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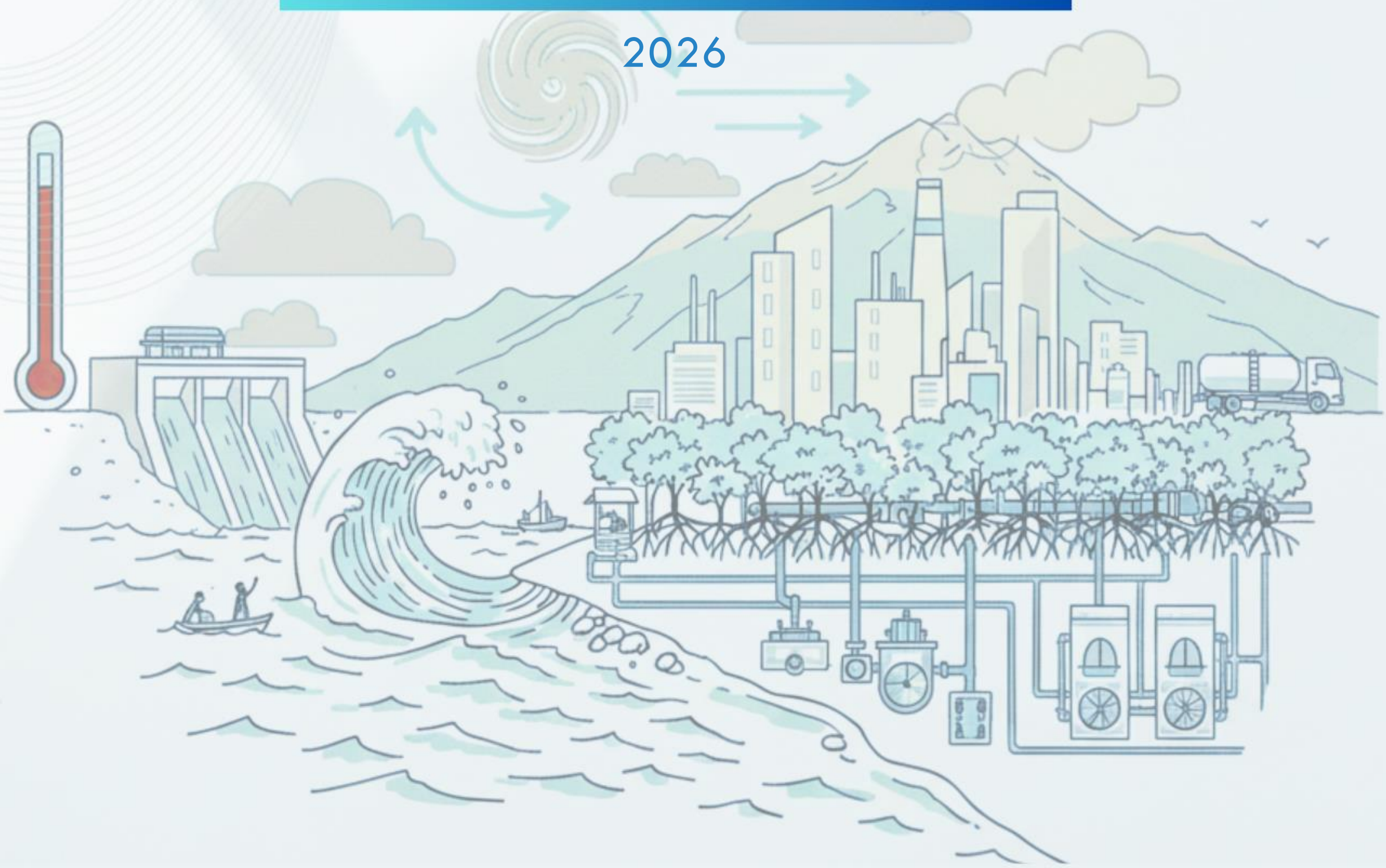
Towards Climate-Resilient Urban Water & Sanitation Systems

Situational Assessment Report

KUNDAPURA, KARNATAKA

2026



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TITLE

Towards Climate-Resilient Urban Water and Sanitation Systems: Situational Assessment of Kundapura, Karnataka

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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, Karnataka 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.

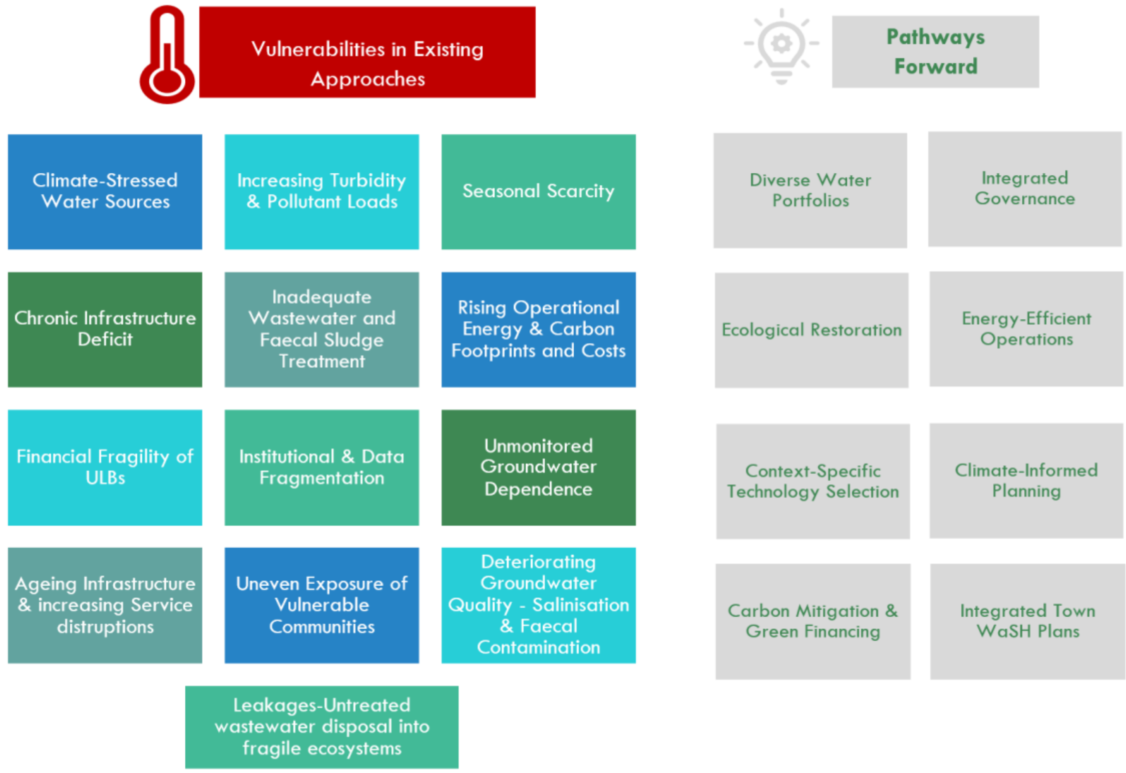

Figure: Systemic Vulnerabilities in existing approaches to WaSH and Pathways forward.

The report presents the study findings for **Kundapura**, a Class-III town, in the Udupi District. Our assessment of Kundapura's WaSH infrastructure & services from a climate lens, revealed some key challenges:

WATER SUPPLY:

Vulnerabilities in Surface Water Dependency: The Haladi River faces cumulative risks from erratic rainfall patterns, sedimentation, and upstream hydropower interventions. Competing sectoral demands for agriculture and power generation exacerbate municipal supply uncertainties, particularly during lean seasons.

Groundwater Contamination and Salinity Risks: Local aquifers face mounting pressures from erratic recharge and seasonal salinity intrusion. Furthermore, shallow groundwater is increasingly vulnerable to pathogen and nitrate contamination from inadequate onsite sanitation infrastructure during monsoon runoff.

Carbon Intensity and Climate Feedback Loops: The transition to a centralised surface water network has substantially increased energy demands, currently generating over 750 tCO_2 annually despite partial coverage. Climate-induced turbidity and seasonal grid outages further compound this footprint by necessitating energy-intensive treatment and diesel backups.

Systemic Fragility and Source Neglect: The rigid centralised network demonstrates low adaptive capacity to climate disruptions and relies heavily on external capital. This overreliance on imported water has simultaneously driven the degradation of traditional, decentralised water bodies, diminishing localised climate resilience.

SANITATION:

Infrastructure Deficits and Land Acquisition Barriers: The municipality currently lacks centralised sewage treatment facilities, with historical development efforts actively constrained by land scarcity and local opposition (NIMBYism). Resident concerns regarding property values and environmental externalities continue to complicate the acquisition of private land for essential sanitation infrastructure.

Unregulated Containment and Sludge Disposal Risks: The absence of formal faecal sludge treatment forces the disposal of untreated septage into open solid waste landfills, elevating the risk of groundwater leaching during monsoons. Concurrently, a lack of construction regulations for household onsite systems (predominantly soak pits) and irregular desludging intervals exacerbate local contamination and greenhouse gas emission risks.

Operational Failures in Decentralised Treatment: While decentralised sewage treatment plants are mandated for specific commercial and residential properties, high maintenance costs frequently render these systems non-operational. The absence of routine municipal inspections and a reliance on privately managed environmental monitoring create critical oversight gaps, frequently resulting in the discharge of untreated wastewater into local drainage networks.

Governance Dependencies and Institutional Fragmentation: Structural governance challenges persist as state and central agencies manage capital infrastructure design and construction, while Urban Local Bodies (ULBs) are tasked solely with operation and maintenance. This institutional dependency restricts municipal autonomy in selecting and adapting sanitation solutions that align with local technical and fiscal capabilities.

Financial Constraints and Staffing Shortages: The municipality operates with a sustained staff vacancy rate of approximately 30% to 35% due to ongoing funding limitations from the State Finance Commission. These chronic resource and staffing constraints directly limit the ULB's capacity to enforce environmental compliance, monitor decentralised systems, and effectively manage daily service delivery.

ENERGY USE & GHG EMISSIONS:

Carbon Burden of Centralised Conveyance: Supplying 5.6 MLD of municipal water necessitates extracting 7.1 MLD from the Varahi River. The abstraction, treatment, and distribution of this surface water require over 1,100 MWh of electricity annually, generating approximately 731 tonnes of CO_2 emissions. This highly carbon-intensive network currently serves only 66% of households, indicating that emissions will escalate significantly as piped coverage expands.

Low-Emission Potential of Groundwater Extraction: In sharp contrast to surface water operations, local groundwater extraction (contributing roughly 688 million litres annually) demands a minimal energy input of 26.8 MWh/year, resulting in just 19.2

tCO_2 of emissions. This disparity highlights the potential carbon benefits of integrating traditional groundwater sources into the formal supply matrix.

Significant Systemic Water Losses: Despite the implementation of 100% metering and billing, systemic inefficiencies remain high. Approximately 3% of extracted water is consumed during treatment processes, while 25% of the treated water is lost within the distribution network, directly translating to wasted energy inputs and inflated operational emissions.

Methane Dominance from Onsite Containment: The sanitation sector's carbon footprint is heavily dominated by onsite containment structures. Lined and unlined soak pits generate an estimated 1,884 tCO_2e annually, while septic tanks contribute an additional 1,275 tCO_2e. These emissions are driven by prolonged anaerobic conditions, which are exacerbated in coastal areas with high water tables.

Greywater Discharge and Sludge Disposal Emissions: The unchecked discharge of untreated household greywater into stormwater drains introduces substantial nitrogen loading into estuarine environments, generating an estimated 352 tCO_2e of nitrous oxide per year. Furthermore, the unregulated disposal of septage into deep anaerobic ponds generates 340 tCO_2e of methane, identifying sludge management as a critical emissions hotspot requiring urgent intervention.

FINANCIAL HEALTH:

Declining Cost Recovery and Revenue Generation: The municipality exhibits a sustained downward trend in cost recovery for water and sanitation services, with ratios dropping below 60% (reaching a low of 50.48% during the 2020-21 period). This decline highlights a structural difficulty in covering ongoing operational and maintenance expenses solely through user charges.

Fluctuations in Collection Efficiency: Revenue generation is further constrained by volatile collection efficiencies, which historically dropped to 72.93% in 2016-17 and have continued to experience significant variations. These inconsistencies, exacerbated by external economic shocks such as the COVID-19 pandemic, deepen the municipality's fiscal instability.

Volatility in External Grant Funding: While the local council has increasingly relied on internal revenue streams from water supply and underground drainage charges, ongoing fluctuations in external financial support from central and state government grants create substantial barriers to reliable, long-term financial planning.

Escalating Operational Costs and Capital Stagnation: A pronounced shift has occurred in municipal spending, redirecting focus away from new infrastructure investment towards managing escalating day-to-day operational expenses. The operating ratio reached a critical threshold in 2022-23, signalling severe financial strain and a diminished capacity for the long-term capital investments required for network sustainability and expansion.

Conclusion: Strategic Outlook and Gap Identification

The situational assessment of Kundapura illustrates the compounding vulnerabilities of a coastal municipality locked into an energy-intensive, centralised water paradigm while grappling with systemic infrastructural deficits in sanitation. The current trajectory characterised by an over-reliance on the climate-sensitive Haladi River, unregulated faecal sludge disposal, and high-emission onsite containment systems, places severe strain on both local ecological health and municipal finances, vividly demonstrating the risks inherent in the local water-energy-climate nexus. As escalating operational costs continually outpace cost recovery and restrict essential capital investment, the town faces a diminishing capacity to adapt to climate-induced disruptions. Navigating these interconnected risks necessitates a fundamental shift towards integrated water stewardship and resilience. Future institutional frameworks must prioritise stabilising cost recovery mechanisms to unlock investments in low-carbon, decentralised alternatives. By rehabilitating local groundwater networks, formalising septage management, and aggressively targeting systemic inefficiencies, the municipality can decouple service provision from high energy demands, ultimately establishing a financially viable and climate-adaptive utility model.

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1. URBAN WATER & SANITATION SYSTEMS IN A CHANGING CLIMATE

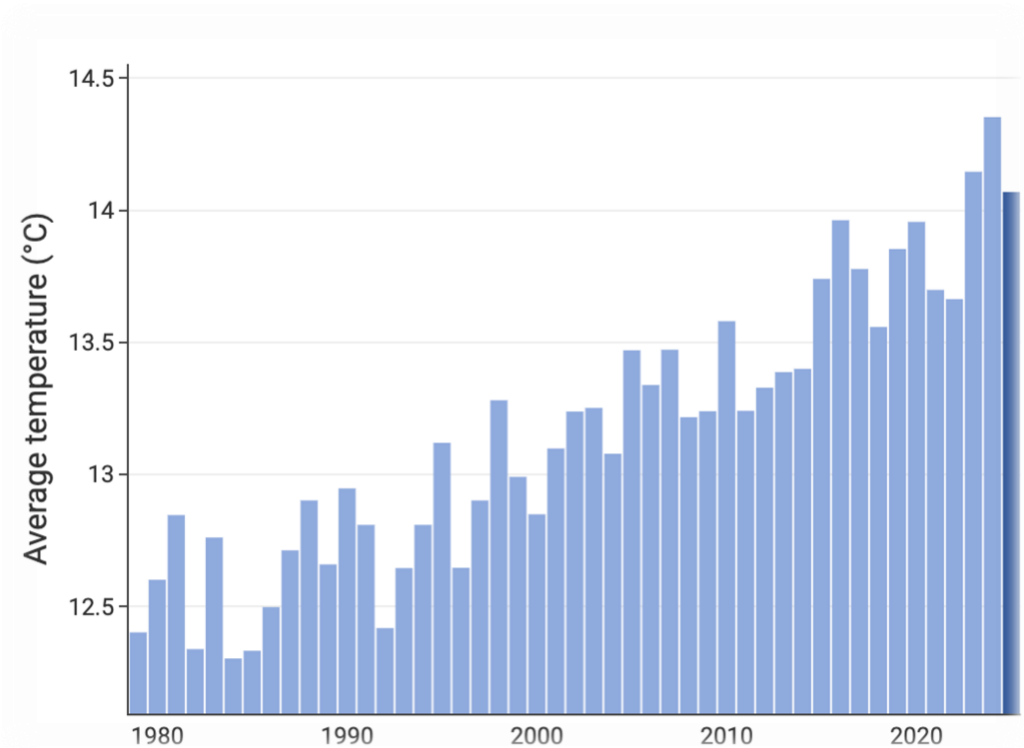
ASHISH DANGI, NEELAM RANA, N.C. NARAYANAN AND PRIYAKSHI GOGOI

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 year[1] (*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 Monitor[1]

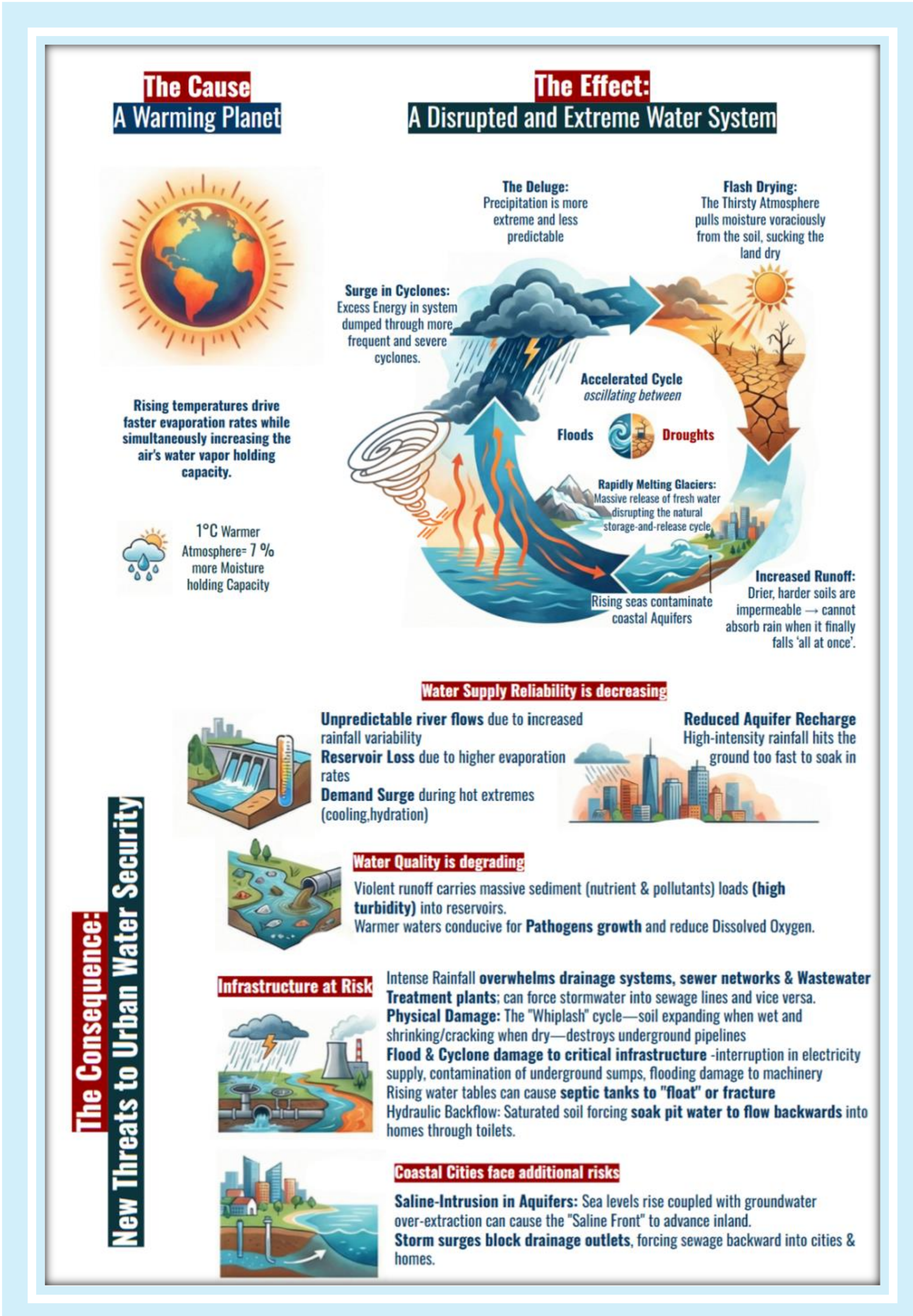
This leads to a volatile cycle: during dry periods, the 'thirstier' atmosphere aggressively evaporates moisture from soil and reservoirs, deepening drought conditions. However, once this moisture-laden air is triggered to release by a cyclone or orographic lift, it discharges with explosive intensity. 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 extremes[4]. 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 billion[5]. 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

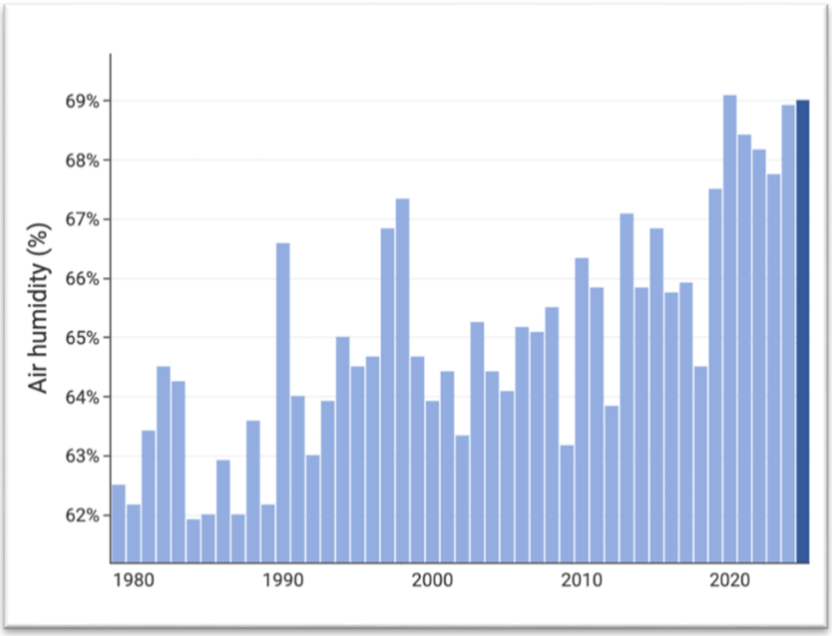
Nowhere are these hydro-meteorological shifts more immediately felt than in coastal cities, where land, ocean, and atmospheric systems intersect. The rapid retreat of glaciers and ice cover is causing sea levels to rise at unprecedented rates, further compromising the water availability and quality in coastal areas[7]. 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 districts[8].

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 capacity[11]. 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 Explorer[12]

Along India's west coast, the coastal districts of Gujarat specifically have become increasingly vulnerable to tropical cyclones in recent years[13]. Further, west coast states are more exposed to sea level rise; every one-metre rise in sea level can inundate almost 5,763 km^2 of land[14]. 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 report[15].

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 in12 coastal towns across Maharashtra, Gujarat, Karnataka, and Karnataka (*Figure 4*).

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

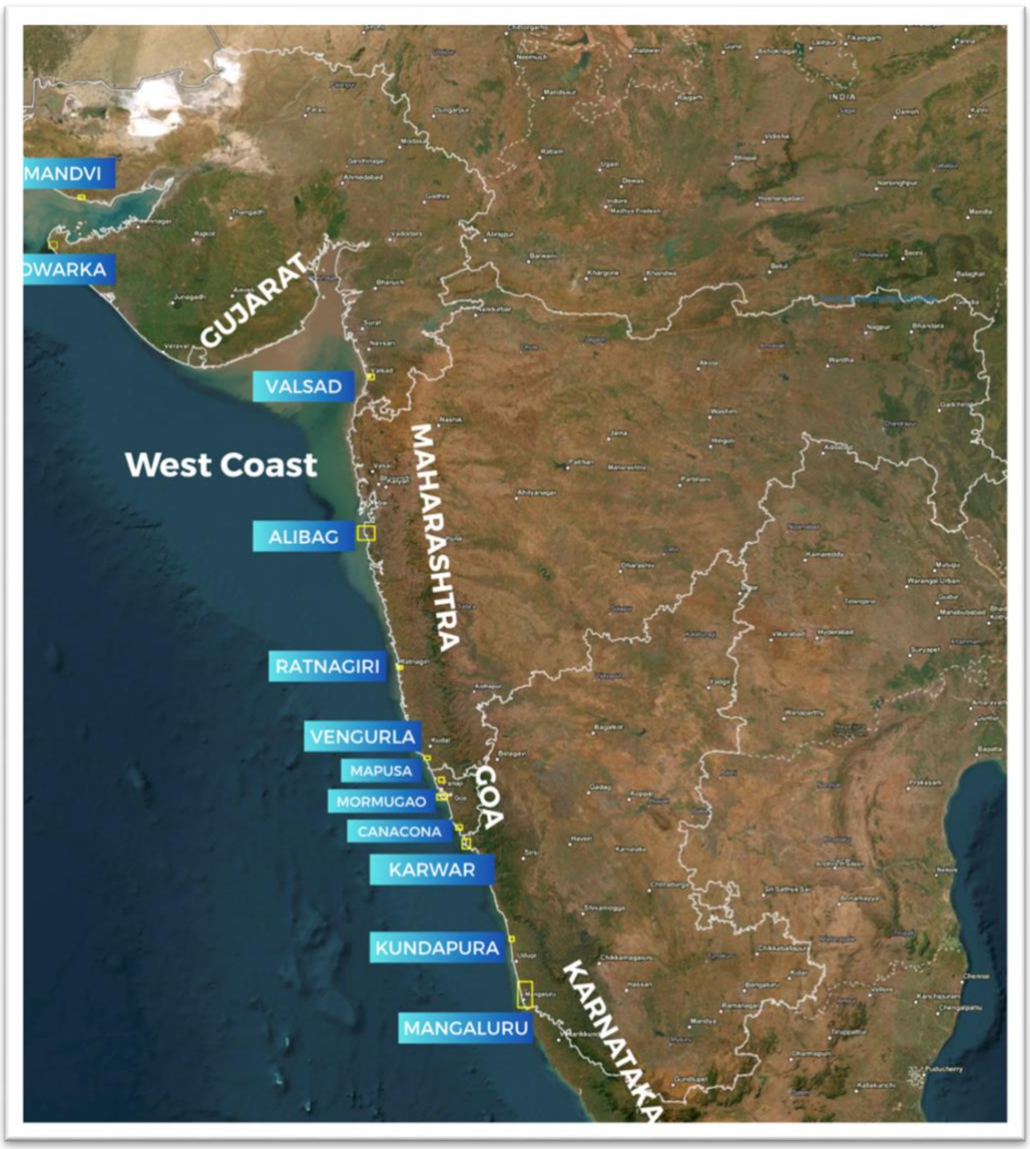


Image Source: Author's Illustration

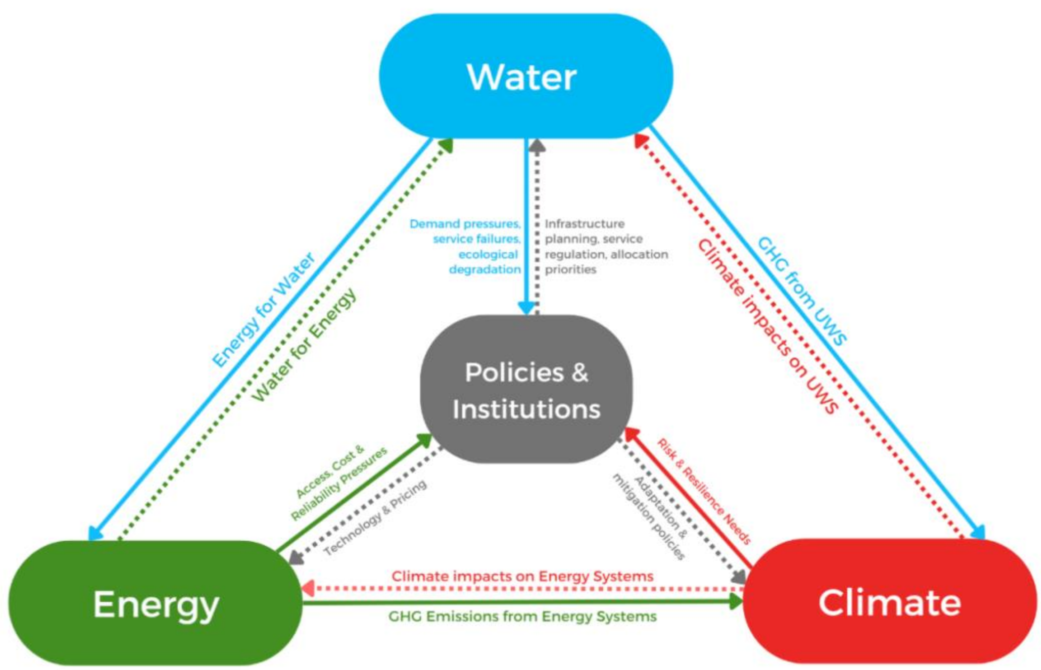
1.5 METHODOLOGY

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

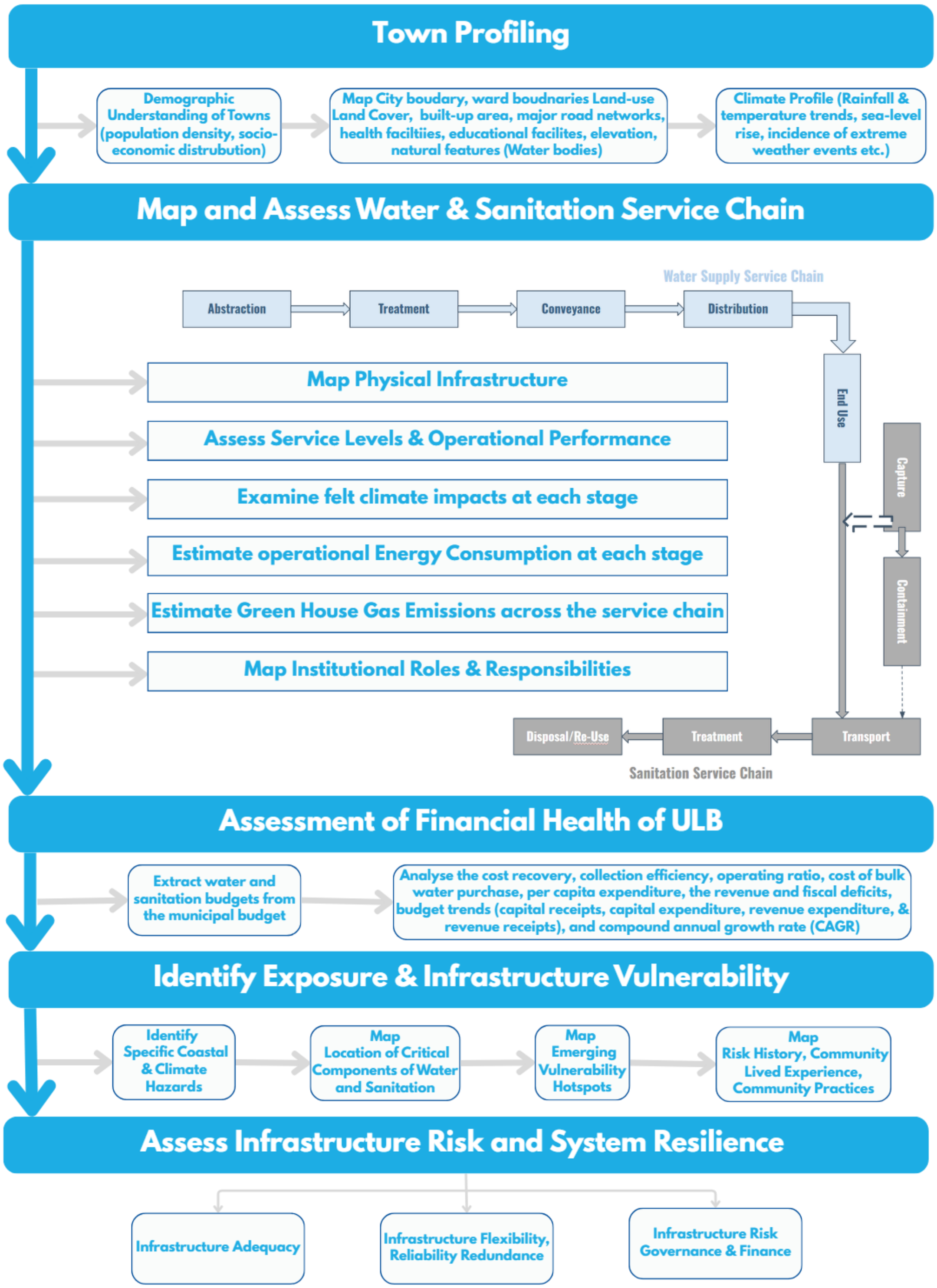
Key Parameters	Selection criteria		
Administrative status	Municipal Corporation	Municipal Council (A and B)	Nagar Panchayat (C and D)
City Size based on population	Class-I to Class IV		
Socio-economic profile	Capturing variability in socio-economic profile of the town population		
Climate Change Exposure 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* ***Kundapura,*** **a Class-III coastal town in Karnataka's Udupi district with a population of approximately 30,444 (Census 2011), situated in one of the four most climate-vulnerable states in India** (Mohanty & Wadhawan, 2021)[20].The report primarily examines the town's adaptive capacity in the water and sanitation sector amid climate change and assesses the sector's GHG emissions to inform the risk assessment of climate change impacts on its infrastructure and services.

Kundapura faces several significant climate risks due to its unique geographical location and environmental conditions. Surrounded by water on three sides—the Panchagangavali River to the north, the Kalaghar River to the east, and the Kodi backwaters along with the

Arabian Sea to the west—the town is particularly susceptible to flooding and inundation. More than 50% of Kundapura lies within the Low Elevation Coastal Zone, at or below 10 meters above mean sea level, which heightens its vulnerability to coastal hazards. The town experiences a tropical monsoon climate with hot and humid conditions year-round. Historically, Kundapura was a Portuguese settlement and trading hub in the 16th century; today, it functions as an important centre for agricultural trade from nearby villages. The Karnataka coast, including Kundapura, is prone to erosion caused by the combined effects of high river floods and strong wave action during the southwest monsoon. The town also faces moderate cyclone risk, which poses threats to infrastructure and daily life. Other critical challenges include saltwater intrusion— particularly in areas without piped water supply—and storm surges that, when coinciding with high tides and intense rainfall, can severely impact local communities and infrastructure. While coastal districts in Karnataka excel in Human Development Index (HDI), Multi-dimensional Poverty Index (MPI), and poverty levels, they remain increasingly vulnerable to direct threats from cyclones in the Arabian Sea and indirect impacts from eastern coastline cyclones.

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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.

Kundapura is a small coastal town located at a latitude of 133728’N and longitude of 744230’E at an average elevation of 87 ft above the sea level. The city has a municipal council established in 1973 that covers an area of 14 sqkm.[21]. Kundapura is in the Udupi district of Karnataka, India and serves as the headquarters of the Kundapura Taluk of Udupi district. The national highway NH-66 passes through Kundapura providing efficient road access. The nearest airport is Mangalore International Airport located 87 kilometers away. The town is also linked to the Konkan Railway line that connects Mumbai with Mangalore. Kundapura is surrounded on three sides by the Panchagangavali River, Kalaghar River, and the Arabian Sea (Ref. Figure 7). It is close to several Hindu pilgrimage sites like Kollur Mookambika.The rivers Panchagangavalli, Varahi, Kodi backwaters provide scenic natural spots.

Figure 7: Location of Kundapura Town on the Southwest Coast of India

Source: Plotted from Google Earth

Demographic Profile: As per the 2011 Census, KTMC had a population of 30,444. Over the years, the town has seen steady population growth, with the growth rate stabilizing at an average of 0.65% per year in recent times. **The estimated population of Kundapura in 2024 is projected to be around 42,000 (Census of India, 2011)[22]**. The sex ratio in Kundapura stands at 1051, which is higher than the state average of 973, while the child sex ratio is 970 compared to the state's average of 948. The literacy rate in Kundapura town is 90.52%, well above the state average of 75.36%. Male literacy is 94.34%, while female literacy is 86.91% (Census of India, 2011). Fishing is the primary occupation of the residents, with coconut cultivation serving as a secondary source of income[21]. KTMC oversees 6,272 households and provides essential services such as water and sewerage (Census of India, 2011). The town is divided into 23 wards[21].

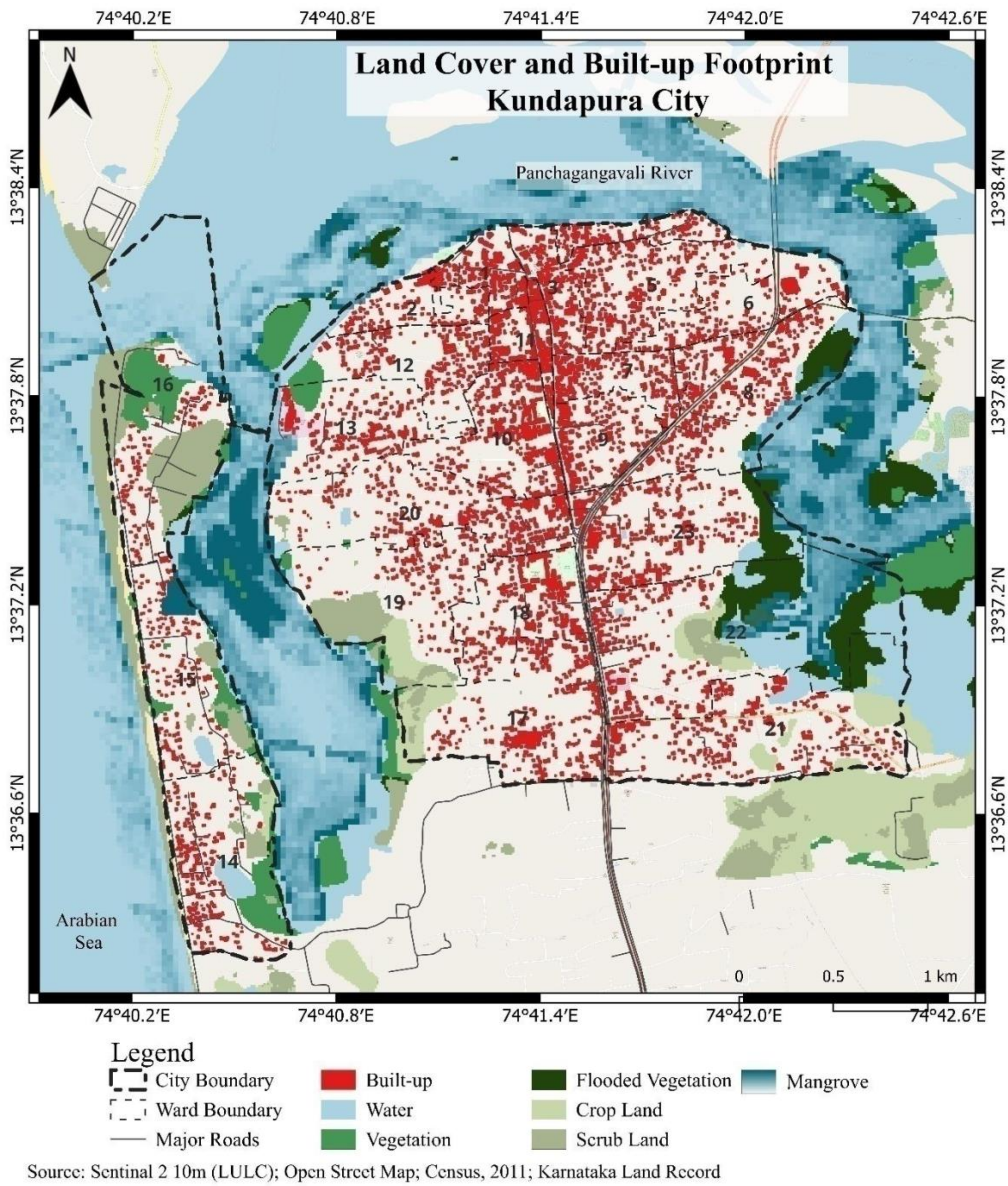
Land-use Land cover: Kundapura lies in the low-lying coastal zone (LECZ) and has a wetland ecosystem with water and flooded vegetation on 3 sides of the town. Kundapura town shows a significant built-upland cover, refer figure 8. A change assessment of in LULC between 2006 -2016 undertaken shows an increase of mixed urban/built-up land and a decrease in agricultural land. (Shekhar Naik, 2018)[23]. The population distribution and the built-up analysis reveal that the wards 2, 3, and 4 near the mouth of the river Panchagangavali have the highest population density and built-up footprint. Wards 7, 11 and 18 are landlocked wards with a significant built-up footprint (Ref. Table 3).

Table 3: Distribution of Population Density and Built-up Footprint of Kundapura Town

Ward	Popul-ation	Area (Sq. Km)	Population Density	% Built up Area	Ward	Popul-ation	Area (Sq. Km)	Populati on Density	% Built up
1	588	0.1	4116	48.73%	14	1799	0.6	3253	15.65%
2	1107	0.2	6530	31.37%	15	1447	0.5	3177	14.40%
3	974	0.1	6621	49.56%	16	1152	0.9	1214	6.55%
4	1614	0.1	14078	40.57%	17	2091	0.6	3503	21.05%
5	1347	0.4	3594	33.52%	18	1954	0.3	5666	30.91%
6	1379	0.3	4755	24.64%	19	1593	0.6	2714	10.84%
7	1169	0.2	6562	47.02%	20	1163	0.6	2031	25.42%
8	1706	0.6	2841	24.61%	21	1389	0.8	1783	16.75%
9	949	0.2	4189	35.62%	22	1165	1.0	1148	9.97%
10	1267	0.4	3516	40.03%	23	1426	0.6	2340	23.09%
11	552	0.1	4826	63.39%					
12	1388	0.3	4104	24.91%					
13	1225	0.4	3155	22.14%					

Source: Census 2011, Land Records and Sentinel data

Figure 8: Land cover and Built-up Footprint of Kundapura City



Climate: The town falls under the coastal agro climatic zone with Udupi District. The district has a tropical monsoon climate, with hot and humid conditions along the coast year-round. The temperature in the summer months, from March to May, ranges between 32-33°C, while in the winter months, from December to February, it ranges from 23-25°C. Kundapura features a coastal landscape, including sandy beaches, river estuaries, and a fragmented plateau extending from the Western Ghats to the Arabian Sea. The Western Ghats are located just 40 km from the sea at their narrowest point. The heaviest rainfall, around 81%, occurs in June, July, and August[24].

Climate Change and Disasters: Town level data on disasters is lacking. Hence, we relied upon district and taluk level secondary data on disasters. While coastal districts in Karnataka excel in HDI, MPI, and poverty levels, they face increasing vulnerability due to direct threats from cyclones in the Arabian Sea and indirect impacts from eastern coastline cyclones. The coastal areas struggle with cyclones and seawater intrusion[25].

Udipi district is classified under a moderate damage risk zone for wind hazards, with a low risk in terms of maximum sustained wind speeds[26]. *Kundapura is vulnerable to cyclones and sea erosion*[27]. Approximately 30% of the coastal zone in the state experiences moderate sea erosion, *with 16% facing severe erosion, especially in Udupi (ibid).*

As compared to other districts, the Udupi district recorded higher average annual rainfall (exceeding 2000 mm between 1992 and 2022). Between 2011 and 2021, Kundapura taluk recorded an average annual rainfall lower than the district's overall average, except for the years 2012, 2014, 2019, and 2020. The town experiences heavy rainfall during the monsoon season, which lasts from June to November, with an average annual rainfall of 4,097 mm. *Over the past six years, 10 villages in Kundapura taluk have been affected by floods. During the floods of 2019 and 2023, residents of Kundapura taluk had to be relocated to safer areas*[27].

Groundwater in Kundapura is classified as safe. In 2023, Kundapura taluk was not affected by the drought. *Kundapura town does not face any significant water shortage issues* (District Disaster Management Authority Udupi, 2024). Reports suggest that Kundapura is vulnerable to climate change risks, especially due to rising sea levels and coastal erosion, but they lack specific data on the severity of these risks and their potential effects on the town's population and infrastructure. To effectively address these challenges, more comprehensive data collection is needed. Although a study by the National Institute of Technology Karnataka highlighted that 46 km of the 95 km coastline in Udupi and Dakshina Kannada districts is severely eroded, there is no specific data on the extent of erosion in Kundapura itself. Gathering localized data is essential for accurate risk assessment and the development of targeted mitigation measures.

In terms of climate change projections, 'Drought' years are projected to decline, in the range of 1 to 3 years under RCP 4.5 scenario, and 1 to 4 years under RCP 8.5 scenario for Short-term (2030s), in most of the districts of Karnataka. *However, no change is expected for Udupi district. Udupi District is anticipated to experience a warming of 0.5°C to 1°C but is not particularly vulnerable to heat waves.*[28,29]

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[28]Heat wave is considered if the maximum temperature of a station reaches at least 40°C or more for plains, 37°C or more for coastal stations and at least 30°C or more for hilly regions. Specific criteria is: heat wave = departure from the normal is 4.5°C to 6.4°C; Sever heat wave = departure from the normal is > 6.4°C. For plains only, heat wave = when the actual maximum temperature ^{3} 45°C ; Sever hear wave = when the actual maximum temperature ^{3} 47°C

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3. STATUS OF WATER INFRASTRUCTURE AND SERVICES

ASHISH DANGI[30] AND NC NARAYANAN

This chapter provides a situational assessment of water infrastructure and services in Kundapura, Karnataka, through a climate lens. It examines how the town is responding to increasing water demand amid growing constraints on availability and quality, as well as pre-existing systemic challenges. The analysis highlights critical gaps, vulnerabilities, and potential opportunities for transitioning toward more climate-resilient urban water systems.

The coastal town of Kundapura is bordered by water on three sides: the Arabian Sea to the west, the Gangolli River to the north, and the Haladi River to the east. Its unique geography supports abundant groundwater reserves, including shallow, deep, and estuarine aquifer systems, in addition to its surface water sources.

3.1 SURFACE WATER SOURCES

Haladi River

The Haladi River is a key freshwater source for Kundapura's domestic water supply (Ref. Figure 9). Originating at an elevation of 870 meters above mean sea level in the forested hills of the Western Ghats near Someswara, it begins as the Varahi River. After meeting the Munda Koduhole near Haladi village, it takes the name Haladi River, flowing westward for about 70 kilometres across a 781 sq. km catchment before entering the Arabian Sea.

The river basin receives an average annual rainfall of 5,516 mm, largely from the southwest monsoon. The climate features hot, humid summers (March–May), dry winters (December–February), and two monsoon phases: the southwest (June–September) and northeast (October–November). Temperatures range between 21.7°C and 32.4°C, and wind speeds increase during monsoons, reaching 6.8 to 9.6 km/h.[31]

High rainfall sustains flow, but seasonal concentration of precipitation means that the river is prone to both flooding and low-flow conditions. This seasonal dependence becomes a major vulnerability. Shifts in monsoon timing, reduced predictability, and the rising intensity of rainfall events can all disrupt the river's flow patterns. Periods of water stress may increase in both frequency and severity, particularly in non-monsoon months. Beyond climate, anthropogenic pressures along the river's course also affect its sustainability as a source.

Figure 9: Haladi River in the West flowing rivers from Tadri to Kanyakumari Basin.

Source: India-Water Resources Information System (WRIS)

In this context, the Haladi River is more than just a natural resource; it is a shared and contested system shaped by both natural forces and human interventions. Ensuring its long-term sustainability will require integrated watershed management that accounts for climatic variability, upstream-downstream equity, and the cumulative impact of human activities across the basin.

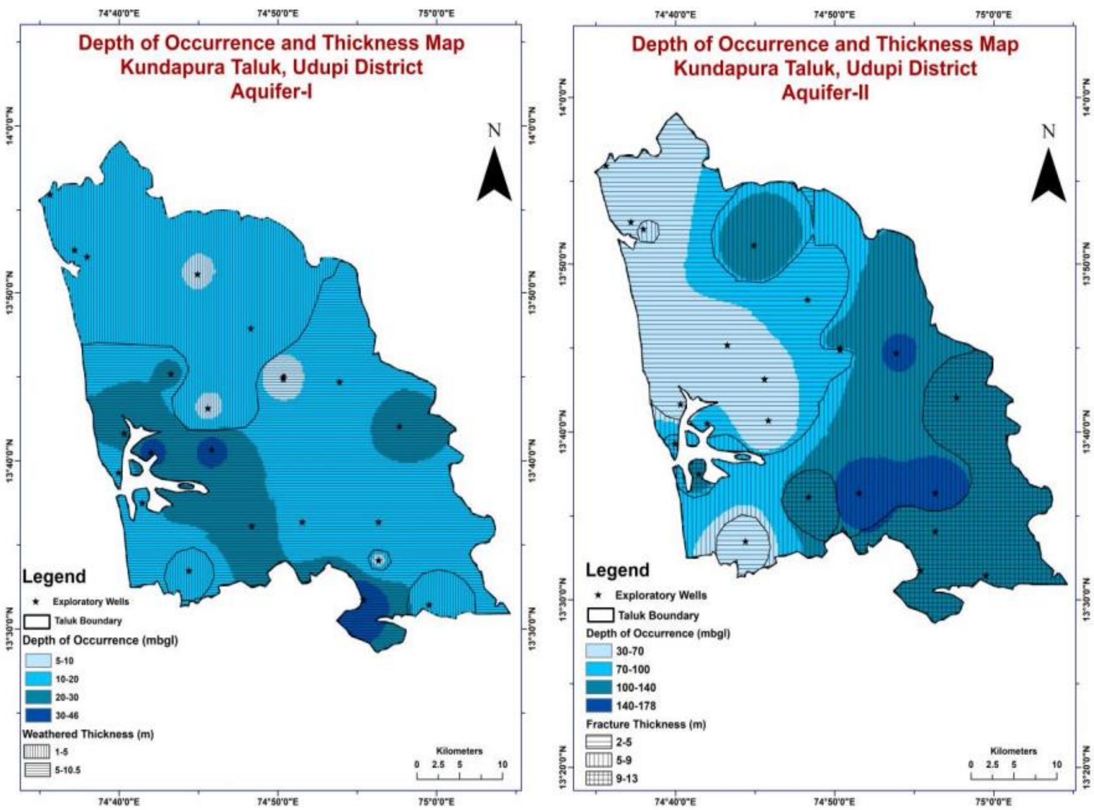
3.2 GROUNDWATER

Ground water is found in mainly two types of aquifer systems

- **Shallow Phreatic Aquifer** *(Aquifer-I)*- Comprising laterite, schist, and weathered Banded Gneissic Complex, this aquifer lies at depths of **10–20 meters below ground level (mbgl),** with a weathered thickness of **1–5 meters**.

- **Deeper Fractured Aquifer** *(Aquifer-II)* - Found at depths of **30–70 mbgl,** this system consists of fractured Banded Gneissic Complex and schistose rocks, with a similar weathered thickness of **2–5 metres** (Ref. Figure 10).

Figure 10: Depth of occurrence and weathered thickness map of Aquifer-I and Aquifer-II in Kundapura Block.

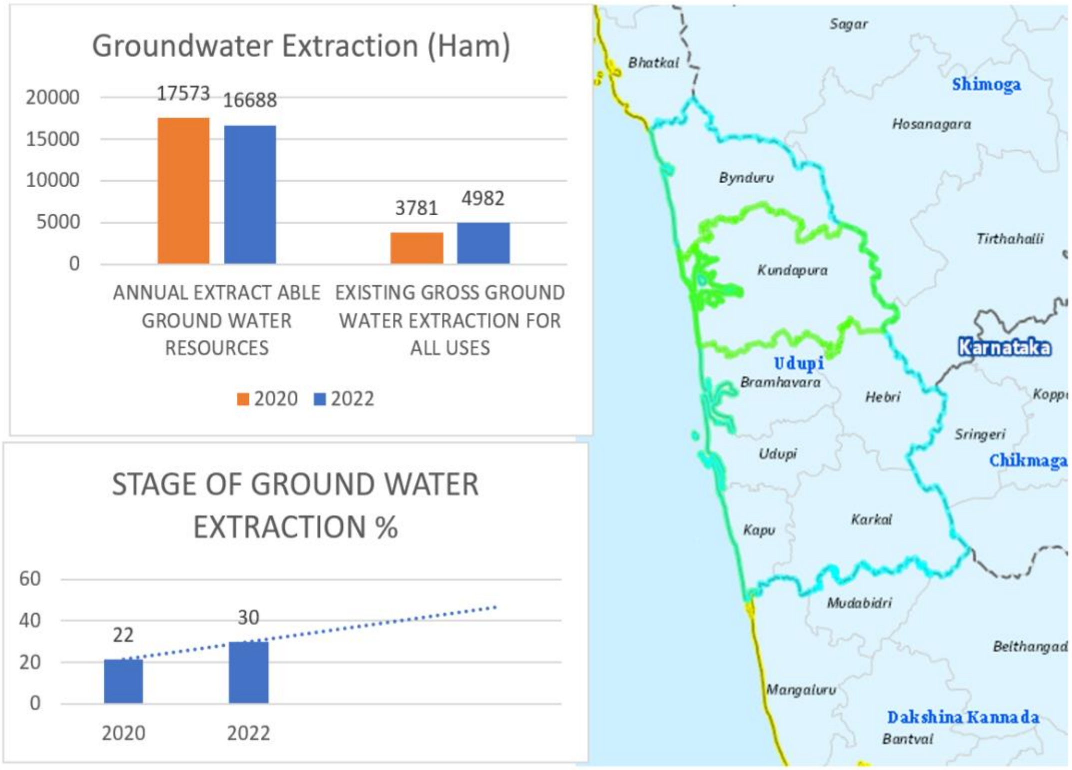


Source: Central Ground Water Board (CGWB), May 2023[32];

As of 2022, the **Central Ground Water Board (CGWB)** classifies **Kundapura Block as 'Safe',** with just **30% of total groundwater resources currently utilised**. However, this relatively stable status masks emerging concerns. **Extraction has been increasing since 2020,** driven by urban expansion and agricultural intensification (Ref. Figure 11). If this trend continues, it could push the aquifer system toward unsustainable use, particularly in densely populated urban areas where higher extraction rates meet limited recharge rates.

Groundwater quality in Kundapura varies with geology (Ref. Table 4). **Sandy aquifers** often yield **potable water,** whereas **lateritic and weathered gneissic zones** produce water that ranges from **sweet to alkaline**. **Dug wells in alluvial areas** frequently yield **saline water during summer,** though they typically recover with monsoonal recharge. According to 2022 data from the National Water Informatics Centre, groundwater in Kundapura is generally **safe for drinking,** though **moderate hardness** may cause scaling in household plumbing.

Figure 11: Status of groundwater extraction in Kundapura block.



Source: CGWB, May 2023[33]

Table 4: Observed groundwater quality at Kundapura telemetry station.

Ground Water Quality		
Station Name	Latitude	Longitude
Kundapura	**13.6286111**	**74.6930556**
Date Collection: 2022		
Carbonate (mg/L)	**0**	
Silicate (SiO2) (mg/L)	**7**	
Total Dissolved Solids (mg/L)	**265**	
Potassium (mg/L)	**9.3**	
Chloride (mg/L)	**46**	
Calcium (mg/L)	**44**	
Bicarbonate (mg/L)	**67**	
Sulphate (mg/L)	**35**	
Magnesium (mg/L)	**6**	
Fluoride (mg/L)	**0.02**	
Total Hardness (mg/L)	**135**	
Sodium Absorption Ratio	**1.16**	
Electrical Conductivity (µS/cm) at 25°C)	**440**	
Sodium (mg/L)	**31**	
Percent Sodium	**31.54**	
pH	**7.21**	
Residual Sodium Carbonate	**-1.59**	
Total Alkalinity (mg/L)	**55**	

Source: CGWB, 2022[34];

3.3 WATER INFRASTRUCTURE

This coastal town has traditionally depended on dug wells and borewells for water, benefiting from the high-water table and the widespread, equitable access provided by coastal aquifers. In densely populated areas, public and community wells ensured shared access, while numerous households, institutions, and commercial establishments maintained private wells within their premises, where land permitted. Beyond the narrow coastal strips and the Kundapura backwaters, where salinity and hardness have posed challenges, the town's unique coastal aquifer system has long been revered for its pristine water quality. For the locals, this pure, life-giving water is more than just a resource; it is a treasured emblem of their land's natural abundance. Water is extracted using small (0.5-1 hp) water pumps placed on top of the well or using a submersible pump in case of deeper dug wells and borewells (Ref. Figure 12). Water is pumped into a household level overhead tank to supply continuous water within the household or supplied directly from the well for outdoor uses.

However, with the increasing demand and *reduced Groundwater availability* particularly during *summers* exacerbated by *deteriorating groundwater quality*, a new mode of water supply through piped water connections emerged. Initially the municipality tapped groundwater to supply tap water to households. Increasing reliance on this new mode of supply led to the first organized water supply system in 2008, under the Karnataka Urban Development and Coastal Environmental Management Project (KUDCEMP).

Figure 12: Water-supply Infrastructure at household

Source: Authors' Illustration

The first organized water supply system in Kundapura was implemented in 2008 under KUDCEMP. This scheme was designed to meet the water demand of 75,663 residents until 2026, with a treatment capacity of 7.60 MLD. The intake works are located on the Varahi River at Jambu, approximately 11 kilometers from Kundapura. Raw water is pumped from the intake to WTP situated on a hillock in Japhthi village, about 2.5 km from the intake, through 400-millimeter (mm) diameter mild steel rising mains. Treated water is then conveyed via a 400 mm diameter rising main to three overhead tanks (OHTs): Ashraya Colony (5 lakh liters, LL), Gandhi Park (5 LL) and Halekote (5 LL) in the 2009 scheme. The clear water transmission main extends along the Kundapura-Shimoga Road, supplying water to four enroute villages: Japhthi, Balkur, Basrur, and Koni (Ref. Figure 13).

Figure 13: Schematic representation of the water supply network for Kundapura.

Distribution	Conveyance	Treatment	Intake
Overhead Tanks 5 LL Ashraya Colony (2008), 5 LL Gandhi Park (2008), 5 LL Halekote (2008), 5 LL Halekote (2021). and 4 LL Kodi (2021). HDPE Distribution pipelines- 107.5 km	2 X 75 hp centrifugal pumps @ WTP 9.3 KM 400 mm MS Clear water Mains	7.6 MLD Treatment plant c. 2008 , renovated in 2021 1x Aerator 1 x Clariflocculator Filter Beds 2X 7.5 LL Clear water reservoir 1x 1 LL Backwash tank 20 hp backwash pump	Jackwell 1x 150 hp VT pump 1 x 100 hp VT pump

Source: Author's illustration using Google Earth satellite imagery

To address infrastructure gaps identified in a **2018 resettlement plan** by the Karnataka Urban Infrastructure Development and Finance Corporation **(KUIDFC)** under **KIUWMIP,** significant upgrades were carried out with Asian Development Bank (**ADB) assistance,** including:

- **Upgraded Intake Works** and DG sets for power backup
- **WTP Renovation** and addition of a 160 kVA backup generator
- **New Clear water feeder mains** (4.8 km) to serve Zone-4 (Kodi)
- **Two new Overhead Tanks (OHTs)** at Kodi and Halekote
- **Expanded Distribution Network** to 107.5 km (including 31.64 km added under KIUWMIP)
- **Metered House Service Connections,** including new installations and meter replacements
- **Retention of raw and clear water mains** (2.2 km and 13 km respectively)

Completed in 2021, these upgrades culminated in the town's **24x7 water supply scheme,** offering continuous household-level service across five supply zones. Each zone is served by a dedicated **OHT or ELSR,** with water distributed by gravity (Ref. Figure 14). The system's **O&M** is outsourced to a private contractor under strict performance-based targets to ensure efficiency, reliability, and service quality (Ref. Table 6).

Figure 14: Water distribution zones in KTMC

Source: Author's illustration using Google Earth satellite imagery

Table 5: Summary of key performance targets for Kundapura's 24x7 Water Supply Scheme O&M Phase IV.

Parameter	Performance Target
Continuous Supply	98% of authorized connections must receive uninterrupted supply.
Emergency Stoppages	Max **12 hours per event**, not exceeding **4 events per year**.
Minimum Pressure	**≥7m** at critical points (4:00 AM - 10:00 PM).
Metering & Records	98% of connections metered, computerized records maintained.
Water Loss Reduction	**≤25%** (Year 1), **≤20%** (subsequent years).
Customer Service	24x7 support; complaints addressed within **24 hours** (general) and **12 hours** (low pressure/quality). Redressal within **7 days** (general) and **24 hours** (pressure/quality).
Leak Repairs	Surface leaks repaired within **24 hours**.
Energy Efficiency	Power factor **>0.9** (contractor bears excess costs if lower). Pumping aligned with demand.
Municipal Workforce	Municipal staff actively deployed by the contractor.
Water Quality	**Min. 0.2 PPM residual chlorine**, monthly monitoring.

Source: KTMC

3.4 WATER DEMAND & SUPPLY

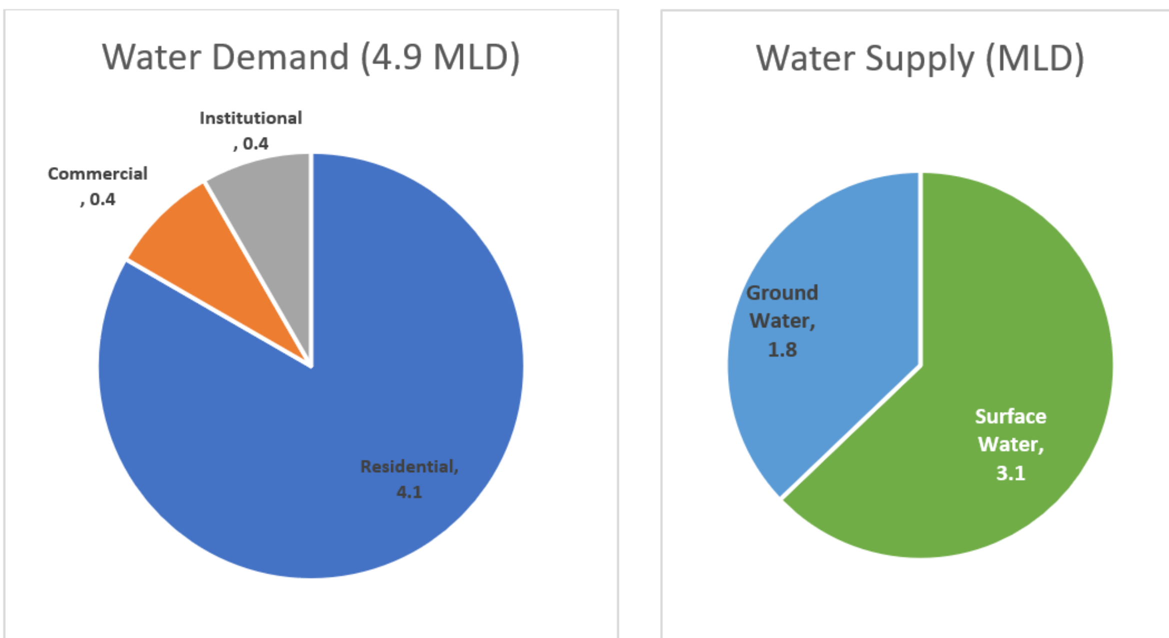
As per the 2011 Census, Kundapura has a population of 30,444, distributed across 6,272 households. The total water demand is estimated at 4.9 Million Litres per Day (MLD), based on a domestic per capita consumption of 135 liters per capita per day (lpcd), with an additional 20% allocation for commercial and institutional demand.[i] Of this demand,

[i] The additional institutional (10%) and commercial (10%) demand is assumed based on piped water supply consumption data for October 2024 across these categories of connections provided by Town Municipal Council (TMC) Kundapura.

approximately 3.1 MLD is consumed[ii] through the piped water network from the Haladi River and the remaining 1.8 MLD is presumed to be met through groundwater withdrawals (Ref. Figure 15).

Note: Population projections for current year through standard population projection methods may be unreliable for a small coastal town like Kundapura due to limited land availability within municipal limits. Additionally, new population growth is largely concentrated in outgrowth areas beyond the municipal boundary, and out-migration is not accounted for in standard projection methods. Consequently, 2011 Census figures are used for demand estimation, though accurate and updated population data is essential for more precise assessments of water demand and resource sustainability.

Figure 15: Water demand estimated based on Census 2011 population and water supplied



Source: Authors' illustration

[ii] Billed piped water consumption for TMC, Kundapura area for the month of October 2024 with 100% metering and billing.

Approximately **66% of households** (4,139 out of a total 6,272 households in KTMC) have transitioned from relying solely on groundwater to using **tap water connections,** either as their primary source or to supplement their existing groundwater access (Ref. Figure 16).

Figure 16: Household Service Connections by category as of Dec, 2024

Data Source: KTMC

3.5 CLIMATE RISKS AND CHALLENGES

Coastal towns like Kundapura are increasingly facing multiple and intersecting threats that compromise water security, sustainability, and climate resilience. These risks stem not only from changing climatic conditions but also from how water systems are structured and governed.

CLIMATE VULNERABILITY OF WATER SOURCES

- *Surface Water:* Increasingly Unreliable: Kundapura's primary surface water source, the Haladi River (a downstream stretch of the Varahi), is highly sensitive to both climate variability and upstream interventions. Although average annual rainfall is high, changing rainfall intensity and seasonal distribution lead to reduced infiltration, higher surface runoff, sedimentation, and pollution undermining water quality and availability. Moreover, the river's flow is regulated by upstream projects like the Varahi Hydropower and Irrigation Project (Ref. Figure 17). These interventions, combined with rising temperatures and evapotranspiration, create significant uncertainty for downstream users, especially during lean seasons.

Figure 17: Varahi hydel power project upstream of Kundapura's water intake from haladi River.

Image Source: Google Earth

- *Groundwater: Strained but Still Essential:* Groundwater has long been central to Kundapura's water supply, especially through dug wells and shallow aquifers. However, recharge is increasingly constrained by erratic rainfall and impermeable urban surfaces. Salinity intrusion in coastal and alluvial wells during summers highlights growing quality concerns. Though currently classified as 'safe' by the CGWB (2023), rising extraction trends and climate-induced recharge variability pose risks to long-term sustainability. Without managed aquifer recharge and conservation measures, shallow and deep aquifers may become less reliable under climate stress. A less visible but critical challenge is the contamination of groundwater from inadequate sanitation infrastructure. Many households continue to use unlined or poorly maintained septic tanks and soak pits, especially in high-density and peri-urban areas. During the monsoon season, rising water tables and surface runoff increase the risk of faecal contamination. This infiltration of pathogens and nitrates into shallow aquifers can pose serious public health risks especially where groundwater is used directly without treatment.

WATER-ENERGY-CARBON NEXUS AND EMISSIONS RISKS

- *Rising Carbon Footprint of Water Systems:* Kundapura's transition from local groundwater sources to a centralised, piped surface water system has significantly increased the energy and carbon footprint. Current electricity-related emissions exceed 750 tCO_2 (see chapter 5) annually despite only 66% piped water coverage. As more households transition to piped supply, energy consumption and associated emissions will rise steeply due to increased pumping, treatment, and transmission demands.

- *Climate Feedbacks Amplify Energy Demands:* Climate impacts are likely to further escalate energy use. For example, during monsoons, high turbidity in river water increases chemical usage and requires frequent filter backwashing, raising both energy consumption and water losses at the plant. Degrading source quality, frequent flooding, and increased sediment loads can exacerbate these operational inefficiencies. This creates a vicious cycle: climate change degrades water sources, prompting energy-intensive treatment, which increases carbon emissions and worsens climate change.

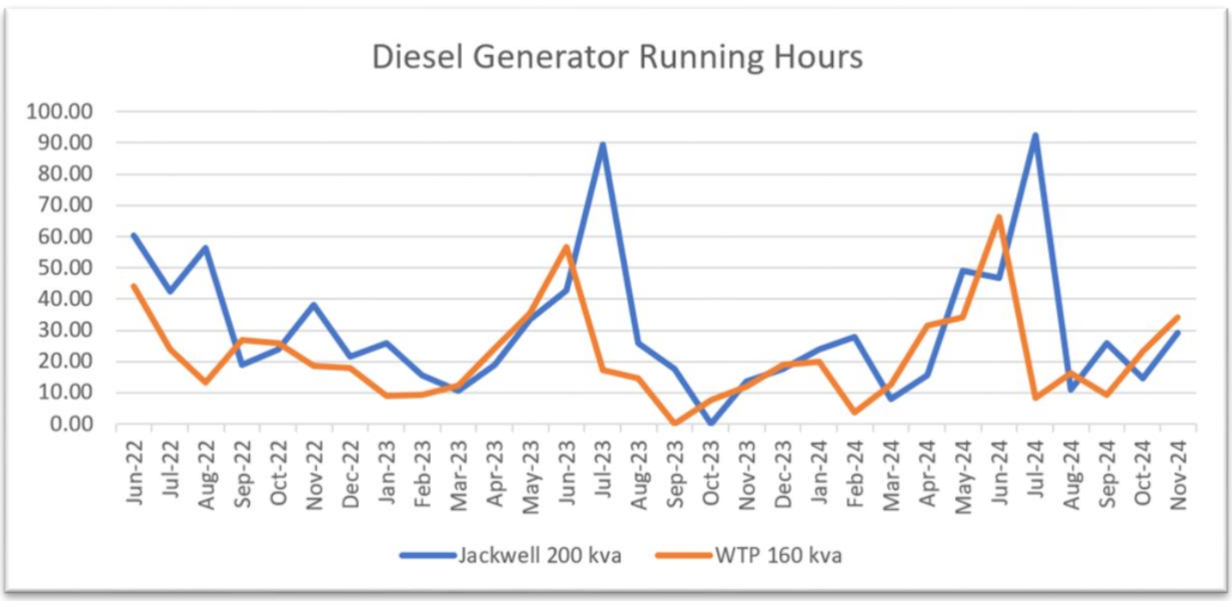
FRAGILITY OF CENTRALISED WATER SUPPLY SYSTEMS

- *Operational and Financial Vulnerabilities:* Kundapura's centralized water system, developed under KUDCEMP and expanded through KIUWMIP, requires high capital investment and ongoing maintenance. The municipality depends on state and multilateral funding, making it vulnerable to policy shifts and bureaucratic delays. Service delivery is outsourced to a private operator, but major costs like energy and chemicals are borne by the ULB. While this limits cost-cutting by the operator, the arrangement raises accountability concerns especially since the same operator is also responsible for water quality testing.

- *Low Adaptive Capacity:* Centralized systems tend to be rigid and slow to respond to changing climatic conditions. Their reliance on fixed infrastructure and long-distance transfers limits their ability to adjust to sudden disruptions from floods, landslides, or power outages. The lack of flexibility discourages innovation and integration of more adaptive solutions like decentralized or nature-based systems.

- *Energy Dependence and Diesel Backup Risks:* To address frequent power outages especially during monsoons, diesel generators are installed at the intake and treatment plant. While they improve resilience, they also increase operational costs and emissions. The heavy reliance on electricity and diesel underscores the water sector's exposure to energy insecurity. Power outages far exceed the running hours of diesel generators, as they are only used when absolutely necessary. However, the running hours indicate a clear trend - power outages peak during the rainy season (May to July) (Ref. Figure18). This highlights the intricate water-energy-climate nexus: water supply relies on energy availability, power generation depends on water availability, and climate influences both the distribution and demand for water and energy.

Figure 18: Running hours for diesel generators in water supply network.



Data Source: TMC, Kundapura

OVERDEPENDENCE ON IMPORTED WATER AND NEGLECT OF LOCAL SOURCES

The increasing reliance on a single surface water source has led to the neglect of local sources like ponds, tanks, and shallow wells. These decentralized sources once provided flexibility, equity, and resilience, especially during supply disruptions or droughts. Imported water systems are vulnerable to breakdowns, climate-induced disasters (e.g., floods, cyclones), and infrastructure failures. Their energy-intensive nature adds to both economic and ecological vulnerability. Diversifying sources and re-integrating traditional systems into the water portfolio is essential for climate resilience.

EMERGING WATER CONFLICTS IN A CHANGING CLIMATE

As rainfall becomes more erratic and seasonal shortages intensify, competition between sectors such as agriculture, domestic use, power, and industry is likely to increase. The Varahi Project is a case in point, where incomplete irrigation infrastructure and downstream drinking water needs are in constant tension. Although Kundapura's municipal water demand constitutes a small fraction of total river flow, upstream interventions can have outsized impacts especially during the dry season when demand peaks. Without equitable and adaptive basin-level governance, these conflicts may threaten water access and regional stability.

In conclusion, Kundapura's water story reflects both resilience and risk. While the town has long benefited from its unique coastal aquifers and high rainfall, rapid urbanization, shifting climate patterns, and increasing dependence on centralized, energy-intensive systems are straining its water sources and infrastructure. Surface water reliability is being challenged by upstream interventions and erratic monsoons, while shallow aquifers face declining recharge and salinity intrusion. At the same time, the shift from local to piped supply has increased energy consumption and carbon emissions, creating a feedback loop that further amplifies climate risks.

Going forward, a balanced approach that restores and integrates traditional water systems, improves efficiency, and diversifies supply sources is critical. Strengthening local recharge, protecting water quality, and reducing operational emissions must go hand in hand with adaptive governance and community engagement.

NOTES & REFERENCES

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[30] 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 KUNDAPURA: 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 Kundapura, 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[35,36,37]. *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*[38]. WaSH services are essential for preventing disease outbreaks, particularly in the aftermath of climate hazards such as heavy rainfall and flooding[39], [40]. 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*[41]. 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 role[42].

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[43]. 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.

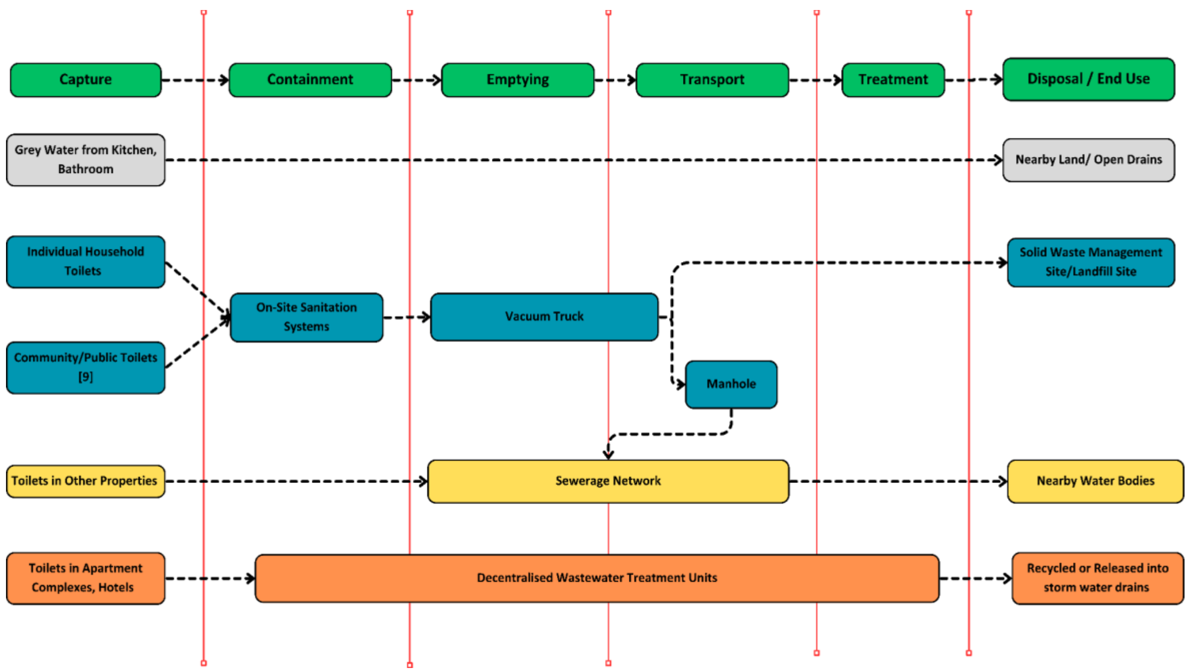
Hence, assessing the current state of sanitation services is essential for identifying infrastructure gaps, vulnerabilities, and climate-related risks. Such an assessment supports the design of proactive adaptation measures, promotes efficient resource use, and enables low-carbon development strategies. 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 *Kundapura.* 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 use[44]. This section outlines the service chain and identifies the key gaps. The entire service chain is depicted in *Figure 19*.

Figure 19: Sanitation Service Chain in Kundapura



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:** The town has been designated as ODF+ (Open Defecation Free Plus), signifying that ULB has successfully met the SBM criteria. This includes ensuring that all individual toilets are fully functional, well-maintained, and equipped with a reliable water supply. Furthermore, all public areas are served by operational public toilets within a one-kilometer radius. The ULB has also completed 100% of the approved Individual Household Latrine (IHHL) applications and achieved full construction of CT and PT in accordance with set targets(Ministry of Housing and Urban Affairs, 2020)[45].According to the 2011 census, out of 6272 households 697 households lacked individual toilets. However, as this data is outdated, we gathered more recent information through interviews with the municipal officials. Based on this updated information through the interview According to municipal officials, approximately 200 households lack individual toilets and therefore rely on community toilets. These households are primarily located in Wards 2, 4, and 20, and are mostly from the fishing community along the coastal belt. During our field visit to Wards 2 and 4 and interactions with residents (from the fishing community) and the ward councillor respectively, we found that, in the past, these households relied entirely on community toilets. However, the majority now have their own toilets, equipped with septic tanks and soak pits.

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 (CT) and Public Toilets (PT)** [46]**:** According to data obtained from the ULB, the city currently has a total of 9 community and public toilets, comprising 4 CT and 5 PT. Of these, 4 CT/PT are located on ULB-owned land, while the remaining 5 are situated in public spaces such as parks, bus stands, and near petrol pumps. Additionally, the ULB has recently received INR 18 lakhs under Swachh Bharat Mission Urban 2.0 (SBM-U) to construct 1 aspirational public toilet with 12 seats[47]. 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.

  To assess the condition of PT, 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 PTs (Ref. Photo below). 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.

Photo : PT in Ward Number 20; Source: IITB Team

- **Containment:** According to ULB officials, approximately 40% of households (out of 6,272) manage toilet waste (excreta and black water) using septic tanks combined with soak pits, while the remaining households rely on soak pit-based OSS. Field interactions revealed that certain households in Wards 2, 4, and 20 still use soak pits that lack a concrete base, allowing wastewater to seep into the ground. This poses a potential risk for groundwater contamination, particularly in areas with a high-water table.

  Further, interactions with residents indicated a shift in the materials used for constructing soak pits: older pits were made with stones and have unlined bottoms, whereas newer households are opting for brick and cement rings. However, a detailed survey is required to gain a more precise understanding of the OSS typology. Furthermore, our field visit revealed that many residents have not cleaned their OSS in the past 10 to 15 years. This indicates that the OSS systems may have been designed with excess capacity or could consist of septic tanks combined with soak pits, or possibly just soak pits, as noted by municipal officials.

  Additionally, greywater from kitchens and bathrooms is primarily discharged untreated into nearby land or open drains.

- **Emptying and Transport:** The city has a 31 km sewerage network; however, the interviews with the municipal officials reveal that there are no direct household connections. Field observations, however, indicate that other property types, such as commercial establishments, may be discharging wastewater into the sewer system. The ULB couldn't provide data on storm drainage network – coverage and typology.

- **Treatment:** Currently, the city doesn't have a STP. The ULB supplies a total 6.8 MLD of water as of 2021-2022, hence generates about 5.44 MLD of wastewater (at 80% thumb rule). The wastewater is being discharged partially treated and untreated into nearby land and water bodies, negatively impacting water quality, public health, and environmental health.

- **End-use Disposal (Septage and Sludge Management)[iii]:** The city does not have a FSSTP. Septage from OSS (households, hospitals, schools, colleges, and offices) is collected by three suction trucks owned by the town council.[iv]The liquid portion is discharged into the manholes of the sewerage network, where it is directly released into marine and aquatic environments. Meanwhile, the solid portion is transported to a sedimentation pond located 12-15 km from the city at the solid waste management (SWM) site (Ref. Photo below). This disposal method could pose a potential risk to groundwater quality. However, during our field visits, we did not observe any signs of a sedimentation pond at the site. This raise concerns that the wastewater may either be improperly discharged into the manholes or openly dumped at the SWM site, where it is left to dry.

Photo: Solid Waste Management Site (a) SWM Site (b) Organic Waste Processing Unit (c) inorganic waste dumping site; Source: IITB Team

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[iii] "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).

[iv] One truck with suction (3500 Liters capacity) and jetting (2000 liters capacity) and two trucks with a suction capacity of 4000 and 1000 liters respectively

- **Decentralised Sewage Treatment Systems:** The city government, in accordance with Karnataka State pollution Control Board (KSPCB) regulations and the Karnataka Municipalities Model Building Byelaws 2017 (Government of Karnataka, 2017)[48], has mandated larger apartment complexes and other properties, such as hospitals and hotels, to install decentralized STPs. The city has several such units (Ref. Photo below); however, many of them are not properly maintained, according to municipal officials. This is primarily due to their relatively high operational costs. Our field interactions with a resident of an apartment complex confirmed this, particularly for smaller apartment complexes that struggle to achieve economies of scale. The high operational costs lead to inadequate operation and maintenance of the systems, resulting in an increased risk of leaks and non-compliance with pollution discharge standards, which poses a significant threat to both environmental and public health.

Photo : Decentralised Sewage Treatment Unit in Apartment Complex; ***Source: IITB Team***

- **Recycling and Reuse:** Decentralised units may occasionally reuse treated wastewater for cleaning common areas; **however, it is typically discharged into stormwater drains when not in use.** However, city-wide water recycling data is not feasible in this case, as the city does not have a treatment plant.

4.3 INSTITUTIONAL ARRANGEMENTS

This section examines the institutional arrangements, outlining the various departments, agencies, and organizations, along with their respective roles in delivering sanitation infrastructure and services. 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, we observed a multi-stakeholder, multi-level governance framework involved in the provision of sanitation infrastructure and services (Ref. Table 6).

While the 74th Constitutional Amendment grants ULBs responsibility for water supply and sanitation, state and central agencies continue to play a prominent role in key decisions, especially for large-scale infrastructure projects where ULBs may lack the capacity to secure necessary funding. This dependence on state or central government funding for capital projects limits the decision-making authority of ULBs in infrastructure development and planning. For example, in Kundapura, the Karnataka Urban Water Supply and Drainage Board (KUWSDB) is overseeing the completion of the remaining sewerage network and the construction of five wet wells, while the KUIDFC is managing the construction of the STPs, with assistance from a Project Development Management Consultant. Furthermore, ULB's role is limited to the operation and maintenance of sewerage networks, with little involvement in the planning and implementation phases of these infrastructure projects.

Smaller sanitation interventions, such as CTs and PTs, are the responsibility of the ULB, which has the authority to make independent decisions on key aspects like land selection, technology choice, O&M, and funding. Under SBM, capital funding is provided for certain PTs. However, the environmental compliance of both CTs and PTs remains unclear. In some cases, local communities, as reported by municipal officials, are involved in the cleaning and maintenance of community toilet blocks, while some PTs have outsourced their O&M to private vendors, who recover costs through user charges.

The city has mandated the installation of decentralized sewage treatment units for apartment complexes and hospitals as part of KSPCB's consent mechanisms. When developing a new building, the owner must submit a detailed building plan for approval. Before construction begins, a Consent for Establishment (CFE) must be obtained from the KSPCB. Upon project completion, a Consent to Operate (CTO) is required from the KSPCB to ensure ongoing compliance with environmental regulations.

Table 6: Institutional Arrangements: Sanitation Services

Intervention	Technology Selection	Land	Capital	Technology Provision	Technology implementation	O&M	O&M Funding
Toilets	Household	House-hold	Household	Local mesons/private vendors	Local mesons/private vendors	Household	Household
OSS	Household	House-hold	Household			Household ULB (Septage removal by ULB vehicles)	Household
Community Toilets	ULB	Govern-ment land	-ULB (own revenue) -Central Government schemes (SBM 1.0)	ULB	ULB	O&M by ULB Cleaning by community	ULB
Public Toilets	ULB	ULB land, Public land such as park, Bus stand	-ULB (own revenue) -Central Government schemes (SBM 1.0) -Lions clubs, and Rotary clubs donation	ULB	ULB	-4 are maintained by ULB -1 is maintained by Sulabh international	Pay and use those that are maintained by the Sulabh International
Sewerage Network	State (KUWSDB)	State (Road)	State Fund	State (KUWSDB)	State (KUWSDB)	Not functional	Not Functional
Sludge and Septage Management	ULB	NA	ULB own revenue	ULB Vacuum trucks	Not Applicable	ULB	ULB
Decentralised Sewage Treatment Units	Private	Private	Private	Private	Private	Private	Private
Note: HH = Households ; ULB = Urban Local Body							

Source: *(Rana, Gogoi, & Narayanan, Forthcoming)*[49]

At household level, the responsibility for sanitation infrastructure, including toilets and on-site sanitation systems, rests with the individual household. For septage management, households can avail themselves of the municipality's vacuum truck services for a fee set by the ULB. Within city limits, the charges are INR 1,750 for residential properties, INR 2,500 for commercial establishments, and INR 1,000 for government offices and institutions. For locations outside the city limits, an additional charge of INR 70 per kilometer is applied for both the outward and return journeys.

Interviews with municipal officials revealed that the ULB's role in disaster governance and planning is limited. The ULB does not have a dedicated city-level disaster management cell and relies on DDMA for support. According to the Disaster Management Act of 2005, the district disaster authority is responsible for identifying buildings and locations that can be used as relief centers or camps during a disaster, as well as ensuring arrangements for water supply and sanitation at these sites, (Government of India, 2005, p. 15)[50]. In practice, however, the ULB plays a crucial role in this process.

The ULB's primary involvement occurs during the relief phase of a disaster, focusing on shelter provision, site selection, and ensuring water and sanitation services. For smaller incidents, such as a tree falling during a storm, the ULB is responsible for clearing debris. In the case of a major disaster, the district disaster office, supported by firefighters and a task force, takes the lead, while the ULB remains focused on shelter provision and site selection. The city has a disaster management plan in place to guide these efforts.

4.4 CHALLENGES AND OPPORTUNITIES IN SANITATION INFRASTRUCTURE AND SERVICES

The town and the municipal council are dealing with various challenges that are hindering progress in provision of equitable and affordable sanitation services to all.

- **NIMBY (Not in My Backyard):** The city currently does not have a STP, and previous efforts to establish one have faced challenges due to limited availability of open government land. As a result, the ULB has had to consider private land acquisition, which has led to some concerns from residents, as seen in the case of Kundapura. Despite having the necessary funds and Detailed Project Reports (DPRs) in place, KUDWSB encountered challenges in moving forward with the STP project due to land acquisition issues. Residents have expressed concerns about potential impacts, including the effect on land value and the possibility of odors or environmental issues, which are important considerations for the community. The authorities are currently working on developing a STP at the same location.

- **Need for Septage and Sludge Management Strategy and Plan:** The city currently lacks both FSSTP and STP. Commercial developments are discharging untreated blackwater directly into water bodies, which poses a significant environmental threat. At the household level, many homes rely on soak pits instead of properly designed septic tanks. Desludging intervals are inconsistent, with longer frequencies often indicating poor system design or septic tank overcapacity. Furthermore, there is a lack of regulations governing the construction of septic tanks, soak pits, or other OSS systems, increasing the risk of groundwater contamination and GHG emissions. Currently, untreated septage collected by the vacuum trucks is disposed of at an open solid waste landfill site, raising concerns about groundwater contamination from leaching, especially during the monsoon season, as well as broader environmental pollution. The city is also grappling with aging infrastructure; for instance, one of the ULB's vacuum trucks is nearing the end of its operational lifespan and is scheduled for decommissioning this year. This situation urgently calls for the attention of the authorities and highlights the need for a comprehensive sludge management strategy that ensures the safe, efficient, and environmentally responsible disposal and utilization of treated sewage byproducts.

- **Need of Robust Monitoring and Evaluation Framework for Decentralised Sewage Treatment Units for Long-term Sustainability:** The city mandates the installation of decentralized STPs for specific property types and sizes. This approach offers valuable opportunities for recycling treated wastewater for non-potable uses and reducing dependence on fresh water, but it also faces some challenges.

  Conversations with municipal officials and residents have revealed that a few treatment plants are not currently operational. The primary factors contributing to this are the high operational costs and the extensive maintenance requirements, which sometimes result in intermittent use. As a result, some plants may not be maintained as effectively as needed, which can affect their performance. Additionally, the ULB does not conduct regular inspections of these plants post-installation, as they are managed by private agencies. Environmental monitoring is handled by property owners through outsourced private agencies, which can raise questions about the consistency and accuracy of the assessments. When managed well, decentralized STPs can offer a sustainable solution, but when not properly maintained, they can contribute to environmental challenges, such as untreated wastewater being released into drainage systems, which may affect water bodies and groundwater.

  To improve the effectiveness of these systems, there is a need for a robust monitoring and evaluation framework, coupled with enhanced regulatory oversight, to ensure that decentralized STPs function efficiently and continue to benefit both the community and the environment.

- **ULB's Limited Role in Infrastructure Development and Planning due to Central-State Dependencies:** While the 74th Constitutional Amendment grants ULBs responsibility for water supply and sanitation, state and central agencies continue to play a prominent role in key decisions, especially for large-scale infrastructure projects where ULBs may lack the capacity to secure necessary funding. This dependence on state or central government funding for capital projects limits the decision-making authority of ULBs in infrastructure development and planning. In Kundapura, for example, KUWSDB is overseeing the completion of the remaining sewerage network and the construction of five wet wells, while KUIDFC is managing the construction of the STPs with assistance from a Project Development Management Consultant.

  This creates a governance challenge, where ULBs, while responsible for managing the O&M of sewer systems, lack authority over design standards and construction quality. This highlights the need for ULBs to have greater autonomy, fiscal capacity, and the ability to select and implement solutions that align with their technical, financial, and institutional capabilities, empowering them to effectively manage urban infrastructure projects.

- **Staffing Challenges:** According to municipal officials, ULB experiences a vacancy rate of 30 to 35% due to limited funding, which is primarily managed by the State Finance Commission (SFC). This financial constraint affects the ability to hire the full complement of staff, as SFC allocations typically cover about 65% of the required staffing needs. By addressing staffing needs, ULBs can enhance service delivery, improve infrastructure maintenance, better monitoring and evaluation, and strengthen urban governance efficiency.

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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 toilets. These are for a more or less a fixed user group." (CPHEEO, 2018, p. 1)

[47] 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

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5. CLIMATE IMPACTS OF WATER & SANITATION SYSTEMS

ASHISH DANGI[51] 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.

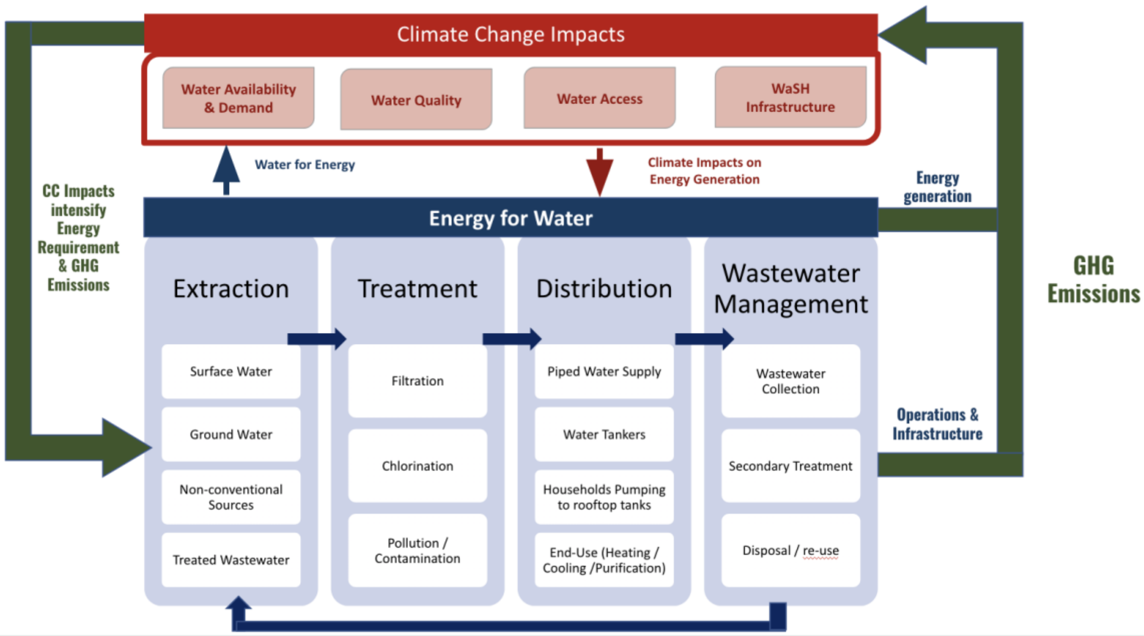
5.1 BACKGROUND

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*[52]. According to another estimate, wastewater treatment plants alone are estimated to account for 3% global electricity consumption[53]. 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) emissions[54]. *Direct emissions in wastewater treatment are estimated to be significant at ~1.57% of global GHG emissions*[55].

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 cycle[56]. 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% [57]. 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 East[58]. 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 WWTPs [59]. *With the increased variability posed by climate change the emission in WWTPs could further increase*[60].

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***[61]. *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 20: The Water-Energy-Climate nexus in Urban Water Cycles.



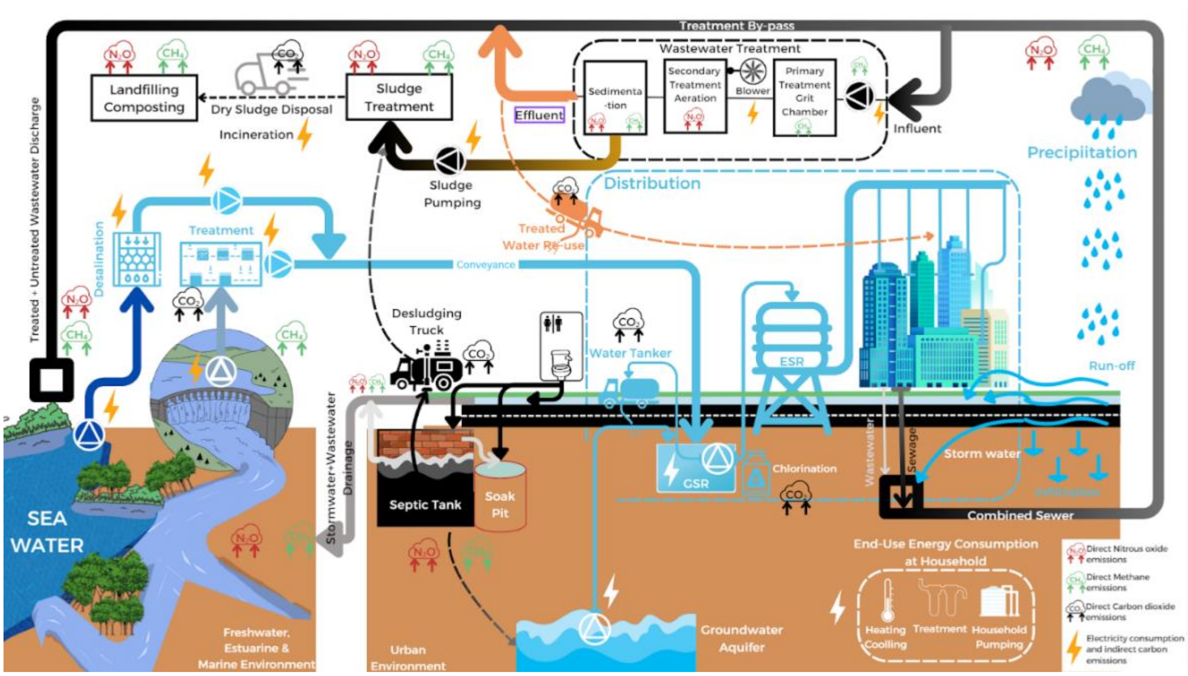
Source: Author's Illustration.

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 management[62]. *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 karnatakals 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 21: 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 7: Scope of emissions methodology for carbon footprint assessment of the urban water cycle

Category	Possible Sources of Emissions	Methodology
Direct Emissions	- Methane (CH_4) emissions from anaerobic decomposition of organic matter in wastewater. - Nitrous Oxide (N_2O) Emissions from nitrification and denitrification of nitrogen compounds wastewater - Methane (CH_4) emissions from the decomposition of organic matter in anaerobic sediments in freshwater reservoirs*	2006 IPCC Guidelines for National Greenhouse Gas Inventories[54] (2019 Refinement[63])
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)[64] 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 sediments[65]. 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 23*.

The Kundapura water supply scheme supplies around 3.1 MLD water to service connections within KTMC and another 2.6 MLD to eight enroute villages, MIT college and Fire Station. In order to supply this total of 5.6 MLD water, 7.1 MLD is extracted from the Varahi River. However, a notable portion of this water is lost throughout the system due to treatment, transmission, and distribution inefficiencies. Figure 23 illustrates the carbon and energy footprint across various stages of the system:

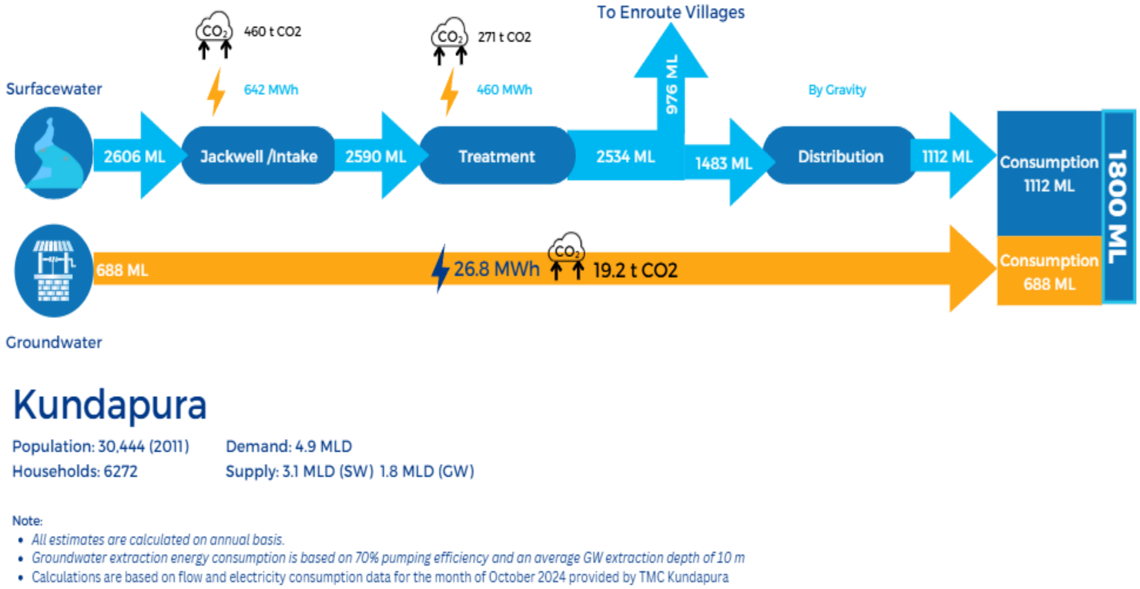
- Surface Water Intake (Jackwell at Jambu):
  Electricity use: **642 MWh/year**
  Associated GHG emissions: **460 tCO_2/year**

- Water Treatment & Conveyance to OHTs:
  Electricity use: **460 MWh/year**
  GHG emissions: **271 tCO_2/year**
  Around **3% of extracted water** is lost at this stage, including consumption forWTP processes like filter backwashing.

- Distribution Losses:
  Although **100% metering and billing** is in place, **25% of treated water** entering the distribution network is lost, pointing to substantial system inefficiencies.

- Groundwater Extraction:
  Groundwater contributes an estimated **688 million litres per year**, but at a much lower energy cost—**26.8 MWh/year**, resulting in only **19.2 tCO_2/year** in emissions.

Figure 22: Carbon and energy footprint of Kundapura's water supply.



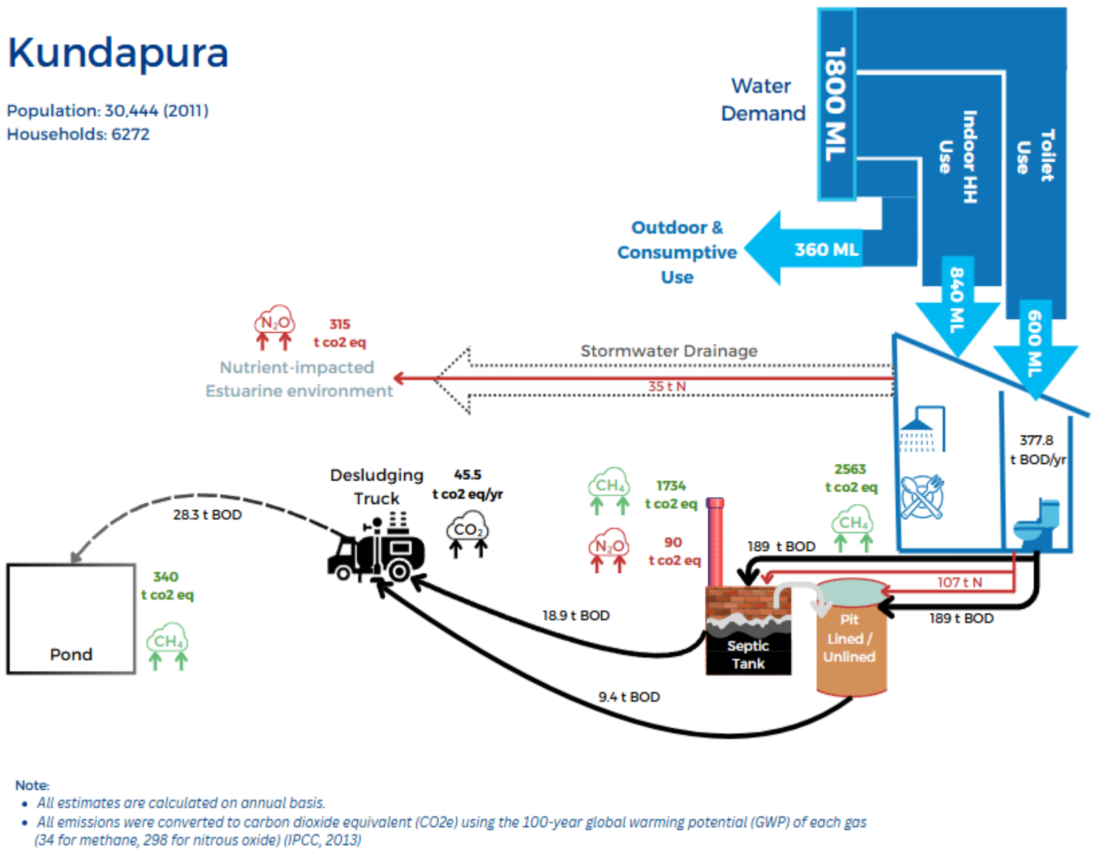
Source: Dangi & Narayanan, forthcoming[66]

The shift from decentralised groundwater-based supply to centralized piped water in Kundapura has led to a marked increase in the town's carbon and energy footprint. Currently, only 66% of households are connected to the piped water network. As piped coverage expands, both **energy consumption and GHG emissions are expected to rise significantly,** unless mitigated through efficiency and resilience strategies. As climate impacts intensify, the town may face a double burden: declining source sustainability and rising operational emissions. Without proactive investments in energy-efficient technologies, water loss reduction, and source protection, the system risks becoming both ecologically and economically unsustainable.

5.5 GREENHOUSE GAS EMISSIONS FROM SANITATION

The GHG emissions throughout the sanitation service chain in Kundapura are illustrated in Figure 24 below.

Figure 23: Greenhouse gas emission estimation of urban waste water management in Kundapura town



Source: Dangi & Narayanan, forthcoming[66]

Wastewater Generation and Biochemical Oxygen Demand (BOD) Load

Kundapura consumes an estimated 1,800 million liters (ML) of water annually, of which 80% (1,440 ML) is used indoors and becomes wastewater.

Domestic wastewater is further categorised into[v]:

- Toilet wastewater: 600 ML/year
- Greywater (from bathing, washing, cooking, etc.): 840 ML/year

[v]Considering 45 lpcd toilet water use as per the National Building Code, BIS, 2016

The total annual **BOD load** from this domestic wastewater is estimated at **377.8 tonnes,** based on an average generation rate of 34 g/person/day[vi].

Direct Methane (CH_4) Emissions from Onsite Sanitation

Methane emissions are a major contributor to sanitation-related GHGs in Kundapura due to the predominance of on-site containment systems:

- Lined/unlined pits (open bottom): ~1,884 tCO_2-eq/year
- Septic tanks: ~1,275 tCO_2-eq/year

Assumption: In the absence of detailed inventory data, it is assumed that 50% of households use septic tanks with soak pits or dispersal fields, while the remaining 50% rely on lined/unlined pits. These systems operate under anaerobic conditions, producing methane as organic matter decomposes.

Emissions from Desludging and Sludge Disposal

- Desludging transport (vacuum trucks): ~45.5 tCO_2-eq/year, handling ~28.3 tonnes of BOD annually

  (Assumes desludging once in 5 years for septic tanks and once in 10 years for pits, based on field interviews)

- Sludge disposal in anaerobic ponds:

  ~340 tCO_2-eq/year, due to methane emissions from anaerobic decomposition in ponds deeper than 2 meters.

[vi] IPCC (2019). Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories; ISBN 978-4-88788-232-4; Intergovernmental Panel on Climate Change: Geneva

Nitrous Oxide (N_2O) Emissions

- From septic tanks : ~90 tCO_2-eq/year

  (This results from the discharge of 107 tonnes of nitrogen in human excreta into onsite containment systems. Pit latrines are not a significant N_2O[lvii]

- From greywater discharged into drains: ~352 tCO_2-eq/year

  This includes nitrogen contributions from household products (13%) as per IPCC[lvii], non-consumed protein in kitchen wastewater (10%), and an additional 10 % to account for Nitrogen from commercial discharge. Field observations indicate that greywater is discharged into stormwater drains, ultimately reaching the estuarine environment, where it contributes to N_2O emissions.

KEY INSIGHTS:

- **On-site systems are a major methane source:** Soak pits emit more methane (1,884 tCO_2-eq) than septic tanks (1,275 tCO_2-eq) due to longer retention and anaerobic conditions especially in high water table coastal areas.

- **Desludging trade-offs:** Frequent desludging may reduce methane from containment systems but increases transport-related emissions, especially if disposal sites are distant.

- **Sludge management risks:** Improperly managed anaerobic ponds contribute significantly to emissions. These sites require urgent upgrades to incorporate treatment or methane capture technologies.

- **Greywater mismanagement is a hidden emitter:** Nitrous oxide emissions from untreated greywater in open drains (352 tCO_2-eq/year) are often overlooked but contribute significantly to overall sanitation-related emissions.

- **Climate feedback loops:** Higher ambient temperatures can intensify GHG emissions from both containment systems and disposal sites. Warming also increases emissions from stagnant water bodies (e.g., sludge ponds and reservoirs).

- **Need of Strategy for GHG Emission Mitigation:** Effective management of greywater presents a significant opportunity to reduce nitrous oxide emissions and thereby lower the town's overall sanitation-related greenhouse gas footprint. High methane emissions from on-site systems have also been identified as a key concern. Soak pits—commonly used in coastal areas with high water tables—emit more methane than septic tanks due to longer retention times and anaerobic conditions. Additionally, anaerobic ponds, often poorly managed, are major sources of methane emissions, highlighting an urgent need for infrastructure upgrades that incorporate effective treatment methods or methane capture technologies. While frequent desludging can help reduce methane emissions from containment systems, it also leads to increased transportation-related emissions, especially when disposal sites are located far from the town.

5.6 CONCLUSION & WAY FORWARD

The combined energy and emissions profile of Kundapura's water and sanitation sectors reveals an escalating carbon burden that directly mirrors the municipality's structural shift towards centralised infrastructure. In the water sector, the transition from low-emission, decentralised groundwater sources to an energy-intensive surface water network has substantially inflated the operational footprint, a trajectory set to worsen as piped coverage expands and climate-induced turbidity demands further treatment inputs. Simultaneously, the sanitation sector is dominated by methane emissions from inadequate onsite containment and deep anaerobic sludge ponds, compounded by significant nitrous oxide leakage from unregulated greywater discharge. Mitigating this dual climate impact requires a decisive pivot in municipal planning. Realigning local utility management with decarbonisation goals will depend on halting the degradation of traditional groundwater resources to diversify the supply matrix, formalising sludge management to eliminate anaerobic hotspots, and implementing robust efficiency measures to curb systemic losses, thereby creating a decentralised, low-carbon pathway for the town's climate resilience.

NOTES & REFERENCES

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

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6. PERFORMANCE AND FINANCIAL ANALYSIS OF WATER SUPPLY AND SANITATION

ABHAY JUNAGHARE[67] 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 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 BACKGROUND

This section analyses the performance analysis against SLBs for urban water supply and sanitation by the Ministry of Housing and Urban Affairs (MoHUA). The section also analyses the revenue streams and grants available to KTMC for water supply and sewerage & sanitation. The revenue sources include central government grants, state government grants, and their own revenue sources. Here, the ratio of grants to own revenue sources is analyzed 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)[68]. 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 performance of the of the utility for water and sanitation services 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 water supply indicators for KTMC for the year 2020-21 show varying trends when compared to national benchmarks and averages (Ref. Table 8). KTMC has made significant progress in the coverage of water supply connections, achieving 91% in 2020-21, which is above the national average of 70%. However, it still falls short of the benchmark of 100%, with a gap of 9% compared to the target for 2021-22 (92%). This indicates that while the coverage is commendable, there's still room for improvement to meet the 100% target. KTMC's per capita supply of 135 litres per capita per day (lpcd) matches the national benchmark of 135 lpcd and is on par with the target for 2021-22. This is a positive trend, suggesting that the town is maintaining an adequate water supply per individual. No gaps are observed in this indicator. With 98% of connections metered in 2020-21, KTMC is performing well, though it still lags behind the benchmark of 100%. The gap here is small, only 2%, and metering plays a crucial role in monitoring water usage and reducing wastage. Therefore, KTMC is relatively close to achieving full metering coverage.

KTMC reported a non-revenue water percentage of 20%, which is better than the national average of 31%, but still above the benchmark of 15%. A 5% gap in NRW indicates that KTMC may need to address issues such as leakage, theft, or inaccurate metering to reduce water losses and improve efficiency. This indicator highlights a significant issue, as KTMC provides an average of only 2.7 hours of water supply per day, far below the 24-hour benchmark. The target for 2021-22 is 8 hours, but even that is considerably less than the benchmark. This shows a substantial gap of 16 hours and points to a critical need for improvement in the infrastructure or water distribution system to ensure a more continuous supply. KTMC has fully met the benchmark for water quality, with 100% of samples meeting the specified potable water standards, and no complaints related to water quality were received. This is a positive trend, indicating that the water supplied is safe for consumption and complies with standards.

Table 8: Performance Indicators for Water Supply at KTMC

Sl. No.	Water Supply Indicators	Calculations	Benchmarks	National Average*	2020-21** (Current)	2021-22 (Target)	Gaps
1	Coverage of Connections	(Total no. of HHs with water supply connections)/ (Total no. of HHs in the City)	100%	70%	91%	92%	-9%
2	Per capita supply (lpcd)	(Water supplied)/ (Population served)	135 lpcd	114 lpcd	135 lpcd	135 lpcd	0 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%	98%	98%	-2%
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	8 hours	10 hours	-16 hours
6.	Quality and treatment	(Number of samples that meet the specified potable water standards)/ (Total number of complaints received related to water supply)	100%	95%	100%	100%	0%
7	Redressal of customer complaints	(Total number of complaints redressed)/ (Total number of complaints received related to water supply)	80%	89%	100%	100%	+20%

*Source: * CPHEEO Guidelines for 24x7 WSS (Drink from Tap), Dec 2021; **Government of Karnataka, 2021*

In terms of customer satisfaction, KTMC stands out by redressing 100% of the complaints received, exceeding the national average of 89% and meeting the benchmark of 80%. This is a notable achievement, showing KTMC's responsiveness and efficiency in addressing water supply-related issues. KTMC has achieved 100% cost recovery, which aligns with the national benchmark and indicates financial sustainability in water supply operations. This is a positive sign, as it suggests that the council is effectively managing its revenues and expenses. The efficiency in collecting charges stands at 85%, which is slightly below the benchmark of 90%. With a 5% gap, KTMC may need to improve its billing and collection mechanisms to ensure better revenue generation, which is crucial for sustaining water supply services. KTMC's performance in water supply indicators for 2020-21 shows positive results in areas such as per capita supply, water quality, and customer complaint redressal. However, there are notable gaps in areas like continuity of supply, coverage of connections, metering, non-revenue water, and efficiency in charge collection, which need attention to meet national benchmarks and targets.

6.2.2 SANITATION

The performance of the utility for water and sanitation services can be assessed based on the SLBs.

The analysis of sewerage and sanitation indicators for KTMC for the year 2020-21 reveals significant gaps when compared to the national benchmarks. KTMC has fully achieved the benchmark for toilet coverage, with 100% of households (HHs) having access to individual or community toilets within walking distance. This is a positive outcome, demonstrating that the town has successfully addressed the issue of sanitation access for all households, which is crucial for public health and hygiene. KTMC has a significant gap in the coverage of sewage network services, with 0% of households connected to the sewage network in 2020-21, compared to the benchmark of 100%. This indicates a complete lack of a functioning sewage network in the town, which is a major area of concern for proper wastewater management and public health. Since there is no sewage network in place (0% coverage), KTMC also reports 0% collection efficiency for these wage network. This directly correlates with the lack of sewage infrastructure and points to a critical gap in waste management practices that need urgent attention.

With no sewage network or treatment capacity in place, KTMC faces a 100% gap in this indicator as well. The absence of a STPs or any treatment capacity means that wastewater generated in the town is not being adequately treated, which is a serious environmental and public health risk. Given the lack of any sewage treatment infrastructure, there are no sewage samples being tested or treated, resulting in a 100% gap for this indicator. Without adequate treatment facilities, the wastewater in KTMC is likely not being managed in an environmentally safe manner, which could lead to contamination of water sources and public health hazards. Since KTMC does not have a sewage treatment plant or any sewage treatment infrastructure in place, there is no reuse or recycling of sewage. This results in a 20% gap, as the benchmark requires at least 20% of treated wastewater to be recycled or reused. The absence of such systems highlights the town's current incapacity to address the sustainable reuse of wastewater.

6.3 REVENUE STREAMS AT KUNDAPURA

This section analyses the revenue streams and grants available to KTMC for water supply and sewerage & sanitation. The revenue sources include central government grants, state government grants, and their own revenue sources. Here, the ratio of grants to own revenue sources is analysed to identify the percentage availability of each source for water supply and sewerage & sanitation. The assessment of financial health of the water utility and sewerage & sanitation is performed here by examining 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 revenue streams. This helps assess KTMC's preparedness to meet current and future demands for water supply and sewerage & sanitation infrastructure and services, and to enhance climate resilience of its residents. These actions ultimately contribute to improved public health outcomes and more sustainable urban environments. This section is structured in four subsections viz., 1) funds received from central government schemes, 2) funds received from state government schemes, 3) KTMC's own revenue, and 4) Ratio of grants to own revenue at Kundapura for water supply and sewerage & sanitation.

Central Government Funds

KTMC received central government grants for Water Supply, Sewerage, and Sanitation under two main budget heads, viz., Finance Commission Grants and the Local Area Development Fund Member of Parliament (MP). Over the period from 2013-14 to 2022-23, the Finance Commission Grants were the primary source of funding, with notable fluctuations (Ref. Table 9).

For instance, large grants were received in 2013-14, 2020-21, and 2022-23, while some years saw significant drops or no funds, such as in 2017-18 and 2019-20. The Local Area Development Fund (MP), on the other hand, was inconsistent, with contributions only in 2014-15 and 2015-16, and no funds in most other years. Overall, KTMC received INR 83,431,469 from Finance Commission Grants and INR 2,848,000 from the Local Area Development Fund (MP), reflecting changing central government priorities and allocations.

Table 9: Funds received by KTMC for Water Supply and Sewerage & Sanitation under Central Government Schemes (in INR)

Year/ Schemes	Finance Commission Grants	Local Area Development Fund – MP
2013-14	17366147	0
2014-15	17967000	294000
2015-16	3900000	2512000
2016-17	13432000	42000
2017-18	0	0
2018-19	20000	0
2019-20	500000	0
2020-21	11784587	0
2021-22	5777801	0
2022-23	12683934	0
Total Grants Received	**83431469.00**	**2848000.00**

Source: Budget Documents, KTMC

State Government Funds

KTMC received state government grants for Water Supply, Sewerage & Sanitation under various budget heads, including Deferred Income for assets, Local Area Development Fund (MLA), and Contributions for Specific Purposes, with fluctuating support over the years (Ref. Table 10). No grants were received in 2013-14 and 2014-15, but funding began in 2015-16 with INR 453,500 from the MLA Fund, INR 209,100 in Contributions for Specific Purposes, and no funds for Deferred Income in Water Supply or Sewerage & Sanitation.

Significant contributions were seen in 2016-17 and 2018-19, with substantial amounts directed to Deferred Income for Water Supply and Contributions for Specific Purposes, including INR 13,120,500 for specific purposes in 2018-19. The largest state grant allocation occurred in 2020-21, with INR 16,800,000 for Sewerage & Sanitation. However, there were periods of low or no funding, particularly in 2019-20, 2021-22, and 2022-23, signalling changes in priorities or project-based funding needs. The total state grants received by KTMC amounted to INR 49,559,540 for Water Supply, INR 29,300,000 for Sewerage & Sanitation, INR 716,200 for MLA, and INR 25,321,454 for Specific Purpose Contributions, reflecting the irregular but notable support for specific infrastructure needs over the years.

Table 10: Funds received by KTMC for Water Supply and Sewerage & Sanitation under State Government Schemes (in INR)

Year/ Schemes	Deferred income in respect of Assets created out of Grants and Contribution - Water Supply	Deferred income in respect of Assets created out of Grants and Contribution - Sewerage & Sanitation	Local Area Development Fund – MLA	Contributions for specific purposes
2013-14	0	0	0	0
2014-15	0	0	0	0
2015-16	0	0	453500	209100
2016-17	2000000	0	261850	0
2017-18	955954	0	850	0
2018-19	2000000	0	0	13120500
2019-20	0	0	0	6803604
2020-21	0	16800000	0	900000
2021-22	0	12500000	0	3726250
2022-23	0	0	0	562000
Total Grants Received	**4955954.00**	**29300000.00**	**716200.00**	**25321454.00**

Source: Budget Documents, KTMC

Generation of Own Revenue

KTMC has seen consistent growth in its own revenue sources for Water Supply and Sewerage & Sanitation, with the largest contribution coming from Water Supply and UGD Charges (Ref. Table 11). These charges grew from INR 7,417,072 in 2013-14 to INR 20,057,851 in 2022-23, reflecting a significant 170% increase. Revenue from Water Supply & UGD Connection Charges also saw steady growth, from INR 195,000 in 2013-14 to INR 744,500 in 2022-23, although it remained a smaller source of income.

Grants received for the SFC Salary Grant and Electricity Grant have fluctuated, with both showing general increases over the years. The SFC Salary Grant peaked at INR 6,325,000 in 2020-21, and the Electricity Grant reached INR 5,500,000 in 2022-23, reflecting increased infrastructure costs. Over the nine years, KTMC's total own revenue amounted to

INR 173,917,135, with the largest share coming from Water Supply and UGD Charges, ensuring financial stability and supporting the town's expanding infrastructure and services.

Table 11: Revenue Income from Water Supply and Sewerage & Sanitation at Kundapura (in INR)

Year/ Own Revenue Sources	Water Supply and UGD Charges	Water Supply & UGD Connection Charges	Grants Received - SFC Salary Grant	Grants Received - Electricity Grant
2013-14	7417072	195000	1050513	1893043
2014-15	9294077	244000	438889	987183
2015-16	8541477	491709	589600	3113000
2016-17	9803521	320000	577910	1857000
2017-18	11589862	391573	836233	3676000
2018-19	11625485	354571	3975000	1850000
2019-20	15173240	580450	0	1350000
2020-21	17032274	590880	6325000	0
2021-22	18954121	589250	3596851	0
2022-23	20057851	744500	2310000	5500000
Total	**129488980.00**	**4501933.00**	**19699996.00**	**20226226.00**

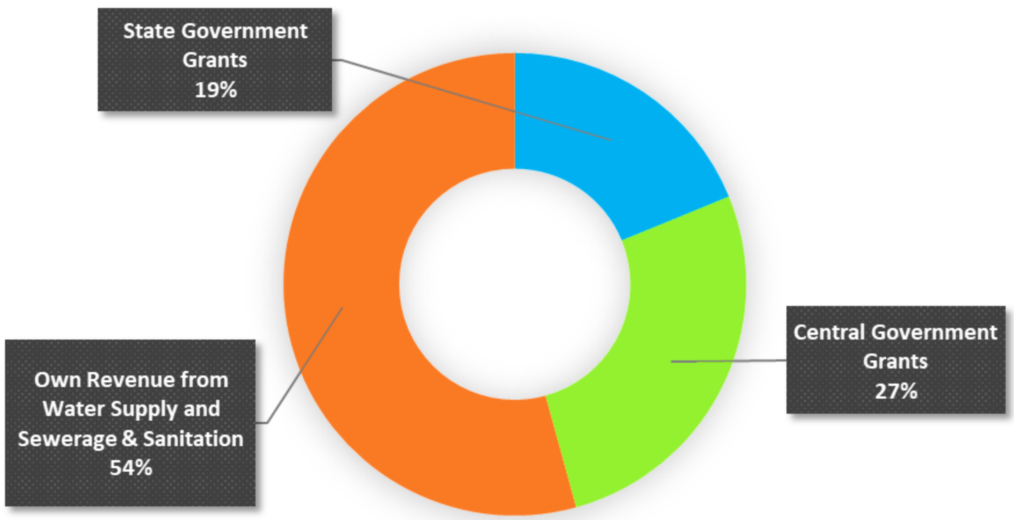
Source: Budget Documents, KTMC

Ratio of Grants to Own Revenue

The contributions made by the central, state, and own resources for water supply and sewerage & sanitation at KTMC from 2013-14 to 2022-23 reflect a balanced and evolving approach to financing infrastructure. While central and state government grants provide essential support, accounting for 27% and 19% of total funding respectively. KTMC has increasingly relied on its own revenue from water supply operations, ensuring the sustainability of services (Ref. Figure 24).

KTMC's financial independence has grown over the years, with the ratio of own revenue to grants steadily increasing. In 2015-16, the ratio spiked significantly to 1.80, and by 2022-23, it reached 2.16, indicating that the town generated more than double the revenue it received in grants. The average ratio of 1.19 for the entire period suggests KTMC has moved from heavy reliance on external funding to greater financial autonomy. This shift in funding structure, with high revenue generation in certain years, demonstrates KTMC's improving capacity to fund water supply and sanitation services locally, contributing to the town's long-term sustainability.

Figure 24: Share of grants vs own revenue for water supply at KTMC Kundapura



Source: Kundapura Town Municipal Council (KTMC), 2025

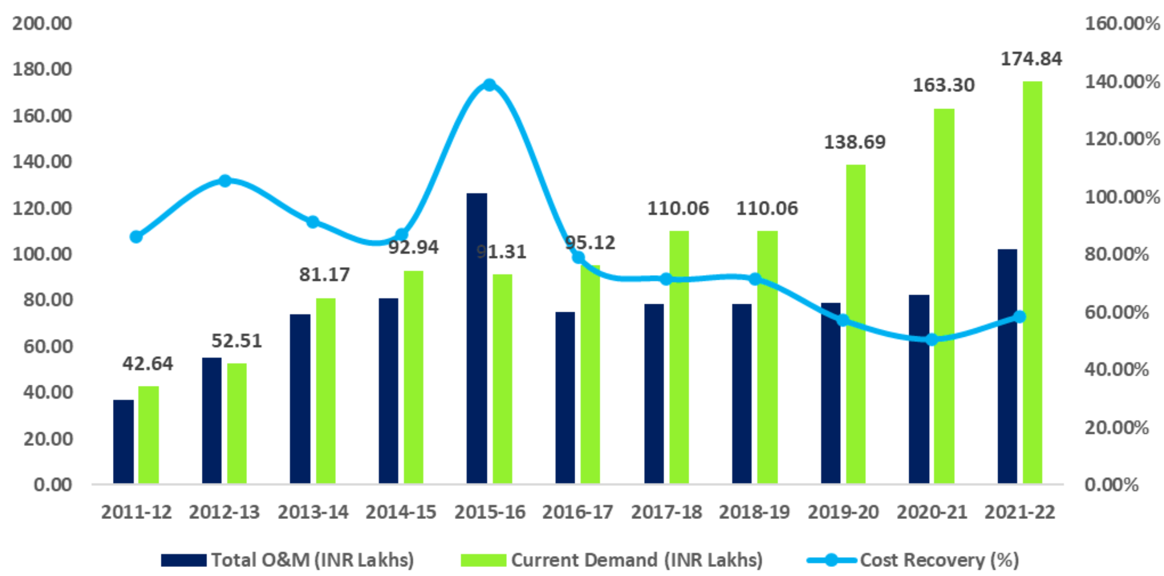
6.4 ASSESSMENT OF FINANCES

The upcoming sections analyse the trends from the SLBs for water supply and sewerage & sanitation at KTMC.

6.4.1 COST RECOVERY FOR WATER SUPPLY AND SEWERAGE & SANITATION

The analysis of cost recovery for water supply and sewerage & sanitation at KTMC from 2011-12 to 2021-22 reveals significant fluctuations in its ability to cover operational and maintenance (O&M) costs through local revenue (Ref. Figure 25). Initially, KTMC had a strong cost recovery, with a ratio of 105.50% in 2012-13, indicating a surplus. However, this trend reversed starting in 2016-17, with the cost recovery ratio gradually declining, reaching a low of 50.48% in 2020-21.

Figure 25: Trend analysis of cost recovery in water supply and sewerage & sanitation charges at KTMC (in INR Lakhs)



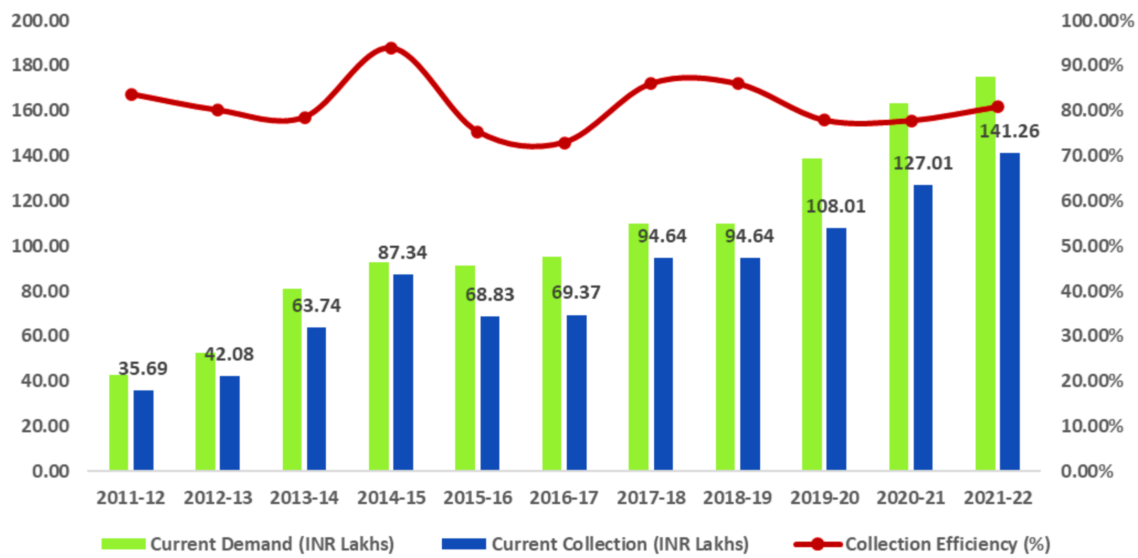
Source: Kundapura Town Municipal Council (KTMC), 2025

The decline suggests growing financial difficulties, possibly due to increased operational costs or decreased revenue collection, with the COVID-19 pandemic potentially exacerbating the situation. Despite slight improvements in 2021-22, the overall trend highlights KTMC's struggle to maintain financial sustainability, relying increasingly on external funding. The analysis underscores the need for better revenue generation, cost management, and possibly tariff adjustments to improve the financial viability of KTMC's water and sanitation services.

6.4.2 COLLECTION EFFICIENCY FOR WATER SUPPLY AND SEWERAGE & SANITATION

The analysis of collection efficiency for water supply and sewerage & sanitation charges at KTMC from 2011-12 to 2021-22 reveals fluctuating trends in the municipality's ability to collect revenue relative to demand (Ref. Figure 26). While the collection efficiency started strong at 83.70% in 2011-12, it declined over the years, reaching a low of 72.93% in 2016-17, indicating challenges in collecting payments.

Figure 26: Trend analysis of collection efficiency in water supply and sewerage & sanitation charges at KTMC (in INR Lakhs)



Source: KTMC, 2025

KTMC saw improvements in 2014-15 and 2017-18, but struggled again in 2019-21, likely due to administrative inefficiencies or external factors like economic conditions and the COVID-19 pandemic. A slight improvement to 80.79% in 2021-22 signals that KTMC managed to regain some ground, but the overall trend highlights the need for better strategies to address fluctuations in revenue collection, such as improving billing processes and enforcement, to ensure sustainable funding for water and sanitation services.

6.5 CONTINUOUS WATER SUPPLY SYSTEM AT KUNDAPURA TOWN MUNICIPAL COUNCIL

The Kundapura 24x7 Water Supply System is a critical component of the KIUWMIP, which is implemented by KUIDFC with the support of the ADB. The programme, under the larger initiative named Jalasiri, focuses on upgrading urban water supply and sewerage systems, particularly in areas where water scarcity and sanitation are pressing challenges. Kundapura, as one of the towns under Tranche 2, is poised to benefit from a comprehensive overhaul of its water and sanitation infrastructure, aimed at improving service delivery and achieving sustainability in water resource management. The ambitious nature of the project is reflected in its financial scale, with the overall project costing an estimated Rs. 2187.72 Crores, funded through a combination of ADB loans, state funds, and AMRUT scheme assistance (KUIDFC, 2025[69]). A Karnataka Municipal Reforms Cell is proposed to coordinate between various stakeholders, including KUIDFC and ULBs, where the ULBs are asked to set up Project Implementation Units (PIUs) at the ULBs for the execution of the project. At KTMC, the Laxmi Civil Engineering Service Pvt. Ltd., Kundapura is appointed as the operator to manage the water supply and sewerage & sanitation services, which is a Kolhapur, Maharashtra based organisation.

6.6 KEY FINANCIAL CHALLENGES

KTMC faces several key challenges in sustaining its water supply and sanitation services. While the council has increasingly relied on its own revenue, particularly from water supply and UGD charges, fluctuations in external funding from central and state government grants have made financial planning difficult. Additionally, although cost recovery and collection efficiency were initially strong, they declined significantly from 2016-17 onwards, particularly during the COVID-19 pandemic, which saw cost recovery drop to just 50.48% in 2020-21. The operating ratio also reached a balance point in 2022-23, signalling potential financial strain. Moreover, while there was substantial growth in capital expenditure, revenue income has seen a decline, and per capita expenditure has fluctuated, indicating rising operational costs and reduced investment in new infrastructure. KTMC must improve its revenue generation, control costs more effectively, and find a balance between operational spending and infrastructure investment to ensure long-term financial sustainability.

NOTES & REFERENCES

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[67]Author's Note: This chapter is based on ongoing doctoral research by Abhay Junaghare 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.

[68]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.

[69] Retrieved from https://kuidfc.com/EN/About.php on August 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 the town. 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 town'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 Kundapura 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 Kundapura, a class III town and an important regional settlement in North Karnataka district of Karnataka. The situational analysis has been based on the detailed sectoral analysis undertaken by sectoral teams and captured in the previous chapters of this report. The resilience assessment of the WaSH infrastructure captures the contextual risks and gaps in the systems.

7.2 METHODOLOGY FOR RESILIENCE ASSESSMENT

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

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

1. *Mapping the Existing Infrastructure and Services:* The existing infrastructure and services have been mapped and analysed based on data gathered from various sources on performance, coverage, socio-spatial variability, technology, governance, key stakeholders, existing policies, climate change initiatives, financial health of the ULB, budgets, and future projects

2. *Identifying the Infrastructure Exposure and Vulnerability:* The climate hazards faced by the settlement have been identified based on literature review. Three critical coastal risks—flooding and inundation, storm surges and coastal erosion, and saltwater intrusion—have been considered. Satellite data has been utilized to assess land use and land cover (LULC), elevation, built-up footprints, road networks, shoreline change detection, mangrove and water bodies, storm surge locations, and flood risk zones. This data has been overlaid with information from municipal bodies on administrative boundaries, flood hotspots, population distribution, critical utility locations to identify the exposure. Primary data on water usage, sanitation practices, water quality, access disparities, socioeconomic vulnerability, behavioural practices, and exposure history collected through discussions, interviews, household surveys, and ground-truthing via transect walks and visual surveys were further collated and overlayed 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.

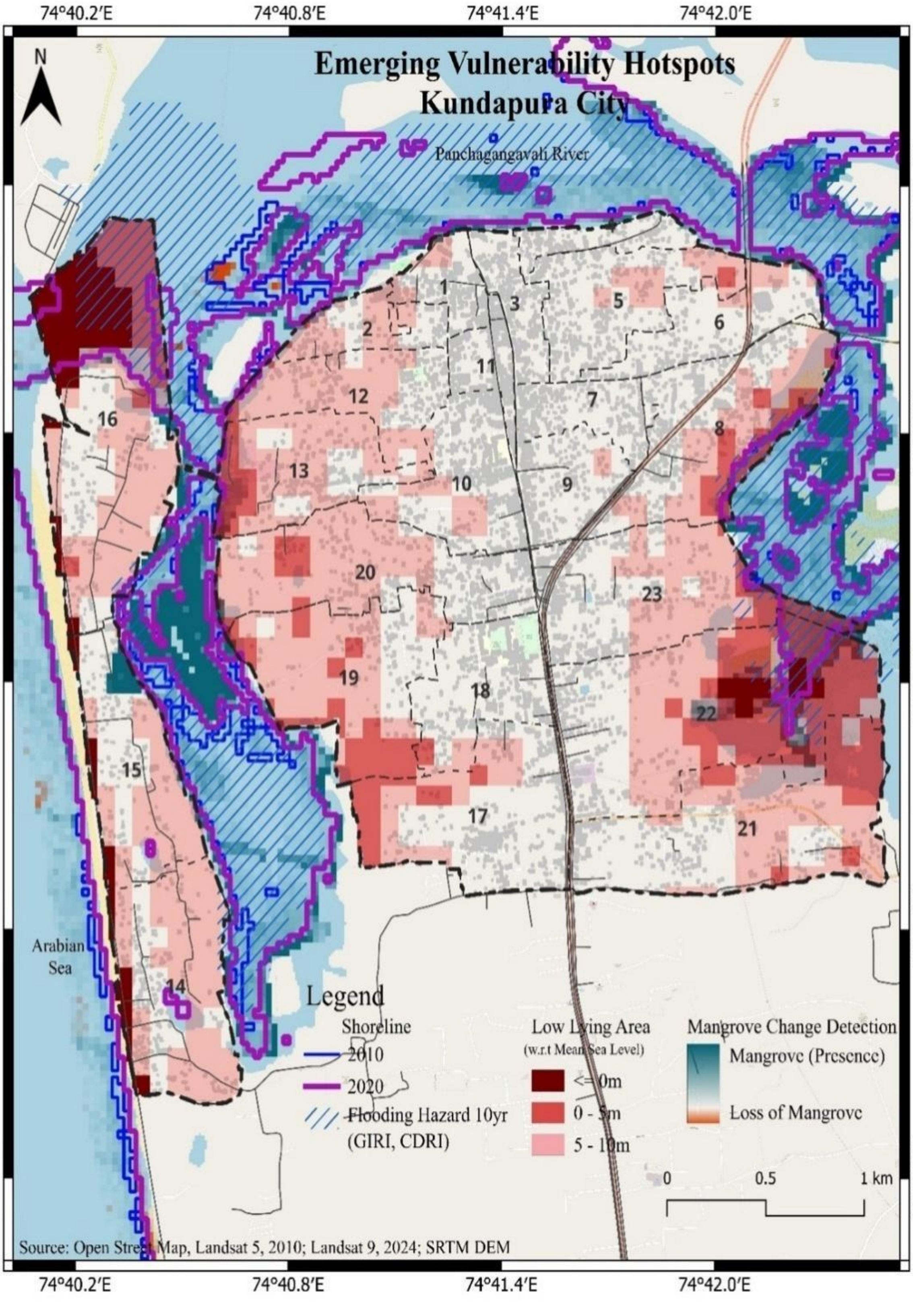
7.3 EXPOSURE TO CLIMATE RISK

Udupi district is highly vulnerable to certain natural and man-made disasters. The major disasters to which Udupi district is prone include flash floods, lightning, landslides, road accidents, chemical hazards, stampedes, fire accidents, and earthquakes. However, Kundapura has been identified as particularly vulnerable to cyclones, accidents, and erosion (DDMA, 2024).

Over the last decade, remote sensed data satellite data (2010 – 2020) has revealed a significant reduction in mangrove cover and notable changes along the shoreline. The loss of mangroves exacerbates coastal erosion-a phenomenon recognized as a major threat along the Udupi district coastline. That mangrove forests protect uplands from stormy winds, waves and floods. In Kundapura, diminished mangrove status along the west coast exposes wards 14–16 to heightened erosion risk, while similar changes around the Panchagangavali River's mouth place wards 1, 2, 3, 12 and 13 at risk of both erosion and salt intrusion. Shifts in the water edge line have also been observed in wards 8, 21, 22, 23, and 24 on the eastern side of town (Figure 27).

The Karnataka coast faces erosion due to the synchronization of high floods in the rivers and strong wave activity during the southwest monsoon. A dynamic equilibrium of erosion and accretion is seen along the coast. Coastal erosion and land submergence have been observed in Kundapura (Government of Karnataka, 2022). The west coast of India is, however, less exposed to storm surges compared to the east coast, with surge heights based on the last 10 years of data being less than 0.654 meters, as seen in the GIRI Platform of CDRI. However, a high tide level, coupled with an intense precipitation event, can expose the communities and result in damage to infrastructure. Hence, storm surges have been considered a risk for the town. Flood hazard mapping over a 10-year period (CDRI, Map Viewer, 2023) under current climate scenarios indicates that wards 22 and 23 in the east, as well as wards 14 through 16 in the west of Kundapura, are particularly susceptible to flooding and inundation. In addition, wards closer to the river mouth have reported incidents of saltwater intrusion. Over 15% of Kundapura's administrative area lies at an elevation of less than 5 meters above sea level, and over 53% of the area have an elevation of less than 10 meters above mean sea level. However, due to natural flood barriers like the backwaters, the beachfront in Wards 14-16, and the presence of flooded vegetation (mangrove zones) in the east, specifically in Wards 8, 22, and 23 (Ref. Table 12).

Figure 27: Emerging vulnerability hotspots of Kundapura town



Source: Open Street Map, Karnataka Land records, Landsat SRTM DEM

Table 12: Ward level Elevation and vulnerability to flooding

Ward	Population (Census 2011)	Very high vulnerability Elevation below mean sea level	LECZ with High Vulnerability (Elevation, 10 m above mean sea level	Low Vulnerability (% ward area >10mamsl)		Ward	Population (Census 2011)	Very high vulnerability Elevation below mean sea level	LECZ with High Vulnerability (Elevation, 10 m above mean sea level	Low vulnerability (% ward area >10mamsl)
1	588	0.0%	26%	74.1%		13	1225	0.0%	79%	20.5%
2	1107	0.0%	60%	40.0%		14	1799	6.9%	73%	27.2%
3	974	0.0%	0%	100.0%		15	1447	6.3%	54%	46.0%
4	1614	0.0%	0%	100.0%		16	1152	22.6%	78%	21.7%
5	1347	0.0%	25%	74.5%		17	2091	0.0%	34%	65.6%
6	1379	0.0%	16%	84.4%		18	1954	0.0%	10%	89.6%
7	1169	0.0%	0%	100.0%		19	1593	0.0%	79%	21.0%
8	1706	0.0%	54%	46.5%		20	1163	0.0%	68%	31.8%
9	949	0.0%	5%	95.2%		21	1389	0.0%	59%	41.1%
10	1267	0.0%	22%	78.5%		22	1165	5.6%	75%	25.2%
11	552	0.0%	0%	100.0%		23	1426	0.0%	53%	46.5%
12	1388	0.0%	71%	28.8%						

Source: Census 2011, Land Records and Sentinel data

However, wards 14 – 16 are highly vulnerable to flooding due to their elevation. These wards accommodate more than 4000 population who along with their built habitat are exposed significantly. The other vulnerable wards are 8, 21, 22, 23 in the east and wards 12, 13, 19, 20 in the west. Ward 2 in the north can be prone to flooding due to river inundation. Groundwater in Kundapura is classified as safe, and the town does not face any significant water shortage issues (District Disaster Management Authority Udupi, 2024).

Although storm surges here are generally moderate, the combination of rising high tide levels, intense precipitation, tropical cyclones, and stronger winds from the Arabian Sea significantly raises the town's vulnerability to flooding and inundation. Notably, Kundapura benefits from its naturally positioned backwaters and the Panchagangavali River, which act as buffers against coastal influences by channelling runoff and effectively serving as a natural flood management solution.

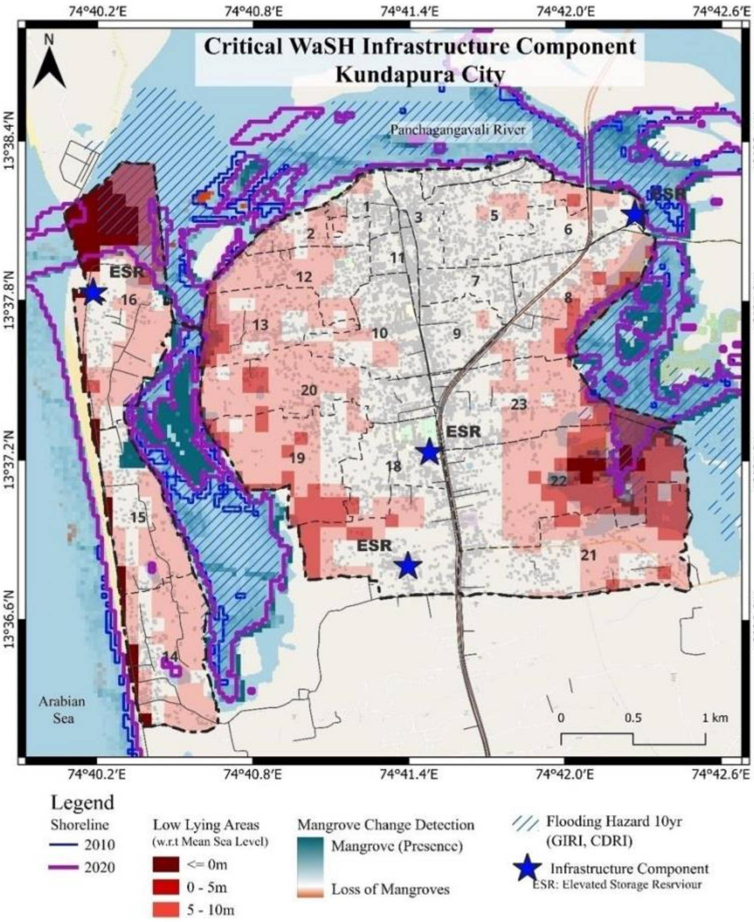
Storm surge is an abnormal water level rise generated by a storm over and above the predicted astronomical tide. Storm tide is the water level rise due to the combination of storm surge and astronomical tide. This rise in water level can cause extreme flooding in coastal areas, particularly when storm surge coincides with normal high tide. However, to avoid confusion, "storm surge" is used interchangeably. Wave action occurring on top of the surge, which can add additional feet to the overall water level (National Oceaninc and Atmospheric Administration, n.d.) [71] .These events can force seawater inland, contaminating freshwater resources. When heavy rainfall and sediment accumulation converge at river mouths, flooding in low-lying areas becomes an almost inevitable consequence—a risk that has been increasing in the east Arabian Ocean.

CGWB observation well at Udupi city lying in the same district and at a similar alignment to the coast, 40 kms south, indicates highly mineralized ground water with Electrical Conductivity at 5300 µs/cm at 25oC indicating that the ground water is highly mineralized (CGWB, 2021)[72]. A study undertaken on seawater intrusion in the coastal aquifers of India in 2020 has also identified tidal activity as the main cause of seawater intrusion in some cases. It is further observed that the effect of seawater is limited up to 200 m throughout the year, which may extend up to 5 km during dry periods. Studies have indicated that the coastal regions in the Karnataka have adequate water sources, which are suitable for various usages. However, continued industrialization in the coastal belt may lead to salinization of coastal aquifer in near future.(P Prusty, 2020)[73] . In Kundapura, instances of salinity intrusion in wells have already been reported near the estuary mouth during primary field engagement with residents undertaken for this project.

Saltwater intrusion presents a critical challenge in two primary ways. For areas without piped water, it compromises the access to safe, fresh water. Moreover, saltwater increases the conductivity of groundwater, which accelerates the corrosion of underground water and wastewater collection pipes. Research has shown that changes in soil and groundwater chemistry due to saltwater intrusion—and rising sea levels in general—can significantly shorten the service life of infrastructure such as ductile iron pipes, which are typically expected to last between 80 and 100 years under ideal conditions (Berrin Tansel, 2022)[74].

Similarly, the accumulation of saline influents in treatment units and sanitation pits—including septic tanks—can impair the removal of pollutants like organic matter and nutrients. High electrical conductivity, a hallmark of saltwater, has been found to adversely affect microbial diversity and the efficiency of organic matter breakdown (Alvaro Javier Moyano Salcedo, 2024)[75]. The map of critical infrastructure components of Kundapura based on data tagged during field explorations shows the location of Elevated Storage Reservoirs, some which could require frequent repair and rehabilitation due to exposure to strong cyclonic winds. (Ref. Figure 28) showing in the absence of any dedicated STP at town level which is primarily dependent on OSS for sanitation, the vulnerability due to interference from saline intrusion in sewerage treatment rises from the individual sanitation units. Since underground piped sewerage systems are difficult to install in the low-lying wards due to the deep installation required for proper conveyance velocity, upgrading individual household systems becomes essential. These systems should be safely contained, regularly de-sludged, and closely monitored to prevent environmental contamination.

Figure 28: Location of critical components of the WaSH Infrastructure in Kundapur administrative boundary



Source: Open Street Map; Karnataka Land Record; Landsat; SRTM DEM

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 studies based on data were 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 indicators of WaSH infrastructure in Kundapura town are 66 %for piped (safe) water supply (Refer Chapter 3) and 100% for access to an individual household sanitation (Refer Chapter 4). However, the adequacy of the WaSH infrastructure needs to be seen in with respect to the access to "safe" water and "safe" sanitation.

While Kundapura has access to adequate and diversified fresh-water sources, with good availability ground water, water is also brought in from outside the city and intermittent piped water supply services is available to most residents. However there remains a notable reliance on groundwater to bridge the supply gap. With access to ground water as well as piped supplied, Kundapura has adequate access to water.

While the town has 100% access to sanitation, some households in low lying wards rely on community facilities. According to municipal officials, some households use septic tanks combined with soak pits, while the remainder depend solely on soak pit-based systems. Desludging is infrequent, Domestic greywater is commonly discharged through open drains. Small decentralised STPs used in the apartment complexes suffer from inadequate maintenance due to high operational costs—these issues can pose significant threat to health and well being.The town has no infrastructure for wastewater treatment, reuse, or recycling and liquid waste. There is a partly laid sewerage network. The sedimentation pond is located 12–15 km away. This raises concerns about groundwater contamination from leaching during the monsoon and environmental pollution. Aging infrastructure can reduce service efficiency and increase vulnerability; for example, the vacuum truck nearing the end of its operational lifespan, and for a town with individual sanitation which regular desludging, can result in concerns of inadequate sewage disposal services. Fragmented development of sewerage network with no STPs for treatment, and the unsuitability of centralized underground sewerage networks for coastal topography and aging infrastructure add to service inadequacy.

7.4.2 RELIABILITY, FLEXIBILITY AND REDUNDANCY

Enhancing flexibility in water systems is critical for ensuring reliable services during disruptive events. Flexibility is the ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation. Redundancy is key to ensuring that water systems continue to operate smoothly, even in the event of component failures.

Source sustainability is an emerging concern for Kundapura, as it is for many emergent coastal cities. Water sourced from upstream dams—often located far from the city—can become a risk-prone component of the water supply system. Such risks arise due to increasing landslides, rockfalls, inadequate management of shared resources, and emerging scarcity caused by variable precipitation. Meanwhile, groundwater is increasingly at risk due to contamination from saltwater intrusion and poorly constructed or unmonitored on-site sanitation systems during flooding and storm surges. In addition, the absence of proper sewerage treatment facilities is leading to contamination of both surface and subsurface water. Collectively, these factors present significant challenges for Kundapura. In Kundapura, water treatment facilities already equipped with generators backups. Further enhancing resilience could involve equipping critical components like pumping stations with alternative energy sources. Reliance of water supply systems on electricity makes them vulnerable to disruptions caused by strong winds and cyclonic formations—common in coastal regions dependant on overhead power transmission networks. The town's WaSH infrastructure offers significant opportunities for resilience through the integration of both existing and emerging technologies, innovative solutions, and smart financing models.

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. Coastal challenges can be eased using locally appropriate combinations of decision analysis, land-use planning, public participation, diverse knowledge systems and conflict resolution approaches that are adjusted over time as circumstances change (*high confidence*).(IPCC, 2019)[76]. In the absence of participative processes there is lack of community ownership to the systems, resulting in increased secondary risks like environmental degradation, irregular dumping of wastes and contamination and health challenges.

There is limited capacity for evidence-based decision-making and an absence of decision-support systems at local level. Data gaps and mismatches have been noted in published SLBs, SBM data, municipal data, and community information. Local authorities have limited autonomy in decision-making in the local infrastructure development, with multiple agencies and unclear asset ownership and accountability resulting in gaps in services and provisions.eg – laying sewerage network but no wastewater treatment facilities lead to dumping of untreated water into drains and water bodies in Kundapura.

At the household level, KTMC is not engaged in the design, construction, or enforcement of standards for toilets and OSS systems. This gap is especially concerning for a coastal city like Kundapura—exposed to floods and storm surges and largely dependent on OSS for sanitation. For Kundapura—a transitioning Class III town, mobilising the capital expenditure for new infrastructure is challenging. KTMC's dependence on funds from the central and state governments, as well as international financial institutions (IFIs), limits its ability to plan new infrastructure or undertake citywide safe sanitation. KTMC's revenue income was only sufficient to cover its operating expenses during that period, there is a rising cost in maintaining and delivering water supply and sanitation services. As a result, the development of water and sanitation infrastructure has been fragmented.The systemic resilience assessment also reveals that it is focused on response and recovery mechanisms post disaster which are largely centralized at the district level at the DDMA. District level disaster management plans do not adequately capture the specific coastal and cascading risks at local level risks which can inform resilience planning at local level.

There is a lack of clear regulatory jurisdiction of local authorities to integrate DRR and Climate Change Adaptation (CCA) for the infrastructure, a dedicated climate cell, process integration of organizational learnings at local level or evaluation of the outcomes from its actions. Town development plans do not include DRR and CCA.

The distance from the district headquarters can create vulnerabilities, as coastal climate hazards often disrupt essential linear infrastructure such as power transmission lines, roads, and telecommunications. According to the SoP, Executive Engineer of the State Power Transmission Corporation acts on directives from the District Collector (DC) to maintain continuous power during disasters. The SoP for the Environmental Officer of the Pollution Control Board advises the Collector on corrective measures in case of contamination. KTMC plays a limited role in disaster governance and planning, focusing mainly on providing sanitation and water supply during the relief phase. There is absence of understanding of systemic risks and contingent liabilities, need for adoption of redundancy and continuity planning and establishing protocols for infrastructure recovery post crisis. There is need for of handholding support for smaller settlements like Kundapura where systems are under transition.

There is no disaster resilience investment planning by local bodies. Current resilience measures are dominated by post-disaster response and recovery activities. There is no provision for a ring-fenced budget for DRR-related initiatives at a local level. There is an absence of safeguards to protect infrastructure maintenance budgets.

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8. STATUS OF CLIMATE CHANGE INITIATIVES IN KUNDAPURA

NEELAM RANA, PRIYAKSHI GOGOI, NC NARAYANAN

Several national and state-level programmes and schemes—both directly and indirectly—address climate change concerns within the water and sanitation sector. This chapter presents the implementation status of key initiatives in the town. The analysis draws primarily on interviews conducted with officials from ULB and the Disaster Management Office.

To strengthen coordination efforts and effectively integrate climate considerations at the town level—as well as to ensure smooth implementation of national and state-level climate policies—it is essential to have a dedicated climate cell or designated personnel within the ULB. Currently, the town lacks specific climate change adaptation and mitigation measures, and there is no comprehensive city-level climate change policy in place. Furthermore, the absence of a climate or environmental cell, or any appointed official responsible for climate-related issues, presents a significant gap in proactive planning and response to emerging climate risks.

To improve water resource management and control wastewater pollution, the town has implemented decentralized sewage treatment units (DSTUs) for commercial, institutional, and residential complexes, as mandated under the Karnataka Municipal Building Bye-laws. These units support the recycling of treated wastewater and reduce reliance on freshwater sources, thereby contributing to climate change adaptation through water conservation. However, assessing the effectiveness of these systems in addressing climate-related challenges remains difficult, as the ULB does not maintain comprehensive records or monitor their environmental compliance.

In an effort to enhance water security, the city has also received funds under the state's Rainwater Harvesting (RWH) schemes. However, according to ULB officials, these funds remain unutilized, thereby limiting the city's potential to strengthen climate resilience through water conservation initiatives.

Table 13: Implementation Status of Programmes /Schemes related to Climate Change in Kundapura

Sl. No.	Initiative	Relevance to Climate Resilience	Status
1	Climate/Environmental Cell	Required institutional mechanism for effective integration of climate considerations into sectoral planning and implementation of state and national policies	Not implemented. No Climate Cell or designated personnel in the ULB.
2	Decentralized Sewage Treatment Units mandated under Karnataka municipal building bye-laws	Potential to reduce dependence on freshwater; supports adaptation through water reuse.	Implemented, but effectiveness unclear due to lack of records and environmental monitoring.
3	State Rainwater Harvesting (RWH) Schemes	Ensuring water security and strengthening adaptive capacity to climate impacts.	Funds received but not utilized, according to municipal officials. Clearly a missed opportunity

Source: Authors' Compilation based on information received from TMC, Kundapura

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, Swachh Bharat Mission (Urban), Central Pollution Control Board, Performance Assessment System for urban water and sanitation (PAS) website, District Disaster Management Plans, and the municipality website. Additionally, the review was instrumental in mapping key stakeholders, defining their roles and responsibilities, and developing the analytical framework for various thematic studies, including GHG emission estimation.

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

Field Work: To address data gaps, validate secondary data, and resolve data discrepancies, the study incorporated rapid field assessments, site visits, and semi-structured interviews. These interviews were conducted with local 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 local 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.

The vulnerability assessment began by identifying low-lying zones and areas with high population density, using building proximity and elevation as primary indicators. Areas that exhibited both low elevation and compact construction were marked as high-priority hotspots. The field studies including visual assessment and semi-structured interviews with residents of three towns were undertaken at different hotspot locations to capture the diversity of issues across different wards and communities and ground truthing of secondary data.

- **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 Service Level Benchmark (SLB) indicators, SBM-U, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), financial reports, and other relevant datasets. We also obtained detailed information on Underground Drainage (UGD) network coverage in the city. Furthermore, data on the number, condition, and operation and maintenance (O&M) structures of community toilets (CTs) and public toilets (PTs) in the city were collected to better understand the scale and performance of the existing sanitation infrastructure.

- **Semi-Structured Interviews:** In Kundapura Town Municipal Council (KTMC), we interviewed (semi-structured interviews) key ULB officials—including the Chief officer (2), Environmental engineer (2) and, SBM-U Coordinator (2), Accountant (2), President (1), Desludging vehicle driver(1), to understand the status of water and sanitation infrastructure and services, as well as to gather information on recent and past extreme events—such as floods, droughts, cyclones and heavy rainfall—and their impacts. These discussions also provided insights into the effects of climate change as experienced locally. Importantly, the interviews helped identify vulnerable areas and communities within the town, which informed the design of the rapid assessment study.

- **Site Visits:** The site visits were conducted to validate the functioning of key water and sanitation infrastructure, including water treatment plants (WTPs), Elevated Level Storage Reservoir (ELSR) and Ground Level Storage Reservoir (GLSR) and solid waste management (SWM) dumping sites. The ULB officials indicated that, in the absence of a STP or FSSTP, a sedimentation pond is used for the disposal of human waste. These visits focused on assessing environmental compliance and facilitated the integration of critical infrastructure data into the GIS platform for further spatial analysis.

- **Rapid Assessments:** 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 primary 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, whether these were connected to the sewage network. Since the city does not have a STP, our questions primarily focused on Onsite Sanitation (OSS) systems. We collected information on the type of OSS sysytems in use, the frequency and cost of septic tank cleaning, the service providers involved, and the affordability and challenges associated with these services. Additional questions addressed methods of greywater disposal, sources of tap water, costs related to water connections, and any support received from the ULB during disaster events. For households without individual toilets, we explored the alternative sanitation arrangements they relied upon.

The assessment also included an examination of decentralized treatment plants in the city to understand their capacity, technology, reuse and recycling practices, and environmental compliance. We visited one decentralized treatment plant operational in an apartment complex. Since the ULB officials were unable to provide a list of existing decentralized systems in residential areas, we identified this plant by directly asking apartment residents about their sanitation arrangements. Additionally, the team visited 1 public toilet located in a busy market junction to assess their condition firsthand.

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 project design necessitated a comprehensive review of secondary data sources pertaining to the water and sanitation sector and climate change across various levels—national, state, district, and town. This exercise highlighted several significant data gaps, which are detailed below.

Water

1. **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).
2. **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.

Sanitation

1. **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)[7] 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

[7] International Institute for Population Sciences. 2020 National Family Health Survey – 5 (2019-2020). District Fact Sheet. Ministry of Health and Family Welfare.

at the town or municipal level is not available. Collecting such data would require a detailed household-level survey.

3. **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 MoHUA guidelines, ULBs are mandated to conduct regular audits of these facilities. However, data on the coverage and adequacy of community and public toilets and operational status is not available with the ULB.
4. **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.
5. **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 Urban Local Body (ULB) does not maintain a detailed sewerage network map.

GHG Emissions

1. **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.

2. **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.

3. **Limited Data on OSS 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 CH_4 and N_2O emissions from faecal waste.

4. **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.

5. **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.

6. **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.

ANNEXURE-III: 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, Karnataka, 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 Karnataka, 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%. NRW is estimated at 25%, with 15% attributable to manual errors. Initiatives include smart metering (3,000 units in Panaji), free water up to 16m^3, 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 Karnataka 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-IV ABBREVIATIONS AND GLOSSARY

ABBREVIATIONS

ADB	Asian Development Bank
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BOD	Biochemical Oxygen Demand
CCA	Climate Change Adaptations
CGWB	Central Ground Water Board
CST	Community Septic Tanks
CT	Community Toilet
CDRI	Coalition for Disaster Resilient Infrastructure
DDMP	District Disaster Management Plan
DM	District Magistrate
DRR	Disaster Risk Reduction
ELSR	Elevated Level Storage Reservoir
FSSTP	Faecal Sludge and Septage Treatment Plant
FSTP	Faecal Sludge Treatment Plant
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
KIUWMIP	Karnataka Integrated Urban Water Management Investment Program
KSPCB	Karnataka State Pollution Control Board
KTMC	Kundapura Town Municipal Council
KUDCEMP	Karnataka Urban Development and Coastal Environmental Management Project
KUIDFC	Karnataka Urban Infrastructure Development and Finance Corporation
KUWSDB	Karnataka Urban Water Supply and Drainage Board

LPCD	Litres Per Capita per Day
LULC	Land Use Land Cover
MLD/ KLD	Million Litres per Day/ Kilo Litres per Day
MOHUA	Ministry of Housing and Urban Affairs
MSL	Mean Sea Level
NBIS	Nature-Based Infrastructure Solutions
NRW	Non-Revenue Water
ODF	Open Defecation Free
OHT	Over Head Tank
OSS	On Site Sanitation Systems
O&M	Operation and Maintenance
PT	Public Toilet
RIS	Risk Information Systems
SBM	Swachh Bharat Mission
SBR	Sequence Batch Reactors
SFC	State Finance Commission
SLBS	Service Level Benchmarks
SOP	Standard operating Procedure
STPS	Sewage Treatment Plants
UGD	Underground Drainage
UNDRR	United Nations Office for Disaster Risk Reduction
WTP	Water Treatment Plant
WASH	Water, Sanitation, and Hygiene

GLOSSARY

Term	***Definition***
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)[77]
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)[78]
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)

[77]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

[78]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.

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