Strengthening Urban Water Security in Indian Cities: A Framework Linking Systemic Challenges and Emerging Technologies

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“Water is not merely a commodity—it is a priceless asset. Securing our future depends on how we conserve and manage it today.”

- Droupadi Murmu
Hon’ble President of India

Source : https://www.presidentofindia.gov.in/press_releases/president-india-graces-jal-mahotsav-2026

Understanding Urban Water Security: Availability, Usability, and Governance

Water Security

Are we safe and Sustainable?

Water security is the ability to ensure reliable, safe, and sufficient water for people, the economy, and ecosystems while effectively managing risks and governance.

Water Scarcity

Is there enough water physically?

Water scarcity refers to the physical availability of water, measured as the balance between supply and demand.

Water Stress

Can we actually use it ?

Water stress refers to the ability to meet water demand, considering availability, quality, and accessibility.

Water Governance

Who decides who gets water ?

Water governance refers to the systems that manage water resources, allocation, and decision-making.

Source : UN-Water (2013). Water Security & the Global Water Agenda: An UN-Water Analytical Brief, FAO (Food and Agriculture Organization) & UN-Water, OECD (2015). OECD Principles on Water Governance

Urbanization and Climate Pressures Driving Water Insecurity

"Smaller towns becoming major hubs"

The Pressure Cooker Effect on Resources

Urbanisation

"The process by which an increasing proportion of a population lives in urban areas, driven by rural-to-urban migration, natural population growth in cities, and the spatial expansion of urban settlements"

Massive "Supply vs. Demand" gap

Resource Scarcity

"Resource scarcity refers to a condition in which the demand for a natural resource exceeds its available supply within a given region or time period"

Water Demand

"Urban dwellers use more water per capita than rural residents (for flushing, washing machines, industry, etc.)"

Housing & Waste

"A need for millions of new homes and systems to process double the current amount of sewage and trash "

Energy

"Cities are heat islands that require massive amounts of electricity for cooling and transport"

Climate Variability

Refers to natural fluctuations in climatic conditions such as temperature, rainfall, and extreme weather events over seasonal, annual, or decadal timescales.

50 % Urban by 2050

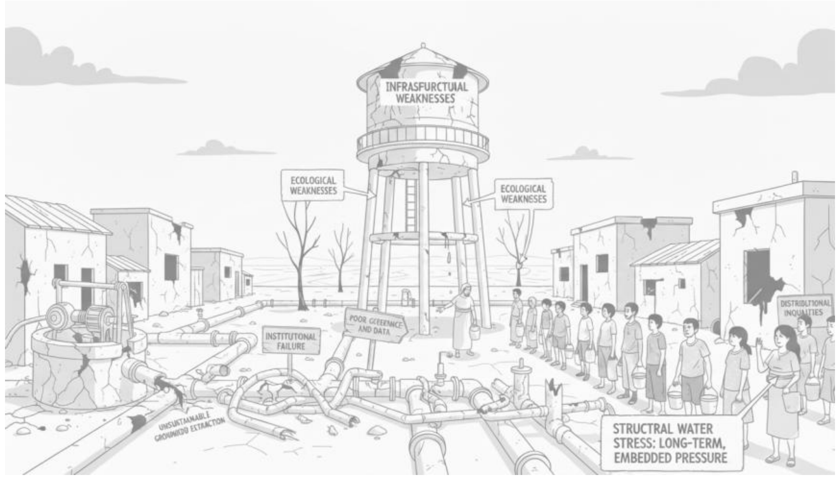
Cities are the engines of the economy. By 2050, these urban areas are expected to contribute over **75-80% of India's GDP**.

If infrastructure (like the water pipes and reservoirs we discussed) doesn't grow at the same speed, we face "structural stress" where the city exists on paper but cannot provide basic services to half its residents.

Source : India Water Portal and Observer Research Foundation (ORF)

Structural Drivers of Persistent Urban Water Stress

If infrastructure (like the water pipes and reservoirs we discussed) doesn't grow at the same speed, we face **"structural stress"** where the city exists on paper but cannot provide basic services to half its residents.



"Structural water stress is long-term, embedded pressure within water systems caused by infrastructural, ecological, and institutional weaknesses that make water insecurity persistent rather than seasonal"

SYSTEM VULNERABILITIES

Drivers

Infrastructure Gaps

- Ageing and under-capacitated distribution networks
- High levels of non-revenue water (leakage and losses)
- Limited treatment and storage augmentation

Unsustainable Groundwater Extraction

- Withdrawal exceeding natural recharge rates
- Declining urban aquifer levels
- Increasing borewell dependency

Poor Governance & Data

- Institutional silos and coordination failures
- Limited real-time monitoring capacity
- Reactive rather than adaptive planning

Distributional Inequalities

- Unequal service provision across urban geographies
- Informal settlements underserved
- Socio-spatial disparities in access

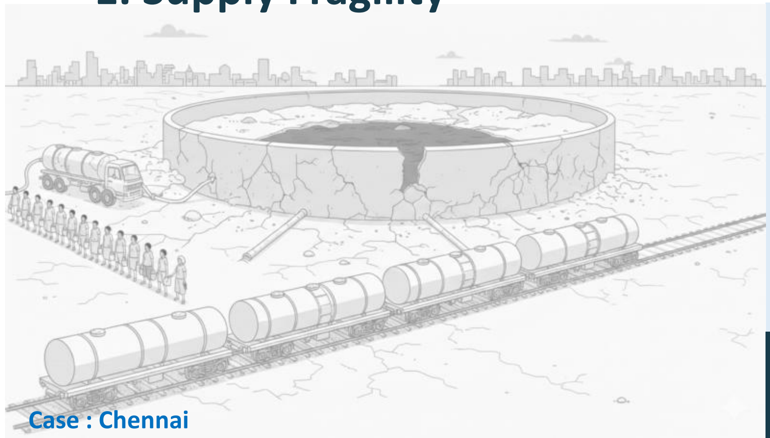
Structural Water Stress

Seasonal → Chronic → Systemic

Source : India Water Portal and Observer Research Foundation (ORF)

Evidence from Indian Cities: System Failures Across the Water Chain

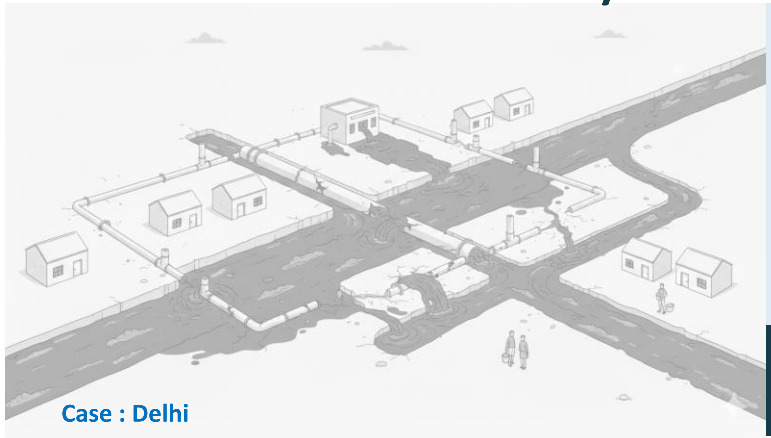
1. Supply Fragility



- Reservoirs ran dry after weak monsoon
- Severe groundwater depletion
- Emergency tanker and rail supply

Shows overdependence on rainfall & aquifers

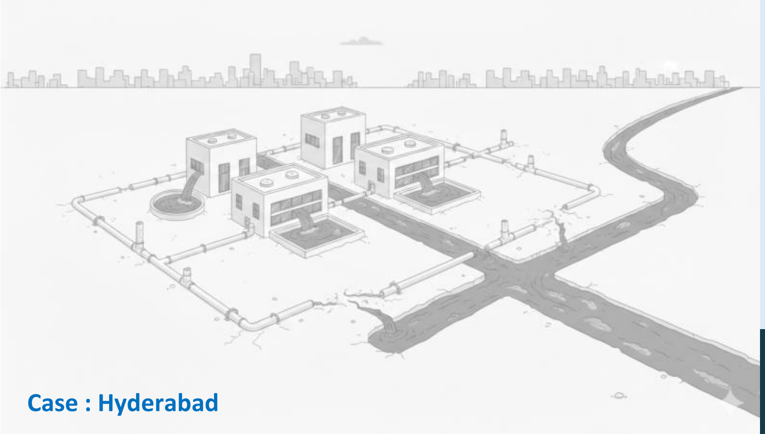
3. Distribution Inefficiency



- Largest source of water pollution
- ~70% distribution losses (Non-Revenue Water)
- Poor infrastructure → leakages & inefficiency

Infrastructure created, but system integration is weak

2. STP'S without Sewer Connectivity



- Several sewage treatment plants underutilized
- Incomplete sewer networks
- Treated capacity not fully translated into environmental improvement

Infrastructure created, but system integration is weak

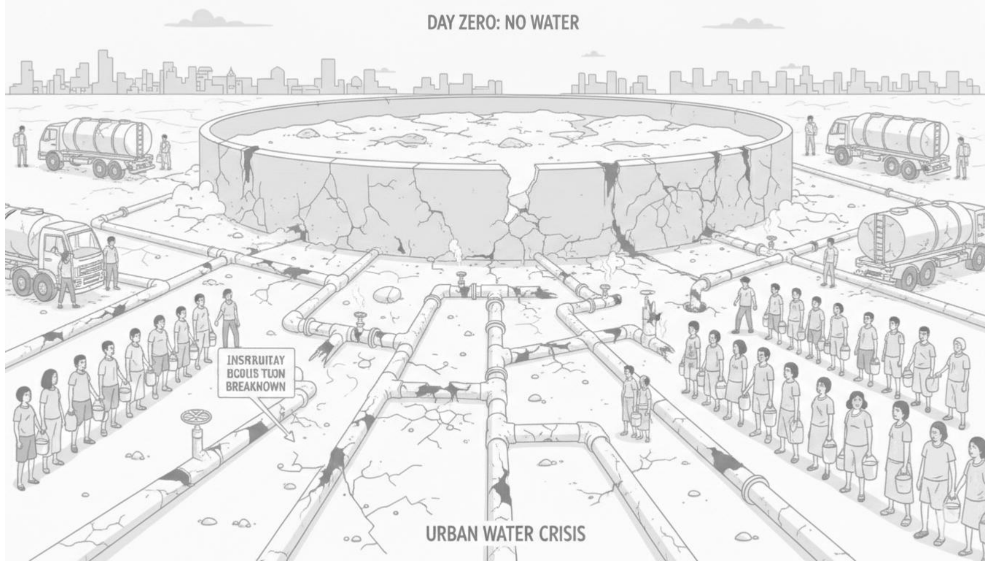
4. Inequitable Access

- Informal settlements rely on shared taps or tanker supply
- Pay significantly higher per liter than piped users
- Unequal distribution despite city-level abundance

Service inequality despite large municipal system.

Source : Wankhade, K., Balakrishnan, K., & Vishnu, M. J. (2014). *Sustaining policy momentum: Urban water supply and sanitation in India*. Indian Institute for Human Settlements.

Limitations of Conventional Approaches : Chennai & Capetown



"Day Zero refers to the point at which a city's water system can no longer provide regular municipal water supply due to critically depleted reservoirs, aquifers, or distribution failure."

Impacts :

- Infrastructure Gaps
- Unsustainable Groundwater Extraction
- Poor Governance & Data
- Climate Variability

CHENNAI

- In 2019, Chennai's four main reservoirs dried up after weak monsoons
- The city depended heavily on seasonal rainfall and groundwater extraction
- Years of over-extraction and poor recharge reduced aquifer levels
- Municipal supply collapsed in many areas
- The city relied heavily on private water tankers and emergency rail transport of water

CAPETOWN

- Between 2015–2017, Cape Town experienced an extreme multi-year drought
- Dam storage levels fell below critical levels
- The government announced a projected "Day Zero" when municipal taps would be shut off
- Strict per capita water limits (50 liters/day) were imposed
- Real-time public dashboards tracked dam levels and usage
- Massive public participation reduced demand significantly
- Day Zero was ultimately avoided

"Chennai illustrates the consequences of **structural water stress** under supply dependence, while Cape Town demonstrates how adaptive governance and demand management can **delay systemic breakdown**."

Source : Rosado, D., Fárez-Román, V., Müller, F., Nambi, I., & Fohrer, N. (2024). *Rethinking urban water management through drivers-pressures-states-impacts-responses framework application in Chennai, India*. Environmental Management, 74, 970–988

Urban water and sanitation persist despite ongoing policies

Recurring Urban Issues	Policy & Programmatic Interventions	Implementation Gaps
Water shortages & source stress	**Source augmentation, river and lake rejuvenation, rainwater harvesting under AMRUT 2.0 and Jal Shakti Abhiyan**	Cities remain highly dependent on groundwater and distant surface sources
Aging infrastructure & leakages	**Pipe replacement, district metered areas, NRW reduction and smart metering under AMRUT**	Infrastructure exists but high leakages and poor asset management persist
Intermittent & inequitable supply	**Universal tap connections and service expansion under Jal Jeevan Mission and AMRUT 2.0**	Supply remains uneven across informal settlements and peri-urban areas
Unsafe sanitation practices	**Household toilets, containment systems, and sanitation infrastructure under Swachh Bharat Mission**	Septic tanks often poorly designed or non-compliant
Untreated wastewater discharge	**Sewage treatment plants, fecal sludge treatment plants, and co-treatment promoted under Swachh Bharat Mission-Urban and Namami Gange Programme**	Sewage networks incomplete and sludge often bypasses treatment
Poor O&M and monitoring	**Institutional reforms, digital monitoring platforms, performance benchmarking under AMRUT 2.0**	Weak operational capacity, fragmented data systems, limited coordination

Source : AMRUT 2.0 and SBM Guidelines

Recurring Urban Issues	Policy & Programmatic Interventions	Implementation Gaps
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"Despite national initiatives, gaps persist across the urban water service chain. Traditional infrastructure alone is insufficient—emerging technologies are essential for resilient, efficient, and data-driven water management."

AIM

To develop a decision-support framework that links systemic urban water security challenges with suitable emerging technological interventions for improving reliability, efficiency, and resilience of water supply systems in Class III Indian cities

1. Identify and map key urban water security challenges across source, treatment, distribution, and delivery stages in Class III Indian cities.
2. Analyze and categorize emerging water technologies based on their functional role in addressing specific water security challenges.
3. Assess technologies using multi-dimensional criteria such as technical feasibility, operational complexity, financial viability, institutional capacity, and scalability, supported by case study insights.
4. Design a structured, user-oriented framework to guide cities in selecting context-appropriate technological interventions for improving reliability, efficiency, and resilience.

SCOPE

1. The study focuses on urban water supply systems in Class III Indian cities where demand pressures and operational complexities are significant.

2. The analysis covers the water supply service chain, including: Water sources (surface and groundwater), Treatment, Transmission and distribution and Delivery to consumers

3. Includes assessment of emerging technologies through selected Indian and international case studies

LIMITATIONS

1. Sanitation systems are not analyzed in detail, but the role of treated wastewater reuse as a supplementary source is acknowledged

2. The research relies primarily on secondary data, including: Academic literature , Government reports and policies , Mission guidelines , Research papers and Documented case studies.

3. Limited primary validation / field testing

End-to-End Approach for Developing a Water Security Framework

1 Literature Review

Review academic literature, policy documents, and reports to understand urban water security challenges and emerging technological solutions.

2 Service Chain Mapping

Map the urban water supply system into stages (source, treatment, distribution, delivery) and identify recurring challenges at each stage

3 Technology Identification & Classification

Identify emerging technologies from global and Indian literature and classify them based on functional roles such as source augmentation, efficiency improvement, and monitoring

4 Problem–Technology Mapping

Link identified water security challenges with relevant technological interventions within the service chain

5 Case Study Analysis

Examine selected Indian and international case studies to understand implementation outcomes, challenges, and mitigation strategies

6 Framework Development

Develop a structured decision-support framework linking challenges, service chain stages, technologies, and evaluation criteria

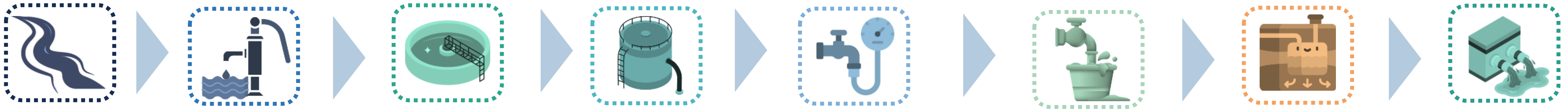
7 Technology Applicability Screening

Screen shortlisted technologies using broad criteria such as feasibility, operational practicality, institutional readiness, indicative cost, and scalability

8 Ground Validation

Test the developed framework on ground to assess its practicality, adaptability, and effectiveness

Systemic Challenges in Urban Water Systems



Source
- Groundwater depletion
- Water scarcity
- Reduced natural recharge
- Source contamination
- Poor source governance

Abstraction/ Intake
- Clogging of intake systems
- Energy inefficiency
- Variable water levels / Seasonal fluctuations
- Intake inefficiencies

Water Treatment
- Inefficient treatment
- Manual operations
- Cost inefficiency
- Waste management problem

Storage / Transmission
- Leakages
- Reservoir deterioration
- Burst pipes/ pressure fluctuations
- Unsafe transmission
- Water loss

Distribution & Service Delivery
- Revenue loss/NRW
- Aging distribution network/Inefficiency
- Intermittent supply
- Illegal connections
- Weak billing systems

End Use / Consumption
- Overuse of water
- Water wastage
- Behavioural issues
- Leakages at household level

Wastewater Generation & Collection
- Low coverage
- Groundwater contamination
- System failure
- Poor management

Wastewater Treatment & Reuse
- Treatment inefficiency
- Inefficient operation
- High costs
- Disposal issues/ Sludge challenges
- Water wastage

Bridging Policy, Performance, and Technology in Urban Water Management

CPHEEO NORMS (What to Achieve)

- 135 LPCD Supply
- 24x7 Water Supply
- Adequate pressure
- Safe Water Quality

"Defines service standards"

Standards → Measurement →

SLB INDICATORS (How to Measure)

- NRW (%)
- Supply hours
- Coverage (%)
- Water quality

"Measures performance"

Performance → Reveals gap →

EXISTING GAPS (Reality in Cities)

- 4-8 hrs Supply
- NRW > 30%
- Groundwater Depletion
- Frequent flooding

"Implementation Gaps"

EMERGING TECHNOLOGIES (Solutions)

- SCADA, Smart Metering
- AI, Digital Twin
- RWH,MAR
- Spong City, RTC

"Bridges the gap"

OUTCOMES / IMPACTS (Results Acheived)

- NRW ↓
- 24x7 Supply
- Flood Risk ↓
- Groundwater ↑
- Efficiency ↑

"Improved Service Delivery"

Technology Selection Based On:

Cost | Feasibility | Scalability | Institutional Capacity

Performance Monitoring & Feedback

Source : Government of India. (2013). *Manual on water supply and treatment* (3rd ed.). Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development.

Case Study Selection Framework: Screening and Evaluation Process

Only scalable & field-proven solutions considered

1 INNOVATION

Focus: Emerging Technology

(AI,IoT,Smart Systems, Nature-based Solutions)

2 SCALE

Focus: Proven Implementation

(City-scale)

3 IMPACT

Focus: Measurable Impact

(NRW↓, Flood↓, Groundwater level↑)

4 CONTEXT

Focus: Indian Relevance

(Scalable across Tier 1,2,3 cities)

5 FINAL SELECTED CASE STUDIES

Nagpur, Chennai, Gurugram, Singapore, Perth, Copenhagen

EXCLUSION EXAMPLE :

Air to water technology
Fog Harvesting
Small – Scale Solar Water Generation

Not scalable at City Wide Implementation

Removed location-specific solutions
Removed cases which has no data (nos.)

Diverse Approaches to Urban Water Security

COMMON GOAL: All six cities aim to improve urban water security through efficiency, sustainability, innovation and better management

CASE STUDY	CORE APPROACH	KEY INTERVENTIONS	KEY OUTCOMES
Nagpur	Infrastructure + PPP	• DMAs.metering,SCADA • Pipeline upgrade	Better supply, pressure, monitoring
Chennai	Policy (RWH mandate)	• Rainwater harvesting • Compliance rules	Improved groundwater, less tanker use
Gurugram	Demand management	• Aerators, leak fixing • Awareness & Training	30-40% water savings
Singapore	Smart technology	• AI,sensors,digital twin • Real-time monitoring	Leak reduction, efficiency, lower costs
Perth	Wastewater reuse	• Aquifer recharge • Treatment systems	New water source, climate resilience
Copenhagen	System optimization	• Smart sewers, RTC • Wastewater reuse	Reduced overflows, better use

KEY TAKEAWAY: Different approaches, one direction – building resilient, efficient and sustainable urban water systems

Nagpur Case: System Issues and Reform Measures

Background / Why the Project was Needed

Before the Reform: Intermittent System /Old System Issue

- Intermittent supply, Few hours daily **(2 to 24 hours depending on area)**
- Unequal distribution across zones
- High water losses; Leakages (**Total water losses were estimated at 291 MLD & Equivalent to 54% of total water supplied**)
- Aging pipeline network, poor pressure
- Increasing demand From urban growth
- Inconvience,Storage dependence

What Nagpur Did

The Reform: City-Wide 24x7 Water Supply Project through PPP

Major Interventions

- Partnership: NMC & Orange City Water
- Rehabilitation, pipeline replacement
- Creation of District Metered Areas (DMAs)
- Universal household metering
- SCADA & Smart Monitoring
- Leak detection, NRW reduction
- Improved billing, Customer service, grievances

Source : OCW (2024), Times of India (2023, 2024, 2026)

Nagpur Case: Evaluation of Outcomes, Gaps, and Key Takeaways

Positive Outcomes

1 Improved Service Levels

Several areas received significantly longer supply duration

Better pressure And more reliable distribution

2 Better System Management

SCADA

Meter-based billing introduced

Faster complaint Resolution systems

Real time-network monitoring

3 Reduced Dependence on Storage

Continuous/ long-duration supply reduced need for rooftop tanks and pumps

4 National Benchmark Project

Became a major case study for urban water reforms in India

Challenges Observed

Full 24x7 supply not achieved uniformly in all zones

NRW reduction remained a long-term challenge

Consumer complaints regarding billing/meters

Need for stronger public communication and trust building

Key Lesson for Other Cities

Continuous water supply requires not only infrastructure, but also:

INFRA-STRUCTURE | STRONG GOVERNANCE | NRW CONTROL | TECHNOLOGY | CITIZEN ENGAGEMENT

Continuous water supply requires not only infrastructure, but also: modern water more norms (strong governance), of NRW controls, involvement of citizen engagement

Source : OCW (2024), Times of India (2023, 2024, 2026)

Chennai Case: System Issues and Reform Measures

Background / Why the Project was Needed

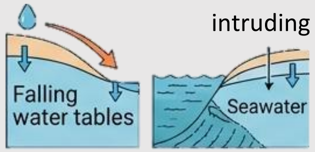
Repeated urban water crises (early 2000s,2019)

Dried reservoirs

Dried reservoirs

Heavy Groundwater Dependency

Seawater intruding



Freshwater aquifer

Seasonal rainfall lost as surface runoff

Rapid urbanization and paved surfaces

Reduced natural recharge zones

What Chennai Did

2003: Mandatory Rainwater Harvesting for all buildings

Install rooftop rainwater collection and recharge systems

Compliance linked to municipal approvals

Shift focus to decentralized local recharge systems

Public campaigns for Participation and awareness

Source : Observer Research Foundation (ORF)

Chennai Case: Evaluation of Outcomes, Gaps, and Key Takeaways

Positive Outcomes

1

Significant groundwater level improvement in several zones

2

Better groundwater quality in coastal areas (reduced salinity)

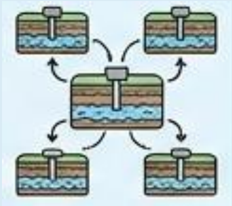
3

Reduced dependence on private tanker water

4

Increased public awareness of water conservation

5



Demonstrated small-scale complement city supply

Challenges Observed

Enforcement weakened after implementation phase

Many properties adopted token compliance (poor use)

Recharge pits and filters became clogged due to poor maintenance

Ongoing urban concretisation percolation capacity

Benefits varied across locations (soil type, density, upkeep)

Key Lesson for Other Cities

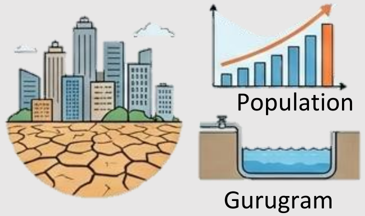
- MANDATES NEED REGULAR INSPECTIONS & PENALTIES
- INTEGRATE RWH APPROVAL WITH BLDG. PERMITS & OC CERTIFICATES
- LINK RWH WITH STORMWATER DRAINAGE & FLOOD MANAGEMENT
- PUBLIC PARTICIPATION AND AWARENESS DRIVE LONG-TERM SUCCESS
- DECENTRA-LISED RECHARGE SYSTEMS ARE A COST-EFFECTIVE STRATEGY
- CITIES WITH HIGH RAINFALL, SCARCE WATER, BENEFIT BY CAPTURING LOCAL RAIN

Source : Observer Research Foundation (ORF)

Gurugram Case: System Issues and Reform Measures

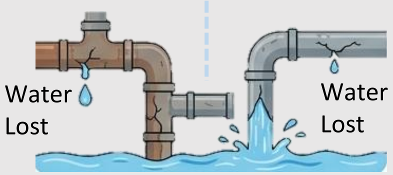
Background / Why the Project was Needed

Growing Urban Water Stress



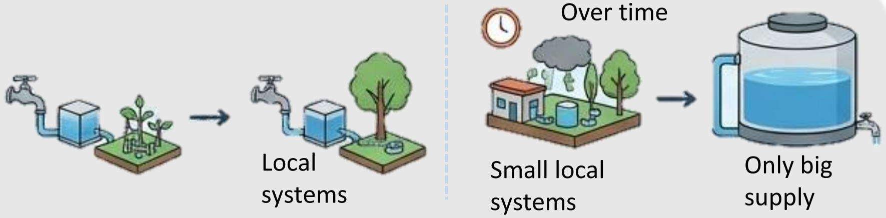
Residential Societies as Major Stakeholders

Aging Plumbing Systems Cause Water Looses



Limited Adoption of Conservation Devices & Poor Awareness

Promote Decentralized Conservation Measures



What Gurugram Did

GuruJal Society Launch Conservation Program (2019)

Leak-Proofing Drivers

Installed Aerators in Taps & Kitchens

Survey 572 Government Schools (RWH assessment)

Institutions Prepare Water Budgets

Awareness & Training Sessions

Provide Technical & Cost-Effective Solutions

Source : NITI Aayog. (2021). *Compendium of best practices in water management 2.0*. Government of India.

Gurugram Case: Evaluation of Outcomes, Gaps, and Key Takeaways

Positive Outcomes

1. Installation of 8,500 aerators in 15 RWAs

2. Tap water consumption reduced by up to 40%

3. Potential saying of 304 million litres/year if school RWH operates full capacity

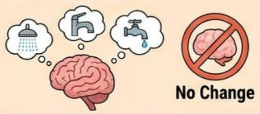
4. Reduced leak-related losses & improved efficiency

5. Increased awareness regarding conservation

6. Low-cost retrofits create large cumulative savings

Challenges Observed

Difficulty in changing resident behaviour

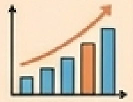


Maintenance issues in installed devices over time

Non-functional RWH systems despite prior installation

Scaling model requires funding/monitoring

Data collection and water metering gaps



Key Lesson for Other Cities

- DEMAND MANAGE MENT= AUGMEN -TATION
- LOW-COST DEVICES CREATE IMMEDIATE, MEASURABLE SAVINGS
- RWAs POWER-FUL PARTNER S
- WATER AUDIT & BUDGETING IDENTIFY WASTAGE
- EXISTING RWH REGULARLY INSPECTED & REVIVED
- CITIZEN AWARENE-SS ESSENTIAL
- COMBINE BEHAVIOUR,T ECHNOLOGY, GOVERNANCE FOR SUSTAINABLE SAVINGS

Source : NITI Aayog. (2021). *Compendium of best practices in water management 2.0*. Government of India.

Singapore Case: System Issues and Reform Measures

Background / Why the Project was Needed

Highly Advanced Urban Water System

MINIMIZING NRW & LEAKAGES CRITICAL

Hidden Underground Leaks

DIFFICULT TO DETECT BY VISUAL INSPECTION

Leak Occurrence Burden

4.5 leaks / 100 km
PIPELINE

Repair Crew Maintenance

WATER LOSSES AND MAINTENANCE

Traditional Monitoring relied on manual surveys

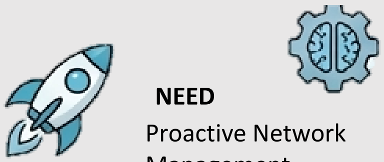
450+ STATIONS

SLOW,LABOUR-INTENSIVE, LESS ACCURATE

Large Data Existed, but fragmented

INFORMATION FRAGMENTED, REDUCED EFFICIENCY

Proactive and Intelligent Approach

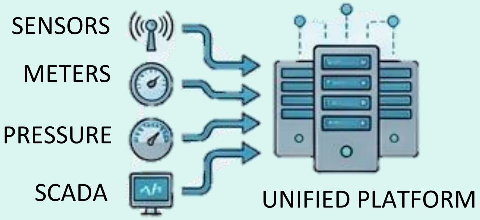


NEED
Proactive Network Management

What Singapore Did

Developed Digital Twin Integrated with AI Analytics

Real-Time Data Connected to unified platform



Predictive Analytics detect abnormal flow & leaks

DETECT ABNORMAL FLOW, PRESSURE CHANGES

Rapid Leak Localization

REDUCE SEARCH ZONES

Risk-Based Targeted Inspections

SHIFT FROM SCHEDULED TO TARGETED

Cloud-Based Interfaces Improve interoperability

BETTER INTEROPERABILITY & DECISION MAKING

Source : Bentley Systems, Incorporated. (2025). *PUB Singapore refines digital anomaly and leak detection practices for their smart water grid program: Digital twins, AI, and machine learning drive intelligent network surveillance, localizing leaks to less than one kilometer.*

Singapore Case: Evaluation of Outcomes, Gaps, and Key Takeaways

Positive Outcomes

1. **Improved leak detection Accuracy to 80%**

2. **Faster identification & repair of hidden leaks**

3. **Reduced water losses, improved system efficiency**

4. **Lower O&M costs through targeted inspections**

5. **Reduced manpower needs for routine surveys**

6. **Better asset management using predictive insights**

7. **Improved service reliability & resilience**

Challenges Observed

- Data integration from legacy systems & multiple sensor formats

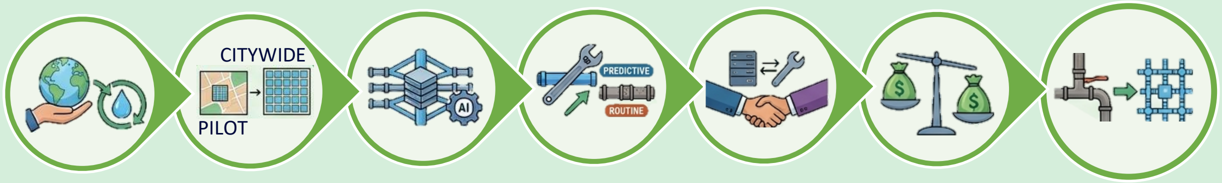
- Continuous model calibration for dynamic conditions

- Organizational resistance to digital operations

- High upfront investment needing justification

- Dependence on quality sensor data & communication

Key Lesson for Other Cities



1. HIGHLY EFFECTIVE FOR STRESS MANAGEMENT & NRW REDUCTION
2. START WITH LEAK-PRONE ZONES/ PILOT DISTRICTS
3. DATA INTEGRATION AS AI ALGORIT - HMS
4. PREDICTIVE MAINTENANCE MORE EFFICIENT THAN ROUTINE INSPECTIONS
5. COORDINATION ESSENTIAL BETWEEN IT & FIELD OPERATIONS
6. UPFRONT COSTS JUSTIFIED BY LONG-TERM O&M & WATER SAVINGS
7. USE DIGITAL TWINS TO MODERNIZE NETWORKS WITHOUT FULL REPLACEMENT

Source : Bentley Systems, Incorporated. (2025). *PUB Singapore refines digital anomaly and leak detection practices for their smart water grid program: Digital twins, AI, and machine learning drive intelligent network surveillance, localizing leaks to less than one kilometer.*

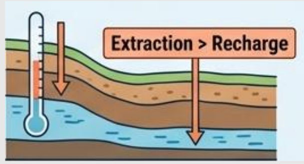
Perth Case: System Issues and Reform Measures

Background / Why the Project was Needed

Declining rainfall and climate variability (Perth water stress)

Annual rainfall dropped 20% reduced inflows to dams

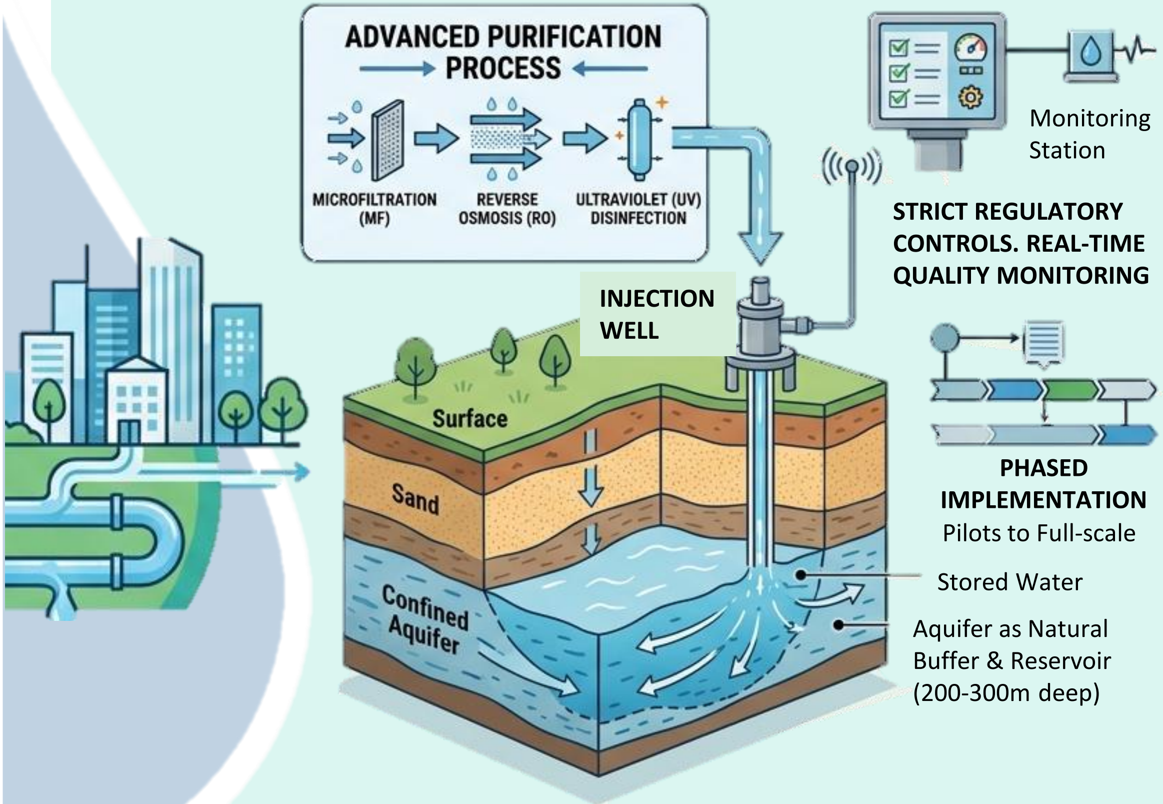
Falling aquifer levels due to high dependence



Large volumes of treated wastewater discharged to sea (Lost resources)

Growing population & drought risk. Need sustainable sources

What Perth Did



Source : Bekele, E., Toze, S., Patterson, B., & Higginson, S. (2011). Managed aquifer recharge of treated wastewater: Water quality changes resulting from infiltration through the vadose zone

Perth Case: Evaluation of Outcomes, Gaps, and Key Takeaways

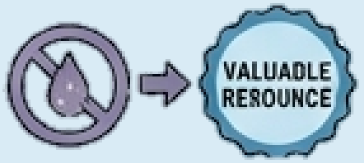
Positive Outcomes

1. **Reliable climate-resilient water source independent of rainfall**

2. **Reduced pressure on natural groundwater and surface reservoirs**

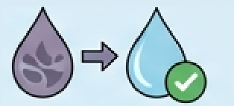
3. **Improved long-term groundwater sustainability through replenishment**

4. **Converted treated wastewater into valuable resource, not ocean discharge**



5. **Enhanced drought preparedness and urban water security**

6. **Demonstrated safe indirect potable reuse through multi-barrier treatment systems**



7. **Increased resilience against future climate change impacts**

Challenges Observed

Public resistance due to "toilet-to-tap" perception & health concerns

Risks related to trace contaminants & micropollutants

Well clogging, injection performance decline, & maintenance complexity

High-capital & operating costs, especially due to energy intensive RO

Need for continuous monitoring & regulatory compliance

Key Lesson for Other Cities

- WATEWATER SHOULD BE VIEWED AS A RESOURCE, NOT WASTE
- MAR CAN PROVIDE LARGE-SCALE DROUGHT – PROOF STORAGE
- PUBLIC COMMUNI-CATION & TRANSPA-RENCY ARE CRITICAL FOR ACCEPTANCE
- MULTI-BARRIER TREATMENT SYSTEMS ESSENTIAL FOR SAFETY & TRUST
- PHASED PILOTS HELP DEMON-STRATE PERFORMA-NCE BEFORE SCALING CITYWIDE
- CITIES WITH DECLINING RAIN & GROUND-WATER STRESS CAN DIVERSIFY SUPPLY
- COMBINING REUSE + AQUIFER STORAGE IS OFTEN CHEAPER THAN NEW DAMS

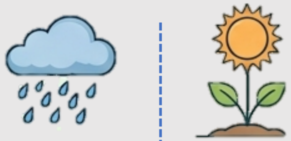
Source : Bekele, E., Toze, S., Patterson, B., & Higginson, S. (2011). Managed aquifer recharge of treated wastewater: Water quality changes resulting from infiltration through the vadose zone

Copenhagen Case: System Issues and Reform Measures

Background / Why the Project was Needed

Growing Water Stress (Climate Variability & Demand)

Seasonal Imbalances



Wet months- High Availability

Dry Summer- High Demand

Groundwater Risks

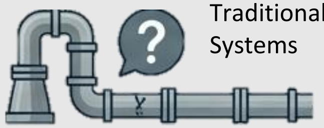
Over-extraction Risk

Wastewater Losses

Wastewater Discharged

Need for Climate Resilience

Traditional Sewers Not Optimized



Traditional Systems

Not Optimized for Storage/ Reuse

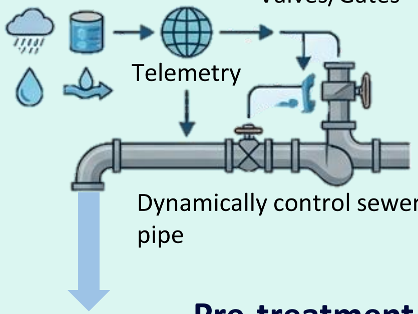
What Copenhagen Did

Implement Smart Sewers with Real-Time Control (RTC)

Sewer network modes

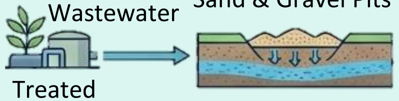
RTC OPTIMIZATION

Use Sensors & Automated Control



Dynamically control sewer pipe

Divert Wastewater for Managed Aquifer Recharge (MAR)



Treated Wastewater

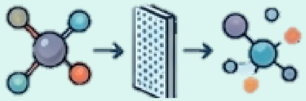
Sand & Gravel Pits

Treated Wastewater

Soil-Aquifer Polishing

Pre-treatment

Nutrient & Micropollutant Removal



Controlled Recharge Rates

RATE CONTROL

RATE CONTROL

Continuous Monitoring & Regulatory Compliance

Monitoring Systems

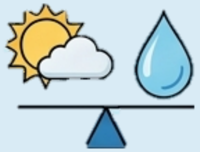
Compliance

Source : Kalalesøe, A. J., & Vangsgaard, P. (2012). ***STORE: Storing treated wastewater for reuse in the Greater Copenhagen area***. Capital Region of Denmark & University of Copenhagen

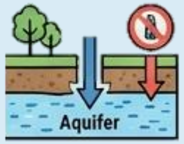
Copenhagen Case: Evaluation of Outcomes, Gaps, and Key Takeaways

Positive Outcomes

1. **Improved seasonal Balancing**



2. **Reduced groundwater pressure**



3. **Better wastewater use**

4. **Increased drought resilience**

5. **Reduced sewer overflows**

6. **Data-driven efficiency**

7. **Urban water security**

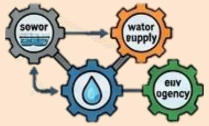
Challenges Observed

Micropollutants & trace organics

Strict regulations

Complex hydrogeology

Public Concerns

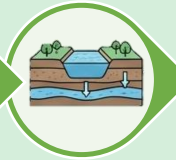


Advanced coordination

High technical requirements

Key Lesson for Other Cities

WATEWATER SHOULD BE VIEWED AS A RESOURCE, NOT WASTE



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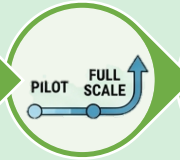

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Source : Kalalesøe, A. J., & Vangsgaard, P. (2012). *STORE: Storing treated wastewater for reuse in the Greater Copenhagen area*. Capital Region of Denmark & University of Copenhagen

Targeting Water Management Strategies : Analysis & Focus City Tier

CASE STUDY ANALYSIS ACROSS POPULATION RANGES

Case Study	Population Range	Equivalent Indian Tier	Applicability	Key Insight
Nagpur (24x7 PPP)	~ 46 lakh	Tier 2	Tier 2,3	Institutional + PPP model
Chennai (RWH)	~ 1 crore	Tier 1	All tiers	Policy-driven, scalable
Gurugram (Gurujal)	~ 8-10 lakh	Tier 2	Tier 2,3	Low-cost demand management
Singapore (Digital Twin)	~ 55 lakh	Tier 1 (Advanced)	Tier 1	High-tech, data-driven
Perth (MAR)	~ 20 lakh	Tier 2	Tier 1,2	Alternative water source
Copenhagen (RTC)	~ 8 lakh	Tier 2	Tier 1,2	Smart System Optimization

OBSERVATION

- Case studies span small to large cities (8 lakh- 1 crore +)
- Solutions range from low-cost to highly advanced systems
- Decentralized and demand-side approaches are most relevant for Tier 3
- Tier 3 cities can adopt selective, scalable interventions

TARGET CITY TIER

PRIMARY FOCUS:
Tier 3 Cities (<1 lakh population)

WHY TIER 3 ?
(REASONS FOR FOCUS)

- Facing **growing water stress but limited infrastructure**
- Have **low financial & technical capacity**
- Require **low-cost, decentralized solutions**
- Opportunity to **avoid future crises through early planning**
- Easier to implement **community-based and scalable interventions**

Functional Role of Emerging Technologies in Urban Water Security

Source Augmentation Technologies

*Explain technologies that **increase water supply***

A. Water Reuse & Advanced Treatment

- DPR, IPR, Decentralized wastewater reuse
- Advanced membrane filtration

B. Rainwater Capture & Aquifer Recharge

- Rainwater & stormwater harvesting
- Managed Aquifer Recharge (MAR)
- Aquifer Storage and Recovery (ASR)

C. Alternative Water Generation

- Desalination
- Atmospheric water generation
- Fog harvesting
- Solar water technologies

These technologies diversify water sources and reduce dependence on conventional surface and groundwater supplies

Efficiency-Enhancing Technologies

*Explain technologies that **improve infrastructure performance***

A. Smart Monitoring & Control Systems

- Smart water meters
- SCADA systems
- District Metered Areas (DMA)

B. Loss Detection & Pressure Optimization

- Leak detection tools (including AI-based)
- Pressure management systems
- Smart valves & automated pressure control

C. Predictive & Automated System Management

- Digital twin models
- Predictive maintenance systems
- Robotic pipeline inspection systems

These technologies optimize water distribution networks and reduce non-revenue water

Monitoring and Decision-Support Technologies

*Explain technologies that **improve governance and planning***

A. Data Integration & Visualization Platforms

- Digital dashboards
- Integrated data platforms
- GIS-based asset mapping

B. Real-Time Monitoring Networks

- IoT-based water monitoring systems
- Smart sewer monitoring systems

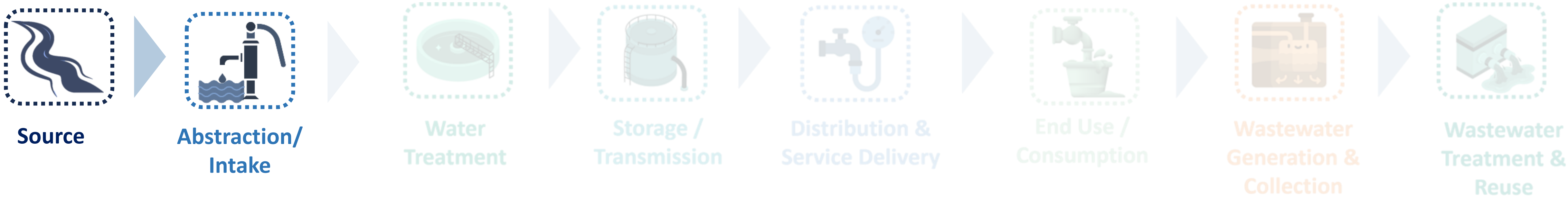
C. Advanced Analytics & Environmental Intelligence

- AI-based demand forecasting
- Satellite-based groundwater monitoring
- Remote sensing for watershed monitoring

These technologies enable real-time monitoring and data-driven decision-making for urban water management

Source: World Bank (2016); IWA (2019); ADB (2020)

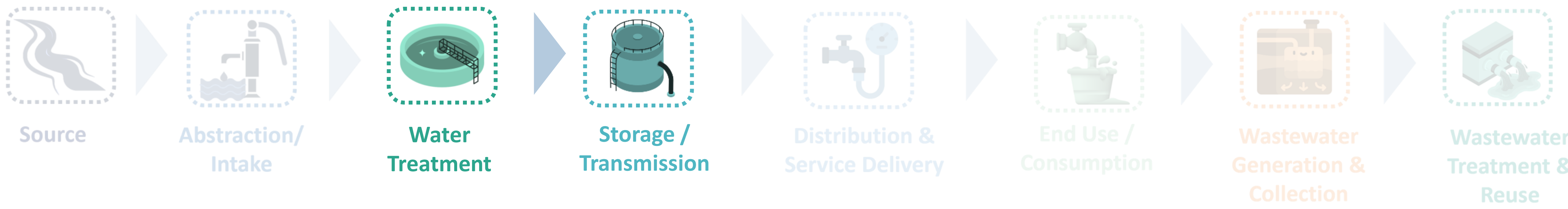
Technical Mapping in Urban Water Systems



Cause	Challenge	Technology	Description	Outcome
1. Over-extraction of groundwater	Groundwater Depletion	Managed Aquifer Recharge (MAR)	Recharges aquifers using treated wastewater/stormwater	Restores groundwater levels
2. Climate Variability	Water scarcity	Rainwater Harvesting Systems	Captures & stores rainwater for reuse	Improves water availability
3. Catchment Degradation	Reduced natural recharge	Watershed Management & GIS Mapping	Uses GIS and remote sensing to restore catchments	Enhances recharge capacity
4. Agriculture & industrial pollution	Source contamination	Real-time Water Quality Sensors	Continuous monitoring of pollutants in water bodies	Early detection & prevention
5. Weak monitoring & regulation	Poor source governance	Satellite-based Monitoring Systems	Tracks water bodies and usage patterns remotely	Improved regulation and planning

Cause	Challenge	Technology	Description	Outcome
1. Energy-intensive pumping	High operational cost	Smart pumps (VFD-based)	Optimizes pump energy usage	Reduces energy consumption
2. Manual operations	Inefficient intake Control	SCADA-based intake systems	Automates intake operations	Improves reliability
3. Sediment load/contamination	Poor raw water Quality	Automated screening & sediment removal	Removes debris and sediments at intake	Protects infrastructure
4. Lack of monitoring	Unpredictable intake performance	IoT flow & quality sensors	Tracks flow and quality in real-time	Better control and planning

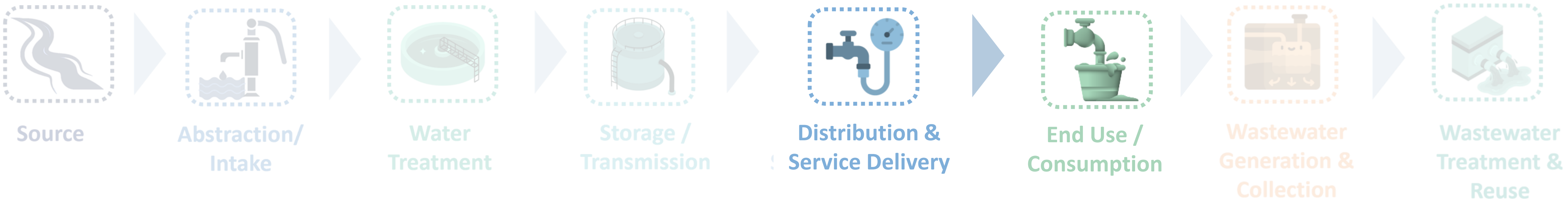
Technical Mapping in Urban Water Systems



Cause	Challenge	Technology	Description	Outcome
1. Aging infrastructure	Inefficient treatment	AI-based optimization	Optimizes plant operations	Improves performance
2. Industrial pollution	Poor water Quality	Advanced filtration (RO/UF)	Removes contaminants	Safe water
3. Emerging pollutants	Hard to remove Contaminants	Advanced Oxidation Processes (AOPs)	Degrades pollutants chemically	Removes toxins
4. High energy use	Unsustainable Treatment	Solar-powered Treatment	Uses solar energy	Reduces energy use
5. Lack of monitoring	Data gaps	IoT water quality sensors	Real-time quality tracking	Early detection

Cause	Challenge	Technology	Description	Outcome
1. Aging pipelines	Leakages / NRW	IoT leak detection	Detects leaks using sensors	Reduces losses
2. Pressure imbalance	Pipe bursts	Smart pressure Management	Controls pressure	Prevents failures
3. Lack of visibility	Inefficiency	Digital twin	Virtual system model	Optimized planning

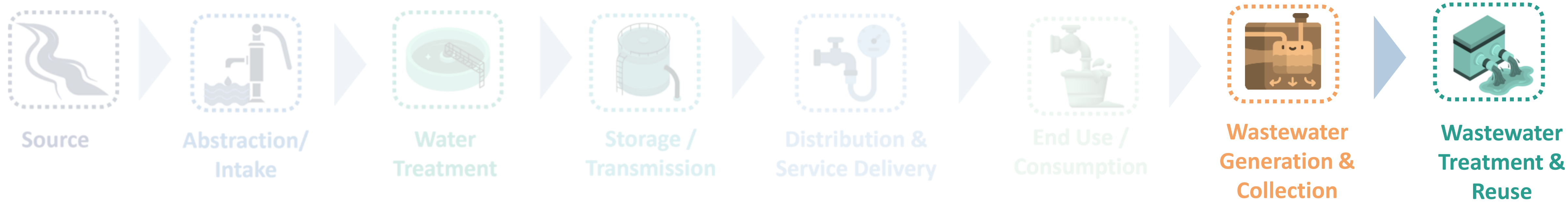
Technical Mapping in Urban Water Systems



Cause	Challenge	Technology	Description	Outcome
1. Poor metering	Non-revenue water	Smart meters	Tracks usage & losses	Reduces NRW
2. Weak enforcement	Illegal connections	Data analytics + metering	Detects anomalies	Prevents theft
3. Manual operations	Intermittent supply	SCADA systems	Automates distribution	Improves reliability

Cause	Challenge	Technology	Description	Outcome
1. High demand	Over-consumption	Smart meters	Provides usage insights	Demand control
2. Lack of awareness	Water wastage	IoT monitoring systems	Tracks consumption	Reduces wastage
3. Poor feedback	Inefficient use	Digital dashboards	Visualizes usage data	Behaviour change

Technical Mapping in Urban Water Systems



Cause	Challenge	Technology	Description	Outcome
1. Poor sewer infrastructure	Overflow	Smart sewer systems	Uses sensors for flow Control	Prevents flooding
2. Lack of monitoring	System failure	Real – Time Control (RTC)	Automate sewer operations	Improves Efficiency

Cause	Challenge	Technology	Description	Outcome
1. Linear water use	Low reuse	Wastewater recycling (IPR/DPR)	Treats wastewater for reuse	Demand control Reduces wastage
2. Lack of infrastructure	Untreated wastewater	DEWATS	Decentralized treatment systems	Behaviour change
3. Resource loss	Ineffiency	Resource recovery technologies	Extracts energy/ nutrients	Circular economy

Urban Water Solutions Matrix: Technologies, Costs, and Funding Sources

Category	Problem	Technology	Example Providers	Block Cost (₹)	Funding Source
Source	Lack of local water sources	Rainwater Harvesting (RWH)	JalBhagirathi, WOTR, Shivam Water Treaters	₹15K–₹1L (HH) / ₹5L–₹50L (community)	AMRUT 2.0, SBM 2.0, Smart Cities, CSR
	Groundwater depletion	Recharge Wells / GWR	ACWADAM, Arghyam	₹3.5L–₹5L per unit (one recharge well)	Atal Bhujal Yojana, MGNREGA, AMRUT
	Source dependency risk	Air-to-Water (AWG)	Maithri Aquatech, Akvo	₹2L–₹10L per unit (one machine/system)	CSR, Innovation Grants, Pilot Projects
	Freshwater shortage	Wastewater Recycling (STP reuse)	VA Tech Wabag, Ion Exchange	₹1Cr–₹10Cr (per plant/project depending on capacity (KLD/MLD))	AMRUT 2.0, PPP, State Govt, Multilateral (ADB/World Bank)
Distribution	High NRW	DMA (District Metering Areas)	SUEZ, SPML Infra	₹10K–₹1.8L per DMA zone/ network section	AMRUT 2.0, Smart Cities Mission
	Leakages	Leak Detection Systems	Primayer, Gutermann	₹10L–₹50L per city project/ zone package	AMRUT, PPP performance contracts
	Pressure variation	Smart Pressure Management	Kirloskar Brothers	₹5L–₹20L per pressure zone / pipeline zone	AMRUT, State Urban Dev Funds
Quality	Poor monitoring	Online Water Quality Sensors	Endress+Hauser, Eutech	₹5L–₹50L per sensor station / monitoring location	Jal Jeevan Mission (Urban), AMRUT
	Unsafe water	Chlorination Automation	Dosatron	₹5L–₹25L per treatment point / ESR / pumping station	AMRUT, SBM 2.0
	Weak lab capacity	Water Testing Labs	CPCB-approved labs	₹20L–₹1Cr per lab setup	Jal Jeevan Mission, State Govt
Demand	No consumption control	Smart Water Meters	Itron, Kamstrup	₹3K–₹10K per HH meter	AMRUT 2.0, Smart Cities, PPP
	High water use	Water Efficient Fixtures	Jaquar, Hindware	₹500–₹5K per fixture	SBM 2.0, CSR, Incentive Programs
	Low awareness	IEC / Awareness Campaigns	NGOs, ULB	₹5L–₹20L per campaign / ward / city program	SBM 2.0, AMRUT IEC funds
Governance	Poor monitoring	SCADA / Smart Systems	Siemens, Schneider	₹50L–₹2Cr per city / utility control system	Smart Cities Mission, AMRUT
	Weak O&M	PPP / Performance Contracts	Veolia, SUEZ	Depends on contract scope & service area	PPP, State Govt, Multilateral Funding

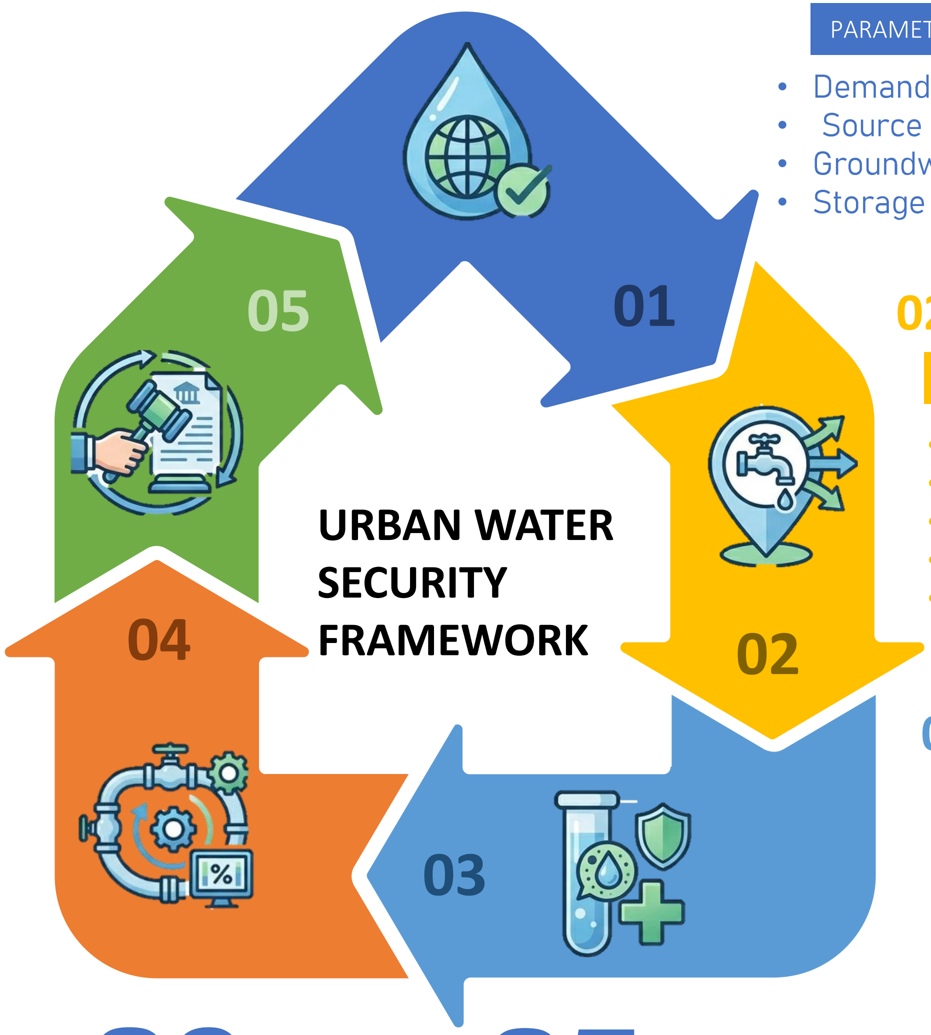
Source: MoHUA (AMRUT 2.0), Jal Jeevan Mission, SBM 2.0, Smart Cities Mission, DPRs & industry estimates.

Comparative Analysis of Urban Water Security Frameworks

Framework	Year	Main Focus / What It Talks About	Parameters / Dimensions	Approx. No. of Indicators	Shared Indicators / Themes	Best Use Case
PAS-CWIS Assessment Framework	2022	Assesses urban sanitation performance using CWIS principles with PAS data; measures inclusive sanitation outcomes and system functions	6 Focus Areas	26 Indicators	Coverage, equity, governance, finance, sanitation chain, accountability	Indian city sanitation benchmarking
Urban Water Security Planning Toolkit	2017	Step-by-step toolkit for improving city water security through integrated planning and local resource management	5 Modules	Multiple tools / module indicators	Demand-supply, NRW, groundwater, RWH, citizen role, governance	Action planning for Indian cities
MDPI Urban Water Security Framework	2019	Holistic urban water security framework combining human needs, ecosystem protection, climate resilience, and socio-economic governance	4 Pillars (DECS)	~20–40 (study dependent)	Availability, quality, resilience, sustainability, governance, equity	Research / strategic planning

Source : Centre for Water and Sanitation (C-WAS), CEPT University, CEPT University (under Bhuj Water Security Project funded by Arghyam), MDPI Journal – Resources

Framework for Assessing Urban Water Security



01 – Water Availability

PARAMETERS
- Demand-Supply
- Source Reliability
- Groundwater
- Storage

COMPONENTS
- Surface Water Source
- Groundwater Source
- Bulk Supply system
- Reservoir / Storage
- Future Demand Projection

02 – Accessibility & Service Delivery

PARAMETERS
- Coverage
- Hours
- Pressure
- Equity
- Affordability

COMPONENTS
- Distribution Network
- Household Connections
- Ward- Level Service Coverage
- Consumer Interface
- Vulnerable Area Supply

03 – Water Quality & Public Health

PARAMETERS
- Treatment
- Testing
- Compliance
- Contamination

COMPONENTS
- Raw Water Intake
- Treatment Plant
- Distribution Quality
- Lab Testing System
- Public Health Monitoring

04 – Infrastructure Efficiency

PARAMETERS
- NRW
- Leakages
- Pumping
- Asset Condition

COMPONENTS
- Pipelines
- Pumps
- ESR/UGR Storage
- Meters
- Monitoring Systems

05 – Governance, Finance & Resilience

PARAMETERS
- Tariff Recovery
- Capacity Planning
- Climate Readiness

COMPONENTS
- ULB Water Department
- Billing System
- O& M Finance
- Emergency Response
- Planning & Policy Unit

20 PARAMETERS **25** COMPONENTS

Urban Water Security Assessment Framework & Scoring Tool

OVERVIEW: Assessment Pillars (Logical structure to map urban water security)

Water Availability → Accessibility & Service Delivery → Water Quality & Public Health → Infrastructure Effiency → Governance, Finance & Resilience

Pillar 1: Water Availability

1. ☐ Is total water demand higher than supply?
2. ☐ Is the city dependent on a single source?
3. ☐ Are reservoirs sufficient for summer months?
4. ☐ Is groundwater declining?
5. ☐ Is source water reliable year-round?
6. ☐ Is population growth increasing demand pressure?
7. ☐ Is there emergency backup source available?

/ 7

Citizen experience is key to true water security

Pillar 2: Accessibility & Service Delivery

1. ☐ Are all wards covered by piped water?
2. ☐ Are slum areas served adequately?
3. ☐ Is water supplied daily?
4. ☐ Are supply hours sufficient?
5. ☐ Is pressure adequate at tail-end zones?
6. ☐ Is tariff affordable for low-income users?
7. ☐ Are complaints resolved quickly?

/ 7

Pillar 3: Water Quality & Public Health

1. ☐ Does treated water meet standards?
2. ☐ Is water tested regularly?
3. ☐ Is residual chlorine maintained?
4. ☐ Are contamination incidents reported?
5. ☐ Are pipelines crossing sewers?
6. ☐ Are disease outbreaks linked to water supply?
7. ☐ Is lab capacity adequate?

/ 7

Select the answers based on in each box :

✔ Yes

✘ No

Pillar 4: Infrastructure Effiency

1. ☐ Is NRW above acceptable limit?
2. ☐ Are pipe bursts frequent?
3. ☐ Are pumps energy efficient?
4. ☐ Is storage capacity sufficient?
5. ☐ Are household meters installed?
6. ☐ Is preventive maintenance conducted?
7. ☐ Is SCADA/digital monitoring available?

/ 7

Pillar 5: Governance, Finance & Resilience

1. ☐ Does tariff recover O&M cost?
2. ☐ Is billing collection efficient?
3. ☐ Is staff capacity adequate?
4. ☐ Is there drought contingency plan?
5. ☐ Is data regularly updated?
6. ☐ Is there annual asset management plan?
7. ☐ Are climate risks integrated in planning?

/ 7

If Supply ≥ Demand	If Supply ≈ Demand	If Supply < Demand
WATER SECURE	MODERATE SECURITY	WATER INSECURE

STATUS CALCULATOR (MAX 35)

(26-35 Marks)	WATER SECURE
(11-25 Marks)	MODERATE SECURITY
(0-10 Marks)	WATER INSECURITY

Urban Water Security: Assessment to Action Framework

STEP 1 : Water Security Screening “START : Screen Core Questions”

1. Supply Meets Demand ?
2. Water Safe ?
3. Service Reliable ?
4. Loss Acceptable?
5. Future Ready ? 2050

?

If All Yes → Water Secure → Maintain & Improve Resilience

If Any No → Not Water Secure → Go to Root Cause Assessment

STEP 2 : Diagnostic Assessment (If Not Secure)

Source Assessment

- Source sufficient ?
- Single source dependency?
- Seasonal Shortage?
- Groundwater stress?
- Storage adequate?

Distribution/ Leakage Assessment

- NRW high?
- Frequent pipe bursts?
- Low pressure zones?
- Tail-end supply weak ?

Quality Assessment

- Treatment adequate?
- Contamination incidents?
- Testing Regular?

Demand Assessment

- Excessive use ?
- Poor metering?
- High Growth pressure?

Governance

- O&M weak?
- Billing poor ?
- Staff shortage?

STEP 3 : Technical Solutions (Matched to Problem)

If Source is Weak:

- Rainwater Harvesting (RWH) - **₹15,000 – ₹1,00,000 per unit**
- New source augmentation – **₹50 lakh – ₹5 crore**
- Treated wastewater reuse – **₹1 – ₹10 crore**
- Managed Aquifer recharge – **₹20 lakh – ₹2 crore**

If Leakages is High:

- Smart Sensors **(₹1,100 – ₹1,800 per unit)**
- DMA zoning **(₹10,000 – ₹1,80,000 per unit)**
- Leak detection program **(₹10–50 lakh annually)**
- Pipe replacement **(₹50 lakh – ₹10 crore)**

If Quality is Poor:

- Treatment upgrade **(₹50 lakh – ₹3 crore)**
- Online monitoring **(₹10 – ₹50 lakh)**
- Chlorination automation **(₹5 – ₹25 lakh)**

If Demand is High:

- Smart metering **(₹3,000 – ₹10,000 per connection)**
- Tariff reform **Minimal CAPEX –policy driven**
- Water-saving fixtures **(₹500 – ₹5,000 per unit)**
- Awareness Programs **(₹5 – ₹20 lakh)**

If Governance is Weak:

- SCADA system **(₹50 lakh – ₹2 crore)**
- Capacity building **(₹10 – ₹50 lakh)**
- PPP / O&M Contracts **Variable (performance-based)**

STEP 4 : Action Plan, Costing & Financing

CapEx estimation (infrastructure, technology) , OpeEx estimation (O&M, staffing, energy), Phased investment (Short / Medium / Long term), Cost prioritisation

Comparative Assessment of Urban Water Security: Gandhidham vs Ichalkaranji

GANDHIDHAM

State: Gujarat
District: Kachchh
City: Gandhidham
Tier: Tier 3

- Major economic hub linked to **Kandla/Deendayal Port**, logistics, warehousing, salt, engineering
- Semi-arid / dry climate
- Low rainfall **(~250–500 mm)**
- Fast-growing urban-industrial town
- Water demand rising due to urbanization + commerce

11 / 35 **WATER INSECURITY**

Water Supply Context

- Heavy dependence on **Narmada bulk water transfer**
- Supplemental groundwater historically used
- Local freshwater sources limited

Issues & Challenges

SOURCE RELATED
- Dependance on distant external source
- Heavy dependence on external bulk transfer system creates supply risk
- Limited local storage

GROUNDWATER RELATED
- Salinity ingress
- Declining groundwater quality/ availability

SERVICE RELATED
- Intermittent supply
- Tail-end pressure issues

GOVERNANCE RELATED
- Limited smart monitoring
- NRW/leakage concerns

Framework Diagnosis

Source-Stressed + Climate-Stressed City

Recommended Solutions

Immediate Action
Leak detection in bulk pipeline/network, Pressure management, Universal metering in high-use areas

Mid Term Action
Managed aquifer recharge, Treated wastewater reuse for industry/commercial users, Smart reservoir/storage monitoring

Long Term Action
Source diversification, Modular desalination (buffer supply if viable), Full SCADA monitoring system

ICHALKARANJI

State: Maharashtra
District: Kolhapur
City: Ichalkaranji
Tier: Tier 3

- Known as major **textile / powerloom city**
- Higher rainfall zone **(~800–1000 mm)**
- Strong industrial economy
- Dense urban settlement + industrial demand

14 / 35 **MODERATE SECURITY**

Water Supply Context

- Major dependence on **Panchganga River**
- Limited secondary backup source

Issues & Challenges

DEMAND RELATED
- High industrial water demand
- Growing urban population pressure

DISTRIBUTION RELATED
- Intermittent supply
- Short supply duration
- Leakage / NRW

SUPPLY RELATED
- High dependence on single river source
- Seasonal variability possible

GOVERNANCE RELATED
- Need stronger digital monitoring and asset planning

Framework Diagnosis

Service-Stressed + Demand-Stressed City

Recommended Solutions

Immediate Action
DMA zones, Smart consumer and industrial metering, Complaint redressal dashboard

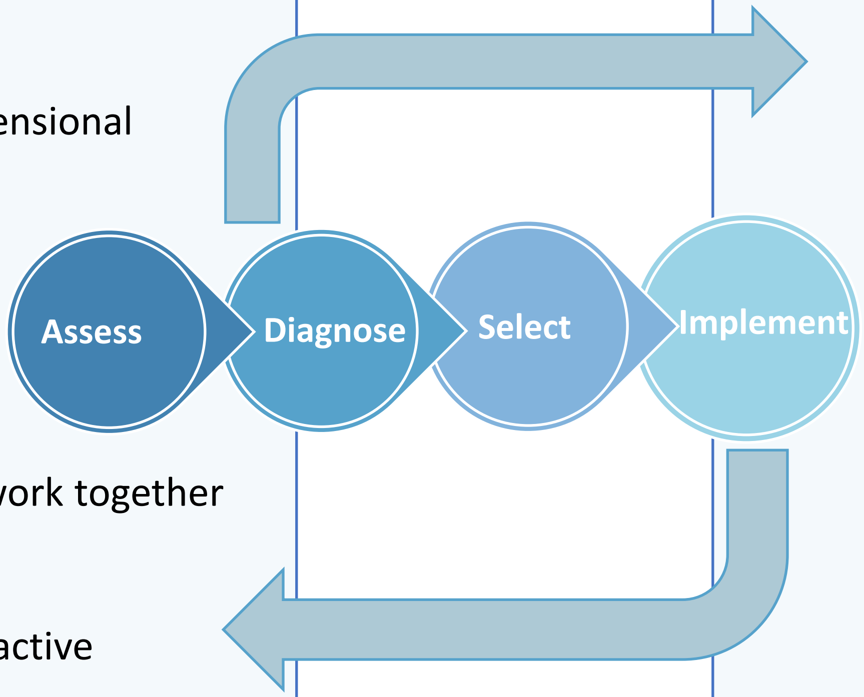
Mid Term Action
SCADA automation, Pressure management valves, Leak reduction program

Long Term Action
Treated wastewater reuse network for textile sector, 24x7 phased water supply, Digital twin for network planning

Source : Sareshwala, Y. (2024). *Strategies for transitioning from intermittent to 24×7 water supply*, Center for Water and Sanitation (CWAS). (2024). *Moving towards water secure and climate resilient cities: Gandhidham water security action plan* and Primary data of CWAS

KEY CONCLUSIONS

- **Multi- Dimensional Stress**
  Urban water stress is multi-dimensional
- **Insufficient Systems**
  Conventional systems alone are insufficient
- **Integrated Solutions**
  Technology+ Governance must work together
- **Proactive Planning**
  Need proactive planning over reactive response



PRACTICAL RELEVANCE OF FRAMEWORK

- **Systematic Diagnosis**
  Helps ULBs diagnose water issues systematically
- **Technology Selection**
  Supports selection of suitable technologies
- **Phased Planning**
  Enables phased planning & budgeting
- **Tier Applicability**
  Applicable for Tier 3 Indian cities
- **Dashboard Conversion**
  Can be converted into dashboard/ toolkit

" The future of urban water security lies not in building more infrastructure, but in making smarter decisions."

This framework transforms urban water planning from reactive crisis management to proactive decision-making

THANKYOU