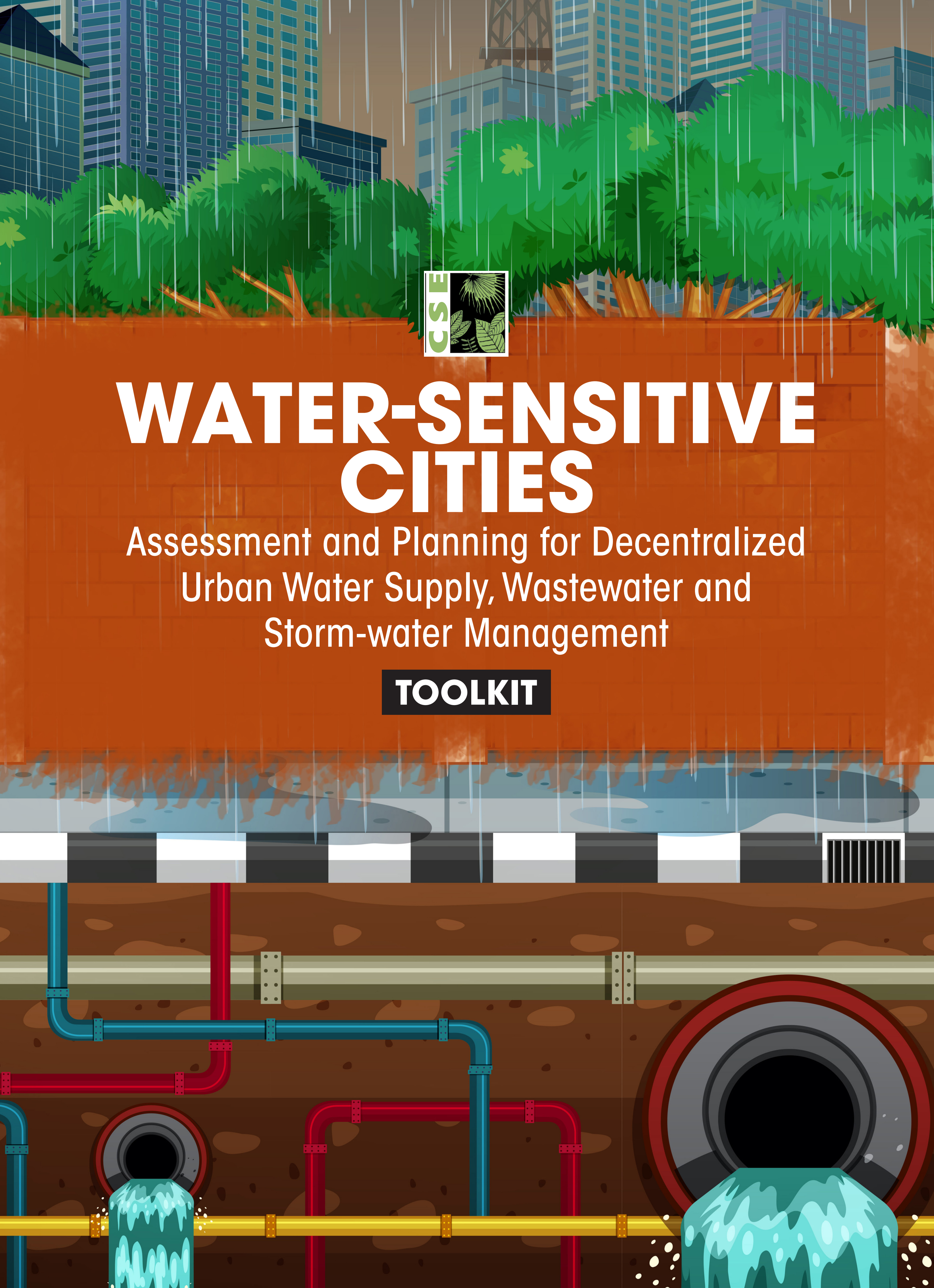

WATER-SENSITIVE CITIES

Assessment and Planning for Decentralized Urban Water Supply, Wastewater and Storm-water Management

TOOLKIT

WATER-SENSITIVE CITIES

ASSESSMENT AND PLANNING FOR DECENTRALIZED URBAN WATER SUPPLY, WASTEWATER AND STORM-WATER MANAGEMENT

TOOLKIT

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Contents

Key terminologies

Blue–green infrastructure (BGI): Natural and semi-natural infrastructure that integrates water management with green spaces

Grey infrastructure: Storm-water infrastructure in built environments such as drains, gutters and pipes

Water supply gap: When the quantity of water supplied is less than the quantity of water demanded

Wastewater: Water that has been used and contaminated with human activities

Grey water: Wastewater generated from household usage such as cleaning and bathing.

Black water: Wastewater containing human waste and faecal matter

Decentralized wastewater treatment system: A wastewater treatment system to treat wastewater near its source, rather than in a large, centralized system

Abbreviations

ULB:	Urban local body
LPCD:	Litres per capita per day
MLD:	Million litres per day
STP:	Sewage treatment plant
WWTP:	Wastewater treatment plant
DWWT:	Decentralized wastewater treatment
WSC:	Water-sensitive cities
MoHUA:	Ministry of Housing and Urban Affairs (India)

1. About this toolkit

1.1 Why this toolkit?

As India urbanizes at a fast pace in the twenty-first century, there is a dire need to address the growing urban sanitation challenge of India. In the absence of appropriate sanitation systems and their effective operations, our rivers and waterbodies continue to be polluted from untreated urban wastewater. At the same time our cities are facing increasing water supply shortages in summer and sequential flooding, exacerbated by climate change.

There is an urgent need to relook and rethink the urban water supply, wastewater and storm-water management—from a well-defined decentralized systems perspective, as well as from equity and justice, sustainability and livability perspectives. This has not so far been attempted in the mission mode and programme-driven approaches in India.

How to plan for decentralized systems of water supply, wastewater and storm-water management is explained in this toolkit.

Challenges of urban water and sanitation

Post-independence, Indian cities were small in their spatial layout. Centralized water supply and centralized sewerage systems were adopted as cost-effective systems in this context. With Indian cities expanding several-fold since Independence, water supply becoming dependent on rivers and reservoirs, and depleting and pollute groundwater tables, the reliance on large, centralized water supply and sanitation systems is becoming tenuous. More and more unplanned settlements come up on the periphery of the cities, and they are less connected and served by the main city water supply and sewer pipelines.

Water and sanitation sector work is currently driven by large capital-intensive infrastructure development that often fails to prioritize equity and justice. Often the expansion of water and sanitation infrastructure leaves out large populations of our cities that are now residing in the periphery of our growing cities, from the fruits of this infrastructure development. The problem is exacerbated by the failure of large centralized systems expansion as well as the growing climate change crisis of water scarcity and urban flooding. Concurrently, the copy-paste approach of green-blue infrastructure development borrowed from the west, gets reduced to some projects here and there, neglecting the need for a reimagined decentralized water supply, wastewater and storm-water management.

What could be the alternative perspective and approach to urban water supply, sanitation systems and storm-water management for our cities has been left ignored in the absence of concrete analysis of city by city planning and assessment of its complete water management regime.

Of the large Indian cities, Bengaluru, Delhi and to some extent Chennai and Udaipur, have tried to address the water challenge. Bengaluru is transporting its treated wastewater to neighboring districts for agriculture use, and for rejuvenating its lakes and water bodies. Delhi undertook a detailed Water Policy formulation where it identified lakes and water bodies and re use of treated wastewater as a means for enhancing its water security. Chennai and Udaipur are re using treated water to meet their industry needs in a significant way.

It is obvious that there is a need for reimagining urban water supply, wastewater and storm-water management, with groundwater and surface waterbodies (lakes and wetlands) incorporated in a decentralized water supply, wastewater and storm-water management approach.

We hope this toolkit will provide useful guidance to city officials, planners and experts, in applying new concepts and frameworks related to enhancing urban water security and climate resilience, from a city wide, decentralized systems and an equity and justice perspective.

Background for this toolkit

In 2023, CSE undertook a critique of the Water Sensitive Cities framework and other frameworks like Water Sensitive Urban Design and Planning (WSUDP), Sustainable Drainage Systems (SUDs) and Green Infrastructure.

These frameworks were found to be inadequate in their application to global south cities. The frameworks are very relevant for countries and cities of the Global North, which are usually planned, have temperate climates, and low population densities, in contrast with cities of the Global South. Therefore, while Global North cities are moving towards addressing their second-generation water management goals that seek to enhance quality of life, Global South cities are beset with large and growing nature of unplanned settlements, increasing in situ urban flooding due to sprawling built-up area and dwindling water supplies in peri-urban areas.

To counter this, a Global South water-sensitive cities framework was proposed by CSE, one that highlights the context and priorities of the Global South. The goal was to ensure that we address water, sanitation and storm water with equity and justice, as well as with a consideration of environment and climate change perspectives.

Table 1: CSE's Water-Sensitive Cities Framework (2023)

Goal: Cities commit to a 'just and equitable access, use, reuse' of water supply, to sewerage/septage and storm-water management	
Principles	Larger and long-term vision (firmly rooted in the equity, rights and justice goals). This applies not just to projects but in inter-city and urban–rural contextualization of interventions.
	Climate change exacerbates already existing water scarcity and flooding risks of cities. Mitigation measures should not further inequity
	'Design' consciously for equity and justice. Abandon a normative, techno-managerial approach to 'design' interventions for water-sensitive cities.
	Reducing conflicts. Recognize existing and future conflicts around water and waste. Address them to the extent possible in programmes and policy.
Index	Functional infrastructure and services: Fix of all existing infrastructure to improve efficiency and treatment outcomes.
	Functional and inclusive infrastructure for unserved area: Building additional grey infrastructure for unserved areas, for serving unplanned and low-income settlements.
	Substantial reuse of treated wastewater and biosolids: More efficient planning for management and reuse of treated wastewater, include reuse, recharge, and protection of groundwater.
	Mitigating in situ urban flooding: Conserving rainwater wherever possible and keeping it as contamination free as possible. Enhancing storm-water drainage capacity to address in situ urban flooding as our cities built-up area increases.

This toolkit is a continuation of this work on water-sensitive cities framing for the Global South. We moved the discourse forward from a techno-managerial normative approach of water-sensitive urban design and planning (WSUDP), where 'scales of planning' were what constituted the guidance. These scales were individual-, neighborhood- and city-level planning.

CSE followed the water-sensitive cities (WSC) framing for the Global South, with a study of dense, unplanned settlements' water supply, sanitation and storm-water management, mobilizing the case of Sangam Vihar, an unplanned settlement in south Delhi.

Cities of the Global South are predominantly unplanned cities, where 'scales of WSUDP planning' need to be guided by a focus of prioritization for improving the water supply, wastewater and storm-water status for the city as a whole, including its unplanned settlements that are also underserved. Very little work has been done in this neglected area of framing WSUDP, sponge cities and other water-sensitive cities frameworks.

There is a lot of talk about centralized versus decentralized systems and sewered versus non-sewered systems. What do we mean by centralized versus decentralized sanitation systems for urban India? How decentralized should a sanitation system be? Or should it only be non-sewered?

This toolkit serves this critical gap in **understanding and planning for decentralized systems approach for urban water sanitation, which is the future pathway for addressing the growing urban water supply, wastewater and storm-water management challenge.**

Clarity therefore is important to define what constitutes decentralized urban water and wastewater management systems, and the need for a long-term (at least 20 years) strategy and planning at the state level. The choice of treatment system and technology is important too, but should come once we have the framework of decentralized water management for a town in place.

This toolkit prescribes a two-step assessment and planning process

- First, at a decentralized unit of assessment of water supply, wastewater and storm water (say a 5–10 sq. km grids in a town/city). This will ensure that all parts of the city, including its dense, unplanned settlements are mapped for assessing the existing water supply, sanitation and storm-water status, and associated challenges and options for improvement.
    - Priority should then be given to addressing the grids first, where the gaps are the highest. This will mostly be its unplanned and informal settlements.
- Next, at the city level, an assessment of all the information generated from all the grids can be analysed to assess and plan for reimagined water supply, sanitation and storm-water management.

Aim and purpose of this toolkit

Aim

The toolkit offers practical guidance on how to visualize, reimagine, assess and plan for water supply, wastewater and storm-water management for cities of the Global South.

Purpose

The toolkit fills this critical gap, offering guidance on visualizing water- and climate-resilient cities. A decentralized water supply, and wastewater and storm-water management are the core of a Global South water-sensitive cities framing. It has the most potential to address equity and justice concerns of our growing unplanned and informal settlements in our cities, while also addressing the growing urban water scarcity, flooding and wastewater management.

2. Urbanization trend in India

The story of urbanization in India is one of a gradual transition from rural to urban settlements. The 2011 Census of India shows more than 7,900 towns and cities with an urban population of 377 million in India, based on the administrative process of declaring what constitutes a rural or an urban settlement.

In India, a space is classified as urban when it has:

- All places with a Municipality, Corporation, Cantonment Board or notified town area committee etc.
- All other places which satisfies the following criteria:
  - A minimum population of 5,000
  - At least 75 per cent of the male main working population engaged in non-agricultural pursuits
  - A density of population of at least 400 persons per sq. km.

There are a total of 4,041 statutory towns (which have local municipal bodies) and 3,894 census towns, which are administered by rural bodies. The number of census towns has grown significantly, bringing into greater focus the general trend of urbanization the Global South (see *Table 2 : Classification of cities and towns and their growth over time*).

It is clear that the number of cities other than the mega-cities, Class 1 and Class 2 cities have grown at a faster pace. The percentage of urban population in Class 1 cities is still increasing.

Unplanned settlements and urbanization

Unplanned settlements are a growing urban phenomenon in the Global South. They cover approximately 12 per cent of Delhi's total area and house one-third of the city's population. Delhi's built-up area increased by 61 per cent in a 50-km radius of the city during 2000–15. Many Indian cities have seen similar or higher increases in their built-up areas. Often, this coincides with significant losses of blue-green cover, further hemorrhaging water sources and supply. Much of these changes can be attributed to increased migration, which has caused the growth and spread of large, dense, unplanned settlements.[1]

Table 2: Classification of cities and towns and their growth over time

Class	Definition (population)	Census 2001			Census 2011			Decade growth rate 2001–11	
		No of towns	Population	% of urban population	No of towns	Population	% of urban population	No of towns	Population
Class I	> 1 lakh	394	196.3	68.7	468	264.9	70.2	18.8	34.9
Of which									
Below million-plus	1–10 lakh	359	88	30.8	415	104.2	27.6	15.6	18.4
Million-plus cities	> 10 lakh	35	108.3	37.9	53	160.7	42.6	51.4	48.4
Of which									
Mega cities@	> 1 crore	3	42.5	14.9	3	48.8	12.9	0	14.8
Class II	50k–100k	496	27.8	9.7	605	41.3	11	22	48.7
Class III	20k–50k	1,388	35.2	12.2	1,905	58.2	15.4	37.2	65.5
Class IV	10k–<20k	1,561	19.5	6.8	2,233	31.9	8.5	43	63.8
Class V	5k–<10k	1,041	6.7	2.4	2,187	15.9	4.2	110.1	138.7
Class VI	<5k	234	0.7	0.2	498	2	0.5	112.8	180.1
Total		5,161	2,86.1	100	7,933	377.1	109.8	53.7	21.8
Statutory towns		3,799	2,65.1	92.7	4,041	318.5	84.5	6.4	20.2
Non-statutory census town and UAs		1,362	21	7.3	3,892	58.6	15.5	185.8	179
Total urban population		**5161**	**286.1**	**100**	**7933**	**377.1**	**100**	**53.7**	**31.8**

Table 3: The nature of urban settlements of Delhi

Category	Estimates as per DUEIIP, 2001	
	Population (in million)	% of total population
Jhuggi-jhopri clusters/squatters	2.07	14.82
Designated slum areas	2.66	19.05
Unauthorized settlements	0.74	5.30
Regularized unauthorized colonies	1.78	12.75
Resettlement colonies	1.78	12.75
Rural villages	0.74	5.30
Urban villages	0.89	6.37
Planned colonies	3.31	23.71
Total	**13.96**	**100.00**

Source: DUEIIP—Status Report for Delhi 21, GOI & MoE&F, January 2001 and Amitabh Kundu

Typically, Indian towns and cities have several categories of settlements. *Table 3* categorizes urban settlements based on their legal and socioeconomic status.

CSE's primary research of the existing status of a large dense unplanned settlement of Delhi (Sangam Vihar in South Delhi) in 2024, provided an opportunity to test the viability of the global south water sensitive cities framework. Findings and recommendations emerging from the research supported a call for re-imagining the urban water supply, sanitation and storm-water management, in concrete ways. The following toolkit draws on the Sangam Vihar case study and provides practicable guidance on assessment and planning of such settlements, in line with the objectives of the Water sensitive cities framework.

Table 4: Findings of the 2024 CSE Report of Sangam Vihar, Delhi, of dense unplanned urban settlement water, wastewater and storm water

Sangam Vihar is an unplanned settlement of more than a million population in South Delhi, crammed into a 5 sq. km area, making it one of the largest, most densely populated settlements in Asia. The findings of CSE's study are as follows:

Water supply

- Residents get an average water supply of 45 litres per capita per day (LPCD) (Government of India recommends 135 LPCD per day).
- The three available sources of water are: tankers, bore wells and piped supply. Residents largely rely on the first two.
- Groundwater supply is rapidly depleting, and there is no potential for in situ groundwater recharge due to the extent of built-up area.

Sanitation

- Almost all of Sangam Vihar's 60,000 properties have underground sealed septic tanks with no outfalls.
- More than 50 desludging trucks (of approx. 4,000 litre-capacity each) amounting to 200 kilolitre of sludge every day from the septic tanks and dispose it partly into a sewage receiving station and partly into open drains.
- Delhi Jal Board is laying a sewer system inside Sangam Vihar to connect the million-plus settlement with one main sewer line on the northern periphery main road.

Storm water

- A normal-intensity rainfall episode of 15 minutes generates 52 million litres of runoff.
- High-intensity rainfall for 15 minutes generates 117 million litres runoff.
- In the absence of a storm-water drainage, all the storm water flows down slope and floods the main road and Daskhinpuri colony on the northern side. It also enters the main sewer line and the entire sewage of neighbouring colonies spills over on to the main road.

Source: Anees, U. (2024) *Water and Wastewater Visioning for Large, Dense, Unplanned Settlements in an era of Climate Risk*, Centre for Science and Environment, Delhi, India.

3. How to use this toolkit

Chapter-wise guidance: Assessment and planning for a water-sensitive city

Chapter 4

Chapter 4 is divided into the following steps:

- Steps 1 and 2: Mapping
  - Provide guidance on choosing a city and settlement for the purpose of the assessment. This may not be required by everyone.
  - Step 2 further provides guidance on defining the geographical bounds of the settlement and the study.
- Step 3: Preliminary research
  - Suggests areas and topics for preliminary research, before a primary assessment is undertaken. The list is not exhaustive.
- Step 4: Primary assessment
  - Outlines the process of the entire primary assessment of the chosen settlement.
  - Step 4 is divided into four sub-steps. The first provides guidance on enumerating the population of the settlement. The next three assess the state of water supply, wastewater and storm water in the settlement.
- Step 5: City-level reframing of its water supply and wastewater management. Objectives include:
  - Expanding the scope of the research to include all unplanned settlements, all waterbodies and all STPs.
  - Developing a long-term vision and its integration with Master Plans and Regional Planning.
  - Assessing best fit, and short-term and long-term solutions. Prioritizing reuse of treated wastewater and harnessing storm water for groundwater recharge as well as assessing storm-water drainage where flooding and rising groundwater tables pose a challenge.
  - Making projections of future water demand and infrastructure requirements.

The assessment underlined in chapter 4 is to be undertaken by using a combination of site visits, household surveying, field testing, and secondary data analysis. The Annexure contains instruments of research such as questionnaires, FGDs to supplement the assessment.

Chapter 5

Chapter 5 provides an overview of planning for intervention and augmentation at the settlement level. Chapter 5 is divided into three sections:

- 5.1: Water supply
- 5.2: Wastewater and sanitation
- 5.3: Storm-water management

The chapter provides guidance on planning for a host of different scenarios. The guidance in this section can be supplemented with the use of other CSE guides and toolkits.

Some of the areas covered in this section include:

- Identifying concrete infrastructure augmentation and service delivery measures for water supply, sanitation and storm-water management in the vicinity of one unplanned settlement.
- Determining whether retrofitting to city water supply mains and to city main sewers and storm-water drainage is possible and a desirable solution.

This assessment and planning can be expanded from one or more unplanned settlements to other unplanned settlements in the city. All the unplanned settlements of a city can be organized into cluster of settlements if that helps in exploring common challenges and solutions. .

Chapter 6

If settlement-level decentralized solutions are not possible, city-wide solutions for inclusive water-sensitive cities city ca be reimagined.

The chapter underlines the process for mapping infrastructure, natural features and unplanned settlements. This includes identifying existing STPs, lakes and waterbodies.

Then, the chapter delves into potential opportunities for centralized and decentralized water supply, sanitation and storm-water solutions.

Annexures

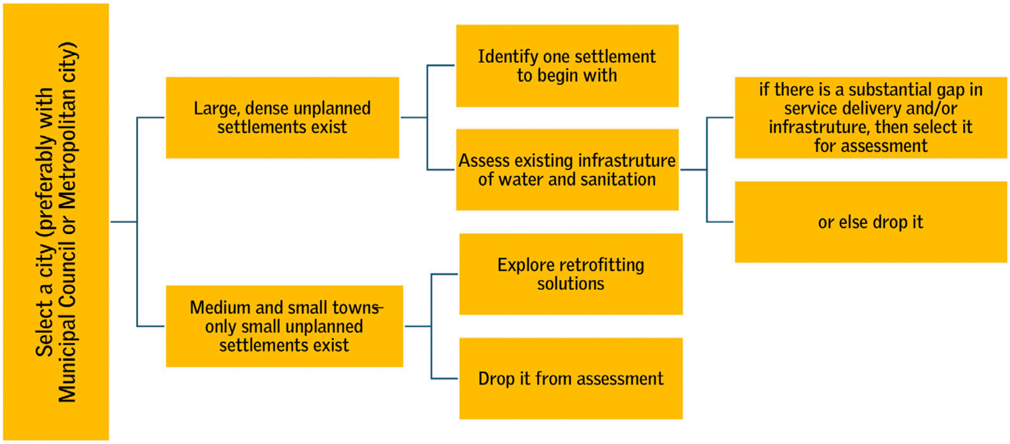
The annexures should be used in conjunction with the toolkit throughout the process. It provides methodological tools, survey and research questions, examples, and calculations that supplement the steps provided in the toolkit.

4. Assessment of current state

Step 1: Identification of city or town

Large, dense, unplanned settlements may not exist in all cities, but are a key feature of most urban spaces. The following decision matrix can be used when attempting to decide where efforts should be focused.

Figure 2: City identification decision matrix



Step 2: Identifying one or more unplanned settlements

Shortlisting unit area of work/study within a dense unplanned settlement

Within the city that has been selected, identify one or more clusters of dense unplanned settlements for this work/study.

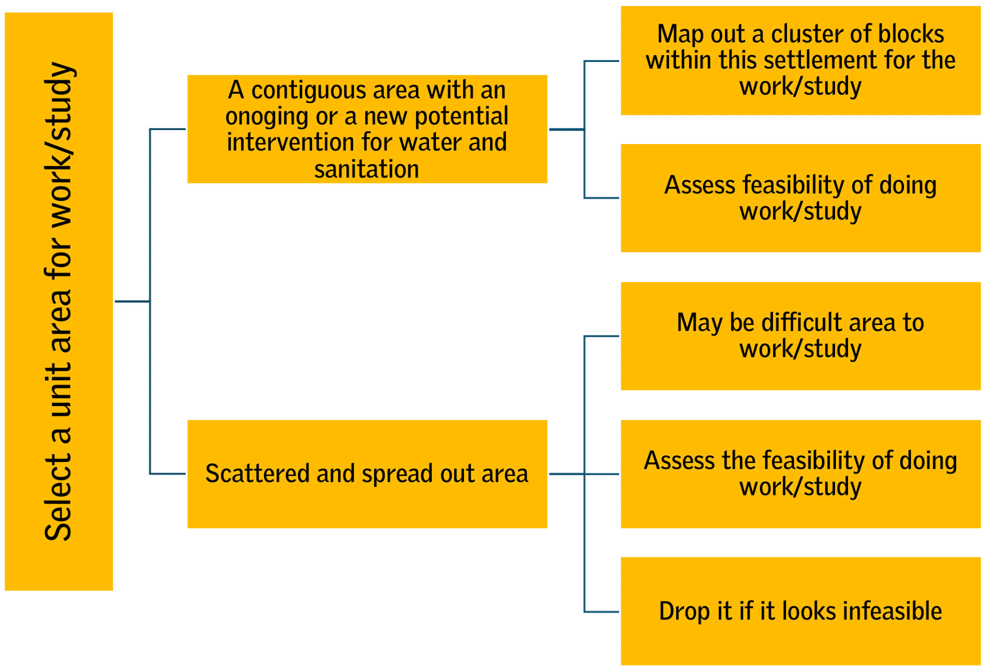
Dense unplanned settlements can be very large and sprawling in their layout. If the purpose of the work/research is to explore interventions, then a unit area of work/study needs to be identified so that an assessment and planning for infrastructure augmentation can be considered.

For the purpose of this toolkit, we refer to any unplanned settlement with more than 100,000 population as a 'dense unplanned settlement', the rationale being that if there is a 135 litres per capita per day (LPCD) of water supply, there will be approx. 100 LPCD wastewater generation. And for a population of 100,000 this will be 10 million litres per day (MLD) of wastewater generated. Wastewater generation of 10 MLD may be difficult to intercept and connect to the main sewer line already existing.

It is up to the city managers and/or administrators and researchers to define the area of assessment and planning based on population and other corroborating factors such as topography, climate and existing sewerage infrastruture of the city.

The decision matrix shown in *Figure 3* can be used to shortlist a dense unplanned settlement.

Figure 3: Shortlisting unit area of study—decision matrix



Mapping the settlement

Before any assessment is undertaken, it is essential to demarcate and categories the unit area of study. This is to ensure accuracy of data collection in larger areas.

If the settlement is officially divided into smaller blocks or segments, these official boundaries can be used.

When this is not the case, the settlement will need to be divided into an appropriate number of smaller blocks for the purpose of assessment. This can be done based on area or population.

Since population in most unplanned settlements is not uniformly spread out, the settlement can be divided into appropriate blocks/sub-unit areas for the purpose of assessment, based on an initial assessment and also based on the size and reach of the field investigation team.

Step 3: Mapping the city infrastructure, institutions and policies

This step involves undertaking a preliminary assessment of the city's water supply, sanitation and storm-water management. The research is done through an analysis off secondary sources. This process would include:

Table 5: Undertaking research and literature review

<table>
<tr><td colspan="3">City level
• Key authorities and key policies
• Urban plans—city master plan, zonal plans and regional plans (if any)
• Water utilities plans for water supply and sanitation
• Drainage plan for the city
• Reports of Central Pollution Control Board on functioning of STP (if applicable)
• State and types of unplanned settlements, population of unplanned settlements.</td></tr>
<tr><th>Water supply</th><th>Wastewater and sanitation</th><th>Storm water</th></tr>
<tr><td>• Quantity of water supply—from all sources—surface and groundwater
• Per capita water supply and gap in supply
• Key authorities and policies on water supply</td><td>• Number of STPs
• Installed capacity and functional level
• Sewerage coverage
• Percentage of non-sewered areas and populations.
• Wastewater generation and its disposal/reuse</td><td>• City drainage map, including major watershed areas
• Main drains and secondary drains
• State of storm-water drains—adequacy, whether built up or covered with concrete
• Urban flooding hotspots and flooding frequency
• Groundwater levels in different parts of the city to assess groundwater recharge potential</td></tr>
<tr><td colspan="3">Tools and sources:
• Government data and census
• ULB
• GIS and remote sensing to map geographic features</td></tr>
</table>

The criteria to measure feasibility of studying the settlement will be dependent upon the researcher, and may include factors such as language, accessibility and cost of funding the study.

Step 4: Detailed primary assessment of water, wastewater and storm water

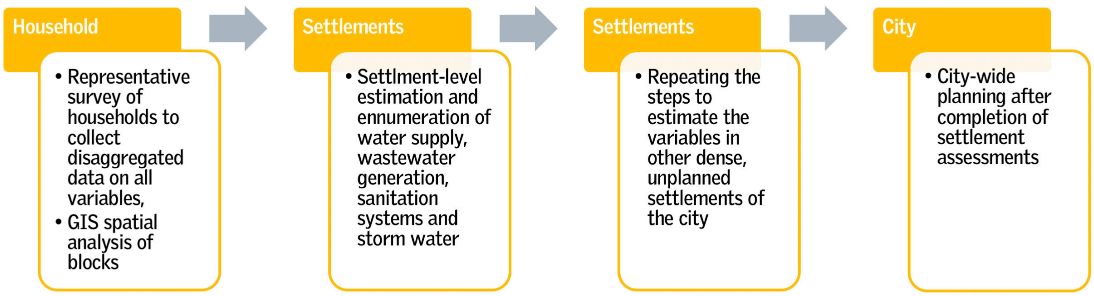
Undertaking assessment

The whole exercise is based on the objective of promoting a decentralized water supply, wastewater and storm-water management perspective as a framing for reimagined water-sensitive cities.

It is important to divide the town or city into grids of 5–10 sq. km and undertake assessment of all the planned and unplanned settlements within each grid.

An aggregation of settlement level findings of the status of water supply, wastewater and storm-water management will be done grid-wise to arrive at the city-wide scenario. Where there are overlaps in the grids, for water supply, wastewater and storm-water issue, these will be addressed at the city-level analysis for arriving at a decentralized systems planning.

Figure 4: Levels of assessment in research



Steps for a settlement-level assessment

- Estimation of population;
- Enumeration of water supply and consumption;
- Enumeration of sanitation systems and assessment of wastewater generation ; and
- Enumeration of storm-water status

In order to assess wastewater generation, we need to start with population estimation, followed by per capita water consumption and then an estimation of grey-water and black-water generation. Only once we know the population of the unplanned settlement and the per capita water supply, can we do an assessment of wastewater generation.

4.1 Estimating total population of the settlement

Planned settlements may be easy to assess in terms of their population.

Assessment of population in the unplanned settlements is difficult, as population densities vary greatly. A careful representative sampling for different blocks or segments of the settlement will need to be done.

For each block, a sample survey must be conducted to gain an understanding of the following parameters, which can be used to estimate the population.

Table 6: Collecting population data

Variables	Block 1	Block 2	Total aggregates for entire settlement
Number of properties			
Average built up area (G+ one or more)			
Average number of dwelling units per floor			
Average household size			
Total aggregate for block			Total settlement population

Table 7: Calculation: total settlement population

Total population of a block = Number of properties x (average built up area x number of dwelling units per floor) x average household size

Total population of settlement = Sum of total populations of all blocks

Here,

- Average built-up area = $\dfrac{\textit{Sum of built-up area of properties in the sample}}{\textit{Number of properties in the sample}}$
- Average household size = $\dfrac{\textit{Sum of size of each HH in the sample}}{\textit{Number of HH in the sample}}$
- Number of dwelling units per floor can be measured as number of kitchens per floor

Future population projection

If the aim is long-term planning and augmentation, there may be a need to estimate future population growth trends. Future projections will inform future water demand and consumption, as well as wastewater generation. This is an important consideration in ensuring that any retrofitted or decentralized solutions account for long-term increases in demand and supply.

While projecting the population is a difficult undertaking for unplanned settlements, if there is data available, it can be done using one of the three population projection methods.

Population projections for future calculations

Population Projection Methods

1. Arithmetical Increase Method - **Pn = Po + n** - *(Suitable for large and old cities with considerable development)*
2. Geometrical Increase Method - **Pn = Po [1 + (r/100)] ^n** – *(Suitable for new and younger cities)*
3. Incremental Increase Method - **Pn = (Po + nx̄) + ((n (n+1))/2)* ȳ** - *(Suitable for average size town having positive growth rate)*

Where

Pn = Prospective population after n decades from present

P0 = Population at the end of last known census

n = Number of decades between now and future

x̄ = Average (arithmetic mean) of population increase in known decades

r = Growth rate, **ȳ** = Average of incremental increases of population in known decades

In this method, the growth rate and averages for the city in question can be used when settlement level data is unavailable.

4.2 Assessment of water supply

For planned settlements, assessing household- and settlement-level water supply is easy from the metering at household level and cross checking with the water utility.

For unplanned settlements, however, water supply assessment can only be done through household-level surveys.

For unplanned settlements, water supply is assessed at the household level because there may be different, non-metered sources of water supply. If the supply is from one source and metered, then that can be used (see *Annexure 4*).

A block-wise consumption estimation through a sample survey of households can be done and average block-wise per capita per day water consumption calculated.

Household-level water consumption is constrained by the size of the water storage tank and by the frequency of water supply from different sources. For example, if a water tanker is the main source of water supply, and one tanker of 3,000-litre capacity is supplied every third day, the average daily consumption is 1,000 litres. If, however, there is more than one water supply source—e.g. bore well, piped water supply and tanker water supply—we need to assess the water storage tank capacity at the household level as well as its filling and emptying frequency to arrive at the household and per capita water consumption.

Potable water supply may be an additional water sourced in bottled form, e.g. 20-litre bottles. This will be easy to assess in terms of number of bottles consumed in a day and then factoring it for household and per capita water supply.

Average per capita water consumption in a block can be arrived at by aggregating the sample per block.

Settlement level per capita water consumption is arrived at by averaging the block-level data.

Further guidance and survey questionnaires on how to estimate water supply are available in Annexures 1, 2 and 3.

Table 8: Calculating water supply through consumption

Example: Determining total and per capita water supply

Let us assume a settlement of 1,000 people. The settlement is divided into 10 blocks. Assume also that the population is evenly distributed, with 100 people per block.

For a representative sample, we decide a total of 10 households are to be surveyed.

For each household, the following variables are sampled:

- Number of members in the household
- Per day total household water consumption from all sources (non-potable)
- Per day total household water consumption from all sources (potable)

Therefore, the consumption of each household in litres per capita per day (LPCD) =

$$\frac{\text{Total quanitty of potable water + Total quanitty of non-potable water}}{\text{Number of household members}} \text{ (in a household)}$$

After deriving the per capita water consumption figure for each household in each block, the per capita consumption for the block can be given as:

$$\frac{\text{Sum of total water consumption of all households}}{\text{Number of households}} \text{ (in the block)}$$

Hence, water consumption for the entire settlement will be:

Total water consumption = sum of total water consumption for each block

$$\text{Per capita water consumption} = \frac{\text{Total water consumption}}{\text{Population}} \text{ (in the settlement)}$$

Water quality

Unplanned settlements may have a problem of inadequate water supply (quantity) or poor water quality, or both.

The aim of the water quality assessment is to understand what and how much augmentation is needed—quantity or quality or both. Accordingly, infrastructure for water quality augmentation can be considered.

Water quality concerns can be understood during the household sample survey and through focused group discussions (FGDs). *Annexures 1 and 2* contain questions to assess the public perception of water quality.

However, there is a need to substantiate the residents' perception-based assessment with a water-quality laboratory assessment.

For this, representative sampling of all water sources will be required on a seasonality-based frequency testing.

Any metrics and assessment of water quality should be substantiated by a laboratory-based scientific assessment.

Affordability

Affordability of water supply has a bearing on the quantity of water purchased (both potable and non-potable water supply in areas where there is no lifeline free water supply, such as in Delhi).

Accordingly, the augmentation of water supply from different sources—public and private—can be assessed.

Affordability is a self-assessment at household level based on their purchasing power and quantity of water purchased, separately for potable and no-potable water (see *Annexure 1 and 2*). This is a proxy check for water purchase. Low affordability can lead to low purchase of water in some blocks of the settlement vis-a-vis others.

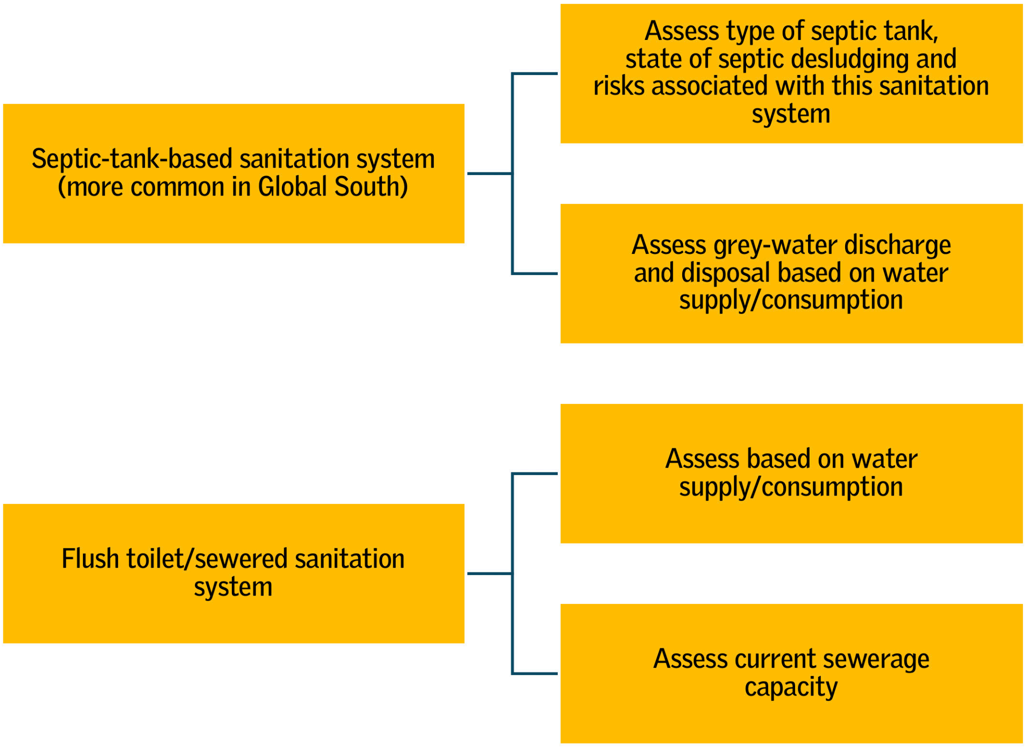
As was done for the other variables, data can be collected through household sampling. Once disaggregated data is collected, it can be aggregated for each block; Affordability metrics should be aggregated block-wise to gauge inequality within the settlements. Block-level data can further be averaged to compare settlements.

4.3 Assessment of wastewater

Once per capita water supply is assessed, it forms the basis of wastewater generation assessment for a block and for the entire settlement.

Wastewater generation and the efficacy of existing wastewater infrastructure is dependent on type of toilet and containment structure. This may differ by city, by settlement, or even by block within the settlement.

Figure 5: Process for assessment of wastewater and sanitation



Total wastewater generation includes grey-water and black-water generation estimation. The two types of wastewater may be released separately (dependent on type of containment structure).

Septic tanks that are usually in the nature of 'holding tanks' of varying sizes are the more frequently used mechanism for wastewater disposal in large, dense, unplanned settlements in the Global South.

Annexures 1 and 2 offer guidance on the questions that should be considered in the survey.

Assessment of containment structure/toilet

Survey questions and considerations for this can be found in Annexure 1 and 2. The following factors need to be examined:

- Type of toilet—flush or not
- Size and dimensions of the septic tank
- Make of septic tank
    - o Size and capacity
    - o Perforation and lining
    - o Age of tank
- Mechanism for septic desludging

Annexure 5 contains example of how this data can be synthesized to represent the settlement.

Assessment of grey-water and black-water generation

Once the block-wise per capita water supply and wastewater generation (based on the toilet/containment system) is assessed, the total wastewater generation for the entire settlement is possible.

If there is no sewerage system in the entire settlement or parts of the settlement, separate assessments of grey- and black-water discharge and flows need to be done to assess:

- Quantity of grey water generated, where bathroom and kitchen water flow separately into street drains;
- Quantity of black water generated for sewered blocks/area of the settlement; and
- Quantity of faecal sludge in septic/holding tanks for non-sewered areas.

Table 8: Wastewater generation

Calculating wastewater generation Of the water consumed by an individual (LPCD) • 80 per cent is transformed into wastewater • Of this, approximately 60 per cent is grey water • 20 per cent is black water **Example** Let's assume the per capita water consumption is 70 LPCD. In this case, the per capita wastewater generated can be given as Wastewater = 70 x 0.8 = 56 LPCD Grey water = 70 x 0.6 = 42 LPCD; black water = 14 LPCD The same method can be used to find the volume of wastewater generated by a block or by the entire settlement.

Once the amount of wastewater per capita and per block is generated, their respective disposal mechanisms can be assessed.

Assessment of septage generation

Septage generation estimation should be done at the household level by:

- Asking the frequency of desludging of household septic tanks;
- Estimating the quantity of septage to be desludged and the desludging mechanism (size of desludging tankers and number of trips they make in a day for the entire settlement); and
- Crosschecking the septage generation in the entire settlement with FGDs in the blocks and with desludging tanker operators and whether there is a disposal point (substation for septage collection as part of a sewer system of a drain or open area where it is disposed).

Points to remember when estimating septage desludging volumes in an unplanned settlement:

Table 9: Factors that affect septic sludge calculation

Variable	Purpose of assessment
Affordability	Desludging can be expensive, and its costs can determine the frequency and quantity of desludging. This should be assessed as the average annual cost of desludging for each block in the settlement. Costs may differ across the settlement.
Frequency	This is important as infrequent desludging is a safety hazard. Frequency depends on the size and type of tank, and the cost of desludging.
Daily quantity of desludging	This may differ by block within the settlement. It is a quantifiable metric that gives valuable insight into the overall state of sanitation in the settlement.
Disposal mechanisms	Needs to be assessed to garner an overall understanding of sanitation and associated health risks of improper disposal.

The research and survey questions that would guide this data collection can be found in *Annexure 1 and 2*.

4.4 Storm water and urban flooding

Contour maps of the settlements in a grid of 5–10 sq. km will inform us what part of a large city watershed our settlement and grid are in. There may be different slopes within a grid. The velocity of storm-water discharge can be calculated based on factors of rainfall intensity and run-off potential of each grid.

Figure 7: Process for assessing storm water

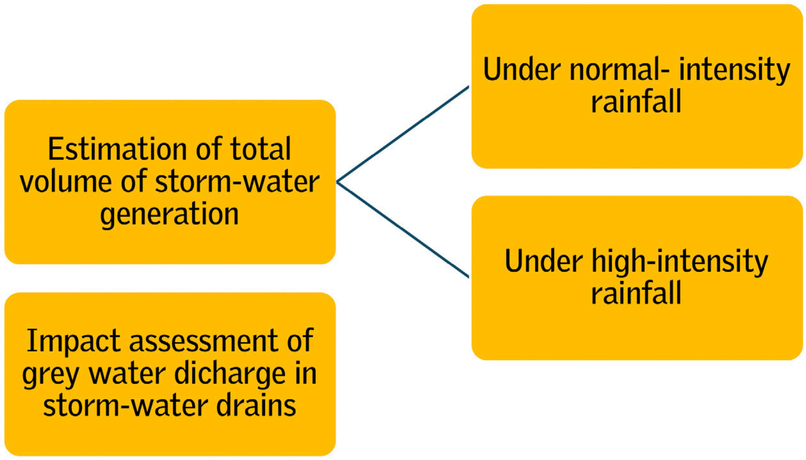


Table 10: Storm-water discharge calculation

<table>
<tr><td colspan="2">Assumptions:
1. Rainfall intensity and depth are equal in all sub-catchments;
2. Exogenous variables include rainfall duration and total paved area [assign specific values to these]
3. The wastewater generated is a proportion of total water supply 80 per cent)
4. All the grey water generated flows through the sub-catchment into outflows as depicted by Figure 11.</td></tr>
<tr><td colspan="2">Calculation of peak discharge (m^3/min)
Q =
Where
• Q = Peak discharge (m^3/min)
• C = Coefficient of runoff, calculated by percentage of paved area
• I = Rainfall intensity for duration of equal to time of concentration (mm/hour)
• A = Catchment area in hectares

Calculation of volume of storm-water generated
V = QD
Where
• D = Duration of rainfall</td></tr>
<tr><td>Normal-intensity rainfall (example)
• I = 50 mm/hour
• Return period = 5 years
• Paved area = 90% of total area
• Coefficient runoff (C) = 0.9</td><td>Peak-intensity rainfall (example)
• I = 100 mm/hour
• Return period = 5 years
• Paved area = 90% of total area
• Coefficient runoff (C) = 0.9</td></tr>
<tr><td colspan="2">Calculation of grey water
• If (as is often the case) grey water outflows from the same drains as storm water, it needs to be accounted for in the assessment of outflows.
We assume that 80 per cent of the water supplied is generated as wastewater. On average, grey water is approximately 75 per cent of total wastewater.
Therefore,
Volume of grey water = (0.75 x 0.80) x total water supply (per sub-catchment area)</td></tr>
</table>

Based on the storm-water discharge calculation, the discharge and volume of runoff can be calculated for each sub-catchment and the settlement. Data of rainfall intensity can be found through the rainfall monitoring authority (Hydrometeorological Division—India Meteorological Department [IMD] for India.

Tables to input storm-water calculations

Tables 11 and 12 are useful in collating and synthesizing the data collected from storm-water discharge calculations.

Table 11: Classification of sub-catchments for storm-water calculations

Catchment name	Flow direction	Area (sq. m)	Area (hectares)	% of paved area

Table 12: Peak and normal discharge—runoff generated

Name of catchment	
Flow direction	
Area (sq. m)	
Area (ha)	
Paved area (%)	
C value	
Peak rainfall (mm/hour)	
Normal rainfall (mm/hour)	
Return period	
Peak discharge	
Normal discharge	

Table 13: Volume of storm-water generated by x minutes of rainfall

Name of catchment	Peak discharge (m^3 /min)	Normal discharge (m^3 /min)	Volume of storm water generated in x minutes at high intensity	Volume of storm water generated in x minutes at normal intensity	Volume of grey water (litres)

5. Exploring solutions: Planning at the settlement level

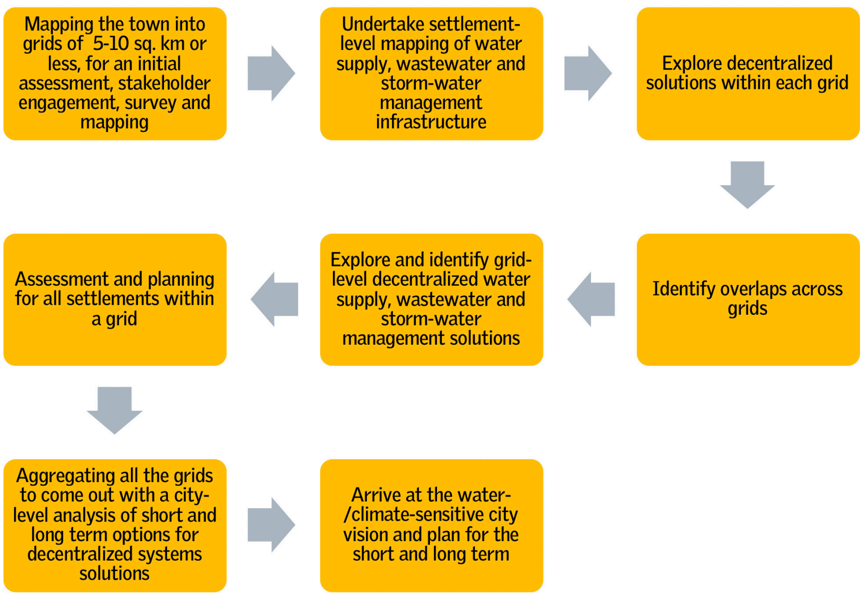
This section provides guidelines to plan and map potential solutions.

The settlement-level to city-level planning framework calls to:

- Map the whole town or city into 10 sq. km grids (depending on the density of population spread) to begin with and later into even smaller grid areas.
- Then undertake settlement-level mapping of water supply, wastewater and storm-water infrastructure inside each grid. Aggregate all the settlements scenario and find decentralized solutions for water supply, wastewater and storm-water management.
- Finally aggregate all grids and see where there is a cross-grid spillover effect. To arrive at a reimagined city-wide water-sensitive and/or climate-resilient city.

Figure 6 depicts the general process for undertaking planning and implementation.

Figure 6: Planning process



5.1 Water supply

An existing water supply system for a settlement may be part of the centralized water supply system of the city or not, partial or full.

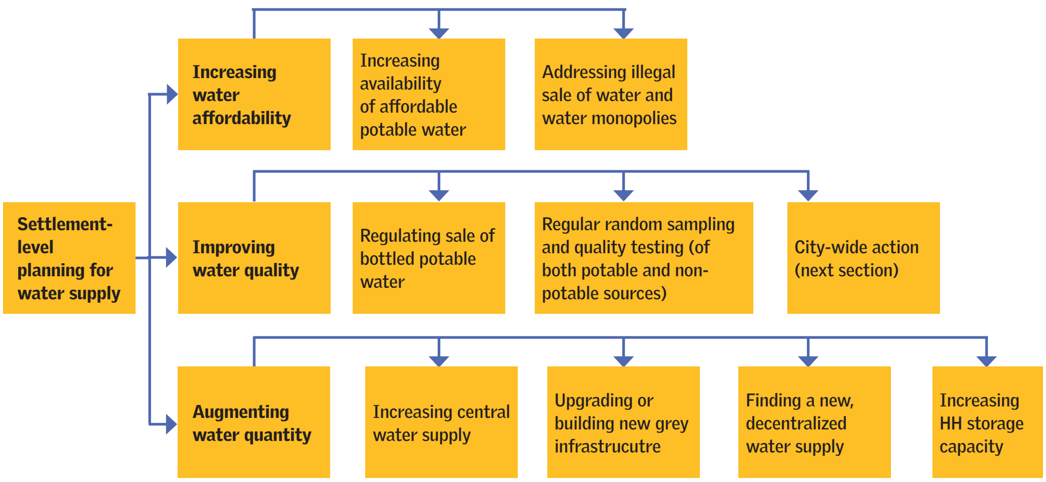
Settlement-level planning for water supply may be possible. A 10 sq. km area may have a mix of planned and unplanned settlements with different levels of water supply, a mix of groundwater sources, tanker-based supply and piped water supply. In addition, what we see commonly today in most cities is the sale packaged drinking water through priced bottles.

At the settlement level, we should focus on quantity, quality and affordability of water. *Figure 7* depicts the avenues for addressing gaps in each of these areas for one settlement. The recommendations are practicable guidance based on CSE's learnings from case studies and are embedded in the principles of the water-sensitive cities framework.

The settlement's primary assessment should clarify the extent, urgency and priority of intervention in all three areas. For example, for many large, dense, unplanned settlements, the most important concern will be the quantity of water supplied, in which case this would be the first point of intervention.

The following sections then provide guidance on exploring the potential for each of these interventions.

Figure 7: Exploring the optimal water-supply-intervention strategies (at the settlement level)



Aggregating the settlement-level water supply scenario will provide us with a set of priority strategies that need to be undertaken to augment the quantity and quality of the water supplied. Overlap with other settlements across the grids will inform us of what should be considered at the city level.

Augmenting quantity of water

Table 13: Centralized solutions

Action	Recommendation
Augmenting water supply from a centralized source	The first and logical step while planning for augmentation of water quantity and quality is to assess deficiencies in existing water supply and potential to augment it through existing supply sources—i.e. piped water supply, tankers or bore wells—and to address water-contamination issues.
	Steps Assess the potential of city water supply to bridge this gap. This could include reducing water losses and wastage or diverting from over-serviced neighbourhoods. This will not be locally possible, it will be within the ULB's jurisdiction to do so.
	Challenges In many cases, water supply issues may be issues of inequity in distribution of water, rather than its scarcity. Issues of corruption and vested interests is an extremely important consideration. In some cases, the settlement may not have any access to piped water supply. In such cases, planning will be needed.

Table 15: Decentralized solutions and alternative approaches

Decentralized water source	The aim should be to augment water supply through as decentralized a system as possible. Reuse of treated wastewater for groundwater recharge and then reuse for drinking water should be incorporated. In cases where connecting the settlement to the existing centralized water source equitably proves difficult, decentralized water sources can be explored.
	Steps Assess decentralized water supply augmentation options, which can include tapping smaller waterbodies and reservoirs and mapping the water augmentation potential from these sources in a radius of 10–15 km of water-supply outreach. Primacy is given to unserved areas and unplanned settlements that are under-served for water supply should be ensured.
	Challenges Existing infrastructure may not allow for a smooth transition to a decentralized system. There may be conflict among neighbouring settlements.
Increasing household storage capacity	If quantity of water supply is adequate, augmenting household storage capacity may be required. This can be done by providing storage. Some considerations in planning for increasing individual HH storage capacity are: • Type of storage tank currently serving household (overhead, underground etc.) • Availability of space in the dwelling for additional tank.

Improving water quality

Poor water quality may need to be addressed at the local or regional level as water quality is often impacted by macro factors. It may, however, also be the case that water quality needs to be improved at the settlement level (see *Table 16*).

Table 16: Planning for addressing settlement-level water-quality issues

Cause	Recommendation
Septic/sewage leakage into piped water supply	Fix broken infrastructure
False packaging of untreated water (potable)	Those who cannot afford RO may be forced to buy potable packaged mineral water. Regulating the sale of potable water at the city level may be needed to ensure quality. Alternatively, the ULB can take up supply of drinking water by installing water ATMs or drinking water stations.
Bad quality of tanker-provided water	Tanker water supply cannot be considered safe. Increasing piped water supply is the only way to ensure there is more control over water quality. Where piped water supply gets contaminated due to sewage en route, water purification at the household level remains the only solution.
Polluted surface or groundwater	Will need to be addressed at the city level.

While some intervention is possible, managing water quality is a more local/regional goal than a community-level goal. Some settlement-level solutions (such as distribution of chlorine tablets) may be band-aid solutions. It is essential to plan for more sustainable, nature-based solutions that improve the overall quality of water sources.

Affordability

Affordability issues often result from the fact that water is an economically inelastic resource, and many individuals are willing and able to pay a higher price for water when it is scarcely available. To make water more affordable at the settlement level, the following can be done:

1. Identify stakeholders and sellers of potable and non-potable water
2. Regulate private sale of water
3. Tackle illegal sale of water and/or water monopolies.
4. Explore ways to subsidize water and water services, such as maintenance of RO and fixing infrastructure.

5.2 Wastewater and sanitation

The sewage treatment capacity in the Global South cities is extremely low. In most Indian states less than 50 per cent of total sewage generated is treated.[2]

Settlement-level planning for wastewater treatment is based on the type of settlement and existing systems of wastewater management. An area of 10 sq. km may have a mix of planned and unplanned settlements with existing sewerage systems partially covering the settlement periphery or intersecting it. Unplanned settlements may have one or more sanitation systems, such as a combination of septic tanks and some areas with sewerage lines.

This section provides guidance on planning for both centralized and/or decentralized sewage treatment options. First, it is proposed that for the given settlement, exploring improvement potential for existing sanitation system and/or retrofitting a sewer system is attempted. Next, if this proves unfeasible, then planning for a new, decentralized sanitation system can be undertaken.

Improving non-sewered sanitation system

Septic tank-based sanitation systems are commonly found in unplanned settlements of the Global South. Many settlements are not serviced by sewer systems, and therefore primarily dispose of their waste through septic systems. However, management of septic systems a major issue for many settlements.

Table 17: Addressing septage and grey water

Action	Recommendation
Ensuring regular septic desludging	Regular and timely desludging of septic tanks and septage holding tanks should be done. There may be a need to set up desludging services to cater to the settlement (by ULB or privately) based on their ability to pay.
Creating or improving drainage channels for flow of grey water	In many unplanned settlements, grey water is discharged into storm drains, causing drains to overflow and flood. Improving drainage and connecting it to main sewer lines or to a treatment system.

Retrofitting sewerage systems

If improving non-sewered system is possible, then the septage volumes need to be considered and assessed for feasibility of co-treatment with an STP nearby or addition into a main sewer line for grey water. If this is not possible, then both grey and black wastewater will need to be treated through a retrofitted sewerage system.

This section offers guidance on assessing the feasibility of retrofitting sewers to an existing main city sewer to cater to the entire or partial wastewater of the settlement. The primary questions to be considered in this process are:

- Will the main sewer line handle the entire wastewater?
- Will internal sewers system be able to handle all the wastewater?

If a new sewerage system laying seems feasible, a sewer-shed assessment will be required for the entire settlement. This involves:

- Assessing the volume of sewage generated in lanes and bylanes of the settlement to arrive at the dimension of lateral and branch/peripheral sewers; and
- Assessing the feasibility of the main sewer line (its width and dimensions) to handle all the settlement wastewater once connected.

CALCULATION OF SEWER CAPACITY (EXAMPLE: PERIPHERAL SEWERS)

The first step is to identify the main sewer line(s) to which these will be connected.

Then, using the following variables, generate an estimate of wastewater
Aggregate variables:

- Total population = P
- Total water consumption and total wastewater
- Total wastewater at 135 LPCD (when consumption is less than this)

Wastewater: As per Government of India guidelines, 135 LPCD is the bare minimum requirement for water.

- Total wastewater generation = 0.80 x (135 x total population [litres per day])
- Total grey-water generation (in the case of non-sewered systems) = 0.60 x (135 x total population [litres per day])

Discharge can be given by the 'Continuity equation of discharge':

- Discharge (Q) = Area (A) x Velocity (V)
- Q = $(\pi D_2 /4)$ x Velocity (where D is the diameter of pipe)

Here, Q can be defined as the peak flow. In CPHEEO Manual, peak factor is given based on population served so it should be taken accordingly. Otherwise, it can be calculated based on the actual data from the field.

For calculating the diameter of sewer, Manning's formula should be used in the continuity equation.

$V = 1/n \, (R)^{2/3} \, (S)^{1/2}$

Here, R is hydraulic mean radius which can be calculated as R=A/P and S is slope.

To calculate R, we need to consider area (A) and wetted perimeter (P).

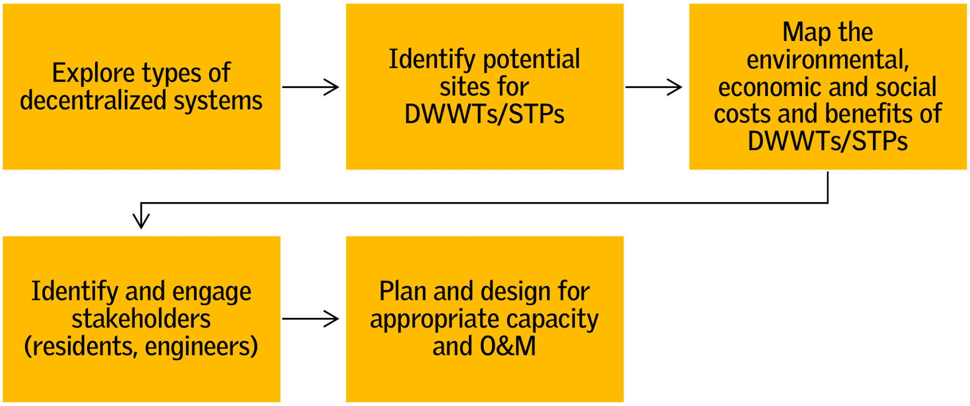
'n' is manning's coefficient which will be different for different type of material of sewer.

Designer should also keep in mind the maximum diameter at sewers running at full capacity and sewers running at half capacity.

Planning for decentralized wastewater treatment: DWWTs or decentralized STPs

If septic systems or retrofitting solutions are not likely to happen in the near term, then other decentralized wastewater treatment systems should be explored.

Figure 10: Process for assessing feasibility of DWWT system



If a decentralized system is not possible, and the settlement cannot be connected to a main sewer line, there will be a need to address wider concerns and reimagine the city-wide sanitation system as discussed in chapter 6.

5.3 Storm water

Storm-water management is highly dependent on several environmental, geographical and social factors, besides rainfall.

At a settlement level, storm-water management will require assessing in-situ storm-water generation as well as ex situ storm generation that enters a settlement. A 10 sq. km area may have a mix of planned and unplanned settlements, storm-water generated from within the settlement and what flows into it, will therefore vary depending on the location of the 10 sq. km grid area.

Solutions will be both in situ and ex situ water conservation, and also discharge measures and infrastructure for what cannot be conserved within a settlement.

In situ versus ex situ storm-water conservation

The ideal way to manage storm water would be to explore potential for in situ storm-water conservation. In situ conservation can minimize time, resources and cost of conserving storm water and increase reuse potential. Exploring avenues for this would involve examining the feasibility of infrastructure and conservation sites, as well as studying any potential limitation or risk of groundwater recharge (in case of high-water tables or coastal areas).

The following factors should be considered:

- Size, population and built-up area of settlement
- Existing grey infrastructure capacity
- Total storm-water generation in
  - Normal-intensity rainfall
  - High-intensity rainfall
- Gradient mapping of settlement
- Groundwater table (to explore whether groundwater recharge will benefit the settlement)
- Blue-green infrastructure, open area for conservation

In settlements with high built-up area and sparse blue-green infrastructure, it may not be possible to set up in situ storm-water conservation. In Sangam Vihar, for example, there was no harvesting potential because of the extent of built-up area. There were also no potential recharge zones in situ, but CSE identified a few areas outside of periphery of the settlement in the neighbouring forest.

In such cases, ex situ conservation in open areas neighbouring the settlement can be considered. Storm-water conservation into open areas and waterbodies outside the settlement can be mapped using GIS and spatial data analysis.

Segregation of wastewater and storm water

When storm-water drains also serve as grey-water drains, urban flooding can be addressed by ensuring that the drains discharge into a wetland that serves as a nature-based solution for treating grey water. This way its discharge is assured.

It is therefore essential in urban planning to explore the feasibility of separating grey water and storm water so as to allow for effective storm-water conservation in designated areas where you deliberately want groundwater recharge to happen. This would involve building new infrastructure. To assess the need and extent of augmentation, it is essential to consult stakeholders such as engineers and residents in this process. The discharge calculations in chapter 4 and 5.2 will primarily inform this exploration.

Transportation of storm water

Treated storm water can be monumental in bridging the non-potable water supply gap. Therefore, planning of any infrastructure should aim to redirect treated storm water (at least partly) back to the settlement. This can then be factored into the planning for increasing quantity of water supplied (section 5.1).

Solid waste management

It is not within the scope of this toolkit to provide guidance on solid waste management; however, it is noteworthy that solid waste can largely hinder the functionality of drainage and sewerage systems. it is therefore an extremely important consideration in planning for and executing any sewerage solutions.

Planning for regular cleaning of storm-water drains by ULBs can aid in addressing urban flooding.

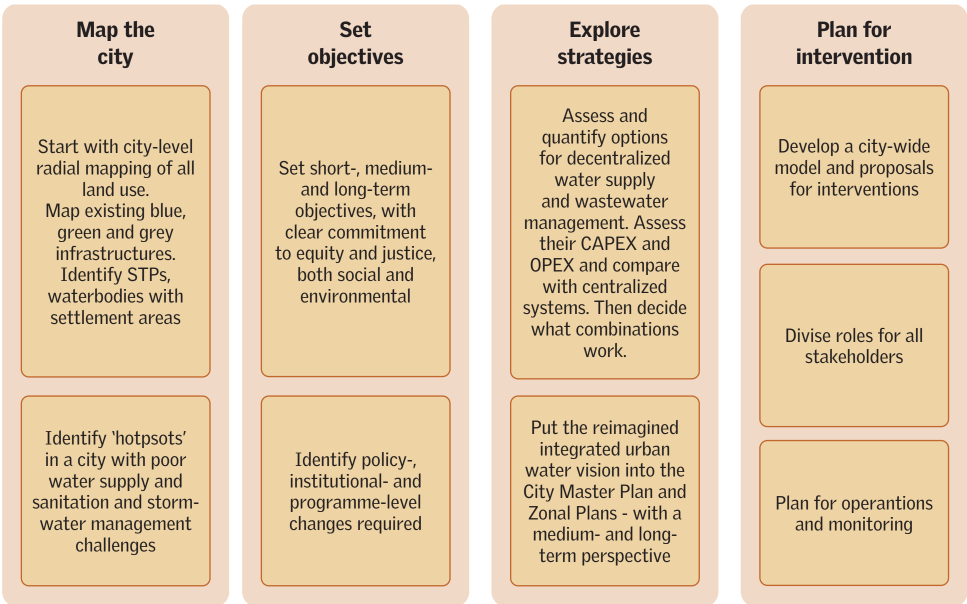
6. Reimagining city-wide water/climate-sensitive planning

Reimagining a city-wide water, wastewater and storm-water management will first require clarity on the aim and purpose of doing so.

For example, a small- and medium-sized town that is not very spread out in terms of scale and population may do with one centralized water supply and wastewater treatment system. However, a decentralized systems planning approach may work well in the long run as the town expands.

State-level long-term decentralized sanitation systems planning is needed. States need to draw 20-year plans, city by city, assessing and planning for decentralized sanitation systems for each town. In doing so, it is essential to ensure that these are backed by state funding, and the progress is monitored every five years. Only then we will ensure that our small, medium and large towns are able to address their sanitation and wastewater challenges in a meaningful way that will make our cities climate- and water-sensitive and resilient.

Figure 9: Planning for a city-wide reimagination of water and wastewater



Source: CSE

6.1 Mapping the city and setting objectives

Reimagining citywide water management and planning in a decentralized manner necessitates the integration of water, wastewater and storm-water treatment and management. By focusing on water security and a circular system, cities can indirectly address multiple challenges, such as using treated storm-water and greywater to fill gaps in water supply.

Critical first steps in planning city-level interventions include:

- Conducting a radial mapping of a 5–10 sq. km area in metros and large cities (with a smaller radial scale for other urban centres). This mapping helps identify potential opportunities and assess the feasibility of decentralized water supply, sanitation and storm-water solutions.
- Conduct a thorough mapping of the city's water treatment infrastructure, including both large and small waterbodies.
- A gradient mapping of the city should also be undertaken, alongside a study of the groundwater table.

Now, opportunities for localized or shorter distance infrastructure to serve dense settlements can be identified.

Mapping the reach of infrastructure

Mapping of the entire city in 5–10 sq. km grids (depending on the size and population density of the city), outlining the water supply in that area, existing and potential surface water resources, wastewater generation and groundwater aquifer mapping form the basis of decentralized city-wide planning.

In the mapping phase, it is important to ensure that unplanned settlements are placed at the centre of city-wide planning. Identify failures if any in the existing water supply and wastewater treatment infrastructure of the city.

Once the entire city is mapped in grids (in urban planning parlance, these can be zonal planning units), hotspots of unplanned settlements—where service levels of water supply and wastewater management are poor and where urban flooding risk is high—the insights from prior assessments (chapter 4) and the planning processes (detailed in *chapter 5*) will guide the 'setting objectives' phase. Here, urban planners can identify which areas of the city's water systems require urgent intervention and prioritize them for augmentation. This comprehensive overview will also highlight the areas in cities where intervention is most needed and provide a clear starting point for action.

6.2 Reimagining water supply

A reimagined urban water supply and wastewater management is needed to manage all urban water, I.e. groundwater, surface water, treated wastewater and storm water. Decentralized water supply, decentralized wastewater and storm-water management should be at the core of this new approach to addressing problems of water scarcity, flooding and wastewater management.

Wastewater is being generated in thousands of millions of litres per day from our STPs. Bengaluru is using it for its lakes rejuvenation and transporting it more than a hundred kilometres for agriculture use through its tank's systems flow. In small and medium towns, water supply systems may not be so stretched as in large metros. However in semi-arid and arid parts of India, water sourcing and water scarcity will be acute.

Urban water supply institutional reengineering is needed to ensure that the current water supply utilities manage all water sources of the city, surface and groundwater and reused treated wastewater as well as storm water. It is important to not only supply but also monitor groundwater recharge, water quality and city water balance.

Water supply system

Water supply is a complicated exercise of infrastructure planning. Existing water supply infrastructure and existing service levels in different parts of the town/city vary significantly across cities. Existing and future water demand needs to be mapped with the existing water supply from surface and groundwater sources and potential augmentation options identified.

Reuse of treated wastewater is an emerging 'new water source' that needs to be factored into urban water supply planning. For large cities, this treated wastewater is a valuable resource that can be used multiple times if managed and treated properly, thereby reducing the city water supply and wastewater footprint significantly.

City master plans and regional plans need to be developed from an integrated urban water management perspective. Water cuts administrative boundaries of states and cities, and even countries. For planning and managing its water, wastewater and storm water, water-sensitive cities city will need to engage within the city and outside the city.

Several dense unplanned settlements and also planned areas in the southern periphery of Delhi borders, can be provided with dedicated water supply if some of the large lakes and waterbodies in a 10–15 km radius are used as decentralized water supply sources. These waterbodies can be connected to treated wastewater supply from nearby STPs, and with proper tertiary treatment the naturally filtered lake water can be pumped and supplied as new water, thereby also reducing Dehi's demand for water.

Decentralized water supply systems should therefore form the core of a reimagined urban water supply and wastewater management systems approach.

6.3 Reimagining wastewater management and sanitation

A city-wide reimagination of wastewater management would entail exploring a combination of centralized and decentralized sanitation systems, where city sanitation systems are imagined in the most decentralized way possible, with centralized systems there to support decentralized solutions.

This includes building decentralized settlement-level STPs or faecal sludge treatment plants or infrastructure at STPs for co-treatment of faecal sludge with sewage.

Reuse of treated wastewater from STPs for the purposes of lake recharge, park maintenance, industrial processes, shallow aquifer recharge and irrigation ensures not only a significant addition of 'new water', but also ensures that treatment standards at the STPs are followed and compliance is monitored all stages of reuse.

Focus on reuse of treated wastewater can influence the design of STPs. In future, when any new STP is conceptualized, the reuse of treated wastewater must—as a separate chapter—be made part of the DPR preparation.

Treated wastewater should be seen as a public good, its reuse therefore decided based on principles of equity and justice. Where public–private partnerships (PPP) are seen as viable by cities, to invest in and manage wastewater infrastructure and provide dedicated water supply sources for industry, this should happen with due public scrutiny and consultation. By adopting a multi-stakeholder approach for infrastructure development on reuse of treated wastewater, and by ensuring regulatory compliance, India can greatly expand its wastewater reuse capacity and secure a regular water resource for future generations.

The way forward for urban sanitation systems planning for Indian cities is to identify different typologies of towns of India and identify where sewered and non-sewered sanitation systems will be the most appropriate. The parameters for opting for a sanitation system for a town, should be the same as outlined by the CPHEEO Sewerage Manual (2018), i.e. water availability and supply, climate and whether the city can afford to install and maintain an expensive sewer system. In addition to what our research from Sangam Vihar shows, i.e. the density of population and volume of wastewater generated.

As a rule, towns with planned settlements where population density is low could have non-sewered sanitation systems, with faecal sludge treatment plants (FSTPs) for a cluster of houses or a colony, or they could have decentralized STPs for each cluster/colony level. Depending on the layout, climate and limitations of water supply.

There is a misconception regarding centralized and what s decentralized sanitation systems are. Non-sewered sanitation systems are wrongly considered decentralized sanitation systems. Decentralized sanitation systems are essentially more than one treatment plant—serving a given compact area—per town. So, if there is only one faecal sludge treatment plant in a town, it is a non-sewered treatment system, and will be called a centralized sanitation system.

The case therefore to be made, if at all, is for decentralized sanitation systems. These can be both non-sewered and decentralized sewage treatment plants (STPs) or faecal sludge treatment plants (FSTPs). This means:

- Two to four decentralized STPs for a town of 100,000 population constitutes a decentralized sanitation system. Smaller decentralized STPs will ensure that sewerage pipelines are not long, the operating cost of pumping sewage can be minimized and treated wastewater can be used locally.
- Similarly a town of 100,000 population with two or more FSTPs will constitute a decentralized non-sewered sanitation system. If there is only one FSTP, then it is also a centralized sanitation system.
- There could also be a combination of FSTPs and STPs located in different parts of a town. For larger cities, there can be multiples of smaller FSTPs and decentralized STPs and/or a combination of STPs and Co-Treatment Plants with STPs to treat septage. The deciding factor being distance for conveyance and cost of transporting septage/sewage.

How decentralized a sanitation system can be depends on the aim and objective of decentralization of urban water and sanitation systems.

One could start with a 10 sq. km unit area for a decentralized systems planning and reduce the unit area over time, depending on how the water supply. Wastewater and storm water can be best managed and best reused in that unit area.

6.4 Storm water

Expanding cities with high rainwater run-off from concrete surfaces is generating in situ urban flooding in many cities, especially in countries with wet seasons and monsoons.

Urban storm-water management has so far been guided by the aim of keeping roads free from waterlogging instead of for recharge of groundwater or creating green-blue infrastructure. Drainage of road-level storm water was therefore the aim of urban storm-water management. It was therefore governed in the institutional terms as 'those who are in charge of managing the road also manage the storm water on the road'.

Short-sighted urban storm-water management needs to change. It is neither equipped to handle rainfall and storm-water management nor is it in a position to address high-intensity rainfall in the era of climate change.

A reimagined storm-water management for cities must be governed by:

- Maximizing storm-water conservation and minimizing urban flooding
  - Through a combination of in situ and ex situ water-conservation initiatives spread across the city; and
  - With a focus on complementing groundwater recharge in and around densely populated areas dependent on groundwater, and not just in areas where water can be easily conserved.
- Preparing for normal- and high-intensity scenarios, especially in climate vulnerable cities, re-working on drainage systems.
- Identifying flooding hotspots and causes for flooding, as well as:
  - Status of groundwater aquifers (their disruption of groundwater flows) and conserving the aquifers from excavation and construction; and
  - Status of drainage channels: Keeping the channels open and preventing concretization covers.

City master plans and zonal plans often speak of water-sensitive urban design and planning (WSUDP) or sponge cities, but with little guidance on how to achieve the same.

When planning at the city level, this toolkit can be used in conjunction with other practitioners' guides for conceptualizing a city-wide climate and water-sensitive cities framing, and for preparing zonal plans.
Additionally, storm-water drainage will need to be done for two scenarios: normal-intensity vs. high-intensity rainfall periods and monsoon. This planning is especially

important in areas that are more vulnerable to extreme weather events and climate change (such as unplanned settlements). Identifying areas where groundwater tables are low and identifying additional infrastructure to make the storm-water flow and reach these areas.

Some important considerations when planning for storm water include:

- Understanding the topography of the city:
    - What is the level of surface water and groundwater?
    - What are the areas where groundwater levels are likely to be low and where they are likely to be high?
    - Therefore, what needs to be done to promote rainwater harvesting in which areas and not in all parts of the city?

- Understanding how the city built-up area has contributed to surface water run-off over the years:
    - Has the runoff increased?
    - Where does it flow and in what quantity based on intensity of rainfall?
    - How much of this normal- or intense-rainfall episomal storm water can be made to flow where?

- The status of drainage channels and rivers of the city:
    - Are the drainage channels blocked and narrowed?
    - Are the drainage channels covered with concrete slabs?

- Change of groundwater aquifers over time:
    - Is there large-scale underground parking or metro train and subways construction hampering the potential of groundwater recharge?
    - Is the underground construction leading to blocking of aquifer flows and rise of water tables in some areas?

These guiding questions and strategies, when used in conjunction with other practitioners' guidelines, will contribute to reimaging cities to be water sensitive.

7. Financing and equity in assessment and planning

In India, the states and urban local bodies (ULBs) are responsible for allocation funding for water, sanitation and storm-water infrastructure projects, which is often done by fundraising from the private sector. Due to the geographic and regional implications of water management, many countries allocate water-management responsibilities to local bodies. Therefore, it is essential to consider inclusive, equitable financing in any planning. This analysis and planning will largely depend on the stakeholders involved.

Any accessible financial modelling tools can be used in the planning phase.

Equity

Local bodies often fail to address concerns of inequity and injustice, and the urban poor remain left out. Experiences from Indian cities show that a differentiated approach is needed to reach the urban poor when it comes to augmenting water systems. Therefore, it is essential that any planning and action be tailored to the specific needs of the urban poor. We need to rethink our approaches to informal settlements, which are deemed 'illegal' and therefore undeserving.

EXAMPLE OF SCENARIOS TO CONSIDER IN FINANCIAL PLANNING

Decentralized STPs example

- May be more cost effective than centralized systems.
- When they are built for unplanned settlements, decentralized systems can ensure equitable and affordable sanitation solutions for low-income households.
- Additionally, this may help address the issue of non-revenue generating water (treated wastewater) having a higher chance of being reused as it is channelled back to low-income unplanned settlements.

Therefore, localized, well-planned decentralized systems can increase economic allocative efficiency, and be an equitable, financially sound investment.

Similar cases can be made for other solutions and planning tools presented in this toolkit.

As outlined by the WSC framework, considerations of equitable distribution of economic and environmental resources is essential in creating climate resilient, water-sensitive cities.

Conclusion

A reimagined urban water supply and wastewater management that manages all urban water, i.e. groundwater, surface water and treated wastewater, is needed.Decentralized water supply, decentralized wastewater and storm-water management should be at the core of this new approach to addressing problems of urban water scarcity, flooding and wastewater management.

Decentralized systems are a relatively more concrete expression of the circular economy principle. It just highlights that this can be a direction. Decentralized systems plus state responsibility to run these decentralized sewage treatment plants (STPs) or non-sewered treatment plants (faecal sludge treatment plants [FSTPs]) is the way forward for urban sanitation in Indian cities, especially our small and medium-sized towns.

Like all knowledge, no one thing or direction is absolute. Where decentralized STPs are required, we must adopt them—city by city and state by state—to assess what combination of systems may be required. As is shown for dense unplanned settlements where wastewater generation is in millions of litres a day, where a combination of centralized and decentralized systems is required, we should go for this.

This toolkit provides what is likely to be the approach to addressing the unique challenges of water supply, sanitation and storm-water management in unplanned settlements of the Global South. It is informed by CSE's Water-Sensitive Cities Framework and years of CSE's work on water and wastewater management.

The toolkit emphasizes the need for decentralized, equity-focused solutions that prioritize underserved areas. It advocates for a two-step process: first, assessing and planning for water and sanitation issues in dense unplanned settlements and, second, integrating these findings into broader city-wide planning where settlement-level interventions are not possible. This approach ensures that urban water-management systems are reimagined to be more inclusive, just and climate resilient, addressing the pressing needs of growing cities in the Global South.

Annexures

Annexure 1: Household survey questions

1.1 Water supply questionnaire

Research question 1: What are the different water sources available in the settlement? What is the percentage share of a particular water source in meeting the water needs of residents in the settlement?

1. What is the primary source of water?

1) Pipeline
2) Private bore well
3) Community bore well
4) Private tankers
5) Tankers
6) Bottles/cans (potable)

2. How often is the water supplied through pipeline (if any)?

1) Daily, hours of supply _______
2) Every alternate day, hours of supply _______
3) Weekly, hours of supply _______
4) Every fifteen day, hours of supply _______

3. How often is the water supplied through bore well?

1) Daily, hours of supply _______
2) Every alternate day, hours of supply _______
3) Weekly, hours of supply _______
4) Every fifteen day, hours of supply _______
5) Other, ____________

4. How do you store water at home?

1) Overhead tank
2) Drums/tanks on streets
3) Underground tank

5. What is the storage capacity of the storage tank? _______________ (in litres)

6. Estimated daily water consumption per dwelling: _______________ (in litres)

7. On a scale of 1-5 (5 being highly satisfied), how satisfied are you with the level of water supply

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ No comments

Research question 2: What are the current challenges and obstacles people are encountering in accessing and using this specific water source?

8. **How would you rate the water quality (taste, odor, and clarity) you access? (5 being highly good)**

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ No comments

9. **How is the drinking water quality?**

1) No discoloration/smell, tastes fine
2) Some discoloration/smell, but tastes fine
3) Discoloration/smell and bad taste
4) Others

10. **Have you experienced any waterborne diseases or illnesses recently? Yes/No**
11. **If, yes which diseases?**
12. **How much distance you travel to get water?**

1) No travel required
2) 0–50 m
3) 50–100 m
4) Above 100 m

13. **Are there individuals in your settlement who take the lead in water distribution? How do they contribute? (local leaders)**

14. **What is the distance between the septic tank and water tank at household level?**

    ____

15. **Where is the greywater (wastewater from kitchen and bathroom) disposed?**

1) To soak-pit/leach pit within premises
2) To plants within premises
3) To the drain outside house
4) To septic tank/pit (constructed for the toilet)
5) Others (specify)

1.2 Sanitation questionnaire

Research question:

What are the factors that influence access to and use of sanitation facilities in dense urban areas, and how do these factors impact the health and well-being of residents?

1. **What type of toilet facility do you have access to?**

- Individual household toilet

- Community toilet
- No toilet facility

2. How many toilets are there in this dwelling unit per floor?

- ________________

3. Approximate numbers of toilet users

- Male: ___
- Female: ___
- Children (less than six year): __

4. Toilet connected to?

- Septic tank/pit
- Drain
- Sewer
- Others

5. If the own /individual toilet is not functional, what do you do?

- Use a public toilet
- Use community toilet
- Open defecation

6. Is there sewerage network near to your HH?

- Yes
- No

7. If yes, when was it laid?

- Newly constructed
- Older than six months
- Older than a year
- Laid way back

8. HH connected to sewerage?

- Yes
- No

9. If no then who will do connections?

- Owner
- DJB
- Any private agency

10. If invert level of sewer line is above the outfall of black water generating from house hold then will you be ready to change your plumbing arrangements for sewer connection? It might cost you something.

- Yes
- No

11. What kind of wastewater goes into sewer?

- Only black water
- Only grey water
- Both

12. Septic tank outfall is connected to

- Soak pit
- Open drain
- Covered drain
- Open land
- Sewer
- Others, specify
- Don’t know

13. Type of septic tank:

- Individual
- Shared

14. Provide dimensions of septic tank:

- Length (feet) ______
- Breadth/diameter (feet) ______
- Depth (feet) ______

15. On what basis you decided the size of the septic tank?

16. Who cleans your septic tank?

- Private desludging truck
- Government desludging truck
- Manual

17. When was the septic tank emptied last time?

- Last six months
- Six to 12 months
- One year or more
- Don’t know

18. Why was the septic tank emptied?
- Regular emptying as safe practice
- Blocked toilet/backflow
- Overflow from access hole/manhole
- Other________________________

19. How much do you pay for cleaning your septic tank?
- Rs 1,000/trip
- Rs 1,500/trip
- Rs 2,000/trip
- More than Rs 2,000/trip

20. Is the septic tank accessible from road for cleaning by using a desludging truck?
- Yes
- No

21. Is there proper access with manholes/covers of septic tank which can be easily opened
- Yes
- No

22. How do you dispose of your household solid waste?
- Municipal collection
- Community bins
- Other

23. Is door-to-door waste collection available?
- Yes
- No

24. If yes, how many times in a week do they come?
- Daily
- Alternate days
- Once in a week
- Never

25. If no, where do you usually put away collected waste?
- In the public bin
- By the road or street side
- In an open space

- In open drainage
- Other______________________

26. If yes, then you pay for door-to-door collection facility?

- Yes
- No

27. If yes then on what basis do you pay?

- Daily
- Weekly
- Monthly

28. If you pay then how much you are paying for door-to-door collection facility?

- For daily ___________________
- For weekly ________________
- For monthly _______________

29. Is garbage segregation available from source?

- Yes
- No

30. Are there any designated areas for waste disposal within your area (garbage dumping ground)?

- Yes
- No

31. If yes, then what is the location of that area?

____

32. What type of solid waste comes out from your household?

- Food waste
- Paper
- Plastic
- Fibre bags
- Glass
- Other___________________

1.3: Storm-water questionnaire

Research question 1: Issues related to the present condition of the drains and catchment areas.

Are drains carrying only storm water or it is a mix of sewage and storm water? What was the basis of design and how it has been planned?

1. Availability of drains near households.

☐ Yes

☐ No,

If yes, specify type:

☐ Open drain natural

☐ Open drain man-made

☐ Covered drain

☐ Others

2. What kind of water flows into the drain?

- Only storm water
- Storm water + black water
- Storm water + grey water
- Mixing of storm water, black and grey water

3. If choking happens in drains who cleans the drains? Does the drainage cleaner charge money from you for cleaning? If yes, specify ____________ ____________

4. Whom do you approach while drains get choked near your HH?

5. How much time they take to resolve the issue of choking?

6. Frequency of cleaning of open/covered drains:

☐ Daily

☐ Weekly

☐ Monthly

☐ Quarterly

☐ Yearly

☐ Never

7. Is outfall of septic tank connected to storm-water drain:

☐ Yes

☐ No

8. Is there any bad odour in drains on regular basis?

- ☐ Yes
- ☐ No

9. Do you see solid waste trapped into drains near to your house?

- ☐ Yes
- ☐ No
- ☐ Sometimes

10. Do you face any problems while drains get choked?

- ☐ Yes
- ☐ No
- ☐ Sometimes

11. After the flooding happens, how long did the water take to drain away?

	In your house	In your street
Less than 30 minutes	☐	☐
30 minutes to one hour	☐	☐
More than six hours	☐	☐
More than one day	☐	☐
Water had to be pumped out	☐	☐
Unsure	☐	☐

12. How long does the flooding affect your property after the rain slows or stops?

- ☐ Only while it's raining
- ☐ It drains away within 4 hours
- ☐ Takes four to 24 hours to drain away
- ☐ Takes more than 24 hours to drain away

Research question 2: What is the topography of the surface, how does flooding affect the area?

13. Where is the outfall of the storm water from household?

- ☐ Adjacent drain
- ☐ Open land
- ☐ Water harvesting pits/wells
- ☐ Nearby sewer lines

14. If there is a drain outside your HH, where does it connect further?

- ☐ Other drain on roadside
- ☐ Sewer line
- ☐ Open land
- ☐ Others
- ☐ Don't know

15. Do you see storm water stagnated on roads, near your HH?

- ☐ Yes
- ☐ No

Table 1.1: Household population and demographic variables

Household no.	Age of house	Type of house	Number of HH members	House owned or rented	Total monthly family income	Number of HH on the property

Annexure 2: FGD questions

2.1 Water supply

Research question 3: To what extent is the major portion of the population in dense urban settlements dependent on groundwater as their primary source of water for various domestic purposes?

1. Water table depth: ____________ (metres below ground level)

1) 0–20 m
2) 20–40 m
3) 40–60 m
4) 60–90 m

2. To what extent is groundwater in the settlement being contaminated as a result of inadequate sewage management practices?
3. Is contamination seen throughout the settlement or in certain pockets only? Name the pockets/blocks.

Research question 4: What are the people's perspectives on the effectiveness of government initiatives addressing water challenges in the settlement?

4. Are you aware of any government initiatives related to water and sanitation in your settlement? If yes, name.
5. What is your perspective regarding piped water supply? How do you see its impact now and in the future?
6. In your opinion, what should be the top priority when addressing water-related challenges in the settlement?

2.2 Sanitation

1. Are you aware of any government water and sanitation programs in your community? If so, please provide a name.
2. Do people face problems with desludging services?
3. Where does the desludging facility discharge faecal sludge?
4. Do people need to pay for sanitation services, or it is a public service by government?
5. Do you think people face problems due to sewer breakdown?
6. Do people face problems when sewer gets overflows? Are sewer and storm-water drains being used conjointly?
7. How well, in your opinion, do government initiatives address sanitation or sewer-related issues?
8. What are the most difficult obstacles to getting and using sanitation and sewer services in the settlement?

9. Who is responsible for cleaning the open drain and sewer if a blockage occurs due to solid waste? Who come for cleaning (Municipal Corporation/ULB or private organization)? Does the sewer cleaner charge residents for the service? If so, who or how much?
10. When sewer gets choked, who cleans it? How? Who pays? How much?
11. In your area, do you get contaminated water? If yes, what impacts do you see usually?
12. What are the major challenges people face in maintaining proper sanitation and hygiene in the area?
13. What are the roles and duties of various players, including the government, the community, and the business sector, in upgrading the settlement's sanitation and sewage services?
14. How many CT/PTs are there in the settlement? What is the status of functioning of CT/PTs? Status of total seats in CT/PT?

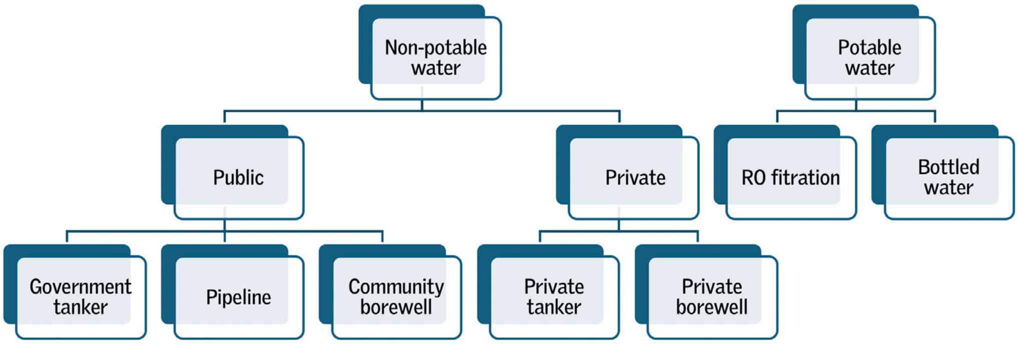
2.3 Storm water

Research question 3: What are the issues related to drainage, health and sanitation and jurisdiction of storm-water management in the area?

1. Do you think that existing drainage system is capable of handling storm-water generated in your area? If no, what are the reasons?
2. Which areas in your locality are the most affected during an event of rainfall?
3. Where is the outfall of storm-water drains in your area?
4. Does the condition of health and sanitation deteriorate during rains or monsoon? If yes, what was the main reason behind deterioration? Is there any health-related issue linked with stagnant water in your community due to improper storm-water management? If yes, specify__
5. Are you aware of any program/policy/project being implemented or in progress about storm-water management in your area? If yes, specify__
6. Who is responsible for draining out the storm-water stagnated in your area?
7. Who collects and clean the garbage emptying from drains during cleaning services? Where do they dispose it of?
8. Has there been any contact with the ULB/Council in the past about your storm-water problem?
9. Does municipality provide enough facility to reduce stormwater flooding?

Annexure 3: Water supply

3.1 Sources of water in India



3.2 Water supply variables

Table 3.1: Household non-potable water supply variables

Household no.	Number of HH members	Primary source	Secondary source	Frequency of water supply	Quantity of water supplied	Type of storage	Capacity of storage facility	Average monthly spending

Table 3.2: Household potable water supply variables

Household no.	Number of HH members	Amount of water from RO per day	Amount of water from bottled sources per day	Perception of quality of bottled water	Average monthly spending on potable water

Annexure 4: Alternative way of calculating and/or cross-checking water supply

Fill in the table below, through data on supply from each source (can be found through ULB or estimated by surveying water service providers)

Table 4.1 Block-wise supply of water from various sources

Block	Average quantity consumed from source 1 (per month)	Average quantity consumed from source 2 (per month)	Average quantity consumed from source 3 (per month)	Total water supplied in the block
Ex: Block A				
Ex: Block B				
Total water supplied from source	Ex: sum of water supply from source 1 for entire settlement			Total water supplied in settlement

The calculation of the total water supply and population of each block can then be used to generate estimates of average household water consumption and per capita water consumption, as well as the demand for water.

Table 4.2 Daily per capita and total water consumption and daily demand

Block	No of households	Total population	Average water consumption per household	Total daily water consumption	Water consumption per capita	Total water demand	Supply gap
Ex: Block A							
Total							

Table 4.3: Calculating water supply

Variable	Calculation
Average water consumption per household (by block	$\frac{\textit{Total water supply of block}}{\textit{No.of households in block}}$
Water consumption per capita	$\frac{\textit{Total water supply}}{\textit{Population}}$
Total water demand	Total population x recommended per capita water quantity (LPCD) Ex: 100,000 x 135 LPCD
Supply gap (per capita and total)	Demand – Supply

Annexure 5: Sanitation

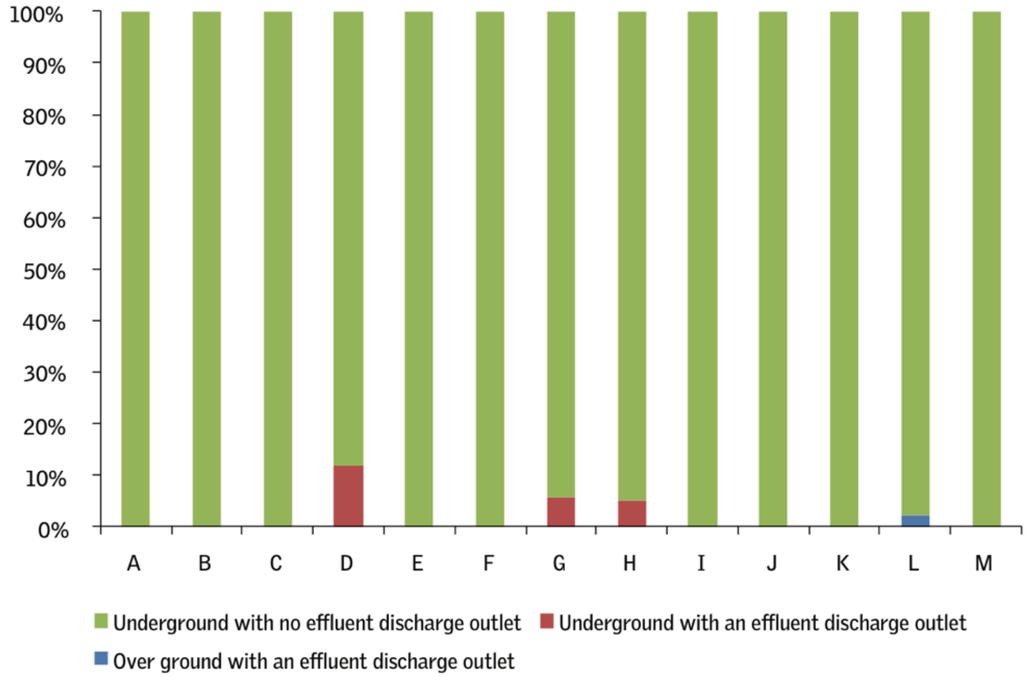
Table 5.1: Household wastewater and sanitation variables

Household no.	Number of HH members	Number of toilets	Type of toilet	Type of sanitation system	Frequency of septic desludging	Annual cost of desludging	Capacity of septic storage facility	Wastewater generated (80% of total supply)

5.1: Example analysis of data on septic tanks

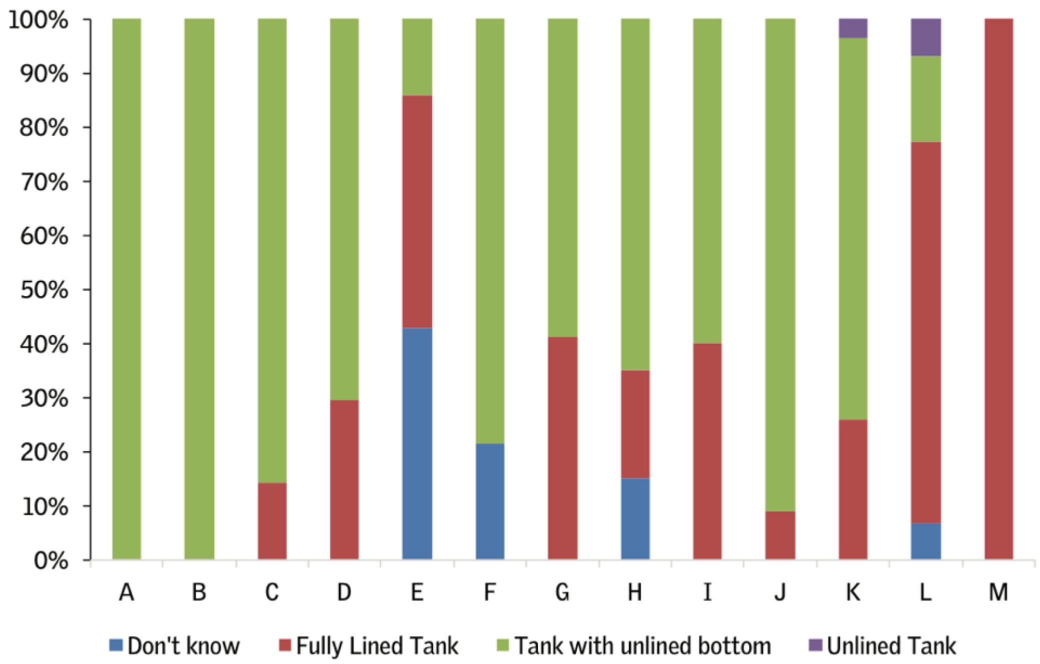
Assessment criteria and results for toilets and septic tank in Sangam Vihar.

Figure 5.1A: Type of septic tank



Source: CSE, 2024

Figure 5.1B: Construction of septic tank



Source: CSE, 2024

Annexure 6: Storm water

6.1 Additional questions to assess the state of storm water

These questions are for ULBs and other parties responsible for storm-water management locally. The aim is to provide a well-rounded and complete picture of storm-water management, especially if data is scare and enumeration is difficult.

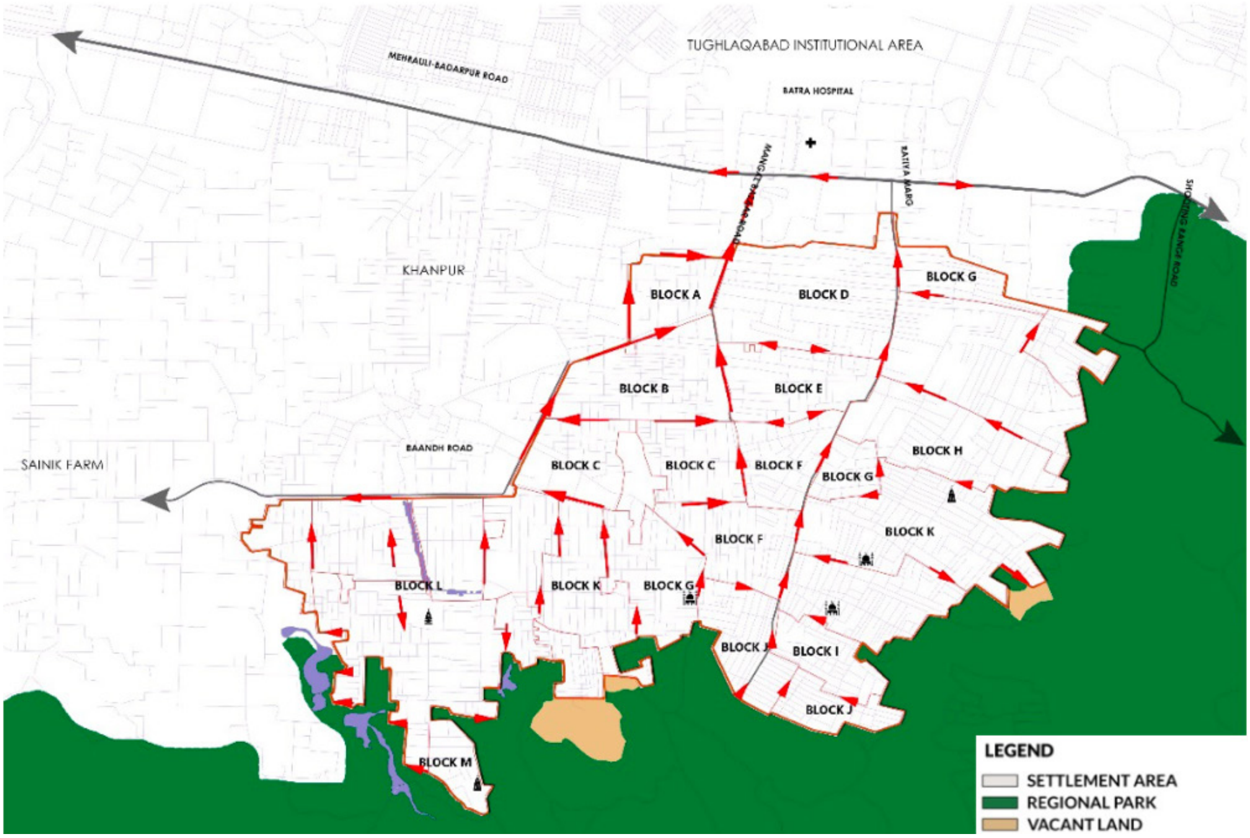
1. How much area has been covered with SW drains and how much is left? What is the basis for selecting the area for laying storm-water drains?
2. Do you have any calculation on runoff generation? If yes, what is the basis? Did you consider any norms/standards?
3. For what capacity existing SW drains are designed? What catchment area has been considered during design?
4. How are the dimensions of different drains calculated for laying of the storm-water drains?
5. How is elevation (and low-lying area) being considered in mapping of the settlement? Are there gradients map of the area and delineation of watersheds?
6. What are the funding arrangements for laying the storm-water Infrastructure?
7. Where does major runoff go during flooding and in normal days?
8. How do you deal with stagnant water during rainy days?

9. What are the plans, if any, for retrofitting, improvements or expansion of the existing drainage infrastructure in the settlement?
10. Who is responsible for O&M of storm-water management infrastructure? How frequently, are the drains cleaned (or is the cleaning need-based)?
11. Are there chances of SW coming from adjacent areas into this settlement?
12. Are you aware of any conflicts with adjacent areas due to storm water coming from there area or storm water of this settlement going to their area?
13. Are urban development and population growth considered in drainage planning? If yes, how?

6.2 Mapping storm-water flows (example of Sangam Vihar)

The direction, flow, and design of the settlements drainage system can be undertaken by engaging in GIS mapping informed by site visits.

Figure 6.2A: Mapping storm-water drainage



Source: CSE, 2024

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Urbanization in the Global South is marked by increasing unplanned and informal settlements. Normative frameworks and approaches of water conservation fall short of addressing critical gaps in equity and justice and climate-change-related risks of our urban water supply, wastewater and storm-water challenges.

This toolkit provides a conceptual and practical understanding for assessment and planning of decentralized systems to address this challenge.

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