Planning Framework for Ageing Drainage Infrastructure in Indian Cities

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AGEING DRAINAGE INFRASTRUCTURE

Ageing is *not* just a function of time,
It is a vulnerability based on **temporal and functional** factors.
Impact is multi dimensional.

Ageing drainage = Design from the past + stresses of the present + lack of renewal

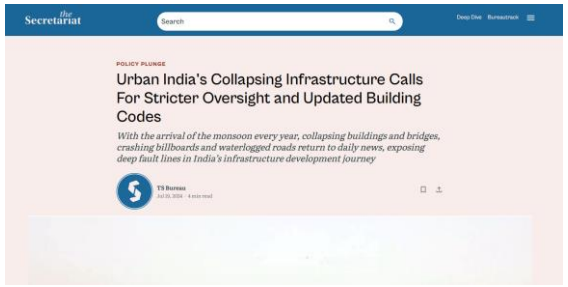
Urban drainage infrastructure is critical

Drainage issues in cities

EXISTING SCENARIO

"Aging infrastructure and high utilization rates combined with extreme weather conditions brought by global warming increase vulnerability and frequent failures during disasters."*Dong, B., Ding, S., Wu, L., & Li, X. (2025) Short-term natural disaster impacts on transportation infrastructure (2025)*

- Outdated
- Urban-Flooding
- Overdevelopment
- Sewage-Mixing
- Clogging & Failure
- Impermeability
- Eco-Deficit
- Poor maintenance



Road cave-ins: Officials blame ageing drainage system, but locals fault battered roads

Siddanth Nair / Aug 09, 2025, 03:16 IST

Hyderabad: The recent incident in which a water tanker fell into a drain after the road caved-in following heavy rainfall at Roah Number 1 in Banjara Hills is not a one-off case in the city.

Reports pointed out that Hyderabad has witnessed at least 15 similar incidents in recent years, particularly in areas such as Goshamahal, Malakpet, Himayatnagar, Kukatpally and Banjara Hills.

In some areas, it has even happened more than once. Goshamahal, for instance, has experienced at least six cases of roads caving in. Malakpet recorded at least two cases, while Banjara Hills saw three, including the recent incident.

You Can Also Check: Hyderabad AQI | Weather in Hyderabad | Bank Holidays in Hyderabad | Public Holidays in Hyderabad

New drainage system for Delhi need of the hour

Siddhanta Mishra & Atul Mathur / TNN / Updated: Jun 30, 2024, 07:50 IST

Retired IAS officer Ramesh Negi emphasized the city's faulty drainage system, worsened by unplanned colonies, as a major concern.

NEW DELHI: Heavy downpour and subsequent waterlogging on Friday has brought focus back on the need to overhaul the city's drainage system. Union home minister Amit Shah held a meeting with senior Delhi officials on Saturday to discuss the issue of waterlogging and find a solution to the nagging problem that returns to haunt the people of the city every time it rains heavily.

While Shah directed the officials to maintain inter-

Delhi finalizes storm water drainage master plan for climate resilience and urban sustainability

Sep 12, 2025, 23:42 IST

New Delhi: In a major move to rid the city of its perennial problems with rainwater, Delhi govt has finalised a futuristic stormwater drainage master plan. The project report prepared by PWD incorporates the use of advanced technologies and global best practices aims to address the chronic waterlogging, urban flooding and infrastructure stress, issues that have gained significance in an era of climate change and rapid urbanisation.

The master plan marks a significant upgrade from the outdated 1976 plan, with the latest study incorporating state-of-the-art tools like ArcGIS, SewerGEMS and SWMM. These technologies have been used to create a unified, integrated model of Delhi's stormwater system, connecting existing drains, waterbodies, wetlands and green spaces. The goal is to optimise existing infrastructure while ensuring long-term climate resilience, urban safety and improved quality of life, according to a govt official.

"Urban drainage systems in many Indian cities are outdated and suffer from poor maintenance, leading to frequent waterlogging and flooding during monsoon seasons."
— Kumar & Gupta, 2021, Environmental Monitoring and Assessment

AGENDA

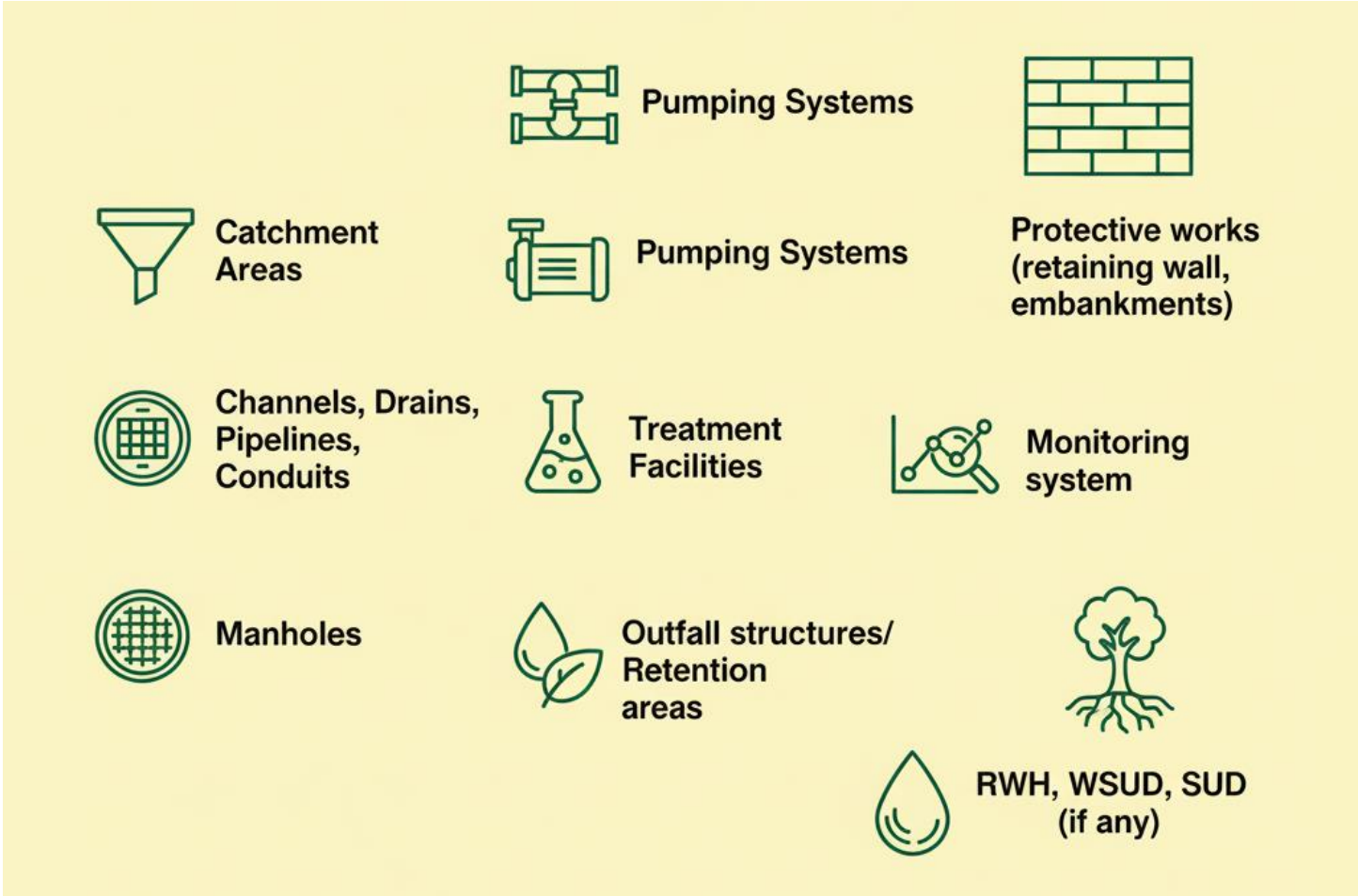
Develop an assessment framework for aging drainage infrastructure and its impact on resilient city planning

URBAN DRAINAGE INFRASTRUCTURES

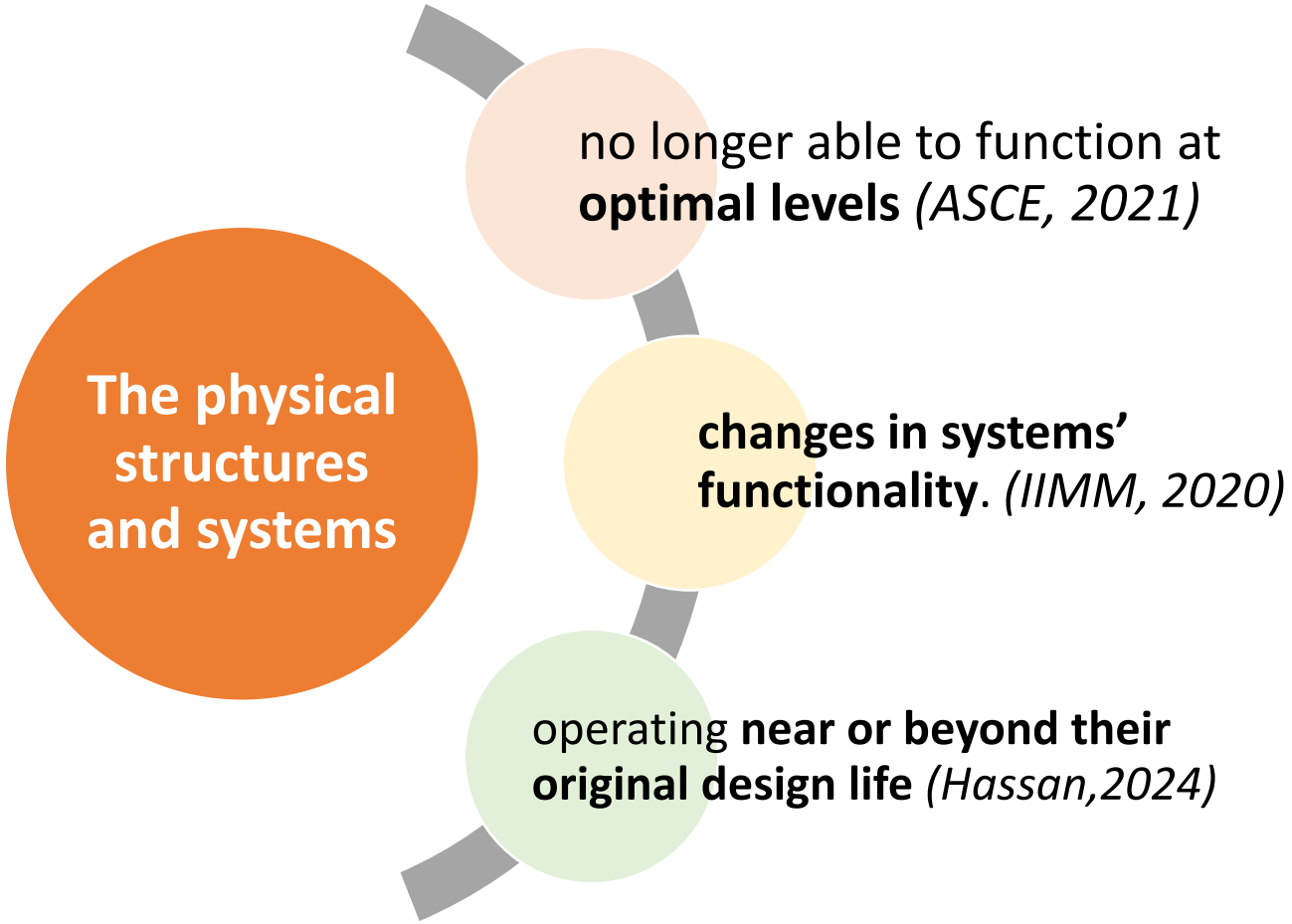
(UDI)–

Integral systems that **collect, convey, mitigate floods, collects water.**

COMPONENTS



WHAT IS AN AGEING INFRASTRUCTURE?



End of Design Period (CPHEEO)

- Over 15-30 years old
- Physical damage and performance drop
- Aging at 70-80% design life or frequent failures

Design life	Service life
• effective and safe use period	• actual time structure remains functional

ISO 15686-1:2011

EFFECTS OF AGEING

Ageing = loss of service

Ageing drainage = Progressive erosion of capacity, condition and service level

INCREASED FAILURE FREQUENCY
(Breaks, Collapses, Outages, Safety Risks)

VULNNABILITY TO CLIMATE STRESSORS
Intense Rainfall, Heat, Sea-Level Rise

HIGHER LIFECYCLE COSTS
(Reactive Maintenance, Emergency Repairs

REDUCED SERVICE RELIABILITY & PERFORMANCE
(Delays, Pressure Loss, Leakage

PUBLIC HEALTH IMPACTS
(Contamination, Disease Spread

ECONOMIC LOSSES
(Downtime, Supply Chain Distruption

ENVIRONMENTAL IMPACTS
(Leaks, Spills, Emissions, Contamination

CAPACITY SHORTHALLS
(Demand Exceds Design)

REGULATORY NON-COMPLIANCE & REPUTATION RISK

"Premature deterioration can lead to a Service Life that impedes the designed life and excessive maintenance, rehabilitation or, in the worst case, replacement before the Design Life has been served." *Collins, F., & Blin, F. (2020)). Ageing of infrastructure: A life-cycle approach*

"Aging infrastructure is prone to accelerated deterioration due to fatigue, wear and tear, and more intense responses to higher stress levels during natural hazards." *Wake Up Call: Enhancing Infrastructure Resilience to Survive Natural Disasters (2024)*

Source - Paul, M., & Polprasert, C. (2008). Sustainable Drainage Systems: Planning, Design and Maintenance.

FACTORS AFFECTING THE AGEING PROCESS

Ageing drainage = Design from the past + stresses of the present + lack of renewal

Physical And Structural	Environmental And Climate	Operational And Maintenance	Urban Development	Material And Design	Management
Mechanical Wear	Chemical Attack	Clogging	Increased Imperviousness	Material Susceptibility (Concrete, Clay, Cast-iron)	Funding Limits
Load/Fatigue	Corrosion	Inadequate Inspections	Capacity Growth	Pipe Size	Lack Of Prioritisation
Cracks, Collapses	Groundwater Effects	Reactive Maintenance	Encroachment On Channels	Slope	Inadequate Data
Root Intrusion	Salt	Late Rehabilitation	Lack Of Segregated Drains	Construction Defects	Governance And Lack Of Asset Management
Joint Movement	More Frequent Intense Rainfall And Flooding			Capacity Under Sizing	

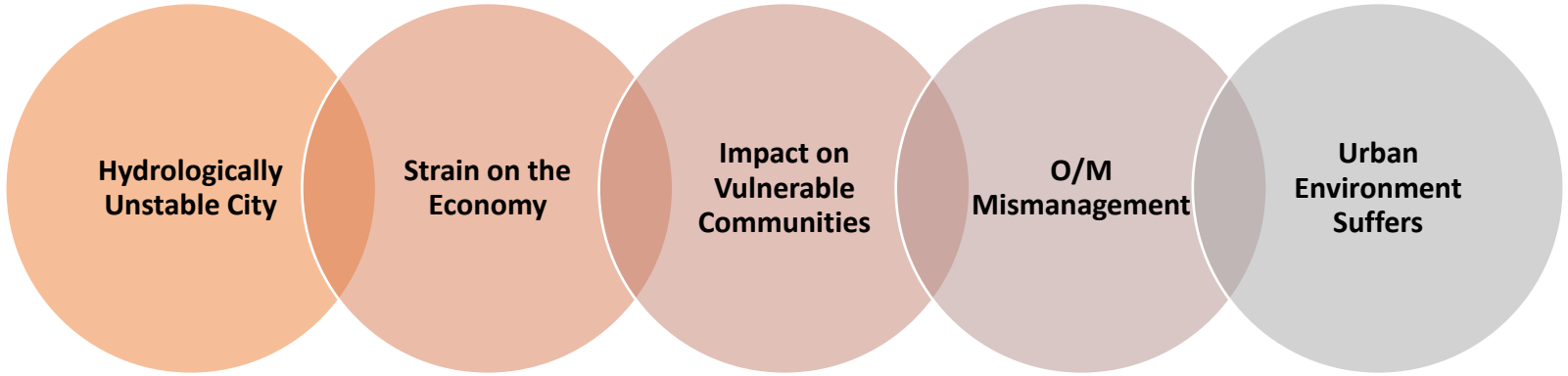
Source : Barraud, S., Bosco, E., & Suiker, A.S.J. (2024). 'Deterioration processes and modelling in urban drainage systems'.

MULTI DIMENSIONAL IMPACTS OF THE AGEING PROCESS

Hydrological & Structural	Health & Environmental	Economic & Infrastructure	Social & Spatial Inequity	Governance Failure
• Physical breakdown • Reduced capacity causing micro-floods	• Sewage intrusion • Disease spread	• Recurring costs • Disrupts transport and trade	• Vulnerable low-income areas • Unequal response	• Reactive maintenance • Fragmented data

DIRECT IMPACT

URBAN OUTCOMES



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NATIONAL DESIGN NORMS

CPHEEO

Design & operational norms (rainfall, velocity, slopes, return periods)

IS STANDARDS

Key IS clauses (1743, 3370, 4091, 456) for durability & safety

STORM WATER MANAGEMENT INDICES

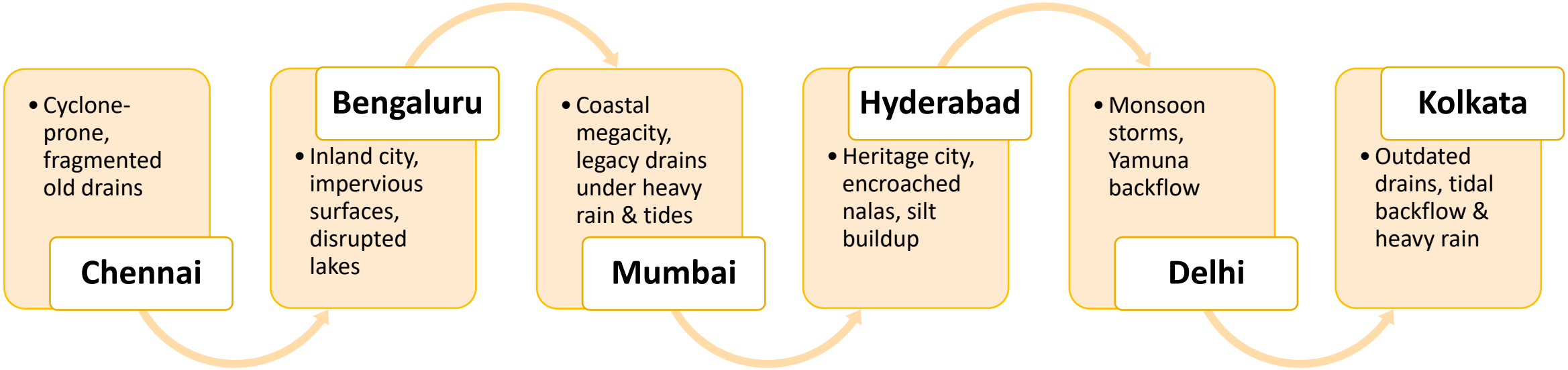
Covers core capacity, environment, system integration, risk & governance

- Ideal value
- High and Moderate vulnerability

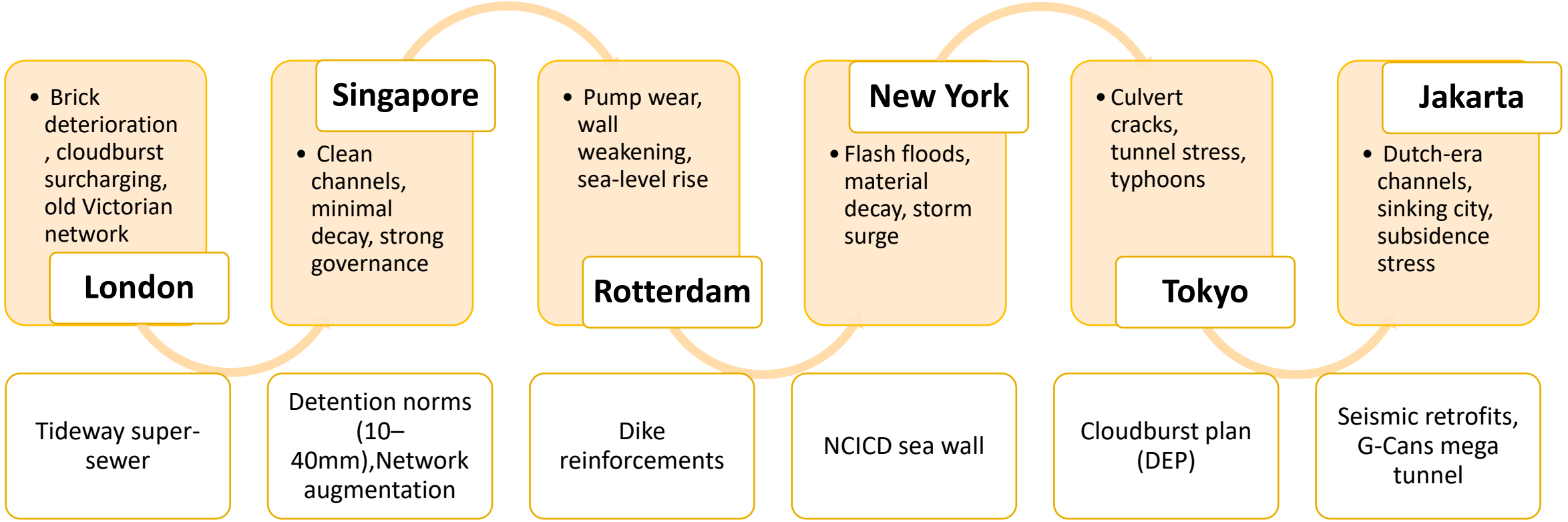
INTERNATIONAL DESIGN NORMS

ISO – Asset Management Standards	SINGAPORE PUB-Drainage Design & Flood Protection Standards	US EPA- SWMM Hydraulic Norms
Digital asset inventory, risk-based renewal, lifecycle planning	Runoff detention, real-time sensors, 100-year storm resilience	Limits on flow, ponding, and velocity to prevent ageing

NATIONAL CASE STUDIES



INTERNATIONAL CASE STUDIES



INFERENCES

Ageing faster

- Jakarta (fastest)
- Mumbai
- Chennai
- Delhi
- Kolkata
- Bengaluru
- Hyderabad

Ageing slower

- London
- Tokyo
- Rotterdam
- Singapore (slowest)- **fast recovery**

Drainage ageing is diverse and context-specific.

Asset age amplifies risk but does not define it.

Performance decay precedes physical failure.

Urbanisation accelerates functional ageing.

Coastal and tidal cities face compound stresses.

Sediment-heavy basins develop hybrid ageing.

Where Cities Still Fail

- Unplanned growth
- Subsidence
- Outdated drainage
- River backflow
- Fragmented governance
- Weak maintenance.

Working Interventions

- Bigger tunnels + pumps, revive lakes/wetlands
- Smart sensors, strict land use
- Nature-based solutions,
- Unified governance

Governance strength determines ageing pace.

Cities age **more** when **stress is high and management is weak**.

Cities age **less** when **stress is absorbed by strong governance + redundancy + proactive maintenance**.

HOW TO UNDERSTAND IF IT IS AGEING ?

A. Evidence of Ageing

Material condition & Performance Decline of the drainage infrastructure.

Factual & measurable = shows ageing

- **Structural Ageing**
- **Functional / Hydraulic Ageing**

B. Drivers of Ageing

Drivers are **stressors** and **pressures** acting on the network.

Contextual = explain why its ageing

- **Environmental & Climate**
- **Urban & Land-Use**
- **Material & Design**
- **Operational & Maintenance**
- **Governance & Institutional**

C. Consequence

These are **urban-scale impacts** visible to people

Socioeconomic & environmental = urgency in tending to

- **Urban Flooding**
- **Public Health**
- **Infrastructure Damage**
- **Environmental Degradation**
- **Social Vulnerability**

ASSESSMENT FRAMEWORK

TO DETECT AGEING DRAINAGE INFRASTRUCTURE IN A CITY

Ageing Drainage Infrastructure ***indirectly*** — doesn't appear physically first , it appears **functionally** .

CONSEQUENCE → **DRIVER** → **EVIDENCE**

CONSEQUENCE	DRIVER	EVIDENCE
Identify *where* symptoms appear	Diagnose *why* it happens	Confirm *how much* ageing exists
Consequence-Based Identification of Suspected Ageing Zones	**Verification of Ageing Drivers**	**Confirmation Using Quantifiable Ageing Indicators**

Suspected Ageing Zones

flood hotspots, slow drainage, surcharging, repeated desilting, contamination, pump/outfall issues, waterlogging

City Ageing Signatures –

Coastal, river, floodplain, old-core, peri-urban, industrial, arid, subsidence-prone, and inland cities each show characteristic drainage ageing patterns.

Ageing Drivers – Indicator of which type of ageing

Structural

- Cracks, corrosion, >40 yrs

Environmental

- Silt, salinity, rainfall > design

O&M

- Poor maintenance, reactive repairs

Urbanisation

- Impervious surfaces, encroachments

Design/Material

- Undersized, wrong slope, legacy materials

Management

- Low budget, fragmented agencies

Quantifiable Ageing Indicators – 35 indicators

A. Structural Condition

- Siltation (%)
- Cross-section loss
- Crack / defect score
- Joint displacement
- Surface corrosion (Manning n ↑)
- Material durability exposure
- Age of structure

B. Hydraulic & Functional Condition

- Hydraulic Stress Ratio (HSR)
- Velocity Adequacy Index (VAI)
- Self-cleansing velocity
- Surcharge frequency
- Drain-down time
- Peak flow / capacity ratio
- Waterlogging duration
- Depth × Velocity criterion

C. Mechanical / Outfall Condition

- Pump efficiency
- Pump evacuation time
- Outfall submergence
- Backflow events

D. Environmental Condition

- Sewage mixing
- TSS / BOD (stormwater quality)
- Groundwater infiltration

E. Urban Context Indicators

- Imperviousness (%)
- Natural drain connectivity (%)
- Waterbody storage / rejuvenation index
- Drainage coverage (%)
- Catchpit / inlet spacing compliance

F. Stressor Indicators

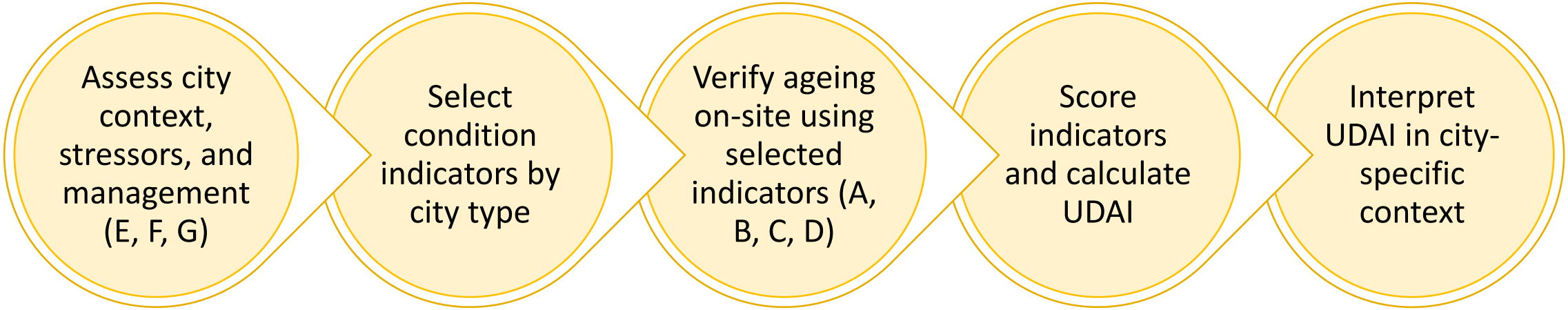
- Encroachment on drains (%)
- Upstream runoff / discharge mismatch (%)
- Climate stress index
- Runoff coefficient change (pre/post development)
- Industrial chemical exposure (pH / chlorides)

G. Management Indicators

- Complaint redressal rate
- Budget adequacy
- Renewal backlog (%)
- O&M staffing adequacy
- IDF update frequency

Criteria for selecting Ageing Indicators

City type determines which condition indicators matter most.



Context specific – Ageing threshold for drivers – E,F,G

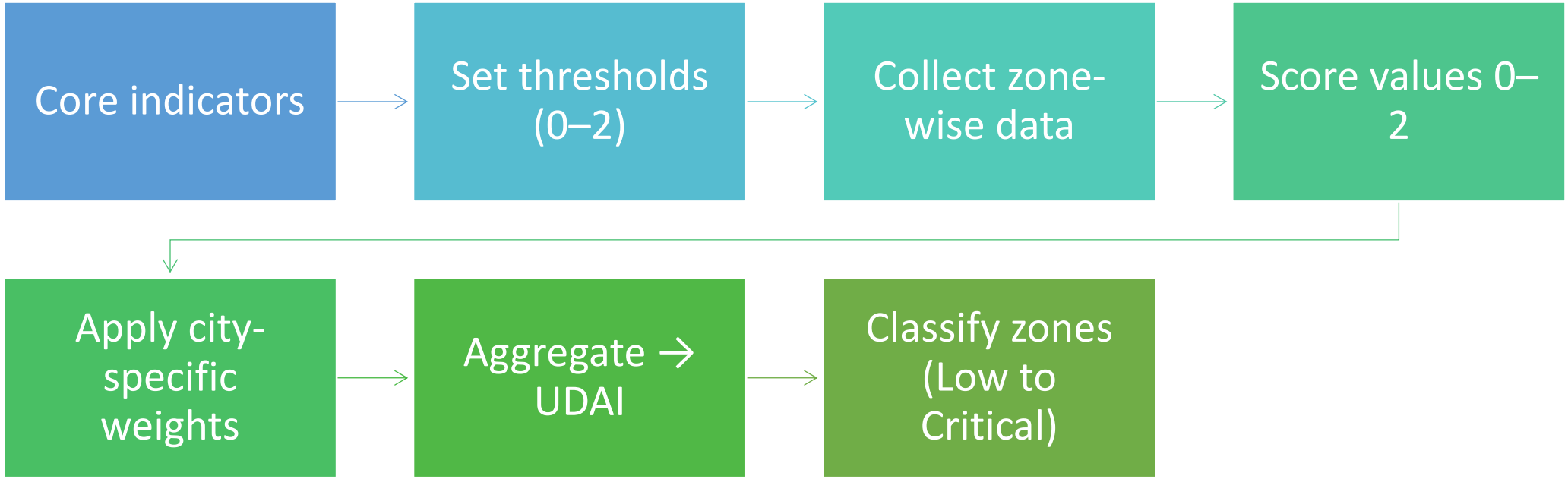
URBAN CONTEXT	
Indicator	**Value**
Imperviousness	> 50%
Natural drain connectivity	< 50%
Waterbody storage	< 50% functional
Drainage coverage	< 50% built vs required
Inlet spacing compliance	< 50% compliant

STRESSORS	
Indicator	**Value**
Encroachment	> 25% width lost
Discharge mismatch	> 30% overload
Climate stress	> 1.2 × design rainfall
Runoff coefficient change	ΔR > 0.4
Chemical exposure	> 1.5× durability limits

MANAGEMENT	
Indicator	**Value**
Complaint redressal	< 50% addressed
Budget adequacy	< 50% of required
Renewal backlog	> 25% assets overdue
Staffing adequacy	< 50% of norm
IDF update	> 15 years

TO MEASURE AGEING DRAINAGE INFRASTRUCTURE IN A CITY

Urban Drainage Ageing Index (UDAI)



Score card – A,B,C,D

Structural Condition Indicators			
Indicator	**Score 0 (Good)**	**Score 1 (Moderate Ageing)**	**Score 2 (Severe Ageing)**
Siltation %	< 30%	30–50%	> 50%
Cross-section loss	< 10%	10–25%	> 25%
Crack / defect score	Hairline / superficial	Moderate cracks	Structural cracks / fractures
Joint displacement	< 5 mm	5–15 mm	> 15 mm
Surface corrosion (n ↑)	n increase < 10%	n increase 10–25%	n increase > 25%
Material durability exposure	Low sulphate/chloride	Medium exposure	High exposure
Age of structure	< 20 years	20–40 years	> 40 years

Hydraulic & Functional Indicators			
Indicator	**Score 0 (Good)**	**Score 1**	**Score 2 (Severe)**
Hydraulic Stress Ratio (HSR)	< 0.7	0.7–1.0	> 1.0
Velocity Adequacy Index (VAI)	≥ 1.0	0.75–1.0	< 0.75
Self-cleansing velocity	≥ 0.6 m/s	0.45–0.6 m/s	< 0.45 m/s
Surcharge frequency	0–1 events/year	2–5 events/year	> 5 events/year
Drain-down time	< 30 min	30–60 min	> 60 min
Peak flow / capacity ratio	< 0.8	0.8–1.0	> 1.0
Waterlogging duration	< 1 hour	1–3 hours	> 3 hours
Depth × Velocity criterion	Within stable range	Occasional exceedance	Frequent exceedance

Mechanical & Outfall Indicators			
Indicator	**Score 0**	**Score 1**	**Score 2**
Pump efficiency	> 70%	50–70%	< 50%
Pump evacuation time	< 30 min	30–45 min	> 45 min
Outfall submergence	< 5% time/year	5–20%	> 20%
Backflow events	None	1–3 per year	> 3 per year

Environmental Indicators			
Indicator	**Score 0**	**Score 1**	**Score 2**
Sewage mixing	< 10% drains	10–30% drains	> 30% drains
Groundwater infiltration	< 10% dilution	10–25%	> 25%
Stormwater TSS/BOD	Within norm	Slight exceedance	Major exceedance

$$\text{Urban Drainage Ageing Index} = \frac{\sum (\text{indicator score} \times \text{weightage})}{\text{no. of indicators}}$$

0.00 - 0.60	0.60 - 1.20	1.20 - 1.60	> 1.60 - 2.000
Low Ageing	Moderate Ageing	High Ageing	Critical Ageing

Weightage- More weight to indicators with more ageing drivers per city type.

LINKAGE TO INTERVENTIONS

Structural ageing	**Physical rehabilitation**
Hydraulic ageing	**Flow-capacity improvements**
Mechanical ageing	**Outfall and pump upgrades**
Environmental ageing	**Contamination control & source management**

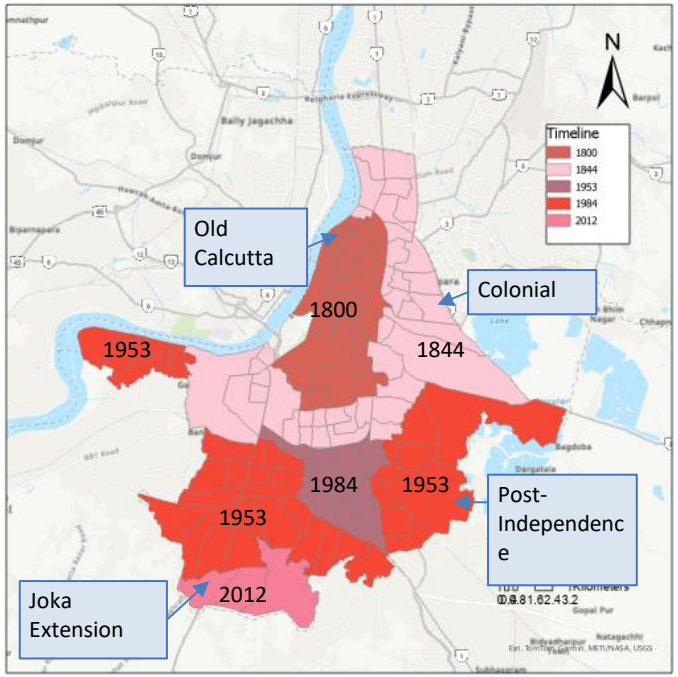
DEACCELERATING AGEING

Urban Context	Reduce load, restore waterbodies, add micro-SuDS, improve inlets
Stressors	Limit inflow and encroachment, add upstream infiltration
Management	Improve O&M, inspections, IDF updates, digital monitoring
Monitoring	Evaluate, adjust, update UDAI, repeat

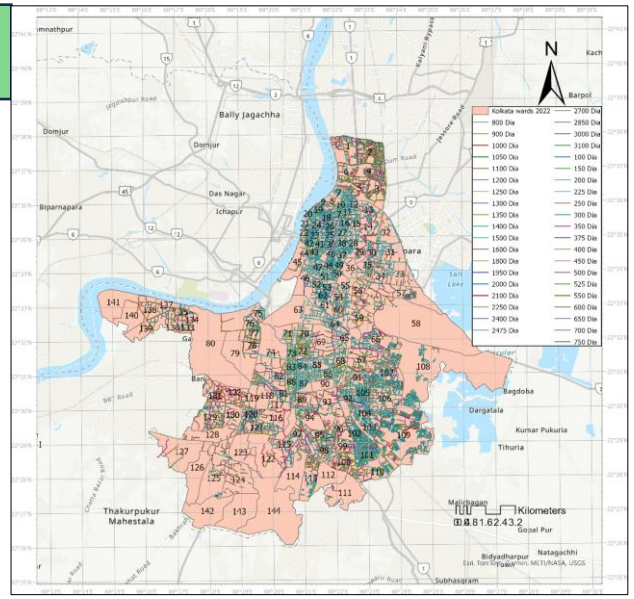
KOLKATA

Why Kolkata Is a Critical Case for Ageing Urban Drainage ?

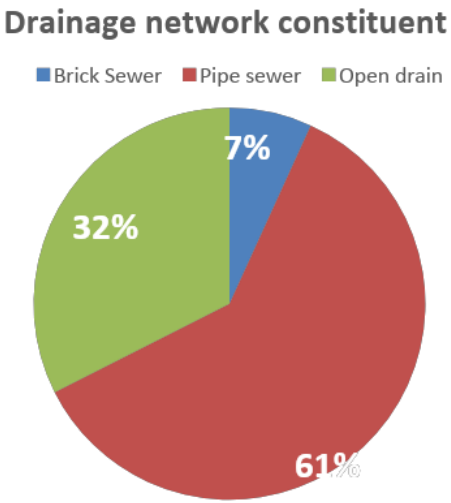
- Legacy Drainage Network
- Low-Lying Deltaic Terrain
- High Urban Density & Growth
- Dense Heritage & environment

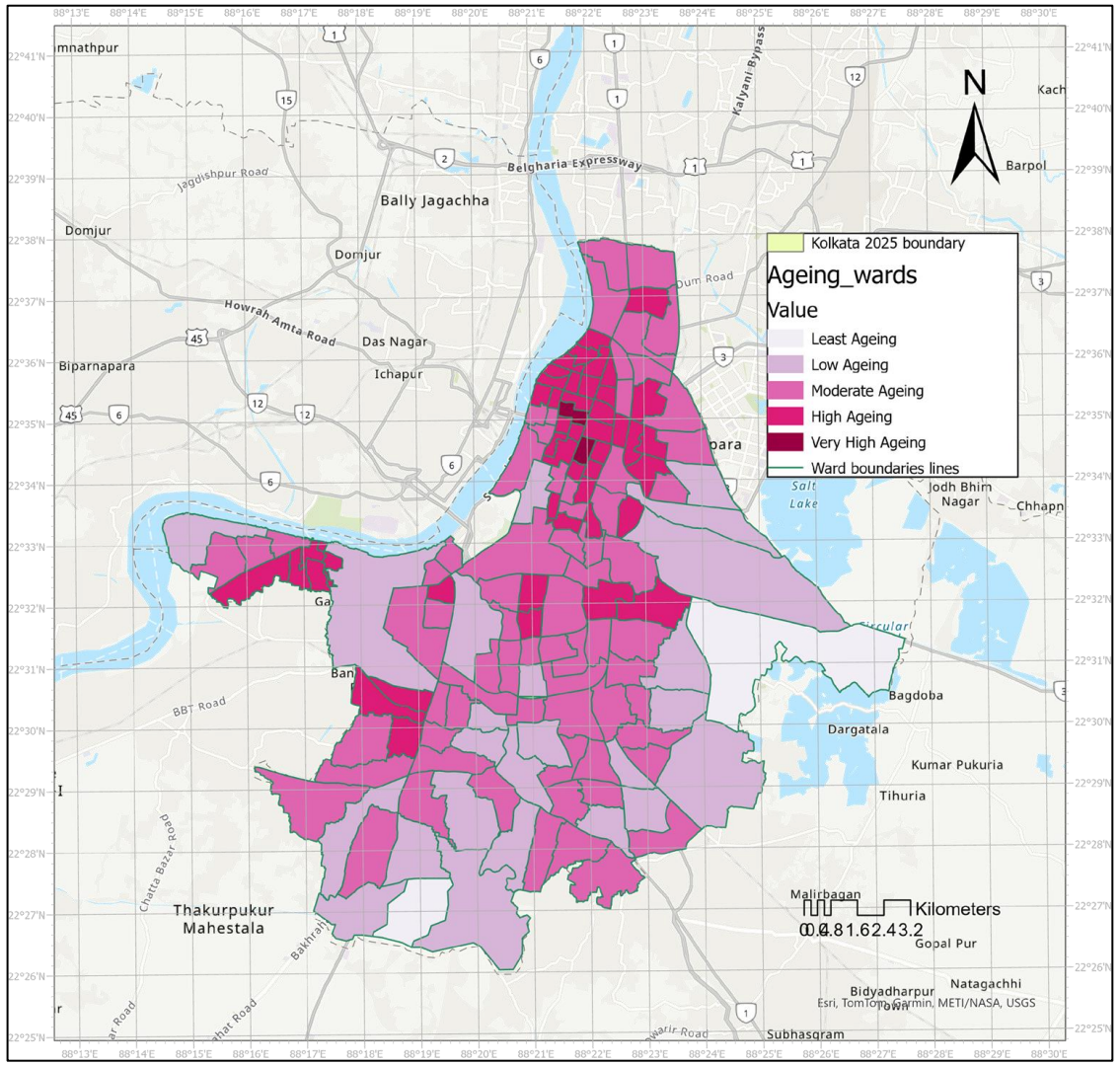


EVOLUTION



DRAINAGE NETWORK





AGEING WARD WISE

Thank You

WASH Economics Conference 2026

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CEPT UNIVERSITY FACULTY OF PLANNING

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