

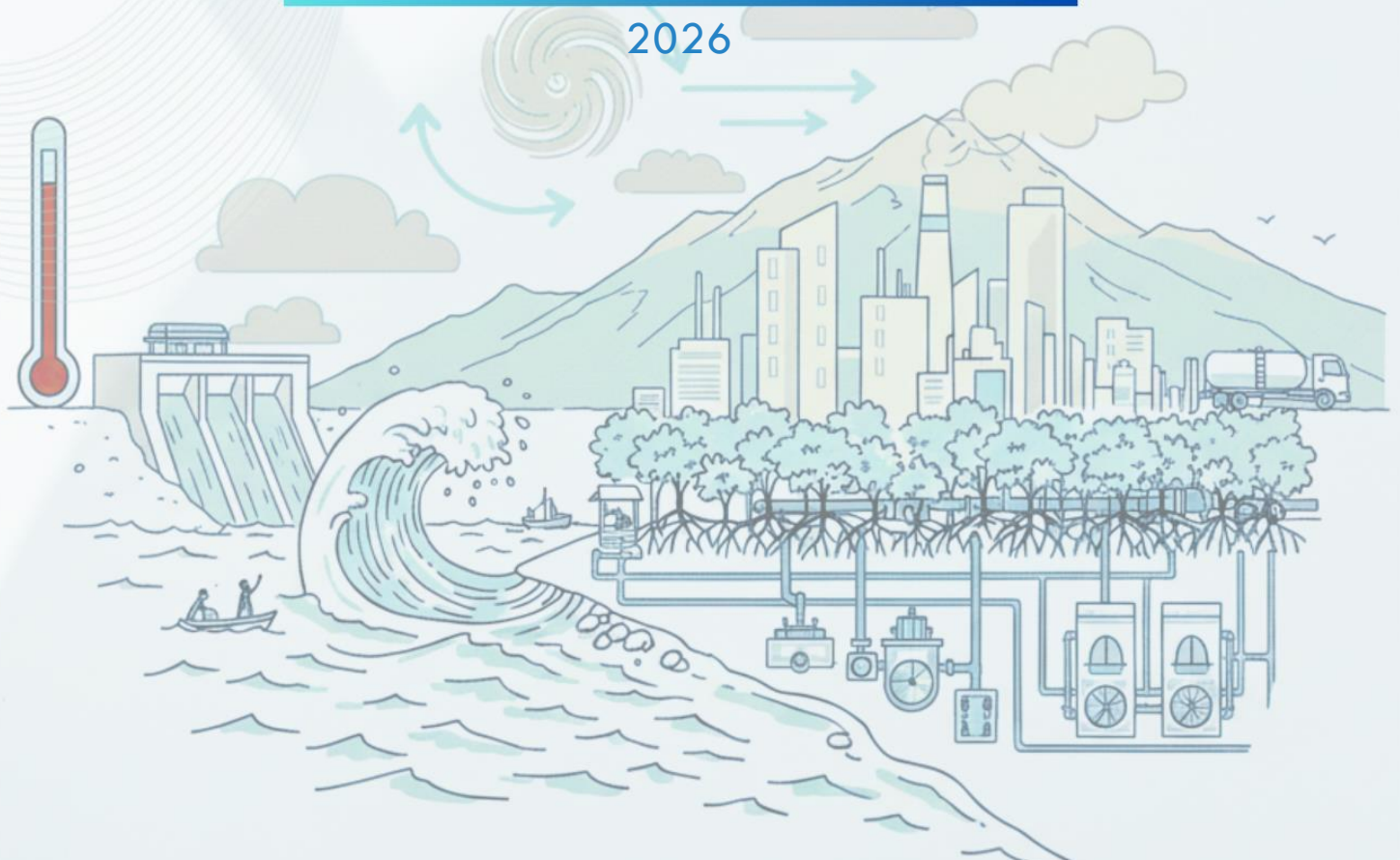


Towards Climate-Resilient Urban Water & Sanitation Systems

Situational Assessment Report

CANACONA, GOA

2026

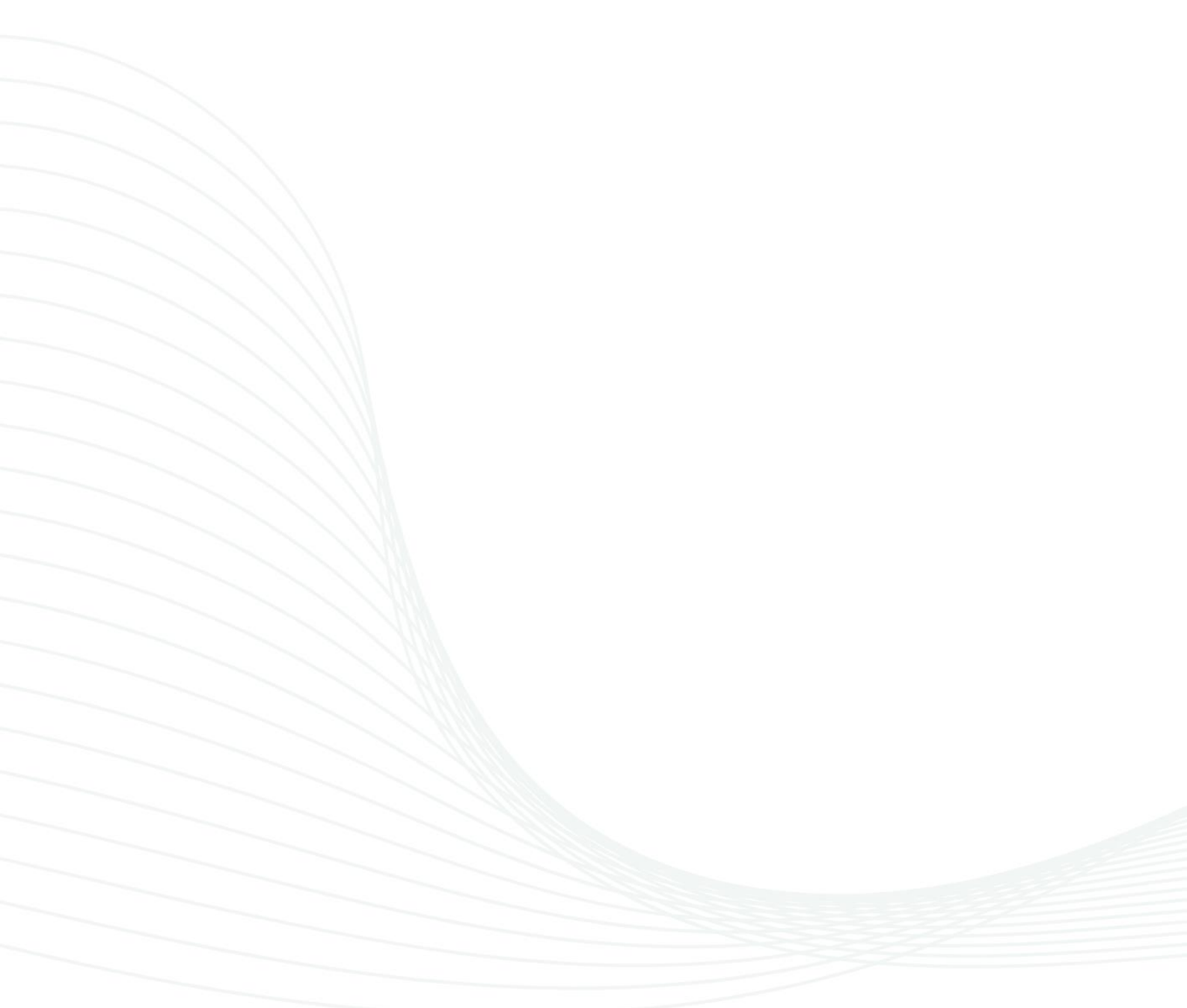


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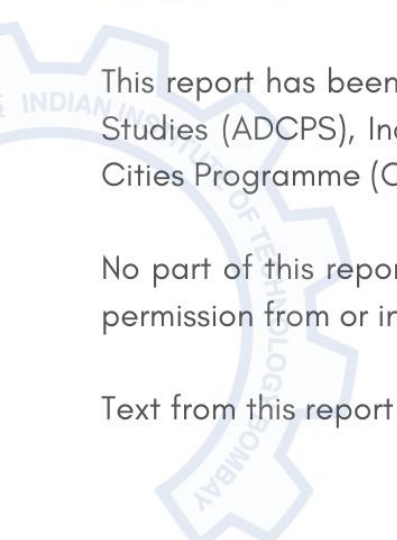
N C Narayanan

Contributing Authors:

Neelam Rana, Ashish Dangi, Abhay Junaghere, Priyakshi Gogoi, Sucharita Roy & Tejash Anand



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TITLE

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

AUTHORS

Dr. NC Narayanan, Professor, ADCPS, IITB - Principle Investigator (PI) CRCC Project

Dr. Neelam Rana, Senior Project Research Scientist, ADCPS, IITB

Ashish Dangi & Abhay Junaghare, Research Scholars, ADCPS, IITB

Priyakshi Gogoi, Sucharita Roy & Tejash Anand, Project RAs, ADCPS, IITB

DESIGN & LAYOUT

Ashish Dangi

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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.

The report presents the study findings for **Canacona**, a Class-II town, in the Canacona Taluka of South Goa District. Our assessment of Canacona revealed some critical challenges of WaSH infrastructure & services:

WATER SUPPLY:

Reliance on Centralised Supply Networks: The region exhibits a strong dependence on long-distance, centralised surface water networks (e.g., Chapoli Dam), paired with a documented decline in the utilisation of localised, traditional water sources. This existing configuration carries a notable carbon footprint due to energy-intensive operations and introduces disruption risks during extreme climatic events.

Sectoral Demand Pressures and Allocation: Seasonal tourism in key destinations introduces substantial strain on existing water resources. Commercial establishments (consuming an estimated 206 KLD) account for volumes equivalent to hundreds of households, which significantly influences distribution patterns and alters supply availability between commercial and residential zones during peak periods.

Operational Dependencies and Systemic Maintenance: The distribution system is heavily reliant on continuous grid power, making water supply susceptible to

interruptions during monsoon storms or grid outages, particularly as backup pumping systems are currently limited. Furthermore, field assessments of existing pump houses and treatment equipment indicate an ongoing need for formalised preventive maintenance protocols to manage operational wear.

Climatic Variability and Topographical Constraints: The performance of the current gravity-fed distribution is actively constrained by the region's undulating topography, resulting in variable pressure and intermittent supply at higher elevations. Concurrently, erratic monsoon patterns and shifting rainfall intensities are introducing new uncertainties regarding long-term surface storage viability and groundwater recharge rates.

SANITATION:

Infrastructural Constraints in Wastewater Management: While building approvals ensure standardised onsite sanitation systems at the household level, the region faces downstream limitations, most notably the absence of local faecal sludge treatment facilities and comprehensive sewerage networks.

Logistical Challenges and Economic Burdens: Desludging logistics are constrained by limited municipal capacity and long transit distances. This forces residents to rely on costly private services, creating a financial strain that often disincentivises regular maintenance.

Climate Impacts and Emissions: Infrequent desludging causes onsite systems to generate elevated methane emissions. Consequently, these systems account for an estimated 90% of the sector's local greenhouse gas emissions.

Environmental and Economic Risks: Unchecked wastewater discharge from rapid urbanisation has led to documented contamination of local groundwater and beaches, presenting distinct risks to public health and the region's tourism-dependent economy.

Stormwater Drainage Performance: Despite a reported 75% coverage rate for stormwater drains, localised waterlogging persists in areas with high groundwater tables, highlighting ongoing operational and maintenance constraints.

GHG EMISSIONS:

Carbon Intensity of Surface Water Abstraction: The abstraction and treatment of surface water from the Chapoli Dam and Talpona River represent the most energy-intensive stages of the water supply chain. These processes generate approximately 1,435 tonnes of CO₂ annually, driven primarily by the high electricity requirements of long-distance pumping and filtration across undulating topography.

Comparative Efficiency of Groundwater Extraction: In contrast to the high energy demands of surface water supply (estimated at 149 MWh/MLD/year), groundwater

extraction presents a notably lower carbon footprint. Pumping from shallow and deep aquifers requires significantly less electricity (ranging from 7 to 28 MWh/ML/year), highlighting a difference in energy intensity across available water sources.

Emissions Dominance of Onsite Containment: Onsite sanitation systems, specifically septic tanks and pits, account for nearly 90% of total sanitation-related greenhouse gas emissions. The prolonged anaerobic decomposition of organic matter within these structures, exacerbated by infrequent desludging, generates an estimated 2,580 tCO₂e/year in methane and nitrous oxide emissions.

Transport Footprint and Estuarine Nutrient Pollution: Logistical operations for desludging transport contribute an additional 91 tCO₂e/year. Furthermore, the unchecked discharge of greywater into stormwater drains results in substantial nitrogen leakage, generating an estimated 185 tCO₂e/year in indirect nitrous oxide (N₂O) emissions within nutrient-sensitive coastal and estuarine ecosystems.

FINANCIAL HEALTH:

Contraction in Capital Receipts: Capital receipts have exhibited a downward trend over recent fiscal cycles, decreasing from ₹7.01 crores in 2019-20 to ₹6.56 crores in 2024-25. This reduction restricts the pool of available funding necessary for initiating and sustaining long-term infrastructure projects.

Conservative Capital Expenditure: Although capital expenditures have seen an incremental increase, reaching ₹4.50 crores in 2023-24, overall capital spending patterns remain conservative. This current level of investment acts as a constraint on the structural modernisation and system expansion required to accommodate rising local demand.

Operational Cost Recovery Challenges: Despite a steady compound annual growth rate (CAGR) of 4.75% in revenue income, generated funds consistently fall short of covering operational expenditures. The widening gap between revenue generation and operational costs, alongside fluctuating fiscal surpluses, points to structural challenges in achieving long-term financial stability.

Volatility and Reliance on External Grants: The departmental financial structure demonstrates a high and volatile dependency on external grants relative to internally generated revenue. The ratio of external grants to own revenue has fluctuated significantly, swinging from 64.70% in 2019-20 to a peak of 147.45% in 2021-22 before adjusting to 64.99% in 2022-23, reflecting an ongoing vulnerability to external funding cycles.

The situational assessment of Canacona reveals a highly interconnected set of operational, environmental, and fiscal constraints that collectively shape the region's current climate resilience. The existing paradigm characterised by an over-reliance on energy-intensive centralised water distribution, combined with systemic deficits in downstream faecal sludge management, not only amplifies local greenhouse gas emissions but also introduces distinct contamination risks to a tourism-dependent coastal economy. Moving forward, navigating these systemic gaps highlights a primary focus area for future institutional planning. Reconciling the disparity between operational cost recovery and capital expenditure will be fundamental to addressing these challenges. By stabilising the financial baseline, future frameworks can better explore the integration of decentralised water sources, the formalisation of wastewater treatment logistics, and the mitigation of carbon-intensive operations, ultimately transitioning the municipality towards a more resilient and self-sustaining service model.

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1. URBAN WATER & SANITATION SYSTEMS IN A CHANGING CLIMATE

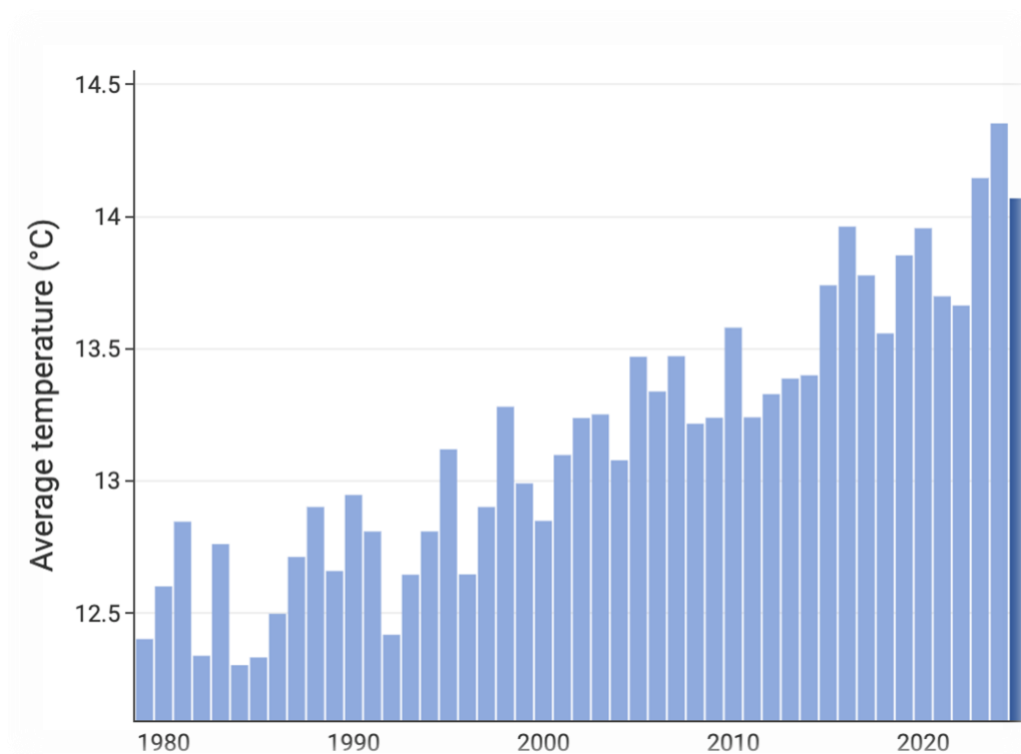
ASHISH DANGI, NEELAM RANA, N.C. NARAYANAN AND PRIYAKSHI GOGOI

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

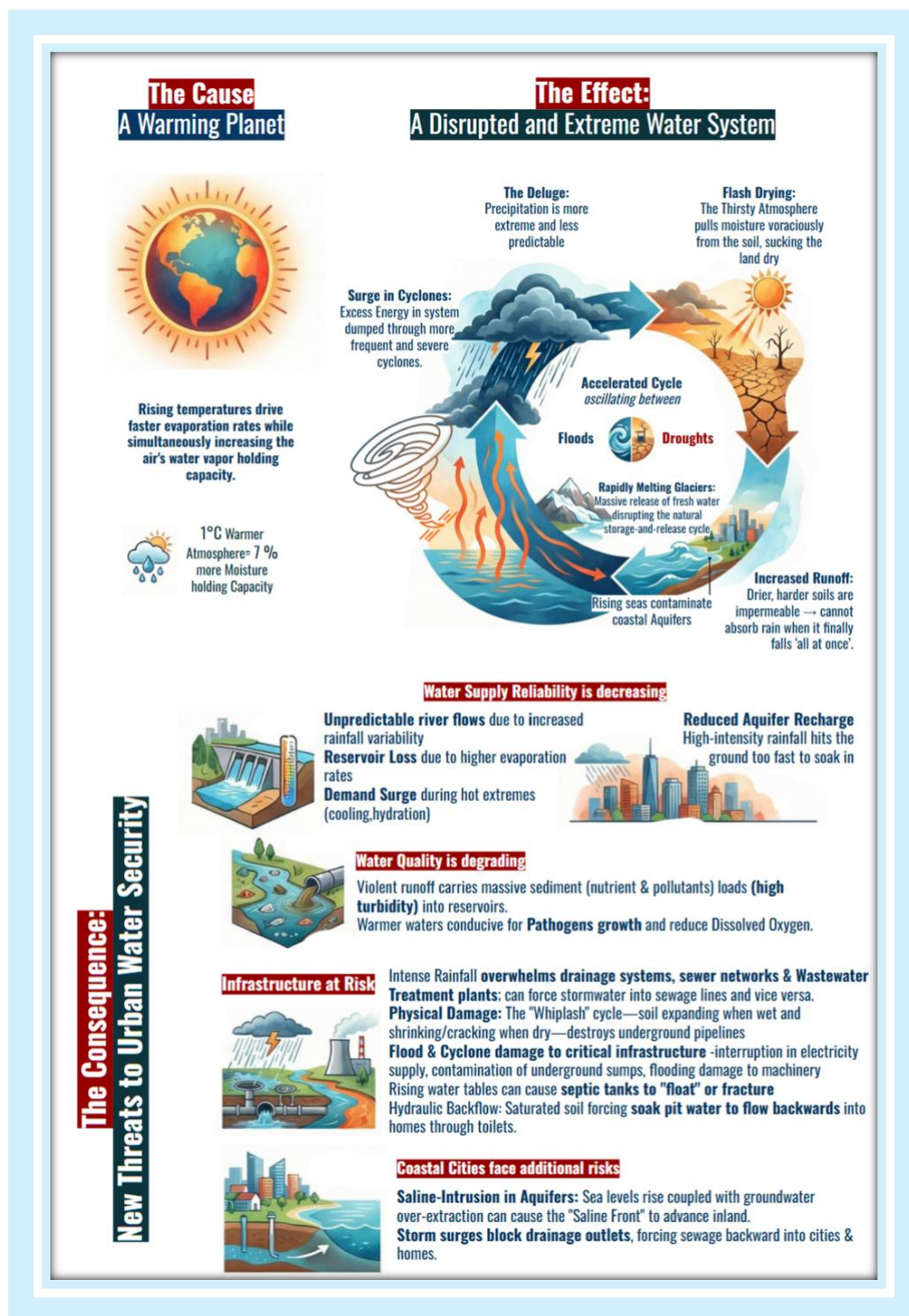
This leads to a volatile cycle: during dry periods, the 'thirstier' atmosphere aggressively evaporates moisture from soil and reservoirs, deepening drought conditions. However, once this moisture-laden air is triggered to release by a cyclone or orographic lift, it discharges with explosive intensity. 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.

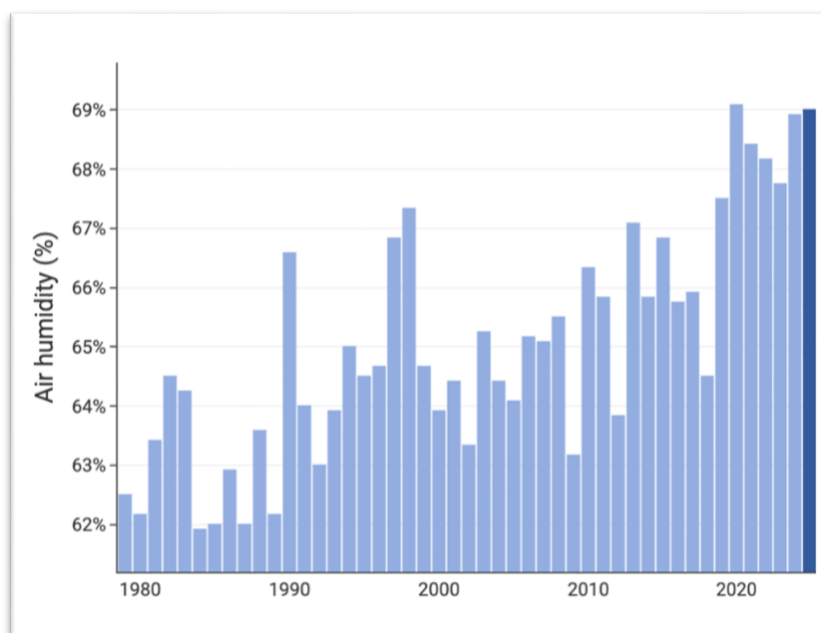
This escalating hydro-climatic volatility inevitably converges on Water management, particularly in cities, where dense populations, concentrated infrastructure, and increasingly fragile ecosystems intersect. Urban water systems spanning water supply, wastewater management, drainage, and groundwater 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

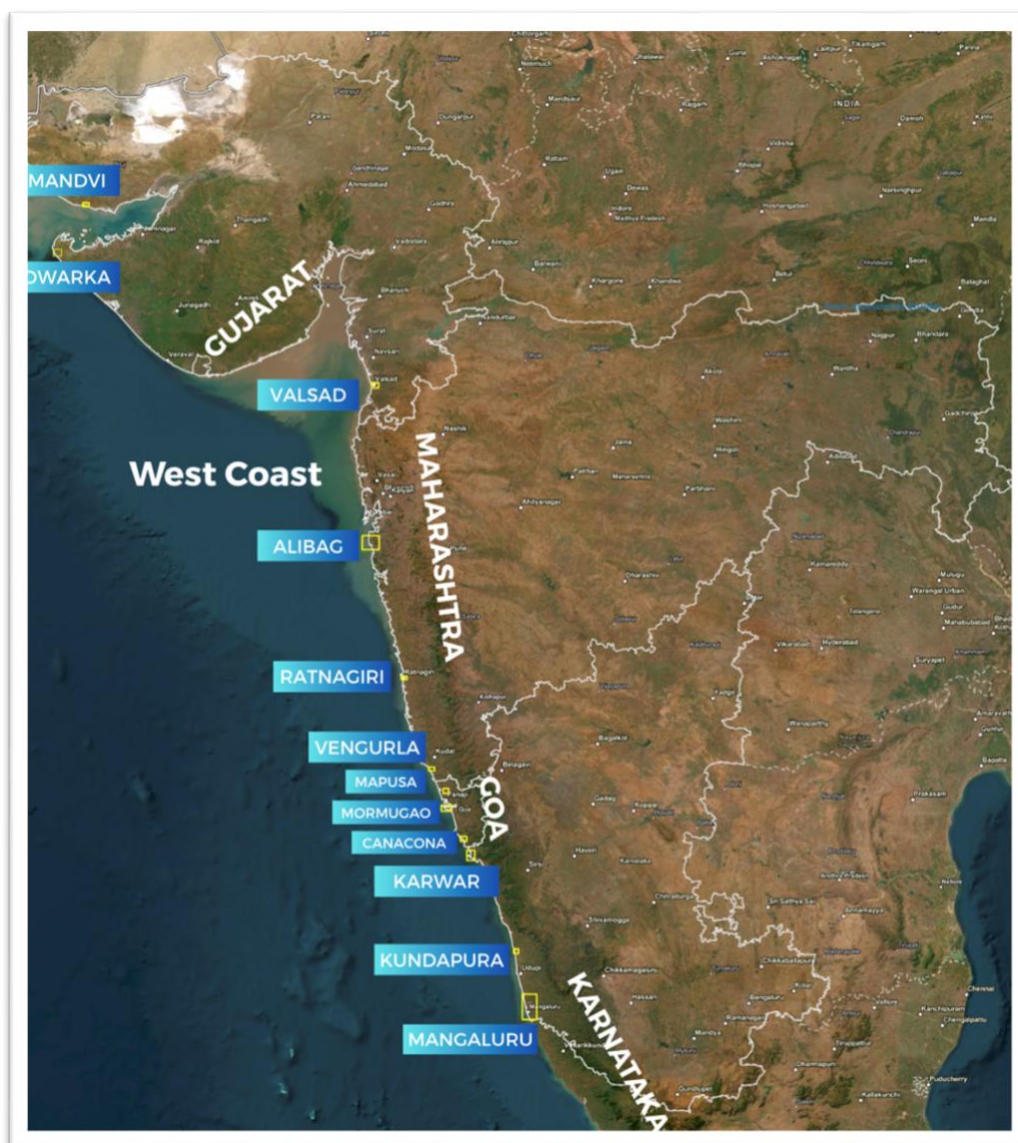


Image Source: Author's Illustration

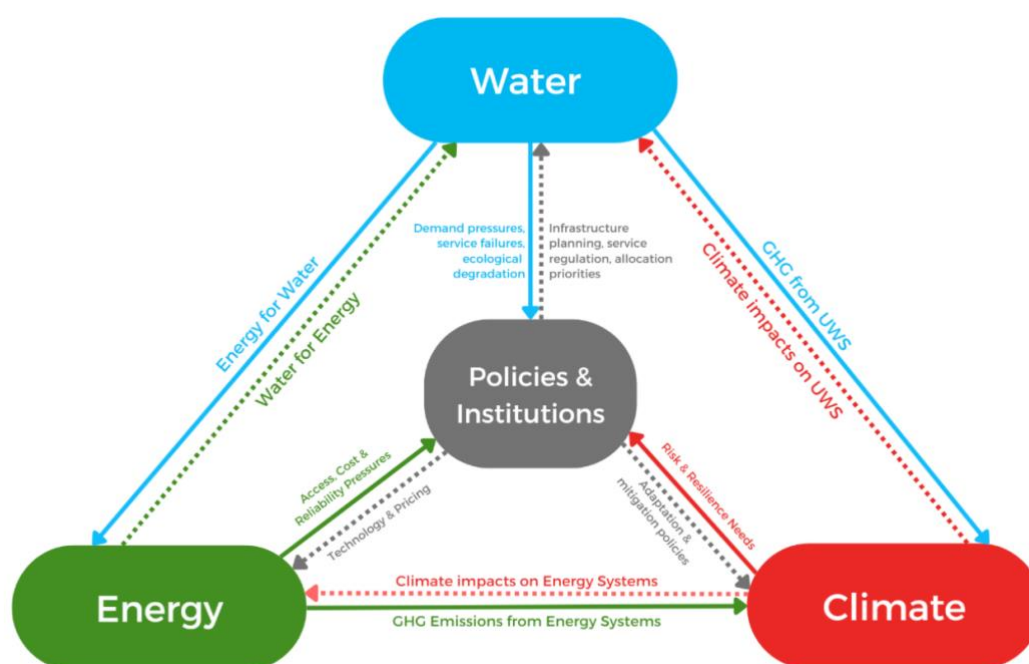
1.5 METHODOLOGY

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

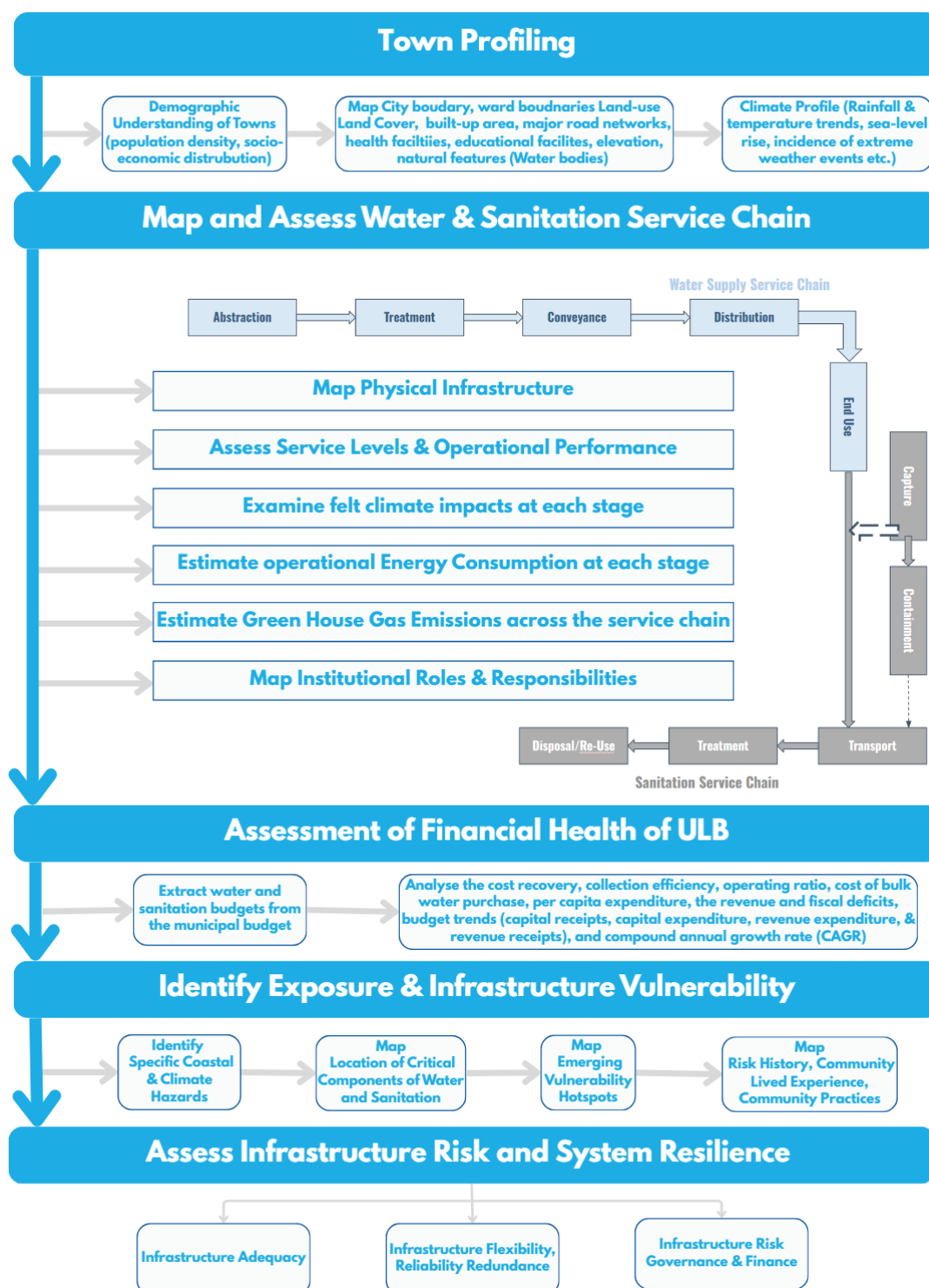
Key Parameters	Selection criteria		
Administrative status	Municipal Corporation	Municipal Council (A and B)	Nagar Panchayat (C and D)
City Size based on population	Class-I to Class IV		
Socio-economic profile	Capturing variability in socio-economic profile of the town population		
Climate Change Exposure 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 presents the study findings for **Canacona**, a Class-IV town in the Canacona Taluka of South Goa District of Goa. Canacona is a small tourist town in South Goa. The town is known for its vibrant tourism industry, attracting both national and foreign tourists to its southern tip beaches like Agonda, Palolem, and Rajbhag. It serves as the administrative headquarter of Canacona taluka, one of the 12 subdistricts of Goa. The town has numerous ponds and traditional water bodies that support local agriculture and daily needs. Agriculture continues to flourish in most urban wards, with built-up land cover not exceeding one third of the land area in any of the 12 urban wards. The town's water supply system relies on multiple sources but faces issues related to ageing infrastructure and increasing water demand due to tourism. The town lacks a sewerage network or local sludge treatment facility and relies primarily on on-site sanitation systems. Canacona faces significant climate risks such as sea level rise, storm surges, coastal erosion, and saltwater intrusion.

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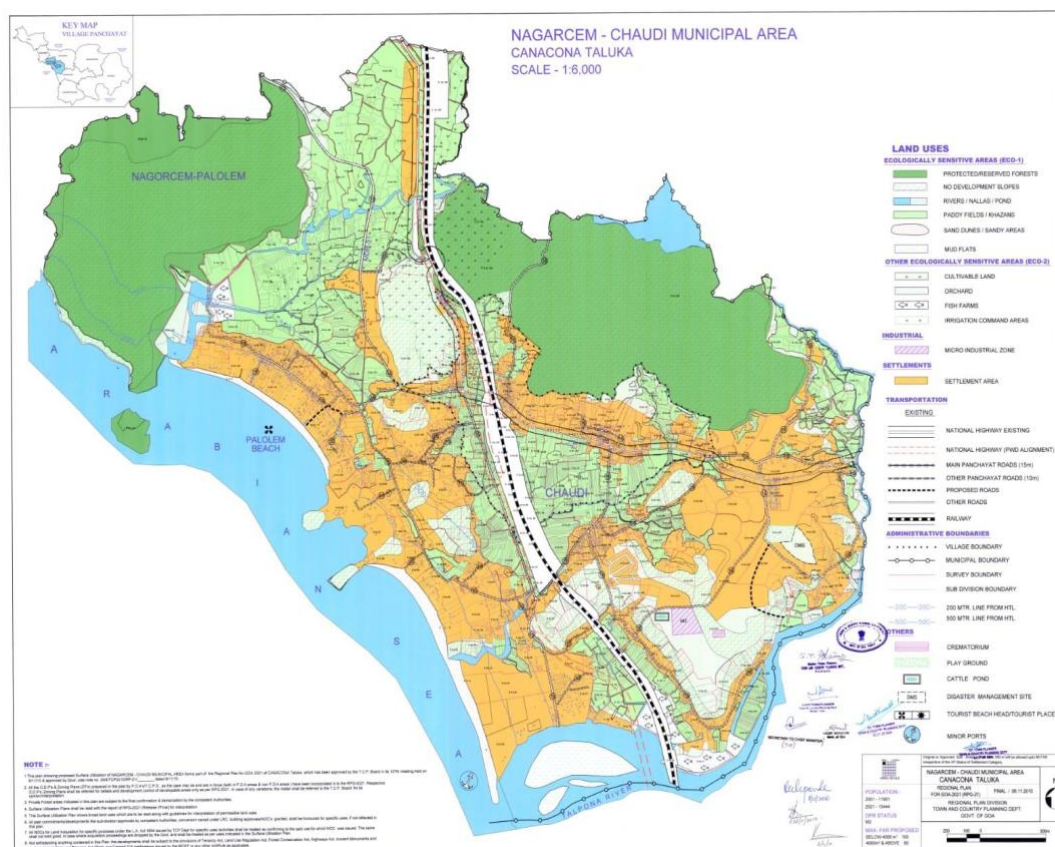
2. TOWN PROFILE

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.

Canacona Municipality, established in 1987, was formerly a village panchayat. Located in the South Goa district, the municipality spans an area of 18.69 square kilometres. It serves as the administrative headquarters of the Canacona taluka, which is the southernmost region of Goa. It is bounded by the Arabian Sea to the west and shares a border with Karnataka to the south.

Figure 7: Canacona City Map



Demographic Profile: The town had 12,434 population in 2011 and currently it is 17,900. The number of households as per latest information from the ULB are around 6047. The Literacy rate of Canacona city is 89.31 % higher than the state average of 88.70 %. According to census 2011, Schedule Tribe (ST) constituted 1.66 % while Schedule Caste (SC) were 0.56 % of total population in Canacona. Out of the total population, 4,326 individuals were engaged in work or business activities. Among this working population, 80.21% were involved in main work, while 19.79% were engaged in marginal work²⁰.

Topography: Canacona is a low elevation coastal town. With numerous ponds and traditional water bodies that have historically supported local agriculture and daily needs, Canacona exhibits wetland ecosystem features. The Talpona river and its estuary mark the southern boundary of the town. The Chapoli dam further inland, at the eastern outskirts on the hilly slopes caters to the region's water needs.

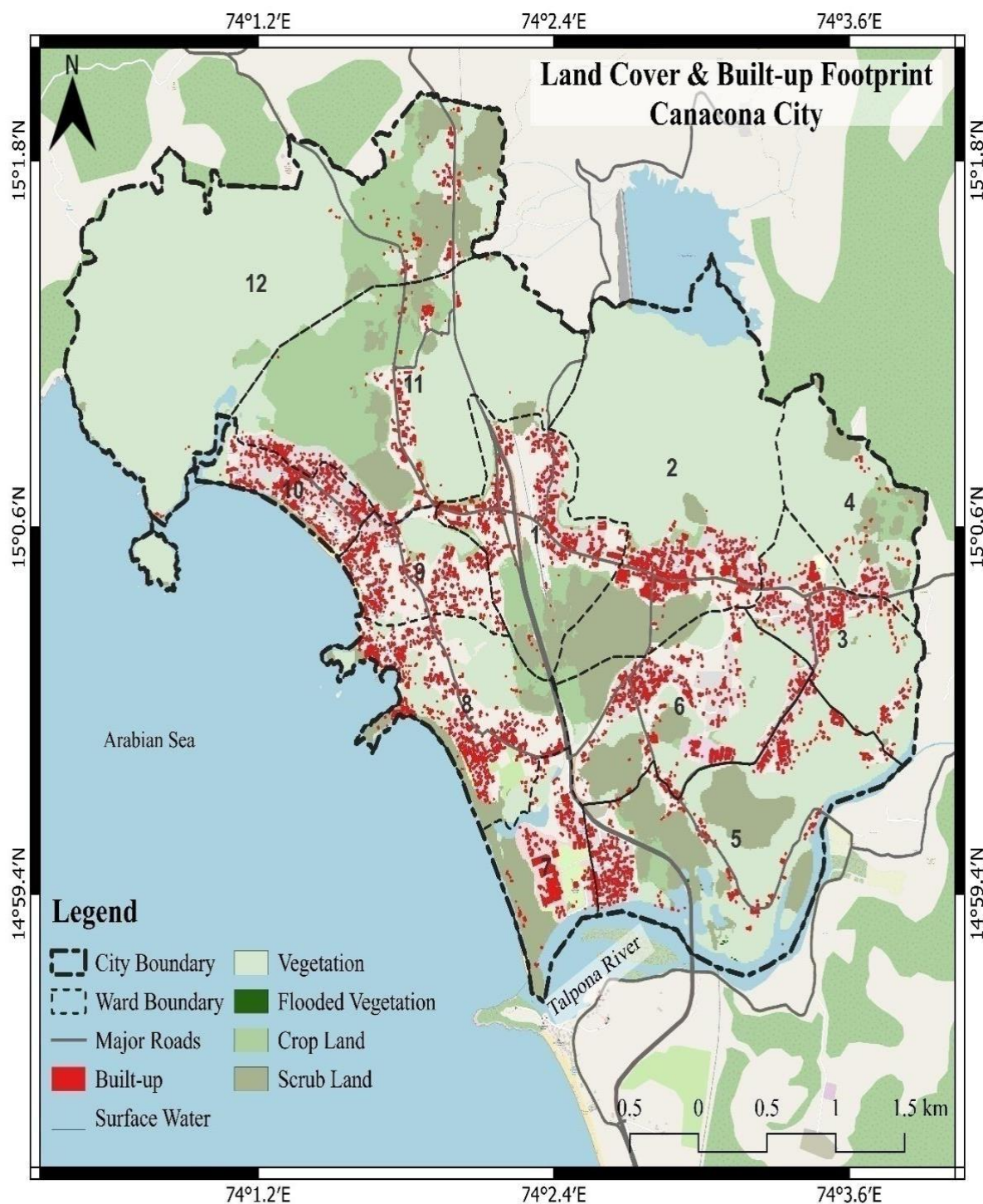
Land use and Landcover: the landcover of Canacona is dominated by agricultural land, vegetation (primarily coconut palm groves) and built-up. (Ref. Figure 8). The built up landcover constitutes less than one fifth of the ward areas with only ward 9 and 10, nest to the popular beach which attracts the tourists, reaching up to nearly one third of the ward area. (Ref. Table 3). Wards 2, 4, 5, 11, and 12 are the larger and inland wards which continue to be primarily rural with agriculture land use accounting for more than 90% of the ward area. The town retains its rural characteristics in most parts. The primarily land use of Canacona is residential and commercial.

Table 3: Ward level Built-up footprint of Canacona (based on remote sensing data)

Ward No	Area (sq. km)	% of total town area	Built up footprint
1	1.1	6.3	15%
2	2.7	15.1	6%
3	0.9	5.1	14%
4	0.9	4.7	4%
5	2.0	11.2	8%
6	1.4	7.5	12%
7	0.6	3.6	15%
8	1.1	6.2	18%
9	0.6	3.3	24%
10	0.4	2.1	32%
11	2.4	13.4	4%
12	3.9	21.5	1%

Source: GIS analysis based on remote sensed data.

Figure 8: : Landcover and Built-up Footprint of Canacona



Source: Open Street Map; Sentinel 2 10m (LULC); Canacona Municipal Council

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

Climate: Canacona municipal council falls under the coastal agro-climatic zone (Ref. Figure 9) within Canacona taluka and South Goa District.

Figure 9: Administrative Divisions of Goa showing Canacona Taluka



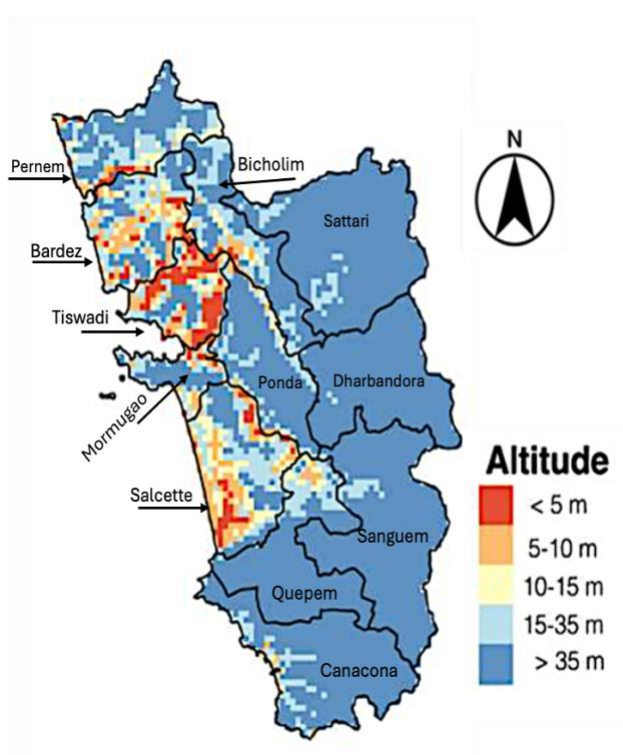
Source: Census Digital Library, 2011²¹

Climate change and Disasters: Town level data on disasters is lacking. Hence, we relied upon district and taluk level secondary data on disasters. According to NITI Aayog's Climate and Energy Dashboard, South 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) (Niti Aayog, 2025)²². The coastal belt of Goa is the only area vulnerable to cyclones.

Six out of the 12 talukas in the state, including Canacona, Mormugao, and Bardez (which include the selected towns), are highly vulnerable to cyclones, based on the severity of the impacts (Ref. Table 4) (Goa State Disaster Management Authority, 2024)²³. As shown in the figure, the 0–5-meter elevation zone is considered the most vulnerable to flooding in Goa (NABCONS, 2023)²⁴. Consequently, the Bardez taluka, Tiswadi, Salcette, Mormugao are more susceptible to flood-related hazards.

Figure 10: Flood Vulnerability of Talukas of Goa



Source: NABCONS, 2023

In terms of flood severity, Canacona taluka is one of the most vulnerable taluks.

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

Sl. No.	Taluk	Cyclone	Floods	Drought	Landslides	Soil Erosion
1	Canacona	High	High	Low	Medium	Low

Source: Goa State Disaster Management Authority, 2024

Typically, flooding in Goa was primarily confined to the overflow of smaller rivers and the inundation of marginal areas in regions like Pernem, Bicholim, Sattari, Bardez, Canacona, Quepem, and Sanguem. However, as outlined in the State Disaster Management Plan, flooding in Goa is not solely caused by intense rainfall events. It is further exacerbated by unregulated urban expansion, insufficient maintenance of natural water storage systems (such as tanks), and poor management of drainage infrastructure, particularly within municipal areas. These factors collectively amplify the destructive potential of increasing flood hazards (Goa State Disaster Management Authority, 2024, pp. 71-72).

For example, the flash floods in Canacona on October 2nd, 2009, were directly attributed by the state disaster plan to heavy rainfall (approximately 271 mm over a brief period of 7 hours). The report notes, "There are no records to suggest that such a rainfall scenario has occurred in the past" (Goa State Disaster Management Authority, 2024, p. 72). The incident led to the flooding of the Talpona and Galgibag rivers. Soil saturation triggered mudslides at higher altitudes (around 300m), submerging agricultural and horticultural areas, while livestock were swept away. At lower altitudes (50m or less), the accumulation of water caused widespread flooding, submerging buildings and leading to the destruction of houses, commercial establishments, and especially mud houses (ibid).

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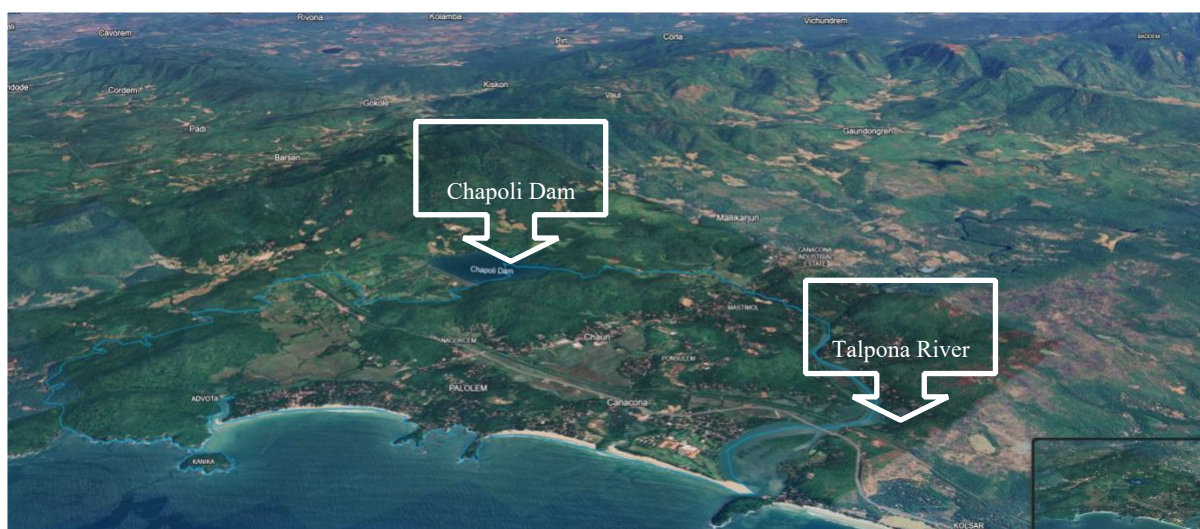
3. STATUS OF WATER INFRASTRUCTURE AND SERVICES

ASHISH DANGI²⁵ AND NC NARAYANAN

This chapter provides a situational assessment of Canacona'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.

Canacona, located in South Goa, is a coastal town bordered by the Arabian Sea to the west and flanked by the Talpona River to the south (figure 11). Its topography features steep slopes of the Western Ghats gradually transitioning into coastal plains and estuarine zones, shaping both the hydrological character and the seasonal vulnerability of its water systems. On the northeastern boundary lies the Chapoli Dam, a critical surface water source serving the region. Much of Canacona comprises hilly terrain, with smaller estuarine systems near Adavota in the north and at the confluence of the Talpona River and the Arabian Sea in the south. These diverse geophysical features contribute to both the richness and the fragility of the town's water resources.

Figure 11: Geographical setting of Canacona Municipal council Area



Source: Author's illustration using Google Earth satellite imagery

3.1 SURFACE WATER SOURCES

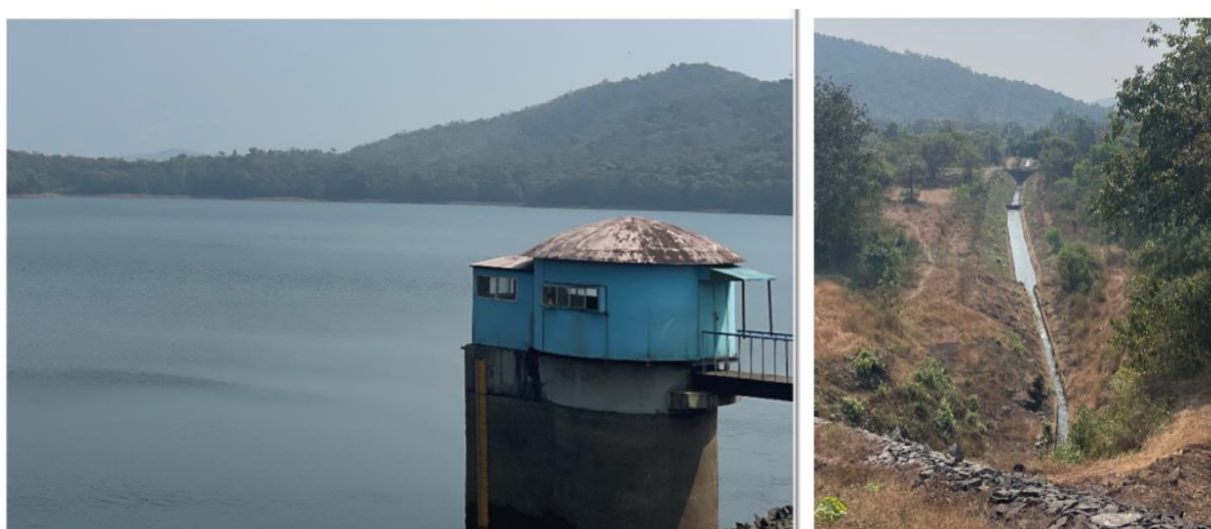
Chapoli Dam:

Chapoli Dam serves as the primary surface water source for Canacona, playing a vital role in supporting both drinking water supply and irrigation in the region. Situated in the northeastern hinterland, the dam is constructed on a nallah originating from the Western Ghats, ensuring dependable monsoon-fed inflows.

Hydrology and Storage Capacity: The dam commands a modest catchment area of 6.83 sq. km, yet benefits from high average annual rainfall of approximately 2,996 mm. With a gross storage capacity of 9.98 million cubic meters (MCM) and a live storage capacity of 8.76 MCM, it ensures water availability throughout the year, even during the dry season. It's 6.83 km² catchment receiving roughly 3,000 mm annual rainfall, largely during the monsoon.

Irrigation and Groundwater Recharge: Chapoli supports irrigation for nearly 550 hectares of cultivable land, facilitated by a 9.25 km-long right bank main canal designed to discharge 1 cumec. Beyond surface irrigation, the dam indirectly contributes to groundwater recharge by sustaining soil moisture and shallow aquifer levels in adjacent agricultural zones.

Figure 12: Chapoli Dam and Irrigation canal



Source: Site Visit by IITB team

Drinking Water Supply: The dam is also central to Canacona's drinking water infrastructure. Raw water is pumped to a nearby PWD treatment plant, which supplies 10 million liters per day (MLD) of treated water to urban and rural households across Canacona. This infrastructure

plays a critical role in ensuring consistent potable water access, especially during peak tourism and summer months.

Design and Flood Management: The Chapoli Dam is an earthen structure, 25.5 meters in height and 760 meters in length. Its un-gated chute-type spillway is engineered to manage a design flood of 85 cumecs, ensuring safety during high-intensity rainfall events. The full reservoir level is maintained at 38.25 meters.

Strategic Importance: By supporting multiple water needs including irrigation, drinking, and aquifer recharge, Chapoli Dam has emerged as a lifeline for Canacona. It enhances resilience against seasonal variability and underpins the town's water security, agricultural stability, and socio-economic well-being.

Chapoli Dam's reliability is deeply intertwined with its climate-sensitive catchment. The intense monsoon recharge between June and September ensures abundant inflow during those months. However, in recent years, water levels have fallen to historic lows (e.g., 42% in June 2023) due to delayed monsoons ²⁶. Adding uncertainty are ecological and climatic shifts. Steep terrain and dense drainage promote high sediment inflow, a problem compounded by periodic fires and land-use changes. Notably, sediment loading threatens to reduce live storage over time, compromising water availability during dry spells. While plans for floating solar panels offer potential benefits like reduced evaporation, deployment on Chapoli Dam has been postponed, citing ecological risk²⁷.

Continuous seasonal variability, sedimentation trends, and catchment disturbances underscore the need for robust monitoring of inflows, storage levels, and groundwater recharge dynamics in the face of climate change.

Talpona River:

The **Talpona River** continues to serve as a supplementary surface water source for the Canacona Water Supply Scheme (WSS), contributing approximately **5 MLD** to the town's overall water supply, in addition to the **10 MLD** drawn from Chapoli Dam (Figure 13). Historically, before the commissioning of Chapoli Dam in 2000, the Talpona was the town's primary drinking water source and remains hydrologically and ecologically important for the region.

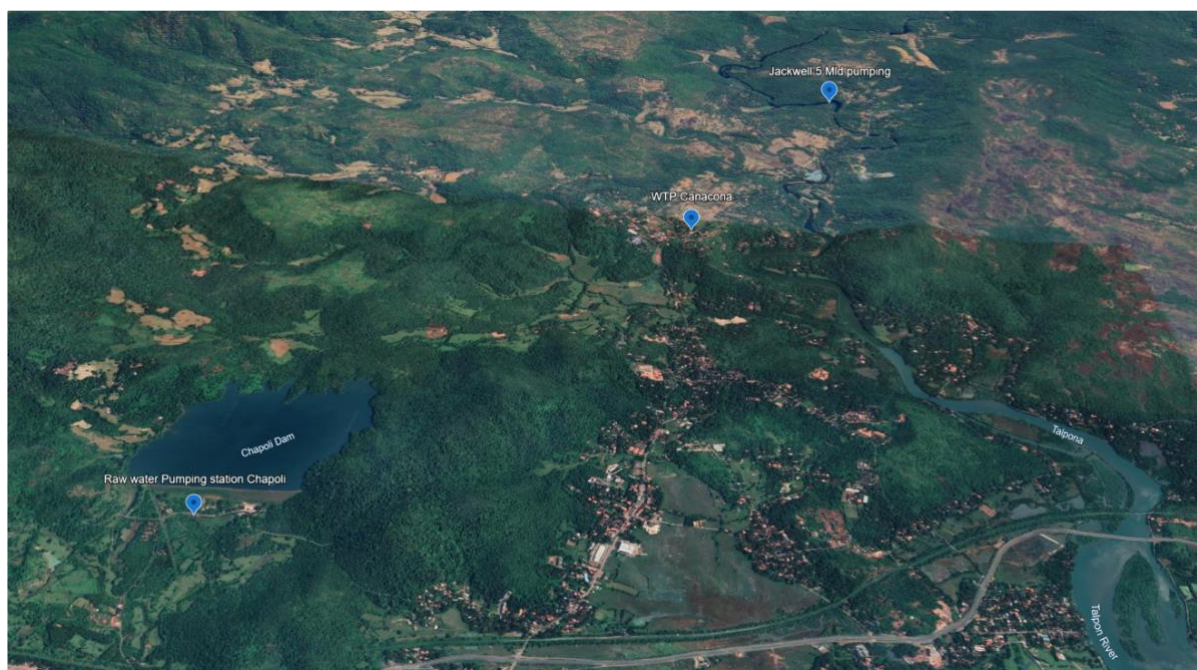
Geography and Hydrology: The Talpona River originates in the dense tropical forests of Ravan Dongar, nestled between the villages of Nane and Kuske in the Sahyadri mountain range, part of the Western Ghats. From there, it flows westward through Canacona Taluka before draining into the Arabian Sea near Talpona village. Spanning a length of approximately 41 kilometres, the river traverses a basin area of 233 sq. km, which constitutes about 6.3% of

Goa's total geographical area. Its key tributaries include Kuske, Nadke, and Gaodongrem streams.

Water Quality and Pollution Concerns: Despite its vital role in the region's water supply, the Talpona River faces growing pollution pressures. The Central Pollution Control Board (CPCB) and the National Green Tribunal (NGT) have declared parts of the Talpona River a polluted stretch, placing it under Priority Class-C. Monitoring by the Goa State Pollution Control Board (GSPCB) has revealed contamination from multiple sources: unregulated sewage discharge, household garbage, and non-biodegradable waste entering the river along its course, particularly near Talpona village²⁸. As a result, river health is deteriorating, impacting both potable water quality and the ecological integrity of the estuarine zone.

Restoration and Monitoring: In response, the GSPCB has developed a river rejuvenation action plan targeting the stretch from Talpona to Gokarna Math, which includes proposals for wastewater interception, sanitation upgrades, and community-based pollution control²⁹. However, sustained implementation, cross-departmental coordination, and public engagement remain critical for ensuring that the Talpona River continues to serve as a safe and resilient source of water for Canacona.

Figure 13: Location of Chapoli dam and pumping station, Talpona River water intake and Water treatment plant in canacona.



Source: Author's illustration using Google Earth satellite imagery

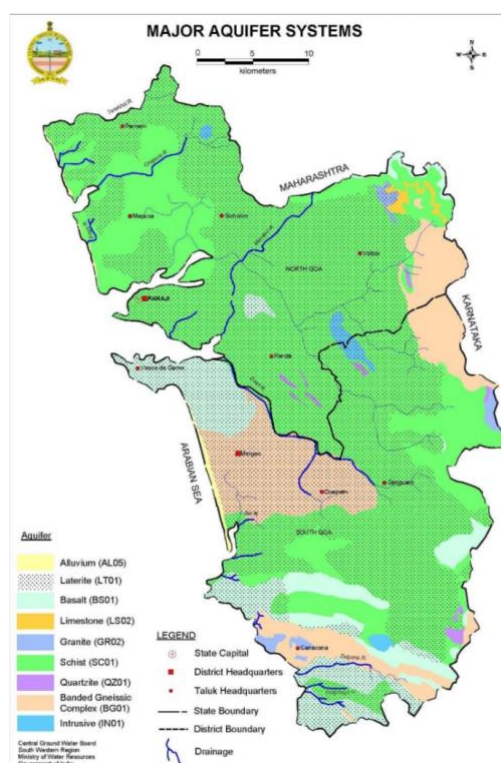
3.2 GROUNDWATER

Groundwater plays a crucial supplementary role in Canacona's water supply, especially in areas not fully covered by piped supply or during dry months when surface water availability may fluctuate. The region's hydrogeology is shaped by a combination of topographical, geological, and climatic factors that together determine groundwater occurrence, recharge, and quality.

Geological Formations and Aquifer Types:

Canacona is underlain by diverse rock formations, including laterites, metamorphic rocks, and granites (Ref. Figure 14). The primary aquifer systems are associated with the **Banded Gneissic Complex (BGC)**, particularly within the Talpona river basin. These aquifers are often characterized by a weathered zone thickness ranging from 5 to 70 meters, with fractures encountered between 20 to 70 meters below ground level (mbgl). Toward the coastal margins, **granite** aquifer systems are also present, with weathered zones of 15–30 meters and deeper fractures at 40–120 mbgl. In northern areas, isolated zones of schist and basalt aquifers are also observed, providing localized groundwater potential.

Figure 14: Principal aquifer systems in Goa.



Source: Central Ground Water Board³⁰

Recharge Potential and Topography:

Canacona's topography marked by forested hills, slopes, and river valleys provides favourable conditions for natural recharge. The hilly terrain and undisturbed landscapes allow rainwater to percolate through the soil and replenish shallow aquifers, particularly during the monsoon season. However, changing rainfall patterns, such as increased rainfall intensity over shorter durations, are limiting effective infiltration and increasing surface runoff. Combined with expanding urbanization and tourism-related development, this reduces the land's capacity to absorb and retain water, thus undermining aquifer recharge.

Water Quality and Usage:

Groundwater in the region is generally suitable for domestic use, particularly in deeper confined aquifers (Ref. Table 5). However, contamination in shallow aquifers—notably by coliform organisms—has been reported, especially in densely populated or low-lying areas with inadequate sanitation. In such areas, the risk of infiltration of untreated wastewater or septic leachate into groundwater systems is high. Seasonal water quality deterioration is also observed in areas with poor drainage or near the coast where saline ingress may occur.

Table 5: Characteristics of Aquifer Systems in Canacona

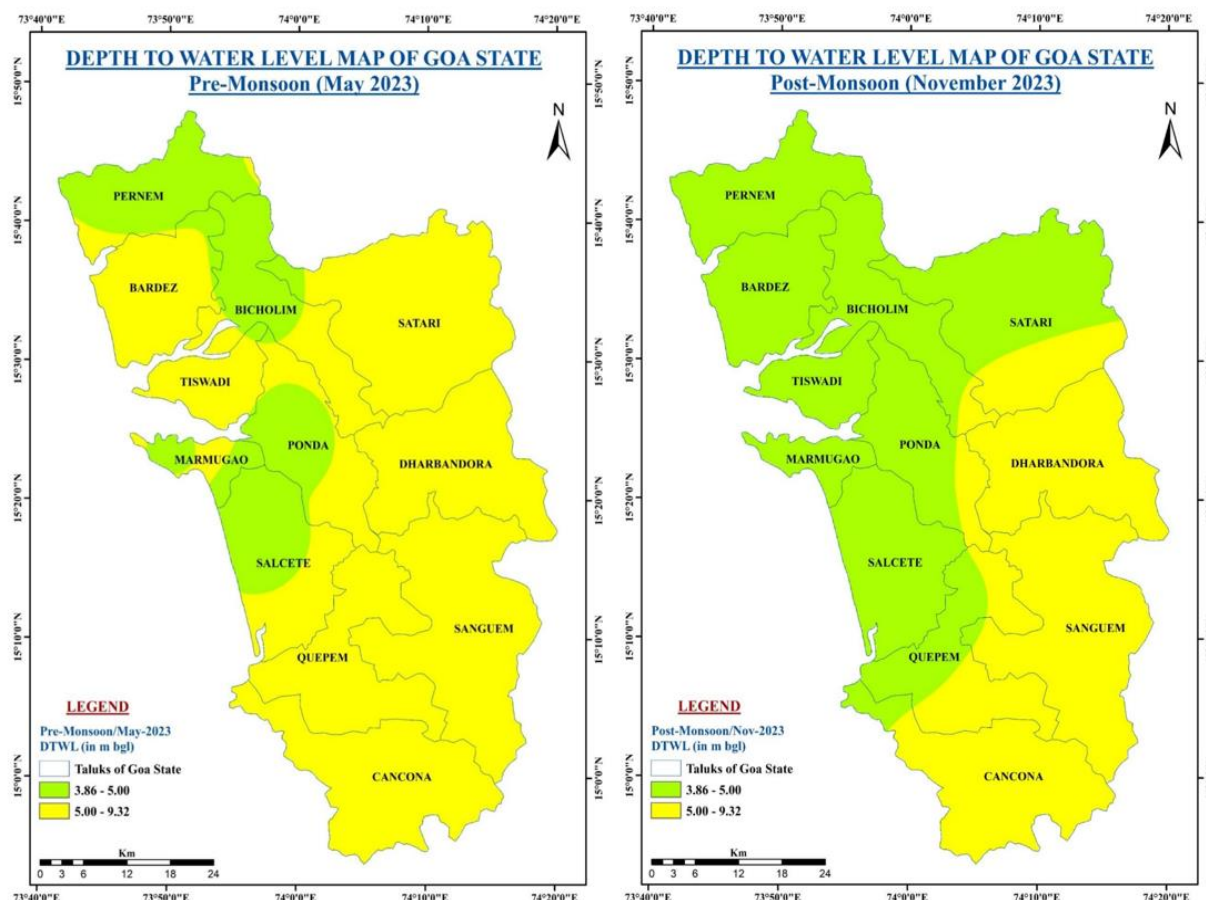
Aquifer System	Type of Aquifer	Thickness of weathered zone (m)	DTWL (Decadal Average) (mbgl)	Fractures Encountered (mbgl)	Transmissivity (m ² /day)	Yield (m ³ /day)	S	Quality (EC in µS/cm)
Banded Gneissic Complex	Semi-confined / Confined	5-70		20-70	Jan-50	10-300	1x10 ⁻³ -10 ⁻⁶	200-500
Schist	Semi-confined / Confined	10-40		20-100	1-150	10-500	1x10 ⁻³ -10 ⁻⁵	200-600
Granite Rocks	Semi-confined / Confined	15-30		40-120	1-100	40-200	1x10 ⁻³ -10 ⁻⁵	200-500
Basic-Basalt	Semi-confined / Confined	10-20	1.79-18.88	20-45	1-232	15-850	1X10 ⁻³ to -5	100-500

Source: Central Ground Water Board³⁰

Depth to Water Level:

In Canacona, groundwater levels ranged between 5 to 9.32 mbgl during both the pre-monsoon (May 2023) and post-monsoon (November 2023) periods, indicating limited seasonal fluctuation (Ref. Figure 15). This suggests low recharge efficiency despite high rainfall, possibly due to steep terrain, increased surface runoff, or urbanisation. The dominance of hard rock aquifers, such as granite and Banded Gneiss, which have limited storage and slow recharge, may also contribute. These patterns point to emerging groundwater stress and highlight the need for improved recharge strategies and regular monitoring.

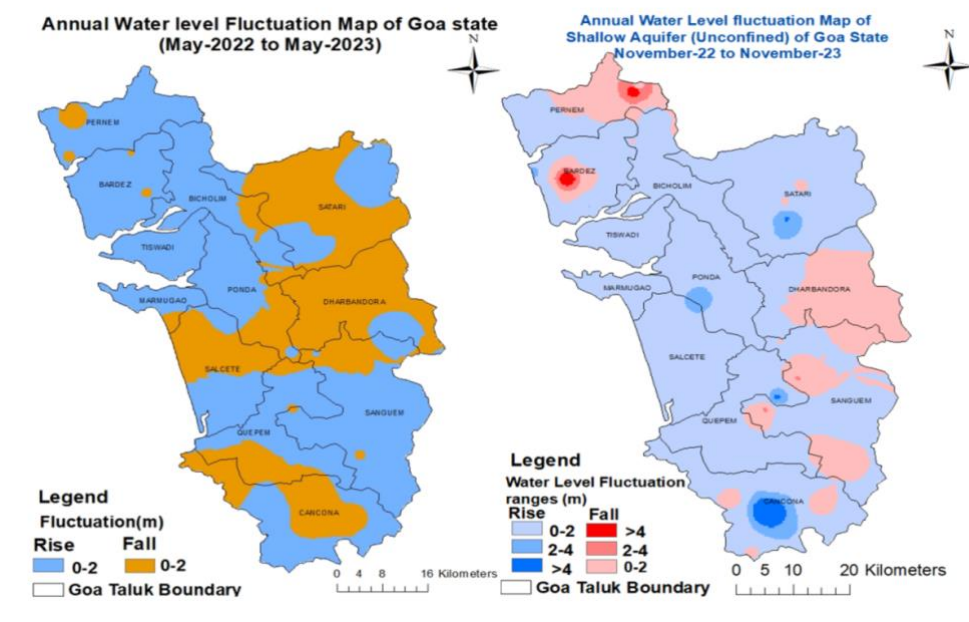
Figure 15: Pre monsoon (May 2023) and Post Monsoon (Nov 2023) Depth to Water Level in Canacona Taluk.



Source: Water Resource Department, Government of Goa & Central Ground Water Board³¹.

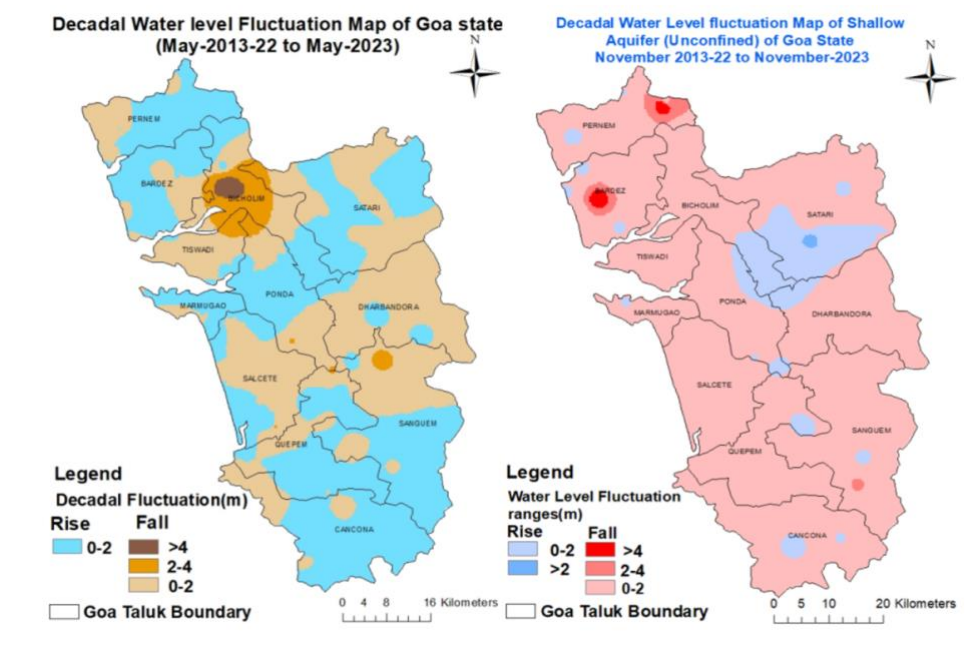
Annual and decadal groundwater level data in Canacona indicate modest but consistent trends (Ref. Figure 16). Between May 2022 and May 2023, water levels rose by 0–2 meters, reflecting moderate recharge, likely driven by monsoonal rainfall. However, post-monsoon observations from November 2022 to November 2023 show a 0–2-meter fall, suggesting rapid drawdown or limited post-monsoon recharge retention. Over a longer period (2013–2023), the pre-monsoon decade-long trend also reflects a 0–2-meter rise, while post-monsoon levels continue to show a 0–2-meter decline (Figure 17). This pattern points to possible seasonal over-dependence on groundwater, limited aquifer storage capacity, and potential impacts of land use changes on recharge dynamics.

Figure 16: Groundwater Level Fluctuations (Shallow Aquifer): Pre-monsoon (May 2022 to May 2023) & Post-monsoon (Nov 2022 to Nov 2023)



Source: Water Resource Department, Government of Goa & Central Ground Water Board³¹

Figure 17: Decadal water Level Fluctuations (Shallow Aquifer): Pre-monsoon (May 2013 to May 2023) & Post-monsoon (Nov 2013 to Nov 2023)

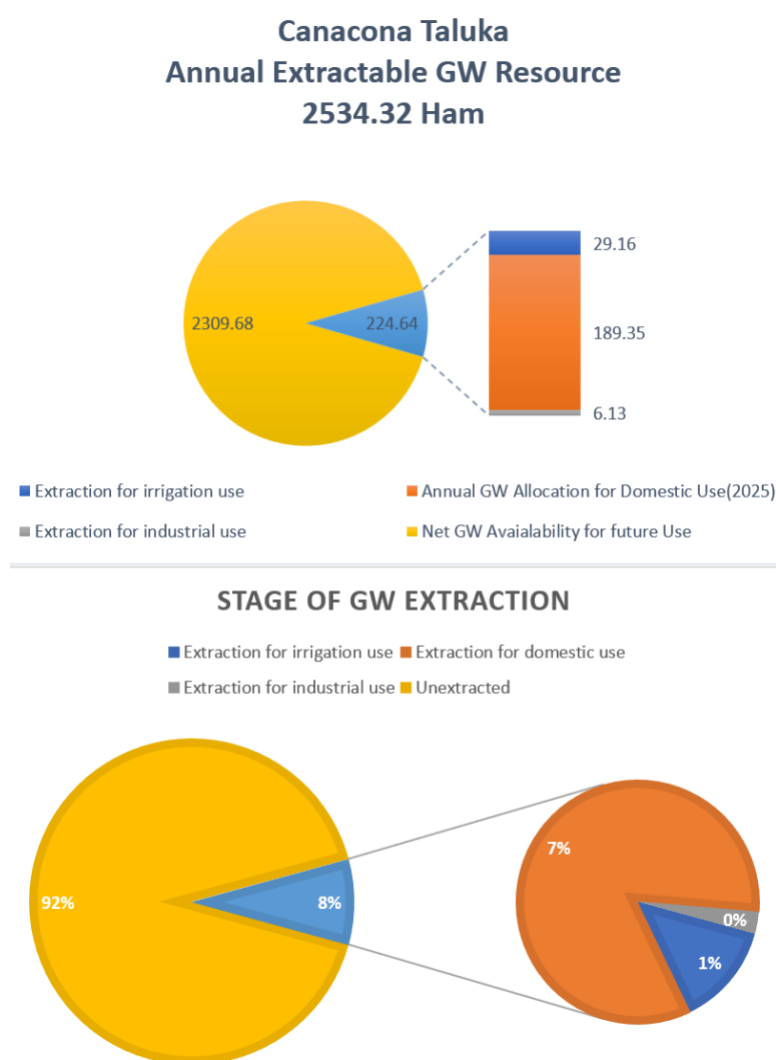


Source: Water Resource Department, Government of Goa & Central Ground Water Board³¹

Ground Water Resource Estimation for Canacona Block:

The groundwater extraction status in Canacona Taluka reflects a largely sustainable scenario (Ref. Figure 18), with 92% of the annual extractable groundwater resource (2,534.32 ham) remaining unused. Only 8% (224.64 ham) is currently extracted, primarily for irrigation (29.16 ham), domestic (189.35 ham), and minimal industrial use (6.13 ham). The dominant share of future availability signals low extraction stress. However, as demand especially for domestic & commercial use increases, careful monitoring and regulation will be necessary to ensure continued sustainability and prevent localized stress, particularly in areas with fractured aquifers or shallow water tables.

Figure 18: Ground Water Resource Assessment (2022) for Canacona Block



In conclusion, while Canacona's groundwater systems currently remain within safe extraction limits, emerging localized pressures driven by rising reliance on borewells, inadequate regulation, and fragmented data, pose sustainability risks. The region's complex hydrogeology, coupled with shifting rainfall patterns and expanding peri-urban demand, necessitates proactive groundwater governance. Strengthening aquifer monitoring, protecting recharge areas, promoting decentralized rainwater harvesting, and regulating unplanned borewell drilling are critical to ensuring that groundwater remains a reliable buffer against surface water fluctuations. In the context of climate change and growing water stress, Canacona's groundwater must be managed as a strategic, not supplemental, water source.

3.3 WATER INFRASTRUCTURE

Canacona's water supply infrastructure has evolved in phases to meet growing demand and changing source availability. Initially dependent on the Talpona River, the system was established in 1978 with a jackwell at Ardhafoond drawing water to a 5 MLD WTP at Shristhal. This facility was supported by two 800 m³ GLSRs, distributing treated water across the town.

In 2008, to augment capacity and address increasing demand, Chapoli Dam was integrated into the system. A new 10 MLD WTP was commissioned alongside a 4,000 m³ Master Balancing Reservoir (MBR), and a 400 mm diameter ductile iron main was laid to improve distribution. Subsequent improvements in 2020 added two additional GLRs at Devabag and Marangan (800 m³ each), extending supply coverage to Palolem, Char Rasta, Kindlebag, and Colomb. Water for Chaudi Market, Delem, and Mokharda continues to be fed from the Shristhal GLSRs via main pipelines (Figure 20).

The system functions entirely through a gravity-based distribution model, eliminating the need for booster pumping stations. While this ensures energy efficiency, the undulating topography of the region poses challenges for equitable supply, especially in higher elevation areas.

The Canacona WTP schematic (Ref. Figure 19) outlines how raw water from Chapoli Dam and Talpona River is processed. The Chapoli intake is handled by a 4-pump system (two on duty), while the Talpona intake operates via a 3-pump jackwell. The plant comprises a clarifier unit, two rapid sand filters, an aerator, and a gas chlorination facility. However, critical equipment such as the flash mixer and clarifier was reported to be non-functional during field visits.

The water supply scheme draws approximately 15 MLD of raw water comprising 10 MLD from Chapoli Dam and another 5 MLD from Talpona River through Ardhafoond jackwell.

Figure 19: Schematic of Canacona Water Treatment plant

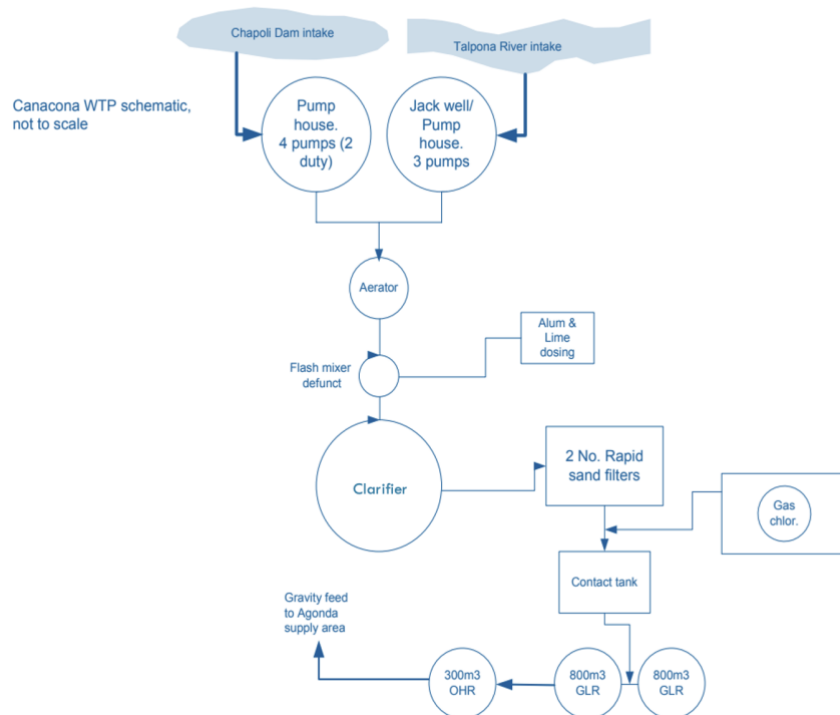


Image Source: PWD, Goa

Figure 20: Schematic of the Canacona Water Distribution System.

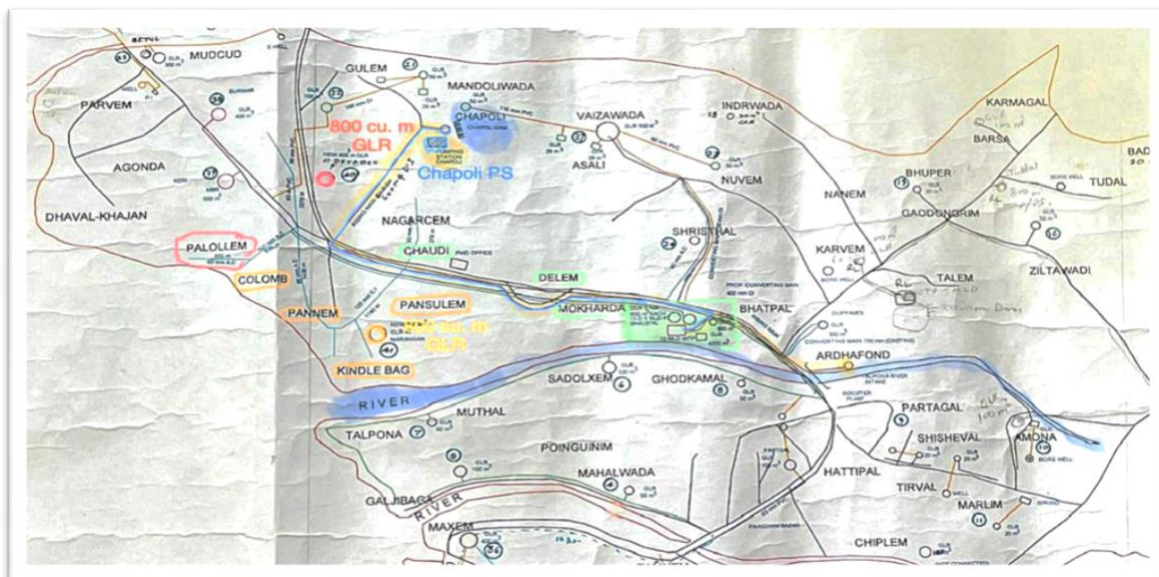


Image Source: PWD, Goa

O&M practices at the plant reflect a reactive model. There is no formal preventive maintenance system, no operating manuals, and limited documentation of daily or scheduled maintenance activities. O&M staff rely on informal, experience-based training, and safety protocols remain weak.

Water quality monitoring is conducted in a small onsite laboratory, though raw and treated water quantities are not measured at intake or output points. Despite generally good housekeeping standards, the overall system lacks robust operational controls, standard procedures, and contingency planning, making it vulnerable to disruptions and inefficiencies.

Thus, while the Canacona water supply system has significantly expanded its capacity and reach over the years, gaps in maintenance, safety, monitoring, and operational resilience require urgent attention to ensure long-term service reliability and climate adaptation readiness.

3.4 WATER DEMAND & SUPPLY

Canacona Municipal Council (MMC) has a population of 12434 spread across 2879 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 6*.

Table 6 : Population Projections

	2025	2031	2041	2051
Estimated Population**	12945	12904	12489	11644
Domestic Demand ¹	1.7	1.7	1.7	1.6
Floating Population Demand ²	0.06	0.10	0.27	0.27
Commercial Demand ³	0.61	1.08	2.80	2.80
Institutional Demand ⁴	0.24	0.25	0.28	0.31
Fire Demand ⁵	0.01	0.01	0.01	0.01
Industries⁶	0.03	0.03	0.03	0.03
Total Demand (MLD)	2.7	3.2	5.1	5.0

¹Estimated at 135 liters per capita / day (lpcd)

²Floating population assumed to be 10 % of population owing to tourism. The floating population demand is assumed to grow at 10% p.a. upto 2041 in line with the tourist visits growth rate for Goa.

³Commercial demand estimated based on actual commercial demand for Jan 2025 and assumed to grow at 10% p.a. upto 2041.

⁴Water demand by institutions based on actual institutional demand for Jan 2025 and assumed to grow at 1%.

⁵Fire demand = $100 \sqrt{P}$ m³ /day where P is the population. (CPHEEO 2024)

⁶ Demand by industries in the area is based on actual consumption data provided by the operator -PWD DIV XX.

** 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 consumption statement provided by PWD Division XX, Margao for the CMC area between 18.01.2025 to 21.02.2025 indicates **4804 water meter connections**. The category wise daily average water consumption based on the above data is as follows:

Figure 21: Category wise connection and daily average water consumption for CMC.

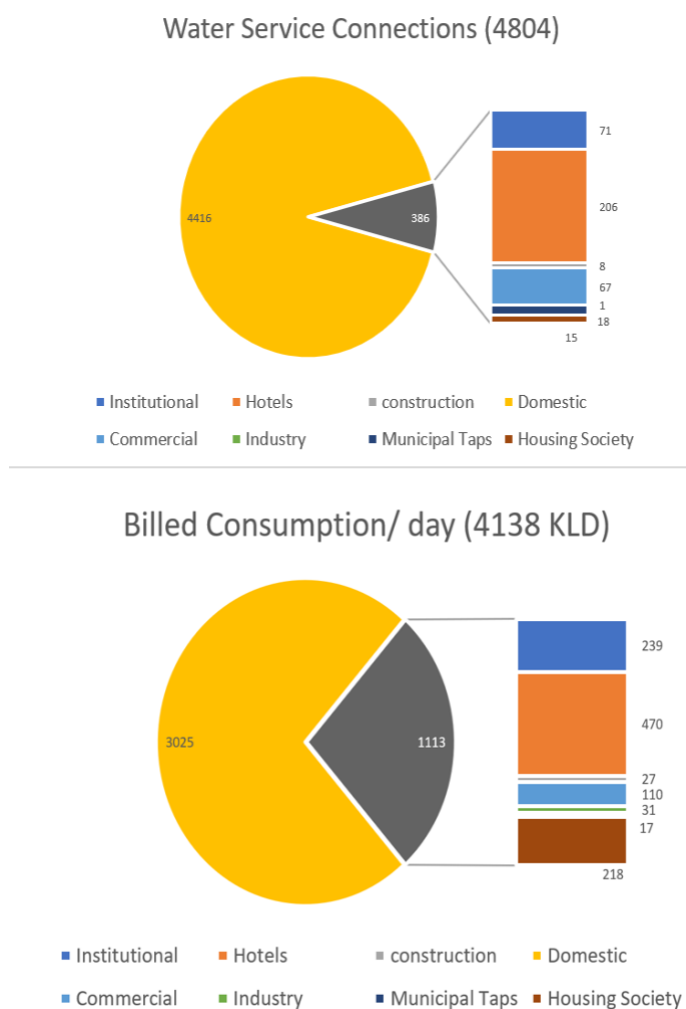
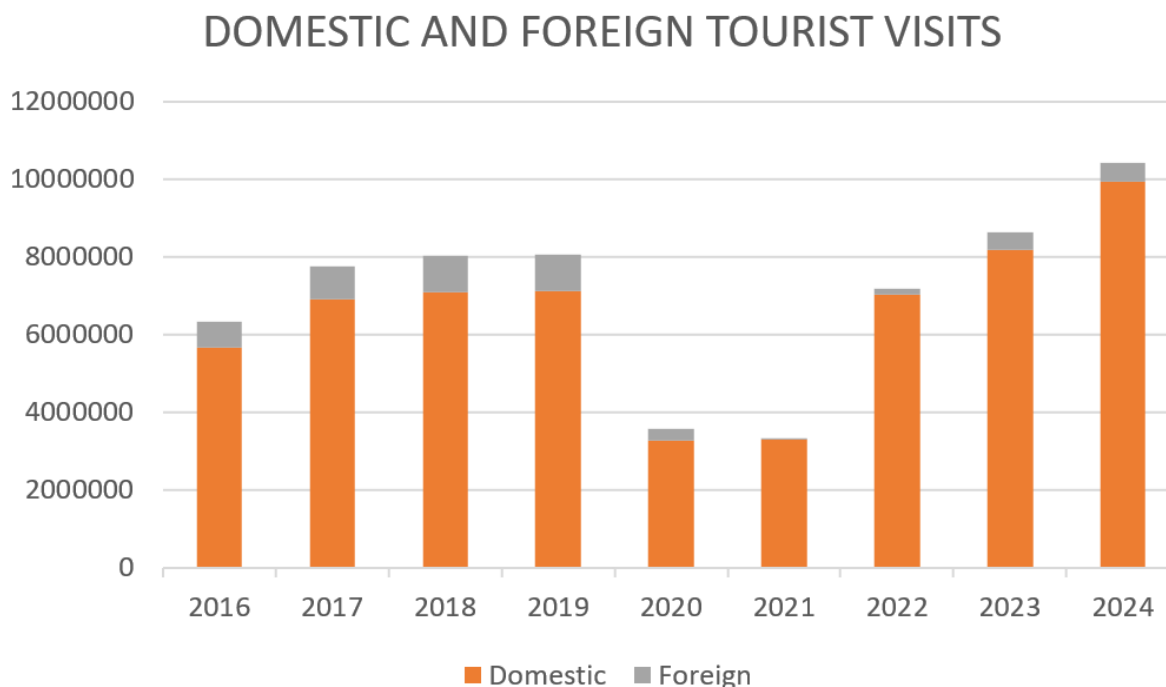


Figure 22: Tourist visits in Goa 2016-2023.



In Canacona, municipal water consumption data indicates that 4,416 household connections consume approximately 3,025 kilolitres per day (KLD), translating to an average per capita daily water consumption of around 159 litres. While the municipality reports 100% coverage of households with piped water connections, actual water usage reveals sectoral disparities. Notably, commercial establishments particularly hotels consume around 206 KLD, which is about 16% of the domestic consumption. This is equivalent to the daily consumption of nearly 300 households, underscoring the disproportionately high demand from the tourism sector.

Given Canacona's growing profile as a tourism hotspot, water demand from hotels and related services is expected to rise significantly. Consequently, commercial water demand projections for the town have accounted for anticipated tourism growth. This trend also highlights the need for targeted demand management strategies and differentiated tariff structures to ensure equitable and sustainable water use across domestic and commercial consumers.

3.5 CLIMATE RISKS AND CHALLENGES

Canacona's urban water system though strengthened in capacity over time, remains increasingly vulnerable to multiple and intersecting risks driven by climate change, ageing infrastructure, and rising tourism-linked demand. The challenges affect not only source sustainability and system efficiency, but also water equity, and long-term resilience.

Frequent Interruptions and Power Dependency

The water supply system's reliance on pumping especially from Chapoli Dam makes it highly vulnerable to power outages. Grid failures, monsoon storms, or scheduled maintenance frequently disrupt operations, particularly in remote and elevated areas. The absence of backup pumping systems or renewable energy support further amplifies the risk of prolonged supply interruptions.

Tourism-Driven Demand and Resource Strain

Tourism in Canacona, especially in popular destinations like Palolem and Agonda, exerts substantial pressure on water supply systems. Hotels and resorts consume 206 KLD equivalent to the demand from over 300 households often with greater reliability and preference than residential areas. Seasonal influxes during peak months strain both source and infrastructure, skewing distribution in favour of commercial zones and exacerbating inequities in access.

Uneven Distribution and Service Disparities

The undulating topography of Canacona affects the performance of its gravity-fed water distribution system. Areas situated at higher elevations or farther from reservoirs face intermittent or reduced-pressure supply. This geographical challenge, combined with infrastructural limitations, leads to unequal access and service reliability across the town, especially during peak demand periods or operational disruptions.

Ageing Infrastructure and Maintenance Gaps

Although significant infrastructure has been added over the years, much of the system—including pump houses, clarifiers, and chlorination equipment—suffers from ageing, under-maintenance, and safety lapses. Field assessments indicate poor record-keeping, absence of formal preventive maintenance protocols, lack of spare parts for key systems (e.g., chlorinators), and unsafe practices like using flexible hoses instead of standard fittings. These vulnerabilities heighten breakdown risks during climatic events or system overloads.

Photos of ageing water infrastructure at Canacona



Source: IITB Team

Overreliance on Imported Water and Neglect of Local Sources

A key structural challenge is Canacona's growing dependence on long-distance, centralized water supply through Chapoli Dam and Talpona River, which has led to neglect of traditional, decentralised sources. The region's ponds and village wells once vital for agriculture and household use are now degraded, overgrown, and underutilized. Many function as mosquito breeding grounds rather than water reserves. This overreliance on external sources poses multiple risks:

- Disruption during droughts or cyclones: Extreme weather can damage infrastructure and interrupt pumped supply.
- High carbon footprint: Energy-intensive operations increase emissions and operational costs.
- Conflict potential: Competing demands may emerge as water scarcity increases in other regions drawing from the same sources.

Photos showing some Neglected Dug-wells in Canacona



Source: IITB Team

Figure 23: News article about neglected local water sources in Canacona town

Neglected, many water bodies in Canacona town dying slowly

Albert Fernandes / Dec 27, 2022, 04:25 IST

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Locals say that the ponds have water throughout the year and have become breeding spots for mosquitoes as the water is...

Canacona: Several water bodies in and around Canacona town area, once considered the lifeline of farmers, are dying a slow death. In the absence of efforts from the water resources department and other government bodies to rejuvenate these water bodies have been invaded by vegetation and have turned into breeding ground for mosquitoes, said locals.

The ponds are situated amidst fields along the stretch from the Konkan Railway station to the municipality building and the KTC bus stand to

Pansulem.

Source: Times of India³²

Climate Variability and Source Vulnerability

Erratic monsoon behaviour marked by both intense rainfall and prolonged dry spells is impacting the recharge and reliability of both surface and groundwater systems. While the Chapoli Dam's storage has generally sufficed, reduced inflows during dry years and rising sedimentation risks could affect its long-term viability. Groundwater recharge is also becoming more uncertain due to urbanisation and changing rainfall intensity.

Strategic Risks and the Need for Local Resilience

The focus on centralized water supply has distracted from the potential of localised, low-carbon, and climate-resilient systems. The degradation of village tanks, the lack of recharge structures, and limited investment in nature-based solutions reduce the town's ability to withstand climate shocks. Moreover, poor data on groundwater abstraction, quality, and recharge further complicates long-term planning.

In summary, Canacona's water system sits at a crossroads. While existing infrastructure meets much of the town's demand, growing tourism, rising climate stress, and systemic inefficiencies expose the region to increasing water risks. Moving forward, a resilient approach must integrate local water sources, reduce emissions, and ensure equitable access while proactively addressing climate-linked vulnerabilities. This will require robust planning, decentralised solutions, and stronger governance of both infrastructure and resources.

The case of Canacona illustrates the complex interplay between climate variability, infrastructural limitations, rising demand, and governance challenges in shaping the sustainability of urban water systems. Despite its relative abundance of surface and groundwater resources, Canacona's water supply is increasingly vulnerable to shifting rainfall patterns, tourism-driven consumption, and ageing infrastructure. The heavy dependence on centralised surface water, coupled with declining attention to local and traditional sources, has created a fragile supply system highly exposed to climatic and operational shocks.

NOTES & REFERENCES

- ²⁵ 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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4. URBAN SANITATION SYSTEMS IN CANACONA: 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 Canacona, 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^{33,34,35}. *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*³⁶. WaSH services are essential for preventing disease outbreaks, particularly in the aftermath of climate hazards such as heavy rainfall and flooding^{37, 38}. 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*³⁹. 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 role⁴⁰.

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 practices'⁴¹. 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.

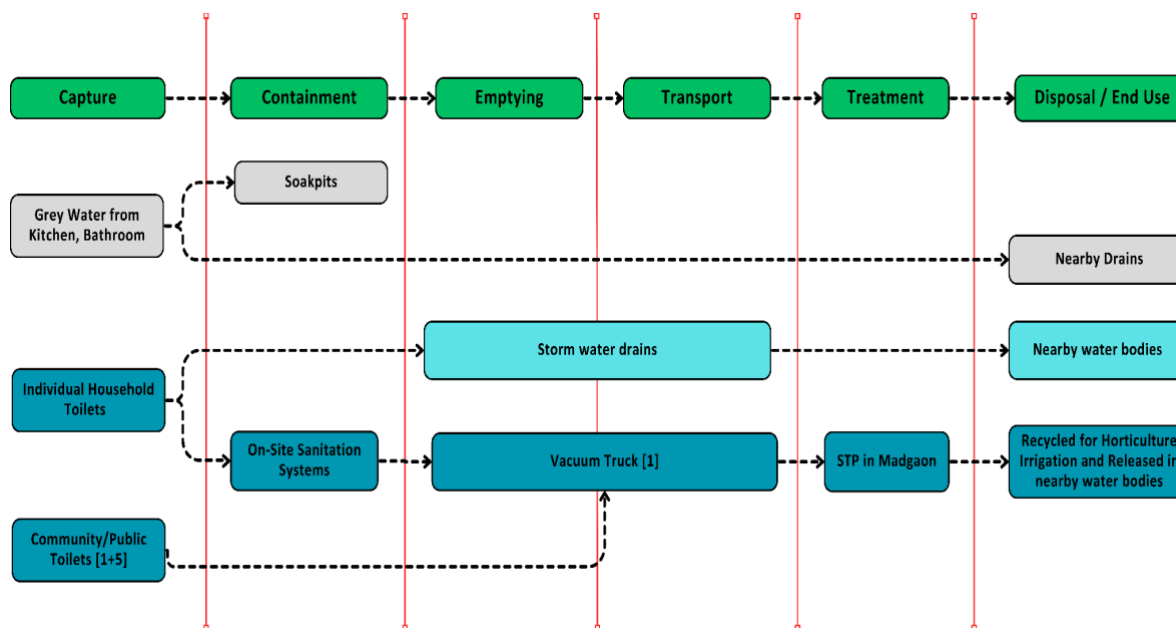
Hence, assessing the current state of sanitation services is essential for identifying infrastructure gaps, vulnerabilities, and climate-related risks. Such an assessment supports the design of proactive adaptation measures, promotes efficient resource use, and enables low-carbon development strategies. 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 *Canacona*. 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 use⁴². This section outlines the service chain and identifies the key gaps. The entire service chain is depicted in *Figure 24*.

Figure 24: Sanitation Service Chain in Canacona



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, out of 2879 households 165 households lacked individual toilets. However, as this data is outdated, we gathered more recent information through interviews with the municipal officials. Data collected from the Canacona Municipal Council reveals that out of 6,353 households, 3,408 do not have individual toilets i.e., 54% depend on community toilets. However, interviews with the SBM-U city coordinator, along with our field assessments and interactions with local residents, indicate that all households in the town, including those in high-density areas predominantly occupied by fishing communities, have individual toilets the city has been officially declared 100% Open Defecation Free (ODF), **which aligns with the**

SLB norms of Government of India and the target (6.2) outlined in the SDGs.

Information on the typology of toilets is crucial—not only for assessing the quality and adequacy of sanitation services, but also for estimating the GHG emissions associated with different toilet systems. However, the last comprehensive assessment was conducted as part of the 2011 Census, and no updated data has been made available, either at the national, state, or city level. Collecting such data would require a dedicated household-level survey, which falls outside the scope of routine assessments.

- **Community Toilets and Public Toilets**⁴³: Currently, the city has one CT located in Ward 10 and a total of five PTs, one of which is still under construction. Additionally, an aspirational public toilet has been established at Palolem Beach in Ward No. 12 to serve the floating population. It is operated by a private agency on a pay-and-use basis⁴⁴.

However, information on **community and public toilet coverage** is unavailable, as the ULB does not maintain any registers or records tracking the number of users or whether the facilities are **able to cater the demand**. ULB officials stated that the **locations of these** public toilets were strategically chosen based on need and footfall.

Photo of an Aspirational Public Toilet near Palolem Beach

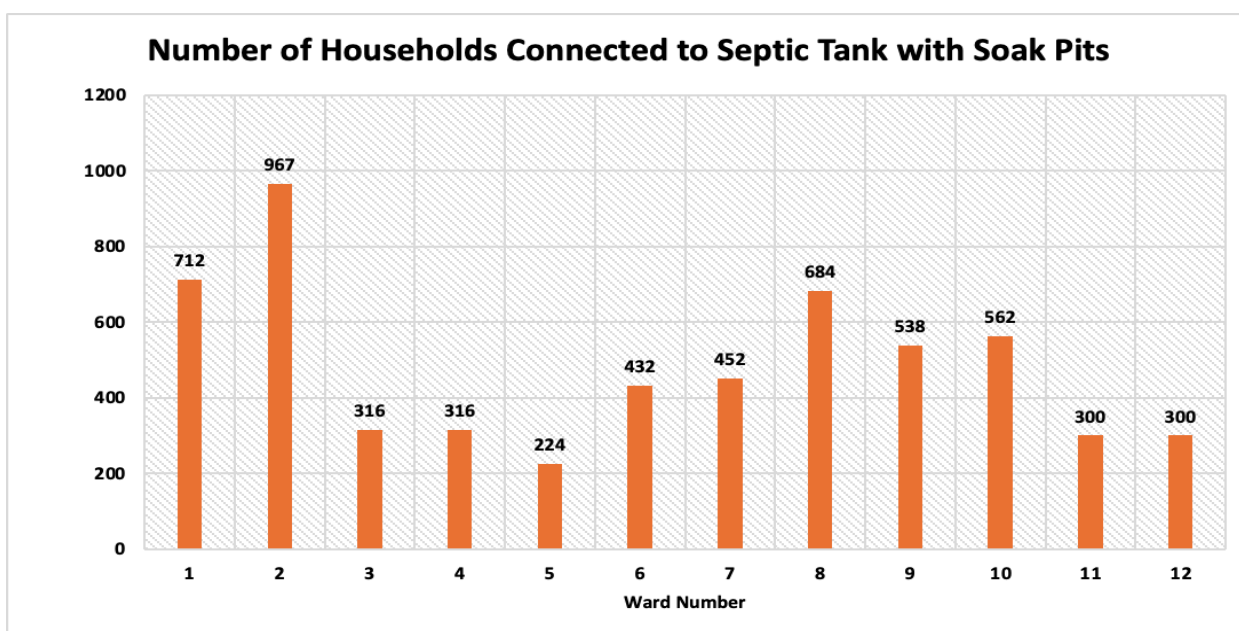


Source: IITB team

To assess the condition of PTs, we spoke with ULB officials, who reported that the facilities are in good condition and well maintained. To verify these claims, our team visited two public toilets. During our visits, we observed that both toilets were indeed clean, well maintained, and had access to running tap water. The water supply to the toilets comes from municipal piped water. However, the ULB does not maintain any formal records of cleaning activities.

- **Containment:** According to the data we have received, approximately 91% of households (HH) rely on OSS systems with septic tanks plus soak pits. The figure below (25) illustrates infrastructure deficiencies by highlighting the wards with the highest number of households whose toilets are connected to a proper containment system, such as a septic tank with a soak pit. A rapid assessment involving interactions with residents indicated the presence of both septic tanks and soak pits. Based on field interactions, we observed that greywater from kitchens and bathrooms is directed into separate soak pits in some households, while in others, it is discharged into nearby drains and open areas.

Figure 25: Ward-wise Number of Households Connected to Septic Tanks with Soakpits



Source: Data from Canacona Municipal Council

- **Emptying and Transport:** The town does not have a sewerage network system and therefore relies on desludging vacuum trucks. Currently, one vacuum truck, owned by the Canacona urban local body and with a capacity of 3,000 liters, operates within Canacona city. On average, the truck makes two trips per day, each covering approximately 80 kilometers (round trip) to dispose of the septage at the nearest STP in Margao.

The city also has 75% coverage with stormwater drains, as per the SLB- 2018-2019. However, interactions with residents in Ward 8, 9, and 12 (where the groundwater table is 10 feet) revealed that waterlogging occurs during the monsoon season. This suggests that the current stormwater drainage coverage may be inefficient, as flooding persists despite the infrastructure in place. However, there is a lack of secondary data regarding typology of storm water drains.

Although the water typically resides within 4-5 hours, the flooding does not seem to have a significant impact on toilets or other essential facilities in the area. As discussed in Chapter 4 (town profile) this issue may be attributed to unregulated urban expansion, inadequate maintenance of natural water storage systems (such as tanks), and poor management of drainage infrastructure, especially within municipal areas.

- **Treatment:** The SBM urban data received from the ULB shows that the town generates 1.94 MLD of wastewater but does not have its own STP. Under an arrangement between the Canacona Municipal Council and the Margao Municipal Council, septage emptied and transported by a vacuum truck is disposed of at the STP in Margao. The Margao STP has a capacity of 20 MLD. The treated water from the plant is then used for irrigation purposes.
- **End-use Disposal (Septage and Sludge Management)⁴⁵:** The city does not have a Fecal Sludge and Septage Management facility. As mentioned earlier, septage is currently collected and transported by a vacuum truck to the STP in Margao.
- **Recycling and Reuse:** The treated wastewater from the Margao STP is recycled for irrigation purposes.

4.3 INSTITUTIONAL ARRANGEMENTS

This sub-section examines the institutional arrangements, outlining the various departments, agencies, and organizations, along with their respective roles in delivering sanitation infrastructure and services (refer Table 9). 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 (CAA), ULBs are primarily responsible for delivering water supply and sanitation services. However, in practice, a multi-stakeholder, multi-level governance framework involved in the provision of sanitation infrastructure and services was observed.

This town has a distinct institutional arrangement for sanitation infrastructure and service delivery, with the PWD taking the lead in nearly all aspects of water and sewerage planning, implementation, and O&M. This framework is further reinforced through inter-city collaborations and central government funding, especially for larger infrastructure. The study findings are consistent with the Comptroller and Auditor General of India's (CAG) Assessment Report for Goa (Comptroller and Auditor General of India, 2024), which underscores that the partial or inadequate devolution of essential functions, as well as administrative and financial powers, from the state to Municipal Councils (MCs) under the 74th CAA remains a widespread challenge across the state⁴⁶.

Sanitation infrastructure such as toilets and on-site sanitation systems at the household level is largely the responsibility of the household itself. For sludge management, households may opt to rely on vacuum trucks, typically provided by the registered private operators. However, there is a lack of regulation concerning both on-site sanitation systems and toilet designs. 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, operation and maintenance (O&M), and funding. SBM, capital funding was provided for some CTs and PTs. The environmental compliance of CTs and PTs is uncertain. The O&M specifically day-to-day cleaning of some of the CTs is given to the communities. The O&M of public toilets have been outsourced to private vendors, who recover the costs through user charges.

For large infrastructure development projects, such as the sewerage network and STP, the Canacona Municipal Council has no direct involvement. As illustrated in the table below, the entire process—including technology selection, land acquisition, capital funding, technology implementation, and operations and maintenance (O&M)—is managed by the central government, state-level departments (such as the Public Works Department), and SIDCGL. This relegates the Canacona Municipal Council to a passive role, undermining the spirit of the 74th CAA and its intended autonomy. Furthermore, this centralized approach disrupts the flow of critical information and finances, limiting the ULB's ability to make informed decisions, take

ownership, and actively manage sanitation infrastructure. As a result, the council's capacity to effectively address the specific needs of its local population is severely compromised. Furthermore, interviews with the ULBs revealed that their role in disaster governance and planning is limited. They primarily focus on providing sanitation and water supply during the relief phase of a disaster.

Table 7: Institutional Arrangements in Sanitation Services

Intervention	Technology Selection	Land	Capital	Technology Provision	Technology implementation	O&M	O&M Funding
Toilets	HH	HH	HH	Local vendors/Mesons	Local Vendors/Mesons	HH	HH
OSS	TCPD at Taluk Level	HH	HH			HH	HH [desludging fee]
						Septage removal by vehicles of ULB	
CT	ULB	ULB	ULB	ULB	ULB	ULB	ULB
			Central Government [SBM 1.0]				
PT	ULB	ULB	ULB	ULB	ULB	ULB [1]	ULB
			1 is funded by Central Government [SBM 1.0]			Private Vendor [4]	Users (User fee paid to private vendor)
Sludge and Septage Management [1 vacuum truck]	ULB	Not Applicable	Central Government [SBM 1.0]	ULB [Vacuum trucks]	Not Applicable	ULB	ULB

Source: Authors' Analysis

4.4 CHALLENGES AND OPPORTUNITIES IN SANITATION INFRASTRUCTURE AND SERVICES

It is evident that the town is falling drastically short of meeting several of the SLB norms set by the Government of India, primarily due to severe infrastructural deficiencies. These significant gaps represent major barriers to achieving the necessary service levels and pose a serious threat to public health and environmental sustainability.

At the household level, the current building plan approval mechanism ensures that toilets and OSS systems comply with design standards, effectively and safely containing faecal matter. However, the city is grappling with severe infrastructure deficiencies in sanitation services, including an insufficient number of vacuum trucks, the absence of a FSTP, a sewerage network, and a sewage treatment plant. These gaps create a significant and urgent challenge in the city's ability to effectively and efficiently manage, treat, and dispose of wastewater.

The repercussions of these infrastructural gaps are far-reaching, resulting in water pollution in both surface and groundwater (particularly in areas with a high-water table), as well as contamination of beaches and creeks and GHG emissions. Further, given that onsite sanitation systems—primarily septic tanks and pits—are responsible for nearly 90% of total sanitation-related emissions, targeted interventions in this area could yield substantial climate benefits. The low frequency of desludging allows sludge to decompose anaerobically on-site, significantly increasing methane emissions. Introducing regular desludging schedules, along with improved containment designs, could help mitigate this issue. Additionally, nutrient leakage from onsite systems into marine and estuarine environments is contributing to indirect nitrous oxide (N₂O) emissions, which pose a serious threat to coastal ecosystem health. These challenges underscore the need for a robust faecal sludge management strategy that addresses both climate and environmental risks through improved system design, regular maintenance, and enhanced regulatory oversight.

This is especially concerning given that the town is a prominent tourism hub, where environmental health is vital to its appeal. This is further corroborated by various media reports and our field interactions with local residents. During our fieldwork, residents shared that well water is contaminated due to septage, resulting in health issues and a widespread reluctance to consume it. Recent media reports highlight the indiscriminate disposal of sewage at Palolem Beach and nearby lakes, posing serious risks not only to visitors but also to the local tourism industry and the health of residents^{47,48}. The poor management of sewage in Canacona taluka, exacerbated by rapid urbanization, has led to an alarming rise in unchecked sewage discharge. New hotel projects and residential developments have been accused of discharging sewage into nearby fields, further aggravating the situation and complicating efforts to address the issue.

Additionally, these deficiencies force residents to rely either on expensive private sector services and, in some cases, resort to improper disposal practices, such as discharging untreated or partially treated wastewater into drains, which ultimately flow into nearby water bodies. For instance, the town's reliance on a single desludging truck, which travels approximately 70 km daily to collect and dispose of septage, is insufficient to meet the needs of all residents. Furthermore, the high cost of Rs. 6000 per trip places a significant financial strain on individual households, making it an unsustainable and unrealistic service option. Our field interactions with residents from apartments, individual households, and commercial establishments such as restaurants revealed that many are forced to rely on private vacuum trucks for septic tank cleaning, at even higher costs (ranging from INR 9,000 to INR 10,000 per trip).

Moreover, while the reliance on the Margao Municipal Council for sewage treatment may have sufficed in the past, it is not a sustainable solution given the growing urban population and increasing concerns about unchecked wastewater being dumped into water bodies.

Furthermore, the current stormwater drainage system may be ineffective, as waterlogging continues despite the reported 75% coverage with stormwater drains, particularly in Ward 9, 12 (where the groundwater table is 10 feet), and Ward 8 as suggested by the residents. This could be due to poor maintenance and clogged drains may be contributing factors. Fortunately, the waterlogging does not appear to significantly affect toilets or other essential facilities in the area.

Clearly, there is an urgent need to address these critical infrastructural gaps in stormwater management, sewage management, and septage management. However, these challenges also present unique opportunities to leapfrog traditional approaches and explore innovative, unconventional sanitation solutions, such as FSSTPs, nature-based solutions, and decentralized systems. These alternatives have the potential to be more financially viable and environmentally sustainable. By embracing these opportunities, the town can make significant strides in improving public health, protecting the environment, and enhancing its resilience to the escalating impacts of climate change. Effective sanitation solutions will not only reduce the risk of waterborne diseases and minimize pollution but also mitigate the environmental harm caused by untreated wastewater. This transformation will elevate residents' quality of life, strengthen the town's adaptive capacity to the increasingly severe challenges posed by climate change, and ultimately foster long-term resilience, ensuring that the town remains a sustainable and thriving hub for both local communities and the tourism sector.

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- ⁴¹ Ministry of Housing and Urban Affairs. (2008). National Urban Sanitation Policy-2008. New Delhi.
- ⁴² UNICEF. (2020). What do safely managed sanitation services mean for UNICEF programmes? WASH Discussion paper.
- ⁴³ 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)

⁴⁴ The Government of India (GoI) launched Swachh Bharat Mission (SBM) 2.0 to build on the successes of SBM 1.0 and address ongoing sanitation issues, aiming to develop healthy, sustainable, and livable urban spaces. A key feature of SBM 2.0 is the introduction of "aspirational toilets," which requires that 25% of the public toilet seats added in any city or urban unit be designated as such. Aspirational toilets, ULBs will have to provide additional PTs in all tourist destinations/ places with high footfall/ iconic cities/ religious destinations. For more information on Aspiration Public Toilet refer to <https://niua.in/intranet/sites/default/files/3234.pdf>

⁴⁵ “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).

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5. CLIMATE IMPACTS OF WATER & SANITATION SYSTEMS

ASHISH DANGI⁴⁹ 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

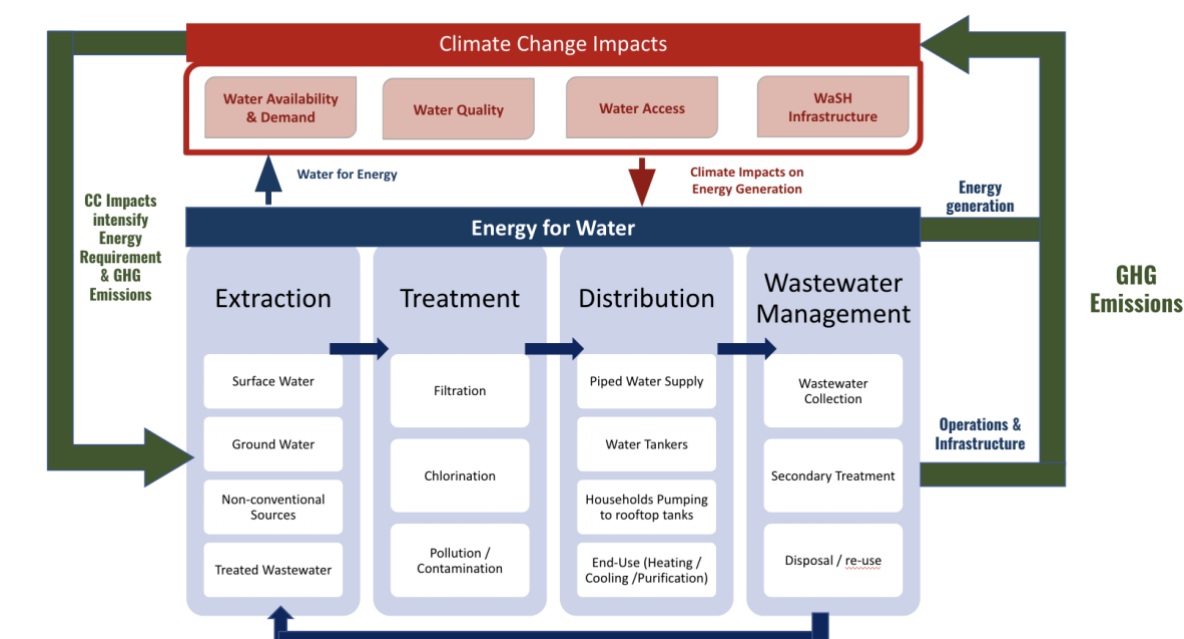
Globally, the water and sanitation systems are increasingly recognised not only as climate victims, but also significant contributors to climate change as the GHG emissions from WaSH continue to grow. Energy is the key input to every step in an urban water cycle right from water extraction to conveyance, 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*⁵⁰. According to another estimate, wastewater treatment plants alone are estimated to account for 3% global electricity consumption⁵¹. 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) emissions⁵². *Direct emissions in wastewater treatment are estimated to be significant at ~1.57% of global GHG emissions*⁵³.

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 cycle⁵⁴. 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%⁵⁵. 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 East⁵⁶. 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 WWTPs⁵⁷. *With the increased variability posed by climate change the emission in WWTPs could further increase*⁵⁸.

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*⁵⁹. *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 26: The Water-Energy-Climate nexus in Urban Water Cycles.



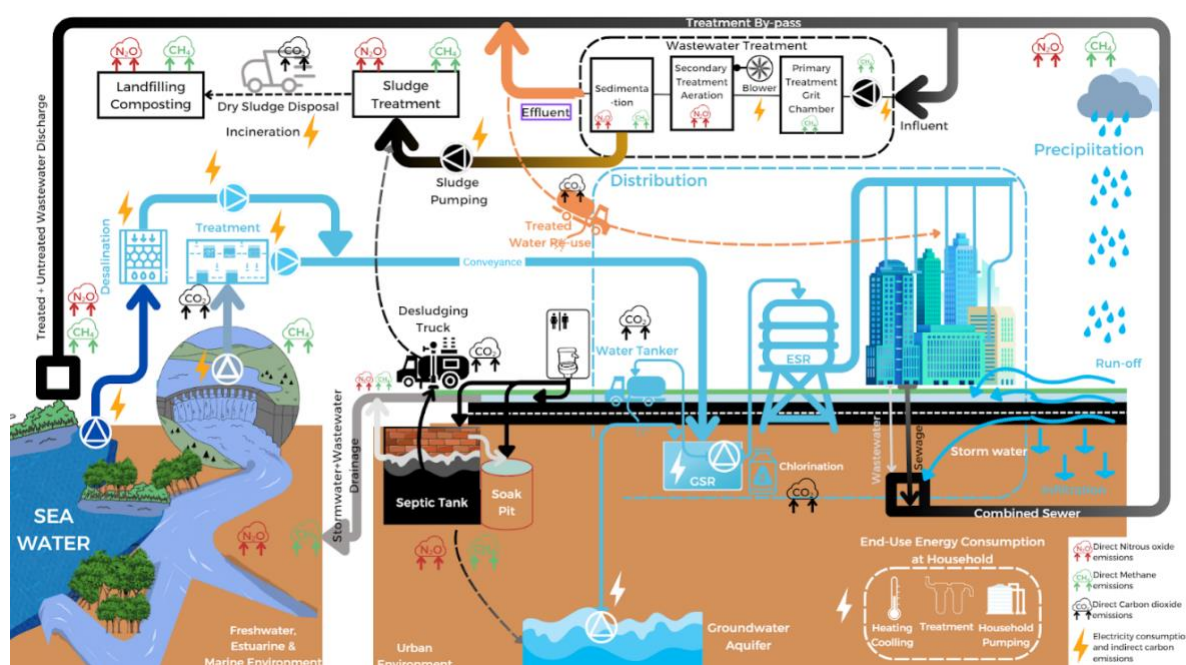
Source: Author's Illustration.

As illustrated in *figure 27*, 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 management⁶⁰. *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 28* schematically illustrates the various steps in a typical urban water cycle in India as well as the electricity consumption and GHG emissions sources.

Figure 27: 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 10*. Each category captures different sources of carbon emissions within the urban water and sanitation systems.

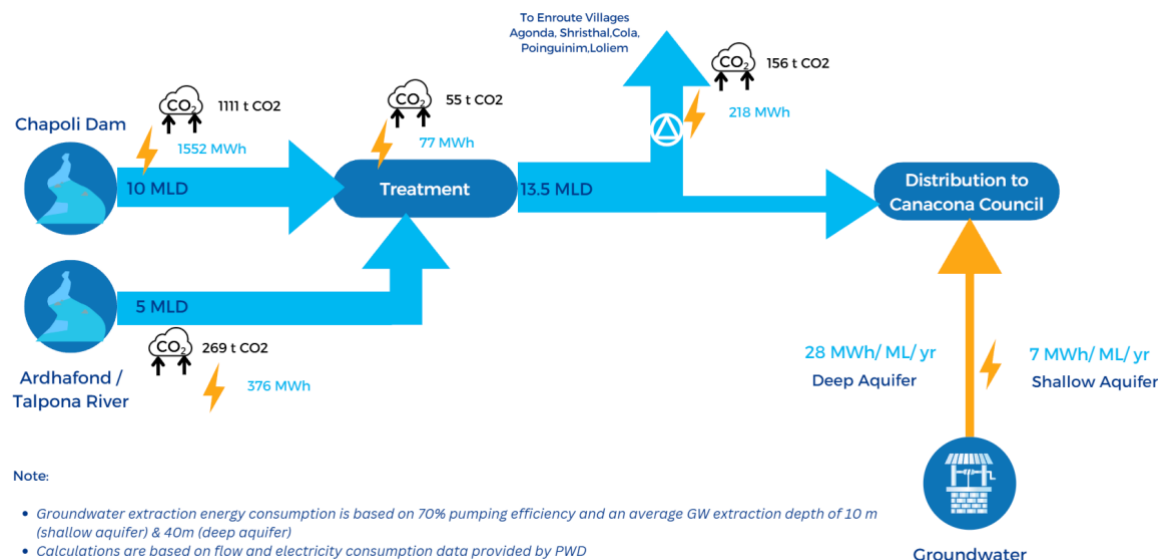
Table 8: Scope of emissions methodology for carbon footprint assessment of the urban water cycle

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 ⁵² (2019 Refinement ⁶¹)
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)⁶² 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 sediments⁶³. 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 28*.

Figure 28: Carbon and energy footprint of Canacona's water supply.



Source: Dangi & Narayanan, forthcoming⁶⁴

Surface Water Abstraction and Treatment:

Canacona's water is primarily sourced from the Chapoli Dam, with an average of 10 ML abstracted daily consuming **1552 MWh/year**, resulting in **1,111 tCO₂/year** in emissions. Additional 5 MLD is abstracted from Ardhafoond intake well (Talpona River) consuming **376 MWh/year**, resulting in **269 tCO₂/year** in emissions.

After accounting for 10% in-plant losses, the system delivers approximately 13.5 MLD of treated water. The treatment process consumes **77 MWh/year**, resulting in **55 tCO₂/year** in

emissions. This makes treatment and abstraction the most carbon-intensive stage in the water supply chain, driven by high energy use for pumping and filtration.

Conveyance to Distribution Zones: Water is transported across a complex topography, with much of the system leveraging gravity-based conveyance.

Groundwater Extraction:

Although accurate consumption data for groundwater use in Canacona is lacking, it is evident that borewells and tanker-supplied water play an increasingly important role, particularly in underserved and peri-urban areas. Based on standard energy intensity estimates, groundwater abstraction requires far less electricity—approximately 7 MWh/ML/year for shallow aquifers and 28 MWh/ML/year for deeper ones—compared to surface water supply, which consumes a high 149 MWh/MLD/year due to long-distance pumping and elevation-related lift.

To put this into perspective, if Canacona's entire estimated demand of 2.7 MLD were met through surface water alone, and accounting for 20% system losses, about 3.38 MLD would need to be produced. This would consume approximately 501 MWh/year and emit around 359 tonnes of CO₂ per year.

These figures underscore the potential climate benefit of diversifying the water supply portfolio. Judicious integration of groundwater, particularly in areas where aquifers remain safe and sustainable, can not only enhance supply reliability but also significantly reduce the energy and emissions footprint of urban water systems. This makes a strong case for integrated, low-carbon water planning in the face of escalating climate challenges.

Key Insights

- **Abstraction & Treatment stages are the largest contributors** to Canacona's urban water-related GHG emissions.
- **Groundwater, where available and safe, offers a low-carbon supplement** to surface water supply, particularly in high-elevation or difficult-to-serve zones.
- Addressing infrastructure inefficiencies, upgrading pumping systems, and **exploring decentralized supply models** could significantly reduce emissions.
- Future assessments should consider **direct emissions from reservoirs** and treatment processes, as well as household-level energy use, to better capture the full emissions profile.

Canacona's reliance on surface water from Chapoli Dam and Talpona River makes the abstraction and treatment stages the most energy- and carbon-intensive components of the water supply chain. Approximately 1,435 tonnes / year of CO₂ are emitted annually from these two stages alone. This is due to the significant energy required for pumping and filtration, particularly over hilly terrain and through ageing systems. By comparison, groundwater abstraction (at 7–28 MWh/ML/ Year) is significantly more energy-efficient, highlighting a key opportunity to decarbonize water supply through integrated groundwater use where aquifers remain safe and sustainable.

Moreover, rising greenhouse gas emissions from water abstraction and treatment, particularly from energy-intensive pumping, highlight the need to align water management with broader decarbonization goals. Integrating safer and more sustainable groundwater, restoring local water bodies, and investing in nature-based solutions can serve as both mitigation and adaptation strategies. Canacona's experience reinforces the urgent need for climate-resilient water planning that is decentralised, energy-efficient, inclusive, and ecologically sensitive.

5.5 GREENHOUSE GAS EMISSIONS FROM SANITATION

Figure 29 presents a comprehensive annual GHG emission profile for the sanitation system in Canacona, accounting for both direct emissions (methane and nitrous oxide) from faecal sludge and wastewater treatment, and indirect emissions from energy consumption in sewage conveyance and treatment. Emissions are expressed in carbon dioxide equivalent (CO₂e) using IPCC's global warming potentials.

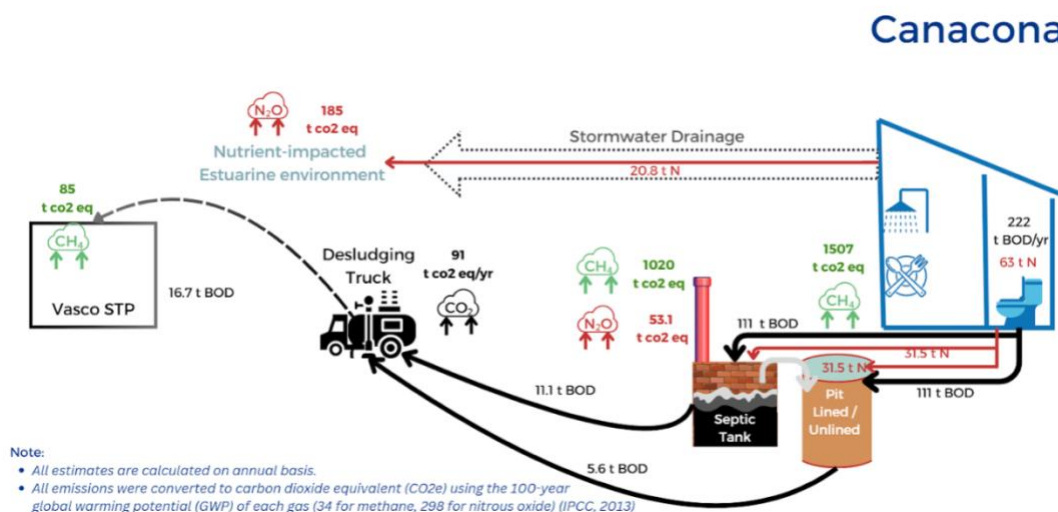
Emissions from Onsite Containment Systems

A major share of GHG emissions arises from anaerobic decomposition of organic matter in septic tanks and pits. As per the estimates:

- Septic tanks emit approximately 1,020 tCO₂e/year in the form of methane (CH₄).
- Lined/unlined pits contribute an even higher 1,507 tCO₂e/year from CH₄ emissions.
- Additionally, nitrous oxide (N₂O) emissions from these systems add 53.1 tCO₂e/year.

This reflects a combined total of over 2,580 tCO₂e/year from onsite containment alone, underscoring the significance of decentralized sanitation in the town's emissions profile.

Figure 29: Carbon and energy footprint across sanitation service chain in Canacona.



Source: Dang & Narayanan, forthcoming⁶⁴

Desludging and Transport Emissions

Desludging practices in Canacona are irregular and largely informal. The desludging truck emissions, based on fuel use and sludge load, amount to 91 tCO₂e/year. About 16.7 tonnes of BOD (biochemical oxygen demand) is transported annually to the Vasco STP, which accounts for a smaller methane emission footprint of 85 tCO₂e/year due to better treatment processes.

Greywater Discharge and Nutrient Pollution

Greywater from bathrooms and kitchens is often discharged untreated into stormwater drains:

- This results in 20.8 tonnes of nitrogen (tN) leaking into the environment, primarily into nutrient-sensitive estuarine waters.
- The figure estimates 185 tCO₂e/year from N₂O emissions due to the nutrient impact on estuarine ecosystems.

This pathway reveals a hidden but significant contributor to GHG emissions and water body degradation.

Key Insights

- Onsite systems dominate emissions: Together, septic tanks and pits account for nearly 90% of total sanitation-related emissions.
- Nutrient leakage to marine and estuarine environments leads to indirect N₂O emissions, with serious implications for coastal ecosystem health.
- Low desludging frequency means sludge decomposes anaerobically in situ, increasing methane release.

5.6 CONCLUSION & WAY FORWARD

The combined energy and emissions profile across the water and sanitation sectors establishes a clear link between current infrastructure configurations and the region's carbon footprint. In the water sector, the high electricity demand of centralised surface-water pumping across undulating terrain represents the primary driver of operational emissions, highlighting a distinct gap that could be balanced by the strategic integration of lower-intensity localised groundwater sources. Concurrently, the sanitation sector is characterised by the overwhelming dominance of onsite containment systems, where irregular desludging cycles promote prolonged anaerobic decomposition, accounting for nearly 90% of sector-linked greenhouse gases alongside significant indirect nitrous oxide impacts on estuarine ecosystems. Addressing these parallel climate footprints identifies a clear transition pathway for future planning, where aligning municipal utility management with broader decarbonisation goals depends on shifting away from energy-heavy, long-distance supply networks and informal septage handling towards integrated, low-carbon, and decentralised resource management models.

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6. PERFORMANCE AND FINANCIAL ANALYSIS OF WATER SUPPLY AND SANITATION

ABHAY JUNAGHARE⁶⁵ 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

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 CMC 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)⁶⁶. 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

The performance⁶⁷ of the water utility and sewerage & sanitation in Canacona can be assessed based on the performance indicators. These nine performance indicators known as the SLBs for urban water supply and sewerage and sanitation in India were proposed by the then ministry of urban development (now MoHUA). These SLBs are able to ascertain the inefficiencies in the urban water supply system (UWSS) and sewerage & sanitation besides providing the corrective measures that are vital to achieve sustainable water supply and sewerage & sanitation. The SLBs can be distinguished into four major indicator groups, viz., access, quality of water supply and treated used water, financial viability and environmental sustainability that further fits into the dimensions of social, economic and environment. Increasing urbanization, unplanned floating tourist population and changing consumption patterns have stressed the existing water supply and sewerage & sanitation infrastructure of the town.

6.2.1 WATER SUPPLY

The analysis of the performance indicators for water supply for CMC based on the provided data suggests that CMC has improved its water supply coverage from 80% in 2018-19 to 90% in 2019-20 (Ref. Table 9). However, it still falls short of the 100% benchmark by 10%. Despite exceeding the national average of 70%, there is room for improvement to achieve full coverage. The supply increased from 100 lpcd in 2018-19 to 135 lpcd in 2019-20, meeting the benchmark. This is a significant improvement, surpassing the India average of 114 lpcd by 21 lpcd. CMC has achieved 100% metering of connections, which meets the benchmark and is far ahead of the India average of 22%. This ensures better tracking of water consumption and reduces wastage. The NRW percentage stands at 20%, which is an improvement compared to the India average of 31%. However, it is still 5% higher than the benchmark of 15%, indicating some water loss due to leakages or unauthorized consumption.

The hours of water supply have improved at 20 hours in 2018-19 and targeted to improve to 24 hours in 2019-20, meeting the benchmark. This is a substantial achievement compared to the India average of just 2.7 hours. CMC has maintained 100% compliance with potable water standards, meeting the benchmark and exceeding the India average of 95%. This ensures safe drinking water for residents. The complaint redressal rate improved from 68% in 2018-19 to 80% in 2019-20, meeting the benchmark. However, it still lags behind the India average of 89%, indicating a need for faster complaint resolution. Hence, CMC has made significant progress in various aspects, particularly in per capita supply, metering, water quality, and continuity of supply. However, gaps remain in coverage, NRW reduction, and customer complaint redressal.

Table 9: Performance Indicators for Water Supply at CMC

#	Water Supply	Calculations	Benchmarks	India Average*	2018-19	2019-20 (T)**	Gaps
1.	Coverage Connections	(Total no. of HHs with water supply connections)/(Total no. of HHs in the City)	100%	70.00%	80%	90%	-20.00%
2.	Per capita supply (lpcd)	(Water supplied)/(Population served)	135 lpcd	114 lpcd	100 lpcd	135 lpcd	35 lpcd
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%	100%	100%	0.00%
4.	Non-revenue water (NRW)	(Total water produced) - (Total water sold)/(Total water produced)	15%	31%	20%	20%	-5%
5.	Continuity of water supply (hours)	Average hours of water supply	24 hours	2.7 hours	20 hours	24 hours	4 hours
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%	0.00%
7.	Redressal of customer complaints	(Total number of complaints redressed)/(Total number of water supply related complaints received)	80%	89%	68%	80%	-12.00%

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

6.2.2. PERFORMANCE OF SEWERAGE & SANITATION

The data on sewerage and sanitation indicators for CMC reveals a stark contrast between progress in toilet coverage and an absolute lack of sewage infrastructure and management (Table 10). CMC has made significant progress in providing access to toilets, increasing coverage from 75% in 2018-19 to 96% in 2019-20. However, there is still a 4% shortfall from the 100% benchmark. Despite this gap, the improvement is commendable. There is no sewerage network service coverage in CMC, with a recorded value of 0% in both years. This is significantly below the benchmark of 100%, indicating a complete absence of sewerage connections in the municipality. The efficiency of sewage collection remains at 0%, showing that no wastewater is being systematically collected. This suggests that either all wastewater is disposed of through septic tanks or untreated discharge into the environment. CMC has no

sewage treatment infrastructure, as reflected by 0% adequacy in treatment capacity. This is a critical concern, as untreated sewage can lead to severe environmental and health hazards.

Since there is no sewage treatment infrastructure in place, no wastewater samples have been tested, resulting in 0% compliance with quality benchmarks. The lack of treatment poses significant risks to water bodies and public health. With no wastewater treatment plants, there is no recycling or reuse of sewage. The benchmark for recycling is 20%, but CMC remains at 0%, reflecting missed opportunities for water conservation and sustainable waste management. The redressal of sewage-related complaints remains at 0%, far from the 80% benchmark. This suggests that either complaints are not addressed or there is no mechanism for resolving sewerage-related issues. While CMC has made notable improvements in toilet coverage, the absence of a sewage network, collection, and treatment presents a major gap. The lack of wastewater treatment poses serious environmental risks, and urgent interventions are required to develop a structured sewerage system.

Table 10: Performance Indicators for Sewerage & Sanitation at CMC

#	Sewerage and Sanitation Indicators	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%	-25.00%
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%	-100.00%
3.	Collection Efficiency of the Sewage Network	(Wastewater collected)/ (Total water supplied + Estimated water use from other sources)	100%	0%	0%	-100.00%
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%	-100.00%
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%	-100.00%
6.	Extent of Reuse and Recycling of Sewage	(Wastewater recycled or reused after appropriate treatment)/ (Wastewater received at STPs)	20%	0%	0%	-20.00%
7.	Efficiency in Redressal of Customer Complaints	(Total number of complaints redressed within the month)/ (Total number of sewage-related complaints received per month)	80%	0%	0%	-80.00%

Source: Canacona Municipal Council, 2025

6.3 REVENUE STREAMS FOR PUBLIC WORKS DEPARTMENT

This section examines the revenue streams available to the PWD, Goa, for water supply, sewerage, and sanitation, as the CMC does not play any role in water and sanitation infrastructure or service provision. This section is structured in four subsections 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 Canacona.

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 (Ref. Table 11). 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.

Table 11: New water connection fees for Domestic consumers

#	New Domestic Connection Fees					Inspection Charges (INR)	Meter Rent (INR)	Water rates per unit (INR)
	Diameter (mm)	Deposit (INR)	Connection Fee (INR)	Labour Charges (INR)	Total (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

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 (Ref. Table 12). 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 12: New water connection fees for Non-Domestic consumers

#	New Non-Domestic Connection Fees					Inspection Charges (INR)	Meter Rent (INR)	Water rates per unit (INR)
	Diameter (mm)	Deposit (INR)	Connection Fee (INR)	Labour Charges (INR)	Total (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 (Ref. Table 13). 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.

Table 13: 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

Regarding new connection charges, these are determined by the diameter of the pipe used for the connection (Ref. Table 14). 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 14: 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

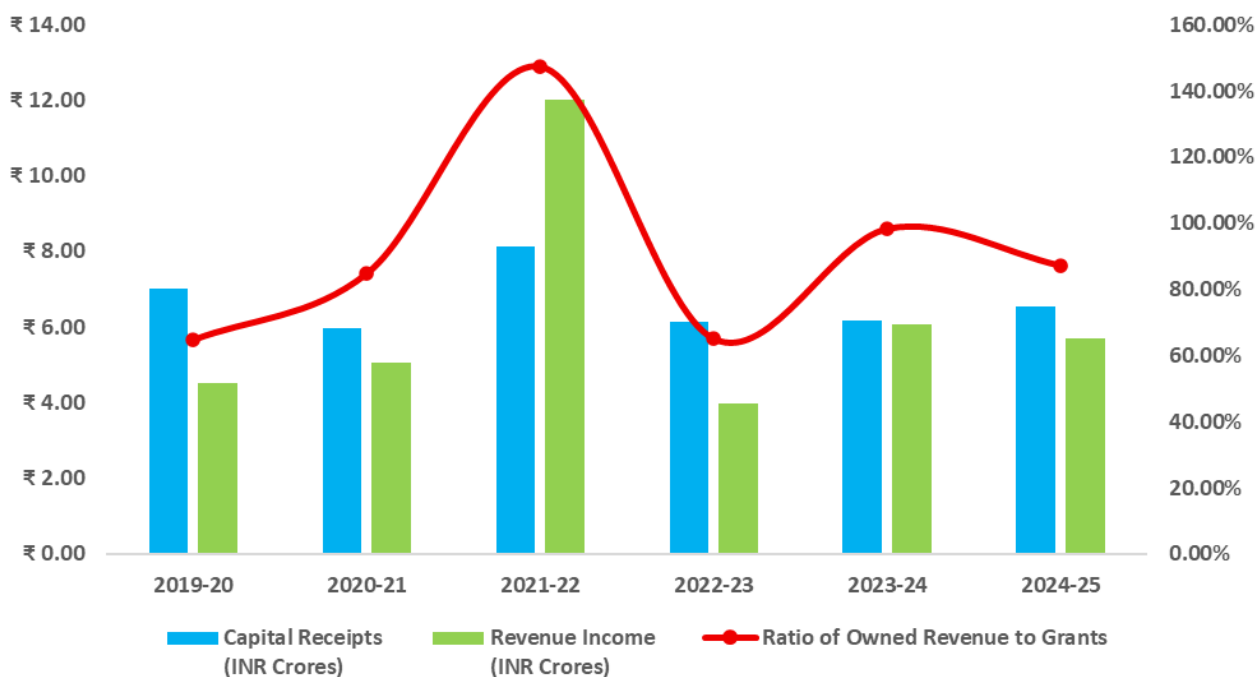
The tariff structure aims to maintain fair and consistent charging based on usage and connection specifics. These charges are collected by PWD at Goa.

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 (Ref. Figure 30). 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. 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 30: Ratio of owned revenue to grants at PWD Goa



Source: Municipal Budget Documents

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.

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.

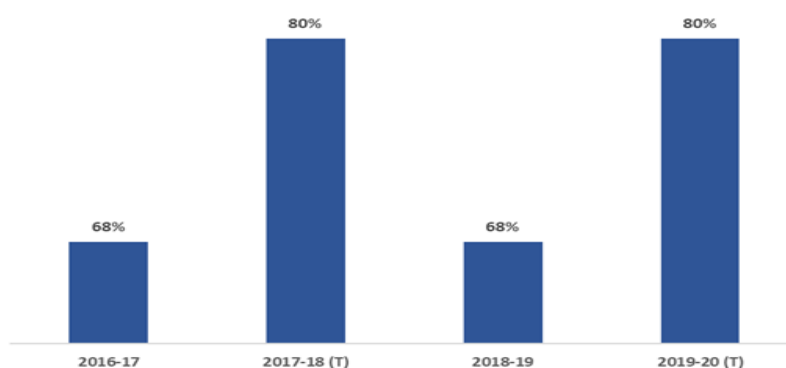
When looking at the total over the six years, the department's ratio of owned revenue to grants is 93.48%. This means that, on average, for every rupee of grants received, the department was able to generate nearly 93 paise on its own. This is a strong performance overall, but it also reflects a gradual 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 FOR WATER SUPPLY

Since there is no sewage connection facility in CMC, the section analyse the trends from the SLBs for water supply at CMC.

Cost recovery for water supply in CMC has shown fluctuating trends, indicating challenges in achieving financial sustainability (Ref. Figure 31). In 2016-17, the cost recovery rate was 68%, meaning the council covered slightly more than two-thirds of its operating expenses.

Figure 31: Trend analysis of cost recovery in water supply charges at CMC

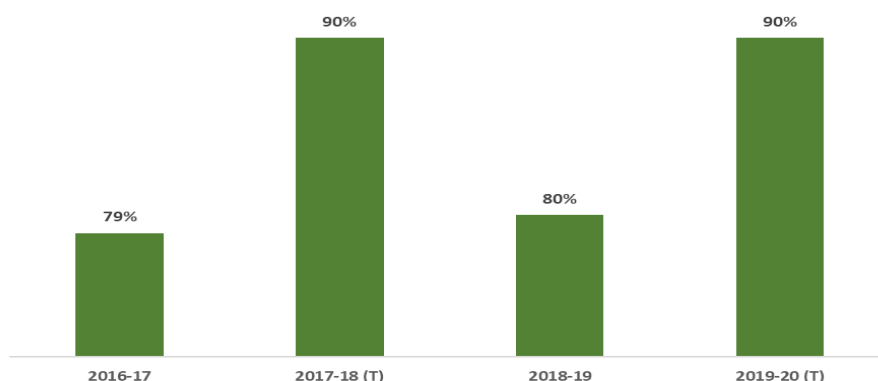


Source: Canacona Municipal Council (CMC), 2025

A target to increase this to 80% in 2017-18 was set, but the improvement was not sustained, as the rate dropped back to 68% in 2018-19 due to inefficiencies or rising operational costs. In 2019-20, another attempt was made to target 80%, aiming to get closer to the ideal 100% cost recovery. These fluctuations highlight the need for consistent revenue collection, reduction of water losses, and regular tariff revisions to ensure stable financial performance and long-term water service sustainability in CMC.

Collection efficiency for water supply charges in CMC has fluctuated over the years, revealing inconsistencies in revenue collection. In 2016-17, the efficiency was 79%, indicating room for improvement (Ref. Figure 32). The target for 2017-18 was set at 90%, but this was not sustained, with efficiency dropping to 80% in 2018-19, possibly due to challenges in collection processes or consumer compliance.

Figure 32: Trend analysis of collection efficiency in water supply charges at CMC



Source: Canacona Municipal Council (CMC), 2025

For 2019-20, the target was again set at 90%, aiming for better financial stability and reduced risk of revenue shortfalls. To achieve consistent high efficiency, CMC needs to strengthen billing systems, enforce timely payments, reduce arrears, and raise consumer awareness. Ongoing monitoring and stricter enforcement will be essential for ensuring financial stability and reliable service delivery.

6.5 KEY FINANCIAL CHALLENGES

The financial challenges of the PWD, Goa at CMC in managing water supply are due to fluctuating cost recovery and collection efficiency, alongside a dependency on external grants. While the tariff structures for domestic and non-domestic connections provide a framework for revenue generation, the rates remain low relative to the actual cost of service

provision, creating a persistent gap between revenue and expenditure. The ratio of owned revenue to grants has shown volatility, with a one-time spike in 2021–22 due to backlog settlements, but otherwise reflecting inconsistent performance and reliance on grants, particularly in years of operational or consumption-related shortfalls. Cost recovery in water supply has struggled to consistently meet even 80%, with drops to 68% in multiple years, underscoring inefficiencies and rising operational costs. Similarly, collection efficiency has failed to reach sustained targets, hovering between 79–90% due to arrears and weak enforcement. Together, these financial constraints highlight PWD's difficulty at CMC in ensuring stable revenue streams and achieving long-term financial sustainability. Unless supported by stronger tariff reforms, improved billing and collection systems, and reduced grant dependency, PWD's ability to expand infrastructure, enhance WASH resilience, and sustain service delivery at CMC will remain compromised.

The financial challenges facing the PWD, Goa at CMC in managing sewerage & sanitation stem primarily from a weak revenue base, high reliance on government grants, and absence of cost recovery mechanisms for sewerage services. While the PWD, Goa, has a structured sewerage tariff system under the Goa Sewerage System and Sanitation Services Management Rules, 2010, Canacona currently has no operational sewerage connections, resulting in zero collection efficiency and cost recovery. This eliminates an important own-revenue stream for CMC. Moreover, the ratio of owned revenue to grants shows volatility, with years such as 2021–22 demonstrating high self-sufficiency due to one-time backlog settlements, but reverting to grant dependence in subsequent years. Such fluctuations highlight the PWD's vulnerability to irregular revenue patterns. The heavy dependence on external grants also raises concerns about long-term financial sustainability, as grants may not keep pace with growing infrastructure and service demands. Without consistent revenue mobilization through tariffs, improved billing systems, and better collection efficiency, PWD faces significant challenges in financing and maintaining resilient water supply and sanitation infrastructure at CMC, which is critical for sustainable service delivery and climate-resilient WASH outcomes.

NOTES & REFERENCES

⁶⁵Author'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.

⁶⁶ 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.

⁶⁷Source: Canacona Municipal Council. (2025)

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 Canacona. 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 Canacona'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 Canacona 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 Canacona, 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)⁶⁸, *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 has a tropical maritime climate. 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 temperature increase compared to the national average though diurnal range in temperature is not very high.

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. 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.⁶⁹ Goa state is already vulnerable to flooding, increasing heavy rainfall trend makes the state even more vulnerable to this hazard.

Canacona town has low elevation, gentle slope, sandy coast and sparse vegetation along the coastline and attracts a large number of tourists. Based on a recent study undertaken on for assessing coastal vulnerability at the village level using a robust framework, Canacona town with its adjacent coastal neighbouring villages Nagercem-Chaudi, which merge into the town boundaries, have been found one of the most vulnerable villages. It is extensively located between low-lying agricultural fields, leading to a high degree of vulnerability far inland.⁷⁰

Canacona has less than 30 % of its administrative land area at an elevation of < 10 m above mean sea level considered as an LECZ. (Refer Figure: 33). However, Ward 10 which is the ward with highest built-up density, a proxy indicator for population density in the absence of latest data on population. Ward 1 and 7 and 8 are the most exposed to inundation and effects of storm surges since nearly 50 % of the land area is highly vulnerable to flooding. (Ref. Table 15)

Table 15: Ward Level Elevation and Vulnerability to Flooding

Ward No	Built- up land cover (%)	Land Elevation above mean sea level (% ward area)		
		Very Highly vulnerable (<5m amsl)	Highly vulnerable (<10 m amsl)	Low vulnerability to flooding (% >10m amsl)
1	15%	34%	57%	43%
2	6%	10%	15%	85%
3	14%	0%	2%	98%
4	4%	0%	1%	99%
5	8%	24%	49%	51%
6	12%	7%	17%	83%
7	15%	30%	79%	21%
8	18%	13%	48%	52%
9	24%	5%	9%	91%
10	32%	23%	33%	67%
11	4%	28%	45%	55%
12	1%		14%	86%

Source: GIS analysis based on Digital Elevation Mapping

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.

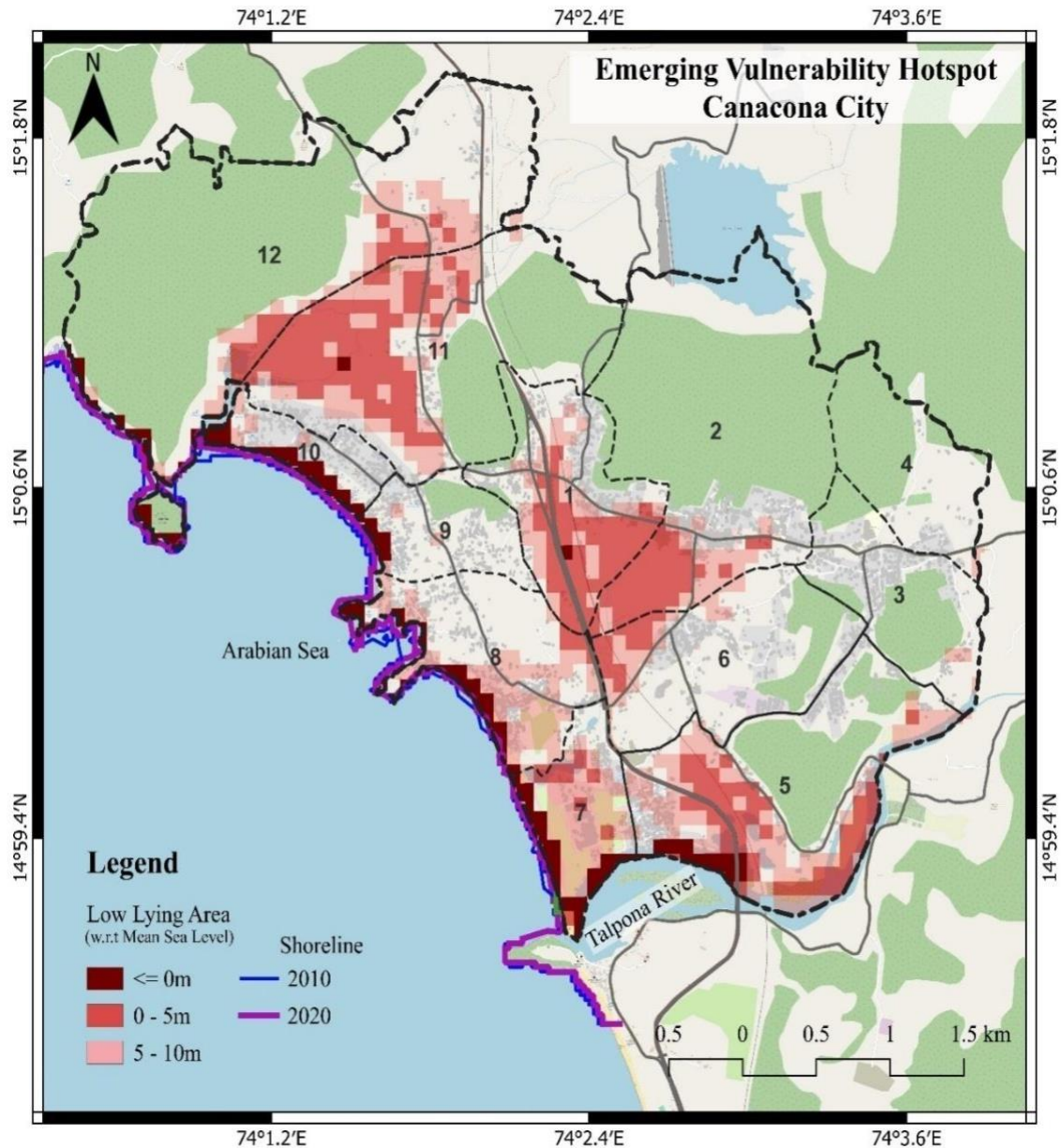
Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area. Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanization 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.⁷¹

The coastline of Canacona with erosion rates between 0.3 and 0.6 m/ year at medium risk. The low coastal slopes were identified as more sensitive to storms and SLR and were accordingly given a high-risk rating.⁷² This study was undertaken in 2014, when Canacona had very little tourist influx. The tourism has increased exponentially over the last decade and hence the risks due to exposure of population has also increased significantly. The rainfall patterns and volumes and stormy nature of rainfall are the changes seen in recent years.

According to NITI Aayog's Climate and Energy Dashboard, South 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). The coastal belt of South Goa where Canacona is located is vulnerable

to highly vulnerable to cyclones, storm tides caused by storms couples with high tides, very intense precipitation, flooding due to inundation and ground water and landslides due to the numerous hills and mountains dotting the low-lying coastal ecosystem.

Figure 33: Emerging vulnerability hotspots in Canacona



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

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.⁷³

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.⁷⁴

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.⁷⁵ Canacona 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.

Storm surge is an abnormal water level rise generated by a storm over and above the predicted astronomical tide. Storm tide is the water level rise due to the combination of storm surge and astronomical tide. This rise in water level can cause extreme flooding in coastal areas, particularly when storm surge coincides with normal high tide. Wave action occurring on top of the surge, which can add additional feet to the overall water level.⁷⁶ The vertical circulation in the ocean becomes disrupted and the sea water goes up and inland contaminating the water resources making them un-usable. When coupled with heavy precipitation events and when a city is located at river mouths, generally loaded with silt accumulation, and facing the brunt of runoff from upstream locations due to the precipitation, flooding and inundation is inevitable for low lying areas of the city. An increasing severity and frequency of such occurrence has been observed in the in east Arabian Ocean.

It has been found that the low-lying alluvial areas close to the rivers have a higher susceptibility to the seawater intrusion due to tidal activity. Based on finite element model, the extent of seawater intrusion has been predicted up to 300 m away from the coastline. Besides tidal activity, marine depositional environments also contribute to groundwater salinity in the state. The depositions are enhanced by high sediment influx by the rivers due to mining activities in upstream. The withdrawal of groundwater is increasing over time, with a rapid increase in the infra structure development for tourism, which may cause serious ground water problems in the state.⁷⁷

Saltwater intrusion impacts not only the access to safe water for locations not covered by piped supplies but can have detrimental impacts on underground piped networks

themselves. Research shows that saltwater intrusion and sea level rise can significantly affect the integrity of water and wastewater collection pipes due to potential changes in soil and groundwater characteristics that increase corrosion rates. Corrosion rate is intensified by increased conductivity of groundwater due to salinity. Coastal areas with subtropical climate have higher corrosion rates. The estimated lifetimes of ductile iron pipes are between 80 and 100 years. However, the actual service lifetimes can be significantly shorter.⁷⁸ Salinity intrusion in wells was noted during the field visits from some parts of the town, closer to the mouth of the river. Accumulation of saline influents in treatment units' sanitation pits or septic tanks can limit their ability to effectively remove pollutants like organic matter and nutrients. Strong adverse effects of high electrical conductivity which is seen in salt water have been found in microbial diversity, richness, and the efficiency of organic matter removal.⁷⁹

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

Coverage of WaSH infrastructure in Canacona is much above national averages with over 91 % households having access to piped (safe) water supply and 100% households having access to a sanitation unit. However, the adequacy of the WaSH infrastructure needs to be seen in with respect to the access to “safe” water and “safe” sanitation.

While Canacona has access to adequate and diversified freshwater sources, with good reserves of ground water, water is also brought in from outside the city and intermittent piped water supply services are made available to most residents. However, Canacona's status as a popular tourist destination significantly increases water demand, especially during peak tourist seasons. Water consumption has been increasing, and large volumes wastewater load is forced on Canacona town's natural ecosystem balance. As per some residents, historically well water had been used by residents for all usages. However, people have stopped using well water and have also reported increased incidences of health issues and of kidney stones which they attribute to contamination in ground water. Residents have also indicated sewage contamination in ground water. While the cause of

such issues are health issues with water quality in Canacona needs further exploration, the change in usage patterns points towards contamination of ground water.

Canacona depends on OSS for city sanitation. Though the standards of construction are regulated by TCPO and Municipal Corporation (Refer Chapter on sanitation) residents have reported sewage contaminations in dug wells during field studies. Field studies also reveal that Canacona has been facing some waterlogging (up to 150 mm) during the monsoon in recent years which disperses in 4 – 5 hours. The increasing annual precipitation and trend of increasing intense precipitation events increases the exposure of ground water to contamination. The municipal administration owns one vacuum truck to transport the sewage collected to the STP at Margao which is 80 km away, for sewage treatment. Private operators also provide desludging services. However, many residents who were engaged during field surveys could not recall when the last de-sludging had been undertaken by them (Refer Chapter on Sanitation).

7.4.2 RELIABILITY, FLEXIBILITY AND REDUNDANCY

Flexibility in water systems can ensure reliable services even during climate events and disasters. Redundancy ensures that systems can withstand failures and continue to operate during disruptions. It minimizes the chances of a single point of failure leading to a catastrophic breakdown. Source sustainability is an emerging concern for Canacona like many other smaller and emergent coastal towns. Water sourced from an upstream dam very far away from the city critical component in the water supply system due to increasing landslides and rockfalls, inadequate management of a shared resource and emerging scarcity due to variable nature of precipitation. The risk of droughts and reduced river flows can strain the Talpona River and Chapoli Dam, especially during dry seasons. Heavy monsoon floods can damage infrastructure, contaminate water sources, and cause disruptions and outages. SAPCC in its Sectoral Adaptation Strategies for Water Supply has mentioned that though Goa is situated in high precipitation zones, it has one of the lowest per capita freshwater availabilities. 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.⁸⁰

Much of Canacona's water supply infrastructure is ageing, with visible signs of wear, leaks, and corrosion in storage tanks, pipelines, and valves. This not only leads to frequent breakdowns and service interruptions but also results in high water losses through leakages. A significant portion of treated water is lost without benefiting consumers, exacerbating supply shortages, and putting additional strain on limited water sources. Flexibility in water systems can help in ensuring reliable services during disruptive events, local ground water resources could be protected and integrated into formal systems through decentralised treatment facilities.

Dependence of water supply systems on electricity can often lead to large scale disruption during strong winds and cyclonic formations as has been noted in many coastal towns and cities with overhead transmission and distribution networks. Goa does not produce any power and is dependent on NTPC plants in other states for supply of power whereas demand for power due to increased urbanization, industrialization, a boom in construction activity, commercialization, consumerism is constantly increasing.⁸¹ The water supply system relies on pumped conveyance, particularly for drawing water from Chapoli Dam. This makes it heavily dependent on a stable electricity supply. Power failures, whether due to grid failures, storms, or maintenance issues can lead to prolonged interruptions in water availability. Additionally, sudden breakdowns in ageing infrastructure further disrupt supply, particularly in remote areas. Water treatment facilities in Canacona have generators which is part of the redundancy due to dependence on electricity.

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. 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). In high mountains, coastal regions and small islands, there are also difficulties in coordinating climate adaptation responses, due to the many interactions of climatic and non-climatic risk drivers (such as inaccessibility, demographic and settlement trends, or land subsidence caused by local activities) across scales, sectors and policy domains. Intensifying cooperation and coordination among governing authorities across scales, jurisdictions, sectors, policy domains and planning horizons can enable effective responses to change in the ocean, cryosphere and to sea level rise (high confidence).⁸²

Municipal Council is significantly dependent on central government grants for developing its WaSH infrastructure (refer chapter on Sanitation). Any reduction in central grants can severely impair Canacona's water supply and sanitation systems. This can exacerbate the vulnerabilities from climate change for a low-lying town like Canacona. CMC hence will have to identify innovative financing models to increase its revenue income for upgradation of its infrastructure. At the household level, the CMC has developed effective regulatory control over the design, construction, and enforcement of standards for toilets and OSS systems. This enforcement mechanism ensures that development adheres to public health

and safety standards. However, there are reports of deteriorating health by residents. In the sectoral adaptation strategies in SAPCC for Goa state, climate-based infrastructure vulnerability assessment of critical services, development of a plan for the resilience of vulnerable structures and redesigning the regional land use planning maps of the most vulnerable areas after considering climatic factors are some of the strategies to achieve it, as has been outlined in the report. This shall need to be mainstreamed at a local administration level.

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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. 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. 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 ULBs 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. Detailed information on the number, condition, and operation and maintenance (O&M) structures of community toilets (CTs) and public toilets (PTs) in the city were also collected to better understand the scale and performance of the existing sanitation infrastructure.

- **Semi-Structured Interviews:** In Canacona Municipal Council (CMC), semi-structured interviews with key ULB officials were conducted – including one Chief Officer, two Sanitation Engineers, one Environmental Engineer, two Swachh Bharat Mission (urban) Coordinators, two Town Planners, and one Accountant – 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.
- **Site Visits:** Regarding sanitation, no site visits were conducted. CT/PT infrastructure was reviewed during the rapid assessment. Regarding water, the team visited the relevant water related infrastructure such as the water treatment plant.
- **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 17 residents. Locations were carefully selected to cover a range of socio-economic backgrounds and areas identified as vulnerable to extreme events during interviews with ULB officials. During these interactions, the questions focused primarily on access to services and service quality. These engagements were aimed at validating and triangulating data gathered from secondary sources. This approach yielded valuable insights into both the state of infrastructure and the lived experiences of residents, especially those from vulnerable communities. 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, what type of onsite sanitation system (OSS). The questions focused on how and where human waste was disposed of. In cases where onsite sanitation systems (OSS) were used,

information was gathered 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.

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 study on Canacona was primarily 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.

Sanitation

- **Typology of Individual Household Toilets and On-site Sanitation 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 Sustainable Development Goals (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) 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.
- **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, adequacy, and operational status of community and public toilets is not available with the ULB, as it does not maintain records on users or demand. While ULB officials stated that public toilets are well maintained and strategically located, field visits to two facilities confirmed that they were clean, functional, and supplied with municipal piped water; however, the ULB does not maintain any formal records of cleaning activities.

- **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.
- **Service Level Benchmarks:** Due to the unavailability of SLB data beyond 2018–19, it was not possible to conduct a comprehensive analysis of the SLB indicators.
- **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.

Water

- **Inadequate Granular Water Consumption Data:** Household-level water consumption is not metered in many areas; bulk metering data (number of connections × billed consumption) does not accurately capture per capita usage or disparities across income groups or geographies (e.g., slums vs. apartments).
- **Unaccounted for Water (UFW) and NRW:** Accurate estimation of transmission and distribution losses is hampered by the absence of metering at intermediate system points and outdated infrastructure records, making it difficult to precisely attribute inefficiencies or quantify water losses.

Energy and Carbon Footprint

- **Groundwater Use Estimation Uncertain:** There is no systematic monitoring of groundwater abstraction volumes, especially from private borewells and tankers. The growing reliance on groundwater is not reflected in official supply data, resulting in underestimation of its energy and carbon footprint.
- **Missing Real-Time Energy Consumption Data:** Energy data for various components (pumping, treatment, household-level usage) are often estimated based on assumed intensities (MWh/MLD) due to a lack of sub-metering across the water supply system.
- **Limited Data on On-Site Sanitation Systems:** There is no centralized inventory of septic tanks, pits, or their design standards. Emission estimates rely on assumed containment types, desludging frequencies, and containment conditions, introducing uncertainty in CH₄ and N₂O emissions from faecal waste.
- **Industrial and Tourism Sector Use Opaque:** Water and wastewater usage and discharge data from hotels, industries, and large commercial establishments are often not disaggregated or reported, masking the full impact of tourism and commercial activity on urban emissions.
- **Stormwater and Greywater Flows Untracked:** Greywater is often discharged into storm drains without treatment or monitoring, leading to nutrient loading and emissions not captured in inventories.
- **Sanitation GHG Methodology Limitations:** Emission estimates are based on global default emission factors and standard GWP values (IPCC 2013), which may not reflect local climatic, operational, or containment-specific variables.

Resilience Assessment

ULB provided two distinct sets of ward boundary shapefiles, and neither aligned with each other nor with the ward-level population data from the Census of India, 2011.

The available population data did not match the ward numbers in either of the spatial boundary files, making it difficult to perform accurate ward-level demographic analysis or overlay census statistics.

Overall

- **Research Boundaries:** While the scope defines what this report covers, the limitations reflect aspects that could not be addressed. These should not be viewed as research gaps but as boundaries determined by data availability and by differing approaches adopted by the research and implementation partners of the 'Climate Resilient Coastal Cities' project^{xiii}. Variations in this report and those based on research by CDD-India reflect these methodological differences.
- **Town-level Focus:** This report addresses issues specific to the town studied. The 'Climate Resilient Coastal Cities' initiative comprises a National Report, four State Reports, and fifteen Town Reports. This document represents one of the three town-level studies from Goa. A broad level state analysis of Goa is provided separately in the Goa State Report, which draws on all three town studies.
- **Data Availability:** The study relies primarily on secondary research, and the extent of analysis is therefore dependent on the quality and availability of published data and literature. Wherever possible, secondary information has been supplemented with primary inputs.

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 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:

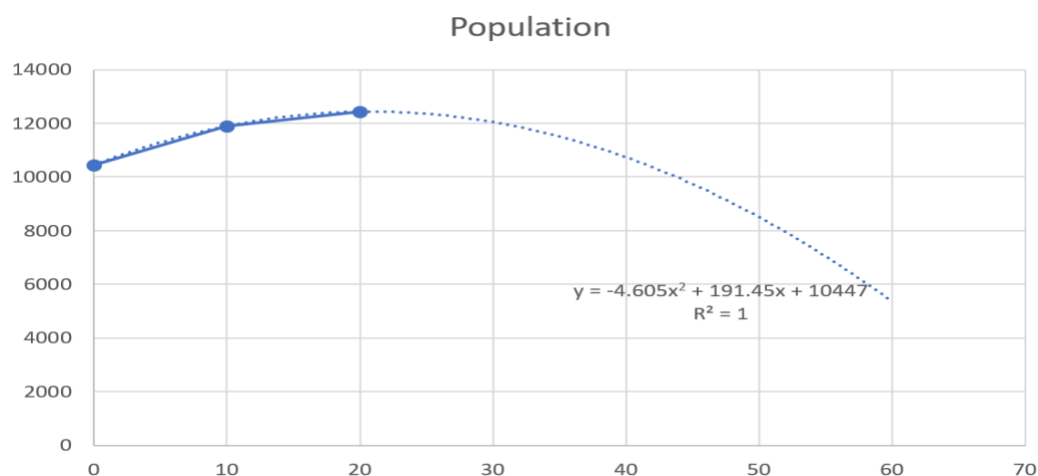
Year	Population	Increment	Incremental Increase	Decadal Growth Factor
1991	10,447			
2001	11,901	1454		1.13917871
2011	12,434	533	-921	1.04478615

Average Increment 993.5

Average Incremental Increase -921

GM Decadal Growth rate 1.090962026

Graphical Method:



For X-axis 1991 is the base year: X=0 (1991), X=10 (2001)

Year	Census Population	Projected Population				
		Arithmetic	Incremental Increase Method	Geometrical Growth Rate	Graphical method	Average
1991	10,447					
2001	11,901					
2011	12,434					
2021		13428	12507	13565	12046	12886
2025		13825	12278	14046	11633	12945
2031		14421	11658	14799	10737	12904
2041		15415	9889	16145	8507	12489
2051		16408	7198	17614	5356	11644



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	Canacona 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) ⁸³
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) ⁸⁴
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)

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

Ministry 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.



Ashank Desai Centre for Policy Studies

II Floor, Old CSE Building
Indian Institute of Technology Bombay
Powai, Mumbai, Maharashtra
400076

www.cps.iitb.ac.in

Email: office.cps@iitb.ac.in

Phone: +91 22 2576 5061