

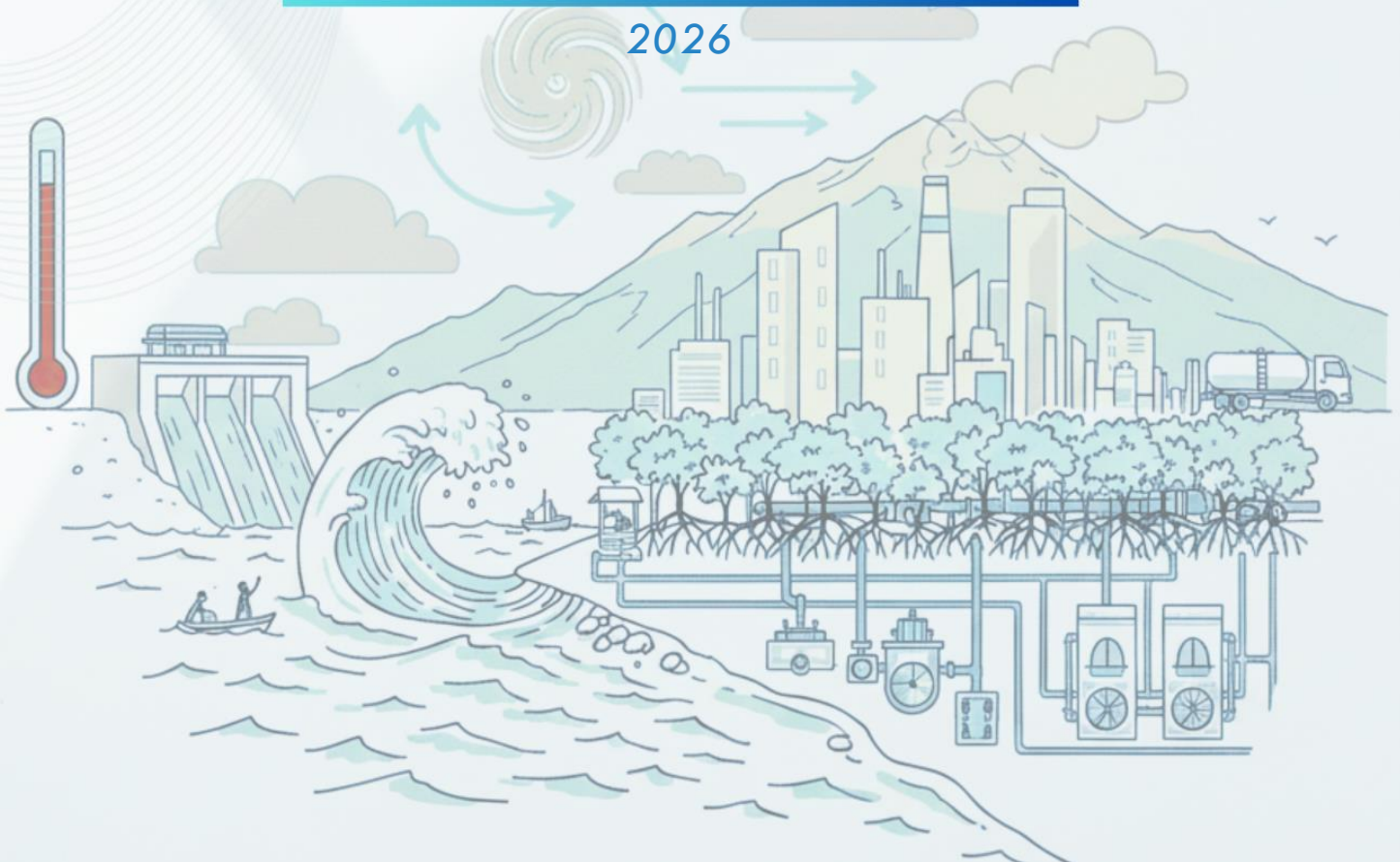


Towards Climate-Resilient Urban Water & Sanitation Systems

Situational Assessment Report

MAPUSA, GOA

2026

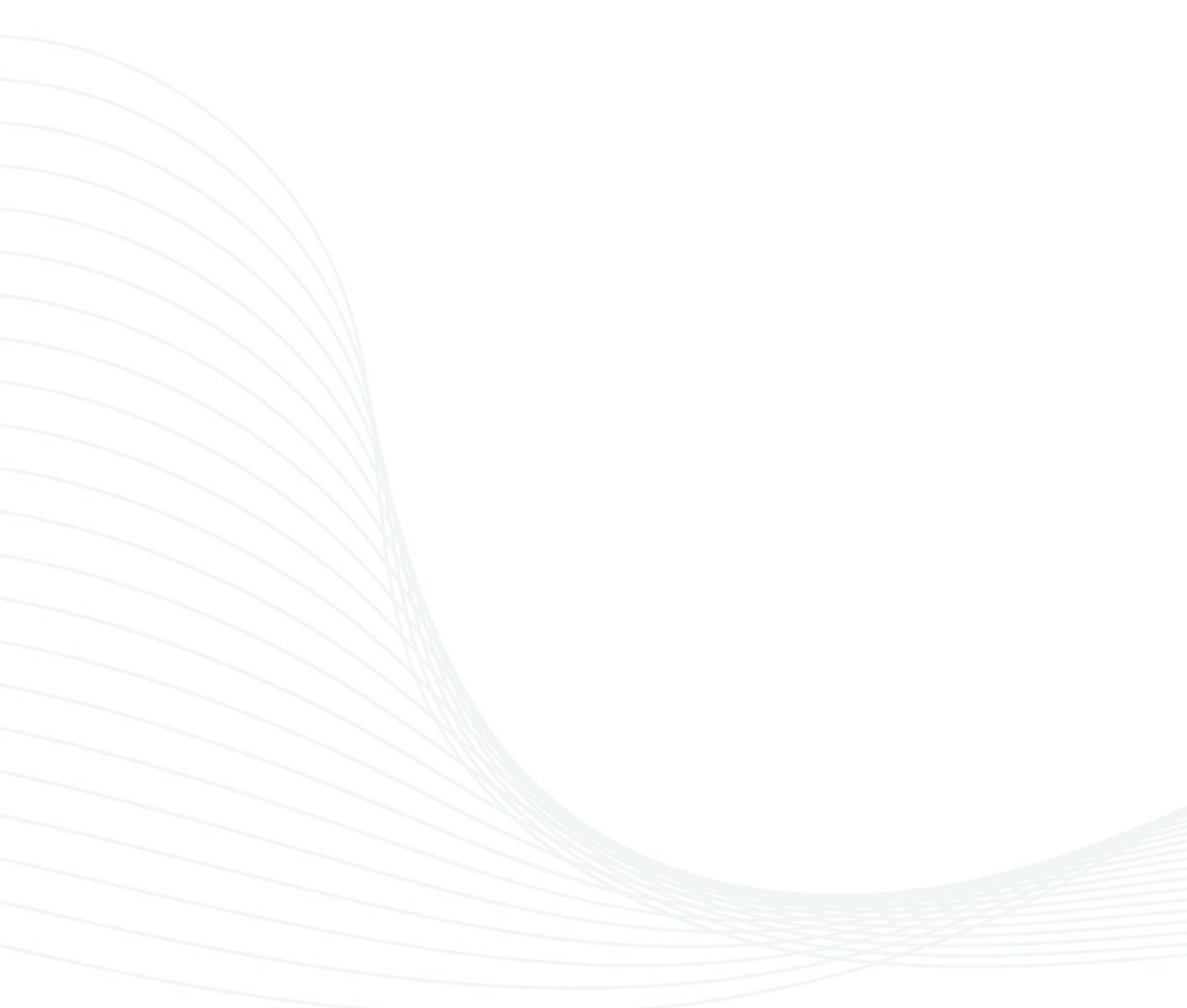


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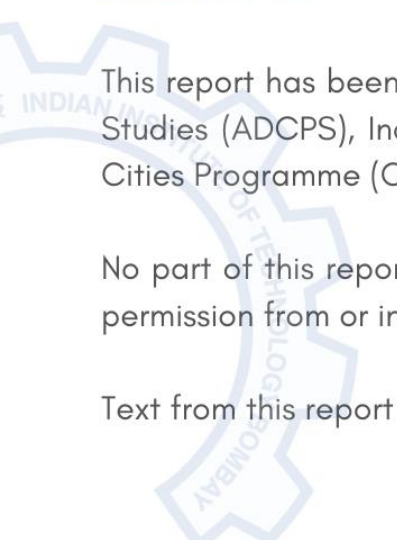
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TITLE

Towards Climate-Resilient Urban Water and Sanitation Systems: Situational Assessment of Mapusa, Goa

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EXECUTIVE SUMMARY

Climate change is fundamentally reshaping global water systems through more frequent extremes and growing hydrological uncertainty. The resulting impacts threaten water security while escalating risks to lives, critical infrastructure, and ecosystems, with coastal cities at the forefront. Against this backdrop, the 'Climate Resilient Coastal Cities' initiative was initiated by Ashank Desai Centre for Policy Studies (ADCPS), IIT Bombay in collaboration with India Sanitation Coalition (ISC) and CDD India with financial support from HSBC India. Under the initiative, ADCPS, IIT Bombay led the scientific research component and conducted comprehensive situational assessments of the Water and Sanitation Systems in 12 coastal towns across Gujarat, Maharashtra, Goa and Karnataka. The primary objective of our assessment is to evaluate the operational and institutional readiness of water and sanitation systems to adapt to an increasingly volatile hydro-climatic regime in these coastal towns. To achieve this, we map the physical water and sanitation infrastructure within the biophysical environment of the city, and evaluate specific risks and challenges to service delivery against local and felt climate realities. Through a comprehensive analysis of greenhouse gas (GHG) emissions, energy footprints, institutional and policy landscape, and municipal finances, the report identifies critical gaps and opportunities for adaptation and mitigation. Rather than prescribing final solutions, this situational assessment provides the crucial evidence base needed to lay the foundation for climate-resilient WaSH futures and to inform future research on actionable, context-specific resilience strategies.

Coastal towns on India's west coast represent extreme cases for analysing the implications of increasing climate variability for urban water security. Unlike the acute disaster risks of the east coast, these towns face chronic, persistent stress: an observed 52% increase in Arabian Sea cyclones since 2001, rapid degradation of protective mangroves, and a reliance on short, seasonal rivers. These towns oscillate between monsoon flash floods and acute summer water scarcity, worsened by saline intrusion into local aquifers. Studying these locations offers critical insights into the long-term resilience challenges that many Indian cities will confront in the coming decades. Our case studies across 12 coastal towns not only highlight the increasing vulnerabilities of existing infrastructure-heavy approaches but also illuminate the pathways forward (figure 1).

The future of urban water security will depend not on a single intervention, but on whether cities can build coherent, adaptive, and low-carbon water systems that align engineering solutions with ecological processes, financial innovation with equitable service provision, and climate foresight with institutional reform.

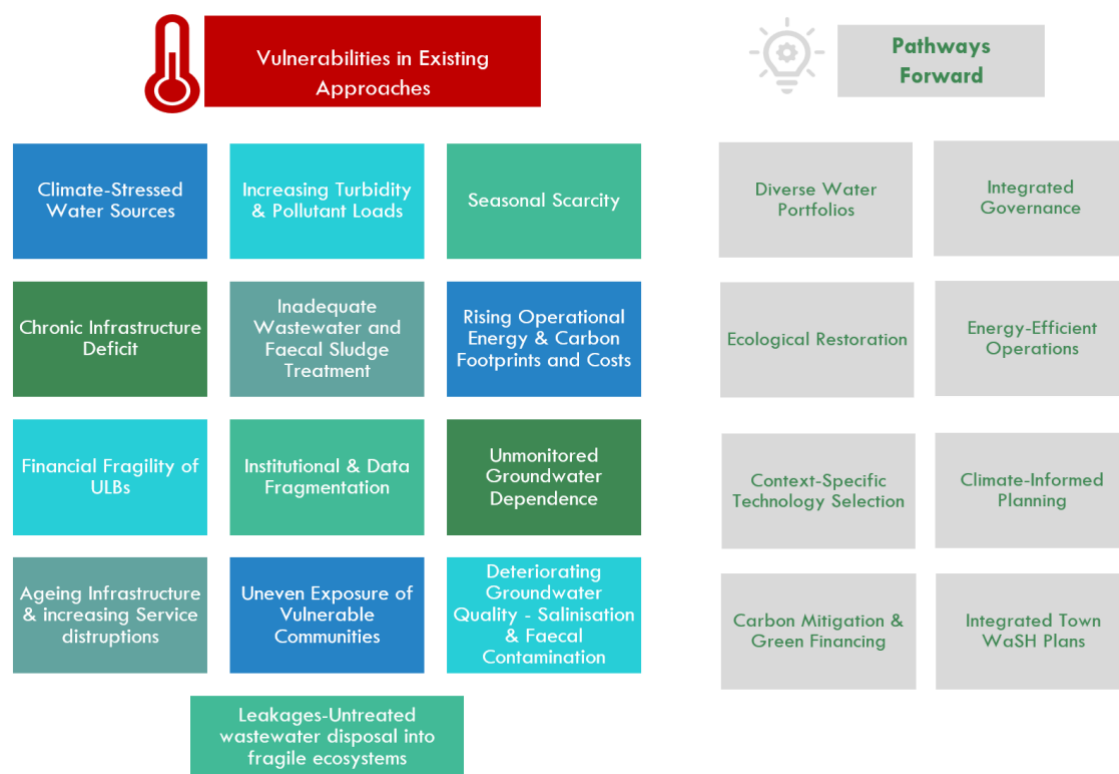


Figure 1: Systemic Vulnerabilities in existing approaches to WaSH and Pathways forward.

This report focusses on **Mapusa**, a Class-III commercial hub in North Goa serving as a vital case study for high-growth coastal towns. Our assessment of Mapusa revealed some critical challenges of WaSH infrastructure & services:

Water Supply:

- **Centralised Source Risks:** Heavy reliance on external surface water (Assonora WTP) exposes Mapusa to hydro-climatic risks and long-distance transmission losses (20–40%), which significantly inflate the carbon footprint of consumed water.
- **Infrastructure Stress:** The ageing networks frequently operating above design capacity to keep up with rising demand are subject to frequent breakdowns and service disruptions. Upgrade works to existing infrastructure are underway in tranches while new works to add capacity have also been ongoing. The infrastructure appears to be perpetually catching-up, making service disruption a norm rather than an exception.
- **Groundwater: A Critical but Neglected Buffer:** Despite acting as an essential safety net during droughts and service interruptions, groundwater remains

dangerously excluded from urban planning and monitoring, severely undermining overall climate resilience, equity, and operational costs.

Sanitation:

- *Gaps in Services:* Inadequate drainage performance, incomplete sewer connections, irregular desludging practices, and the absence of local treatment capacity disproportionately affect vulnerable communities, increasing exposure to flooding, sanitation failures, and associated public health risks.
- *Public Septage Capacity and Affordability:* Dependence on private desludging operators charging INR 6,000–10,000 per trip raises affordability concerns and undermines service reliability.
- *Governance Constraints: Sanitation management is segmented:* Decision-making over major sanitation infrastructure remains largely outside the ULB, limiting its role in planning, financing, and operations and constraining its ability to respond effectively to local needs and ground realities.

Energy- GHG Emissions:

- *Energy-Emission Hotspot:* Water operations consume ~312 MWh annually for each MLD of water supplied, contributing to over **20,000 tonnes of CO₂ eq. annually**. In contrast, local groundwater extraction requires up to 90% less energy.
- *On-Site Dominance:* Mapusa relies heavily on septic tanks and pits, which emit over **5,600 t CO₂eq./year** (methane).
- *Nutrient & Flood Risk:* Stormwater drains act as vectors for greywater, contributing to N₂O emissions in sensitive estuarine ecosystems (**413.5 tCO₂e/year**).
- *The Water-Energy-Climate Nexus:* Our analysis reveals a projected rise in both the energy intensity and the overall GHG footprint of the urban water cycle in response to the observed climate change impacts.

Financial Health:

- *Sustainability Gap:* PWD faces 0% cost recovery for sewerage services, creating total dependence on state subsidies. Despite steady growth in revenue income (4.75% CAGR), it continues to fall short of covering operational costs, indicating inefficiencies in revenue generation.

- *Limited Devolution:* Aligning with the CAG Report-2024, there is a critical need to devolve financial and administrative powers to the Mapusa Municipal Council to enable context-specific, climate-resilient planning and revenue generation.
- *The Capital Financing Gap:* There is a concerning decline in capital receipts, which have dropped from ₹7.01 crores in 2019-20 to ₹6.56 crores in 2024-25, making it harder to secure funding for long-term infrastructure projects.

Moving Forward, the town's vulnerability to climate variability demands a diversified water portfolio that integrates regulated groundwater and rainwater harvesting to rejuvenate local sources and reduce dependence on energy-intensive surface water transfers. Achieving long-term sustainability will necessitate the implementation of flood-resilient sanitation and nature-based drainage solutions tailored to the town's unique riverine topography. By prioritising energy efficiency, formalising climate-risk budgeting, and addressing socio-economic disparities in service delivery, Mapusa can transition into a low-carbon, climate-ready urban center. While emission reduction may not be the immediate priority at this stage of WaSH development, conventional approaches to adaption risk inflating the sector's carbon footprint through conventional approaches to adaptations. *Synergistic decarbonisation of WaSH not only unlocks cost-effective carbon abatement strategies for the larger climate mitigation effort but also opens up green financing avenues to a financially constrained sector.*

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1. URBAN WATER & SANITATION SYSTEMS IN A CHANGING CLIMATE

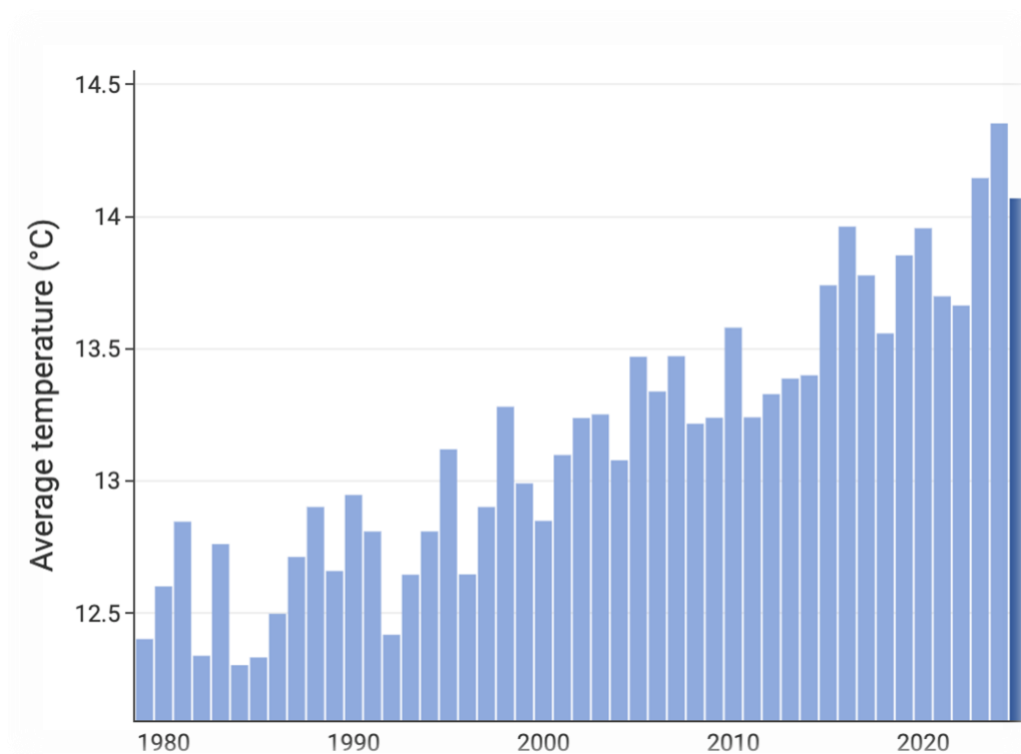
ASHISH DANGI, NEELAM RANA, N.C. NARAYANAN AND PRIYAKSHI GOGOI

This chapter establishes the universal climate-WaSH context and methodology utilised for our study of 12 coastal towns in India. It examines the impact of an intensifying global water cycle on urban water security, focusing on the emerging climate risks along India's West Coast. It is a shared chapter across all reports in this series. Town-specific findings begin in Chapter 2.

1.1 BACKGROUND

The global average air temperature over land shows a significant rising trend over the past decades with 2025 recorded as the third hottest year¹ (Figure 1). The persistent warming of the atmosphere effectively turns it into a larger sponge that can hold more water.

Figure 1: Global annual average land temperature (1979-2025).



Data Source: Global Water Monitor¹

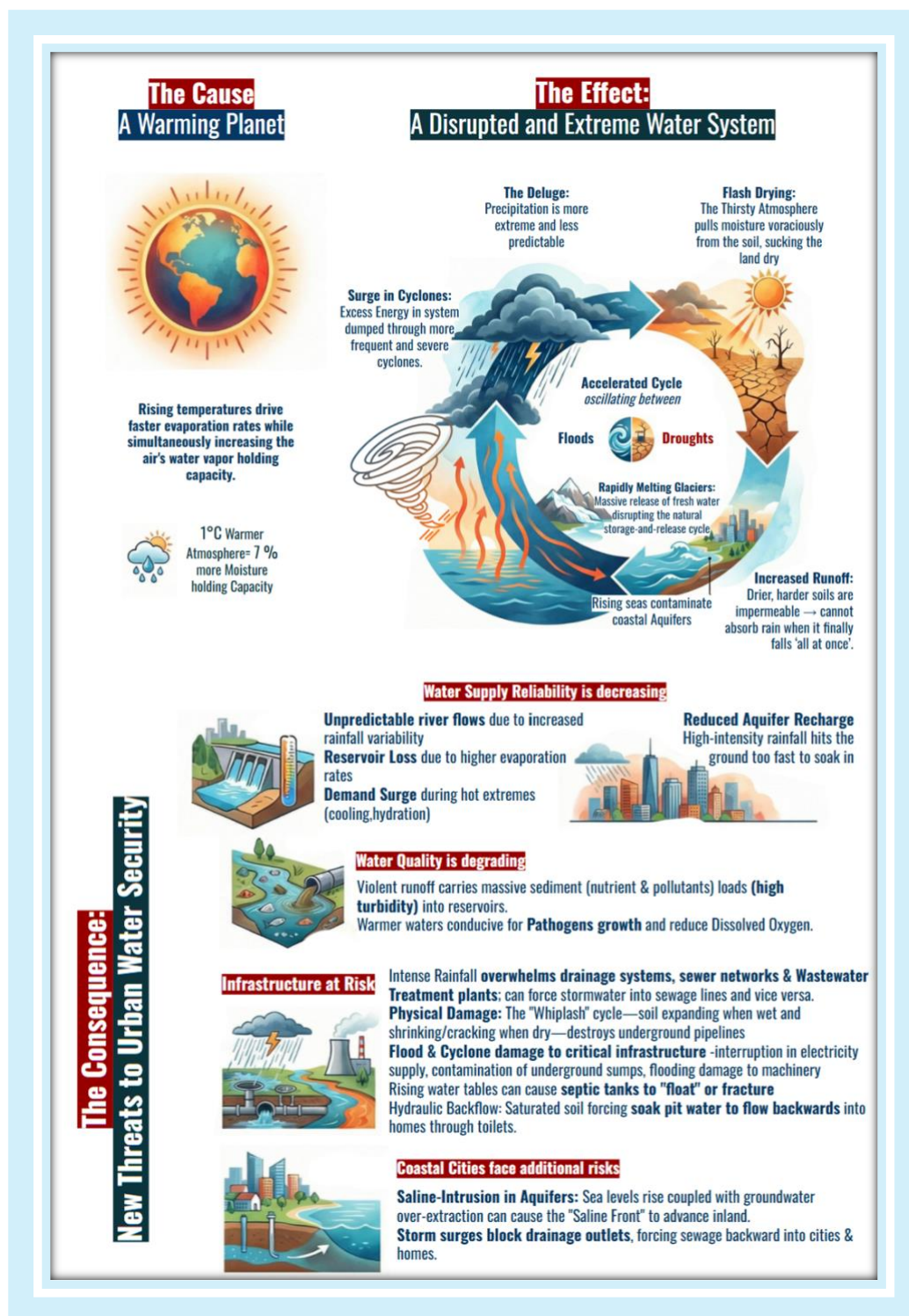
This leads to a volatile cycle: during dry periods, the 'thirstier' atmosphere aggressively evaporates moisture from soil and reservoirs, deepening drought conditions. However, once this moisture-laden air is triggered to release by a cyclone or orographic lift, it discharges with explosive intensity. Thus, cities are confronted with a dual reality referred to as the *climate whiplash*: longer, more intense dry spells that threaten source sustainability, interspersed with violent, short-duration rainfall events that overwhelm drainage infrastructure. These hydro-climatic shifts due to intensification of the hydrological cycle, destabilise water availability while escalating the threat of water-related disasters to human lives, critical infrastructure, and natural ecosystems. In fact, these hydrological extremes now constitute some of the most tangible and widespread impacts of climate change.

Between 2001 and 2018, over 74% of global natural disasters were water-related, causing over 300,000 fatalities and ~ 1.7 trillion USD in economic damages worldwide causing immense human and economic losses^{2,3}. Global Climate Risk Index 2021 ranks India as the seventh-most exposed and vulnerable country to climate extremes⁴. With high risk of concurrent flood incidents, the country is among the most vulnerable countries to climate change as per Intergovernmental Panel on Climate Change (IPCC) sixth assessment report. More than 300 extreme events have hit the country in recent decades, causing losses of more than INR 5,600 billion⁵. A recent evaluation indicates that more than 75% of districts in India, including 95% of coastal districts, are hotspots for extreme events.⁶

However, focusing solely on these acute disasters obscures the more insidious, *long-term erosion of water security* that cities now face. The fundamental shift in the hydrological baseline is creating a crisis of chronic unreliability. The rising temperatures on one hand result in a surge in water demand and volatility in water availability on the other. Furthermore, warmer temperatures actively degrade water quality by promoting algal blooms and reducing dissolved oxygen levels, meaning that even when water is physically available, it is increasingly difficult and energy-intensive to treat. Ultimately, these shifts threaten to render conventional infrastructure obsolete, transforming water security from a manageable operational challenge into a persistent existential risk for growing urban populations.

Figure 2 illustrates the intensification of the water cycle driven by global warming and its cascading consequences for urban water security. A disrupted natural system reduces reliability of water supply, degrades water quality and places infrastructure at risk. Coastal cities are particularly vulnerable in this changing regime, facing compounding threats from surging cyclones, sea-level rise, and storm surges that overwhelm drainage networks and force saline intrusion into freshwater aquifers.

Figure 2: Intensification of the water cycle due to global warming and its impact on urban water security.



Source: Author's Illustration

Nowhere are these hydro-meteorological shifts more immediately felt than in coastal cities, where land, ocean, and atmospheric systems intersect. The rapid retreat of glaciers and ice cover is causing sea levels to rise at unprecedented rates, further compromising the water availability and quality in coastal areas⁷. More intense rainfall combined with rising sea levels amplify storm surges, salinity intrusions and surface run-off placing coastal settlements at heightened risk. These shifts not only impact freshwater resources but also exacerbate existing vulnerabilities to flooding and inundation. A warmer atmosphere and ocean provide additional energy for storm intensification, leading to a greater number of extreme weather events. Cyclones, in particular, pose catastrophic threats not just to lives and infrastructure, but to the very backbone of urban resilience: access to WaSH. By damaging water supply and wastewater infrastructure, such events jeopardise public health and disrupt the essential services that coastal cities rely on, placing them at even greater risk. These hazards compound the existing pressures of urbanisation, placing critical water infrastructure under significant stress and exposing vulnerabilities in already stretched systems. These new risks are especially critical in India, where approximately 18% of its population resides in 72 coastal districts⁸.

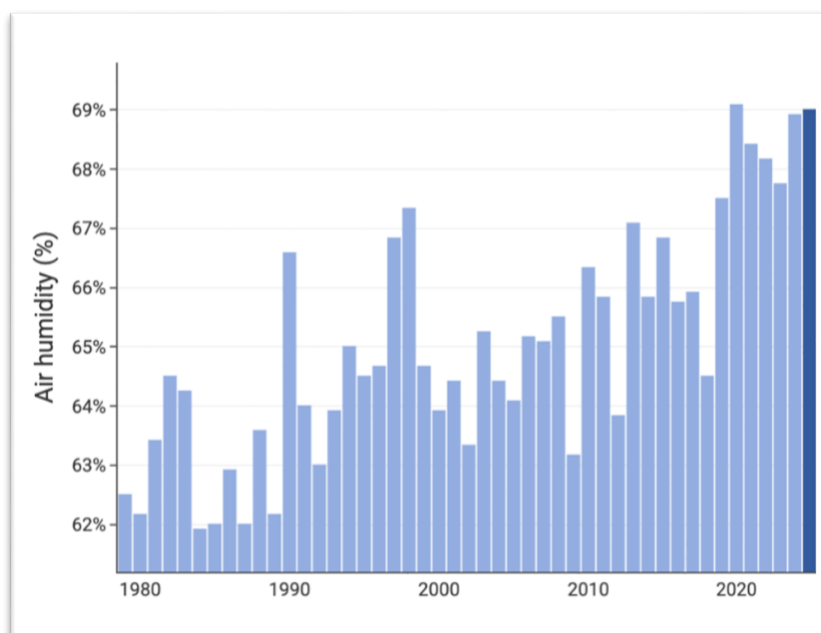
This escalating hydro-climatic volatility inevitably converges on Water management, particularly in cities, where dense populations, concentrated infrastructure, and increasingly fragile ecosystems intersect. Urban water systems spanning water supply, wastewater management, drainage, and groundwater regulation, were designed for a different climatic reality and are now struggling to cope. For instance, the January 2025 wildfires in Los Angeles exposed critical vulnerabilities in urban water systems. Firefighting efforts were crippled when water storage tanks ran dry; officials acknowledged the system was "designed to put out house fires, not multiple neighbourhoods on fire"⁹. Traditional management focused solely on balancing supply and demand becomes obsolete. Instead, WaSH systems must evolve into adaptive instruments for disaster preparedness and public health. In an era of uncertainty, safeguarding urban liveability requires transforming these interdependent systems to withstand the dual threats of chronic scarcity and acute extremes, *making resilient WaSH infrastructure the cornerstone of sustainable cities*.

1.2 THE RISING CLIMATE THREAT TO INDIA'S WEST COAST

The West Coast of India is rapidly emerging as a new frontier of climate risk, driven by a dangerous synergy between the warming Arabian Sea and the region's unique topography. While the Bay of Bengal has historically been the more active basin, recent data reveals a paradigm shift: the Arabian Sea has witnessed a 52% increase in the frequency of cyclonic storms and a threefold rise in very severe cyclonic storms during the recent epoch (2001–2019).¹⁰ This intensification is fuelled by rising Sea Surface Temperatures and Ocean Heat Content, which act as a massive "moisture pump" ensuring a constant supply of water vapour

to the warming air with a greater water holding capacity¹¹. This is corroborated by long-term atmospheric data showing a sharp surge in India's average annual air humidity, particularly in the 2020s where levels have consistently exceeded 68% (*Figure 3*). When this moisture-laden air intercepts the steep barrier of the Western Ghats, the resulting orographic lift triggers explosive, high-intensity rainfall events.

Figure 3: Annual time series of air humidity over Indian landmass.



Data Source: Global Water Monitor Data Explorer¹²

Along India's west coast, the coastal districts of Gujarat specifically have become increasingly vulnerable to tropical cyclones in recent years¹³. Further, west coast states are more exposed to sea level rise; every one-metre rise in sea level can inundate almost 5,763 km² of land¹⁴. Making the west coast more susceptible to coastal flooding and cyclones is the significant loss of the complex mangrove ecosystem, which will continue to increase beyond 2100 as per IPCC 2023 report¹⁵.

Furthermore, historically established as fishing villages and trading posts near river mouths or perched along the slopes of the Konkan and Sahyadri mountains, the coastal settlements have evolved into thriving industrial hubs, port cities, and tourist centres. The region's undulating terrain, fragile slopes, rising sea levels, erratic weather patterns, and increasing cyclonic activity exacerbate its vulnerability. Challenges such as land submergence, wave shoaling, shoreline erosion, salt intrusion, groundwater flooding, and coastal inundation are increasingly evident. These threats contribute to environmental degradation, contamination of land and water, disruptions in essential services, and potential infrastructure failures.

1.3 SYSTEMIC VULNERABILITIES AND THE CLIMATE MULTIPLIER EFFECT

Densely populated coastal cities have long grappled with rising demand amid diminishing water availability. Over the years, infrastructure expansion, intensified water pumping, and landscape modification became embedded in policy and practice as conventional approaches to water management. Yet these approaches often degrade natural environments both within and beyond city boundaries. Water flows are altered through water extraction, river diversions, reservoir construction, and flood control measures. Impermeable built surfaces reduce rainwater infiltration and groundwater recharge, while the loss of vegetation disrupts processes like transpiration that help sustain the natural water cycle. At the same time, cities generate massive amounts of wastewater that flows back into the natural cycle, often untreated and poorly managed. In their determined efforts to cope up, cities have often compromised the very ecosystems they depend upon. In the water-stressed context of India, short-term needs are often understandably prioritised over long-term sustainability particularly for a need as vital as water: the lifeblood of urban life. However, this trade-off may no longer be tenable.

Even without climate pressures, water management in Indian cities faces deep structural challenges: widening demand–supply gaps, shrinking freshwater sources, falling groundwater tables, and the degradation of rivers, wetlands, and aquifers. Conventional approaches such as large dams, long-distance water transfers, deeper extraction, and engineered flood-control measures, have historically prioritised short-term supply augmentation at the expense of ecological stability.

The consequences are far-reaching:

- *Altered river flows and disrupted drainage systems* due to unplanned urban development
- *Low groundwater recharge* caused by impermeable surfaces
- High dependence on *energy-intensive pumping*, increasing carbon emissions
- *Large volumes of untreated wastewater* discharged into rivers, seas, and aquifers
- *Increased vulnerability to floods and salinity intrusion* as coastal ecosystems such as mangroves and estuaries decline

As a result, urban water systems across India operate under chronic stress, with climate change amplifying existing weaknesses and introducing new, compounding risks.

Further exacerbating the risks posed by climate change is the inadequate infrastructure and services in critical areas such as housing, sanitation, water, and public health, particularly for

socio-economically disadvantaged groups^{16,17,18,19} and are now exposed to climate change-related risks.

Governance and Policy Gaps: A Structural Barrier to Resilience

Despite clear evidence of climate impacts, policy responses across water, energy, and urban development remain fragmented. Governance arrangements continue to operate in sectoral silos:

- *Water policies* focus on augmenting supply rather than reducing demand or building resilience.
- *Energy policies* rarely account for the energy footprint of WaSH services and the water footprint of energy generation and distribution.
- *Climate strategies* frequently overlook the carbon footprint and vulnerabilities of water and wastewater infrastructure.

Urban Local Bodies (ULBs) face chronic financial and technical capacity constraints. Many rely on ad-hoc, project-driven solutions that respond to immediate complaints but do little to address systemic vulnerabilities. Institutional inertia, overlapping jurisdictions, and limited accountability impede long-term planning. Meanwhile, the most severe impacts are disproportionately borne by marginalised communities, deepening socio-spatial inequities.

Without integrated governance mechanisms, cities remain locked into cycles of over-extraction, infrastructure stress, ecological decline, and rising climate vulnerability. For comprehensive insights on policy landscape refer to our policy analysis reports.

1.4 REIMAGINING URBAN WATER RESILIENCE IN THE FACE OF CLIMATE CHANGE

Climate change on one hand, underscores the urgent need for effective urban water management to enhance the health resilience of populations and mitigate its impacts on cities. On the other, it intensifies existing water-related challenges brought by urbanisation, threatening the sustainability of urban water systems. As temperatures continue to rise, conventional water management approaches focused on large-scale infrastructure, and reactive coping strategies may prove insufficient under these compounded pressures. In fact, such strategies could worsen long-term vulnerabilities by disrupting the natural water cycle, especially in fragile coastal ecosystems.

Climate change thus acts as a wake-up call, urging policymakers to reassess the fragile relationship between urban water systems and the natural water cycle. Ensuring long-term water security and resilience demands a new paradigm that not only addresses the immediate

impacts of climate change but also strives to harmonise existing water systems with natural cycles.

With this understanding, a study titled *“Landscape analysis for four coastal states on climate resilient water and sanitation infrastructure”* was initiated under the Climate Resilient Coastal Cities (CRCC) initiative financially support by HSBC India. The study focuses on evaluating the existing water and sanitation systems in the backdrop of emerging climate realities in 12 coastal towns across Maharashtra, Gujarat, Goa, and Karnataka (*Figure 4*).

Figure 4: Case study towns across 4 west coastal states of India

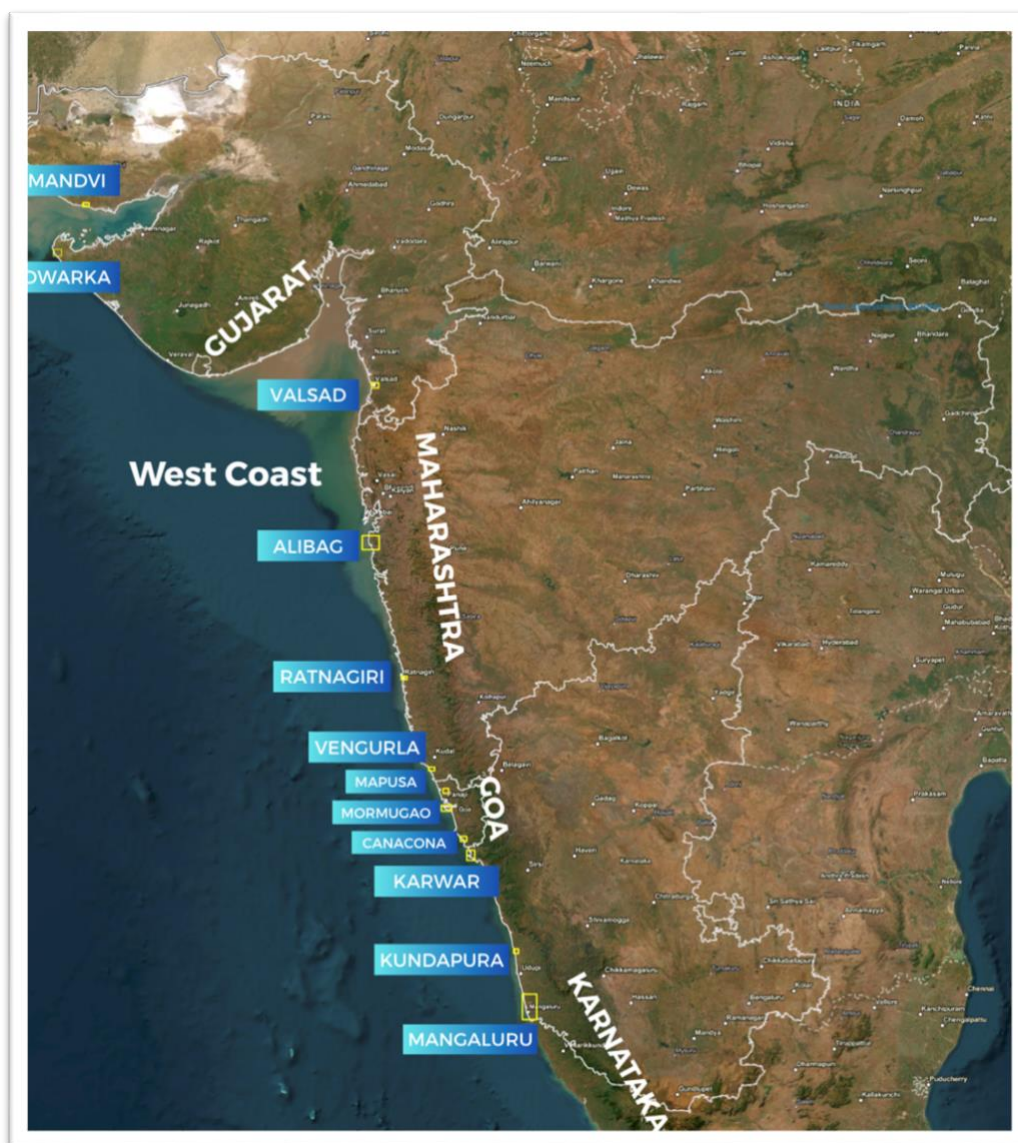


Image Source: Author's Illustration

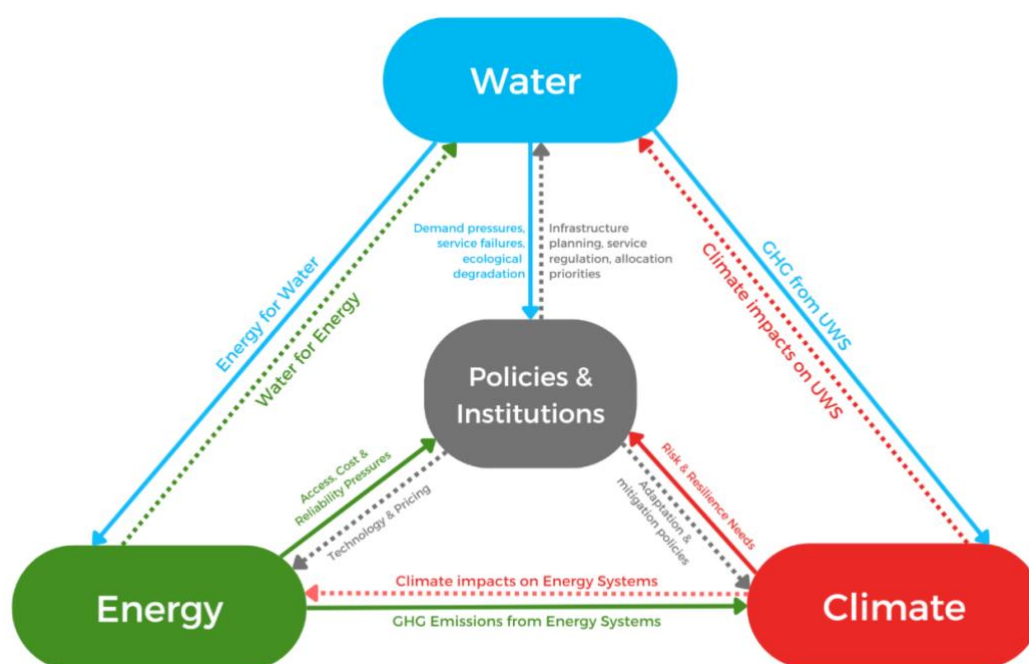
1.5 METHODOLOGY

The *primary objective* of our study is to assess the operational and institutional readiness of the Urban Water & Sanitation sector to adapt to a changing hydro-climatic regime, while identifying pathways for low-carbon and sustainable service delivery. The methodology is structured to build a cumulative evidence base, moving from baseline profiling to detailed diagnostics and resilience evaluation.

1.5.1 ANALYTICAL FRAMEWORK

The process begins with a systematic literature review to establish the analytical framework governing the interaction between climate impacts and water and sanitation (WaSH) infrastructure.

Figure 5: The Water-Energy-Climate Nexus in urban water systems.



Source: Author's Illustration

Our methodological approach is grounded in a systems-thinking framework that conceptualises urban water and sanitation (WaSH) not as an isolated sector, but as a dynamic component of the Water-Energy-Climate nexus. As illustrated in [Figure 5](#), this approach

evaluates the bi-directional interactions between these three critical domains, all of which are mediated by central governance structures.

The framework is structured around four primary nodes and their interacting flows:

1. **The Water-Climate Interaction:** The framework assesses the dual relationship between WaSH infrastructure and climate change. It evaluates the physical climate impacts on Urban Water Systems (UWS) such as extreme weather events, altered hydrological cycles, and coastal hazards while simultaneously quantifying the GHG emissions from UWS, establishing the carbon footprint of current water management practices.
2. **The Water-Energy Interdependency:** It maps the resource interdependencies, specifically focusing on the Energy for Water requirement. This involves auditing the energy intensity of extracting, treating, and distributing water, as well as conveying and treating wastewater.
3. **The Energy-Climate Linkage:** The framework acknowledges that the energy systems powering WaSH are themselves vulnerable to climate impacts, while their baseline GHG emissions dictate the overall carbon intensity of the urban water cycle.
4. **Policies & Institutions:** Placed at the core of the framework, institutional governance acts as the primary mediating force. The framework analyzes how governing bodies respond to systemic stressors such as demand pressures, ecological degradation, and risk/resilience needs and how they shape the physical systems through infrastructure planning, resource allocation, technology pricing, and the implementation of adaptation and mitigation policies.

By applying this holistic framework, the situational assessment moves beyond simple infrastructure mapping. It allows us to systematically identify operational vulnerabilities, calculate environmental footprints, and evaluate the institutional readiness required to build climate-resilient WaSH systems.

1.5.2 TOWN SELECTION CRITERIA

The town selection followed a two-step process. First, a set of criteria was developed through a comprehensive literature review (*outlined in Table 1*). These criteria were designed to ensure diversity among the case study towns in terms of WaSH infrastructure and services, geography, demographics, and climate vulnerability, administrative status, thus enabling a more representative and contextually grounded analysis.

- **Current understanding of climate risks:** The selection process considered the known climate risks each town faces, as these are critical for assessing the vulnerability of WaSH infrastructure to climate-related hazards.
- **Variation in infrastructure and urban characteristics:** Towns were selected to reflect diversity in water and sanitation infrastructure and service levels, population size, climatic conditions, and economic activities—factors that influence exposure and adaptive capacity and GHG emissions.
- **Socio-economic profile:** Differences in socio-economic conditions lead to varied water consumption and sanitation practices. These factors are crucial for understanding a town's climate resilience and estimating GHG emissions in the WaSH sector.
- **Administrative status:** The administrative status of a town significantly influences its capacity for climate change planning and response, especially in critical sectors like water and sanitation. Towns with higher administrative status—such as municipal corporations or class-I and beyond—tend to have greater autonomy, better institutional structures, and access to financial and technical resources. They are more likely to have dedicated departments, skilled personnel, and the ability to integrate climate considerations into urban development plans. These towns also benefit from larger budgets, greater revenue-generating powers, and enhanced eligibility for national and international funding schemes focused on climate adaptation and mitigation. In contrast, smaller towns or panchayats often rely heavily on state or district-level agencies, leading to delays in planning and implementation. Moreover, higher status towns typically have better data systems and monitoring capabilities, which are essential for assessing climate risks and emissions. Their greater political visibility further enhances their chances of being included in pilot projects or targeted policy interventions. Thus, a town's administrative status directly shapes its ability to design and implement effective, context-specific climate-resilient infrastructure and services.

The above process generated a preliminary list of towns, from which the final selection was made in consultation with the state Directorates of Swachh Bharat Mission Urban (SBM-U).

Table 1: Town Selection Criteria

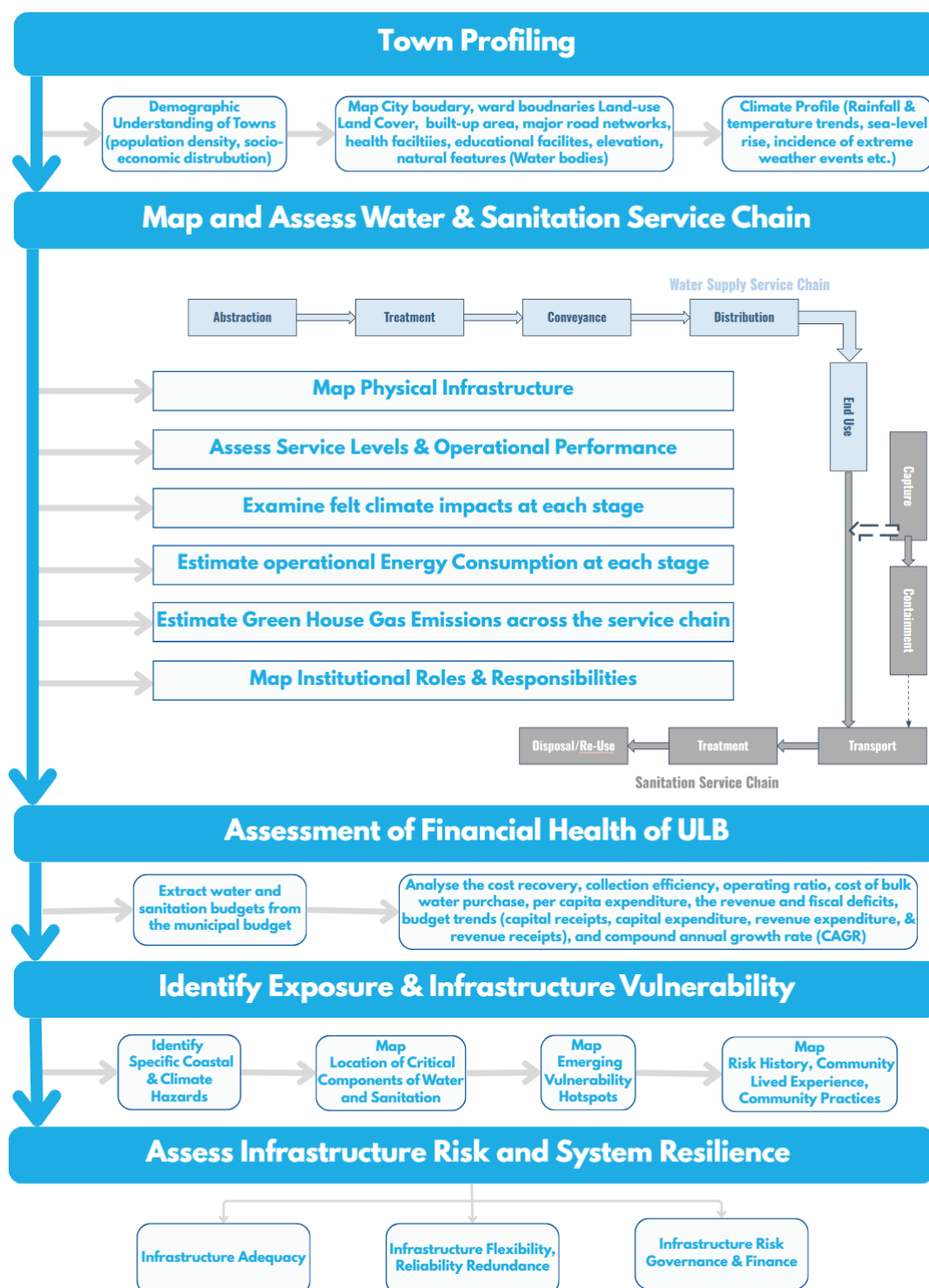
Key Parameters	Selection criteria		
Administrative status	Municipal Corporation	Municipal Council (A and B)	Nagar Panchayat (C and D)
City Size based on population	Class-I to Class IV		
Socio-economic profile	Capturing variability in socio-economic profile of the town population		
Climate Change Exposure and vulnerability	Low Risk/vulnerable	Medium Risk/vulnerable	High Risk/vulnerable
Sanitation Infrastructure Services Status	Only On-site Sanitation	OSS + % networked system	OSS+ % networked + Non-networked (NBS/Conventional/ FSSTP)
Economic Contributions /Profile	Industrial, agricultural, tourism, service sectors		
State government and ULB support	Past and current partnerships, collaborations		

Table 2 : Selected Towns

State	Town	Population (2011)	Class
Maharashtra	Alibag	20,743	Class-III
	Ratnagiri	76,229	Class-II
	Vengurla	12,392	Class-IV
Karnataka	Mangaluru	4,99,487	Class-I
	Kundapura	30,444	Class-III
	Karwar	77,139	Class-II
Goa	Canacona	12,434	Class-IV
	Mormugao	94,393	Class-II
	Mapusa	39,989	Class-III
Gujarat	Dwaraka	38,873	Class-III
	Mandvi	51,376	Class-II
	Valsad	1,70,060	Class-I

1.5.3 STEP-BY-STEP APPROACH TO SITUATIONAL ASSESSMENT

Figure 6: Methodological framework for the situational assessment and resilience evaluation of urban WaSH systems.



As illustrated in *Figure 6*, our town-level situational assessment follows a logical, multi-step progression that begins with town profiling to establish demographic, spatial, and climatic baselines. We then map the entire water and sanitation service chain to evaluate physical infrastructure, operational performance, environmental footprints, and institutional responsibilities. This is followed by a financial health assessment of the Urban Local Body to analyse municipal budgets and expenditure trends. Next, we identify specific vulnerabilities by mapping coastal hazards against critical infrastructure locations and emerging risk hotspots. These steps finally culminate in a comprehensive resilience assessment that evaluates the overall adequacy, flexibility, reliability, and financial risk governance of the system.

1.5.4 DATA COLLECTION

To assess the resilience of water and sanitation infrastructure, the study employed a mixed-method approach combining extensive desk-based research with targeted fieldwork. Initial reviews of national and municipal datasets (e.g., Census, SBM-U) established the analytical framework and identified critical data gaps, which were subsequently addressed through stakeholder consultations with ULB and state-level officials. This was complemented by on-ground validation, including technical site visits to key infrastructure assets (WTPs, reservoirs) and rapid assessments of vulnerability hotspots, where semi-structured interviews with residents provided critical insights into service delivery challenges and local climate impacts. Detailed data collection steps and questionnaire for ground truthing (resident interviews) are provided in Annexure-I of the report.

The study also identified several critical data gaps that limit comprehensive assessment and effective decision-making. These gaps, detailed in Annexure-II, highlight the need for improved data collection, systematic reporting, and stronger integration of information across institutions to better inform future planning and resilience-building efforts.

This situation assessment report focuses on Mapusa, a Class-III town in the Bardez Taluka of North Goa District. Mapusa is about 7 kms inland from the coast alongside the Mapusa River. At the confluence of a riverine and coastal wetland ecosystem, Mapusa serves an important role as an important regional market centre for the villages nearby and has the Bardez taluk administrative headquarters. Increasing annual rainfall, cyclonic storms, intense precipitation events and high ground water tables in monsoons, in recent years, has led to frequent flooding in the city located on the floodplains of the river systems in the region. The Goa State Climate Change Action Plan has prioritised the taluks of Mormugao, Bardez, Tiswadi and Salcete for adaptation efforts, as these regions host most of the state's population and economic activities, and are at higher risk due to climate change (NABCONS, 2023, p. 147)²⁰.

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2. TOWN PROFILE

NEELAM RANA, PRIYAKSHI GOGOI, SUCHARITA ROY, TEJASH ANAND & N.C. NARAYANAN

This chapter presents a detailed town profile, covering demography, climate, topography, land use and land cover, as well as key climate risks highlighted in literature.

Mapusa town is in Bardez Taluka, North Goa District, and serves as the headquarters of Bardez Taluka. The town covers a total area of 11.32 sq km and is divided into 15 wards. It is also home to the main market of the taluka.

Demographic Profile: The town has 9,466 households and a population of 39,989, with a nearly 50-50% male and female population, as per Census 2011. The population density is 3532.6. The town includes 154 Scheduled Tribe (ST) members and 1,638 Scheduled Caste (SC) members.

The town has a 92.05% literacy rate. The total workforce consists of 16,248 individuals, with 14,566 engaged in main work, including 121 cultivators, 13,882 other workers, 502 household industry workers, and 61 agricultural workers. Additionally, there are 1,682 marginal workers in the area.

Figure 7 : Administrative Divisions of Goa



Source: Census Digital Library, 2021²¹

Topography: The town of Mapusa is in a riverine ecosystem with the land sloping towards its east and the south towards the Moira River, also known as the Mapusa river. Mapusa has an elevated land profile with more than 70 % of the town area at an elevation of over 10 m above sea level.

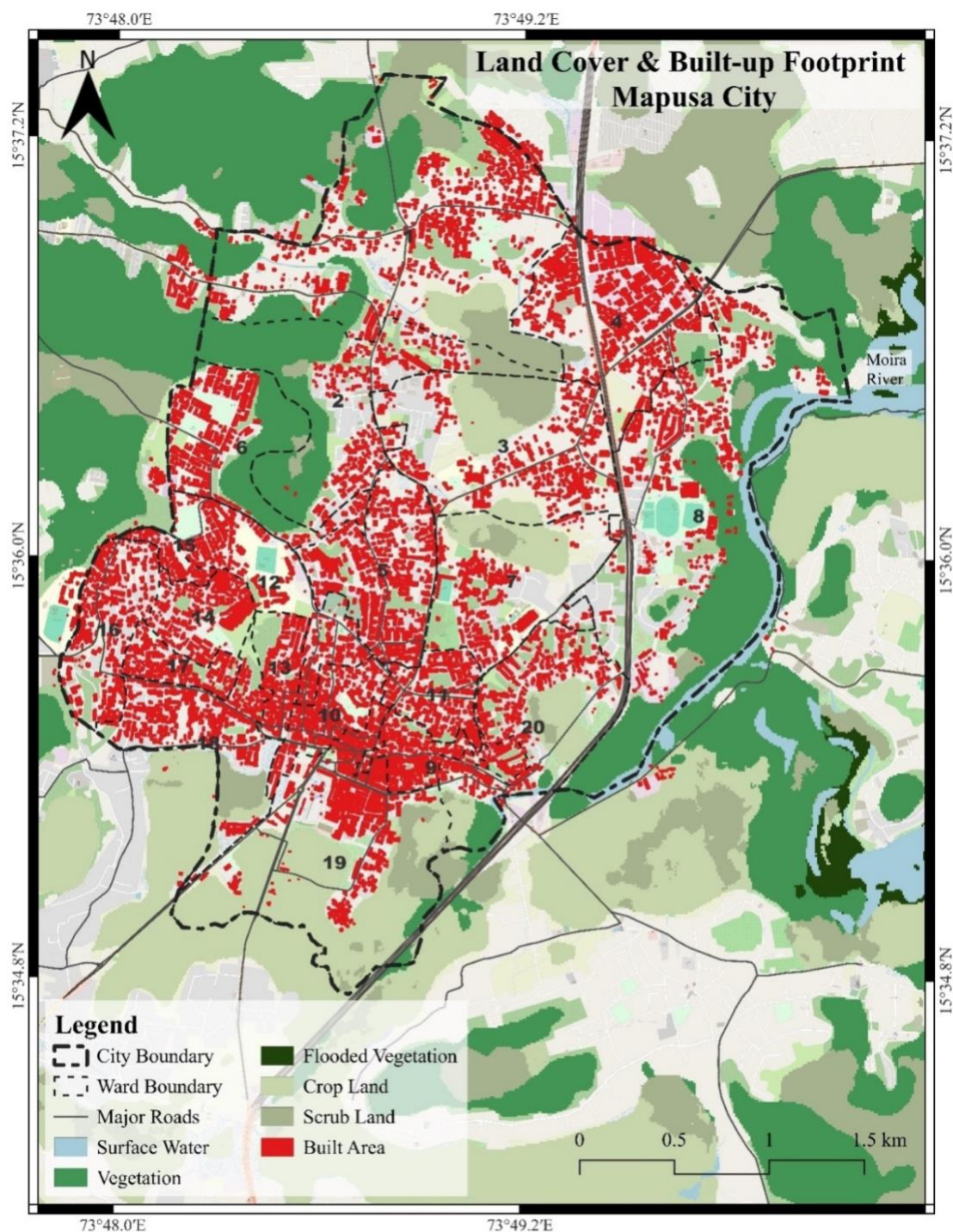
Land use and Landcover: The town primarily consists of built up, crop land, scrub land and flooded vegetation in the flood plains. (Ref. Figure 8 and Table 3). The built-up footprint reveals Ward 1 in the north, 8 in the east and most parts of ward 19 - the southernmost wards, are the largest wards of the town with scattered built footprints and significant vegetated land consisting of coconut farms and others. Ward 8 is primarily covered by flooded vegetation and houses large institutional open spaces like stadiums. Ward 19 of the city on its southern end has large public facilities, some high rises and a much-clustered development surrounded by cropland and scrubland. Wards 9, 10 and 11 form the center of the city, the smaller wards constituting around 6 percent of the administrative land with highest built-up density (more than and with sewerage network coverage. Wards 13 – 17 towards the southwest of the city around Khorlim is a mix of low rise and multistoried development interspersed with scattered vegetation. The road leading to the nearby Assangaon - a Portuguese village of interest to tourists, shows multiple scattered developments. Towards the southwest are the three neighboring small villages – Verla, Parla and Canca, well connected to Mapusa town.

Table 3 : Ward level Built-up footprint (based on remote sensed data)

Ward no	Land share (%) total town area)	Built up footprint	Ward no	Land share (%) total town area)	Built up footprint
1	14.7	19%	11	1.7	60%
2	7.1	17%	12	3.4	40%
3	7.5	23%	13	1.2	57%
4	6.0	45%	14	1.8	55%
5	4.1	53%	15	0.5	65%
6	4.3	32%	16	2.9	47%
7	5.2	20%	17	1.1	67%
8	16.2	13%	18	3.9	40%
9	1.6	70%	19	9.8	20%
10	1.7	65%	20	6.0	26%

Source: GIS Analysis

Figure 8: Land use and Built-up Footprint of Mapusa



Source: Derived from Sentinel 2 10m (LULC), 2024; Open Street Map; Mapusa Municipal Council

Climate Profile: The average annual rainfall in Mapusa town is 3,096.97 mm, according to the Census 2011 data. As per the State Statistical Handbook-2023, the Mapusa rain station recorded a total of 4,041.2 mm of annual rainfall during 2021-22²². The maximum and minimum temperatures in the town are 31.53°C and 23.51°C, respectively, as per the Census 2011. 2 major rivers drain North Goa district i.e., Tiracol and Mandovi. Mandovi river also drains Mapusa town.

Climate Change and Disasters: Town level data on climate change impacts and disasters is lacking. Hence, we relied upon district and taluk level secondary data on disasters. According to NITI Aayog's Climate and Energy Dashboard, North Goa District fall within a moderate damage risk zone for wind hazards (with wind speeds reaching up to 39 m/s) and moderate cyclonic activity (featuring maximum sustained wind speeds ranging from 48 to 63 knots)²³. The coastal belt of Goa is the only area vulnerable to cyclones. However, within the taluk, *MMC appears to be less directly impacted by cyclones, according to interviews with ULB officials. That said, cyclone Tauktae in 2021 brought strong winds that uprooted trees, damaging houses in Mapusa and causing debris accumulation in certain areas. Similarly, Cyclone Mora in 2017 triggered heavy rainfall, resulting in ankle-deep flooding in several low-lying areas around the town. This caused water to enter numerous properties within the MMC, with the situation exacerbated by a poorly maintained drainage system*^{24,25,26,27,28}. As shown in the below figure 9, the 0-5 meter elevation zone is considered the most vulnerable to flooding in Goa²⁹. Consequently, *the Bardez taluka is particularly susceptible to flood-related hazards, and in terms of flood severity, Bardez taluka is the one of the most vulnerable talukas in the state (as show in the table 4).*

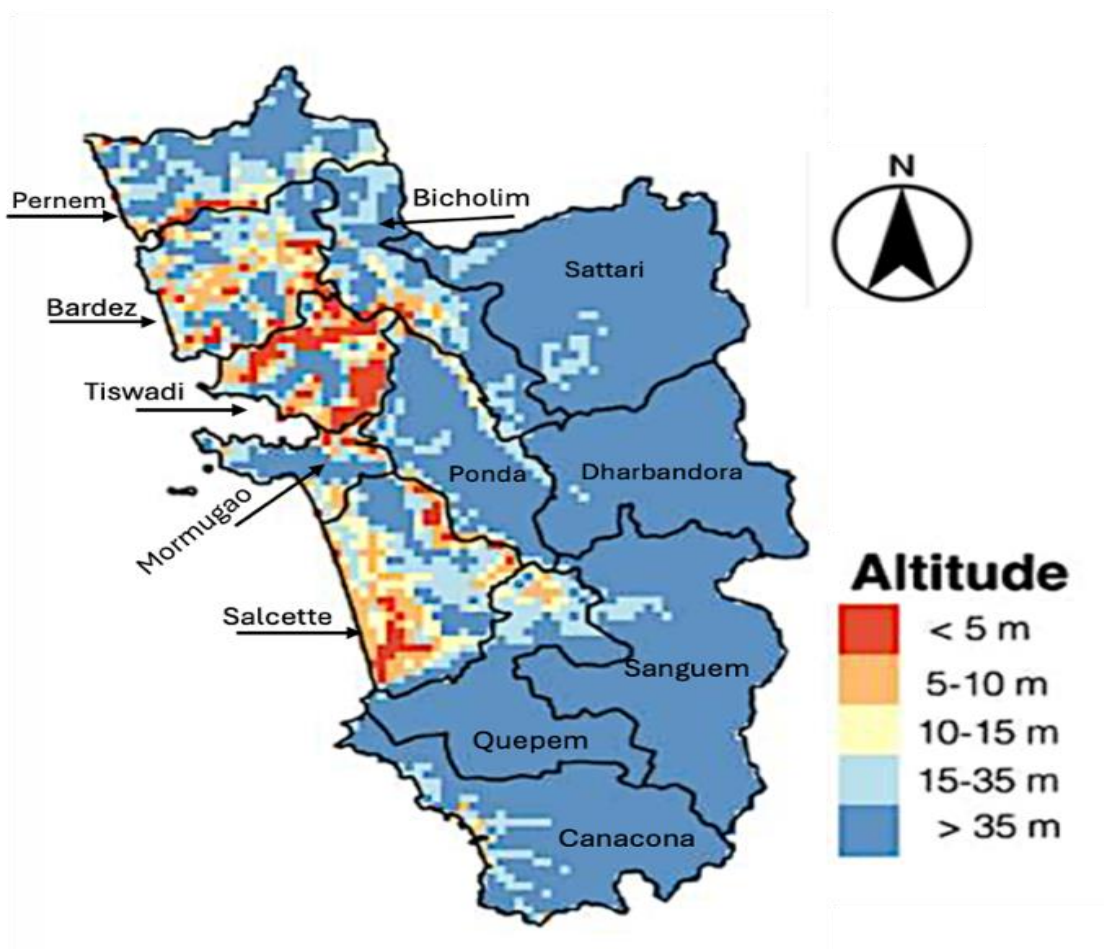
Goa is currently experiencing a rise in sea levels. Long-term data from the Mormugao station indicates that the sea level in this area has been rising at a rate of 1.45 mm per year, with 95% confidence, from 1969 to 2013²⁹. According to an UNDP study, a 1-meter rise in sea level could affect 7% of Goa's population and result in damages estimated at Rs. 8,100 crore²⁹. *The Bardez taluka (which includes the selected town of Mapusa), with a coastal elevation of less than 35 meters and spanning 30 km of coastline, are particularly susceptible to sea-level rise and flooding. This leads to coastal erosion and saltwater intrusion.*

Table 4 : Multi-hazard vulnerability (level of severity) in Bardez taluka of Goa

Taluk	Cyclone	Floods	Drought	Landslides	Soil Erosion
Bardez	High	High	Low	Medium	Low

Source: (Goa State Disaster Management Authority, 2024)³⁰

Figure 9 : Flood Vulnerability of Taluka of Goa



Source: (NABCONS, 2023)

Approximately 26.8 km of Goa's 139.64 km coastline (about 19%) has experienced river and coastal erosion between 1990 and 2018³¹. *Bardez Taluka, in particular, has seen erosion rates exceeding 0.6 meters per year²⁹. The issue of saltwater intrusion is expected to worsen due to sea-level rise from climate change, compounded by the indiscriminate use of groundwater (ibid). Although all talukas in Goa are classified as being in the 'safe category' and the region is in a high precipitation zone, it has one of the lowest per capita freshwater availabilities²⁹. This makes saltwater intrusion especially concerning, as many of Goa's surface water sources for drinking, such as rivers, are already heavily affected by salinity, including Mandovi river in Mapusa³².*

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3. STATUS OF WATER INFRASTRUCTURE AND SERVICES

ASHISH DANGI³³ AND NC NARAYANAN

This chapter provides a situational assessment of Mapusa's water sector, mapping the town's existing infrastructure from source to consumer. By analysing the systemic challenges along with emerging climate risks, the chapter uncovers the structural and environmental pressures that define the town's current water security landscape.

Mapusa, the largest town in Bardez taluka, is strategically located amidst a network of rivers, groundwater reserves, and coastal influences that shape its water availability. The town is flanked by the Mapusa River (also known as Moira) to the east, the Chapora River to the north, and the Arabian Sea approximately 6 km to the west ([Figure 10](#)).

Figure 10: Geographical setting of Mapusa Municipal council Area.



Image Source: Municipal boundary of Mapusa plotted in Google Earth

The Mapusa River, a tributary of the Mandovi River, plays a key role in the region's hydrology. Originating from the Dumacem and Anthane jungles, it flows eastward and then southward

before joining the Mandovi River at Penha de França. However, challenges such as heavy siltation, pollution, and hydrophyte overgrowth have impacted its water quality.

Hence, the town depends on the Assonora River, located about 13 km to the east, as a primary surface water source for municipal supply. Groundwater sources, including wells and borewells, also contribute marginally, but concerns such as illegal extraction, contamination, and seasonal scarcity remain pressing issues.

3.1 SURFACE WATER SOURCES

Mapusa relies on the Assonora water supply scheme for its water supply which draws water from multiple sources, including:

3.1.1 TILLARI IRRIGATION SCHEME

The Assonora Water treatment Plant intakes raw water from adjoining minor irrigation canal under this scheme. The Tillari Irrigation Project is a joint initiative between the Governments of Goa and Maharashtra, designed to enhance irrigation and water supply in North Goa and parts of Maharashtra. It is situated in the Tillari River Basin, covering Sawantwadi taluka (6,676 ha) in Sindhudurg district, Maharashtra, and Bicholim, Bardez, and Pernem talukas (16,970 ha) in Goa.

The project was initiated in the 1980s with an initial estimated cost of ₹217.22 crore, later revised to ₹1,390.04 crore. It includes:

- A main earthen dam and pickup weir, located in Maharashtra.
- An irrigation-cum-outlet power tunnel for water release.
- A large canal network, with the common stretch in Maharashtra and the Goa segment covering extensive distributaries.
- Provision for 57.43 MCM of water for domestic and industrial use in Goa, in addition to irrigation.

The cost-sharing ratio is 73.3% for Goa and 26.7% for Maharashtra, based on water utilisation.

The project has been instrumental in supporting agriculture, drinking water, and industrial use in North Goa. It has already created an irrigation potential of 5,741 hectares, with ongoing work on distributaries such as Revora I, Revora II, Siolim, and Tivim in Goa. Additionally, a Command Area Development (CAD) program has been implemented, with 1,043 ha of irrigated land developed under Water User Associations.

Challenges and Future Outlook

While the project has significantly improved water security, it faces challenges such as:

- Dependence on Maharashtra for upstream infrastructure and water releases.
- Delays in completing the remaining canal networks and distributaries in Goa.
- Climate risks such as droughts, erratic rainfall, and potential conflicts over water allocation.

Despite these challenges, the Tillari project remains a critical water source for Bardez, Bicholim, and Pernem, supporting both irrigation and urban water needs. However, sustainable management, climate adaptation strategies, and improved coordination between Goa and Maharashtra will be key to ensuring its long-term viability.

3.1.2 AMTHANE DAM

The Assonora WTP also intakes raw water from the Amathane dam using a 100 mm diameter pipeline. The Amthane Dam in Bardez Taluka is a crucial Minor Irrigation (M.I.) Tank that supports both agriculture and drinking water supply. Given Goa's undulating terrain, minor irrigation schemes like Amthane play a vital role in providing water for irrigation, enhancing groundwater recharge, and supporting rural water supply. Since the establishment of the WRD in 1980, minor irrigation coverage has expanded significantly, with Amthane contributing to this effort. Beyond irrigation, Amthane serves as a key raw water source for the Assonora WTP, which supplies potable water to Mapusa and surrounding areas. It supplements the Tillari Irrigation Scheme, ensuring a steady supply during peak demand. Maintaining Amthane's capacity through desiltation and climate resilience measures is essential for securing its long-term role in North Goa's water management.

3.1.3 ASSONORA RIVER

The Assonora River, a significant tributary of the Mandovi River, originates near Mencurem village in Bicholim Taluka and flows through Assonora and Sirsaim in North Goa's Bardez Taluka. Spanning a drainage area of approximately 55 sq. km, this river plays a vital role in the region's water supply and ecosystem balance. The Assonora WTP draws raw water from this river to supply drinking water to Mapusa and surrounding areas. Given its importance, the Goa State Pollution Control Board (GSPCB) monitors its water quality at designated locations ([Ref. Table 5](#)). However, like many rivers in Goa, it faces challenges such as siltation, pollution, and seasonal flow variations, necessitating sustainable management efforts to ensure its long-term viability as a reliable water source.

Table 5: Water quality of Assonora River

5.RIVER ASSANORA AT ASSANORA					
Sr.No.	Parameters	Feb-20	March - 20	April- 20	Limit for class C rivers as per CPCB classification based on designated best use of rivers
1	pH	6.9	6.5	6.7	6.0-9.0
2	Dissolved Oxygen mg/l	6.7	6.5	6.9	4 mg/l or more
3	BOD mg/l	BDL	BDL	BDL	3 mg/l or less
4	Total Coliform MPN/100ml	2200	1300	1300	5000 or less MPN/100ml
Remarks: All parameters are within permissible limits of Class C from February 2020-April 2020					

Source: National Mission for Clean Ganga (NMCG)³⁴

3.2 GROUNDWATER

Bardez Block, with Mapusa as its administrative headquarters, relies on a mix of semi-confined to confined aquifers predominantly found in schist formations (Ref. [Figure 11](#) and [Table 6](#)). The weathered zone varies in thickness from 10 to 40 meters, influencing groundwater recharge and availability. Depth to water level (DTWL) fluctuates across locations, while fractures are encountered at depths ranging from 20 to 100 meters, affecting groundwater movement and storage capacity.

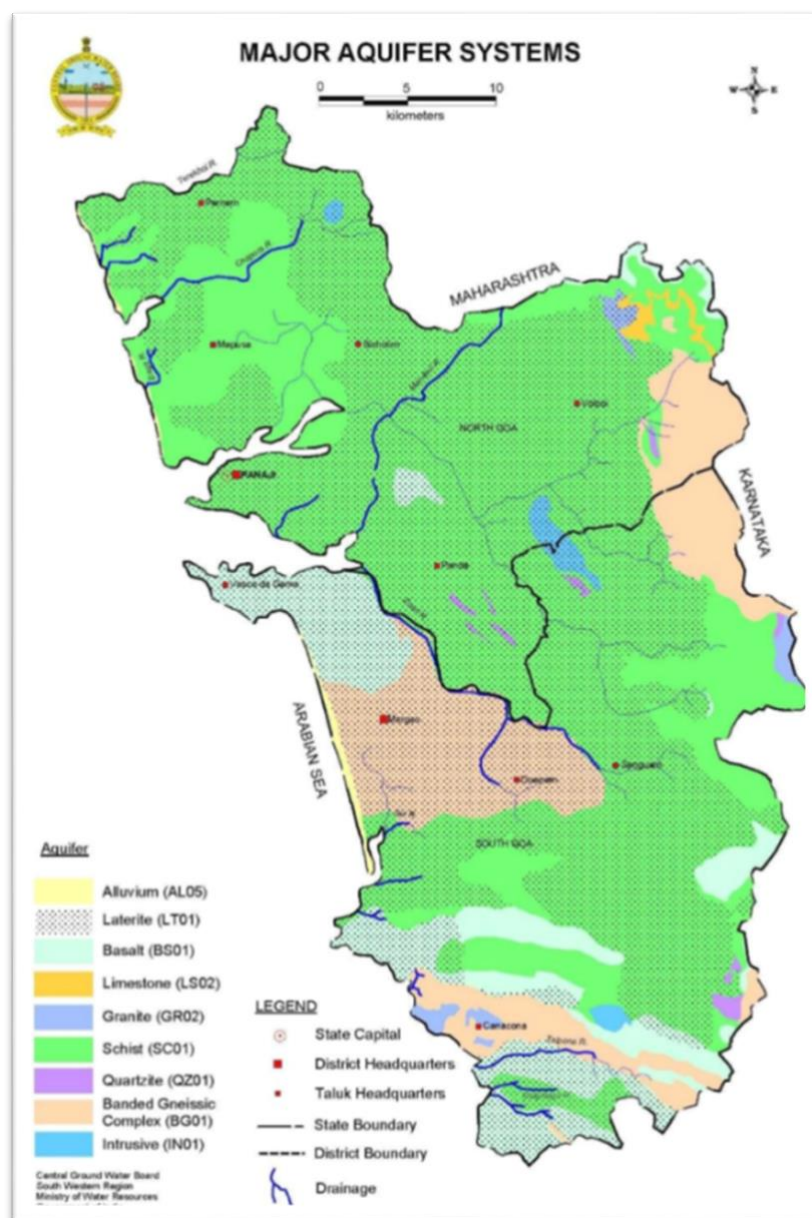
The aquifer exhibits transmissivity between 1 and 150 m²/day, which determines the ease of groundwater flow. Yield potential varies significantly, ranging from 10 to 500 m³/day, depending on local geological conditions and the degree of fracturing. The storage coefficient (S) ranges between 1×10^{-3} and 10^{-5} , indicating limited water retention in the fractured rock system. Water quality in Bardez Block is generally suitable for consumption, with electrical conductivity (EC) levels between 200 and 600 $\mu\text{S}/\text{cm}$. However, localized contamination risks, particularly in shallow aquifers, arise due to unregulated wastewater disposal and increasing urbanization.

Table 6: Characteristics of Aquifer Systems in Bardez block

Aquifer System	Type of Aquifer	Thickness of weathered zone (m)	DTWL (Decadal Average) (mbgl)	Fractures Encountered (mbgl)	Transmissivity (m ² /day)	Yield (m ³ /day)	S	Quality (EC in $\mu\text{S}/\text{cm}$)
Schist	Semi-confined / Confined	10-40		20-100	1-150	10-500	1×10^{-3} - 10^{-5}	200-600

Source: Central Ground Water Board³⁵

Figure 11: Principal aquifer systems in Goa.

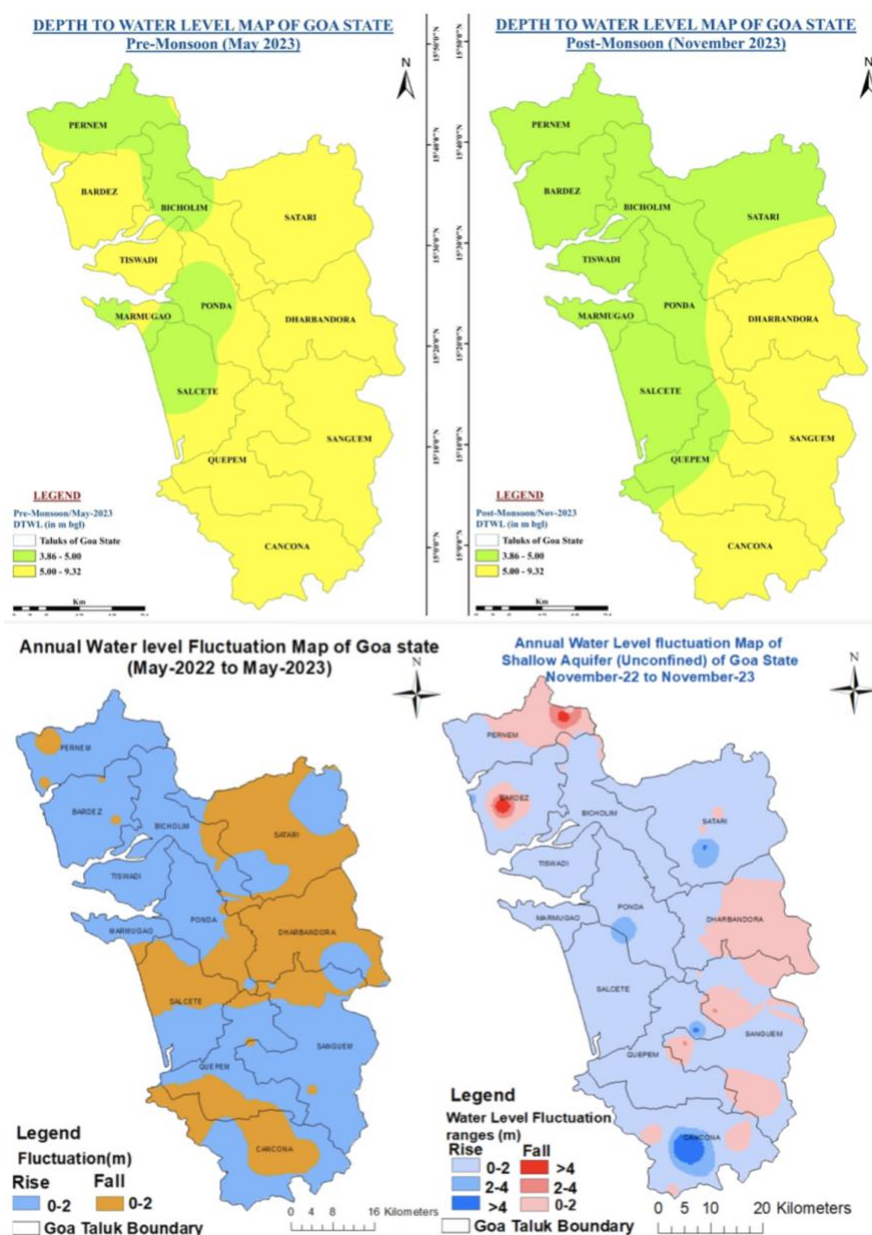


Source: Central Ground Water Board³⁵

Depth to Water Level: As per the Dynamic ground water Resources of Goa 2024 report³⁶, the pre monsoon depth to water level ranges between 5-9.32 m with most aquifer systems getting recharged during monsoon to a depth level ranging between 3.86-5 m. Groundwater level fluctuations in Mapusa's shallow aquifers reveal both seasonal variability and concerning

long-term trends. Between **May 2022 and May 2023 (pre-monsoon)**, water levels **rose by 0–2 meters**, indicating modest recharge likely aided by monsoon rainfall and possibly reduced extraction during the wet season. However, during the **post-monsoon period (November 2022 to November 2023)**, a **fall of 0–2 meters** was observed across most areas, with **localized declines exceeding 4 meters** in and around Mapusa (**Figure 12**).

Figure 12: Depth to Water Level and Groundwater Level Fluctuations (Shallow Aquifer) in Mapusa Block.

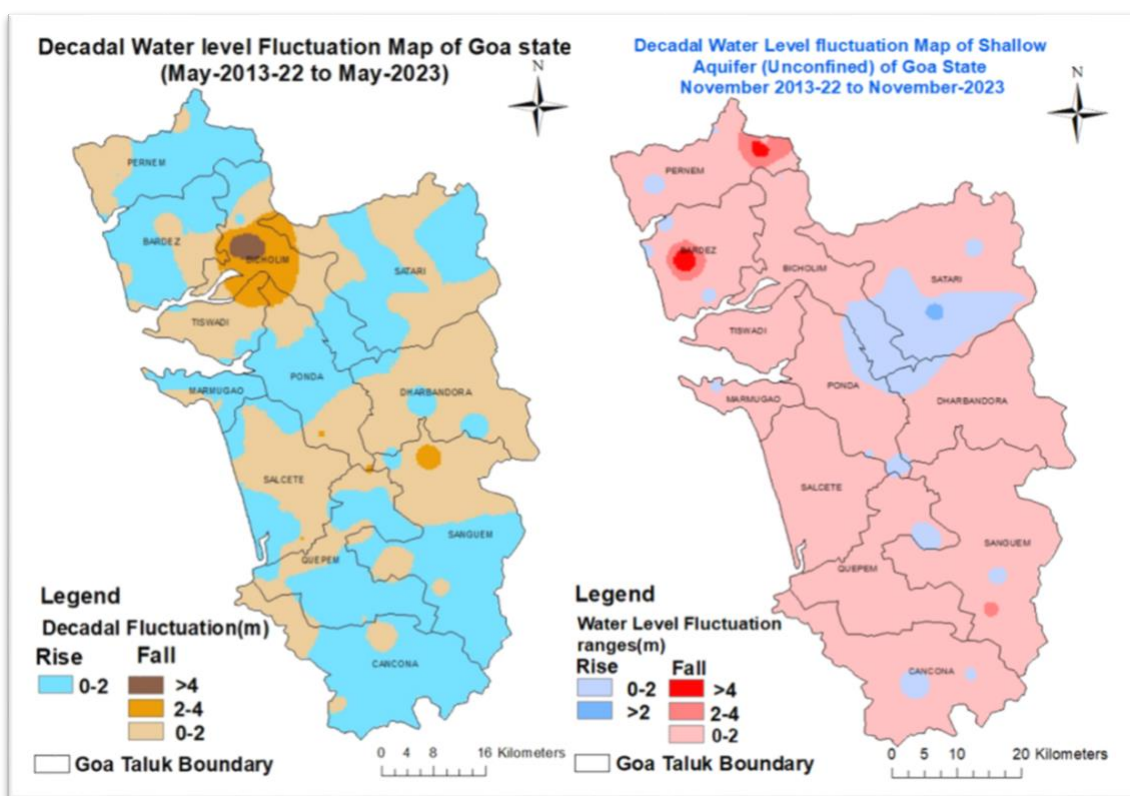


Source: Water Resource Department, Government of Goa & Central Ground Water Board³⁶.

A *decadal analysis (2013–2023)* paints a more nuanced picture (*figure 13*). While most of the Bardez block (in which Mapusa is located) experienced a *pre-monsoon rise of 0–2 meters*, the *eastern part* of the block showed signs of *localised groundwater decline*. Post-monsoon levels across the taluka also reflect a general fall of 0–2 meters, with some areas around Mapusa showing deeper drops, again exceeding 4 meters.

These patterns suggest **growing pressure on groundwater resources**, particularly in areas experiencing urban expansion, high borewell density, and limited natural recharge. The post-monsoon decline, in particular, raises concerns about the **increasing reliance on groundwater even during the recharge season**, possibly linked to intermittent surface water supply and expanding commercial use. Without improved monitoring, demand management, and recharge interventions, these trends could compromise the long-term sustainability of local aquifers.

Figure 13: Decadal water Level Fluctuations in Mapusa Block (Shallow Aquifer)

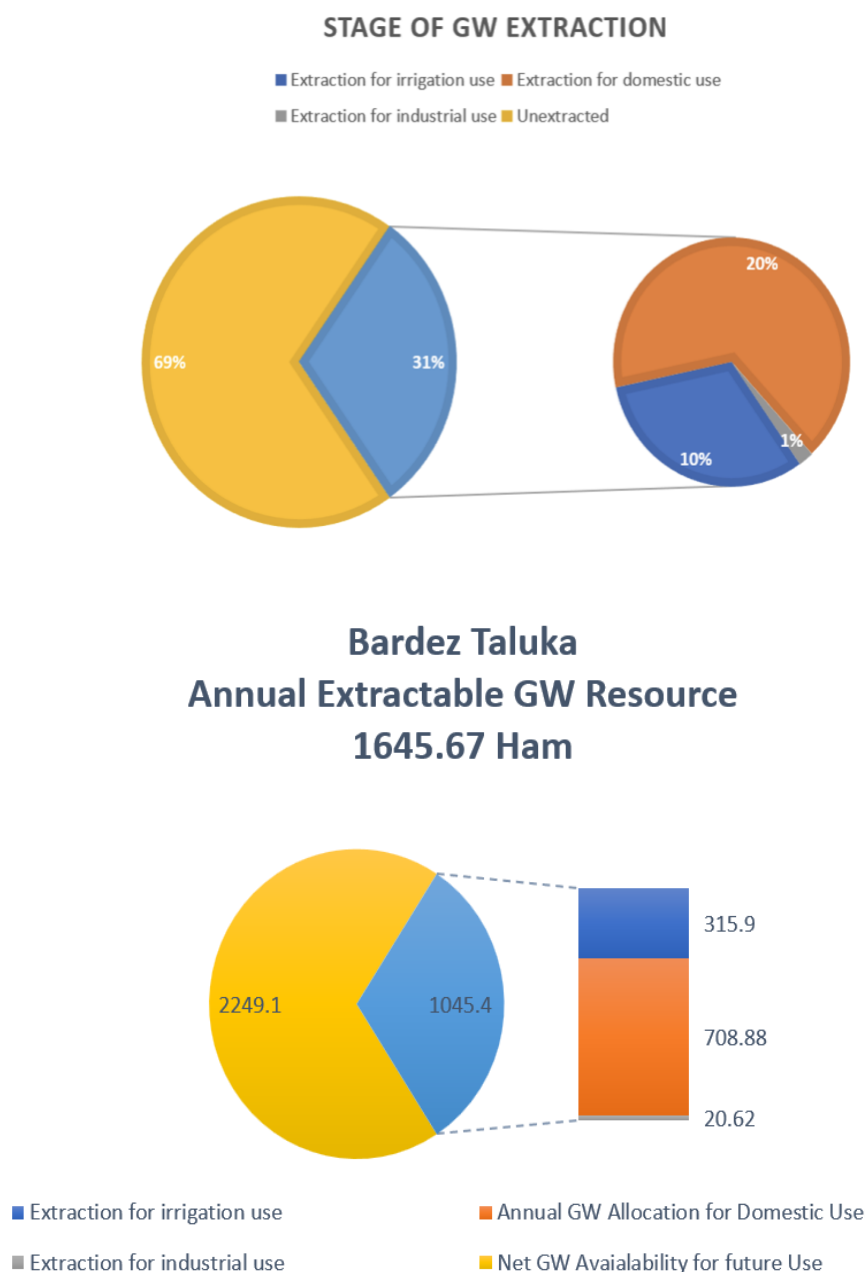


Source: Water Resource Department, Government of Goa & Central Ground Water Board³⁷.

Ground Water Resource Estimation for Mapusa Block: The Bardez Block has an annual extractable groundwater resource of 3,294.5 ham, with a total extraction of 1,004.25 ham, leading to a groundwater extraction stage of 31%, categorizing it as safe according to the

Dynamic Groundwater Resources of Goa (2022) Report (Ref. Figure 14). These figures highlight that while groundwater availability in Bardez remains within safe limits, rising domestic demand and irrigation requirements can pose sustainable challenges.

Figure 14: Ground Water Resource Assessment (2022) for Mapusa Block



Data Source: Water Resource Department, Government of Goa & Central Ground Water Board³⁷

3.3 WATER INFRASTRUCTURE

The **Assonora WTP** is one of the most critical water supply infrastructures in North Goa, supplying potable water to Mapusa, Siolim, Aldona, Saligao, Porvorim, Thivim, and parts of Bicholim taluka. The plant has a **total designed capacity of 92 million liters per day (MLD)**, divided among three treatment units: **12 MLD, 30 MLD, and 50 MLD** (See [Table 7](#) for details).

Raw Water Sources and Intake System

The Assonora WTP relies on multiple water sources to ensure an uninterrupted raw water supply:

- **Tillari Irrigation Scheme:** Water is sourced through a **1000 mm diameter DI pipeline**. This scheme plays a major role in supplying raw water to the WTP.
- **Amthane Dam:** Water is conveyed via **1000 mm and 500 mm DI pipelines**, serving as a supplementary source during peak demand periods or disruptions in the Tillari supply.
- **Assonora River:** Though not the primary source, the river serves as a local backup for emergency water supply requirements.

Water Treatment Process

Raw water from these sources undergoes a series of treatment processes at the Assonora WTP, including:

- **Coagulation and Flocculation:** Removal of suspended solids and particulate matter.
- **Sedimentation:** Allowing heavier particles to settle at the bottom.
- **Filtration:** Using rapid sand filters to eliminate finer impurities.
- **Disinfection:** Chlorination ensures the removal of pathogens before distribution.

Treated Water Transmission and Distribution

Once treated, potable water is transmitted through a **complex network of pumping stations and pipelines** to various parts of North Goa, including Mapusa. The key transmission mains include:

- **900 mm DI pipe** – Used for transmitting water from the 12 MLD and 30 MLD units.
- **600 mm DI pipe** – Serves as a transmission main for the 30 MLD unit.
- **400 mm DI pipe** – Connected to the 12 MLD unit for localized supply.
- **800 mm MS pipe** – Dedicated to the 50 MLD unit, facilitating bulk transmission.

Pumping Infrastructure

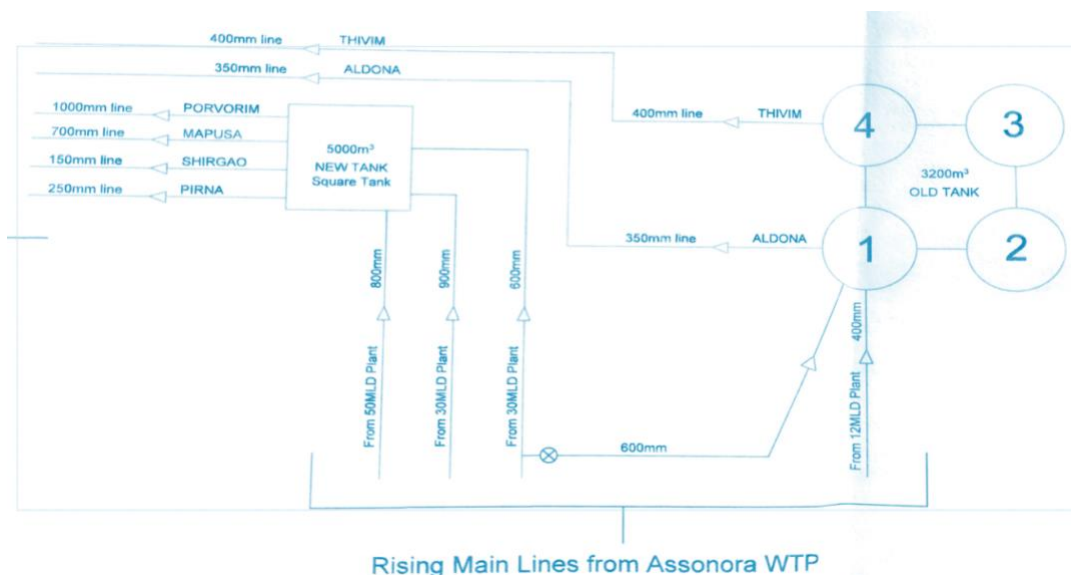
The treated water is stored in a **Master Balancing Reservoir (MBR)** (Figure 15) before being pumped to the distribution system. A new **30 MLD pumping main** is planned, which will connect to the existing **900 mm raising main** to enhance supply flexibility and reliability.

Table 7: Overview of the Water treatment units at Assonora plant

Overview of 12 MLD Plant Commissioned 1967		Overview of 30 MLD Plant – Commissioned 1994		Overview of 50 MLD Plant- Commissioned 2012	
Components	Description/Condition	Components	Description/Condition	Components	Description/Condition
Filter Beds	4 no's / Good Condition Filter media replaced in 2014	Filter Beds	6 no's / unsatisfactory Filter media replaced in 2018	Filter Beds	4 no's / Good Condition Filter media replaced in 2014
Aerator	Good Condition	Aerator	Good Condition	Aerator	Good Condition
Treated water Elevation pumps	3 Installed , 2 operate 24/7 / Good condition	Treated water Elevation pumps	4 Installed , 3 operate 24/7 / Good condition	Treated water Elevation pumps	3 Installed , 2 operate 24/7 / Good condition
Clear Water Sump	1200m ³ / Unsatisfactory state	Clear Water Sump	6200 m ³ (1200+1500+3500)/ Unsatisfactory (1200)	Clear Water Sump	1200m ³ / Unsatisfactory state
Raw water Pumps	3 installed , 2 operable simultaneously / Good condition	Clariflocculator	1 nos of 48 m dia / Good condition	Raw water Pumps	3 installed , 2 operable simultaneously / Good condition
Clariflocculator	1 nos of 32 m dia / Good condition	Clariflocculator Bridge	1 nos / Good Condition	Clariflocculator	1 nos of 32 m dia / Good condition
Clariflocculator Bridge	1 nos / Good Condition			Clariflocculator Bridge	1 nos / Good Condition

Data Source: Public Works Department, Works Division – XVII

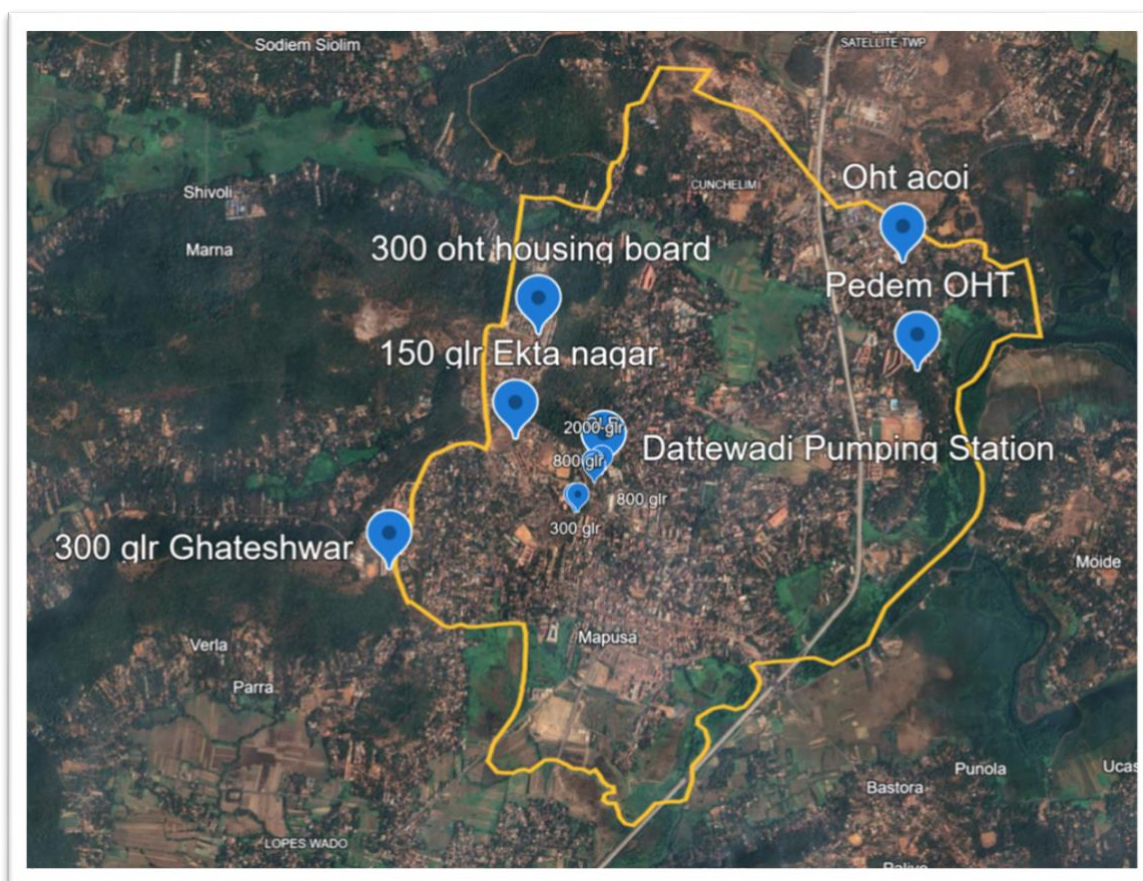
Figure 15: Schematic of Water Supply from Assonora WTP



Data Source: Public Works Department, Works Division – XVII

Distribution system: The distribution system for Mapusa and surrounding areas operates through a network of Ground Level Storage Reservoirs (GLSRs) and Elevated Level Storage Reservoir (ESLR) as shown in *figure 16*, which act as intermediate storage and pressure-balancing structures. Water from the main transmission pipelines is tapped into the two GLRs at Dantewadi pumping station, and from there on it is pumped to the GLRs and OHRs around Mapusa town.

Figure 16: Mapusa's Water distribution network components



Data Source: Site Visits by author.

3.4 WATER DEMAND & SUPPLY

Mapusa Municipal Council (MMC) has a population of 39989 spread across 9466 households as per census 2011. In the absence of recent census data, we use standard population projection methods to estimate current population and consequently, the water demand. The estimated water demand based on projected population (Annexure-III) for the town is shown in *Table 8*.

Table 8 : Population Projections

	2025	2031	2041	2051
Estimated Population**	43743	44505	44766	43803
Domestic Demand ¹	5.9	6.0	6.0	5.9
Floating Population Demand ²	0.20	0.20	0.20	0.20
Commercial Demand ³	0.59	0.63	0.69	0.76
Institutional Demand ⁴	0.59	0.59	0.59	0.59
Fire Demand ⁵	0.02	0.02	0.02	0.02
Total Demand (MLD)	7.3	7.4	7.5	7.5

¹Estimated at 135 liters per capita / day (lpcd)
²Floating population assumed to be 10 % of population and demand estimated @ 45 lpcd.
³Commercial demand estimated @ 10 % of domestic demand growing @1% / year as per CPHEEO (2024)
⁴Water demand by institutions estimated @ 10 % of domestic demand.
⁵Fire demand = $100 \sqrt{P}$ m³ /day where P is the population. (CPHEEO 2024)

****** While we maintain strong reservations about the capacity of static models to capture the highly fluid realities of coastal growth, we employ this averaged methodology primarily out of pragmatic necessity: it is the established industry standard for Detailed Project Reports (DPRs) for WaSH projects, ensuring our analysis remains interoperable with existing municipal frameworks and policy planning.

The water demand is primarily met through tap water connections serviced by PWD. As per the water supply connection data provided by PWD Sub-division II (Div XII) there are a total 14509 connections in the Mapusa water supply zones. However, the water supply zones extend beyond the municipal boundary of Mapusa council and hence it is not possible to estimate the percentage coverage of water supply based on available data. The details of water connections in Mapusa zone are shown below in *Table 9*.

Table 9 : Water Connections in Mapusa

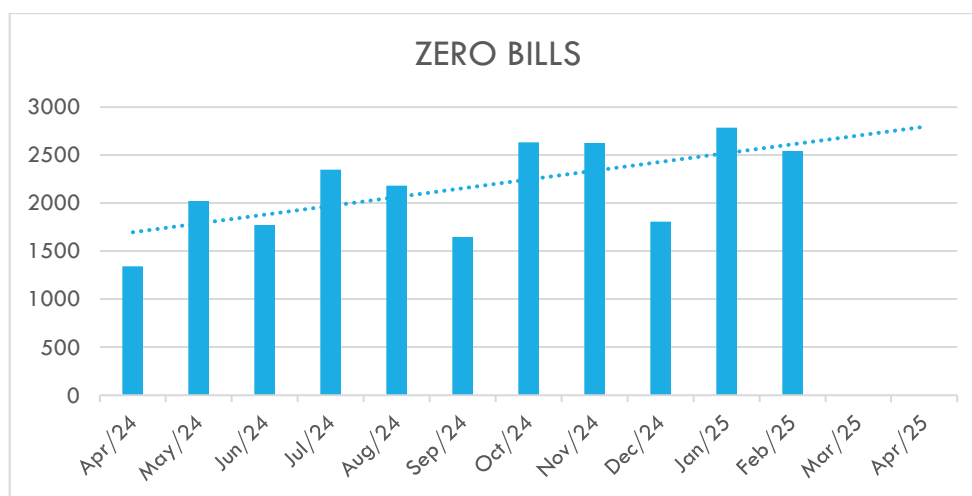
ZONE	DOMESTIC	COMMERCIAL	GOVERNMENT	MUNICIPALITY(MC)	TOTAL
MPA	1489	8	1	0	1498
MPB	1435	30	4	6	1475
MPC	1351	187	13	2	1553
MPD	1494	58	7	2	1561
MPE	2686	46	9	0	2741
MPF	1826	23	2	0	1851
MPU	2125	30	4	0	2159
MP5	1457	11	6	0	1474
MP3	646	4	1	0	651
Total	14509	397.00	47.00	10.00	14963

Source: PWD Sub-division II (Div XII)

In September 2021, the Government of Goa introduced the "Save Water to Get Free Water" initiative, allowing households to receive up to 16,000 liters of free water per month. This policy aimed to promote water conservation while reducing the financial burden on residents.

Since the implementation of this scheme, there has been a noticeable increase in the number of zero-metered connections, reflecting a rising trend in households receiving zero water bills (*Figure 17*). This trend suggests that a significant portion of consumers are managing their water usage within the free allowance, potentially indicating improved water conservation practices.

Figure 17: Trend in zero bills issued in the Mapusa zone



Source: by PWD Sub-division II (Div XII)

3.5 CLIMATE RISKS AND CHALLENGES

Mapusa's urban water system is increasingly vulnerable to a complex interplay of climate variability, ageing infrastructure, rising water demand, and emissions intensity, especially due to its dependence on centralized surface water systems. These risks not only affect source sustainability but also undermine the resilience and equity of water service delivery in the region.

Source Vulnerability and Climate Sensitivity

The town's heavy reliance on surface water sourced from the Tillari Irrigation Project, Amthane Dam, and Assonora River exposes it to hydro-climatic risks such as droughts, erratic rainfall, and pollution events. All three sources face challenges of siltation, reduced flow during lean seasons, and deteriorating water quality. With no significant source diversification, Mapusa remains dependent on long-distance water transfers and inter-state coordination, particularly with Maharashtra, adding governance-related risks to physical vulnerabilities. Meanwhile, groundwater resources, although classified as "safe" at the Bardez block level, are showing localized depletion and contamination, particularly due to increasing borewell use in peri-urban areas, inadequate recharge, and poor wastewater management.

Groundwater is vital yet poorly monitored

Groundwater is not the primary engineered source but it is becoming the critical buffer during summer scarcity, service interruptions, and droughts. Yet it remains absent from urban water

planning and is poorly mapped and monitored only at the block level despite the increasing vulnerability to salinity intrusions and contamination.

Groundwater is not a replacement for surface water but without it, cities will face higher costs, higher emissions, more inequalities in access and lesser overall resilience to climate change.

Overburdened System and Infrastructure Gaps

Mapusa's water supply network is overstretched, operating close to or beyond its design capacity. While expansion plans exist, delays in approvals and implementation aggravate water stress, especially during peak demand periods. The undulating terrain compounds this issue, making gravity-based distribution inequitable; elevated localities frequently suffer from low pressure or intermittent supply, deepening intra-city disparities.

Ageing Infrastructure and Water Losses

The network suffers from ageing pipes, pumps, and valves, contributing to frequent breakdowns and high levels of NRW. A large volume of treated water is lost before it reaches users, wasting energy and straining sources, particularly damaging in a climate-stressed context where every drop counts.

Power Dependency and Interruption Risks

The system's heavy reliance on pumped conveyance makes it highly vulnerable to power outages and grid instability, both of which are expected to intensify under future climate scenarios. This reliance creates bottlenecks and disruptions, particularly affecting vulnerable and remote areas.

Water Quality and Contamination Concerns

Pollution of raw water sources, especially the Assonora River, poses risks of untreated sewage, industrial discharge, and urban runoff entering the system. This increases treatment burden, costs, and the potential for health hazards. Combined with poor sanitation infrastructure in some parts of Bardez, there is also a risk of groundwater contamination, especially in shallow aquifers.

Competing Demands and Tourism Pressures

The seasonal influx of tourism hub of North Goa strains the existing network, often prioritizing commercial and hospitality sectors over local residents. This competition for resources poses a long-term threat to water security.

NOTES & REFERENCES

³³Author's Note: This chapter is based on ongoing doctoral research by Ashish Dangi under the supervision of Prof. N. C. Narayanan at the Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Key findings and interpretations presented here are part of a broader analysis that is currently being prepared for publication in a peer-reviewed academic journal. Readers are requested to cite this report appropriately and direct any academic queries to the author.

³⁴Excerpt from Monthly Progress Report by States / UTs' for the month ending May 2020 under the National Mission for Clean Ganga (NMCG)
https://nmcg.nic.in/writereaddata/fileupload/ngtmpr/17_Goa%20MPR%20May%202020.pdf

³⁵Aquifer Systems of Goa, Sep 2013. Central Ground Water Board, Ministry of water Resources , Government of India, South West Region, Bangalore. Accessed on June 25, 2025,https://www.cgwb.gov.in/old_website/AQM/Goa.pdf

³⁶DYNAMIC GROUNDWATER RESOURCES OF GOA – 2024. (MARCH 2025). Water Resource Department Government of Goa & Central Ground Water Board, South Western Region, Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti, Government of India. Accessed on June 25 2025.

<https://www.cgwb.gov.in/cgwbpm/public/uploads/documents/174823987024232641file.pdf>

4. URBAN SANITATION SYSTEMS IN MAPUSA: STATUS, INSTITUTIONS AND CHALLENGES

NEELAM RANA, PRIYAKSHI GOGOI, NC NARAYANAN

Assessing the state of sanitation services is critical for identifying infrastructure gaps, service-related vulnerabilities, and climate-related risks, and for informing adaptive, resource-efficient, and low-carbon development strategies. This assessment also involves mapping institutional arrangements to clarify the roles of Urban Local Bodies (ULBs), their interactions across governance levels, and the interdependencies among key stakeholders. This chapter addresses these objectives through a detailed case study of Mapusa, drawing primarily on secondary data supplemented by semi-structured interviews with ULB officials, district disaster management officers, and residents to validate findings and address data gaps. The chapter examines the sanitation service chain and reviews the institutional framework governing sanitation services, and concludes by identifying key challenges and opportunities for strengthening sanitation infrastructure, service delivery, and governance.

4.1 BACKGROUND

Climate risks are significantly exacerbated by inadequate infrastructure in critical, interlinked sectors such as water and sanitation which disproportionately affecting socio-economically disadvantaged communities^{37,38,39}. *Climate change-induced water stress and insecurity have been linked to a rise in waterborne infectious diseases, threatening to reverse progress toward the SDGs and exacerbating existing social and health inequities*⁴⁰. WaSH services are essential for preventing disease outbreaks, particularly in the aftermath of climate hazards such as heavy rainfall and flooding^{41, 42}. In this context, *ensuring access to safe, reliable water, sanitation, and hygiene services* is widely recognized as a *low-regret adaptation measure*—offering substantial benefits *regardless of the severity of future climate scena*⁴³. The IPCC highlights *universal access to WaSH*—specifically the achievement of SDG targets 6.1 and 6.2—as a *high-confidence adaptation strategy*, underscoring its central role⁴⁴.

India has only one national-level policy dedicated to urban sanitation—the National Urban Sanitation Policy (NUSP), introduced in 2008. The policy defines sanitation as the 'safe management of human excreta, including its safe confinement, treatment, disposal, and associated hygiene-related practices⁴⁵. In the context of climate change, the policy links sanitation to GHG emissions and advocates the adoption of low-energy solutions, such as

decentralized or onsite wastewater treatment technologies and distributed utilities. City Sanitation Plans (CSPs) are expected to incorporate these concerns, including the impacts of climate change, diminishing water resources, and the need for energy-efficient infrastructure (ibid).

Although sanitation is not explicitly identified as a focus area in India's *National Action Plan on Climate Change (NAPCC)*, it is closely linked to climate action through missions on water, sustainable habitats, and energy. The *National Water Mission (NWM)* emphasizes water conservation and efficiency—critical for sustainable sanitation systems, especially in water-stressed urban areas. The *National Mission on Sustainable Habitat (NMSH)* more directly addresses sanitation-related concerns, including urban waste management, wastewater recycling, and climate-resilient infrastructure, thereby contributing to both mitigation and adaptation objectives. Sanitation is also aligned with the NAPCC's broader emphasis on *energy efficiency and GHG emission reduction*, as centralized wastewater treatment plants are significant sources of methane and nitrous oxide. Innovations such as *waste-to-energy systems and resource recovery from faecal sludge* further support this agenda. Additionally, *State Action Plans on Climate Change (SAPCCs)*—developed in line with the NAPCC—are increasingly acknowledging sanitation as a key sector for climate intervention, particularly in climate-vulnerable regions. Though the NAPCC predates the *SDGs*, it has gradually evolved to align with global frameworks. National programs such as *SBM and AMRUT* have also begun integrating climate resilience and sustainability into urban sanitation planning and implementation.

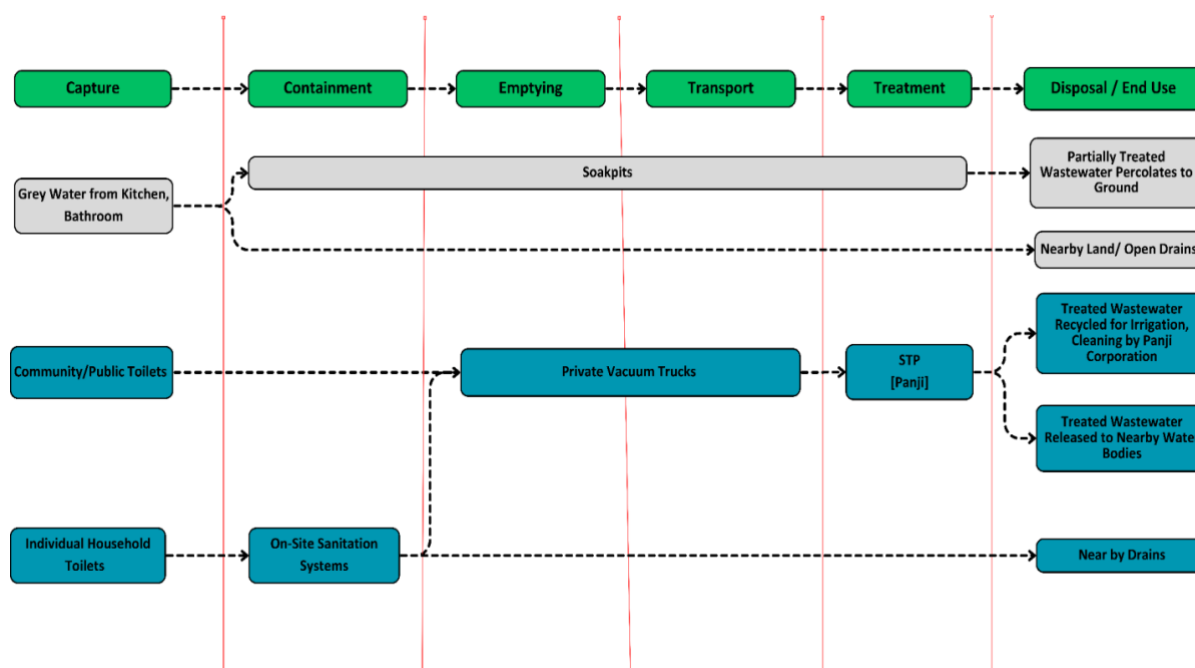
Hence, assessing the current state of sanitation services is essential for identifying infrastructure gaps, vulnerabilities, and climate-related risks. Such an assessment supports the design of proactive adaptation measures, promotes efficient resource use, and enables low-carbon development strategies. A critical component of this process is mapping existing institutional arrangements—clarifying responsibilities, particularly the role of ULB, their engagement across different governance levels, and the interdependencies among key stakeholders. This chapter seeks to address these objectives through a detailed case study of *Mapusa*. Data collection was primarily conducted through secondary sources, supplemented by primary data gathered via semi-structured interviews with ULB officials, district disaster management officers, and residents. These interviews helped fill information gaps and validate secondary data.

The chapter is organized into the following sections: Section two discusses the sanitation service chain, covering all critical stages—toilet access, containment, transportation, treatment, and final disposal or end-use. *Section three* reviews the institutional framework, detailing the roles and responsibilities of various stakeholders involved in sanitation governance. *The final section* concludes the chapter by highlighting key challenges and opportunities for improving sanitation infrastructure, service delivery, and governance.

4.2 SANITATION SERVICE CHAIN

Human waste must be safely managed throughout the entire sanitation service chain, which may have different stages, including capture, containment, emptying, transport, treatment, and disposal or end use⁴⁶. This section outlines the service chain and identifies the key gaps. The entire service chain is depicted in *Figure 18*.

Figure 18 : Sanitation Service Chain in Mapusa



Source: Authors' Analysis and Illustration

- **Capture:** This includes toilets (individual household level, community, public). The primary function of a toilet is to capture excreta while effectively separating people from the waste to ensure safety and hygiene.
 - **Toilets:** According to the 2011 census, of the 9,466 households, 2,647 lacked individual toilets. However, as of the latest data obtained from the SBM-U City coordinator, all households in the city now totalling 11,722 are equipped with individual toilets, complete with septic tanks and soak pits. The town has been

declared Open Defecation Free Plus (ODF+), which aligns with the SLB of Government of India and the Sustainable Development Goal target (6.2).

- Community Toilets (CT) and Public Toilets (PT)⁴⁷: As per the information obtained from the Mapusa Municipal Council, currently, the town has six fully functional community toilets, which are maintained by the ULB. Additionally, there are two functional and one under-construction public toilets that operate on a user-fee model, maintained by non-profit organizations. These CT and PT have 24x7 water supply connection according to the SLB 2020-21 data received from the municipal council. However, according to the SBM-Urban Dashboard, the town of Mapusa has 9 CTs and 19 PTs⁴⁸.
- **Containment:** According to data obtained from the municipal council and Sewerage and Infrastructural Development Corporation of Goa Limited (SIDCGL), *nearly 100% of households (HH) rely on OSS systems, specifically septic tanks with soak pits*, to safely contain faecal waste.
- **Emptying and Transport:** The town has recently developed a sewerage network spanning approximately 38.3 kilometers. However, PWD officials stated that the first monsoon season the sewerage network encountered led to an overflow, revealing need of technical improvement within the system. Since then, the operation of the sewage lines in that particular area has been delayed. Currently, the city depends on private desludging trucks to transport septage from residential areas and public toilets to the Corporation of the City of Panaji (CCP) STPs.
The city has achieved 90% coverage of stormwater drainage systems, according to the Service Level Benchmarks for 2020-2021. However, the town continues to experience drainage problems during the monsoon season. For instance, the rains of 2022 led to flooding in Wards 16, 17, and 18.
- **Treatment:** In Mapusa, a STP with an installed capacity of 5.4 MLD has been constructed, but it remains non-operational due to the sewerage network being incomplete and no households being connected (Field visit dated Feb 2025). To address this issue, an arrangement has been made allowing the Mapusa Municipal Council to transport and treat its sewage at the nearest operational STP in Panaji, using private vacuum trucks. Panaji has two SBR plants, with capacities of 1.5 MLD and 12.5 MLD, respectively. Field observations have revealed that greywater from residential kitchens and bathrooms is being discharged into nearby drains and soak pits.

- **End-use Disposal (Septage and Sludge Management)**⁴⁹: *The city does not have a Faecal Sludge and Septage Management facility (FSSTP).* The septage is currently collected and transported by private vacuum trucks from different types of properties (residential, commercial, institutional) to the STP in Panaji.
- **Recycling and Reuse**: A portion of the treated wastewater is utilized for maintaining green spaces in Panaji, for that Panaji city has a dedicated pipeline system. It is also used for road cleaning purposes. The remaining treated water is discharged into the nearby water body (River Mandovi) as per the information obtained from the SIDCGL.

4.3 INSTITUTIONAL ARRANGEMENTS

This section examines the institutional arrangements, outlining the various departments, agencies, and organizations, along with their respective roles in delivering sanitation infrastructure and services (*Ref. Table 10*). It also emphasizes the role of the urban local body in disaster governance.

Sanitation is a state subject, and under the 74th Constitutional Amendment Act, ULBs are primarily responsible for delivering water supply and sanitation services. However, in practice, we observed a multi-stakeholder, multi-level governance framework involved in the provision of sanitation infrastructure and services.

The town has unique institutional arrangements *for sanitation infrastructure and service provision, involving various departments at both the city and state levels*, Special Purpose Vehicle (SPV) and as well as inter-city collaborations. This includes the dominance of SPVs, state-level departments such as PWD and SIDCGL, alongside central and state government involvement.

At the household level, while toilets and OSS are primarily the responsibility of property owners, the municipal council and the Planning and Development Authority (PDA) as part of the building plan approval process. Household toilet designs must be approved as part of the technical sanctions under the Goa (Regulation of Land Development and Building Construction) Act, 2008, by the PDA. Upon receiving approval from the PDA, the ULB issues a construction license. After construction is completed, the PDA conducts an inspection and issues a completion certificate. Finally, the ULB grants an occupancy license, provided all regulations are met, including the installation of scientifically designed toilets. If individuals fail to comply with the Act's provisions, such as not meeting sanitation standards, the ULB has the authority to revoke the occupancy license. This enforcement mechanism ensures that development adheres to public health and safety standards. For sludge management, households may opt to rely on the services of ULB's vacuum trucks at a certain fee. At the ULB level, smaller sanitation

interventions like CT and public toilets PT are primarily the ULB's responsibility, with independent decision-making power in key areas such as land selection, technology choice, O&M, and funding. For septage management, ULB primarily relies upon the private vehicles.

Table 10 : Institutional Arrangements in Sanitation Services

Intervention	Technology Selection	Land	Capital	Technology Provision	Technology implementation	O&M	O&M Funding
Toilets	HH	HH	HH	HH	HH	HH	HH
OSS	HH	HH	HH	Local mesons/private vendors	Local mesons/private vendors	HH Septage removal by Private vehicles	HH
CT	ULB	ULB	State government fund	ULB	ULB	ULB	ULB own revenue
PT	ULB	ULB	SBM 1.0 State government fund	ULB	ULB	Non-government organisation	User Fee (Pay and use)
Sewerage Network	SPV	State	International Agency in ODA	SPV	SPV	PWD	Yet to be commissioned
STP	SPV	PWD	International Agency in ODA	SPV	SPV	PWD	Yet to be commissioned

Source: (Rana, Gogoi, & Narayanan, Forthcoming)⁵⁰

Large and critical sanitation infrastructure, such as sewerage systems and STPs, sees a significant role by the SPV, led by a retired PWD engineer, particularly in the technology selection, approval, and implementation stages. At the state level, SIDCGL plays a primary role in providing sewerage connections to households. Meanwhile, the capital for current infrastructure is provided by an international agency through Official Development Assistance (ODA), and the PWD is responsible for the O&M of this infrastructure. The ULB is largely

excluded from this process. In fact, during our meeting with them, they were unaware of both the financial and information flows.

4.4 CHALLENGES AND OPPORTUNITIES IN SANITATION INFRASTRUCTURE AND SERVICES

The town is not fully meeting several of the SLB norms set by the Government of India. The challenges outlined below are key barriers to achieving the required service levels, but they also present valuable opportunities in provision of equitable and affordable sanitation services to all.

- **Infrastructure Challenges:** The town faces challenges with its sanitation infrastructure, particularly the absence of a fully functioning sewage treatment plant and sewerage network system, largely due to significant technical issues during monsoon seasons, such as flooding in certain areas. The inefficient drainage system and sewerage network has resulted in poor drainage and frequent sewage overflows, which have become a persistent issue in Mapusa. Timely resolution of these challenges will not only safeguard investments but also enhance the town's ability to adapt to climate change. Improved sewage management and service delivery will bolster resilience, public health, enabling the town to better cope with extreme weather events and growing environmental pressures. In such situations, the council could explore flood-resilient solutions to further enhance the town's infrastructure. Hence, climate-proofing future infrastructure is essential, making it an integral part of the infrastructure planning. This approach is also emphasized as a key measure for climate resilience and adaptation in the Goa State Climate Change Action Plan-2023.
- **Dependence on Private Operators for Septage Management and Affordability Concerns:** Due to the absence of its own desludging vacuum trucks or FSSTP, the city currently relies on private operators. While this arrangement provides a practical solution, investing in local capacity and infrastructure is key to moving toward greater self-reliance in septage management. Additionally, such dependence raises affordability concerns, particularly as the municipal council has no control over service charges, which can range from INR 6,000 to INR 10,000 per cleaning. Ensuring effective regulation is essential to maintain affordability for residents, uphold best practices, and support long-term sustainability.
- **Inadequate Devolution of Administrative and Financial Powers to Municipal Council:** The study highlights a multi-stakeholder, multi-governance framework with limited devolution of administrative and financial powers to ULBs in areas such as sanitation infrastructure and services, as outlined in the 74th CAA. *Sanitation governance is*

primarily led by the SPV and state-level institutions, overseeing key aspects such as technology approval, selection, implementation, and capital provision for large-scale infrastructure projects. The exclusion of the ULB from this process has left them unaware of both the information regarding access to services and the relevant financial data. These findings align with the CAG Report-2024⁵¹. Enhancing devolution would empower municipal councils, fostering greater participatory governance and clearer accountability. By taking an active role in the planning, implementation, and operation & maintenance (O&M) of sanitation infrastructure, ULBs can better utilize their grassroots knowledge to create tailored, context-specific solutions. *Furthermore, exclusion from sanitation responsibilities also prevents ULBs from accessing crucial revenue streams, such as user fees, which are vital for the long-term sustainability of services.* This fragmented institutional framework limits the ability of ULBs to manage resources efficiently and address local needs effectively. As highlighted in the CAG report, the state government must take proactive measures to ensure the effective devolution of administrative power, funds, and functions to ULBs, in alignment with the provisions of the 74th CAA.

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- ⁴⁷ As per SBM guidelines “Public Toilets are toilets which are provided for the floating population/ general public in places such as markets, train stations, tourist places, near office complexes, or other public areas where there are a considerable number of people passing by. PTs are to be accessible to one and all and well-connected to important areas and pedestrian junctions. Community Toilets are the shared facilities provided by and for a group of residents or an entire settlement. CT facilities are used primarily in low-income and/or informal settlements / slums, where space and/or

land are constraints in providing individual household toilet. These are for a more or less a fixed user group.” (CPHEEO, 2018, p. 1)

⁴⁸Ministry of Housing and Urban Affairs. (2025). SBM-Urban Dashboard. Retrieved March 2025, from SBM Mission Progress: <https://sbmurban.org/swachh-bharat-mission-progess>

⁴⁹“Faecal Sludge is raw or partially digested, in a slurry or semisolid form, the collection, storage or treatment of combinations of excreta and black water, with or without grey water. It is the solid or settled contents of pit latrines and septic tanks” (NFSSM, 2017, p9). “Septage is the liquid and solid material that is pumped from a septic tank, cesspool, or such onsite treatment facility after it has accumulated over a period of time”. Septage is the combination of scum, sludge, and liquid that accumulates in septic tanks” (ibid).

⁵⁰Rana, Neelam; Gogoi, Priyakshi& Narayanan, N. (forthcoming). Sanitation Governance in Small and Medium Towns in India. Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Mumbai, Maharashtra. India

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5. CLIMATE IMPACTS OF WATER & SANITATION SYSTEMS

ASHISH DANGI⁵² AND NC NARAYANAN

This chapter focusses on the climate impacts of the water and sanitation systems, i.e., the greenhouse gas (GHG) emissions throughout the service chain. By estimating stage-wise energy consumption and GHG emissions, our assessment provides baseline evidence for planning climate mitigation strategies in the WaSH sector.

5.1 BACKGROUND

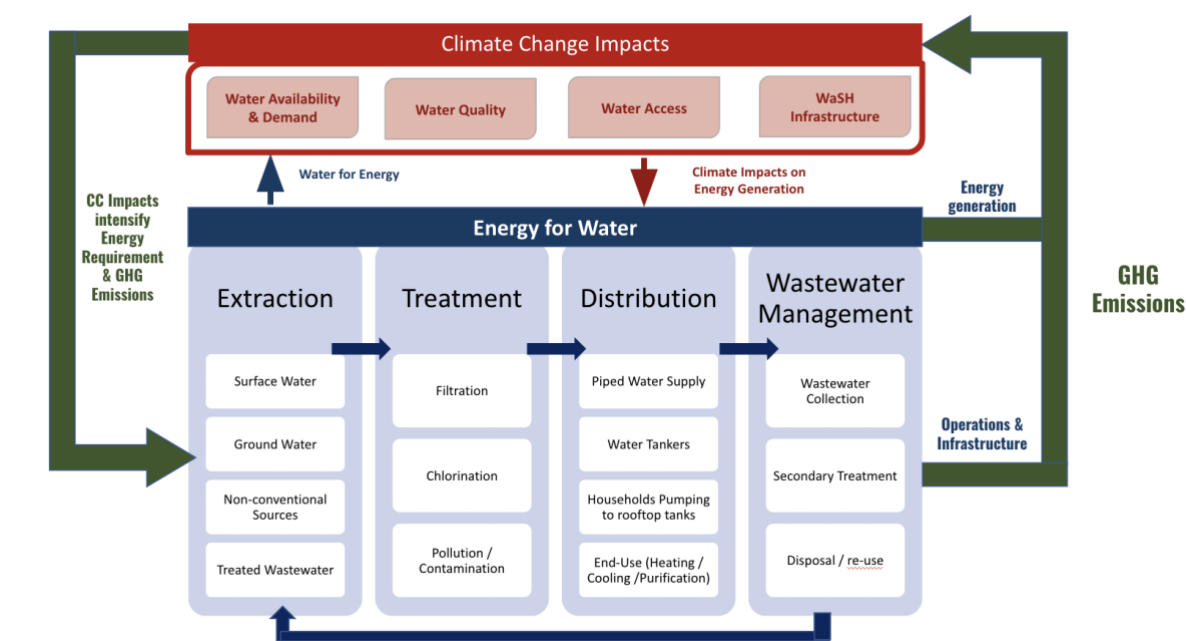
Globally, the water and sanitation systems are increasingly recognised not only as climate victims, but also significant contributors to climate change as the GHG emissions from WaSH continue to grow. Energy is the key input to every step in an urban water cycle right from water extraction to conveyance, treatment, distribution, and end-use; as well as for wastewater collection, conveyance, treatment, and re-use. This energy use further translates into GHG emissions associated with energy generation. Water sector which includes the collection and treatment of wastewater, accounts for *4% of total global electricity consumption and around 3% of global greenhouse gas emissions*⁵³. According to another estimate, wastewater treatment plants alone are estimated to account for 3% global electricity consumption⁵⁴. Additionally, biological degradation of the organic matter present in sewage and grey water across the containment, transport, treatment and discharge pathways in a sanitation service chain results in direct methane (CH₄) and nitrous oxide (N₂O) emissions⁵⁵. *Direct emissions in wastewater treatment are estimated to be significant at ~1.57% of global GHG emissions*⁵⁶.

Climate change impacts on water availability, quality, and access as well as on wastewater and stormwater management, are going to *further exacerbate the scenario* by directly increasing the energy and carbon intensity of the water cycle. Additional water demand by cities is often met by higher energy use in the water cycle⁵⁷. For instance, between 2005 and 2015, while Beijing's water supply increased by only 10%, the energy consumption associated with water supply surged by 215%⁵⁸. In fact, *Water sector's electricity consumption is projected to significantly increase* with rising scarcity and could rise to as high as 16% of total energy consumption for countries faced with severe water scarcity such as those in Middle East⁵⁹. With the rise in sewage generation and treatment capacity, *the energy and carbon footprint of wastewater is likely to increase dramatically in the near future* in the absence of interventions. For example, domestic wastewater emissions increased by 400% between

2000-2014 in China due to growth in WWTPs⁶⁰. *With the increased variability posed by climate change the emission in WWTPs could further increase*⁶¹.

Just as water systems are becoming increasingly energy-dependent, *energy generation remains heavily reliant on water*, with energy-sector's water consumption projected to rise by 60% between 2014 and 2040 and *the future water demand for projected energy use in 2030 likely to surpass the available supply*⁶². *Clean energy transitions could exacerbate the water stress* as biofuels production, concentrating solar power, carbon capture and storage, green hydrogen and nuclear power can have more significant water demands.

Figure 19: The Water-Energy-Climate nexus in Urban Water Cycles.



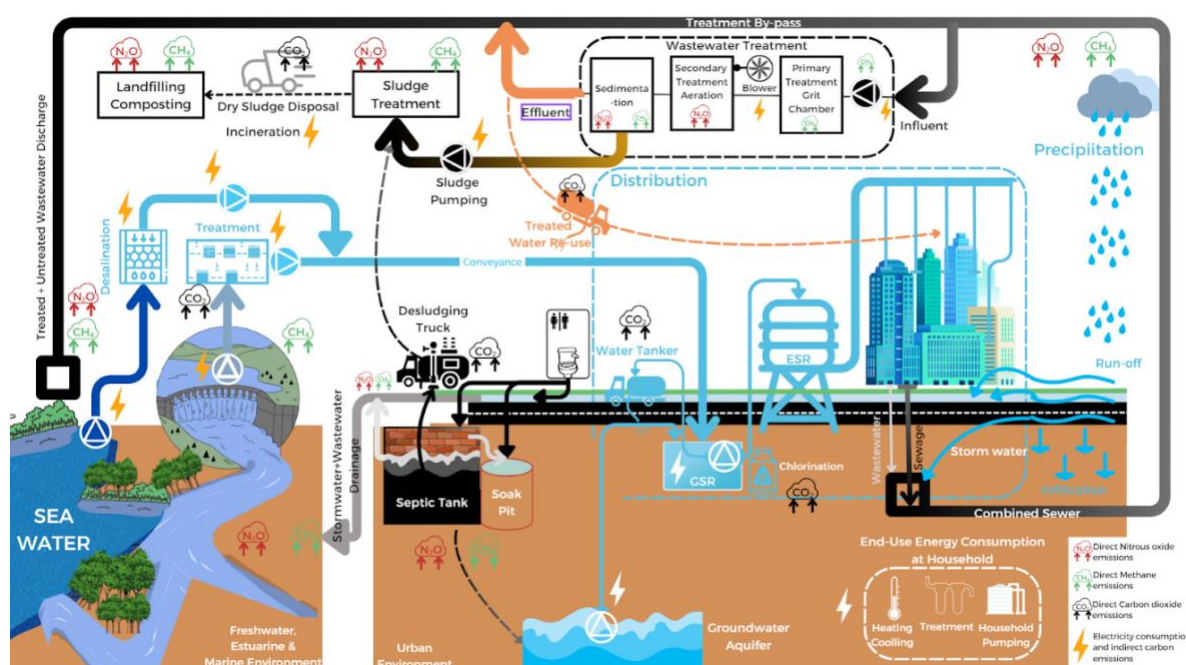
Source: Author's Illustration.

As illustrated in *figure 19*, urban water cycles relying on conventional energy-dependent approaches remain trapped in a vicious cycle where intensification of climate impacts results in increased carbon and energy footprint of urban water cycles which in turn results in worsening of climate impacts. **This escalating interdependence demonstrates exactly why designing climate-resilient urban water and sanitation systems is such an urgent priority.** The unavoidable overlap of water consumption and carbon emissions in urban environments means that achieving true resilience requires explicit coordination between water and carbon management⁶³. *An assessment of the energy and carbon footprints is therefore crucial, not only for ensuring the sustainability of urban water and sanitation systems, but also for informing broader macro-policy goals like energy security and greenhouse gas (GHG) mitigation.*

5.2 SOURCES OF GHG EMISSIONS IN URBAN WATER AND WASTEWATER SYTEMS

Energy is the most vital input for operating a typical urban water and wastewater system. Energy is often consumed in the form of electricity for powering pumps and machinery, resulting in indirect greenhouse gas (GHG) emissions, depending on the mode of power generation. Energy is also consumed in the form of fossils fuels in trucks that are used to transport water, sludge, material and chemicals throughout the service chain-resulting in direct GHG emissions. Direct GHG emissions can also come from large water reservoirs due to sedimentation. Further, biological degradation of the organic matter present in sewage and grey water results in direct methane (CH₄) and nitrous oxide (N₂O) emissions. Additionally, there is embedded energy and carbon footprint associated with the physical infrastructure and the materials and chemical used. *Figure 20* schematically illustrates the various steps in a typical urban water cycle in India as well as the electricity consumption and GHG emissions sources.

Figure 20: Graphical representation of various steps and processes in a typical urban water cycle showing sources of energy consumption and greenhouse gas emissions.



Source: Author's Illustration

5.3 SCOPE OF GREEN HOUSE GAS ESTIMATION

Assessing the carbon footprint of urban water systems requires a comprehensive approach that accounts for emissions across different stages of water abstraction, treatment, conveyance, distribution, and wastewater management. These emissions originate from various

processes, including direct GHG releases, energy and chemical consumption in operations, and emissions embedded in materials that make up the physical infrastructure. In this estimation, emissions are classified into three broad categories: *Direct Emissions*, *Indirect Emissions*, and *Embedded Emissions mentioned in Table 11*. Each category captures different sources of carbon emissions within the urban water and sanitation systems.

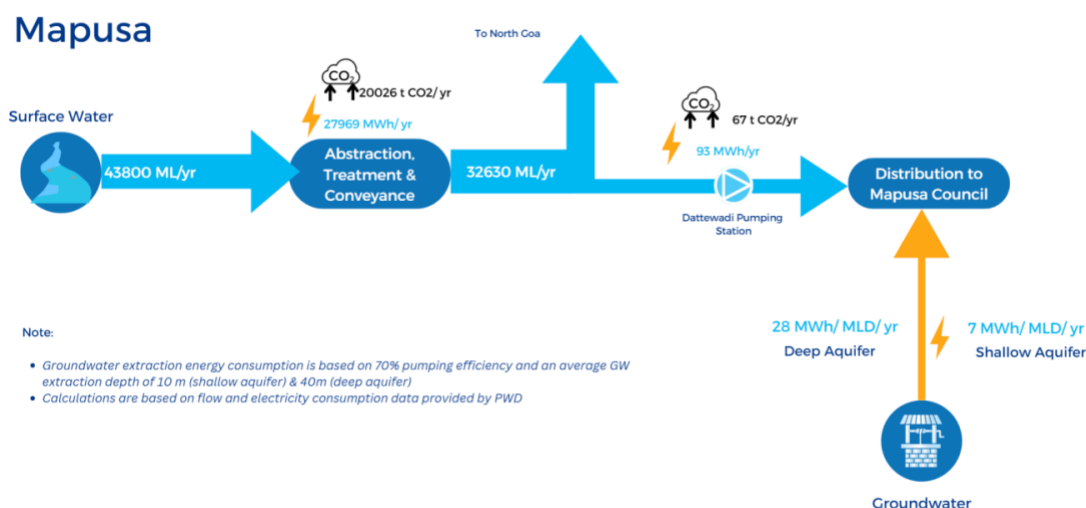
Table 11: Scope of emissions methodology for carbon footprint assessment of the urban water cycle

Category	Possible Sources of Emissions	Methodology
Direct Emissions	- Methane (CH₄) emissions from anaerobic decomposition of organic matter in wastewater. - Nitrous Oxide (N₂O) Emissions from nitrification and denitrification of nitrogen compounds wastewater - Methane (CH₄) emissions from the decomposition of organic matter in anaerobic sediments in freshwater reservoirs*	2006 IPCC Guidelines for National Greenhouse Gas Inventories ⁵⁵ (2019 Refinement ⁶⁴)
Indirect Emissions	- Indirect emissions from electricity consumption - Life cycle GHG emissions associated with the chemicals used in water and wastewater treatment processes (alum, hypo, chlorine etc.)* - Emissions from diesel combustion for transportation	Electricity consumption data obtained from urban local bodies and an average grid emission factor 0.716 tCO₂/MWh (FY 2022-23, Central Electricity Authority)⁶⁵ for Indian grid used for CO₂ estimation. Diesel consumption for desludging trucks based on information obtained from interviewing truck operators.
Embedded Emissions	- Life cycle GHG emissions associated with the materials used in the physical infrastructure. *	Not estimated due to non-availability of data on material footprint.
*Emissions not considered in the estimation due to non-availability of reliable activity data for the same.		

5.4 GREENHOUSE GAS EMISSIONS FROM WATER SUPPLY

The energy-intensive nature of water supply spanning extraction, treatment, conveyance, and distribution results in substantial indirect GHG emissions, primarily from electricity use. Additionally, household-level pumping, purification, and heating contribute to the carbon footprint, although such household level energy use is not accounted for here. Emissions related to treatment chemicals, construction materials, and logistics also remain outside the scope of this estimation due to data constraints. Furthermore, scientific studies suggest that freshwater reservoirs may also release direct GHG emissions due to anaerobic decomposition of organic matter in sediments⁶⁶. However, these are excluded from this analysis given methodological limitations. Hence, our assessment focuses solely on electricity-related emissions across key components of the water supply chain, as shown in *Figure 21*.

Figure 21: Carbon and energy footprint of Mapusa's water supply.



Source: Dangi & Narayanan, forthcoming⁶⁷

Mapusa's urban water supply system, sourced primarily from the Assonora Water WTP, exhibits a high carbon footprint due to its energy-intensive operations especially during the abstraction, treatment, and conveyance phases. On average, 120 MLD of raw water is abstracted from three sources and treated at the WTP. However, only about 90 MLD of clear water is produced, reflecting nearly 25% losses during treatment and in-plant operations. The energy used for abstraction, treatment, and initial pumping consumes a substantial **27,969 MWh/year**, resulting in **20,026 tonnes of CO₂ emissions annually**. This makes the treatment and pumping stage the most carbon-intensive component of Mapusa's water supply chain,

primarily driven by the large-scale use of high-capacity pumps (540 HP and 780 HP) for clear water transmission to distribution zones.

Further emissions arise from intra-city distribution activities. Water is tapped at the Dantewadi pumping station and transferred to various GLRs and Overhead Reservoirs OHRs. While parts of the distribution system utilise gravity, elevation differences and the town's complex topography necessitate additional energy for lifting water into the elevated storage reservoirs (ESRs). Distribution alone adds **93 MWh/year**, translating into **67 tCO₂/year** in emissions. Although this is modest compared to WTP operations, it contributes to the cumulative emissions burden and reflects inefficiencies in managing terrain challenges.

Accurate water consumption data within the Mapusa distribution zone remains unavailable due to the non-functional flow meter and absence of records. Consequently, the proportion of total water demand being met through surface water and groundwater sources cannot be determined. However, if groundwater is used in some pockets as is the case in other Goan towns there exists an opportunity for emission reduction. Based on standard benchmarks, groundwater abstraction is significantly less carbon-intensive, consuming about **7 MWh/MLD/year for shallow aquifers** and **28 MWh/MLD/year for deeper aquifers**, compared to **313 MWh/MLD/year** for surface water supplied via Assonora. This stark difference points to the energy and emissions efficiency of integrating regulated, local groundwater into the supply mix.

The actual quantity of water delivered to end users is unknown because of a lack of consumption monitoring. However, similar to other PWD-managed systems in the region, transmission and distribution losses are estimated to be in the range of 20–40%, due to leakages, unauthorised tapping, and infrastructure inefficiencies.

These losses have a major implication on the carbon footprint: the energy used to pump, treat, and convey water that never reaches users adds significantly to emissions without yielding any utility. For example, if 90 MLD is produced and 30–35% is lost, only 58–63 MLD is effectively consumed, meaning the per unit emissions of actual consumed water are substantially higher than calculated using production figures alone. On the contrary, in decentralised systems such as ground water, transmission losses are negligible, and the water is often used close to the point of extraction, minimising waste and emissions.

Key Insights:

- Assonora WTP is the largest contributor to Mapusa's water supply-related GHG emissions, driven by high electricity use for pumping and treatment.
- 25% in-plant losses at the WTP, combined with estimated 20–40% distribution losses, mean that *a substantial portion of energy and emissions does not translate to actual water delivered to end users.*

- Current GHG estimates underestimate true carbon intensity per unit of consumed water, due to the lack of monitoring systems and accounting for system losses.
- Groundwater, if sustainably managed, offers a low-emission, decentralised supplement to Mapusa's water supply, particularly in underserved or high-elevation zones.
- Better flow monitoring, leakage control, and integration of groundwater into the water supply mix could significantly reduce the emissions footprint and improve climate resilience.

5.5 GREENHOUSE GAS EMISSIONS FROM SANITATION

Figure 22 provides a detailed emissions inventory for Mapusa's sanitation chain, capturing direct and indirect GHG emissions from various stages: containment, transport, treatment, and disposal.

CONTAINMENT SYSTEMS (SEPTIC TANKS AND PITS):

- Methane (CH₄) emissions:
 - Septic Tanks: 2,278 tCO₂e/year
 - Pits (lined/unlined): 3,366 tCO₂e/year
- Nitrous Oxide (N₂O) emissions:
 - Septic Tanks: 118.7 tCO₂e/year

These on-site systems account for the largest share of emissions due to anaerobic conditions in poorly maintained pits and tanks.

DESLUDGING AND TRANSPORT:

- Desludging trucks handling ~37.2 t BOD generate 80 tCO₂e/year from diesel combustion.

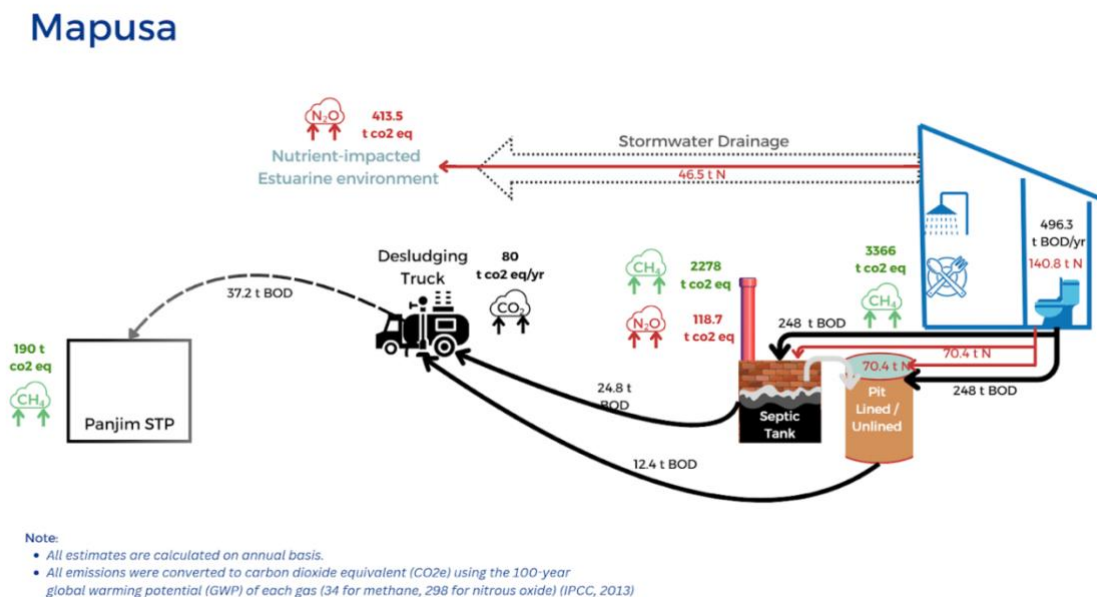
FAECAL SLUDGE TREATMENT AT PANJIM STP:

- Receives a limited volume of faecal sludge (37.2 t BOD) and contributes 190 tCO₂e/year in CH₄ emissions.

NUTRIENT DISCHARGE VIA STORMWATER:

- 46.5 tonnes of nitrogen (tN) is released untreated into stormwater drains, leading to **413.5 tCO₂e/year** of indirect N₂O emissions in estuarine zones.

Figure 22: Carbon and energy footprint across sanitation service chain in Mapusa.



Source: Dangi & Narayanan, forthcoming⁶⁷

Key Insights:

- High On-Site Sanitation Emissions:**
 Over **5,600 tCO₂e/year** is emitted from septic tanks and pits alone, underlining the dominance of on-site systems in Mapusa's emissions profile.
- Low STP Utilisation:**
 Only a small portion of faecal waste reaches the STP, highlighting gaps in desludging frequency, coverage, and sewer connectivity.
- Nutrient Pollution Adds to Climate Risk:**
 Stormwater drains serve as vectors for nitrogen-rich greywater, significantly contributing to N₂O emissions in nutrient-sensitive estuarine ecosystems.
- Desludging Logistics Are Energy-Intensive:**
 While comparatively lower in GHG output (80 tCO₂e), truck emissions point to the need for route optimization and vehicle efficiency.

5.6 CONCLUSION & WAY FORWARD

The GHG estimation for Mapusa clearly illustrates the compounding vulnerabilities at the heart of the urban water-energy-climate nexus. Surface water abstraction and treatment remain highly energy-intensive, and when coupled with substantial transmission and distribution losses, they significantly inflate the carbon footprint of municipal water provision. In parallel, the sanitation sector's reliance on on-site containment with inadequate nutrient management acts as a major, yet often neglected, source of methane and nitrous oxide emissions.

Moving forward, breaking these water-energy-climate feedback loops requires a transition from isolated infrastructural planning to an integrated and climate-sensitive water cycle management. By strategically optimising the source mix to include lower-carbon groundwater where aquifers permit, rejuvenating local water sources and aggressively targeting systemic network losses, and integrating nature-based sanitation solutions along with realising the co-generation potential in existing systems, the city can decouple water security from escalating energy demands. Ultimately, transforming these hidden climate liabilities into assets for urban resilience will demand a shift from merely tracking emissions to actively recovering resources and embedding energy efficiency into municipal-level planning.

NOTES & REFERENCES

- ⁵² Author's Note: This chapter is based on ongoing doctoral research by Ashish Dangi under the supervision of Prof. N. C. Narayanan at the Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Key findings and interpretations presented here are part of a broader analysis that is currently being prepared for publication in a peer-reviewed academic journal. Readers are requested to cite this report appropriately and direct any academic queries to the author.
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6. PERFORMANCE AND FINANCIAL ANALYSIS OF WATER SUPPLY AND SANITATION

ABHAY JUNAGHARE⁶⁸ AND NC NARAYANAN

This chapter evaluates the operational and financial health of the water supply and sanitation systems. It begins by assessing current service delivery against established performance benchmarks for both the water and sewerage networks. Next, it analyses the underlying revenue streams, focusing on retail tariffs mandated by PWD Goa and the sector's reliance on external grants versus internally generated revenue. Finally, the chapter provides a comprehensive financial assessment to pinpoint the primary fiscal challenges hindering sustainable service delivery in these sectors.

6.1 INTRODUCTION

In order to analyse the financial performance against the SLBs for urban water supply and sanitation by the MoHUA, we *examine the revenue streams available to the PWD, Goa, for water supply, sewerage, and sanitation, as MMC does not play any role in water and sanitation infrastructure or service provision.* The revenue sources include central government grants, state government grants, and their own revenue sources. Here, the ratio of grants to own revenue sources is analysed to identify the percentage availability of each source for water supply and sewerage & sanitation. The assessment of financial health of the water utility and sewerage & sanitation is performed here by examining the capital receipts, capital expenditure, revenue expenditure, & revenue receipts from the city municipal budget statements. The water and sanitation budgets are created from the municipal budget to analyse the cost recovery, collection efficiency, operating ratio, cost of bulk water purchase, per capita expenditure, the revenue and fiscal deficits, budget trends (capital receipts, capital expenditure, revenue expenditure, & revenue receipts), and compound annual growth rate (CAGR)⁶⁹. The above given ratios are essential to identify the financial health of the water utility and sewerage & sanitation at ULB.

6.2 PERFORMANCE ANALYSIS: SERVICE LEVEL BENCHMARKS

6.2.1 WATER SUPPLY

The performance indicators for water supply at MMC reveal areas of strength, but also significant challenges when compared to benchmarks and the national averages for India (Table 12). These indicators provide insights into the efficiency, sustainability, and quality of water supply services. *The coverage of water supply connections in MMC stands at 79%*

in 2020-21, which, although an improvement over the 70% in 2019-20, still falls short of the 100% benchmark. This indicates that nearly a quarter of households do not have access to water connections, which is a major concern for equitable water distribution. Despite being higher than the India average of 70%, the 21% gap from the target suggests that MMC must invest in infrastructure to expand connections, ensuring that all households are reached by the water supply network. MMC's per capita water supply stands at 150 litres per capita per day (lpcd) in 2020-21, significantly above the benchmark of 135 lpcd. This is a positive sign, as the per capita supply in MMC is well above the India average of 114 lpcd. The 15 lpcd surplus above the benchmark reflects that MMC is providing a relatively abundant water supply compared to many other regions in India. This highlights effective resource allocation, although maintaining this supply in the face of increasing demand and sustainability challenges will require careful planning.

Metering is a crucial aspect of water supply management, as it helps monitor consumption and ensures accurate billing. *MMC has made notable progress, increasing its metering rate from 22% in 2019-20 to 98% in 2020-21.* This brings the performance almost in line with the national average of 98% and just 2% shy of the 100% benchmark. This improvement is commendable, but the remaining unmetered connections could lead to inefficiencies, including difficulties in detecting unauthorized usage or leaks. Therefore, complete metering should be prioritized to improve operational efficiency. Non-revenue water, which includes water lost due to leakage, unauthorized usage, or metering inaccuracies, is a significant concern for MMC. *The NRW in 2020-21 is 30%,* which is well above the benchmark of 15% and even higher than the India average of 25%. The 15% gap indicates that a large portion of the water produced is not accounted for, which can be wasteful and lead to financial losses. Addressing this issue will require a comprehensive strategy to reduce leaks, enhance metering accuracy, and tackle illegal connections. *The continuity of water supply in MMC remains a significant challenge, with the average supply duration reported at just 5 hours per day in 2020-21,* a stark contrast to the 24-hour supply benchmark. While this matches the India average, the large gap of 19 hours from the ideal target indicates that water supply interruptions are frequent. This limited supply can cause significant inconvenience for residents, and improving supply continuity will be crucial to meet the needs of the population, especially in areas with high demand.

MMC has demonstrated excellent performance in water quality, achieving 100% compliance with potable water standards in 2020-21. This is in line with both the benchmark and the India average. The high percentage of treated water that meets quality standards indicates effective water treatment processes and quality assurance mechanisms. As water quality remains a key priority for public health, MMC should continue to maintain and improve its water treatment protocols to ensure the safety of the supply. *In terms of addressing customer complaints, MMC has seen a decline from 89% redressal in 2019-20 to 72% in 2020-21.* While the performance remains above the India average of 78%, the drop of 8% from the benchmark of 80% highlights an area that needs attention. Improving the response time and efficiency in complaint resolution is critical for maintaining public trust and satisfaction. A streamlined customer service system and better tracking of

complaints could help improve this metric. MMC has made progress in several key areas of water supply, particularly in per capita supply, metering of connections, and water quality. However, significant gaps remain in coverage, continuity of supply, NRW reduction, and financial sustainability.

Table 12: Performance Indicators for Water Supply at MMC

#	Water Supply	Calculations	Benchmarks	India Average*	2019-20	2020-21(T)**	Gaps
1.	Coverage Connections	(Total no. of HHs with water supply connections)/(Total no. of HHs in the City)	100%	70.00%	79%	100%	-21%
2.	Per capita supply (lpcd)	(Water supplied)/(Population served)	135 lpcd	114 lpcd	150	135	15
3.	Metering of connections	(No. of metered connections + No. of metered Public Standposts)/(Total no. of connections + Total no. of Public Standposts)	100%	22.00%	98%	98%	-2%
4.	Non-revenue water (NRW)	(Total water produced) - (Total water sold)/(Total water produced)	15%	31%	30%	25%	15%
5.	Continuity of water supply (hours)	Average hours of water supply	24 hours	2.7 hours	5	5	-19
6.	Quality and treatment	(Number of samples that meet the specified potable water standards)/(Total number of water supply related complaints received)	100%	95%	100%	100%	0%
7.	Redressal of customer complaints	(Total number of complaints redressed)/(Total number of water supply related complaints received)	80%	89%	72%	78%	-8%

Source: * CPHEEO Guidelines for 24x7 WSS (Drink from Tap), Dec 2021; ** Mapusa Municipal Council, 2025

6.2.2 SANITATION AND SEWERAGE

The sewerage and sanitation performance indicators for MMC reveal several areas of concern when compared to established benchmarks (Table 13). These indicators, which

assess various aspects of sewage and sanitation management, highlight significant gaps that need addressing. The benchmark for toilet coverage is 100%, meaning every household (HH) should have access to individual or community toilets within walking distance. However, *MMC currently has a coverage of 75%, with a 25% gap*. This indicates that a quarter of the population lacks adequate access to sanitation facilities, suggesting a need for more infrastructure and better planning to ensure universal access. The sewage network service coverage is a critical performance indicator, with the benchmark set at 100%. *MMC shows a worrying gap, with 0% of households directly connected to the sewage network*. This represents a complete lack of sewage infrastructure, implying that MMC lacks the necessary sewage treatment and conveyance systems to address the city's wastewater disposal needs.

The indicator for Collection Efficiency of the Sewage Network measures the effectiveness of wastewater collection and is another critical area for MMC. The benchmark of 100% collection efficiency is not met, with the city reporting 0% efficiency. This suggests that wastewater collected is not effectively managed, which could lead to sanitation-related issues, pollution, and health risks. *There is a dire need to implement a functioning sewage collection system*. According to the benchmark for Adequacy of Sewage Treatment Capacity, MMC should have adequate sewage treatment capacity to handle all wastewater generated. With a 0% adequacy rating, it's evident that the city's sewage treatment facilities are non-existent or insufficient. This severely impacts the quality of sewage management, as untreated wastewater could end up polluting local water bodies. The performance on sewage treatment quality is critical in ensuring public health and environmental safety. The benchmark calls for 100% of wastewater samples to meet specified secondary treatment standards, but MMC records 0% quality in sewage treatment. This indicates that any sewage treatment that occurs does not meet the required standards, posing significant environmental and health risks.

Reuse and recycling of sewage is vital for sustainable water management. MMC shows no recycling or reuse of sewage, with a 0% rate, compared to a 20% benchmark. This represents a missed opportunity to optimize wastewater as a resource and reduce the strain on local water supplies. The ability to address customer complaints is an important part of governance and service delivery. The benchmark is 80% of complaints redressed within a month, but MMC shows a 0% rate. This lack of responsiveness can lead to public dissatisfaction and undermine trust in the municipality's ability to manage sanitation services effectively. The performance indicators for Mapusa Municipal Council show large gaps in all key areas of sewage and sanitation management. *There is an urgent need for MMC to invest in infrastructure development*, including sewage networks and treatment facilities, and to improve financial and operational efficiency.

6.3 REVENUE STREAMS

This sub-section analyses the revenue streams available to PWD, Goa at MMC for water supply and sewerage & sanitation. The revenue sources include central government grants,

state government grants, and their own revenue sources. Here, the ratio of grants to own revenue sources is analysed to identify the percentage availability of each source for water supply and sewerage & sanitation. The assessment of financial health of the water utility and sewerage & sanitation is performed here by examining trends for cost recovery and collection efficiency. This helps assess MMC's preparedness to meet current and future demands for water supply and sewerage & sanitation infrastructure and services, and to enhance climate resilience of WaSH. These actions ultimately contribute to improved public health outcomes and more sustainable urban environments. *This sub-section is structured viz., 1) retail water tariff (PWD), 2) retail sewerage tariff (PWD), 3) Ratio of grants to own revenue at PWD, Goa for water supply and sewerage & sanitation, and 4) Assessment of Finances for Water Supply and Sewerage & Sanitation at Mapusa.*

Table 13: Performance Indicators for Sewerage & Sanitation at MMC

#	Sewerage Sanitation Indicators	and Calculations	Benchmarks	2018-19	2019-20 (T)**	Gaps
1.	Coverage of Toilets	(Total number of HHs with access to individual or community toilets within walking distance in the city)/ (Total number of HHs without individual or community toilets within walking distance)	100%	75%	96%	-25%
2.	Coverage of Sewage Network Services	(Total number of HHs with direct connection to the sewage network)/ (Total number of HHs in the city)	100%	0%	0%	-100%
3.	Collection Efficiency of the Sewage Network	(Wastewater collected)/ (Total water supplied + Estimated water use from other sources)	100%	0%	0%	-100%
4.	Adequacy of Sewage Treatment Capacity	(Treatment plant capacity)/ (Total water consumed + Total number of HHs with direct connection to sewage network)	100%	0%	0%	-100%
5.	Quality of Sewage Treatment	(Number of samples that pass specified secondary treatment standards)/ (Total number of wastewater samples tested in a month)	100%	0%	0%	-100%
6.	Extent of Reuse and Recycling of Sewage	(Wastewater recycled or reused after appropriate treatment)/ (Wastewater received at STPs)	20%	0%	0%	-20%
7.	Efficiency Redressal of Customer Complaints	(Total number of complaints redressed within the month)/ (Total number of sewage-related complaints received per month)	80%	0%	0%	-80%

Source: Mapusa Municipal Council, 2025

6.3.1 RETAIL WATER TARIFF – PWD, GOA

The tariff structure for new domestic water connections outlines the fees based on the diameter of the connection (Table 14). For smaller connections (15/20 mm), the total fees amount to INR 1,000, with a meter rent of INR 50 and a water rate of INR 3.50 per kilolitre (KL). As the connection size increases, so do the fees: for connections between 20 mm and 25 mm, the total fee is INR 3,000 with a water rate of INR 9.00 per KL, and for connections between 25 mm and 50 mm, the total fee rises to INR 4,000 with a water rate of INR 15.00 per KL. Larger connections (50 mm to 100 mm) incur a total fee of INR 7,000, with a water rate of INR 25.00 per KL, while connections over 100 mm require a deposit of INR 10,000, but the water rate is not specified in the table. Additionally, the connection and labour charges are not applicable in this structure.

The tariff structure for new non-domestic water connections varies based on the diameter of the connection, with higher fees reflecting the larger volume of water typically consumed by non-domestic users (Table 16). For a 15/20 mm connection, the total fee is INR 5,000, which includes a meter rent of INR 50 and a water rate of INR 3.50 per kilolitre (KL). As the connection diameter increases, the fees rise, i.e., for connections between 20 mm and 25 mm, the total fee is INR 9,000 with a water rate of INR 9.00 per KL, and for connections between 25 mm and 50 mm, the total fee is INR 20,000 with a water rate of INR 15.00 per KL. For larger connections (50 mm to 100 mm), the total fee is INR 25,000 with a water rate of INR 25.00 per KL, while connections over 100 mm require a total fee of INR 30,000, but the water rate is not specified.

Table 14: New water connection fees for Domestic consumers

	Diameter (mm)	Deposit (INR)	Connection Fee (INR)	Labour Charges (INR)	Total (INR)	Inspection Charges (INR)	Meter Rent (INR)	Water rates per unit (INR)
1.	15/20	1,000	0	0	1,000	Rs. 100 per connection per year	50.00	3.50 per KL
2.	>20 till 25	3,000	0	0	3,000		80.00	9.00 per KL
3.	>25 till 50	4,000	0	0	4,000		125.00	15.00 per KL
4.	>50 till 100	7,000	0	0	7,000		350.00	25.00 per KL
5.	>100	10,000	0	0	10,000		1,000.00	

Source: Department Public Works (PWD), Government of Goa, 24-17/PWD/PCE-EO/2023-24/73

Table 15: New water connection fees for Non-Domestic consumers

	Diameter (mm)	Deposit (INR)	Connection Fee (INR)	Labour Charges (INR)	Total (INR)	Inspection Charges (INR)	Meter Rent (INR)	Water rates per unit (INR)
1.	15/20	5,000	0	0	5,000	Rs. 500 per connection per year	50.00	3.50 per KL
2.	>20 till 25	9,000	0	0	9,000		80.00	9.00 per KL
3.	>25 till 50	20,000	0	0	20,000		125.00	15.00 per KL
4.	>50 till 100	25,000	0	0	25,000		350.00	25.00 per KL
5.	>100	30,000	0	0	30,000		1,000.00	

Source: Department Public Works (PWD), Government of Goa, 24-17/PWD/PCE-EO/2023-24/73

The connection and labour charges are not included in the fees, and a significant annual meter rent applies, particularly for the smallest connection size.

6.3.2 RETAIL SEWERAGE TARIFF – PWD, GOA

The Goa Sewerage System and Sanitation Services Management Rules, 2010, outline a clear tariff structure for the provision of sewerage services in the state (Table 16). The tariff is categorized based on the type of service, with domestic users being charged Re. 1 per cubic meter (Cu. M.) of wastewater generated, while commercial and industrial users face higher rates of Rs. 5 per Cu. M. Public places are charged Rs. 3 per Cu. M. In addition to the per-unit charges, a one-time security deposit is required based on the category: domestic users pay Rs. 500, commercial and public places pay Rs. 1,000, and industrial users pay Rs. 3,000 per connection. A surcharge of 2% on the billed amount is applied for delayed payments, rounded to the next higher rupee.

Regarding new connection charges, these are determined by the diameter of the pipe used for the connection (Table 17). Domestic connections with pipes up to 150 mm are charged Rs. 200, while those with pipes greater than 150 mm incur a charge of Rs. 350, along with a Rs. 100 per unit fee. Commercial and industrial connections follow a similar structure, with higher rates for larger diameter pipes and additional per-unit costs based on the pipe size. Public places, like commercial and industrial categories, incur a one-time connection fee depending on pipe size, with no per-unit charges applicable.

Table 16: Sewerage Tariff Structure at Goa

#	Category	Tariff *	Security Deposit (One Time)
1.	Domestic	Re. 1 per Cu. M. of wastewater generated	Rs. 500 per connection
2.	Commercial	Rs. 5 per Cu. M. of wastewater generated	Rs. 1,000 per connection
3.	Industrial	Rs. 5 per Cu. M. of wastewater generated	Rs. 3,000 per connection
4.	Public Places	Rs. 3 per Cu. M. of wastewater generated	Rs. 1,000 per connection

*Surcharge for delayed payment 2% of billed amount. Rounded to next higher rupee.

Source: The Goa Sewerage System and Sanitation Services Management Rules, 2010, Government of Goa

Table 17: New Sewerage Connection Charges at Goa

#	Category	Connection Charges Based on Pipe Diameter		Per Unit in Group
		Upto 150 mm	More than 150 mm	
1.	Domestic	Rs. 200 per connection	Rs. 350 per connection	Rs. 100 per unit
2.	Commercial	Rs. 500 per connection	Rs. 750 per connection	Rs. 250 per unit
3.	Industrial	Rs. 1,000 per connection	Rs. 2,000 per connection	Rs. 500 per unit
4.	Public Places	Rs. 1,000 per connection	Rs. 2,000 per connection	Not Applicable

Source: The Goa Sewerage System and Sanitation Services Management Rules, 2010, Government of Goa

The tariff structure aims to maintain fair and consistent charging based on usage and connection specifics. These charges are collected by PWD at Goa.

6.3.3 RATIO OF GRANTS TO OWN REVENUE

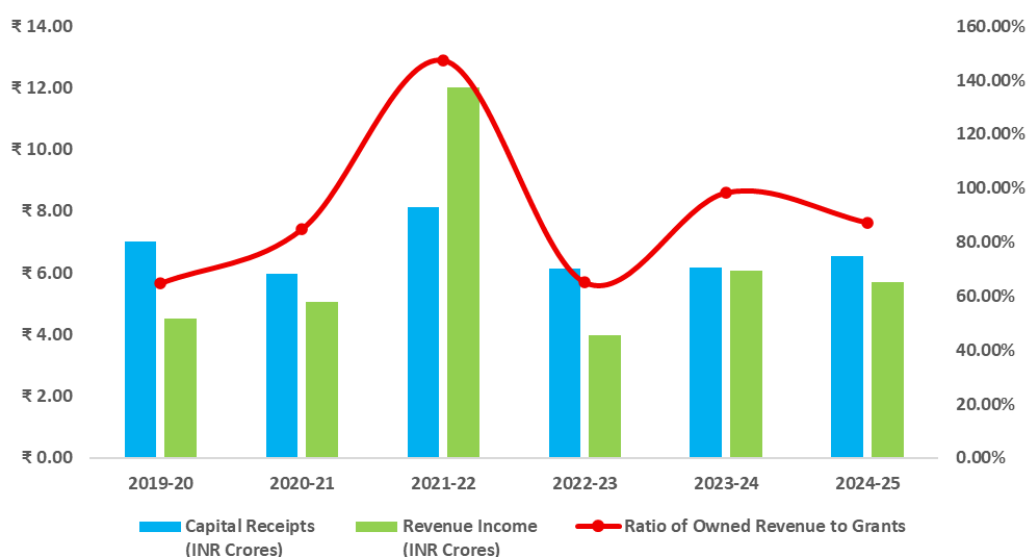
The data presented provides a clear view of the ratio of owned revenue generated by PWD for Water Supply and Sewerage, Goa to the grants received over a period of six years, i.e., from 2019 to 2025 (Figure 23). The ratio, expressed as a percentage, is a key indicator of the department's financial autonomy, highlighting how much of the water supply and sewerage revenue is self-generated as opposed to being reliant on external grants. In 2019-20, the ratio of owned revenue to grants was 64.70%, meaning that for every rupee of grant received, the department generated around 65 paise of revenue on its own.

A major jump occurred in 2021-22, where the ratio spiked dramatically to 147.45%. In this year, the revenue income outstripped the capital receipts, with owned revenue more

than compensating for grants. This unusually high ratio points towards the one-time settlement offer given by the PWD to the consumers having backlogs. This fiscal strategy has improved the internal revenue collection. This period marked the highest level of financial self-sufficiency observed in the data. However, the ratio reverted to more modest levels in 2022-23, dropping to 64.99%, which was nearly identical to the 2019-20 figure. This suggests that the department might have faced challenges in maintaining the revenue generation momentum from the previous year, possibly due to fluctuations in water consumption, tariff adjustments, or other operational issues. From 2023-24 onward, the ratio shows a steady improvement, reaching 98.33% in 2023-24, which indicates near independence from grants. By 2024-25, the ratio stands at 87.16%, which remains strong but lower than the peak achieved in 2021-22. This suggests a trend where the department is consistently improving its revenue generation capabilities, even if it cannot fully eliminate its dependence on grants.

This figure indicates a moderate dependency on grants, with owned revenue being just over half of the total funding required for water supply operations. However, the subsequent year, 2020-21, saw a significant improvement in the ratio to 84.83%. This increase suggests that the department was able to enhance its revenue generation while reducing its reliance on grants, indicating a more efficient or expanded revenue model.

Figure 23: Ratio of owned revenue to grants at PWD Goa



Source: Municipal Budget Documents

When looking at the total over the six years, the department's ratio of owned revenue to grants is 93.48%. This means that, on average, for every rupee of grants received, the department was able to generate nearly 93 paise on its own. *This is a strong performance overall, but it also reflects a gradual reliance on grants, especially in the years where the ratio dropped significantly (2022-23).* Thus, the department has made notable progress in improving its financial self-sufficiency over the years, especially from 2020-21 to 2021-

22. However, the fluctuations in the ratio across the years suggest that while the department is moving toward greater independence, there are external factors that continue to influence its ability to generate owned revenue consistently. The overall trend is positive, indicating a growing ability to reduce reliance on grants, but more work is needed to sustain and possibly improve these results in the future.

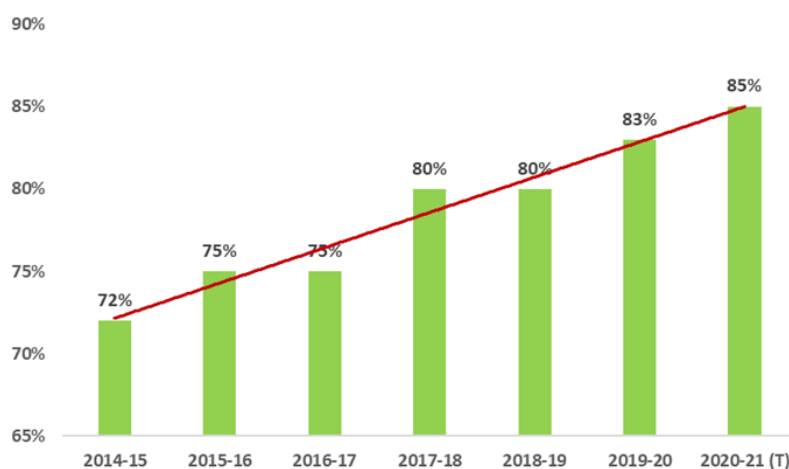
6.4 ASSESSMENT OF FINANCES

This sub-section analyses the trends from the SLBs for water supply and sewerage & sanitation at MMC.

6.4.1 WATER SUPPLY

The analysis of cost recovery for water supply at MMC from 2014-15 to 2020-21 shows a steady and positive improvement in covering operational and infrastructure costs through water tariffs and fees (Figure 24). Starting at 72% in 2014-15, cost recovery increased to 75% in 2015-16, and further rose to 80% by 2017-18, reflecting enhancements in billing, collections, and water conservation efforts.

Figure 24: Trend analysis of cost recovery in water supply charges at MMC



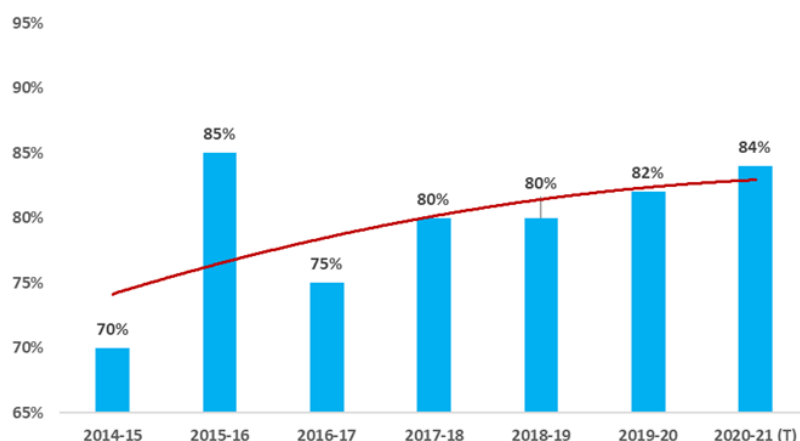
Source: Mapusa Municipal Council (MMC), 2025

Between 2018-19 and 2020-21, cost recovery reached 83%, with a target of 85% set for 2020-21, demonstrating MMC's focus on financial sustainability and reducing reliance on subsidies. *This gradual progress highlights effective management strategies, including improved metering, billing systems, and cost-saving measures, ensuring the financial viability of the water supply system and facilitating future infrastructure maintenance and expansion.*

The analysis of collection efficiency for water supply at MMC from 2014-15 to 2020-21 reveals a generally positive trend, despite some fluctuations (Figure 25). Collection

efficiency, which reflects the percentage of billed water charges actually collected, was initially low at 70% in 2014-15, suggesting challenges in payment collection. However, a significant improvement to 85% in 2015-16 indicates that the MMC likely implemented better billing systems, customer awareness, and enforcement.

Figure 25: Trend analysis of collection efficiency in water supply charges at MMC



Source: Mapusa Municipal Council (MMC), 2025

While efficiency dropped to 75% in 2016-17, it steadily increased in subsequent years, reaching 80% by 2018-19 and targeting 84% in 2020-21. This gradual improvement demonstrates ongoing efforts to optimize collection processes, including better customer engagement, digital payment options, and stricter follow-ups on overdue accounts. Overall, the rise from 70% to a projected 84% by 2020-21 reflects enhanced financial management, supporting the sustainability of water supply operations and infrastructure development.

6.4.2 SEWERAGE & SANITATION

The analysis of cost recovery for sewage management at MMC from 2014-15 to 2020-21 reveals a persistent 0% cost recovery, meaning no revenue has been generated to cover sewage management expenses. This indicates complete reliance on government funding or external financial support, making the system financially unsustainable in the long term. The lack of cost recovery hampers the municipality's ability to maintain, develop, and invest in sewage infrastructure, potentially affecting the quality of services. The absence of a sewage tariff or user charges, coupled with ongoing infrastructure development, further exacerbates financial constraints. Moving forward, MMC may need to introduce user charges or service fees to ensure the sustainability of sewage management and reduce the burden on the municipal budget.

From 2014-15 to 2020-21, *the collection efficiency* for sewage charges at MMC has remained at 0%, indicating that no revenue has been generated from sewage services. This suggests that the sewage system is entirely subsidized through the municipal budget

or government grants, without any user charges or sanitation tariffs in place. The lack of revenue collection raises concerns about the financial sustainability of sewage management, potentially limiting investment in infrastructure, maintenance, and service expansion. It may also point to administrative inefficiencies, lack of enforcement, or resistance to paying for sanitation services. To address this, MMC should implement a structured sewage charge system, possibly based on water consumption or property size, and consider public awareness campaigns and better enforcement mechanisms to improve collection efficiency and ensure the long-term viability of sewage services.

6.5 KEY FINANCIAL CHALLENGES

6.5.1 Water Supply

The key financial challenges faced by the PWD, Goa at MMC in water supply management are primarily related to the inconsistent cost recovery and collection efficiency. Despite improvements in cost recovery, which rose from 72% to a target of 85% by 2020-21, there remains a gap in covering the full operational and infrastructure costs through user charges, necessitating reliance on subsidies or external funding. Additionally, collection efficiency has been fluctuating, with a low of 70% in 2014-15, improving to 84% by 2020-21. The variations suggest challenges in ensuring timely payments, inefficient billing systems, and possible resistance from consumers. These issues affect the financial sustainability of the water supply system, hindering PWD's ability to invest in infrastructure, maintenance, and improvements. Achieving consistent cost recovery and collection efficiency will be crucial for reducing financial strain and ensuring long-term sustainability of the water supply services.

6.5.2 Sewerage and Sanitation

The key challenges faced by PWD, Goa in sewage and sanitation management at MMC include the lack of cost recovery and collection efficiency. With no revenue generated from sewage services (0% cost recovery), PWD is heavily reliant on government funding and subsidies, which leads to financial unsustainability and a growing burden on the department budget. This dependence can delay infrastructure improvements, maintenance, and service expansion. The absence of any sewage charge collection (0% collection efficiency) further exacerbates the situation, suggesting administrative inefficiencies, lack of enforcement, or resistance to paying for services. Without a structured revenue mechanism, PWD faces ongoing financial strain, making it difficult to invest in necessary upgrades, and potentially leading to degraded service quality. These challenges highlight the urgent need for PWD to implement revised user charges, establish a sustainable collection system, and raise public awareness to ensure the long-term financial viability of sewage services.

NOTES & REFERENCE

⁶⁸Author's Note: This chapter is based on ongoing doctoral research by Abhay Junaghere under the supervision of Prof. N. C. Narayanan at the Ashank Desai Centre for Policy Studies (ADCPS), Indian Institute of Technology Bombay. Key findings and interpretations presented here are part of a broader analysis that is currently being prepared for publication in a peer-reviewed academic journal. Readers are requested to cite this report appropriately and direct any academic queries to the author.

⁶⁹ Capital receipts are comprised of reception of grants from central and state government through its schemes. Capital expenditures are the funds used to acquire or upgrade the infrastructure that are typically large purchases. Revenue expenditures are the recurring operating expenditure that are short term and essential to run daily operations. Revenue receipts are the recurring receipts of income generated from the daily service provisions. Cost recovery is the ratio of the total annual operating revenues to the total annual operating expenses. Collection efficiency is the ratio of current revenues collected in the given year to the total operating revenues billed during the given year. The operating ratio is the ratio of revenue expenditure to revenue income, which helps assess the financial sustainability. A value greater than 1.0 indicates that revenue income exceeds operating expenses, ensuring financial stability. The revenue deficit is calculated as the difference between the revenue expenditure and revenue income. The fiscal deficit is calculated as the difference between the total expenditure and total revenue income's is annual growth rate over a specific period.

7. RESILIENCE ASSESSMENT OF WASH INFRASTRUCTURE

SUCHARITA ROY, TEJASH ANAND, AND N.C. NARAYANAN

Urban infrastructure faces mounting pressure from rapid urbanization and intensifying climate-related extreme events. Inadequate infrastructure amplifies losses and increases disaster risks, underscoring the need for resilient systems that can absorb shocks, maintain essential services during crises, and recover while reducing future risks. This chapter examines the exposure and vulnerability of water, and sanitation infrastructure in Mapusa. The assessment draws on detailed sectoral analyses presented in previous chapters. By synthesising these findings, the section identifies contextual risks, systemic gaps, and vulnerabilities affecting the resilience of Mapusa's WaSH infrastructure.

7.1 BACKGROUND

Urban infrastructure today faces dual pressures: rapid urbanization and extreme natural events driven by climate change. The World Risk Report 2016 highlights that inadequate infrastructure amplifies losses to life and property while increasing the likelihood of disasters arising from extreme natural events. Resilient infrastructure, by definition, refers to systems capable of absorbing, rebounding, and adapting to hazards and shocks to ensure continuity and safety.

Urban infrastructure in coastal cities like Mapusa is increasingly pressured by rapid urbanization, rising service expectations, and extreme natural events spurred by climate change. Inadequate infrastructure not only heightens the risk of loss of life and property; it also increases the likelihood that a natural hazard will escalate into a disaster. Accordingly, resilient infrastructure is defined as systems and networks that can absorb shocks, maintain essential services during crises, and swiftly recover while simultaneously reducing future risks.

This section captures the exposure and vulnerability of the WaSH infrastructure of Mapusa, a class III town and an important regional settlement in North Goa district of Goa. The situational analysis has been based on the detailed sectoral analysis undertaken by sectoral teams and captured in the previous chapters of this report. The resilience assessment of the WaSH infrastructure captures the contextual risks and gaps in the systems.

7.2 METHODOLOGY FOR RESILIENCE ASSESSMENT

Adopting resilient infrastructure not only helps reduce the intensity of adverse consequences from disasters but also provides an opportunity to shift to lower carbon pathways. The risk of infrastructure failure during disruptive events depends on several factors, including exposure to hazards, locational limitations, technology, sensitivity of the infrastructure, its governance, access to funding, and systemic agility. The Sendai Framework for Disaster Risk Reduction identifies the resilience of critical infrastructure as key for risk reduction.

An assessment of the resilience of the WaSH infrastructure, the town has been undertaken in the context of climate change to inform future planning and build climate-resilient WaSH infrastructure and services in the town. Guided by the Global Methodology for Infrastructure Resilience -UNDRR (2023)⁷⁰, *a three-step, contextualised methodology has been developed*. This methodology analyses the adequacy, reliability, and flexibility of WaSH infrastructure in the face of climate change and the robustness of governance and finance to handle future risks. This framework enables a comparative understanding of system resilience for WaSH infrastructure across towns and cities, irrespective of the level of urbanization, population size, and local body capacity. It helps identify trends and patterns across various classes of cities and develop a structured approach towards building resilience of WaSH infrastructure in coastal cities.

1. *Mapping the Existing Infrastructure and Services*: The existing infrastructure and services have been mapped and analysed based on data gathered from various sources on performance, coverage, socio-spatial variability, technology, governance, key stakeholders, existing policies, climate change initiatives, financial health of the ULB, budgets, and future projects
2. *Identifying the Infrastructure Exposure and Vulnerability*: The climate hazards faced by the settlement have been identified based on literature review. Three critical coastal risks—flooding and inundation, storm surges and coastal erosion, and saltwater intrusion—have been considered. Satellite data has been utilized to assess land use and land cover (LULC), elevation, built-up footprints, road networks, shoreline change detection, mangrove and water bodies, storm surge locations, and flood risk zones. This data has been overlaid with information from municipal bodies on administrative boundaries, flood hotspots, population distribution, critical utility locations to identify the exposure. Primary data on water usage, sanitation practices, water quality, access disparities, socioeconomic vulnerability, behavioural practices, and exposure history collected through discussions, interviews, household surveys, and ground-truthing via transect walks and visual surveys were further collated and overlaid to identify ward level exposure and infrastructure vulnerability.

3. *Assessing the resilience:* The adequacy, flexibility and reliability of the infrastructure, its governance and financial sustainability and systemic gaps have been identified and assessed along with the exposure and vulnerability. The summary of risks to WaSH infrastructure provide insights into the resilience measures needed for the coastal town.

7.3 EXPOSURE TO CLIMATE RISK

Goa experiences a hot summer (April- June) followed by a pleasant monsoon (June-September) season; temperatures temporarily rise again in the month of October, following pleasant winter months (November - March). Goa is witnessing higher levels of temperature increase compared to the national average. The long period average mean temperature in Bardez taluka ranges around 27^o Centigrade.

The state is already vulnerable to flooding, increasing heavy rainfall trend makes the state even more vulnerable to this hazard. *The average annual rainfall in Goa is about 3000 mm, nearly three times higher than the national average with most of the rain concentrated between June – August months. Mean annual rainfall in Goa has increased by about 68 % over the last century.* Mean annual rainfall in North Goa is found to have increased from about 3000 mm in 1901 to about 5000 mm in 2015 (an increase of 66 %). The frequency of light and moderate rainfall events has declined over the last century, whereas the frequency of extreme rainfall events has increased in Goa over the last century. The number of rainy days experiencing heavy rain, i.e. 64.5 – 124.4 mm rainfall in a day, has increased by about 60 %. Rainy days with extreme rainfalls (very heavy and exceptionally heavy), have increased by an alarming more than 100 % and these result in devastation (NABCONS, 2023)²⁰.

Mapusa lies in the riverine system of Goa close to the Mapusa river also called the Moira River which belongs to the Mandovi river system. A very large quantity of fresh water for Goa flows down from the Mandovi. Core catchment of Mandovi or Mahadayi as it is called lies in the heavy rainfall, thickly forested, approximately 200 sq. km of mountain topography of Khanapur taluka of Karnataka State. Every variation in the Mahadayi water level in these upper reaches is thus crucial for Goa's water security. *Mapusa River (stretch from Mapusa to Britona) has been identified by the Central Pollution Control Board as one of the 8 most critically polluted river stretches of Goa.* It has been indicated that the untreated wastewater, sewage that are released is responsible for increasing pollution of the river water.⁷¹

Mapusa is at 7 kms from the coast and has approximately 17% of administrative land at an elevation of less than 5 m above MSL and less than 30 % land lying at an elevation less than 10m above MSL. This low-lying land lies towards the south and southeast of Mapusa and is prone to flooding due to precipitation (Refer Figure 26). Mapusa has seen flooding in recent years due to heavy rainfall events during monsoons. Mapusa has lesser

vulnerability from coastal erosion or sea level rise compared to other coastal towns and cities.

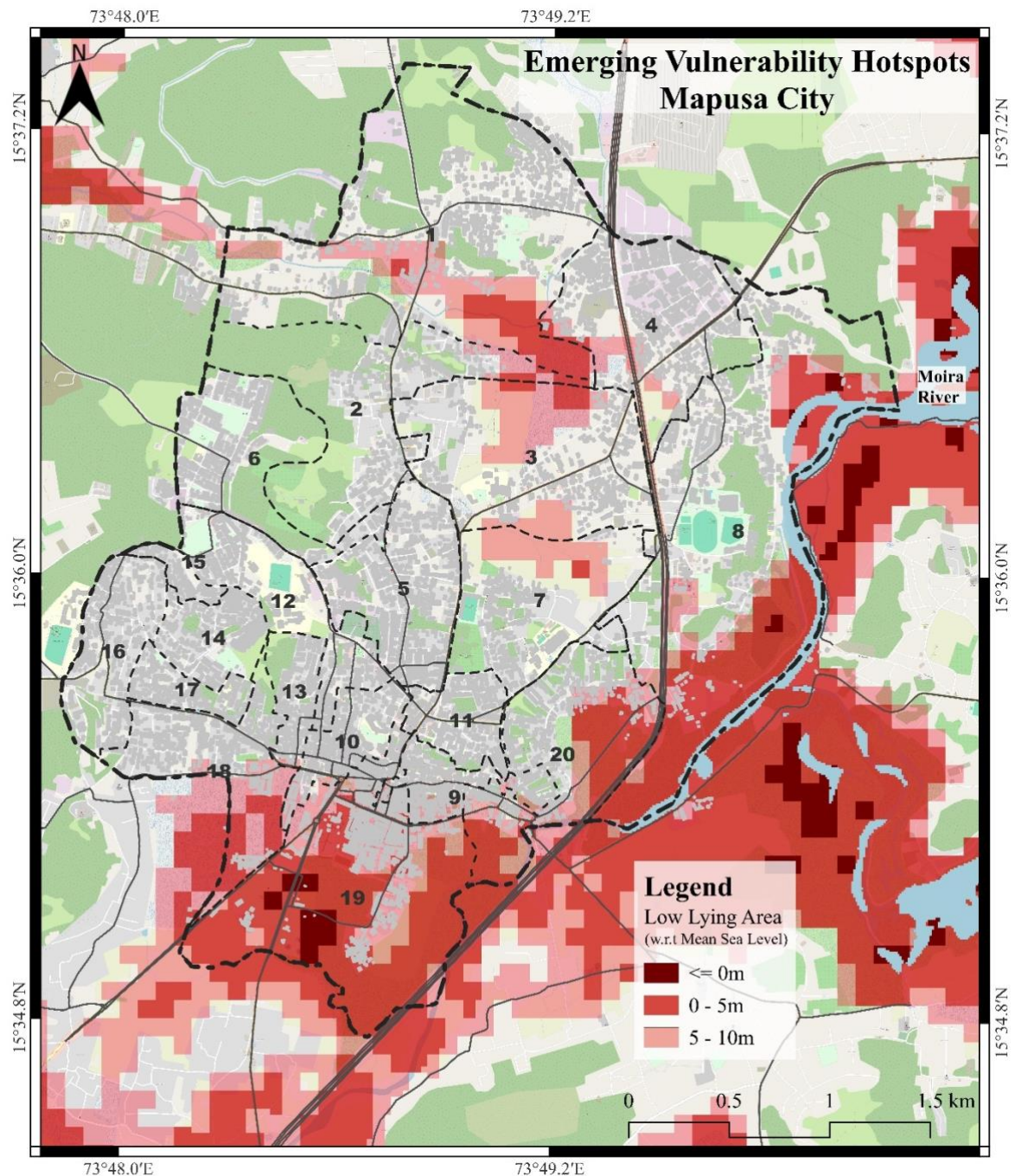
MMC does not get directly impacted by cyclones, according to local body officials engaged with during field studies. However, some cascading risks like uprooted trees, damage to some houses in Mapusa and debris accumulation was faced in certain areas due to Cyclone Tauktae in 2021. Similarly, Cyclone Mora in 2017 triggered heavy rainfall, resulting in ankle-deep flooding in several low-lying areas around the town. Poorly maintained drainage system and drainage issues in monsoon seasons have been identified as the primary reason for the flooding experience by Mapusa in recent monsoons. Tropical cyclones produce torrential rainfall leading to flooding, damaging winds, storm surge and coastal flooding near the coast within the storm path which can result in severe damage to critical infrastructure.

Draft State Water Policy (2015) for Goa states that despite copious annual rainfall, rivers of Goa have very low flow for the non-monsoon months resulting in scarcity of drinking water for the period especially in the months of April to start of June. Moreover, the narrow width of the state, steep slopes of Western Ghats, porous sub-stratum, non-uniform distribution of rainfall over time and space cause temporal imbalances of water availability in the state. This also explains the paradox that though Goa is situated in high precipitation zones, it has one of the lowest per capita freshwater availabilities.

In low elevation coastal zones and floodplains, severe flooding occurs when the soil is saturated and infiltration is minimum, water levels in creeks and rivers are elevated after a prolonged spell of monsoon rains and ground water levels rise - the flood water is unable to recede. These flood-like situations result in inundations which can continue from several hours to many days as seen in many low-lying coastal cities and towns. In a dense built-up area, an intense rainfall burst within a brief period can also result in flash flooding. Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area. Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanization of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.⁷²

Around 30 % of the administrative area lies less than 10 meters above mean sea level (MSL). The increasing monsoon rainfall and the increasing number of very heavy rainfall days have heightened the city's vulnerability to flooding and inundation. The Mapusa River is a natural conveyance system however due to issues of siltation and pollutions has lesser carrying capacity. The town also does not have adequate drainage systems or retention bodies to hold the runoff. The high groundwater level during monsoons further aggravates the situation during monsoons. Mapusa has been facing urban flooding in the recent years.

Figure 26: Emerging vulnerability hotspots in Mapusa town



Source: Derived from Open Street Map; Landsat 9 (Shoreline), 2020; Landsat 5 (Shoreline), 2010; Mapusa Municipal Council; SRTM DEM

However, Mapusa faces significant flooding despite this, which indicates that the infrastructure is unable to handle the excess rainfall. The footprint of the town is primarily towards its south and southwest.

Table 18: Ward level Elevation and vulnerability to flooding.

Ward no	Highly vulnerability to flooding (<5 m)	Vulnerable to flooding	Low vulnerability to flooding (>10m)	Ward no	Highly vulnerability to flooding (<5 m)	Vulnerable to flooding	Low vulnerability to flooding (>10m)
1	7.3%	22%	78%	11	0.0%	0%	100%
2	2.2%	6%	94%	12	0.0%	0%	100%
3	3.8%	27%	73%	13	0.0%	3%	97%
4	2.1%	12%	88%	14	0.0%	0%	100%
5	0.0%	0%	100%	15	0.0%	0%	100%
6	0.0%	0%	100%	16	0.0%	0%	100%
7	1.4%	19%	81%	17	0.0%	0%	100%
8	37.2%	47%	53%	18	19.4%	40%	60%
9	0.5%	30%	70%	19	67.3%	96%	4%
10	1.2%	12%	88%	20	34.7%	59%	41%

Source: GIS Analysis

Land use surface in urban settlements is made of roofs, streets and others paved surfaces and can be estimated from the built-up footprint of the city. Runoff flows through impervious surfaces to the storm-sewers or towards the natural conveyance regime of the ecosystem. It also changes the hydrologic cycle, increasing the overland flow, reducing groundwater flow and with peak discharge increases the flood frequency.

Based on the ward level elevation analysis (*Ref. Table 18*), Wards 8, 19 and 20 are the most prone to flooding because they are low lying. These are wards which have among the least built footprint; an indicator considered a proxy for population distribution.

The riverine water system of Goa and the creeks and backwaters are vulnerable to high-intensity precipitation scenarios predicted for the state. The brackish water areas have very rich ecosystems and exist along creeks and rivers. Some are protected by sluice and gate systems, whereas others are at risk of ingress saline water due to climate change. Groundwater extraction is not well regulated, and saltwater intrusion is likely to increase into the groundwater system. As the sea level rises, this problem will be further exasperated. The high groundwater levels in certain areas challenge the soil's water percolation capacity (NABCONS, 2023).

As mentioned in the State Action Plan for Climate Change though Goa is in high precipitation zones, it has one of the lowest per capita freshwater availabilities. The draft state water policy 2015 presents various challenges the state faces in utilizing water resources. The rivers are prone to tidal variations up to 40 km inland and seasonal water availability variations. Water sources in the mining zones, water scarcity has been increasing due to the withdrawal of groundwater and the non-replenishment of wells.

However, with depth to water level (May 2019) both pre and post monsoon recorded in the Bardez and specifically in Mapusa shows it in the range of less than 2 mbgl. Mapusa and the Bardex taluka are in the safe ground water category as per CGWB reports.⁷³ However, surveys undertaken in the field reveal that tankers play an important role in filling the gaps in municipal water supply in some of the locations in ward 9 and 11.

Mapusa is in a relatively safe zone with respect to earthquakes and falls under seismic zone III (MSK intensity VII), which means it is exposed to moderate seismic activity and is more prone to minor to medium-intensity earthquakes. Seismic activities can compound coastal risks like subsidence of land, change in ecological system, diversion of river flow or tsunami leading to extreme high waves as has been witnessed in Kutch coasts. Similarly, co- occurrence of two or more hazards has often been witnessed for example earthquakes and landslides, earthquakes and heavy precipitation. In a recent study appearing in Science Advances, the researchers report that episodes of heavy snowfall and rain likely contributed to a swarm of earthquakes over the past several years in northern Japan. The study is the first to show that climate conditions could initiate some quakes.⁷⁴

7.4 VULNERABILITY OF THE WASH INFRASTRUCTURE

The vulnerability of the WaSH infrastructure analyses the status of the infrastructure with respect to its adequacy, reliability, and risk governance. Adequacy has been investigated respect to coverage of the services, suitability of technology, safety of infrastructure based on its age. Reliability of the services has been studied based on data where available on outages, response and recovery including contingencies and redundancies, ownership and accountability and provision of monitoring and regulation of the systems. The infrastructure risk governance looks at the financial stability and safeguards, autonomy in decision making, and jurisdictions regarding preparedness and recovery in the context of disasters.

7.4.1 ADEQUACY OF INFRASTRUCTURE

Water is sourced from an interstate Irrigation Project, a crucial minor irrigation tank that supports both agriculture and drinking water supply and the Assonora River, facing challenges such as siltation, pollution, and seasonal flow variations. Much of the existing water supply infrastructure is ageing, leading to frequent breakdowns, leaks, and high levels of non-revenue water. Nearly one third of the water procured is lost before water reaches consumers, reducing efficiency and wasting a crucial resource.^{75,76,77} (Refer Chapter 3)

Mapusa's undulating terrain poses challenges for equitable water distribution. Hilly areas and locations farther from storage and pumping stations experience lower supply pressure and frequent shortages, while other areas receive more consistent supply, creating disparities in access.

The town faces challenges with its sanitation infrastructure, which is primarily due to technology inadequacies. The town depends on onsite sanitation systems and the sewerage network development had to be halted due to overflow and backflow in sewage in low-lying areas. Poor drainage system and faulty sewerage network has for a frequently flooded town is a cause of concern. (Refer Chapter 4)

7.4.2 RELIABILITY, FLEXIBILITY AND REDUNDANCY

Reliability of large-scale water systems are often dependent on access to adequate water sources, adequate capacities to handle the systems, reliable access to energy for pumping and conveyance. Similarly, the success of offsite sewerage conveyance and treatment through centralised sewerage networks and STPs for safe sanitation systems is dependent not only on land availability, willingness of residents to convert individual household systems, but also dependent on access to energy for pumping the sewage to the treatment plant in low lying areas and reverse terrain conditions and for the treatment process, access to funding for technology and its operation and maintenance. Capacities of local bodies in terms of skills, staffing and funding for continuous operation of the systems is another dependency which often leads to unreliable services and higher susceptibility to shock events, particularly in smaller cities and settlements.

Source sustainability and reliability is an emerging need for most burgeoning cities including Mapusa. The town relies heavily on water sourced from upstream dams located far away. Breakdowns and leakages while sourcing has resulted in frequent outages, high levels of non-revenue water, and inadequate access.

Dependence on highly energy-intensive pumping systems in water procurement, makes the water systems susceptible to outages. Strong winds and cyclones, as faced by Mapusa, can damage overhead electrical networks, and can impact impacting water pumping and treatment facilities. Much of Goa's electricity is procured from outside the state and this increases the vulnerability of energy dependent infrastructure.

There is need to build in redundancy in water supply system as Mapusa's water supply system is prone to frequent breakdowns and outages. Long networks of centralized sewerage are not only difficult to maintain for undulating and low-lying terrains but can be unfeasible due to corrosion, leakages, reverse flows, and need for frequent uphaul.

7.4.3 INFRASTRUCTURE RISK GOVERNANCE AND FINANCE

Effective governance is essential for resilient infrastructure. This involves the policies, frameworks, norms, processes, and tools that public bodies use to plan, decide on, implement, and monitor the entire lifecycle of public infrastructure. In the context of resilience, governance transformation may include progressive decision-making, regular

updates to codes and standards, comprehensive regulatory frameworks, and dedicated risk and resilience funding.

The involvement of multiple agencies in WaSH infrastructure development has limited the ability of ULBs to efficiently manage resources and address local needs. This is a finding from the multiple towns and cities explored to assess the resilience in WaSH infrastructure. Similarly in sanitation, Special Purpose Vehicles (SPVs) and Public Works Department lead infrastructure development, has resulted in lack of clarity on service access and coverage at a local level.

IPCC in its Summary for Policy Makers – the special Report of 2019 highlights how intensifying cooperation and coordination among governing authorities across scales, jurisdictions, sectors, policy domains and planning horizons can enable effective responses.

As an example, the water supply system of Mapusa is dependent on outside the state water sources - Tillari Irrigation Scheme, on interstate resource sharing pacts and revenue sharing. Similarly in sanitation, Special Purpose Vehicles (SPVs) and state-level institutions lead infrastructure development, overseeing technology approval, selection, implementation, and capital provision for large-scale projects. *This exclusion of ULBs has left them unaware of data on service access.* The state government must take proactive measures to ensure effective devolution of administrative power, funds, and functions to ULBs, in line with the 74th CAA provisions is undertaken in true sense.

Governance arrangements, in many contexts, too fragmented across administrative boundaries and sectors to provide integrated responses to the increasing and cascading risks from climate-related changes in the ocean and/or cryosphere (high confidence). The capacity of governance systems is not sufficiently rapid or robust to adequately address the scale of increasing projected risks (high confidence).⁷⁸

Private sector service providers like desludging services and water tankers meet a critical gap during service fluctuations and outages. Due to the absence of its own desludging vacuum trucks or FSSTP, the city relies on private operators. Effective regulation is essential to maintain affordability for residents, uphold best practices, and support long-term sustainability.

SAPCC in its Sectoral Adaptation Strategies for Water Supply specifically mentions that though Goa is situated in high precipitation zones, it has one of the lowest per capita freshwater availabilities. The rivers are prone to tidal variations up to 40 km inland and lead to seasonal water availability variations. The key adaptation strategies for water sectors outlined are adaptation of water-related infrastructure appropriate planning of water to ensure water supply to all, maintenance of water resources to avoid flooding and to keep related infrastructure functional during peak events and disasters and raising awareness (NABCONS. , 2023).

NOTES & REFERENCE

- ⁷⁰UNDRR, C. (2023). Global Methodology for Infrastructure Resilience Review. United Nations Office for Disaster Risk Reduction (UNDRR) and Coalition for Disaster Resilient Infrastructure (CDRI).
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- ⁷⁷TOI. (2024, February 22). WATER supply to most parts of Bardex affected for 2 days. Goa.
- ⁷⁸IPCC. (2019). Summary for Policy Makers, Special Report: Special Report on the Ocean and Cryosphere in a Changing Climate, Sixth Assessment Report. IPCC.

ANNEXURE-I: DATA COLLECTION & VALIDATION

Desk Based Research: An extensive desk study was conducted to review existing literature and collect secondary data from various government sources. The study utilized secondary data and information from a range of national, state, district, and town-level sources, including the Census, National Family Health Survey, SBM-U, Central Pollution Control Board, Performance Assessment System for urban water and sanitation (PAS) website, District Disaster Management Plans, and the municipality website. Additionally, the review was instrumental in mapping key stakeholders, defining their roles and responsibilities, and developing the analytical framework for various thematic studies, including GHG emission estimation.

The desk study not only informed the overall research design but also facilitated the identification of data gaps and discrepancies, which subsequently guided the development of data collection protocols as well as the planning and execution of the fieldwork.

Field Work: To address data gaps, validate secondary data, and resolve data discrepancies, the study incorporated rapid field assessments, site visits, and semi-structured interviews. These interviews were conducted with residents, as well as district and municipal officials from the town planning, water and sanitation, sewerage, public works, and disaster management departments. Field work also involved mapping of the critical infrastructure in the water and sanitation sector.

Secondary Data Collection from Town Water and Sanitation Departments: Meetings with ULB were held to collect a wide range of documents and data, including city maps, land-use and land cover maps, and electricity bills. Additional information was gathered on SLB indicators, SBM-U, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), financial reports, and other relevant datasets. We also obtained detailed information on Underground Drainage (UGD) network coverage in the city. Furthermore, data on the number, condition, and operation and maintenance (O&M) structures of community toilets (CTs) and public toilets (PTs) in the city were collected to better understand the scale and performance of the existing sanitation infrastructure.

Semi-Structured Interviews: In Mapusa Municipal Council (MMC), we interviewed (semi-structured interviews) key ULB officials—including the, Environment inspector (2) and, SBM-U Coordinator (1), to understand the status of water and sanitation infrastructure and services, as well as to gather information on recent and past extreme events—such as floods, droughts, cyclones and heavy rainfall—and their impacts. These discussions also

provided insights into the effects of climate change as experienced locally. Importantly, the interviews helped identify vulnerable areas and communities within the town, which informed the design of the rapid assessment study.

As Goa is primarily governed at the state level, major infrastructures such as STPs and WTPs are operated and maintained by state authorities. Accordingly, we held interviews with engineers from PWD, Chief Engineers (3), Subdivision Engineer (1), Engineers in Sewage & Infrastructure Development Corporation of Goa Ltd., the Director of Directorate of Municipal Administration (DMA), and the Senior Project Engineer of Goa State Urban Development Agency (GSUDA) (2).

- **Site Visits:** Regarding sanitation, no site visit was conducted, as town does not have STP or Faecal Sludge Treatment Plant (FSTP). For water, the team visited infrastructure such as WTPs, Elevated Level Storage Reservoir (ELSR) and Ground Level Storage Reservoir (GLSR). These visits focused on gathering information on operational status, environmental compliance, and electricity consumption. These site visits also facilitated the integration of critical infrastructure into the GIS platform for further spatial analysis.
- **Rapid field assessment:** The assessment process included on-ground observations and semi-structured interviews with the residents, with a particular focus on hot-spots such as low-income neighbourhoods, areas vulnerable to extreme events, low-lying areas and densely populated clusters. These were determined during interviews with the ULB officials and using spatial proximity between WaSH structures to highlight zones with high vulnerability. Areas exhibiting both low elevation and high building density were mapped as potential hotspots for field investigation. Municipal officials were asked to suggest locations that would yield greater diversity for sampling.

These interviews were designed to validate and triangulate data gathered from secondary sources on WaSH, offering valuable insights into the state of local infrastructure and the lived experiences of residents—particularly during past high-precipitation events, cyclones, and storms—with a focus on vulnerable communities.

The process involved on-ground observations and in-depth conversations with residents (19#), particularly in low-income neighbourhoods and areas identified as vulnerable to extreme events during interviews with ULB officials. The emphasis was on understanding challenges related to access, affordability, and reliability of water and sanitation services in the context of climate change. Residents were asked whether they had private toilets on their premises, and if so, the questions focused on how and where human waste was disposed of. In cases where onsite sanitation systems (OSS) were used, we gathered information on the type of system, frequency and cost of septic tank cleaning, service providers involved, and affordability and other challenges of these services. Additional questions covered methods of

greywater disposal, sources of tap water, costs associated with water connections, and any support received from the ULB during disaster events. For households without individual toilets, we explored the alternative sanitation arrangements they relied on.

The team engaged with 19 residents across the city, carefully selecting locations to cover a range of socio-economic backgrounds. Our questions with residents focused primarily on service access and quality.

A preassessment of the town was undertaken to low-lying zones through digital elevation mapping and identification of densely built-up localities using spatial proximity between buildings. These areas where both criteria overlapped were designated as vulnerability hotspots and prioritized for field visits. Eleven hotspots were identified through this method. These locations were further explored through semi structured surveys, visual observations and consultation with municipal officers to understand the coverage and type of access to basic services, disparities if any and efficiency of the services and any emerging concerns with respect to emerging risks.

The study findings were shared during a stakeholder and expert consultation workshop held on 13th August 2025, with participation from State Public Works Departments, ULBs, and State Pollution Control Boards. The feedback and comments received have been incorporated into the town assessment reports, details of which are provided in the annexure-III. The workshop also helped define the way forward for the research team.

ANNEXURE-II: DATA GAPS

The analysis of Mapusa's urban water system and associated GHG emissions is constrained by several critical data gaps and methodological limitations:

Lack of Updated Demographic Data: The absence of population data beyond the 2011 Census makes it difficult to accurately assess current and future water demand, per capita supply, and wastewater generation. This affects both service planning and emissions estimation.

Absence of Accurate Consumption and Supply Data: Operational flow meters are not installed or non-functional at critical points in the supply network, including at distribution inlet points for Mapusa. This hampers the estimation of actual water supplied, sectoral consumption (domestic vs commercial), and non-revenue water.

Uncertainty in Groundwater Use and Recharge: There is no disaggregated data on groundwater abstraction volumes, recharge rates, or the number of active borewells. This limits the ability to assess groundwater sustainability and its share in the overall water supply.

Unaccounted Transmission and Distribution Losses: GHG emissions calculations for water supply do not include energy and emissions associated with transmission and distribution losses, which could be as high as 20–40%. This likely leads to an underestimation of total emissions.

Incomplete Sanitation and Wastewater Data: Reliable data on household sanitation access, desludging frequency, treatment coverage, and wastewater flows is lacking. The absence of wastewater flow or sludge volume tracking affects the estimation of methane and nitrous oxide emissions from sanitation systems.

Tourism-Driven Seasonal Demand Not Captured: Peak-season variations in water demand and wastewater generation due to tourism are not separately accounted for in the absence of data from hotels, guesthouses, or temporary residents.

These data limitations underscore the need for improved monitoring systems, updated demographic surveys, and coordinated data sharing among local utilities, government departments, and urban bodies to inform more accurate and climate-resilient water and sanitation planning. Further, the project design necessitated a comprehensive review of secondary data sources pertaining to the water and sanitation sector and climate change across various levels—national, state, district, and town. This exercise highlighted several significant data gaps, which are detailed below.

1. *Typology of Individual Household Toilets and OSS Systems*: Understanding the typology of individual household toilets and on-site sanitation systems is essential for assessing current levels of access to sanitation infrastructure and determining whether these constitute improved sanitation services. This information is a key indicator for tracking progress towards the SDGs and is relevant for climate adaptation frameworks. Additionally, it plays a critical role in estimating GHG emissions from the sanitation sector. However, the last comprehensive assessment of household toilet typologies was conducted during the 2011 Census, and no updated data is currently available from national, state, or city-level sources. The National Family Health Survey-5 (2019–2020)¹ provides district-level data on access to improved sanitation facilities, defined as the “population living in households that use an improved sanitation facility.” However, disaggregated data at the town or municipal level is not available. Collecting such data would require a detailed household-level survey.
2. *Operational Status of Community and Public Toilets*: Community and public toilets are intended to serve populations without access to individual sanitation facilities, as well as the floating population in public spaces. The operational status of these facilities—including aspects such as functionality, availability of water supply, and cleanliness—is a key requirement under the ODF+ certification framework. According to the Ministry of Housing and Urban Affairs (MoHUA) guidelines, ULBs are mandated to conduct regular audits of these facilities. However, data on the coverage and adequacy of community and public toilets and operational status is not available with the ULB.
3. *Data on Storm Water Drainage*: The role of stormwater drainage systems in urban resilience is well recognized. However, the data available at the town level is limited to information on overall coverage and does not provide details on the typology of the drainage systems—such as whether they are open or closed, underground or surface-level, mapped or unmapped, or man-made or natural. A comprehensive understanding of these aspects would require detailed studies.
4. *Integrated role of Sewerage Network, Creeks, and Nallahs*: It is essential to determine whether natural and man-made water bodies—such as creeks and nallahs—are integrated into the town's wastewater and stormwater management systems, and to clarify their functional roles, whether they carry greywater, blackwater, stormwater, or a combination of these. Equally important is evaluating the degree of interconnection between these natural channels and engineered infrastructure. However, such information is not available through secondary data sources, and the ULB does not maintain a detailed sewerage network map.

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ANNEXURE-III: POPULATION PROJECTIONS

Population forecasting is a critical component of water infrastructure planning. Accurate projections help in determining future demand, sizing infrastructure appropriately, and ensuring climate-resilient water service delivery. In this appendix, population projections for the town are made using historical census data from 1981, 1991, 2001, and 2011. To improve robustness, four standard projection methods have been applied:

1. Arithmetic Increase Method

This method assumes that population increases by a constant absolute number in each decade, based on the average of past increases.

$$P_n = P_0 + n \times \bar{I}$$

Where:

- P_n : Projected population after n decades
- P_0 : Last known population
- $\bar{I}$: Average increase per decade = (Sum of past population increases) ÷ (Number of decades)

Strengths:

- Useful where population growth is stable and linear

Limitations:

- Does not account for accelerating or decelerating growth
- May underestimate or overestimate population in dynamic urban areas

2. Incremental Increase Method

This method improves upon the arithmetic method by incorporating the average increment in population increase, assuming growth is accelerating or decelerating.

$$P_n = P_0 + n \times \bar{I} + \frac{n(n-1)}{2} \times \bar{R}$$

Where:

- $\bar{R}$: Average incremental increase per decade = (Sum of changes in decadal increases) ÷ (Number of increments)

Strengths:

- Captures trend in rate of growth
- More reflective of population dynamics than the arithmetic method

Limitations:

- May become inaccurate if future trends deviate sharply from past patterns

3. Geometrical Growth Rate Method

This method assumes the population grows at a constant percentage (compound) rate, calculated from historical growth.

$$P_n = P_0 \times (1 + r)^n$$

Where:

- r : Average decadal growth rate = [(Population in latest year ÷ Population in previous year) – 1]

Strengths:

- Suitable for rapidly growing urban areas
- Accounts for compounding effects of growth

Limitations:

- May overestimate population if growth slows in future
- Sensitive to anomalies in historical data

4. Graphical Method

In this method, historical population data is plotted on a graph, and a curve is drawn to best fit the trend. Future population is estimated by extrapolating the trend line.

Strengths:

- Visually intuitive & Can reflect non-linear growth patterns

Limitations:

- Subjective: results depend on visual judgment and quality of trend fit
- Requires careful interpretation of curve shape

Final Projection Approach

To establish a baseline in the absence of recent census data, we adopt an average four distinct projection methods. This mitigates individual model extremes and balances simplicity with compounding trends to offer a rather stabilised estimate. While we maintain strong reservations about the capacity of static models to capture the highly fluid realities of coastal growth, we employ this averaged methodology primarily out of pragmatic necessity: it is the established industry standard for urban planners and Detailed Project Reports (DPRs), ensuring our analysis remains interoperable with existing municipal frameworks and policy planning.

Detailed Calculations:

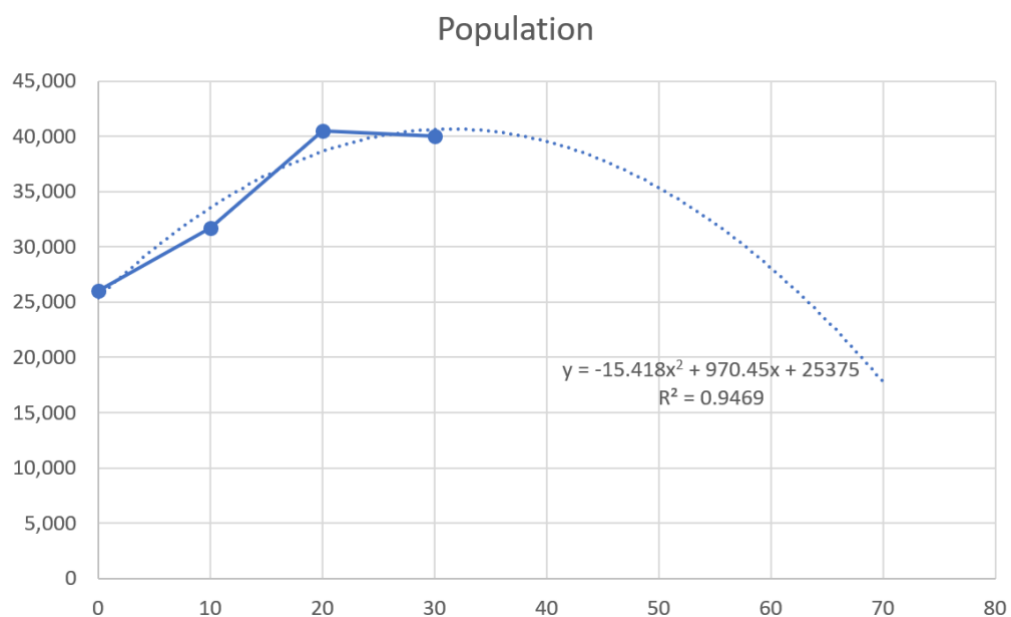
Year	Population	Increment	Incremental Increase	Decadal Growth Factor
1981	25,998			
1991	31,667	5669		1.21805524
2001	40,487	8820	3151	1.27852338
2011	39,989	-498	-9318	0.98769976

Average Increment 4663.666667

Average Incremental Increase -3083.5

GM Decadal Growth rate 1.154339441

GRAPHICAL METHOD



Note: For X-axis 1981 is the base year: X=0 (1981) X=10 (1991)

POPULATION PROJECTIONS

Year	Census Population	Projected Population				
		Arithmetic	Incremental Increase Method	Geometrical Growth Rate	Graphical method	Average
1981	25,998					
1991	31,667					
2001	40,487					
2011	39,989	39989	39989	39989	39989	39989
2021		44653	41569	46161	39524	42977
2025		46518	41338	48889	38226	43743
2031		49316	40066	53285	35353	44505
2041		53980	35479	61509	28097	44766
2051		58644	27809	71003	17758	43803

PROJECTED POPULATION BASED ON HISTORICAL POPULATION DATA



ANNEXURE-IV: STAKEHOLDER CONSULTATION WORKSHOP: KEY HIGHLIGHTS AND WAY FORWARD

WORKSHOP TITLE: 'CLIMATE RESILIENT URBAN WATER AND SANITATION INFRASTRUCTURE SERVICES IN COASTAL TOWNS'

Programme Highlights

On **13th August 2025**, the **Stakeholder Consultation Workshop on Climate Resilient Urban Water and Sanitation Infrastructure Services** was held at **VMCC, Room No. 21, Indian Institute of Technology Bombay, Mumbai, Maharashtra**, in a **hybrid format** accommodating both in-person and online participation. The workshop brought together **policymakers, experts, practitioners, and project partners** from Maharashtra, Goa, Gujarat, and Karnataka to discuss challenges and opportunities in enhancing the resilience of water and sanitation systems in coastal towns. It provided a platform to **share project findings, examine policy and governance frameworks, and explore strategies for integrated, climate-responsive urban infrastructure planning**, fostering dialogue aimed at strengthening the adaptive capacity of urban water and sanitation services.

The workshop commenced with **registration from 9:00 AM to 9:30 AM**, followed by a **welcome address by Prof. NC Narayanan, Ashank Desai Centre for Policy Studies, IIT Bombay**, at 9:30 AM, who set the context for the discussions ahead. This was followed by an overview of the project by **Mr. Romit Sen, HSBC-India**, highlighting the objectives, scope, and significance of the Landscape Analysis for Climate Resilient Coastal Cities.

From **9:55 AM to 10:50 AM**, the **project highlights** were presented. Prof. NC Narayanan began with an overview of the background, tracing the history of water and sanitation research conducted by the lab, which laid the foundation for the HSBC project. He highlighted the rationale for the project, the significance of the West Coast, and why this region was chosen. This was followed by a presentation on the **Urban Water-Energy-Climate Nexus** by Mr. Ashish Dangi, which outlined the research framework and underscored the interconnections between water, energy, and climate. Subsequently, **Dr. Neelam Rana** presented on **Policy, Governance, and Finances in WaSH and Climate Change**, providing a comprehensive overview of the current landscape, key challenges, and potential opportunities for enhancing climate resilience. The presentation highlighted that policies remain largely focused on **adaptation**, which is appropriate in a developing country context where ensuring access to basic services such as water and sanitation continues to be a priority. The session emphasized the importance of generating evidence on GHG reductions in the WaSH sector to inform mitigation policies. The

session concluded with a **discussion and Q&A**, allowing participants to clarify key aspects of the study and share preliminary observations.

The session was followed by **tea and town-level poster presentations from 10:50 AM to 11:25 AM**, enabling participants to engage directly with the project team and explore data, findings, and visual insights from individual coastal towns.

State-wise discussions were held from 11:25 AM to 12:45 PM, moderated by domain experts:

- **Karnataka:** Mr. Vishwanath S, BIOME Environmental Solutions
- **Goa:** Mr. Depinder Kapur, National Institute of Urban Affairs (NIUA)
- **Maharashtra:** Ms. Lubaina Rangwala, World Resources Institute (WRI)
- **Gujarat:** Prof. Ajay Deshpande, IIT Bombay

These sessions facilitated a deep dive into state-specific and town-specific challenges, opportunities, and lessons learned from local implementation of urban water and sanitation systems, including climate and disaster resilience considerations.

From **12:45 PM to 1:15 PM**, participants gained practical insights from **field implementation in three coastal towns of Maharashtra—Malvan, Dhanu, and Guhagarh**. The session was presented by **Mr. Irfan from the Centre for DEWATS Dissemination (CDD), India**, highlighting on-the-ground experiences, key challenges in service delivery, and innovative approaches adopted to enhance the resilience of water and sanitation infrastructure in smaller towns. Additionally, Mr. Irfan showcased the **vulnerability assessment tool developed by CDD-India as part of the project**, which aids in evaluating climate and disaster risks to water and sanitation infrastructure at the local level.

After the **lunch break**, the **Feedback and Way Forward Session** was held from **2:15 PM to 4:15 PM**. This session brought together **key partners and experts**, including Mr. Amit Mishra (India Sanitation Coalition), Mr. Irfan (CDD India), Mr. Romit Sen (HSBC India), Mr. Vishwanath S, Mr. Depinder Kapur (NIUA), Ms. Lubaina Rangwala (WRI), and Prof. Ajay Deshpande (IITB), who discussed **actionable recommendations, capacity-building needs, and strategies for future collaboration**. The session also featured contributions from **state and city representatives**, such as **PWD officials from Goa, CO Vengurla, MPCB officials, and officials from Mangaluru and Karwar**, whose feedback, suggestions, and observations provided valuable insights and guidance for the project team.

The workshop concluded with a **vote of thanks from 4:15 PM to 4:30 PM**, followed by **high tea at 4:30 PM**, marking the close of a productive day of knowledge sharing, deliberation, and collective strategizing for climate-resilient urban water and sanitation infrastructure in coastal towns.

Key Discussion Points

1. Maharashtra

During the Maharashtra session, several observations and recommendations were shared. Ms. Lubaina Rangwala emphasized that climate financing currently favors large cities, while small and medium-sized towns remain underserved. She highlighted the need to make tier-3 cities future-ready, through cross-sectoral and networked thinking, incremental funding, and decentralized options that generate co-benefits, particularly for coastal livelihoods.

Mr. Irfan from CDD shared insights from work in Malvan, Dhanu, and Guhagarh, emphasizing the importance of source strengthening in smaller towns and accounting for tourism's impact on local water, sanitation, and solid waste management systems. He noted technical and financial gaps in implementing infrastructure plans and suggested the development of localized, climate-resilient treatment systems.

Alibag, Vengurla, and Ratnagiri: While no specific sectoral recommendations were recorded for these towns, the general discussion reinforced the importance of focusing on smaller towns with limited service delivery infrastructure.

2. Karnataka

Mr. Vishwanath S highlighted the potential of treated wastewater for groundwater recharge, emphasizing co-benefits in cost savings, water conservation, energy savings, and climate change mitigation. He noted that political and operational challenges often limit the functionality of STPs and stressed the need to incorporate these challenges into reports.

Groundwater recharge in coastal towns was flagged as challenging due to high salinity levels. Discussions around financial sustainability highlighted discrepancies in cost recovery, with **Mangaluru** and Kundapura achieving over 95%, whereas Karwar had not yet reached the 50% mark. Mr. Vishwanath S also underscored the low level of service delivery and the need for adaptation-focused interventions.

Karwar: The Commissioner noted that STPs frequently stop functioning due to drought, monsoon flooding, and high tides, which cause corrosion in metal components. It was recommended to replicate models from Mangaluru and Kundapura, including engaging private vendors for utility management.

Mangaluru Officials highlighted that STPs are outdated, with end-of-life expected by 2026, and suggested adopting modern sewerage network techniques to detect and fix missing connections. Pricing and cost recovery remain a challenge, with reported O&M losses of INR 15–16 crore, although updated data indicates higher recovery.

3. Goa

PWD officials shared that Goa relies heavily on deep borewells and has implemented a 100% metering system with annual tariff increases of 5%. Non-revenue water (NRW) is estimated at 25%, with 15% attributable to manual errors. Initiatives include smart metering (3,000 units in Panaji), free water up to 16m³, and slab-wise tourism tariffs. They aim to supply 24×7 water and are planning energy audits to optimize energy use per cubic meter.

Mr. Vishwanath S and Goa, PWD officials noted that energy audits for water supply are underway, but GHG emissions are not currently a primary focus for the state. Challenges include high turbidity in raw water and local religious constraints on supply timing. Officials emphasized the need for unified platforms for dialogue and knowledge-sharing to improve WASH infrastructure performance.

Mapusa: The town sources water primarily from the Sal River, with a high water table and salinity concerns. Financial challenges were noted regarding one-time settlement schemes for water revenue, which were not continued after 2021–22.

4. Gujarat

Prof. Ajay Deshpande highlighted models for small and medium towns to assess WASH systems and evolve into climate-resilient cities. He recommended standards for abstraction and infrastructure and suggested policy advocacy measures. Ms. Nagma Modi, representing Valsad town, noted severe waterlogging and flooding in coastal areas of Valsad, requiring immediate attention. Mr. Depinder Kapur explained methods used to estimate population growth and future water demand for planning purposes.

5. Expert Panel Comments and General Observations

Across states, several general observations emerged. Prof. Satish Agnihotri suggested triaging ODF data with health metrics to identify towns where sanitation systems are failing or where positive outcomes can be studied. Mr. Vishwanath S emphasized the need to ring-fence water utilities and upgrade tariffs to achieve economies of scale. Prof. Ajay Deshpande recommended differential vulnerability assessments, highlighting that ULBs often lack the capacity to interpret complex assessments. Updated CRZ regulations were noted as an important tool for empowering ULBs.

Lubaina stressed the need for future-ready cities, equitable distribution of climate finance to smaller towns, and community awareness. Vishwanath S highlighted low-cost technologies and the importance of understanding groundwater extraction and aquifer potential. Mr. Depinder Kapur underscored the need to consider both sewer-connected and non-sewered decentralized systems as viable solutions.

PWD officials from Goa noted ongoing energy audits, while Gujarat representatives stressed the importance of industrial wastewater management in Valsad and policy-led sewage treatment.

Way Forward

In the **short term**, the team will incorporate the suggestions and feedback received, including additional town- and state-specific information, into the respective reports. In the **medium term**, the team plans to develop research papers, publications, and other outreach and communication materials in collaboration with advocacy and implementation partners, namely the **India Sanitation Coalition (ISC)** and **CDD-India**, aiming to achieve broader recognition and secure buy-in from government stakeholders and the academic community. In the **long term**, the team aims to engage governance stakeholders and local academic institutions through targeted capacity-building exercises, leveraging the forthcoming toolkit designed to assess and enhance the resilience of water and sanitation infrastructure and services in coastal towns across India.

ANNEXURE-V ABBREVIATIONS AND GLOSSARY

ABBREVIATIONS

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
CCA	Climate Change Adaptations
CDRI	Coalition for Disaster Resilient Infrastructure
CST	Community Septic Tanks
CT	Community Toilet
DDMP	District Disaster Management Plan
DM	District Magistrate
DRR	Disaster Risk Reduction
ESLR	Elevated Level Storage Reservoir
FSSTP	Faecal Sludge and Septage Treatment Plant
FSTM	Faecal Sludge Treatment and Management
GIRI	Global Infrastructure Risk Model and Resilience Index
GIS	Geographic Information System
GLSR	Ground Level Storage Reservoir

IFIS	International Financial Institutions
IPCC	Intergovernmental Panel on Climate Change
MMC	Mapusa Municipal Council
LPCD	Litres Per Capita per Day
LULC	Land Use Land Cover
MLD/ KLD	Million Litres per Day/ Kilo Litres per Day
MSL	Mean Sea Level
NBIS	Nature-Based Infrastructure Solutions
NRW	Non-Revenue Water
ODF	Open Defecation Free
OSS	On Site Sanitation Systems
O&M	Operation & Maintenance
PT	Public Toilet
RIS	Risk Information Systems
SAPCC	<i>State Action Plans on Climate Change</i>
SBM	Swachh Bharat Mission
SBR	Sequence Batch Reactors
SLBS	Service Level Benchmarks

SOP	Standard operating Procedure
SPV	Special Purpose Vehicle
STPS	Sewage Treatment Plants
UNDRR	United Nations Office for Disaster Risk Reduction
WRD	Water Resources Department
WTP	Water Treatment Plant
WASH	Water, Sanitation, and Hygiene

GLOSSARY

<i>Term</i>	<i>Definition</i>
ADEQUACY	Making available in a universal and equitable manner which is sufficient, acceptable and affordable for all.
BASIC INFRASTRUCTURE	Infrastructure that provides essential services to individuals, households, communities, and businesses and includes water, drainage, sanitation networks, local road, river, and rail networks, health and education facilities, post-harvest processing and storage facilities etc. (CDRI, 2023) ⁷⁹
CLIMATE ADAPTATION	Adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change (UNFCCC, https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction).
EXPOSURE	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or

	cultural assets in places and settings that could be adversely affected. (UNDRR)
FLEXIBILITY	Ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation. (CDRI, 2023)
GREY INFRASTRUCTURE	Engineered physical structures that underpin energy, transport, communications (including wireless and digital), built form, water and sanitation, and solid-waste management systems and that protect human lives and livelihood. (CDRI, 2023)
HAZARD	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. (UNDRR)
INFRASTRUCTURE	CDRI has defined infrastructure as “Individual assets, networks and systems that provide specific services to support the functioning of a community or society” (CDRI, 2023)
INFRASTRUCTURE GOVERNANCE	Infrastructure governance can be understood as the policies, frameworks, norms, processes and tools used by public bodies to plan, make decisions, implement and monitor the entire life cycle of public infrastructure. (OECD)
INFRASTRUCTURE RESILIENCE	Infrastructure systems and networks, the components, and assets thereof, and the services they provide, that can resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented. (CDRI,2023)
NATURE BASED INFRASTRUCTURE SOLUTIONS	Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, and resilience and biodiversity benefits (UNEP, 2022c).
ODF	A city / ward can be notified/declared as ODF city/ ODF ward if, at any point of the day, not a single person is found defecating in the open (Ministry of Housing and Urban Affairs, 2020) ⁸⁰
ODF+	A city / ward / work circle can be notified/declared as SBM ODF+city/SBMODF+ward/SBMODF+work circle if, at any point of the day, not a single person is found defecating and/ or urinating in the open,

	AND all community and public toilets are functional and well maintained (Ministry of Housing and Urban Affairs, 2020).
REDUNDANCY	Alternative or back-up means created within an infrastructure system to accommodate disruption, extreme pressures, or surges in demand. (CDRI)
RELIABILITY OF SERVICES	The ability of the system to maintain its required capacity and performance during a given period under stated conditions or disastrous events. (CDRI, 2023)
RESILIENCE	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. (AR6, IPCC)
SENSITIVITY	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. (AR6, IPCC)
SYSTEM RESILIENCE	The resilience of social, economic, territorial and environmental systems, at all scales, that conditions the ability of infrastructure assets and the services they provide to resist and absorb disaster impacts. (Definition adopted in CDRI Biennial Report)

⁷⁹CDRI. (2023). Map Viewer. Retrieved from Global Infrastructure Risk Model and Resilience Index, Measuring Risk and Resilience in Infrastructure Solutions: <https://giri.unepgrid.ch/map>

⁸⁰Ministry of Housing and Urban Affairs. (2020). Declaring your City/Town SBM ODF+ and SBM ODF++ Toolkit for Urban Local Bodies. New Delhi: Government of India.



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