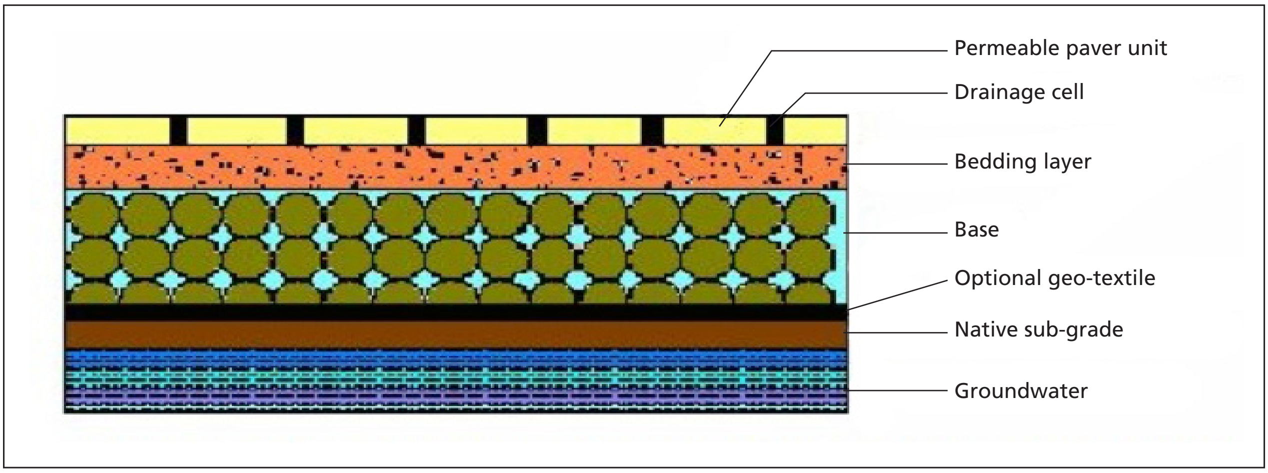
Source: CSE, 2016

Filter drains and trenches: Filter drains and trenches are linear excavations filled with stone that ideally collect surface water runoff laterally as sheet flow from impermeable surfaces. They filter surface water runoff as it passes through the stone allowing water to infiltrate into soil or flow.



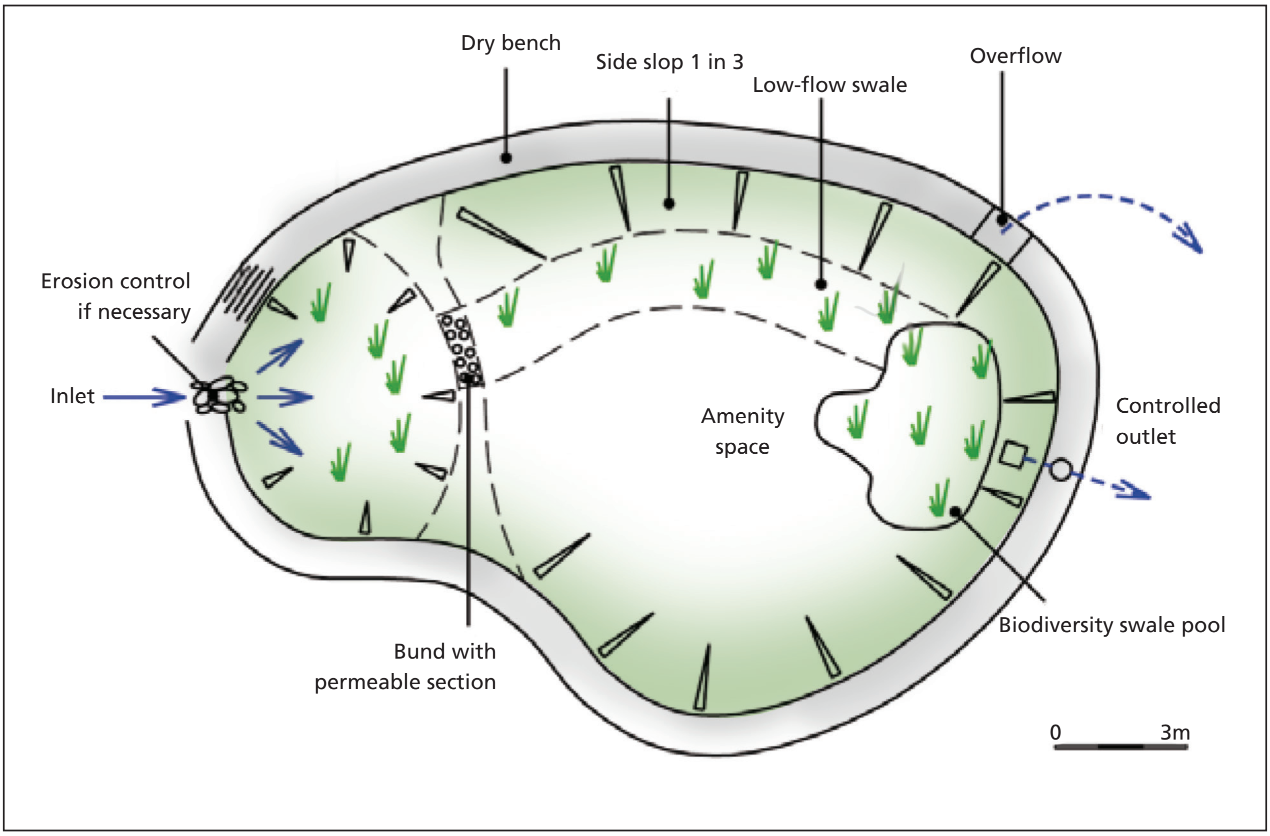
Source: CSE, 2016

Permeable pavements: Permeable pavements provide a surface that is suitable for pedestrian or vehicle traffic while allowing surface water runoff to percolate directly through the surface into underlying open stone construction.



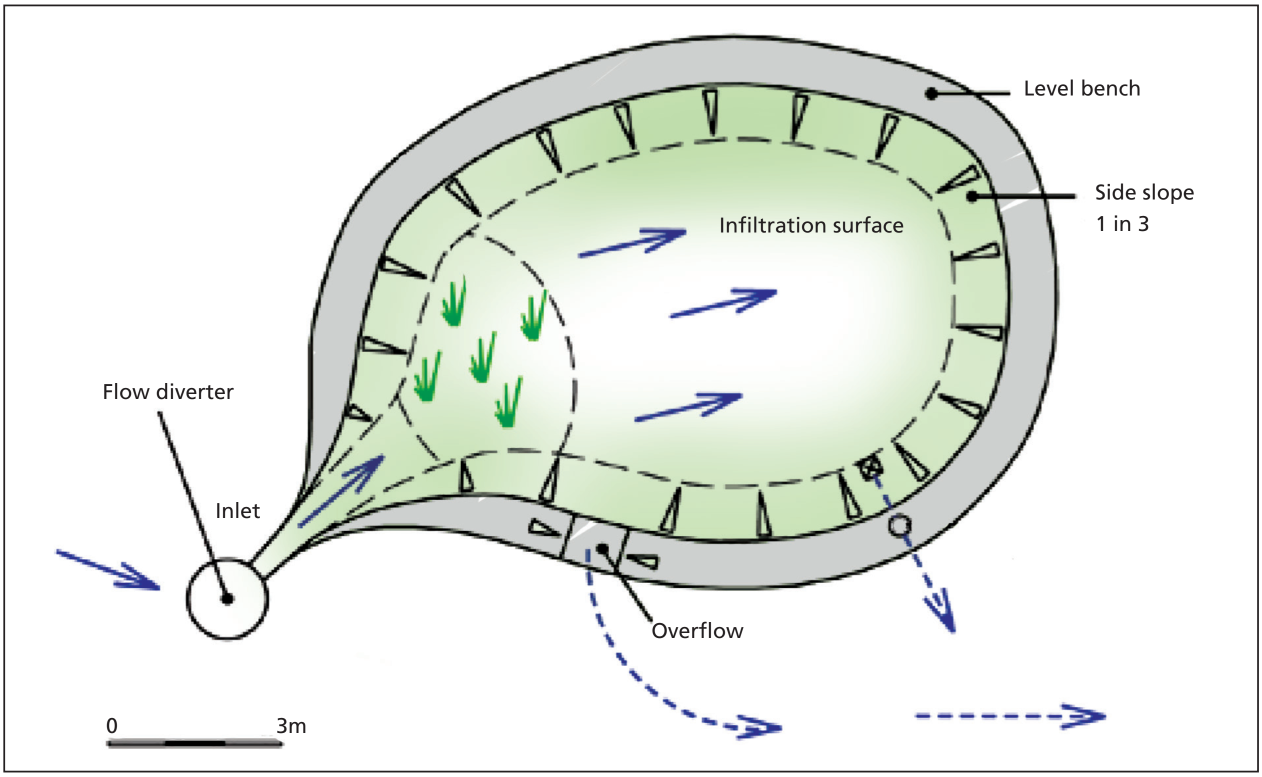
Source: CSE, 2016

Detention basins: Detention basins are vegetated depressions in the ground designed to store surface-water runoff and either allow it to soak into the ground or flow out at a controlled rate. Within development, these basins are usually small grassed areas, sometimes with a micro-pool or planted area at a low point where some standing water can accumulate.



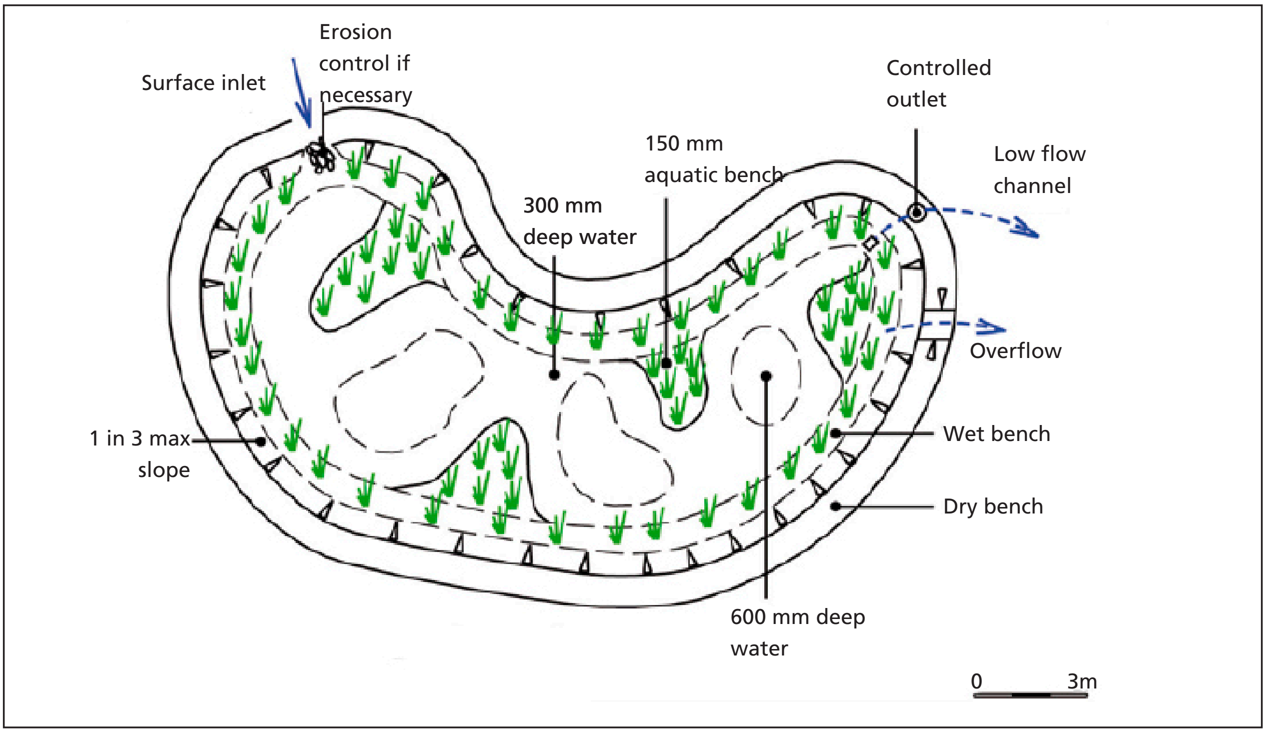
Source: CSE, 2016

Infiltration basins: The basins collect surface-water runoff from small areas and are usually off-line to prevent siltation.



Source: CSE, 2016

Ponds: Ponds are depressions in the ground that contain a permanent or semi-permanent volume of water.



Source: CSE, 2016

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This report was prepared by the Centre for Science and Environment (CSE) as a guiding document to mainstream the approach of Water-Sensitive Urban Design and Planning (WSUDP) principles in the NCT of Delhi. It advocates stormwater harvesting in parks and open spaces in Delhi as a measure to augment the drainage system of the city, and to address issues related to waterlogging and urban flooding.

The report showcases the potential of run-off moderation and infiltration in stormwater harvesting systems in parks and green open spaces in Delhi. It provides an overview of the NCT of Delhi, and also examines potential pilot cases, in the form of select parks, for implementation of WSUDP strategies.

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