INDIA WATER SYSTEMS ATLAS

UTTAR PRADESH

THE ABRIDGED VERSION

The master abridged reading of Part A, Part B and Part C

Nine clusters, seven active nodes — the impact, the remedy, the verdict

G. L. Sudhakar

Contents

The Proposition 6
How This Volume Is Built 8
How This Volume Is Built — The Thirty-Domain Method 11

THE NODES — The Cities Where the Crisis Is Felt 28

N1 Lucknow 29
N2 Kanpur 33
N3 Prayagraj 37
N4 Varanasi 41
N6 Gorakhpur 46
N7 Meerut 50
N8 Ghaziabad–Noida 54

THE CLUSTERS — The Water Systems Beneath 58

C1 Terai 59
C2 Western Extraction 63
C3 Upper Central 67
C4 Awadh 71
C5 Eastern Flood-Quality 75
C6 Bundelkhand 79
C7 Yamuna System 83
C8 Vindhyan Ecology-Energy 87
C9 Middle Ganga 91
Traditional Water Hydrology 95
The Close 97
The State Verdict 99
References 100

The Proposition

Uttar Pradesh's water crisis is, at root, not a scarcity problem but a system-disconnection problem. Parts of the state are genuinely water-short; but even there, the deeper failure is that the water system — the rock that holds water, the soil that lets it through, the rivers and canals that move it, the rain that recharges it, the crops and industries that drink it, the forests that protect the catchment — is managed in separate pieces while the water itself is one connected thing. The groundwater officer does not sit with the irrigation engineer; agriculture does not plan with power; the urban water body does not reconcile its leaking pipes with the aquifer those leaks force open. Seven hands manage the water of a district, and they never share a table.

The full Uttar Pradesh Atlas reads the state across thirty water-system domains — climate, geology and geomorphology, rivers, floods, dams, groundwater and aquifers, quality, soil, agriculture, irrigation, consumption, urbanisation, forests, ecology, population, industry and energy, governance and future risk. Water is the outcome of those domains interacting, not a number to be read off in isolation. This volume is built on that whole picture: it states the water condition, then the domains that produce it — the supply set in the geology and climate, the demand driven by crop, power and population, and the delivery failures, urban and rural, that convert a manageable system into a crisis.

Read as one state average, Uttar Pradesh looks uniformly stressed. Read by how its land actually behaves as a water system, it resolves into something far more useful: not one crisis but four, each with a different mechanism and a different remedy — recharge collapse in the hard-rock south, extraction excess in the western plain and the Yamuna corridor, quality failure in the east, and urban concealment along the Ganga cities — set against one genuine asset, the Terai recharge front. The single most damaging thing that can be done to this state's water is to treat it as one problem and apply one rule.

This is the combined, abridged reading of Parts A, B and C of the Uttar Pradesh Atlas — the architecture, the diagnosis, and the transformation — drawn together so the whole argument can be carried in one volume. It is built on one discipline above all: honesty about evidence. Every headline figure here matches the value recorded in the Atlas source register, traceable to the agencies named in the references — chiefly the Central Ground Water Board's GWRA-2024 assessment for groundwater. Where a number is measured, it is shown and sourced; where a trend is documented but no firm value exists, the direction is given and the absence is marked rather than filled. Nothing in this volume is asserted that the evidence volumes did not first establish.

How This Volume Is Built

Before the evidence, the architecture — because the order in which Uttar Pradesh is read determines what can be seen. The Atlas reads the state through two kinds of unit: nodes and clusters. This volume presents the nodes first and the clusters second, deliberately. The nodes are the cities, where the crisis is felt, where the population concentrates, and where the decisions are taken; the clusters are the water systems underneath, which explain why each city's water behaves as it does. Beginning at the capital and the great cities is beginning where the reader already stands; the clusters then supply the system logic that makes the urban crisis legible.

The node — the city as a water unit

Seven cities are read as active nodes because their water behaviour is governed by urban density rather than by the character of the cluster around them. They are N1 Lucknow, N2 Kanpur, N3 Prayagraj and N4 Varanasi (in the Middle Ganga cluster); N6 Gorakhpur (in the

Eastern cluster); and N7 Meerut and N8 Ghaziabad–Noida (in the Western cluster). The fifth node position, N5, is deliberately left vacant and is never renumbered: the gap preserves the integrity of the eight-position frame as the architecture was set, and is itself part of the record. Each node is read at the block level, beneath the district average — because the district average is precisely where an urban crisis hides.

The cluster — the land as a water system

The seventy-five districts are grouped into nine hydro-geographic clusters, formed not by administrative convenience but by how the land actually behaves as a water system. Districts join a cluster when they share the same water mechanism: the same geology, the same recharge behaviour, the same dominant stress. Nine clusters emerge from the state's real hydrological structure, running as a transect of the Indo-Gangetic plain from the recharge-rich Himalayan foreland in the north to the hard-rock Vindhyan margin in the south.

The equation beneath the map — and the demand on top of it

The logic that cuts the map is physical. Water outcome is the product of three things on the supply side: geomorphology — the shape and slope of the terrain, which decides whether rain lingers long enough to soak in or runs off; soil condition, which decides whether the water that pauses can pass into the ground; and lithology, the rock beneath, which decides whether what gets through is stored or lost. But the outcome is set as much by the demand placed on that supply: the cropping pattern and the irrigation it requires, the price of the power that lifts the water, the population and industry concentrated on it, and the delivery systems — the urban pipe and the rural canal — that decide whether demand is met from the surface or punched into the aquifer. Rainfall and reservoir levels are measured; the conversion efficiency of the landscape between them, and the demand-and-delivery system on top of it, are not. That is the disconnection at the centre of the whole Atlas.

Two delivery failures that recur

Two mechanisms appear so often across the nodes and clusters that they are worth naming once, here. In the cities, the piped supply network does not reach everywhere, and where it does it leaks — Meerut's non-revenue water, the share lost before it reaches a tap, runs at about 65%, the highest in the state. Every litre the pipe fails to deliver is made up by a private borewell drawing on the over-drawn block, so unchecked urban groundwater mining is, at root, a piped-supply failure. In the countryside, the canal system exists but its last-mile distribution fails: tail-end farmers do not reliably receive surface water, so they pump groundwater instead, and the surface buffer that should relieve the aquifer never reaches the field. Fix the pipe and the canal last mile, and a large part of the groundwater draw simply stops having a reason to exist.

The measure of stress

Where this volume calls a cluster or the state water-stressed, the judgement rests on the Falkenmark Index — the most widely used international measure of water stress, expressed as cubic metres of water available per person per year. The figure for each cluster is computed, not asserted: the numerator is the annual groundwater recharge for the cluster, taken from the Central Ground Water Board's district resource assessments, and the denominator is the cluster population. Below 1,700 m^3 per person is stress; below 1,000 is scarcity; below 500 is absolute scarcity. Read this way, the state's institutional core turns out to sit in absolute scarcity on its best ground — the paradox this volume exists to explain.

The five-layer reading

Each unit — node or cluster — is read the same way, in layers: the data, the content the data describes, the narrative that connects it, the interpretation of what it means, and the conclusion of what must change. In this volume that method is compressed to three visible

beats per section: the Impact (the water condition and the domains — supply, demand and delivery — that produce it), the Remedy (what must change, and which hands must share the table), and the Verdict (the judgement in a single reading). Each section carries one image and about two pages of text, and is designed to stand on its own.

How This Volume Is Built — The Thirty-Domain Method

Before the evidence, the method — because how Uttar Pradesh is read determines what can be seen, and a reader (or a reviewer) is entitled to know the rule by which attention was allocated. This volume does not discuss every factor equally. It assesses the state across thirty water-system domains, grades each domain for how strongly it bears on water in each cluster, and then writes in proportion to that grade. The grading is stated here so the selection is transparent and auditable, not a matter of the author's taste.

The thirty domains

The Atlas reads water through thirty domains, spanning the supply base, the demand placed on it, the systems that deliver it, its quality, and the institutions that govern it. They are: Climate & Rainfall; Geology & Lithology; Geomorphology & Slope; Soil & Infiltration Capacity; Groundwater & Aquifers; Surface Water — Rivers; Floods & Floodplains; Dams & Reservoirs; Recharge Behaviour; Water Quality; Water Availability (Per Capita); Agriculture — Cropping Pattern; Irrigation — Systems & Efficiency; Water Demand — Agriculture; Urbanisation & Growth; Urban Water Supply & Delivery; Rural Water Supply & Delivery; Industry & Industrial Water Use; Energy — Power for Pumping; Ecology & Wetlands; Forests & Catchment; Soil Health & Land Degradation; Population & Demography; Livestock & Animal Water; Governance & Institutions; Finance & Funding Capacity; Data, Monitoring & Information; Climate Variability & Extremes; Risk & Future Vulnerability; Policy Implementation Capacity.

The one rule that governs every domain — the water vector

Each domain enters the analysis only through its effect on water — never on its own terms, and never on another domain. Agriculture enters as cropping pattern driving groundwater draw, not as farm output or rural income; energy enters as the price of pumping power driving extraction, not as the power sector; climate enters as rainfall driving recharge and temperature driving evaporative and crop-water demand, not as weather in general. The single question asked of every domain is: how does it act on the water — its usage, storage, recharge, or contamination? A domain may appear as a link in a chain only when that chain ends in water (higher temperature → higher crop-water demand → greater groundwater withdrawal is admissible; temperature's effect on crop yield, in itself, is not). Everything outside the water vector, however true, is outside this volume.

How each domain is graded

For every cluster, each domain is assigned an impact grade on a one-to-ten scale: High (7–10), a primary driver of that cluster's water outcome, treated in detail; Medium (4–6), a contributing driver, noted in proportion; and Low (1–3), a limited direct influence, assessed but not detailed because it does not materially move the outcome. Each unit — every node and every cluster — opens with a domain assessment table that sets out its load-bearing domains, each traced to its direct effect on surface water, canal supply and aquifer recharge, with the key figure, its honesty glyph, the remedy and the lead owner. A short climate-stress note follows, because temperature and rainfall compression change the trajectory: a hotter year raises crop-water demand and evaporation while the same annual rainfall, now compressed into roughly half the days, sharply cuts the infiltration window — and in cities a sealed surface with undersized drainage turns that compressed rain into flood, then tanker-borne scarcity. The grade then decides the prose: high-tier domains carry the detailed analysis, medium-tier noted in proportion, low-tier recorded in the table but not expanded.

Common background — stated once, not repeated

Some domains affect water similarly across the whole state and are stated here once as common background rather than repeated in every cluster: population growth, which raises water usage and draw everywhere; rising per-capita and domestic consumption; and baseline drinking-water demand. These are assumed throughout; the cluster analyses do not restate them, and instead foreground what is distinctive to each. Where a common-background domain becomes a primary driver in a particular cluster — as population does in the Middle Ganga institutional core — it is raised to detailed treatment there. Note that climate and rainfall is NOT treated as common background: it varies sharply by cluster (the high-rainfall Terai against arid Bundelkhand) and is therefore graded cluster by cluster like any other distinctive driver.

A note on the impact scores

The domain-impact grades and the dimension scores shown in the methodology plates are structured expert assessments of each domain's bearing on water security — analytical judgements, not measured quantities. They are offered as a transparent, consistent basis for prioritisation, not as data extracted from a source. Wherever a measured value is used in this volume — a groundwater stage, a rainfall figure, a depth — it is drawn from the Atlas source register and its named sources, distinguished by the honesty convention below. The two must not be confused: the scores rank importance; the Schema figures report measurement.

Domain groups — a second lens for prioritisation

For integrated assessment, the thirty domains are also organised into six functional groups (G1–G6) by their role in the water system, following the cycle from natural setting to institutional action: G1 Natural Foundation, the geology, soils, rainfall and recharge that

create and store water; G2 Resource Use & Demand, how water is drawn across agriculture, industry, households and energy; G3 Delivery Systems, the infrastructure that conveys and delivers it; G4 Ecological Balance, the wetlands, forests and flows that sustain long-term resilience; G5 Socio-Economic Context, the human and economic factors that shape demand and equity; and G6 Governance & Institutions, the policy, finance, data and accountability that enable action. Each domain is assigned to exactly one functional group by its primary water role, giving a clean partition of all thirty across the six groups — though several domains carry secondary influence elsewhere, which the domain assessment for each unit draws out where it bears on that unit's water story. These functional groups are kept deliberately distinct from the nine hydro-geographic clusters (C1–C9) that structure the rest of this volume; the two use different organising logics and should not be conflated.

From diagnosis to action

Finally, the priority domains are traced from diagnosis to action: each is linked to its key remedies, the body that must own them, the supporting institutions, and an implementation horizon, so that an identified impact resolves into a named responsibility on a stated timeline. The traceability framework in the methodology plates illustrates this for ten priority domains; the full document carries it across all applicable domains.

The honesty convention

Every measured figure in this volume is characterised, not merely stated. A sourced value carries its source. A value that is estimated is marked as an estimate. Where a firm value is genuinely absent, the gap is marked GAP and never filled by interpolation. Where data is drawn from an open or unverified source, that is flagged as a caveat rather than presented as established. The objective is not to claim that every number is exact — in India's water data environment no honest author could — but to be transparent about what each number is, so the larger argument rests on a pattern that is fairly represented rather than on any single figure.

A note on the node gauge dials. The semicircular gauge on each node plate is an illustrative dial; its coloured arcs are drawn on even quartiles (0–25 / 25–75 / 75–100 / >100). The governing classification, however, is the GWRA-2024 standard used throughout this volume: Safe ≤ 70%, Semi-Critical 70–90%, Critical 90–100%, Over-Exploited > 100%. Every node's stated stage value and its Safe / Semi-Critical / Critical / Over-Exploited label follow the GWRA-2024 bands, not the dial's quartile shading. Where the dial's arc colour and the GWRA label appear to differ, the GWRA label governs.

PLATE 1 OF 4 — METHODOLOGY PLATE — V4

UTTAR PRADESH WATER SYSTEMS
THE 30–DOMAIN FRAMEWORK



A UNIFORM SYSTEMS ASSESSMENT ACROSS ALL 75 DISTRICTS AND 9 GEOGRAPHIC CLUSTERS (C1–C9)

Thirty functional domains spanning natural systems, infrastructure, socio-economic factors, institutions and risks are assessed uniformly across all regions. These domains capture the multi-dimensioned drivers of water security and outcomes.

THE 30 DOMAINS

1. Climate & Rainfall
2. Geology & Lithology
3. Geomorphology & Slope
4. Soil & Infiltration Capacity
5. Groundwater & Aquifers
6. Surface Water – Rivers
7. Floods & Floodplains
8. Dams & Reservoirs
9. Recharge Behaviour
10. Water Quality
11. Water Availability (Per Capita)
12. Agriculture – Cropping Pattern
13. Irrigation – Systems & Efficiency
14. Water Demand – Agriculture
15. Urbanisation & Growth
16. Urban Water Supply & Delivery
17. Rural Water Supply & Delivery
18. Industry & Industrial Water Use
19. Energy – Power for Pumping
20. Ecology & Wetlands
21. Forests & Catchment
22. Soil Health & Land Degradation
23. Population & Demography
24. Livestock & Animal Water
25. Governance & Institutions
26. Finance & Funding Capacity
27. Data, Monitoring & Information
28. Climate Variability & Extremes
29. Risk & Future Vulnerability
30. Policy Implementation Capacity

SCORING GUIDE (IMPACT ON WATER SECURITY: 1–10 SCALE)

7 – 10	4 – 6	1 – 3	0
HIGH IMPACT (Critical Driver)	MEDIUM IMPACT (Moderate Driver)	LOW IMPACT (Limited Driver)	COMMON BACKGROUND* (Not a Primary Driver)

* Common background domains: Population & Demography, Governance & Institutions, Finance & Funding Capacity, Data, Monitoring & Information. These are enabling conditions that influence all domains but are not primary differentiators.

DOMAIN SELECTION LOGIC

Comprehensive Coverage
Covers natural, built, social, economic and institutional dimensions.

Water Security Relevance
Each domain has a direct or indirect bearing on water security outcomes.

Comparability
Applicable and scorable across all 75 districts and 9 clusters (C1–C9).

Actionability
Each domain maps to measurable issues and policy responses.

Traceability
Each domain links to remedies, owners and implementable actions.

This 30-domain framework is the foundation for all assessments in this Atlas. It ensures uniformity, transparency and traceability across all districts and clusters.

Plate 1 — The 30-Domain Framework — methodology, not Atlas findings; expert-assessed where scored.

G. L. Sudhakar — Independent Researcher / Analyst — Water Systems

PLATE 2 OF 4 — METHODOLOGY PLATE — V4

UTTAR PRADESH WATER SYSTEMS
DOMAIN IMPACT MATRIX (EXPERT ASSESSMENT)

All 30 domains scored across 5 impact dimensions (1–10 scale)

PURPOSE: This matrix reflects structured expert assessment of each domain's influence on water security across five dimensions. Scores (1–10) are analytical judgments, not measured values. Higher scores indicate greater influence on achieving water security outcomes.

TOP 10 HIGH IMPACT DOMAINS
(By Overall Impact Score)

Rank	Domain	Overall Impact (1–10)
1	Groundwater & Aquifers	9.4
2	Agriculture – Cropping Pattern	9.0
3	Water Quality	8.7
4	Climate & Rainfall	8.5
5	Floods & Floodplains	8.4
6	Water Availability (Per Capita)	8.2
7	Irrigation – Systems & Efficiency	8.1
8	Urban Water Supply & Delivery	8.0
9	Surface Water – Rivers	7.9
10	Data, Monitoring & Information	7.8

These domains exert the strongest overall influence on water security in Uttar Pradesh.

IMPACT DIMENSIONS (1–10 SCALE)

WATER SECURITY
Influence on availability, reliability and sustainable water resources.

POPULATION DEPENDENCY
Extent to which human populations depend on the domain for water security.

ECONOMIC IMPACT
Influence on economic activities, productivity and livelihoods.

CLIMATE SENSITIVITY
Vulnerability or responsiveness to climate variability and extremes.

RISK & FUTURE VULNERABILITY
Potential to create risks or future stress under changing conditions.

DOMAIN IMPACT TIER STRUCTURE

CRITICAL DOMAINS (9 – 10)
High influence across multiple dimensions.
Require immediate attention and strategic leadership.

HIGH IMPACT DOMAINS (7 – 8.9)
Major influence on water security outcomes.
Require coordinated action and resource prioritization.

MODERATE DOMAINS (4 – 6.9)
Some direct influence but context and location specific.
Improve selectively where impact is material.

BACKGROUND DOMAINS (0 – 3.9)
Contextual support domains.
Not primary drivers but enable system resilience.

All 30 domains are Essential. The tier structure helps prioritize actions and allocate resources effectively in line with urgency and impact.

IMPACT LOGIC FLOW

NATURAL SYSTEMS (Climate, Geology, Rivers, Ecology)
↓
WATER AVAILABILITY (Quantity, Quality, Reliability)
↓
HUMAN DEMAND & USE (Agriculture, Industry, Domestic, Energy)
↓
RISKS & VULNERABILITIES (Climate, Floods, Quality, Degradation)
↓
GOVERNANCE & RESPONSE CAPACITY (Institutions, Finance, Data, Policy)

Water security outcomes emerge from the interaction of all domains across these linked layers.

HOW TO USE THIS MATRIX

- Focus on high impact (7–10) domains for strategy, laws and investment.
- Compare domain scores for differences in sub-districts and clusters.
- Use for resource allocation across departments and schemes.
- Integrate insights with local context and data for decision-making.

ASSESSMENT NOTES

These scores represent structured expert assessment based on available knowledge, experience and evidence.

They are analytical judgments, not measured values.

Scores will be refined as more data becomes available.

A UNIFORM, TRANSPARENT AND TRACEABLE EXPERT ASSESSMENT FRAMEWORK
ENABLING EVIDENCE-BASED PLANNING FOR WATER SECURITY IN UTTAR PRADESH

Plate 2 — Domain Impact Matrix (Expert Assessment) — methodology, not Atlas findings; expert-assessed where scored.

G. L. Sudhakar — Independent Researcher / Analyst — Water Systems

PLATE 3 OF 4 — METHODOLOGY PLATE — V4

UTTAR PRADESH WATER SYSTEMS FUNCTIONAL DOMAIN GROUP MATRIX

The 30 domains organised into 6 functional groups for integrated assessment

PURPOSE: This matrix shows how the 30 domains are organised into six functional groups that represent the complete water system cycle—from natural foundation to institutional action. It enables integrated scoring, analysis and planning across all districts and clusters.

GROUP (6)	ROLE IN THE WATER SYSTEM	DOMAINS INCLUDED (Total = 30)	NO. OF DOMAINS
1. NATURAL FOUNDATION	Defines the natural setting that creates, stores, moves and sustains water in the landscape.	1 Climate & Rainfall 2 Geology & Lithology 3 Geomorphology & Slope 4 Soil & Infiltration Capacity 5 Groundwater & Aquifers 6 Surface Water – Rivers 7 Floods & Floodplains 8 Dams & Reservoirs 9 Recharge Behaviour 10 Water Quality	10
2. RESOURCE USE & DEMAND	Captures how water is demanded and used across agriculture, industry, households and energy.	11 Water Availability (Per Capita) 12 Agriculture – Cropping Pattern 13 Irrigation – Systems & Efficiency 14 Water Demand – Agriculture 15 Urbanisation & Growth 16 Urban Water Supply & Delivery 17 Rural Water Supply & Delivery 18 Industry & Industrial Water Use 19 Energy – Power for Pumping	9
3. DELIVERY SYSTEMS	Represents the infrastructure systems that store, convey and deliver water to users.	6 Surface Water – Rivers 7 Floods & Floodplains 8 Dams & Reservoirs 16 Urban Water Supply & Delivery 17 Rural Water Supply & Delivery 13 Irrigation – Systems & Efficiency 9 Recharge Behaviour 19 Energy – Power for Pumping	8
4. ECOLOGICAL BALANCE	Reflects the ecological components that maintain balance, resilience and long-term sustainability.	20 Ecology & Wetlands 21 Forests & Catchment 22 Soil Health & Land Degradation 10 Water Quality 6 Surface Water – Rivers 9 Recharge Behaviour	6
5. SOCIO-ECONOMIC CONTEXT	Represents the human, economic and societal factors that influence water security.	23 Population & Demography 24 Livestock & Animal Water 18 Industry & Industrial Water Use 12 Agriculture – Cropping Pattern 14 Water Demand – Agriculture 15 Urbanisation & Growth	6
6. GOVERNANCE & INSTITUTIONS	Covers the institutional, financial, data and policy systems that enable action and accountability.	25 Governance & Institutions 26 Finance & Funding Capacity 27 Data, Monitoring & Information 28 Climate Variability & Extremes 29 Risk & Future Vulnerability 30 Policy Implementation Capacity	6

HOW THIS GROUPING SUPPORTS ANALYSIS

SYSTEM VIEW — Shows the complete water system from natural to institutional dimensions.

INTEGRATION — Enables cross-domain linkages within and across groups for system outcomes.

PRIORITISATION — Helps identify critical groups and domains driving water security in each district.

STRATEGY DESIGN — Supports design of integrated strategies and multi-sector interventions.

LOCAL RELEVANCE — Allows adaptation to local context while maintaining statewide uniformity.

TRACEABILITY — Maintains full traceability from domain to remedy, owner and monitoring framework.

This functional grouping ensures that assessments are not siloed, but integrated—reflecting the real-world interdependence of domains that determine water security in Uttar Pradesh.

GROUP CODE LEGEND (Used in all Atlas Plates)

- G1 — Natural Foundation
- G2 — Resource Use & Demand
- G3 — Delivery Systems
- G4 — Ecological Balance
- G5 — Socio-economic Context
- G6 — Governance & Institutions

A UNIFORM, INTEGRATED AND TRACEABLE FRAMEWORK
FOR EVIDENCE-BASED WATER SECURITY PLANNING IN UTTAR PRADESH

Plate 3 — Functional Domain Group Matrix (G1–G6) — methodology, not Atlas findings; expert-assessed where scored.

G. L. Sudhakar — Independent Researcher / Analyst — Water Systems

PLATE 4 OF 4 — METHODOLOGY PLATE — V4

UTTAR PRADESH WATER SYSTEMS
DOMAIN → REMEDY → OWNER TRACEABILITY

From diagnosis to action — every domain linked to what must change and who must act

PURPOSE:
This traceability plate links each of the 30 domains to the primary remedies required and the lead ownership for implementation. It ensures that assessments translate into accountable, actionable and time-bound interventions.

REMEDY TYPE LEGEND
- P — Policy / Regulation
- I — Infrastructure / Engineering
- N — Nature-based / Ecological
- B — Behaviour / Demand / Management
- D — Data / Digital / Monitoring
- F — Finance / Incentives

FUNCTIONAL GROUP (6)	DOMAINS (No.)	KEY REMEDIES (What must change)	LEAD OWNER(S) (Primary)	REMEDY TYPES (Primary)
G1 NATURAL FOUNDATION	1 – 10	• Protect & restore catchments and wetlands (20, 21) • Enhance recharge & infiltration; manage aquifers (9, 5) • River & floodplain restoration; environmental flows (6, 7) • Soil & land health; reduce degradation (4, 22) • Water quality protection at source (10)	• Forest Dept. • Jal Shakti Dept. • Irrigation Dept. • State Pollution Control Board • Rural Development Dept.	N I P N I P N I N P P N D
G2 RESOURCE USE & DEMAND	11 – 15	• Promote water-smart agriculture & cropping (12, 14) • Improve irrigation efficiency & micro-irrigation (13) • Align water demand with availability (11) • Control urbanisation footprint; plan water-sensitive cities (15) • Right sizing of water use across sectors	• Agriculture Dept. • Minor Irrigation Dept. • Urban Development Dept. • Panchayati Raj Dept. • Planning Department	B I P I F B P P I N P B F
G3 DELIVERY SYSTEMS	16 – 19	• Universal & reliable urban water supply (16) • Strengthen rural water systems & O&M (17) • Reuse, recycle & efficiency in industry (18) • Energy-efficient pumping; reliable power (19) • Reduce leakage & non-revenue water	• Jal Nigam (Urban) • Jal Jeevan Mission / PHED • Industries Department • Energy Department • Local Bodies	I F D I D I B I F I B D
G4 ECOLOGICAL BALANCE	20 – 22	• Protect & revive wetlands, lakes & ponds (20) • Afforestation & catchment treatment (21) • Restore soil health; reduce degradation (22) • Biodiversity conservation in water landscapes • Maintain ecological flows & connectivity	• Forest Dept. • Environment Dept. • Rural Development Dept. • Wildlife Dept. • Irrigation Dept.	N I P N P F N B N P I N
G5 SOCIO-ECONOMIC CONTEXT	23 – 24	• Manage population growth & urban density (23) • Secure livestock & animal water needs (24) • Livelihood diversification & water productivity • Water literacy, behaviour change & community action • Gender equitable and inclusive water access	• Planning Department • Animal Husbandry Dept. • Rural Development Dept. • Education Dept. • Women & Child Dev. Dept.	P B I B B F B D P B
G6 GOVERNANCE & INSTITUTIONS	25 – 30	• Strengthen institutions & inter-departmental coordination (25) • Sustainable finance & funding models (26) • Integrated data systems & real-time monitoring (27) • Climate risk planning & disaster preparedness (28) • Risk assessment & resilience planning (29) • Strong policy implementation & accountability (30)	• Water Resources Dept. • Finance Department • NIC / State Data Centre • Relief / Disaster Mgmt. Dept. • Planning Department • Chief Secretary's Office	P D F P D I P D P D P D

HOW THIS TRACEABILITY DRIVES ACTION

- **CLEAR DIRECTION** — Every domain points to specific change actions.
- **ACCOUNTABILITY** — Lead owners identified for each domain.
- **INTEGRATION** — Connects nature, people, infrastructure and governance.
- **PRIORITISATION** — Focus resources on high-impact, high-leverage interventions.
- **MONITORABLE** — Enables tracking of progress across all domains.

This traceability framework ensures that assessment does not end with diagnosis.
It becomes a roadmap for implementation, enabling Uttar Pradesh to achieve long-term water security.

REMEDY TYPE QUICK VIEW

P	I	N	B	D	F
Policy / Regulation	Infrastructure / Engineering	Nature-based / Ecological	Behaviour / Management	Data / Digital / Monitoring	Finance / Incentives

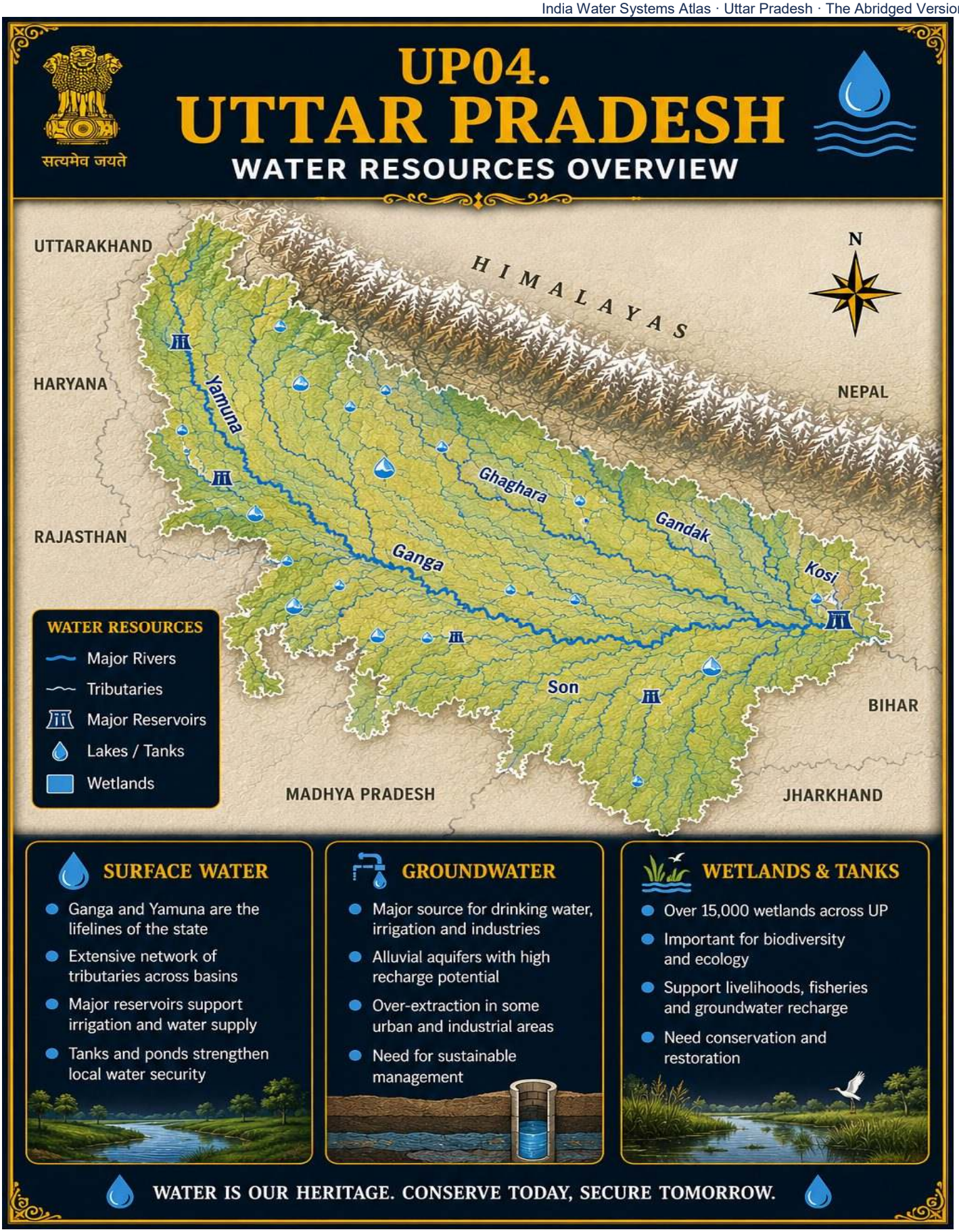
A TRANSPARENT, ACCOUNTABLE AND ACTION-ORIENTED FRAMEWORK
CONNECTING DIAGNOSIS TO SOLUTIONS — ACROSS ALL 30 DOMAINS

Plate 4 — Domain → Remedy → Owner Traceability — methodology, not Atlas findings; expert-assessed where scored.

G. L. Sudhakar — Independent Researcher / Analyst — Water Systems

The Physical State — Four Readings

Before the nodes and clusters, four readings of Uttar Pradesh as a whole — the maps against which every cluster boundary and every node was drawn. They are the physical state the rest of this volume resolves into focus.



Uttar Pradesh — water-resources map of Uttar Pradesh.

UP01. UTTAR PRADESH PHYSIOGRAPHY

THE LANDSCAPE THAT SHAPES WATER

सत्यमेव जयते

HIMALAYAN FOOTHILLS
Source of rivers and recharge

GANGA PLAIN
Vast alluvial plain, agricultural heartland

RIVERS & DRAINAGE
Ganga and its tributaries form the lifeline

ALLUVIAL SOILS
Deep, fertile soils with high water retention

DIVERSITY
From Terai wetlands to semi-arid Bundelkhand



AT A GLANCE

- **Area:** 2,43,286 sq km
- India's Most Populous State
- **Major Rivers:** Ganga, Yamuna, Ghaghara, Gomti, Son, Betwa, Ken, Chambal
- Predominantly Alluvial Plain
- Agriculture is the Lifeline



PHYSIOGRAPHIC ZONES

- **Terai & Bhabar:** Himalayan foothills, high recharge, wetlands
- **Ganga Plain:** Flat alluvial plain, highly productive, densely populated
- **Vindhya Plateau (Bundelkhand):** Undulating terrain, hard rocks, water stress prone
- **Eastern Plateau & Plains:** Transition zone with varied topography



WHY IT MATTERS

- Physiography controls water availability and flow
- Alluvial plains support agriculture, settlements and industry
- Plateau and uplands face water stress and drought
- Understanding the landscape is key to water security



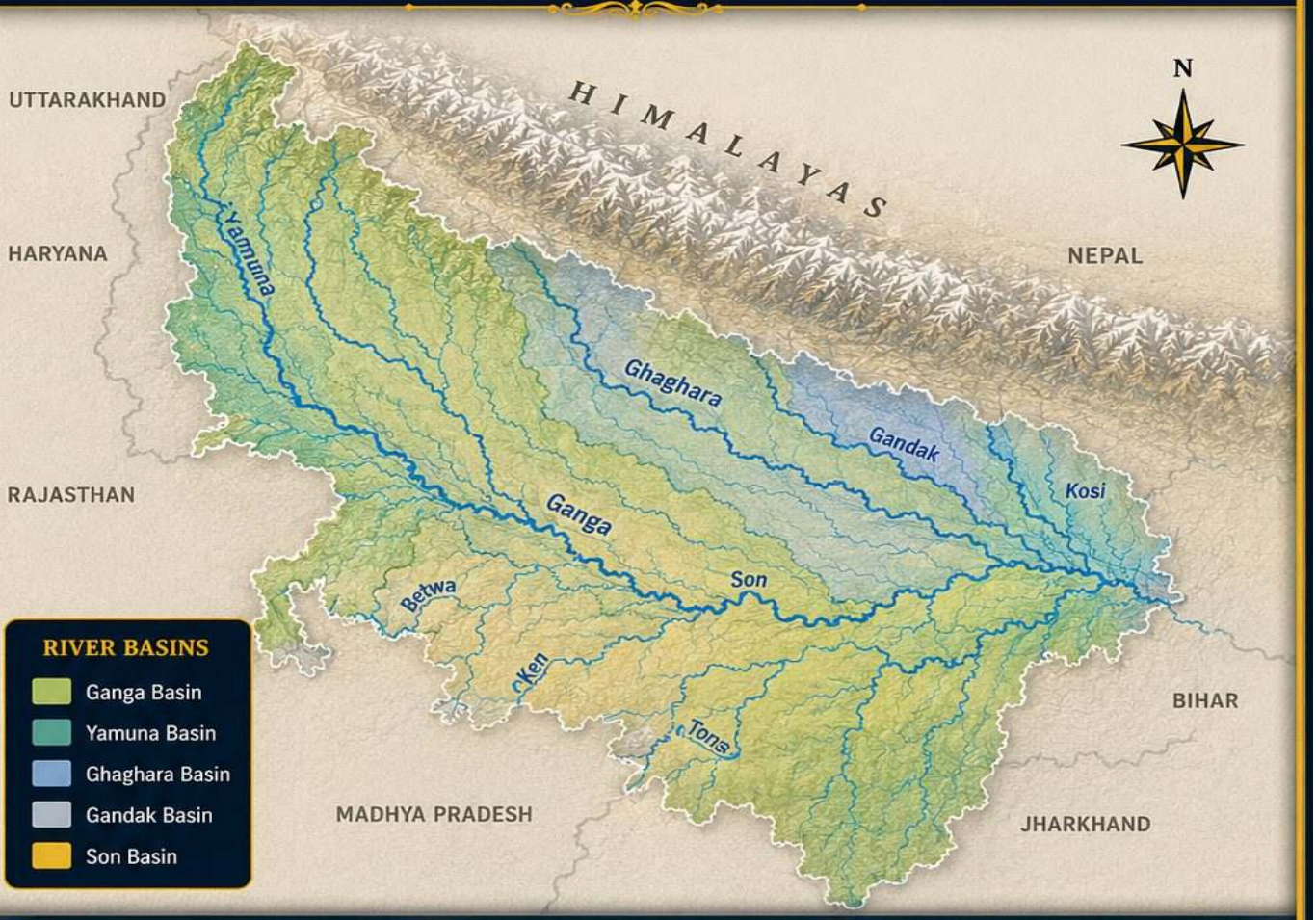
UNDERSTANDING THE LANDSCAPE. SECURING THE FUTURE.

Uttar Pradesh — physiographic divisions.

सत्यमेव जयते

UP03. UTTAR PRADESH

MAJOR RIVERS AND BASINS



MAJOR RIVERS

- **Ganga** – Lifeline of Uttar Pradesh
- **Yamuna** – Western boundary river
- **Ghaghara** – Major tributary in central-east
- **Gandak** – Supports eastern water systems
- **Son** – Key river of southern UP

KEY FACTS

Ganga Basin covers over 85% of the state area

Rivers support irrigation, drinking water, fisheries and ecosystems

Confluence of rivers creates fertile plains and rich biodiversity

ATLAS RELEVANCE

Important for water resource planning and flood management

Ensures irrigation sustainability and food security

Supports ecosystem balance and climate resilience

RIVERS SUSTAIN UTTAR PRADESH. WATER SECURES THE FUTURE.

Uttar Pradesh — rivers and major basins.



Uttar Pradesh — administrative structure.

THE NODES — The Cities Where the Crisis Is Felt

Seven cities are read as nodes because their water is governed by urban density, not by the cluster around them. They are presented first, beginning at the capital, because they are where the population, the demand and the decisions concentrate. Each is read at the block level — beneath the district average, where an urban crisis hides.

NODE N1 · THE AGGREGATION TRAP

Lucknow — The District Average That Hides a City

A capital whose crisis is hidden inside its own average — and the method by which every node in this volume is read.

Domain assessment — Lucknow — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	○ Stage of GW Development: 66.5% district / 107.29% city block (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: Screened, below BIS limit. 0/1558 HPs arsenic-detected; 0 above BIS...	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 4188513	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Dominant Cropping System: Rice – Wheat rotation (Ganga-Yamuna doab)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Wastewater & Sanitation	○ Untreated Sewage: Bharwara 345 MLD UASB STP; Lucknow STP on NMCG non-compliant list	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	○ Gross Reservoir Storage: 0.0 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	○ Average Annual Rainfall: 879.8 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 401.3 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam

Population & Demography	○ Labour Force in Agriculture: 59.3 (state 2019)	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

|THE IMPACT. Lucknow is the capital of Uttar Pradesh — the seat of the government that must answer for the water of seventy-five districts, a city grown from some thirty-five lakh people in 2011 to well over four million spread along both banks of the Gomti. It is placed first in this volume because its concealment is the cleanest and the most consequential, and because the method it forces is the method by which every other node is read.

Begin with the supply side, because it is favourable, and that is the point. Lucknow sits on the middle Ganga–Yamuna doab — deep, recharge-capable loamy alluvium over a multi-tier Indo-Gangetic aquifer, the best ground in the state. Geology, soil and recharge all say the same thing: this land can supply its city. The crisis is therefore not natural but institutional — a failure of how the demand is delivered and how the resource is measured, not of what the ground can give.

Now the demand side. The capital concentrates domestic, institutional and commercial demand onto the shallow first aquifer. The reason that demand falls on groundwater rather than on the piped network is the delivery failure that recurs across every urban node in this volume: the piped supply system, introduced in 1892 for a population of two lakh, now stretches across a city twenty times that size and cannot keep pace. Every gap in the pipe is filled by a private or institutional borewell drawing directly on the over-exploited block. Where the pipe does not reach, the tubewell does — unmetered, uncounted, and pulling on the very aquifer the city is depleting. The absence of universal piped supply is not a side issue; it is the mechanism of the unchecked draw.

This is the whole of the node thesis in one comparison. The district groundwater stage reads

66.5% — comfortably safe — and that is the figure that enters the state and national groundwater assessments, the number on which Lucknow is classified, budgeted and planned for. Beneath it, the Lucknow City block is over-exploited at 107%. The district average is the arithmetic mean of an over-drawn city and a still-comfortable countryside, and it describes a place that exists on neither. The district scale itself is the disguise. Urban wastewater, returned largely untreated, compounds the draw with a quality burden the stage number never registers.

THE REMEDY. The remedy begins with refusing the aggregate. The single most important act is to measure at the block, not the district — to make the 107% visible in a system that currently sees only the 66.5%. Until the unit of measurement matches the unit of the crisis, nothing downstream can be managed.

Then the delivery failure must be closed at its root. Extending reliable piped supply removes the reason households and institutions drill private borewells in the first place; treated-wastewater reuse cuts the fresh draw rather than returning the load to the river; and in-city recharge puts water back where the demand actually sits. None of this is a groundwater-department task alone. It requires the urban body that controls the pipe network and the built footprint, the groundwater cell that must monitor at block level, the data cell that must report the block truth, and the wastewater line that converts a liability into a supply. The governing metric must switch from district stage to city-block stage.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Urban water body** — extend piped supply; in-city recharge; demand management
- ☐ **Groundwater cell** — block-level monitoring, not district average
- ☐ **Data cell** — report the block truth that the aggregate hides
- ☐ **Wastewater line** — treated reuse to cut the fresh draw

Groundwater trajectory — Lucknow district (pre-monsoon depth, 2011–2020; stage GWRA-2024)

	2011	2014	2017	2020	Δ / src

Depth (m bgl)	7.58	7.35	9.42	8.24	▲ 9%
GW Stage (%)	—	—	—	**66.5**	GWRA-2024
T+5 [PRJ]	☐ Declining under BAU as city-block draw spreads; stabilises only if piped supply displaces private borewells and block-level monitoring replaces the district average.				

The district depth holds near 8 m and the stage reads a comfortable 66.5% — but both are the aggregate that conceals the Lucknow City block at 107%. The trend to watch is not the district line but the gap beneath it.

THE VERDICT. The capital's crisis is hidden inside its own average — a city block at 107% beneath a district reading 66.5% — and it is fed by a pipe network that cannot reach, so the borewell does. The remedy is to stop hiding it, extend the supply that removes the reason to drill, and manage the block that actually fails. In Lucknow the disconnection is not in the rock; it is in the arithmetic and the pipe.

N1 01 **LUCKNOW**
THE SYNTHESIS VOLUME

V5 (REGENERATED) METHODOLOGY COMPLIANT

LUCKNOW AT A GLANCE

The Integrated Urban Node Under Pressure.

Revive aquifers. Protect rivers. Secure the city's water future.

POPULATION (2023)	PER CAPITA WATER AVAILABILITY (2023)	GROUNDWATER EXTRACTION STAGE (TO) GWRA-2024	SURFACE WATER DEPENDENCE	SEWERAGE TREATMENT CAPACITY	DRINKING WATER SUPPLY COVERAGE (JJM, 2023)
~3.6 MILLION	~740 m^3/person/year	66.5% SEMI-CRITICAL	~34%	~52%	~98%
District Population (UP Total Share: ~8.5%)	(UP Avg: ~865 m^3) LOW STRESS	City Avg (TO) GWRA-2024 (SRC-N1-001)	(Gomti River & Local Nullahs)	(Approx.)	Functional Household Tap Connections

GROUNDWATER EXTRACTION STAGE (TO): 66.5% SEMI-CRITICAL

Elevated aquifer stress and declining water security.

GOVERNING METRIC GWRA-2024

NODE AGGREGATION (N1-LUCKNOW) GWRA-2024 (SRC-N1-001)

66.5%

SEMI-CRITICAL

High groundwater stress due to over-extraction, urban expansion and reduced recharge.

THE AGGREGATION TRAP — THE NODE HIDES THE CRISIS



OVERALL VERDICT: SEMI-CRITICAL

Groundwater stress, pollution and rapid urban growth threaten Lucknow's long-term water security.

THE ISSUE

- High groundwater extraction: 66.5% (TO) – Semi-Critical.
- Pollution in Gomti and drains affecting water quality and recharge.
- Urban expansion and impervious surfaces reducing natural recharge.

THE REMEDY

- Enhance recharge through parks, ponds, rooftops and recharge wells.
- Expand and upgrade STPs; ensure 100% treated wastewater reuse.
- Strengthen pollution control in drains and industrial clusters.

THE VERDICT



OVERALL VERDICT: SEMI-CRITICAL

Aquifer stress, urban pressure and pollution jeopardize sustainable water security.

CRITICAL NEXT STEPS (0–2 YEARS)

- Implement citywide recharge and rainwater harvesting.
- Upgrade and expand sewage treatment capacity.
- Real-time monitoring of groundwater levels and water quality.

PRIMARY OWNERS (Lead)

Lucknow Municipal Corporation | Uttar Pradesh Jal Nigam (Urban) | Irrigation & Water Resources Dept., UP | UP Pollution Control Board | Urban Development Dept., UP

NODE SCORECARD (Impact Dimension Scores 1–10)

Water Security	Population Dependency	Economic Impact	Climate Sensitivity	Risk & Future Vulnerability
5.0	6.5	6.0	5.5	7.0

OVERALL IMPACT SCORE 6.0

A resilient Lucknow depends on clean rivers, healthy aquifers, efficient infrastructure and responsible growth.

Safe (0–25%) | Semi-Critical (25–75%) | Critical (75–100%) | Over-Exploited (>100%)

N1-01

NODE N2 · QUALITY AS THE BINDING CONSTRAINT

Kanpur — Where Industry Outweighs the Aquifer

Visible supply infrastructure mistaken for the health of the resource beneath it.

Domain assessment — Kanpur — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	○ Stage of GW Development: 79.1% (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: 2	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 3028679	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Dominant Cropping System: Rice – Wheat rotation (Ganga-Yamuna doab)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Industry & Industrial Water Use	○ Industrial Effluent: Jajmau ~400 tannery sites; 16,000+ industrial units; chromium effluen…	Canal/recharge axis: concentrated industrial draw competes with irrigation and domestic supply; effluent degrades the aquifer and river it abstracts from — quantity stress and quality failure together.	Meter draw; enforce ZLD/effluent compliance; reuse.	Industries / UPPCB
Wastewater & Sanitation	○ Untreated Sewage to River: Major untreated discharge to Ganga; non-compliant STP capacity	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	○ Gross Reservoir Storage: 4.0 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	○ Average Annual Rainfall: 709.6 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 70.1 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

THE IMPACT. Kanpur sits on the same deep middle-doab alluvium as Lucknow, so its supply geology is equally capable — and equally beside the point. Its defining variable is industry. Jajmau alone carries roughly 400 tannery sites within a registered base of more than 16,000 industrial units, drawing groundwater and discharging chromium-laden and organic effluent into the Ganga. The Atlas records Kanpur among the urban centres named for large-scale groundwater mining alongside contamination — stressed and toxic at once, a rare and telling combination.

The demand here is industrial before it is domestic, and the delivery failure is the same urban one seen at the capital: where the piped network is partial, both industry and households fall back on the first aquifer through private borewells, drawing it down while the effluent load degrades both the groundwater and the river beside it. The visible infrastructure of supply — the pipes, the plants, the intakes — masks the true condition of the resource. Here the pipework is visible and the resource is not.

The error this node guards against is the reading of infrastructure as security. A dense network of supply assets is taken as proof that the water problem is solved, when the resource — judged on contamination and aquifer condition rather than the reach of the pipe — is failing. In Kanpur, quality is the binding constraint, and it is invisible to anyone counting only taps and treatment plants.

THE REMEDY. Separate the question of supply infrastructure from the question of resource health, and measure the aquifer independently of the pipe network so the resource is judged on its own condition. Then bring the load under control: meter industrial draw so it is known and limited, and intercept effluent before it reaches the river rather than treating the Ganga as the disposal route. Reliable piped and treated-surface supply to industry reduces the private-borewell draw that the partial network now forces.

The hands at the table are the industrial line, which controls draw and discharge; the pollution-control authority and the river mission, which must intercept the effluent; the groundwater cell, which must measure the aquifer on its own terms; and the urban body, which must stop reading its supply network as a proxy for water security. The governing metric is the aquifer stage and the river's effluent load — not the network's reach.

AT THE TABLE — DOMAINS CONVENED

☐ **Industry** — metered draw, effluent treatment at source
☐ **Pollution control / river mission** — interception before the Ganga
☐ **Groundwater cell** — aquifer measured independently of the pipe
☐ **Urban water body** — supply-vs-resource separation; reliable piped supply

Groundwater trajectory — Kanpur Nagar (pre-monsoon depth, 2011–2020; stage GWRA-2024)

Metric	2011	2014	2017	2020	Δ / src
Depth (m bgl)	18.29	10.89	10.88	10.85	▼ 41%
GW Stage (%)	—	—	—	79.1	GWRA-2024
T+5 [PRJ]	☐ Stage rising toward critical under BAU; the binding constraint is contamination, so quality, not depth, sets the real trajectory.				

Depth steadied near 11 m after 2014, but the governing signal is the 79.1% semi-critical stage on an aquifer already carrying tannery-borne contamination. Quantity looks managed; quality is the failing variable the depth line cannot show.

THE VERDICT. Infrastructure is not the same as water security. Kanpur draws a stressed, contaminated aquifer (79.1%, semi-critical) while its visible supply system suggests a solved problem. Govern it on the resource and the river — the aquifer stage and the effluent load — not on the pipework that draws upon them.

N2 02 **KANPUR**
THE SYNTHESIS VOLUME

V5 (REGENERATED) METHODOLOGY COMPLIANT

KANPUR AT A GLANCE

The Industrial & Urban Node Under Stress.

Restore aquifers. Control pollution. Secure Kanpur's water future.

POPULATION (2023)	PER CAPITA WATER AVAILABILITY (2023)	GROUNDWATER EXTRACTION STAGE (T0) GWRA-2024	SURFACE WATER DEPENDENCE	SEWERAGE TREATMENT CAPACITY	DRINKING WATER SUPPLY COVERAGE (JJM, 2023)
~4.51 MILLION	~640 m³/person/year	79.1% SEMI-CRITICAL	~29%	~38%	~86%
District Population (UP Total Share: ~10.6%)	(UP Avg: ~865 m³) LOW STRESS	City Avg (TO) GWRA-2024 (SRC-N2-002)	(Ganga Mainstem & Local Nullahs)	(Approx.)	Functional Household Tap Connections

GROUNDWATER EXTRACTION STAGE (TO): 79.1% SEMI-CRITICAL
High aquifer stress and declining water security.

GOVERNING METRIC GWRA-2024

NODE AGGREGATION (N2-KANPUR) GWRA-2024 (SRC-N2-002)

79.1%
SEMI-CRITICAL
High groundwater stress driven by over-extraction, pollution load and limited aquifer recharge.

THE AGGREGATION TRAP — THE NODE HIDES THE CRISIS



OVERALL VERDICT: SEMI-CRITICAL
Aquifer stress and pollution from industries, sewage and drains threaten Kanpur's long-term water security.

THE ISSUE

- Over-extraction: 79.1% (TO) – Semi-Critical.
- Industrial pollution from tanneries, dyes, chemicals and drains.
- Inadequate sewage treatment and reuse.

THE REMEDY

- Enhance recharge through water bodies, parks, rooftops and wells.
- Upgrade and expand STPs; ensure 100% treated wastewater reuse.
- Strict pollution control in industrial clusters and drain management.

THE VERDICT



OVERALL VERDICT: SEMI-CRITICAL
Aquifer stress, pollution and urban pressure jeopardize Kanpur's water security.

CRITICAL NEXT STEPS (0–2 YEARS)

- Restore drains and water bodies; prevent polluted inflows.
- Upgrade and expand sewage treatment capacity.
- Real-time monitoring of groundwater levels and quality.

PRIMARY OWNERS (Lead)

Kanpur Nagar Municipal Corporation	Uttar Pradesh Jal Nigam (Urban)	Irrigation & Water Resources Dept., UP	UP Pollution Control Board	Urban Development Dept., UP

NODE SCORECARD (Impact Dimension Scores 1–10)

Water Security	Population Dependency	Economic Impact	Climate Sensitivity	Risk & Future Vulnerability
4.5	6.5	6.0	5.5	7.5

OVERALL IMPACT SCORE 6.1

A resilient Kanpur depends on clean rivers, healthy aquifers, controlled pollution and responsible growth.

Safe (0–25%) · Semi-Critical (25–75%) · Critical (75–100%) · Over-Exploited (>100%)

N2-02

NODE N3 · VISIBLE SURPLUS, STRESSED AQUIFER

Prayagraj — Stress Beneath the Confluence

Groundwater trajectory — Prayagraj (pre-monsoon depth, 2011–2020; stage GWRA-2024)

Metric	2011	2014	2017	2020	Δ / src
Depth (m bgl)	9.93	9	10.65	7.68	▼ 23%
GW Stage (%)	—	—	—	72.7	GWRA-2024
T+5 [PRJ]	☐ Stage semi-critical and rising under urban and event demand; recharge and demand management required to hold the line.				

The depth record is shallow and uneven beside the confluence, but the stage stands at 72.7% and rising with nitrate. The rivers display abundance; the aquifer beneath is already semi-critical.

The most visible water in the state is not its most secure.

Domain assessment — Prayagraj — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	○ Stage of GW Development: 72.7% (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Nitrate Concentration: 0.71-84.1 (avg 14.8)	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 3126909	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Dominant Cropping System: Rice – Wheat rotation (Ganga-Yamuna doab)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.

Floods & Floodplains	○ Flood Exposure: MODERATE-HIGH (Ganga-Yamuna confluence)	Surface/recharge axis: undersized urban drainage turns compressed rain into flood, then scarcity — the same water that floods should have recharged. Flood and tanker are one failure.	Convert flood to managed recharge; floodplain restraint.	Irrigation (Flood) / UPSDMA
Wastewater & Sanitation	○ Untreated Sewage: Untreated discharge at Ganga-Yamuna confluence; sewerage gaps	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	○ Gross Reservoir Storage: 1.5 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	○ Average Annual Rainfall: 843.1 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: 10.8	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 166.2 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

THE IMPACT. Prayagraj is a measurable contradiction. On deep middle-doab alluvium at the confluence of the Ganga and the Yamuna, its surface water is the most visible anywhere in the state — and yet the node's groundwater extraction stage is 72.7%, already semi-critical and rising under urban demand, with measured groundwater nitrate running 0.71 to 84.1 mg/L and averaging around 14.8. The two great rivers arrive carrying the accumulated organic and effluent load of everything upstream, so the visible abundance is itself degraded.

The demand-and-delivery pattern is the urban one again: a growing city, a piped network that does not fully reach, and the gap filled by groundwater drawn from a semi-critical block. The number to watch is not the river volume but the gap between it and the stressed, quality-affected aquifer beneath. The geology is capable; the urban draw and the upstream load together make the node's water far less secure than its spectacle suggests.

The contradiction sharpens at the scale of the event. Prayagraj periodically hosts gatherings of tens of millions on the riverbank — the most concentrated short-term water-and-sanitation demand anywhere in India — drawing on the same shallow aquifer and discharging back into

rivers that arrive already loaded. The city's water system is asked to perform two contradictory feats at once: supply a dense permanent population from a semi-critical aquifer, and absorb episodic surges that no purely surface reading would ever flag as a groundwater problem. The spectacle of abundance is the cover under which a quietly stressed and quality-burdened system is run.

THE REMEDY. Govern the node on its groundwater stage and water quality, not on the visible river volume. Recharge and demand management inside the urban footprint arrest the rising stage; reliable piped supply reduces the borewell dependence the partial network forces; nitrate and contamination tracking manage the quality trend rather than discovering it; and event-scale planning treats the periodic mass gatherings as a known, recurring load on the aquifer and the rivers.

The coordination runs between the urban body, the groundwater cell, the pollution-control line that manages the confluence, and the event administration. The river that defines the city must be treated as a load to be reduced and a quality to protect, not an inexhaustible supply. The metric is the 72.7% stage and the nitrate trend, both held and reversed.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Urban water body** — footprint recharge; piped supply; demand management
- ☐ **Groundwater cell** — stage and nitrate tracking
- ☐ **Pollution control / river mission** — confluence load reduction
- ☐ **Event administration** — mass-gathering water and sanitation planning

THE VERDICT. The most visible water in the state is not its most secure. A 72.7% groundwater stage and rising nitrate sit beneath the country's most famous confluence. Prayagraj must be read on the aquifer it draws, not the rivers it displays.

N3 03 | **PRAYAGRAJ** — THE SYNTHESIS VOLUME | V5 (REGENERATED) METHODOLOGY COMPLIANT

PRAYAGRAJ AT A GLANCE

The Confluence City & Cultural Node Under Pressure.

Revive aquifers. Protect rivers. Secure Prayagraj's water future.

POPULATION (2023)	PER CAPITA WATER AVAILABILITY (2023)	GROUNDWATER EXTRACTION STAGE (TO) GWRA-2024	SURFACE WATER DEPENDENCE	SEWERAGE TREATMENT CAPACITY	DRINKING WATER SUPPLY COVERAGE (JJM, 2023)
~6.16 MILLION	~650 m^3/person/year	72.7% SEMI-CRITICAL	~32%	~40%	~88%
District Population (UP Total Share: ~14.8%)	(UP Avg: ~865 m^3) LOW STRESS	City Avg (TO) GWRA-2024 (SRC-N3-003)	(Ganga & Yamuna Mainstems & Local Nallahs)	(Approx.)	Functional Household Tap Connections

GROUNDWATER EXTRACTION STAGE (TO): 72.7% SEMI-CRITICAL

Elevated aquifer stress and declining water security.

GOVERNING METRIC GWRA-2024

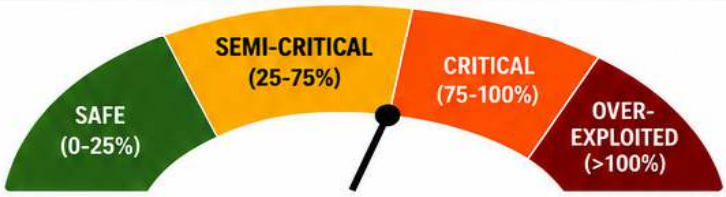
NODE AGGREGATION (N3-PRAYAGRAJ) GWRA-2024 (SRC-N3-003)

72.7%

SEMI-CRITICAL

High groundwater stress due to over-extraction, pollution load and reduced aquifer recharge.

THE AGGREGATION TRAP — THE NODE HIDES THE CRISIS



OVERALL VERDICT: SEMI-CRITICAL

Aquifer stress, pollution and unplanned urban growth threaten Prayagraj's long-term water security.

THE ISSUE

- Over-extraction: 72.7% (TO) – Semi-Critical.
- Pollution in drains and outfalls degrading rivers and aquifers.
- Urban expansion and encroachment reducing natural recharge.

THE REMEDY

- Enhance recharge through parks, tanks, riverfronts and recharge wells.
- Upgrade and expand STPs; ensure 100% treated wastewater reuse.
- Strengthen pollution control in drains and industrial clusters.

THE VERDICT



OVERALL VERDICT: SEMI-CRITICAL

Aquifer stress, pollution and urban pressure jeopardize Prayagraj's sustainable water security.

CRITICAL NEXT STEPS (0–2 YEARS)

- Restore drains; intercept and treat pollution before it reaches rivers.
- Upgrade and expand sewage treatment capacity.
- Real-time monitoring of groundwater levels and water quality.

PRIMARY OWNERS (Lead)

Prayagraj Municipal Corporation | Uttar Pradesh Jal Nigam (Urban) | Irrigation & Water Resources Dept., UP | UP Pollution Control Board | Urban Development Dept., UP

NODE SCORECARD (Impact Dimension Scores 1–10)

Water Security	Population Dependency	Economic Impact	Climate Sensitivity	Risk & Future Vulnerability
4.5	6.0	6.0	5.5	7.0

OVERALL IMPACT SCORE 6.1

A resilient Prayagraj depends on clean rivers, healthy aquifers, controlled pollution and responsible growth.

Safe (0–25%) | Semi-Critical (25–75%) | Critical (75–100%) | Over-Exploited (>100%)

N3-03

G. L. Sudhakar — Independent Researcher / Analyst — Water Systems

NODE N4 · MEASURED ON THE WRONG VARIABLE

Varanasi — The Right River, the Wrong Number

Groundwater trajectory — Varanasi (pre-monsoon depth, 2011–2020; stage GWRA-2024)

Metric	2011	2014	2017	2020	Δ / src
Depth (m bgl)	20.64	11.43	12.42	10.46	▼ 49 %
GW Stage (%)	—	—	—	88.3	GWRA-2024
T+5 [PRJ]	☐ Stage near-critical at 88.3% under BAU; arsenic exposure makes safe-source substitution, not depth alone, the governing target.				

Even where the recorded depth eases, the stage sits at 88.3% — among the highest in the state — on an arsenic-affected aquifer beside a heavily loaded river. The right river is present; the wrong number governed until now.

A city on a river can still run dry beneath it.

Domain assessment — Varanasi — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	○ Stage of GW Development: 88.3% (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: Screened, below BIS limit. 0/1309 HPs arsenic-detected; 0 above BIS...	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 2973430	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Dominant Cropping System: Rice – Wheat rotation (Ganga-Yamuna doab)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Floods & Floodplains	○ Flood Exposure: MODERATE-HIGH (riverine, ghats)	Surface/recharge axis: undersized urban drainage turns compressed rain into flood, then scarcity — the same water that floods should have recharged. Flood and tanker are one failure.	Convert flood to managed recharge; floodplain restraint.	Irrigation (Flood) / UPSDMA

Wastewater & Sanitation	○ Untreated Sewage to River: Untreated discharge to Ganga; STP among NMCG non-compliant list	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Climate & Rainfall	○ Average Annual Rainfall: 925.8 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 16.5 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

THE IMPACT. Varanasi carries three failures at once, and the river hides all of them. On deep doab alluvium beside one of the world's most venerated rivers, the visible presence of the Ganga is read as water security — while the groundwater extraction stage stands at 88.3%, among the highest of any node in the state.

The second failure is quality of nature's making: Varanasi is one of the three landmark arsenic hotspots of the eastern belt, with concentrations exceeding 300 parts per billion in roughly a tenth of samples against a safe limit of ten. The third is quality of the city's own making: the Ganga's biochemical oxygen demand at the Varanasi reach runs at 64.8 — a river under heavy organic load — so even the visible water is degraded. The same urban delivery gap applies: a partial piped network pushes demand onto an arsenic-affected aquifer drawn at 88.3%, and untreated wastewater returns to the river that the city then reads as its supply.

The contradiction is the diagnosis: a river in plain sight, an aquifer drawn at 88.3% and contaminated, and a quality that worsens as the draw deepens. Certifying the node safe on surface abundance — while it draws groundwater at 88.3% from an arsenic-affected aquifer beside a heavily loaded river — is the entire error captured in one figure. The right river is present; the wrong number governs.

THE REMEDY. Switch the governing metric from surface presence to groundwater stage and quality, both tracked. Recharge inside the city to relieve the shallow aquifer; cap the urban draw so the 88.3% stage comes down against a stated baseline; extend piped supply from safe sources so households leave the arsenic-affected first aquifer; map the contaminated pockets so safe layers are used and unsafe avoided; and treat the river as a cultural and ecological asset to protect rather than a supply to assume.

The hands at the table are the urban body, the groundwater cell, rural and urban water supply for safe-source substitution, and the pollution-control line. The target is twofold and measurable: the 88.3% stage reduced, and the river's organic load lowered — neither of which the surface-abundance reading would ever have called for.

AT THE TABLE — DOMAINS CONVENED

☐ **Urban water body** — in-city recharge; safe-source piped supply; draw cap
☐ **Groundwater cell** — stage and arsenic-quality tracking
☐ **Pollution control / river mission** — river load reduction

THE VERDICT. A city on a river can still run dry beneath it. Varanasi draws 88.3% from a contaminated aquifer beside a river assumed to be limitless. It must be governed on the right number — the aquifer stage and its quality, not the river's presence.

N4-04 | **VARANASI NODE (N4)** | **THE SYNTHESIS VOLUME** | V4 (REGENERATED) METHODOLOGY COMPLIANT

VARANASI AT A GLANCE

THE RIGHT RIVER, THE WRONG NUMBER

Visible river abundance masks severe groundwater stress.

POPULATION (2023)
~1.40 MILLION
District Share: 12.3%
(UP Total: ~11.4 M)

PER CAPITA WATER AVAILABILITY (2023)
~1,050 m³/person/year
(UP Avg: ~865 m³)
LOW STRESS

GROUNDWATER EXTRACTION STAGE (SCHEMA VALUE)
88.3%
SEMI-CRITICAL
Groundwater Blocks:
88.3% Semi-Critical
0% Critical

RIVER SYSTEM
RIVER GANGA
Perennial Flow
(But Heavily Polluted)

SEWERAGE COVERAGE (2023)
~55%
Treatment Capacity:
~180 MLD
(Secondary)

DRINKING WATER SUPPLY COVERAGE (JJM, 2023)
~70%
Functional Household Tap Connections

GROUNDWATER EXTRACTION STAGE: 88.3% SEMI-CRITICAL
GOVERNING METRIC
SCHEMA-BACKED VALUE

The city is over-extracting a contaminated aquifer. A city on a river can still run dry beneath it.

THE ISSUE

- Over-extraction: 88.3% groundwater extraction stage (Semi-Critical).
- Arsenic contamination in groundwater across wide pockets.
- Ganga is heavily polluted; high organic & faecal load through the city stretch.
- Surface abundance masks groundwater stress.
- Old city: dependence on deep/hand pumps; rising pumping depths.
- Climate variability: intense monsoon, long lean period.

THE REMEDY

- Managed aquifer recharge: ponds, tanks, stepwells, injection wells.
- Arsenic mitigation: treatment, blending, and safe source substitution.
- Sewage interception & full treatment before discharge. Zero direct drains to Ganga.
- 24x7 water supply in phases; reduce groundwater dependence.
- Revive wetlands & traditional water bodies for recharge and storage.
- Demand management, water budgeting and behaviour change.

THE VERDICT



OVERALL VERDICT:
SEVERE CONCEALED GROUNDWATER CRISIS
Surface water is visible.
Groundwater is vanishing.
Immediate action required.

NODE SCORECARD (Impact Dimension Scores 1–10)

Water Security	2.6
Population Dependency	7.8
Economic Impact	6.4
Climate Sensitivity	5.5
Risk & Future Vulnerability	8.6

KEY DRIVERS
- Over-extraction
- Arsenic contamination
- Sewage pollution load
- Groundwater dependence
- Urban density pressure
- Climate variability

PRIMARY OWNERS (Lead)

- Urban Development Dept.
- Jal Nigam (Urban)
- Irrigation Dept.
- Pollution Control Board
- Municipal Corporation
- District Administration
- Community & Local Institutions

CRITICAL NEXT STEPS (0–2 YEARS)

- Intercept all drains; ensure 100% sewage treatment.
- Scale managed aquifer recharge across urban and peri-urban areas.
- Arsenic mitigation & safe drinking water access for all.
- Implement 24x7 water supply to reduce groundwater stress.
- Revive ponds, tanks and wetlands for recharge.
- Strengthen monitoring, enforcement and community participation.

A permanent river does not guarantee a secure future.
Sustainable cities protect what flows beneath.

High Risk | Moderate Risk | Low Risk

VARANASI'S WATER SECURITY DEPENDS ON PROTECTING ITS GROUNDWATER, CLEANING ITS RIVER AND MANAGING ITS GROWTH.

Source: CGWB GW Assessment (2023) – Varanasi District
CPCB Water Quality (2023) – Ganga (Varanasi Stretch)

Note: All figures are latest available; subject to revision.

N4-04

NODE N6 · EXCESS AND QUALITY, NOT DEFICIT

Gorakhpur — The Eastern Exception

Too much water of the wrong quality at the wrong time — not too little.

Domain assessment — Gorakhpur — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	○ Stage of GW Development: 63.8% (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: 311	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 2500636	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Dominant Cropping System: Rice (kharif) – Wheat (rabi)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Floods & Floodplains	○ Flood Exposure: HIGH	Surface/recharge axis: undersized urban drainage turns compressed rain into flood, then scarcity — the same water that floods should have recharged. Flood and tanker are one failure.	Convert flood to managed recharge; floodplain restraint.	Irrigation (Flood) / UPSDMA
Climate & Rainfall	○ Average Annual Rainfall: 1091.8 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 74.5 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Ramgarh Tal (large natural urban lake, 300+ bird spec...	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

THE IMPACT. Gorakhpur inverts the urban pattern of the rest of this volume, and its supply conditions are why. It sits in the high-rainfall eastern Gangetic plain — low-gradient Bhat–Bangar alluvium over a shallow, water-rich multi-tier aquifer, near the flood-prone Rapti and Ghaghra. The land does not lack water; it holds too much, too shallow.

Its issue is the eastern condition carried into an urban setting: waterlogging and flood on one side, and on the other the regional arsenic and quality burden, with arsenic measured up to 311 micrograms per litre against a safe limit of ten and roughly 45% of tested wells unsafe. The demand-and-delivery logic inverts too — the problem is not a pipe that cannot reach a falling aquifer, but a shallow contaminated table that makes even abundant local water unsafe to draw. A high water table that would be an asset elsewhere is here a drainage and quality liability.

The human consequence is what makes the node distinctive. This is the region historically scarred by waterborne encephalitis, where stagnant flood water, a shallow contaminated water table and dense settlement combined into a public-health emergency that ran for decades. Water here is not a resource to be conserved but a hazard to be managed: the same shallow aquifer that guarantees supply also guarantees exposure, and the monsoon that recharges the plain also floods it. Gorakhpur is the clearest proof in the volume that more water is not safer water — that a node can be water-rich and water-sick at once.

THE REMEDY. The remedy is the opposite of the western nodes' extraction discipline: manage excess and quality, not abstraction. Flood and drainage management converts the hazard into managed recharge rather than damage; arsenic and bacteriological testing with safe-source substitution makes the abundant water usable; and the public-health line is treated as part of the water system, not a separate concern downstream of it.

The coordination runs across the flood, drainage, rural-water and health domains — a combination no extraction-focused water office would convene on its own. The metric is not the stage but the flood-affected area, the contamination exceedance and the waterborne-disease incidence, brought down together.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Flood / irrigation line** — drainage, managed recharge
- ☐ **Rural water supply** — arsenic testing, safe-source substitution
- ☐ **Health line** — waterborne-disease surveillance
- ☐ **Groundwater cell** — shallow-aquifer quality mapping

Groundwater trajectory — Gorakhpur (pre-monsoon depth, 2011–2020; stage GWRA-2024)

Metric	2011	2014	2017	2020	Δ / src
Depth (m bgl)	16.4	4.46	6.01	5.16	▼ **69 %**
GW Stage (%)	—	—	—	**63.8**	GWRA-2024
T+5 [PRJ]	→ Stage stays Safe; the trajectory that matters is contamination and flood exposure, not abstraction.				

The water table is shallow and the stage Safe at 63.8% — and that is precisely the trap. Gorakhpur's crisis is excess and quality, not deficit; the depth line confirms abundance while arsenic up to 311 ppb makes the abundance unsafe.

THE VERDICT. Gorakhpur is water-rich and water-sick at once. Its crisis is excess and quality, not deficit — and the remedy is drainage, treatment and public health, not abstraction control. Read on extraction stage alone, the eastern exception disappears from view.

N6 06 **GORAKHPUR**
THE SYNTHESIS VOLUME

V5 (REGENERATED) METHODOLOGY COMPLIANT

GORAKHPUR AT A GLANCE

The Agricultural & Floodplain City with Strong Aquifers.
Sustain aquifers. Protect rivers. Secure Gorakhpur's water future.

POPULATION (2023)	PER CAPITA WATER AVAILABILITY (2023)	GROUNDWATER EXTRACTION STAGE (TO) GWRA-2024	SURFACE WATER DEPENDENCE	SEWERAGE TREATMENT CAPACITY	DRINKING WATER SUPPLY COVERAGE (JJM, 2023)
~2.85 MILLION	~1,120 m³/person/year	63.8% SAFE	~24%	~28%	~92%
District Population (UP Total Share: ~6.7%)	(UP Avg: ~865 m³) LOW STRESS	City Avg (TO) GWRA-2024 (SRC-N6-006)	(Rapti, Rohin & Local Nallahs)	(Approx.)	Functional Household Tap Connections

GROUNDWATER EXTRACTION STAGE (TO): 63.8% SAFE
Groundwater is in the safe zone with sustainable use and healthy recharge.

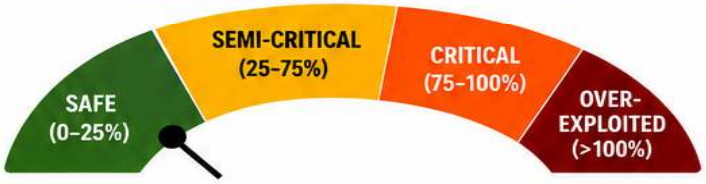
GOVERNING METRIC GWRA-2024

NODE AGGREGATION (N6-GORAKHPUR) GWRA-2024 (SRC-N6-006)

63.8%
SAFE

Aquifer stress is low with good recharge from rapti floodplain, rainfall and surface water bodies.

THE AGGREGATION TRAP — THE NODE HIDES THE CRISIS



OVERALL VERDICT: SAFE
Low aquifer stress; good recharge and dependence on surface water keep Gorakhpur in the safe zone.

THE ISSUE

- Localized extraction in urban pockets and along canals.
- Pollution in drains and low-lying areas during monsoon.
- Flooding risk and poor drainage cause water logging.

THE REMEDY

- Enhance recharge through ponds, wetlands, floodplain restoration and percolation wells.
- Strengthen drain interception and STPs; promote treated wastewater reuse.
- Enforce land use regulations in floodplain and urban areas.

THE VERDICT



OVERALL VERDICT: SAFE
Healthy aquifers, good recharge and responsible use secure Gorakhpur's water future.

CRITICAL NEXT STEPS (0–2 YEARS)

- Desilt and restore ponds, channels and wetlands.
- Upgrade and expand sewage treatment capacity.
- Real-time monitoring of groundwater levels and water quality.

PRIMARY OWNERS (Lead)
Gorakhpur District Administration · Uttar Pradesh Jal Nigam (Urban) · Irrigation & Water Resources Dept., UP · UP Pollution Control Board · Urban Development Dept., UP

NODE SCORECARD (Impact Dimension Scores 1–10)

Water Security	Population Dependency	Economic Impact	Climate Sensitivity	Risk & Future Vulnerability
6.0	5.5	4.5	4.5	5.0

OVERALL IMPACT SCORE 5.1

A resilient Gorakhpur depends on healthy aquifers, clean rivers, and strong floodplain management.

Safe (0–25%) · Semi-Critical (25–75%) · Critical (75–100%) · Over-Exploited (>100%)

N6-06

NODE N7 · DEMAND EXCESS IN URBAN FORM

Meerut — NCR Extraction

The western deficit, carried into the city — and the clearest proof of the pipe-loss mechanism.

Domain assessment — Meerut — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	○ Stage of GW Development: 76.9% (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: 1	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 1960911	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Urban Water Supply & Delivery	○ Non-Revenue Water: 65% (highest NRW in UP)	Canal/recharge axis: non-revenue water and service gaps convert directly into compensatory groundwater mining; sealed urban ground also removes the recharge that would refill it — flood-then-tanker.	Cut NRW; extend piped supply to remove the reason to drill.	Jal Nigam / Nagar Nigam
Climate & Rainfall	○ Average Annual Rainfall: 856.9 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 91.3 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

THE IMPACT. Meerut carries the western extraction crisis into a major urban node, and it

carries the quality damage with it. On the same deep, fertile upper-doab alluvium as the Western cluster, it draws at a stage of 76.9% with a district mean groundwater level near 12.41 metres below ground and falling, under combined NCR urban, industrial and agricultural demand.

Meerut is also where the urban delivery failure is most starkly documented. Its non-revenue water — the share of supply lost to leaks, theft and unbilled use before it reaches a tap — runs at about 65%, the highest in Uttar Pradesh. Nearly two-thirds of the water the system produces never serves a customer, so the shortfall is made up by private borewells drilled straight into the over-drawn aquifer. The Atlas names Meerut explicitly for large-scale urban groundwater mining. This is the mechanism in its plainest form: a leaking, under-delivering pipe network is not a billing problem but a groundwater problem, because every litre the pipe fails to deliver is a litre pulled from the block instead.

The quality damage tracks the draw. Measured nitrate across the surrounding transects runs from 8 to 298 mg/L — the signature of intensive fertiliser use and effluent on a heavily pumped aquifer. Falling levels and rising nitrate together mean the node is losing both the quantity and the quality of its groundwater at once, on ground that is urbanising over what was prime irrigated land.

THE REMEDY. The remedy is the Western-cluster discipline applied at node scale, with the pipe network as the first lever. Cutting non-revenue water from 65% toward a managed level recovers supply that is currently lost and removes the reason for much of the private-borewell draw; urban and agricultural demand are then planned together rather than separately, with metering, mandated reuse and recharge, and surface substitution where canal supply can reach.

Ownership sits with the urban body together with the district groundwater cell, the energy utility that prices the pumping power, and agriculture on the urban fringe. The metric is the node stage and the rate of water-level decline; the target is both arrested, with the non-revenue-water figure as the leading indicator.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Urban water body** — cut non-revenue water from 65%; recharge
- ☐ **Groundwater cell** — stage and decline monitoring
- ☐ **Energy utility** — pumping-power rationalisation
- ☐ **Agriculture** — efficiency on the urban fringe

Groundwater trajectory — Meerut (pre-monsoon depth, 2011–2020; stage GWRA-2024)

Metric	2011	2014	2017	2020	Δ / src
Depth (m bgl)	10.27	10.62	11.89	12.41	▲ 21 %
GW Stage (%)	—	—	—	76.9	GWRA-2024
T+5 [PRJ]	☐ Depth deepening steadily and stage rising; arrested only if 65% non-revenue water is cut so the borewell draw loses its reason.				

This is the clean decline signal: depth deepens year on year, 10.3 to 12.4 m, while the stage climbs to 76.9%. The mechanism is the leaking pipe — every litre lost to 65% non-revenue water is pulled back out of the aquifer.

THE VERDICT. Meerut is the western deficit in urban form, and the clearest proof of the pipe-loss mechanism: 65% non-revenue water is not a billing failure but a groundwater failure. Fix the network and you remove the reason to mine the aquifer.

PART C
PLATE CE-07

C2
WESTERN EXTRACTION SYSTEM

WESTERN EXTRACTION SYSTEM

SYSTEM PRESSURES

DEMAND BEYOND NATURE'S LIMITS



WHERE WATER IS TAKEN FASTER THAN NATURE CAN REPLENISH.

KEY SYSTEM PRESSURES

DECLINING GROUNDWATER
Falling water tables across most blocks.
Decline of 0.3–1.0 m per year in many areas.

OVER-EXTRACTION
Extraction exceeds recharge in > 60% of blocks.
Pumping far beyond sustainable limits.

CANAL LOSSES
High conveyance losses (30–50%) reduce surface water availability for beneficial use.

AGRICULTURAL PRESSURE
Water-intensive crops, multiple cropping and free power drive excessive use.

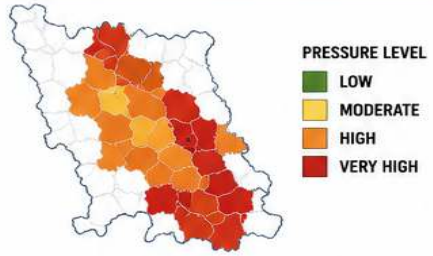
INDUSTRIAL DEMAND
Rapid industrialization increases groundwater dependency and pollution load.

URBAN GROWTH
Expanding cities increase demand for domestic, industrial and commercial water.

ENVIRONMENTAL IMPACTS

- Depletion of aquifers and falling water levels.
- Drying of wells, tubewells and springs.
- Reduced baseflow in rivers and drains.
- Soil degradation and loss of fertility.
- Loss of wetlands and biodiversity.

WHERE PRESSURES ARE HIGHEST



CRITICAL DISTRICTS
Muzaffarnagar, Meerut, Ghaziabad, Bulandshahr, Aligarh, Baghpat, Saharanpur, Hapur, Gautam Budh Nagar, Shamli, Hathras

SOCIO-ECONOMIC EFFECTS

- Higher cost of pumping and energy.
- Increasing risk for farmers and livelihoods.
- Water scarcity and unreliable supply.
- Rising conflicts over water resources.
- Unsustainable growth and long-term economic risks.

KEY NUMBERS

- **0.3 – 1.0 m** — ANNUAL DECLINE IN WATER LEVEL IN MANY BLOCKS
- **> 60%** — BLOCKS ARE OVER-EXPLOITED
- **30 – 50%** — CANAL WATER LOST IN CONVEYANCE
- **> 80%** — GROUNDWATER USED IN AGRICULTURE
- **15 – 20%** — INDUSTRIAL SHARE IN GROUNDWATER EXTRACTION
- **~2.3 CRORE** — PEOPLE DEPENDENT ON GROUNDWATER

THE VERDICT

UNSUSTAINABLE TODAY. UNSAFE TOMORROW.

REDUCE EXTRACTION. RESTORE BALANCE. SECURE THE FUTURE.

- Reduce demand and over-extraction
- Increase recharge and conservation
- Protect aquifers and ecosystems
- Act now for water security tomorrow

N7 Meerut — system pressures in the NCR extraction belt (Plate CE-07).

NODE N8 · MODERNITY OUTPACING ITS WATER

Ghaziabad–Noida — Modern Surface, Depleted Below

The newest urban form sitting on the oldest mistake.

Domain assessment — Ghaziabad–Noida — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	☐ Stage of GW Development: 124% / GBN 107% (GWRA-2024)	Recharge/canal axis: district average hides the city block; piped-supply gaps push demand onto the aquifer the city is already over-drawing.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: Screened, below BIS limit. 0/462 HPs arsenic-detected; 0 above BIS...	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 2657159	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Dams & Reservoirs	○ Gross Reservoir Storage: 0.0 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	○ Average Annual Rainfall: 633.5 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Urban: sealed surface + undersized drains → floods on the day, scarcity and tankers weeks later — recharge runs off, not in.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. Population growth scales urban demand against this shrinking supply — the two blades close together.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 21.9 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.

Climate stress on the water balance: compressed rainfall on a sealed, impervious surface with undersized drainage produces flooding on the day and tanker-borne scarcity weeks later — the same water that should have recharged the aquifer runs off. Rising temperature and population widen the gap each year.

THE IMPACT. The state's most modern urban node is among its most over-drawn. On the deep upper-doab alluvium of the Western cluster, Ghaziabad is over-exploited at 124% and Gautam Buddha Nagar at 107%, drawing far beyond recharge under dense residential, commercial and industrial demand — the NCR industrial belt sitting directly on the aquifer it depletes.

Here the delivery failure wears its most deceptive face. The planned sectors and glass towers suggest a fully serviced, modern water system, but the piped supply has not kept pace with the vertical and lateral growth, and the gap is filled by deep private and group-housing borewells — modern in appearance, drawing on an aquifer past 100% of recharge. Industrial effluent and nitrate degrade what remains. Modernity is mistaken for sustainability: the built environment ranks this the best-managed water node in the state; the aquifer ranks it among the worst.

This is concealment of a different kind from Lucknow's. Lucknow hides its deficit in an average; Ghaziabad–Noida hides it behind the appearance of planned modernity. The newest urban form draws down the oldest resource faster than anywhere else in the state, and degrades it as it goes.

THE REMEDY. The discipline must be strongest precisely where the visible modernity suggests it is least needed. Hard extraction limits in both over-exploited districts; piped and treated-surface supply extended so new construction is not served by private borewells; mandatory rainwater recharge and treated-wastewater reuse written into the built footprint; industrial metering; and treated surface substitution where it can be delivered.

The coordination runs across the urban, industrial, groundwater and wastewater domains. The metric is the over-exploited stage of both districts; the target is a measurable fall from 124% and 107% toward the sustainable line.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Urban water body** — extraction limits; piped supply to new build; mandatory recharge
- ☐ **Industry** — metering and reuse
- ☐ **Wastewater line** — treated reuse in the footprint
- ☐ **Groundwater cell** — over-exploitation enforcement

Groundwater trajectory — Ghaziabad (pre-monsoon depth, 2011–2020; stage GWRA-2024)

Metric	2011	2014	2017	2020	Δ / src
Depth (m bgl)	6.49	6.73	9.03	9.14	▲ 41 %
GW Stage (%)	—	—	—	124	GWRA-2024
T+5 [PRJ]	☐ Over-exploited and deepening fast under BAU; only hard extraction limits and piped supply to new build reverse it (GB Nagar stage 107%).				

Depth deepens 6.5 to 9.1 m in a decade and the stage stands at 124% — over-exploited, with Gautam Buddha Nagar at 107% beside it. The modern surface hides the fastest-falling aquifer of any node.

THE VERDICT. The newest urban form sits on the oldest mistake — drawing more than returns, at 124% and 107% of recharge, behind a modern surface that hides it. Ghaziabad–Noida must align its water to its image: the planned modernity has to reach the aquifer beneath it.

PART C
PLATE CE-06

C2
WESTERN EXTRACTION SYSTEM

WHERE WATER IS TAKEN FASTER THAN NATURE CAN REPLENISH.

WESTERN EXTRACTION SYSTEM

INDUSTRIAL WATER DEMAND

GROWING INDUSTRIES. RISING DEMAND. INCREASING PRESSURE.



KEY FACTS

INDUSTRIAL UNITS
> 50,000
Large, medium and small units

INDUSTRIAL WATER USE
~15–20%
Of total groundwater extraction

WATER INTENSIVE SECTORS
Sugar, paper, textiles, chemicals, distilleries, steel, electroplating, food processing

DEPENDENCE ON GROUNDWATER
> 70%
In many industrial clusters

RISING CONCERN
Over-extraction + pollution risk from untreated effluents

MAJOR INDUSTRIAL SECTORS AND WATER USE

SUGAR INDUSTRY	PAPER INDUSTRY	TEXTILE INDUSTRY	CHEMICAL INDUSTRY	DISTILLERIES	ELECTROPLATING
2.5 – 4.0	50 – 100	100 – 150	20 – 60	12 – 20	10 – 30
m^3 water per tonne of sugar	m^3 water per tonne of paper	m^3 water per tonne of fabric	m^3 water per tonne of product	litres water per litre of alcohol	m^3 water per 1000 m^3 plating

MOST INDUSTRIES USE GROUNDWATER BECAUSE SURFACE WATER IS SCARCE AND UNRELIABLE.

WHY INDUSTRIAL WATER DEMAND IS RISING

- Rapid industrialization and expansion of industrial clusters.
- Growth in water-intensive sectors with high consumption.
- Inadequate access to assured and treated surface water.
- Low water recycling and reuse within industries.
- Easy availability of groundwater at low cost.

WHERE INDUSTRIAL DEMAND IS HIGHEST



- Meerut
- Ghaziabad
- Saharanpur
- Muzaffarnagar
- Aligarh
- Bulandshahr
- Hapur
- Bijnor

INDUSTRIAL CLUSTERS ARE ALSO GROUNDWATER HOTSPOTS.

THE IMPACT

- Increased groundwater depletion in industrial belts.
- Risk of groundwater contamination from untreated industrial effluents.
- Higher operational cost due to falling water levels.
- Regulatory and environmental compliance challenges.
- Competition with agriculture and drinking water needs.

KEY NUMBERS

> 70%	15–20%	> 50,000	0.3 – 1.0 m	HIGH RISK
Industries dependent on groundwater	Share of industrial use in total groundwater extraction	Industrial units in the Western plains	Annual decline in water level in many industrial blocks	Of groundwater pollution from industrial discharges

THE VERDICT

HIGH DEMAND. HIGH RISK.

INDUSTRIES MUST ADAPT OR THE SYSTEM WILL COLLAPSE.

- Promote water efficiency in industries.
- Mandate recycling and reuse.
- Provide treated surface water to industries.
- Protect groundwater for future generations.

N8 Ghaziabad–Noida — industrial and urban demand on the NCR aquifer (Plate CE-06).

THE CLUSTERS — The Water Systems Beneath

Nine hydro-geographic clusters, formed by how the land behaves as a water system — the same geology, recharge behaviour and dominant stress grouping districts together. They run as a transect of the plain from the recharge-rich Terai in the north to the hard-rock Vindhyan margin in the south, and they supply the system logic that explains every node above.

CLUSTER C1 · STRATEGIC RECHARGE RESERVE

Terai — The Reserve

The state's recharge engine — to be protected, not spent.

Domain assessment — Terai — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	• Stage of GW Development: 60.7% (GWRA-2024)	Recharge axis: stage sets the extraction-vs-recharge balance; the governing water-security metric for the unit.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	☐ Arsenic Concentration: 3025	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 2302569	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Paddy Area: 1720.0 000 ha	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Surface Water – Rivers	○ Perennial River Length: 2140.0 km	Surface axis: river condition sets dilution capacity and the usable surface fraction; evaporation and effluent both shrink it, pushing demand onto groundwater.	Intercept effluent; restore environmental flow; treat river as asset.	Irrigation / NMCG
Urban Water Supply & Delivery	○ Urban Built-up Area: 11640.0 sq km	Canal/recharge axis: non-revenue water and service gaps convert directly into compensatory groundwater mining; sealed urban ground also removes the recharge that would refill it — flood-then-tanker.	Cut NRW; extend piped supply to remove the reason to drill.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	☐ Gross Reservoir Storage: 4.5 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.

Climate & Rainfall	☐ Average Annual Rainfall: 1119.0 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: 65.9	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	☐ Total Forest Cover: 544.9 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Total Waterbody Count: 24800.0 count	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	☐ Soil Type / Character: Terai loam (Mollisol)	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.
Geology & Lithology	○ Geomorphic / Lithological Character: Bhabar-Tarai piedmont; Quaternary alluvium over Siwal...	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Consumption / Demand Driver: Irrigation-dominant; Terai high cropping intensity	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: the recharge surplus that defines this asset is itself temperature- and rainfall-sensitive; a hotter, more compressed monsoon erodes the very recharge advantage that must be protected.

THE IMPACT. The Terai is not in crisis, and that is precisely why it is the most important cluster to get right. On the supply side it is a Bhabar–Tarai piedmont: coarse boulder-and-pebble fans near the foothills grading into fine, waterlogging-prone Tarai alluvium, on Mollisol loam rich in humus. Rainfall is the highest in the state — around 1,159 mm in its wettest districts — and the multi-tier Indo-Gangetic aquifer beneath recharges strongly. Its Falkenmark reading of 1,063 m³ per person and mean extraction stage of 60.7%, with no district over-exploited, both sit safely inside the band.

On the demand side the pressure is still moderate — agriculture is productive but not yet at the water-intensive extreme of the west, and urban concentration is low. The forest cover that the rest of the state has largely lost is, here, still substantially intact, and it functions as recharge infrastructure: the canopy that protects the catchment is the same canopy that lets the foreland bank its rain. This is the one cluster where the conversion system — geomorphology, soil and lithology working together — still does its job.

But the cluster is not without stress, and reading it as simply 'safe' would miss the system. Pre-monsoon depths run deep in places and decline at over a metre a year where extraction concentrates; arsenic appears in the Ghaghara sub-basin at 0.64 to 104 micrograms per litre with some 37% of samples over the limit; and flood exposure along the Sharda, Ghaghra and Rapti is recurrently high. The Terai is an asset under quiet pressure — and assets this valuable are the first to be drawn down to relieve crises elsewhere. The danger is not that the Terai is failing but that it will be spent.

THE REMEDY. The remedy is protection, coordinated across the domains that make the Terai an asset. The recharge front, the forest that holds the catchment and the floodplain that absorbs and recharges the flood must be governed as one system, not three. Forest cover is treated as recharge infrastructure and held; flood is managed to convert hazard into recharge rather than damage; and groundwater development is kept below the line so the surplus is never cashed out.

The hands at the table are the forest department, the irrigation and flood line, and the groundwater cell — convened to keep an asset an asset. The metric is the recharge-front integrity held flat, with no net new exploitation. The Terai's value to the state is as a standard for what a working water system looks like, not as a supply to be transferred to the over-drawn plains.

AT THE TABLE — DOMAINS CONVENED

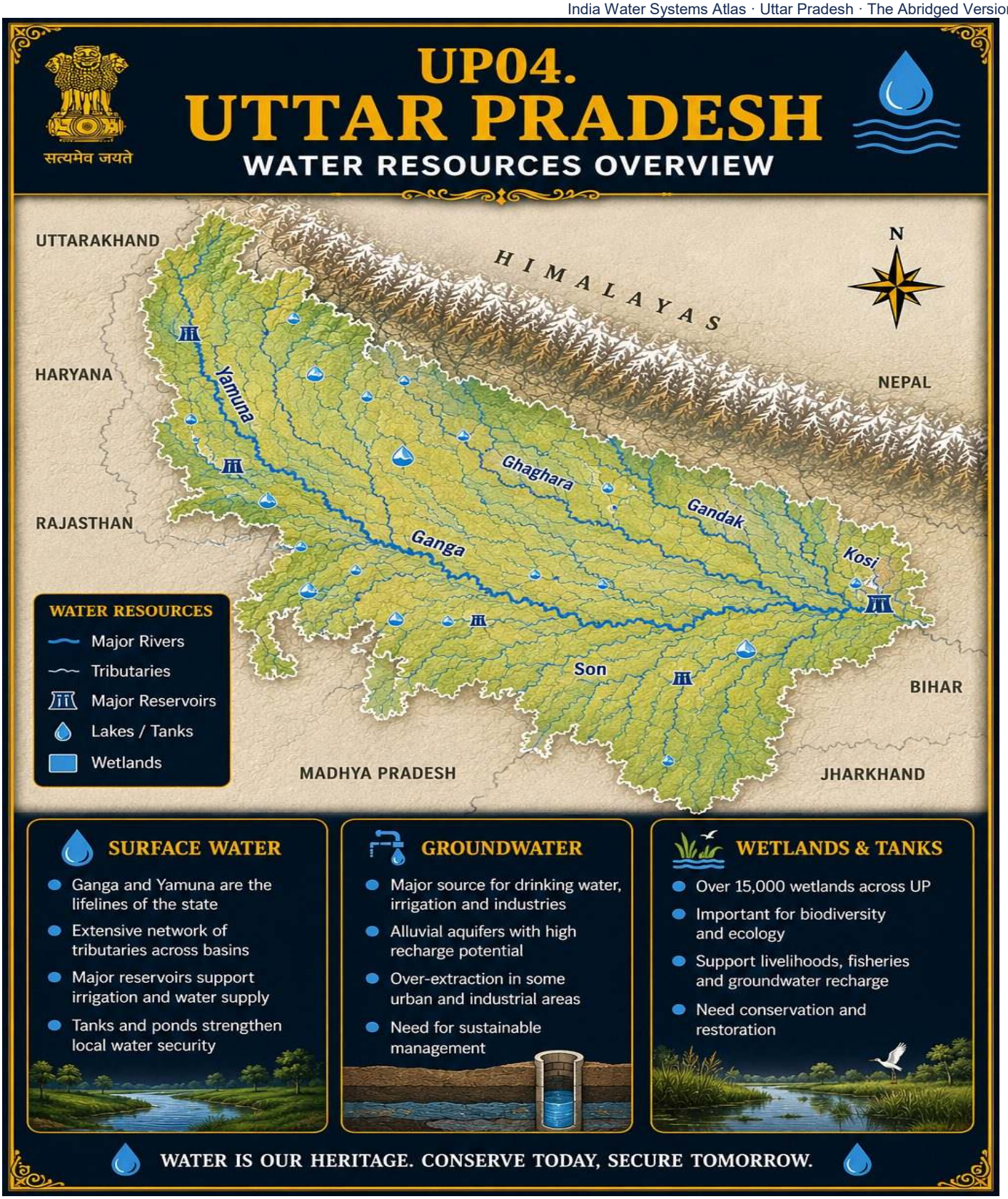
☐ **Forest department —** catchment forest held as recharge infrastructure
☐ **Irrigation / flood line —** flood converted to managed recharge
☐ **Groundwater cell —** development held below the line

Groundwater trajectory — C1 Terai (cluster weighted depth, 2004–06 → 2024; stage GWRA-2024)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	○ GAP	○ GAP	○ GAP	○ GAP	○ GAP
GW Stage (%)	—	—	—	**60.7**	GWRA-2024
T+5 [PRJ]	○ Depth spine withheld (GAP) — cluster depth aggregate rests on the T-20 source under review; no projection asserted. Stage 60.7% (GWRA-2024) governs. The Terai's risk is that the surplus is spent: development held below the line, forest and floodplain governed as recharge.				

The cluster depth spine is withheld pending review of its T-20 source, so no depth trajectory is asserted here; the stage reads a safe 60.7% (GWRA-2024). The warning the prose sets out still holds on quality and recharge grounds: the Terai is an asset under quiet pressure, to be protected rather than spent.

THE VERDICT. The Terai is the state's one reserve of genuine resilience — and the most important cluster to protect, precisely because it is not in crisis. Its remedy is restraint: govern recharge front, forest and floodplain as one system, and resist the pressure to spend the surplus.



C1 Terai — the northern recharge front.

CLUSTER C2 · OVER-DRAWN CORE (DEMAND)

Western Extraction — The Over-Drawn Core

The state's agro-industrial engine and its deepest manufactured deficit.

Domain assessment — Western Extraction — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 90.7% (GWRA-2024)	Recharge axis: alluvial storage masks chronic over-draft; stage above the recharge line means each dry year is mined, not borrowed.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	● Arsenic Concentration: 3	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	● Canal Command Area: 577582	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Crop Dominance: Sugarcane-wheat bowl; highest cropping intensity, most water-intensive	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Urban Water Supply & Delivery	○ Non-Revenue Water: 65% (highest NRW in UP)	Canal/recharge axis: non-revenue water and service gaps convert directly into compensatory groundwater mining; sealed urban ground also removes the recharge that would refill it — flood-then-tanker.	Cut NRW; extend piped supply to remove the reason to drill.	Jal Nigam / Nagar Nigam
Industry & Industrial Water Use	○ Industrial Effluent: NCR industrial belt (Ghaziabad/Noida/Meerut); high industrial water d...	Canal/recharge axis: concentrated industrial draw competes with irrigation and domestic supply; effluent degrades the aquifer and river it abstracts from — quantity stress and quality failure together.	Meter draw; enforce ZLD/effluent compliance; reuse.	Industries / UPPCB
Wastewater & Sanitation	○ Non-Compliant STPs: Ghaziabad, Meerut, Greater Noida, Bulandshahr, Hapur STPs non-compliant	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	☐ Gross Reservoir Storage: 1.0 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	● Average Annual Rainfall: 845.9 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	● Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. On an already over-/fully-drawn aquifer this is the difference between stress and collapse.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	● Total Forest Cover: 112.0 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.

Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Haiderpur Wetland (Ganga/Solani barrage wetland; Rams…	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Alluvial (Khadar + Bhangar); usar/reh salinity-alkalinity pockets	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.
Geology & Lithology	○ Geomorphic / Lithological Character: Upper Ganga-Yamuna doab; deep alluvial plain; recharg…	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Consumption / Demand Driver: Irrigation + heavy urban/NCR domestic+industrial draw	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: rising temperature lifts crop-water demand and evaporation while rainfall compression cuts the recharge window; on an aquifer already drawn near or beyond recharge, this converts chronic stress into structural deficit. Population growth scales the demand side further.

THE IMPACT. The western plains are the state's economic engine and its deepest structural water deficit, and the two are the same fact. The supply base is deep, flat upper Ganga–Yamuna doab alluvium — among the most fertile ground in India, a generous aquifer that should be an asset. The demand placed on it is what turns the asset into a deficit.

On the agriculture side, the cluster carries the most water-intensive cropping in the state: cultivated area share around 82%, dominated by sugarcane and wheat, irrigated over 90% from groundwater. The energy domain is the accelerator — free or flat-rate power removes any marginal cost to pumping, so there is no price signal to restrain the draw. Onto this agricultural base is layered the dense NCR industrial belt of Ghaziabad, Noida, Meerut and Bulandshahr, with its own heavy water demand and effluent load. Across twenty-seven districts the mean extraction stage is 90.7%, five districts are over-exploited, and the cluster draws roughly 79.8 TMC a year beyond a sustainable seventy-per-cent line — the single largest recovery quantum in the state.

The rural delivery system compounds the draw rather than relieving it. The canal network exists, but its last-mile distribution fails: tail-end farmers do not reliably receive surface water, so they pump groundwater instead. The surface buffer that should take pressure off the aquifer does not reach the field, and the aquifer absorbs the shortfall. The damage is not only quantity. Pre-monsoon depths have fallen to 12 to 19 metres across much of the doab; nitrate runs from 8 to 298 mg/L on measured transects, roughly a quarter of the cluster's

groundwater is now unfit for irrigation, and industrial effluent compounds the load. This is a demand-manufactured crisis on fertile ground — the aquifer drawn faster than it refills, and degraded as it falls.

THE REMEDY. No new source closes a gap this size; only a reduction in what is drawn does — and that reduction must be coordinated across the domains that create the demand. Agriculture realigns crops and irrigation efficiency away from the most water-intensive pattern; energy rations the free power that makes unlimited pumping possible; industry is metered and pushed to reuse; and the canal last-mile is repaired so surface water actually reaches the tail-enders and displaces the groundwater they now pump.

The hands that must share the table are agriculture, energy, industry, the irrigation line that owns the canal distribution, and the district groundwater cell — the five that between them create and could curb the demand. The metric is the stage of the over-exploited districts and the recovery quantum drawn down toward the sustainable line. The west cannot be supplied out of its deficit; it can only be disciplined out of it.

AT THE TABLE — DOMAINS CONVENED

☐ **Agriculture —** crop realignment, irrigation efficiency
☐ **Energy utility —** rationing of free pumping power
☐ **Irrigation line —** repair canal last-mile to displace GW draw
☐ **Industry / Groundwater cell —** metering, reuse, over-exploitation enforcement

Groundwater trajectory — C2 Western Extraction (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—
GW Stage (%)	—	—	—	90.7	GWRA-

					2024
T+5 [PRJ]	☐ Critical and worsening — ~79.8 TMC/yr above the sustainable line; only managed demand, power tariff reform and canal last-mile repair bend it down.				

No published cluster depth series exists; the governing signal is the 90.7% stage — critical, five districts over-exploited. The trajectory is set by demand, not geology.

THE VERDICT. The western plains carry the state's largest manufactured deficit — about 79.8 TMC a year above the sustainable line, on its most fertile ground, accelerated by free power and a canal that fails at the last mile. No new supply closes a gap this size; only managed demand does.

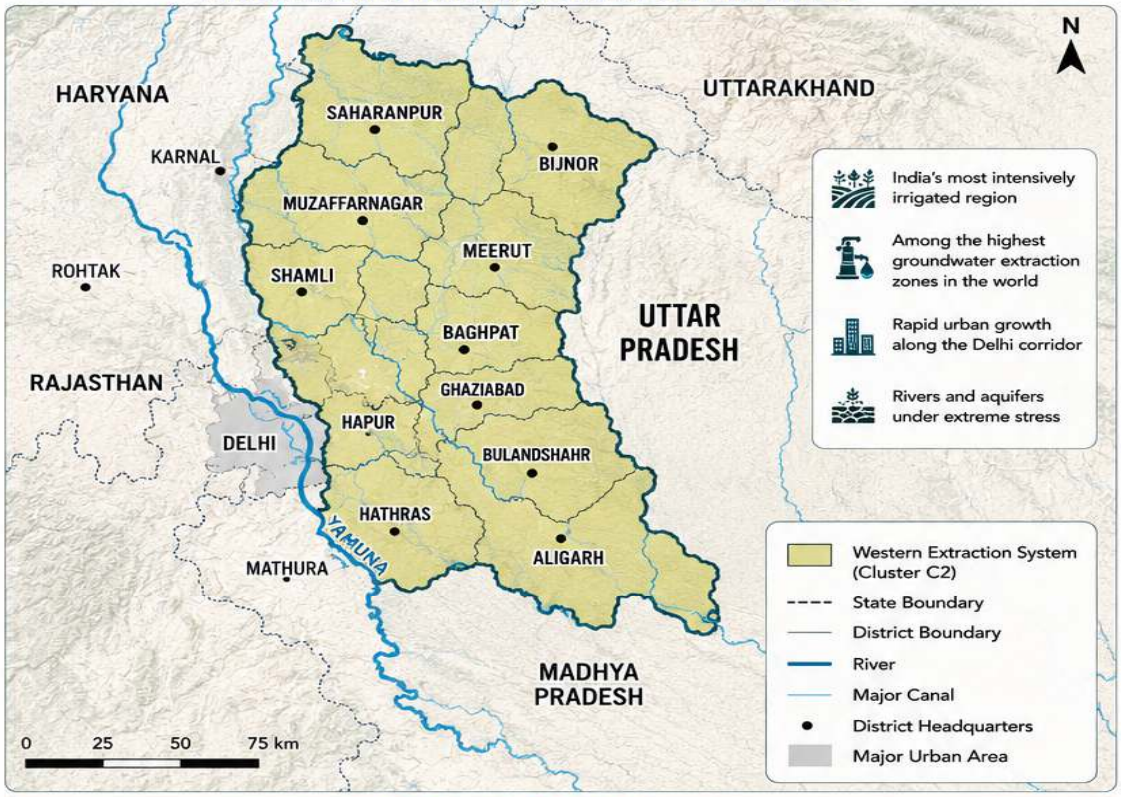
PART C
PLATE
CE-01

C2
WESTERN EXTRACTION SYSTEM

WESTERN EXTRACTION SYSTEM

CLUSTER LOCATOR

A HIGH EXTRACTION ZONE UNDER SEVERE STRESS



WHERE WATER IS TAKEN FASTER THAN NATURE CAN REPLENISH.

This cluster covers the intensively irrigated and highly urbanised western plains of Uttar Pradesh—a landscape of extraordinary productivity built on deep and depleting groundwater.

LOCATION CONTEXT



- Western UP lies in the upper Ganga–Yamuna Doab.
- It includes 11 key districts forming the productive agricultural and industrial heartland.
- Bounded by the Yamuna to the west and the Himalayan foothills to the north.



POPULATION (2023 est.)
~ 2.3 CRORE
(Approx. 12% of Uttar Pradesh)

NET SOWN AREA
~ 55 LAKH ha
Among the highest crop intensity in India

GROUNDWATER EXTRACTION
~ 35–40 BCM/YEAR
One of India's most overstressed zones

MAJOR CITIES
Meerut, Ghaziabad, Saharanpur, Aligarh, Bulandshahr, Hapur, Shamli, Muzaffarnagar

CRITICAL REALITY
Water is extracted faster than it is replenished.

THE FOUNDATION OF ABUNDANCE IS UNDER THREAT.
SUSTAIN TODAY. SECURE TOMORROW.

Source: CGWB, IWMI, Census of India 2011 & 2023, UP State Water Resources Department.

C2 Western Extraction — cluster locator (Plate CE-01).

CLUSTER C3 · SILENT DEPLETION (PREVENTION)

Upper Central — The Foodbowl That Mines Itself

The nation's grain, grown on water the state does not price, meter or replace.

Domain assessment — Upper Central — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 71.6% (GWRA-2024)	Recharge axis: stage sets the extraction-vs-recharge balance; the governing water-security metric for the unit.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	☐ Arsenic Concentration: 260	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 6817354	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Crop Dominance: UP #1 wheat (~31.8% India), #1 sugarcane (~41%), #1 rice area	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Industry & Industrial Water Use	○ Agro-Industry Employment: ~8500 sugar +12000 ancillary	Canal/recharge axis: concentrated industrial draw competes with irrigation and domestic supply; effluent degrades the aquifer and river it abstracts from — quantity stress and quality failure together.	Meter draw; enforce ZLD/effluent compliance; reuse.	Industries / UPPCB
Dams & Reservoirs	○ Barrage/Weir/Anicut Count: 1.0 count	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	☐ Average Annual Rainfall: 825.3 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	☐ Total Forest Cover: 103.0 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Ramganga/Ganga riverine water bodies + canal-command...	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Alluvial (deep loamy Bhangar); canal-command, locally potash-deficient	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.

Geology & Lithology	○ Geomorphic / Lithological Character: Central Ganga plain; deep loamy alluvium; moderate-hi…	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Sectoral GW Dependency: GW meets ~70% irrigation, ~90% rural domestic, >75% urban, ~95% in…	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: rising temperature raises crop-water demand and evaporation while rainfall compression shortens the infiltration window — recharge falls as demand rises, against a growing population.

THE IMPACT. The upper-central belt is where the state quietly eats its own foundation. The supply base is deep loamy Bhangar of the central Gangetic plain — the soil that makes the state India's foremost foodgrain producer at around 57.5 million tonnes a year. The demand that draws this output from below is the cluster's defining feature: groundwater supplies roughly 70% of irrigation and 90% of rural drinking water, in a wheat-rice rotation across some 60% of the cultivated area, at a cultivated-and-irrigated share near 62% and 56%.

What makes the depletion silent is the structure of the demand. The water is pulled not by a managed public system but by millions of private wells — 98.3% of all groundwater schemes here are privately owned, the densest such development in India, each drilled and deepened on its owner's judgement with no regulating hand. The energy subsidy is the accelerator and the absence of metering is the blind spot. As the shared table drops, every well must deepen to keep yielding; deeper wells need bigger pumps; the flat-rate tariff means the extra lift costs almost nothing at the margin. Each farmer's rational response — drill deeper, pump harder — lowers the table for every neighbour, compelling them to do the same. It is a classic common-pool collapse running in slow motion.

The rural delivery failure is part of the mechanism here too: where canal command is thin or its last mile unreliable, groundwater is the only dependable irrigation, so the private well is not a choice but a necessity. Pre-monsoon depth has already reached 13.71 metres, the stage stands at 71.6% on a Falkenmark of 735 that signals scarcity, and heavy metals are beginning to appear with depth — zinc and nickel shallow, copper and cadmium deep — the early warning that the aquifer is being drawn into layers never meant to be tapped.

THE REMEDY. Because the depletion is silent and incremental, the remedy is prevention, applied before the stage crosses into over-exploitation. The single most powerful lever is the price of the pumping power: as long as the marginal lift is free, no efficiency measure can compete with the incentive to deepen. Metering makes the invisible draw visible; crop and irrigation efficiency reduce demand at source; canal-command extension and last-mile repair give farmers a surface alternative to the private well; and recharge holds the table where it still can be held.

The hands at the table are agriculture, the energy utility, the irrigation line, the groundwater cell, and the panchayat water-user groups who must own the shared-resource discipline at field level. The metric is the stage held under the over-exploitation threshold and the rate of water-level decline arrested. C3 is the cluster where acting late is far more expensive than acting early — and where the system currently provides every incentive to act late.

AT THE TABLE — DOMAINS CONVENED

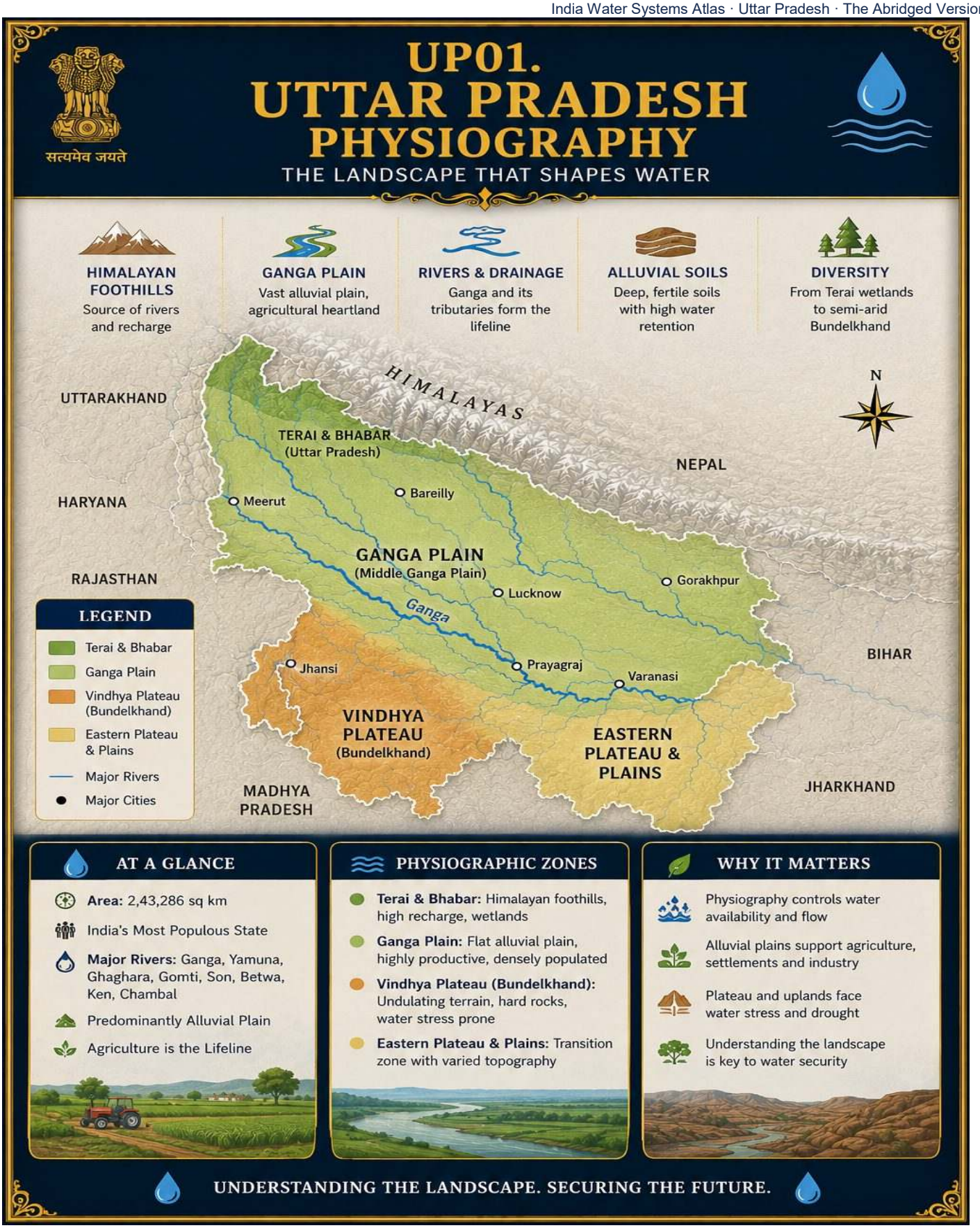
- ☐ **Energy utility** — tariff reform — end the free marginal lift
- ☐ **Agriculture** — metering, crop and irrigation efficiency
- ☐ **Irrigation line** — canal-command extension, last-mile repair
- ☐ **Panchayat water-user groups** — shared-resource discipline

Groundwater trajectory — C3 Upper Central (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—
GW Stage (%)	—	—	—	71.6	GWRA-2024
T+5 [PRJ]	☐ Crossing from safe into stress under BAU; prevention — metering, power pricing, recharge — is far cheaper now than relief later.				

Depth as a clean series is unpublished here; the stage at 71.6% on a Falkenmark of 735 marks silent, self-accelerating depletion — a common-pool collapse in slow motion.

THE VERDICT. The nation's grain is grown on water the state does not price, meter or replace. C3's depletion is silent, incremental and self-accelerating — a common-pool collapse in slow motion. It is the clearest case for prevention before the threshold, not relief after it.



C3 Upper Central — physiography and position.

CLUSTER C4 · CONTAMINATION BENEATH ABUNDANCE

Awadh — Wet Land, Poisoned Water

Not poisoned by its geology like the east — poisoning itself through its agriculture.

Domain assessment — Awadh — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 63.1% (GWRA-2024)	Recharge axis: stage sets the extraction-vs-recharge balance; the governing water-security metric for the unit.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	☐ Arsenic Concentration: 12	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 4474913	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Cultivated/Irrigated Share: ~62% cult / 56% irr	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Surface Water – Rivers	○ Functional Traditional Tanks: 14.0 % of total stock	Surface axis: river condition sets dilution capacity and the usable surface fraction; evaporation and effluent both shrink it, pushing demand onto groundwater.	Intercept effluent; restore environmental flow; treat river as asset.	Irrigation / NMCG
Floods & Floodplains	☐ Flood Exposure: HIGH	Surface/recharge axis: mismanaged flood is lost recharge and damage, not security; managed, the floodplain is a recharge asset.	Convert flood to managed recharge; floodplain restraint.	Irrigation (Flood) / UPSDMA
Climate & Rainfall	☐ Average Annual Rainfall: 976.9 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	● Total Forest Cover: 85.9 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Bakhira Tal (largest natural floodplain wetland of In…	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Alluvial (Bhangar + Khadar along Ghaghra/Saryu); usar/reh near Rae…	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.

Geology & Lithology	○ Geomorphic / Lithological Character: Ghaghra-Saryu alluvial transition; Khadar floodplain…	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Distress Migration: 228.0 000 persons/year	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: rising temperature raises crop-water demand and evaporation while rainfall compression shortens the infiltration window — recharge falls as demand rises, against a growing population.

THE IMPACT. Awadh is the cluster where having water and having safe water come apart most sharply. On the supply side it is a wet, well-watered transition plain — active Ghaghra–Saryu Khadar floodplain grading into older Bhangar, flooded most monsoons along the Rapti–Ami and the Ghaghra, with a comfortable stage of 63.1% on a Falkenmark of 741. By every quantity measure the cluster is abundant; flooding, if anything, is its visible problem.

The demand side is where the poison enters. Agriculture irrigates to as much as 84.2% of net area, and the same intensive irrigation that makes the cluster abundant is what contaminates it. At Rae Bareli, measured groundwater nitrate reaches 571 mg/L against a drinking limit of 45, and the Water Quality Index climbs to 411.5, well past the 300 mark that renders water unfit for human use. Nitrate at that level is the fingerprint of decades of fertiliser over-application leaching down into a shallow, flood-recharged table. This is the crucial distinction from the east: the east's arsenic and fluoride are geogenic, leached from the rock; Awadh's signature contaminant is man-made, manufactured by its own agriculture.

That is Awadh's distinctive identity: not scarcity, not the absence of a brake, but the paradox of contamination beneath abundance. The reassuring stage and the unsafe water occupy the same ground, and a system reading only quantity would certify the cluster secure while its people drink water unfit for use. Where the east is poisoned by its geology, Awadh is poisoning itself through its agriculture.

THE REMEDY. The remedy is not more water — the cluster has water — but safe water, and the prevention of the contamination at source. That means managing fertiliser application so

the nitrate stops being manufactured; testing and safe-source substitution where the shallow table is already compromised; and switching the governing metric from extraction stage to contamination exceedance, because the stage is the number that hides the crisis here.

The hands at the table are agriculture, which controls the fertiliser load; rural water supply and the health line, which must test and substitute; and the groundwater cell, which must map the contaminated pockets. The metric is the Water Quality Index and the nitrate exceedance brought down — a target a quantity-only reading would never set.

AT THE TABLE — DOMAINS CONVENED

☐ **Agriculture** — fertiliser management at source
☐ **Rural water supply / health** — testing, safe-source substitution
☐ **Groundwater cell** — contamination mapping

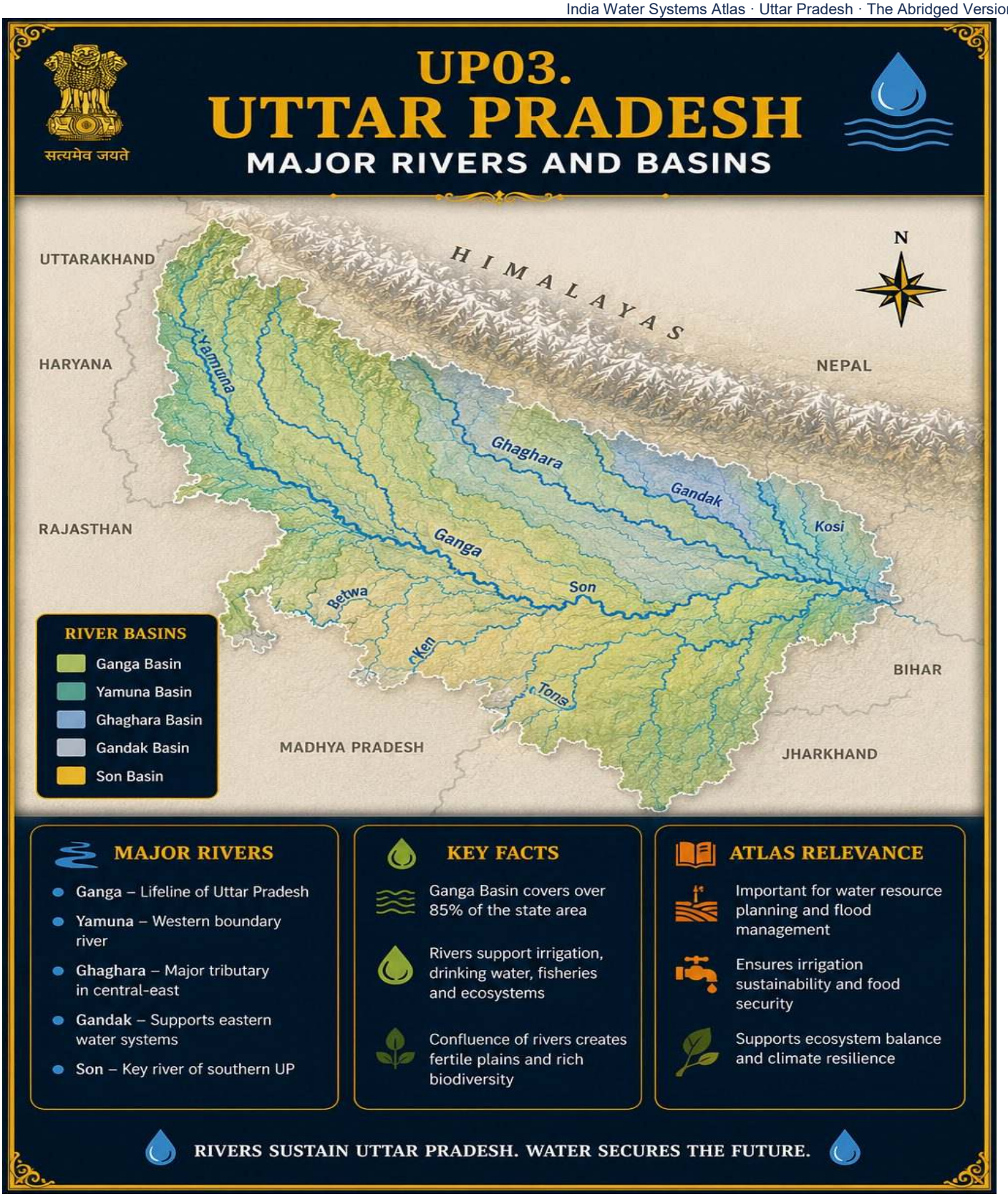
Groundwater trajectory — C4 Awadh (cluster weighted depth, 2004–06 → 2024; stage GWRA-2024)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	○ GAP	○ GAP	○ GAP	○ GAP	○ GAP
GW Stage (%)	—	—	—	**63.1**	GWRA-2024
T+5 [PRJ]	○ Depth spine withheld (GAP) — cluster depth aggregate rests on the T-20 source under review; no projection asserted. Stage 63.1% (GWRA-2024) governs, and the governing target is contamination exceedance, not depth: the cluster has water but not safe water.				

Depth deepens sharply to 38 m while the stage stays a comfortable 63.1% — abundance on paper. The real crisis is nitrate the stage cannot see; the depth confirms the draw, the quality confirms the danger.

THE VERDICT. Awadh has abundance and unsafe water on the same ground. It is not

poisoned by its geology but by its own agriculture — nitrate, not arsenic. The remedy is safe water, not more water, and the governing number must be contamination, not stage.



C4 Awadh — the Ghaghra–Saryu floodplain transition.

CLUSTER C5 · QUALITY CRISIS

Eastern Flood-Quality — The Abundance Paradox

Water plentiful and unsafe — the crisis the quantity metric cannot see.

Domain assessment — Eastern Flood-Quality — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 61.4% (GWRA-2024)	Recharge axis: stage sets the extraction-vs-recharge balance; the governing water-security metric for the unit.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	☐ Arsenic Concentration: Screened, below BIS limit. 0/1426 HPs arsenic-detected; 0 above BIS...	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 2482911	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	☐ Dominant Cropping System: Rice (kharif) – Wheat (rabi)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Surface Water – Rivers	○ Ganga BOD at Varanasi: 64.8 mg/L	Surface axis: river condition sets dilution capacity and the usable surface fraction; evaporation and effluent both shrink it, pushing demand onto groundwater.	Intercept effluent; restore environmental flow; treat river as asset.	Irrigation / NMCG
Floods & Floodplains	☐ Flood Exposure: HIGH	Surface/recharge axis: mismanaged flood is lost recharge and damage, not security; managed, the floodplain is a recharge asset.	Convert flood to managed recharge; floodplain restraint.	Irrigation (Flood) / UPSDMA
Urban Water Supply & Delivery	○ Urban Supply Coverage: Low piped coverage; high private tubewell dependence	Canal/recharge axis: non-revenue water and service gaps convert directly into compensatory groundwater mining; sealed urban ground also removes the recharge that would refill it — flood-then-tanker.	Cut NRW; extend piped supply to remove the reason to drill.	Jal Nigam / Nagar Nigam
Wastewater & Sanitation	○ Untreated Sewage: Limited STP coverage; eastern towns largely untreated	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	○ Gross Reservoir Storage: 0.0 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	☐ Average Annual Rainfall: 955.3 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief

Forests & Catchment	☐ Total Forest Cover: 33.7 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Surha Tal (oxbow lake/bird sanctuary, Ganga-connected...	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Eastern Gangetic alluvial (Bhat/Bangar/Dhuh); potash-deficient (Jau...	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.
Geology & Lithology	○ Geomorphic / Lithological Character: Eastern Ganga plain; low-gradient alluvium; high wate...	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Consumption / Demand Driver: Irrigation-dominant despite high water table; rural domestic...	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: rainfall compression sharpens flood peaks while shortening the infiltration window; rising temperature raises demand. The unit is water-rich but increasingly unable to hold or recharge what falls.

THE IMPACT. The eastern cluster is where the quantity metric lies most completely. On the supply side it is low-gradient eastern Gangetic alluvium — Bhat, Bangar and Diara soils — with rainfall the highest in the state at 900 to 1,019 mm and a shallow, water-rich multi-tier aquifer. The stage map records the east as safe at a mean of 61.4%, none over-exploited. It is not safe.

The water is plentiful and unsafe, and the contamination is geogenic — nature's, not agriculture's. Arsenic reaches up to 3,192 parts per billion in the Ballia–Varanasi–Ghazipur belt with 46.5% of samples over the limit, and the Ganga itself carries a biochemical oxygen demand of 64.8 at Varanasi — a river under heavy organic load. The demand side is not the driver here; the crisis is in the quality of an abundant resource, not the quantity of a scarce one. A district passes every quantity test while the water it holds is unfit to drink, and seasonal flooding coexists with chronic contamination.

The issue is that the crisis is invisible to the instrument used to measure it. Read on stage alone, the east disappears from view; read across quality, river and flood, it is one of the state's gravest crises. This is the abundance paradox in its purest form — the more water a place has, the more confidently the wrong metric certifies it safe, and the longer the real crisis goes unaddressed.

THE REMEDY. The remedy is not additional water but safe water, coordinated across quality, supply and flood. Rural water supply and the health line lead arsenic and fluoride testing and safe-source substitution where the aquifer is compromised; the irrigation and flood line converts recurrent flood into managed recharge rather than damage; and the groundwater cell maps the contaminated pockets so the safe aquifer layers are used and the unsafe avoided.

Crucially, the governing metric is switched from stage to contamination exceedance — because tracking the wrong number here is the error that has perpetuated the crisis for decades. The hands at the table are rural water supply, health, the flood line and the groundwater cell. The target is the exceedance brought down, not the stage held.

AT THE TABLE — DOMAINS CONVENED

☐ **Rural water supply / health** — arsenic and fluoride testing, substitution
☐ **Irrigation / flood line** — flood converted to managed recharge
☐ **Groundwater cell** — contaminated-pocket mapping

Groundwater trajectory — C5 Eastern Flood-Quality (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—
GW Stage (%)	—	—	—	**61.4**	GWRA-2024
T+5 [PRJ]	→ Stage stays Safe; the real trajectory is contamination — arsenic to 3,192 ppb — which the stage metric cannot register.				

The stage reads a safe 61.4% and none over-exploited, and that is the abundance paradox: the quantity metric certifies safe while the water is unfit. Switch the governing number to exceedance and the crisis appears.

THE VERDICT. The east is plentiful and unsafe — the crisis the quantity metric cannot see. Switch the governing number from extraction stage to contamination exceedance and the gravest of the four crises comes into view. Here, abundance is the disguise.

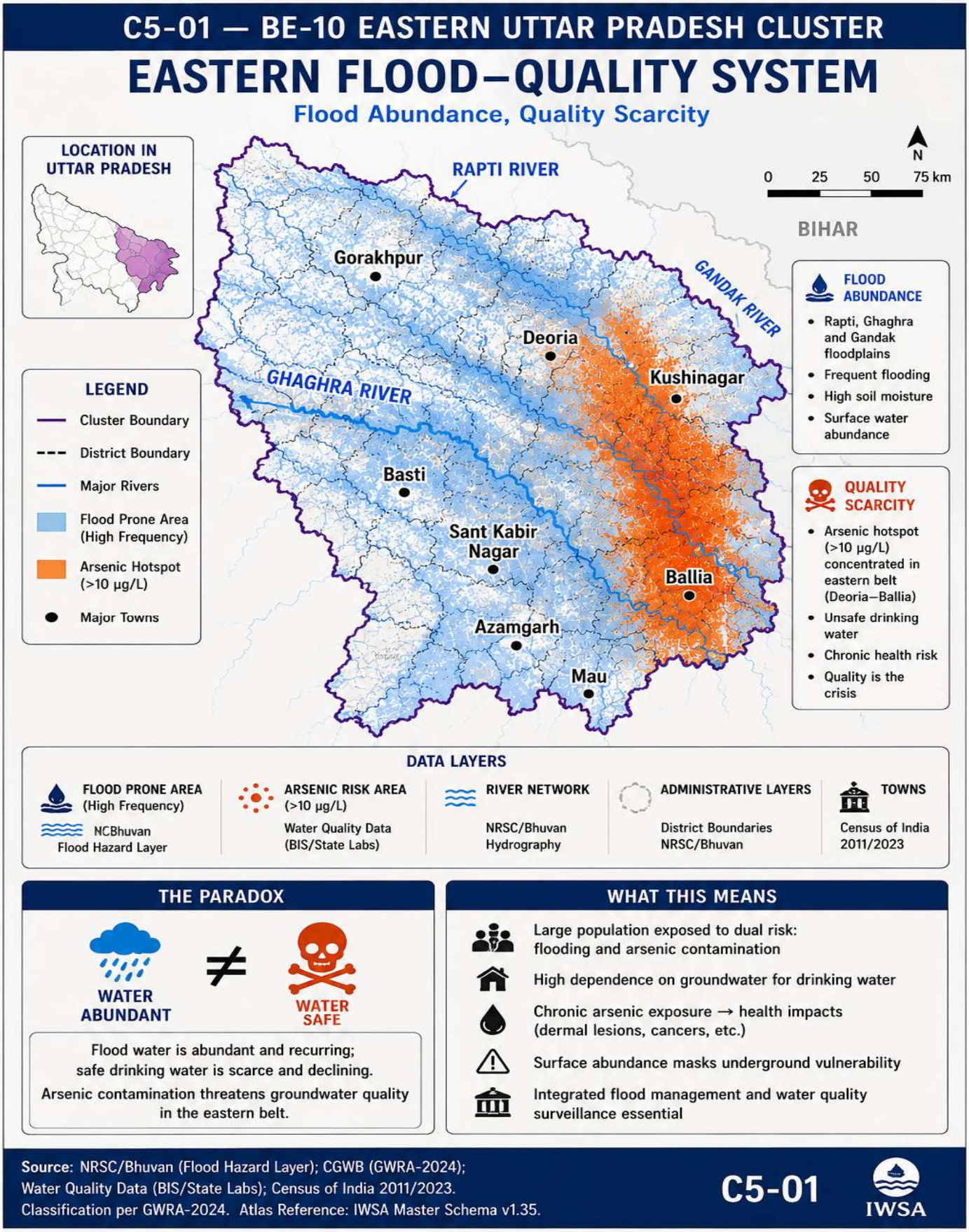


Plate C5-01 — BE-10 Eastern Flood–Quality System: flood abundance, quality scarcity.

CLUSTER C6 · HARD-ROCK STORAGE FAILURE

Bundelkhand — The Hard-Rock Frontier

Not drought — a landscape that can no longer hold the rain it still receives.

Domain assessment — Bundelkhand — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 73.0% (GWRA-2024)	Recharge axis: thin hard-rock storage (~10–15% of rainfall); every point of stage bites because the aquifer cannot refill. Surface/canal cannot compensate.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Fluoride / Iron-Nitrate pockets: Geogenic fluoride + iron/nitrate pockets (Bundelkhand belt)	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 253447	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	☐ Cultivated Area Share: >70	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Surface Water – Rivers	○ Major River: Betwa ~50% region supply	Surface axis: river condition sets dilution capacity and the usable surface fraction; evaporation and effluent both shrink it, pushing demand onto groundwater.	Intercept effluent; restore environmental flow; treat river as asset.	Irrigation / NMCG
Dams & Reservoirs	☐ Gross Reservoir Storage: 32.5 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	☐ Average Annual Rainfall: 778.6 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Hard-rock: compressed high-intensity rain runs off the crust almost entirely; recharge collapses though mm is unchanged.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: 80.3	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. On an already over-/fully-drawn aquifer this is the difference between stress and collapse.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	☐ Total Forest Cover: 329.7 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	☐ Water Body Count: 416	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Bundelkhand soils from granite/gneiss weathering: black (Mar/Kabar)…	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.

		aquifer. Salinity (usar/reh) further removes usable water.		
Geology & Lithology	☐ Runoff vs Recharge: ~85% runoff / ~15% recharge	Recharge axis: hard-rock lithology caps recharge at ~10–15% — runoff-dominated; the binding physical constraint on the whole water balance.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	☐ Agrarian Distress / Out-migration: HIGH distress + seasonal migration	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: on thin hard-rock storage, a hotter year and compressed high-intensity rain together collapse the already small recharge fraction while raising crop-water demand — the deficit widens far faster than the rainfall average implies.

THE IMPACT. Bundelkhand is routinely called drought-stricken, and the description is wrong in a way that has cost decades. The cause is in the supply geology: this is a Precambrian granite craton — granite, gneiss, migmatite — where roughly 85% of precipitation runs off and only about 15% recharges, against far higher recharge on the alluvial plains. Transmissivity is low, between 20 and 250 m² per day, so the ground cannot bank water even when rain falls. The rain still comes; the rock can no longer hold it.

Recharge has collapsed — at Lalitpur, by more than a third over twenty years while extraction barely moved — and the Betwa, supplying about half the region, drains the rest away. The reservoirs help, with sixteen dams holding around 400 TMC of gross storage, but cannot substitute for an aquifer that will not hold. On the demand side the pressure is modest by western standards, which is exactly why the stage number misleads: at a mean of 73.0% on a Falkenmark of 852 the numbers look less acute than the west, but the mechanism is worse, because the failure is structural, not behavioural. The quality compounds it: granitic fluoride runs 0.13 to 2.55 mg/L, and Mahoba's documented 'water debt' shows poor drinking quality across the terrain.

Naming the crisis as drought has sent relief where restoration was needed. Tankers have been sent for years; a tanker has never repaired a catchment. The west over-draws a generous aquifer; Bundelkhand simply cannot store the rain it receives, and no amount of demand discipline alone fixes a storage failure.

THE REMEDY. On fracture geology the remedy inverts the alluvial logic: catch and hold water on the surface, because it cannot be stored below — and this is inherently coordinated, community-owned work. Watershed treatment, tanks, check dams and catchment restoration are led by the rural-development and watershed line through the panchayat; agriculture shifts to low-water crops suited to the storage the land can actually offer; and the reservoirs are managed as the primary store the aquifer cannot be.

The proof that it works already exists in the cluster. In the village of Jakhni in Banda — one of the most drought-broken districts — the people mended their field bunds so each field held its own rain, deepened the old ponds and revived the wells, and enforced it as a shared rule. No grand budget, no outside contractor; a settlement of barely sixteen hundred people decided to hold its own rain, the wells came back, and paddy grew on land that measured rain in disappointments. The remedy is restoration, owned locally; the metric is recharge and surface storage rebuilt, not relief delivered.

AT THE TABLE — DOMAINS CONVENED

☐ **Rural development / watershed** — tanks, check dams, catchment restoration
☐ **Panchayat** — community-owned water rule (the Jakhni model)
☐ **Agriculture** — low-water crops matched to storage
☐ **Irrigation** — reservoirs managed as the primary store

Groundwater trajectory — C6 Bundelkhand (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—
GW Stage (%)	—	—	—	73.0	GWRA-2024
T+5 [PRJ]	☐ Structural, not behavioural — recharge collapse on hard rock; reversed only by surface storage and catchment restoration (the Jakhni model).				

On fracture geology a stage series misleads; the 73.0% figure understates a structural failure — ~15% recharge, recharge down a third at Lalitpur over 20 years. The rock cannot bank the rain it still receives.

THE VERDICT. Bundelkhand is not drought — it is a landscape that can no longer hold the rain it still receives. The crisis is structural, in the rock, and the remedy is restoration, not relief. Jakhni already proved it can be done; the task is to do it at scale.

C6-01 — BUNDELKHAND CLUSTER

DROUGHT BY DESIGN. NOT BY FATE.

Low Rainfall. High Stress. Depleting Aquifers.

CLUSTER OVERVIEW



A chronically drought-prone region with intense groundwater stress and recurring water scarcity.

- Low & Erratic Rainfall
- High Extraction
- Frequent Droughts
- Agrarian Distress

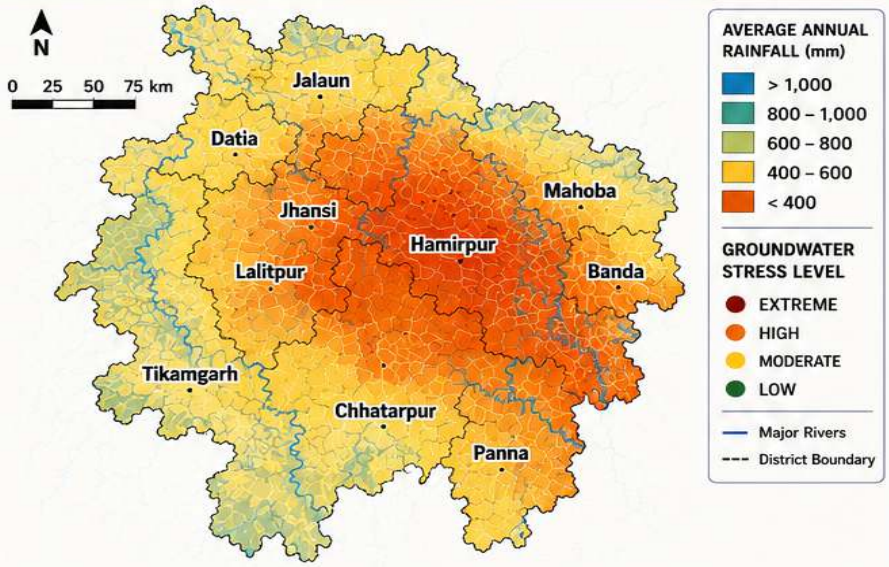
GROUNDWATER STAGE (CLUSTER)

73.0%

CLUSTER MEAN

Average groundwater stage across the Bundelkhand cluster.

BUNDELKHAND: RAINFALL & GROUNDWATER STRESS

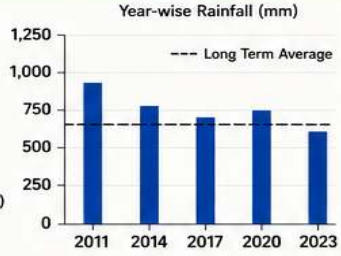


RAINFALL VARIABILITY (CLUSTER AVERAGE)

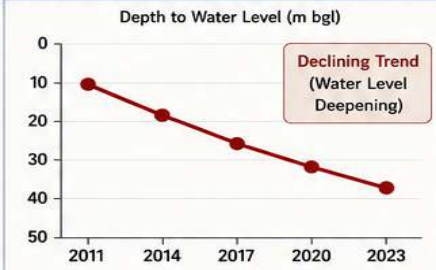
Average Annual Rainfall

707 mm

(Normal 1971–2020)



GROUNDWATER LEVEL TREND (CLUSTER AVERAGE)



KEY STRESS FACTORS

- Low and erratic rainfall
- High groundwater extraction for irrigation
- Low recharge due to degraded watersheds
- Droughts and crop failures
- Rising population and water demand

WHAT THIS MEANS

- Water scarcity for drinking, irrigation & livestock
- Health risks due to poor water quality
- Higher cost for water access and management
- Livelihood vulnerability and out-migration
- Agrarian distress and low productivity

THE WAY FORWARD

- Strengthen watershed development & rainwater harvesting
- Promote micro-irrigation and water-use efficiency
- Enhance aquifer recharge (check dams, percolation tanks)
- Regulate extraction and ensure equitable access
- Monitoring, data-led planning and community participation

DATA LAYERS

- Rainfall Data (IMD) 1971–2020 Normal
- Groundwater Data (CGWB) 2011–2023
- Watershed / Rainfall Datasets (NRSC / Bhuvan)
- District Boundaries (NRSC / Bhuvan)
- Census of India 2011 / 2023

THE PARADOX

WATER ABUNDANT DURING MONSOON ≠ **WATER SAFE THROUGH THE YEAR**

Rain falls. It flows away.
Recharge is minimal.
Groundwater keeps falling.
Scarcity is human-made.
Solutions are possible.

Source: CGWB Groundwater Resource Assessment (GWRA-2024); IMD Climate Data; Watershed / Rainfall Datasets (NRSC / Bhuvan). Classification per GWRA-2024. Atlas Reference: IWSA Master Schema v1.35.

C6-01 IWSA

Plate C6-01 — Bundelkhand: drought by design, not by fate (73.0% cluster mean).

CLUSTER C7 · OVER-DRAWN CORE + DEAD RIVER

Yamuna System — The Over-Drawn Core, with a Dead River

Extraction excess and surface-water death in one geography.

Domain assessment — Yamuna System — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 81.0% (GWRA-2024)	Recharge axis: alluvial storage masks chronic over-draft; stage above the recharge line means each dry year is mined, not borrowed.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	☐ Arsenic Concentration: Screened, below BIS limit. 0/596 HPs arsenic-detected; 0 above BIS...	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 1445314	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Crop Dominance: Wheat-rice-potato doab; intensive irrigated cropping	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Surface Water – Rivers	☐ Yamuna Pollution Load: ~85 domestic	Surface axis: river condition sets dilution capacity and the usable surface fraction; evaporation and effluent both shrink it, pushing demand onto groundwater.	Intercept effluent; restore environmental flow; treat river as asset.	Irrigation / NMCG
Urban Water Supply & Delivery	○ Urban GW Mining: Large-scale GW mining (Agra named); high urban demand on stressed doab aq...	Canal/recharge axis: non-revenue water and service gaps convert directly into compensatory groundwater mining; sealed urban ground also removes the recharge that would refill it — flood-then-tanker.	Cut NRW; extend piped supply to remove the reason to drill.	Jal Nigam / Nagar Nigam
Industry & Industrial Water Use	○ Industrial Effluent: glass industry cluster	Canal/recharge axis: concentrated industrial draw competes with irrigation and domestic supply; effluent degrades the aquifer and river it abstracts from — quantity stress and quality failure together.	Meter draw; enforce ZLD/effluent compliance; reuse.	Industries / UPPCB
Wastewater & Sanitation	○ Untreated Sewage to River: major untreated discharge	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	○ Gross Reservoir Storage: 0.5 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	☐ Average Annual Rainfall: 638.4 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief

		On an already over-/fully-drawn aquifer this is the difference between stress and collapse.		
Forests & Catchment	☐ Total Forest Cover: 93.1 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Sur Sarovar / Keetham Lake (man-made reservoir; Ramsa...	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Yamuna-doab alluvial; usar/reh saline-alkaline (Aligarh/Etah/Etawah...	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.
Geology & Lithology	○ Geomorphic / Lithological Character: Yamuna-Ganga doab + Yamuna-Chambal ravines; alluvium...	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Consumption / Demand Driver: Irrigation + urban (Agra) domestic+industrial	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: rising temperature lifts crop-water demand and evaporation while rainfall compression cuts the recharge window; on an aquifer already drawn near or beyond recharge, this converts chronic stress into structural deficit. Population growth scales the demand side further.

THE IMPACT. The Yamuna cluster fails on two fronts at once, and the fronts compound. On the supply side it is Ganga–Yamuna doab alluvium across eighteen districts — capable ground, drawn too hard. The mean stage is 81.0%, three districts are over-exploited with Agra past 117%, and the aquifer is pulled to the deepest levels in the state, about 21.5 TMC above the sustainable line. The cropping is the western demand pattern carried south: wheat, potato and mustard in rabi, bajra and paddy in kharif, on heavily irrigated land.

Meanwhile the river itself, in its Uttar Pradesh reach, has been reduced from a water source to a waste channel. Over 3,000 MLD of largely untreated sewage and industrial effluent enter it; Firozabad's glass cluster and Agra's leather industry discharge into it; its biochemical oxygen demand and ammonia run high while dissolved oxygen falls. The urban delivery failure feeds the river's death — partial sewerage and treatment mean the cities' waste returns to the Yamuna untreated — and the river's death feeds the aquifer's decline: a dead river cannot relieve a falling water table, so the groundwater is drawn harder precisely because the surface water is unusable.

Quality closes the loop — saline and fluoride-affected pockets reduce the usable fraction further. The two failures are one system: extraction excess and river death reinforcing each other, and neither fixable while the other is ignored.

THE REMEDY. The remedy must treat both fronts together, because neither succeeds alone. The groundwater cell enforces extraction discipline in the over-exploited districts; the pollution-control and urban line intercepts sewage and industrial effluent before the river and

restores ecological flow; industry — glass and leather — is pushed to treat and reuse; reuse and efficiency, not new supply, close the groundwater gap; and the canal last-mile is repaired so surface irrigation displaces some of the groundwater draw.

The logic that binds them is direct: a restored river becomes a usable source that takes pressure off the aquifer, and a disciplined aquifer leaves enough flow to keep the river alive. The hands at the table are the groundwater cell, the pollution-control and river-restoration line, industry, the irrigation line and the urban bodies. The metric pairs the stage of the over-exploited districts with the river's organic load — both reduced together.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Groundwater cell** — extraction discipline in over-exploited districts
- ☐ **Pollution control / river mission** — effluent interception, ecological flow
- ☐ **Industry (glass, leather)** — treat and reuse
- ☐ **Irrigation / urban bodies** — canal last-mile repair; sewage interception

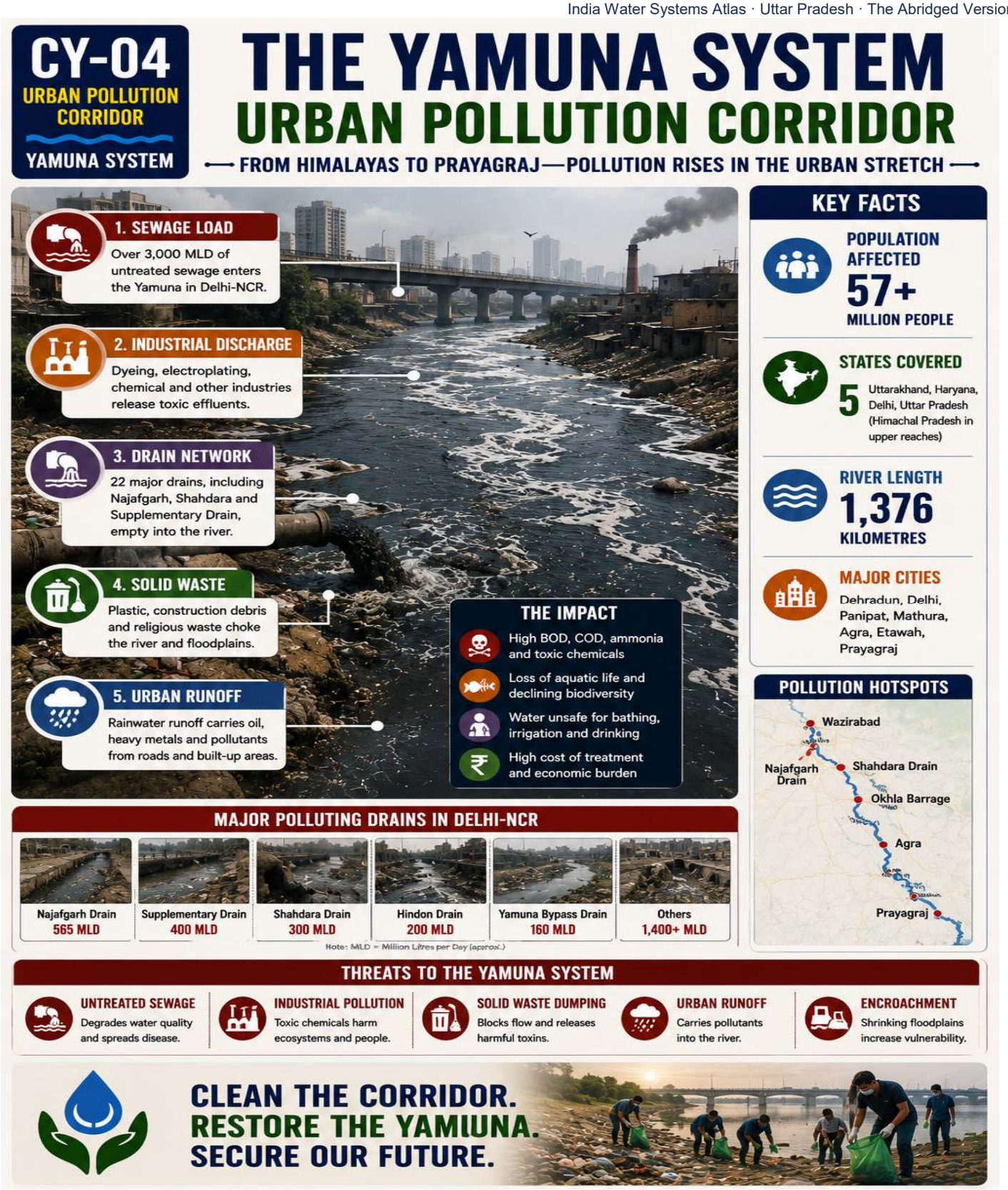
Groundwater trajectory — C7 Yamuna System (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—
GW Stage (%)	—	—	—	81.0	GWRA-

					2024
T+5 [PRJ]	☐ Aquifer and river declining together — ~21.5 TMC over the line, Agra past 117%; both recover only if disciplined and revived as one system.				

The 81.0% stage marks deep extraction; the dead river compounds it, since a waste-channel Yamuna cannot relieve the aquifer. Two failures, one system, each worsening the other.

THE VERDICT. The Yamuna cluster carries extraction excess and a dead river in one geography, each making the other worse. The remedy is to treat both at once: discipline the aquifer and revive the river, so that each relieves the other instead of compounding it.



C7 Yamuna — urban pollution corridor (Plate CY-04).

CLUSTER C8 · HARD-ROCK ASSET, COUPLED SYSTEMS

Vindhyan Ecology-Energy — The Interlocked Frontier

A comfortable cluster one industrial decision away from stress.

Domain assessment — Vindhyan Ecology-Energy — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	☐ Stage of GW Development: 60.4% (GWRA-2024)	Recharge axis: thin hard-rock storage (~10–15% of rainfall); every point of stage bites because the aquifer cannot refill. Surface/canal cannot compensate.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	○ Arsenic Concentration: 29	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	○ Canal Command Area: 317292	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	○ Dominant Cropping System: Paddy-dominant (Rice) – Wheat (rabi)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Industry & Industrial Water Use	○ Energy/Mining Cluster: coal/power/mining	Canal/recharge axis: concentrated industrial draw competes with irrigation and domestic supply; effluent degrades the aquifer and river it abstracts from — quantity stress and quality failure together.	Meter draw; enforce ZLD/effluent compliance; reuse.	Industries / UPPCB
Dams & Reservoirs	○ Gross Reservoir Storage: 148.6 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	○ Average Annual Rainfall: 955.0 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Hard-rock: compressed high-intensity rain runs off the crust almost entirely; recharge collapses though mm is unchanged.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	○ Drought-Prone Area: No drought or desert. Drought-prone 0.0% of district.	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously. On an already over-/fully-drawn aquifer this is the difference between stress and collapse.	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief
Forests & Catchment	○ Total Forest Cover: 1231.4 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Water Body Count: 1236	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Vindhyan red-yellow 'bhonta'	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.

	(ferric/aluminium-rich; lime/P/N/K-poo…	aquifer. Salinity (usar/reh) further removes usable water.		
Geology & Lithology	○ Geomorphic / Lithological Character: Vindhyan plateau; consolidated sandstone/limestone/sh…	Recharge axis: hard-rock lithology caps recharge at ~10–15% — runoff-dominated; the binding physical constraint on the whole water balance.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Consumption / Demand Driver: Irrigation-limited (hard rock) + energy/industrial (Sonbhadra…	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: on thin hard-rock storage, a hotter year and compressed high-intensity rain together collapse the already small recharge fraction while raising crop-water demand — the deficit widens far faster than the rainfall average implies.

THE IMPACT. The Vindhyan cluster is the smallest in the volume and the most tightly coupled, and its supply base is distinct from every alluvial cluster and from Bundelkhand's granite. This is the Vindhyan plateau — consolidated Precambrian sandstone, limestone and shale across Mirzapur, Sonbhadra and Chandauli — where groundwater is limited and fracture-dependent: low storage, high well-to-well variability, borewells chasing secondary-porosity fractures rather than a continuous aquifer.

The numbers look comfortable — stage 60.4%, Falkenmark 562, pre-monsoon depth 5.35 metres — but on this rock the stage is misleading, because the rock will not bank water. The real store is on the surface: twenty large dams holding some 11,354 MCM, about 401 TMC, and red-yellow 'bhonta' soils that shed rather than absorb. The demand side confirms the constraint: only about 20% of the monsoon cropped area is irrigated and the rest is rainfed, because the hard rock simply cannot supply more — pulses, oilseeds and millets dominate, not the water-intensive rice and wheat of the plains.

Onto this limited-water base sits the state's energy and mining heartland: Sonbhadra's coal mining and the Renukoot–Anpara thermal-power clusters, with documented heavy-metal contamination — arsenic, cadmium, lead, chromium — in Mirzapur groundwater and elevated fluoride around Chandauli. The cluster also carries 2,408 km² of forest and the Kaimur Wildlife Sanctuary, an ecological load. So the coupling is not abstract: water, energy, mining and forest are bound together, and a decision in any one moves the others.

THE REMEDY. Because the systems are interlocked, the remedy is to govern them as a nexus rather than separately. Energy and mining draw and contaminate the limited groundwater; the forest protects the recharge and the ecology; the reservoirs are the real store. A standard water framework that looks only at the comfortable stage would miss every one of these couplings and would be blindsided by the next industrial expansion.

The hands at the table are unusual for a water plan: the energy and mining authorities, the forest department, the pollution-control line and the groundwater cell, convened together because no one of them can hold the balance alone. The metric is not the stage but the heavy-metal contamination, the forest cover held, and the reservoir storage protected. C8 is comfortable today and one large industrial decision away from stress.

AT THE TABLE — DOMAINS CONVENED

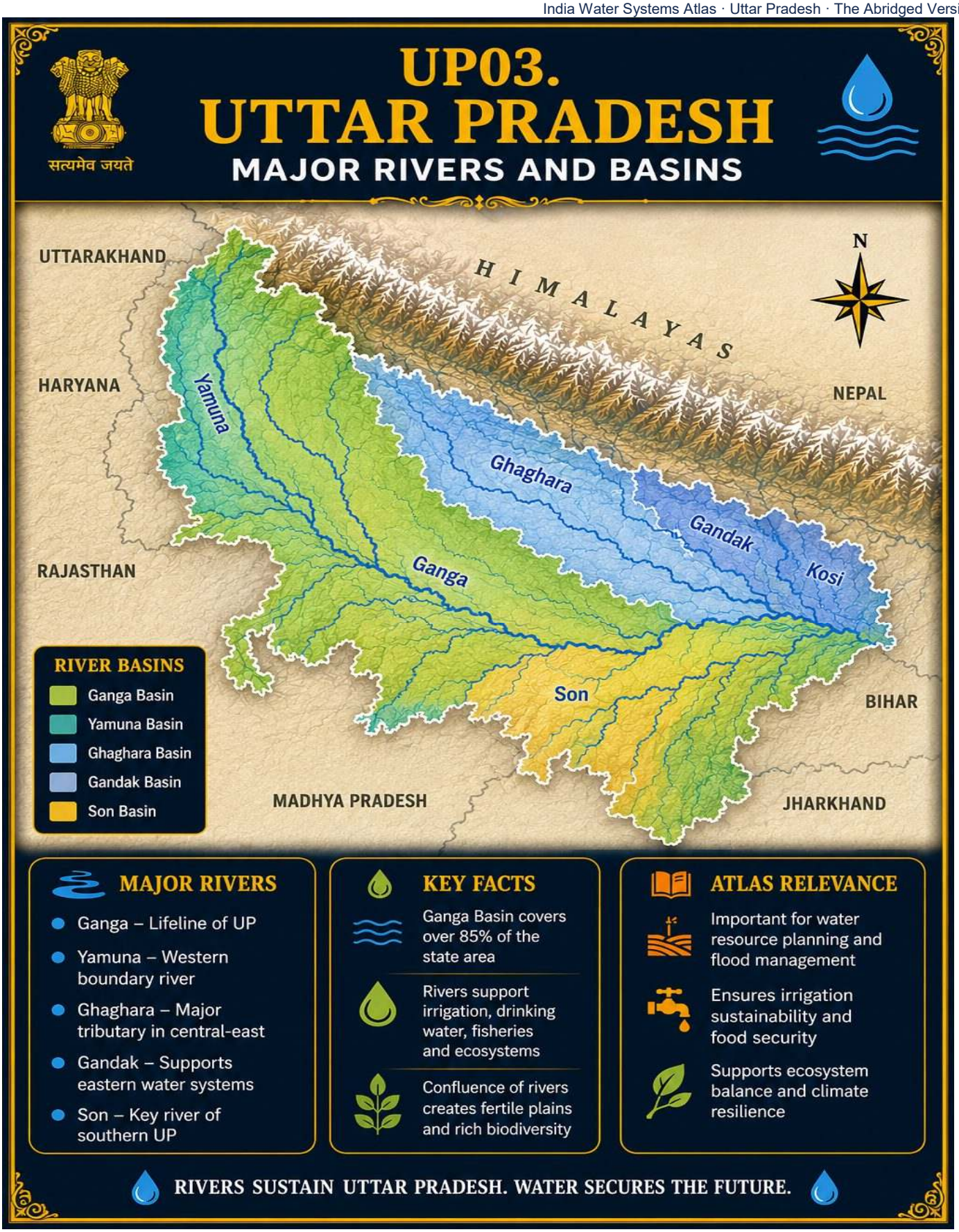
- ☐ **Energy / mining authorities** — draw and contamination control
- ☐ **Forest department** — recharge and ecology protection
- ☐ **Pollution control** — heavy-metal monitoring
- ☐ **Groundwater cell** — fracture-aquifer and reservoir balance

Groundwater trajectory — C8 Vindhyan Ecology-Energy (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—
GW Stage (%)	—	—	—	60.4	GWRA-2024
T+5 [PRJ]	→ Comfortable today, one industrial decision from stress; govern water-energy-mining-forest as a nexus or be blindsided.				

The 60.4% stage reads safe, but on consolidated hard rock the stage misleads — storage is fracture-dependent and the real store is ~401 TMC of surface reservoir. Coupling, not the stage, is the risk.

THE VERDICT. The Vindhyan frontier is comfortable on the surface and interlocked beneath — water, energy, mining and forest bound into one system. Its stage reads safe, but on hard rock the stage misleads. Govern it as a nexus, or be blindsided by the next industrial decision.



C8 Vindhyan — the hard-rock and reservoir country.

CLUSTER C9 · INSTITUTIONAL DEFICIT

Middle Ganga Urban-Institutional — The Paradox

The best geology in the state, the worst per-capita position — by institution, not nature.

Domain assessment — Middle Ganga — each load-bearing domain traced to surface water, canal supply and aquifer recharge

Domain	Key figure	Water impact (surface / canal / recharge)	Remedy	Owner
Groundwater & Aquifers	● Stage of GW Development: 76.8% (GWRA-2024)	Recharge axis: stage sets the extraction-vs-recharge balance; the governing water-security metric for the unit.	Govern on stage; hold extraction below recharge against a stated baseline.	CGWB / Minor Irrigation
Water Quality	☐ Arsenic Concentration: 2	Direct bearing on surface water, canal supply or aquifer recharge.	Map contaminated pockets; substitute safe-source supply; track the trend.	UPPCB / Jal Nigam
Irrigation – Systems & Efficiency	☐ Canal Command Area: 2216101	Canal axis: canal-vs-groundwater split sets the extraction load; conveyance loss and low efficiency mean more water drawn at head for the same delivery at the root zone — worsened by evaporation under heat.	Shift canal share up, micro-irrigation, align crop water to availability.	Irrigation / Minor Irrigation
Agriculture – Cropping Pattern	☐ Dominant Cropping System: Rice – Wheat rotation (Ganga-Yamuna doab)	Demand axis: crop water-intensity is the demand engine; paddy/sugarcane multiply the temperature effect — rising ET means the same crop needs progressively more water each hotter season.	Diversify away from water-intensive crops; price water-true.	Agriculture Dept.
Floods & Floodplains	○ Flood Exposure: MODERATE-HIGH (riverine, ghats)	Surface/recharge axis: mismanaged flood is lost recharge and damage, not security; managed, the floodplain is a recharge asset.	Convert flood to managed recharge; floodplain restraint.	Irrigation (Flood) / UPSDMA
Urban Water Supply & Delivery	○ Urban GW Supply Dependency: 70	Canal/recharge axis: non-revenue water and service gaps convert directly into compensatory groundwater mining; sealed urban ground also removes the recharge that would refill it — flood-then-tanker.	Cut NRW; extend piped supply to remove the reason to drill.	Jal Nigam / Nagar Nigam
Industry & Industrial Water Use	○ Industrial Effluent: Jajmau ~400 tannery sites; 16,000+ industrial units; chromium effluen...	Canal/recharge axis: concentrated industrial draw competes with irrigation and domestic supply; effluent degrades the aquifer and river it abstracts from — quantity stress and quality failure together.	Meter draw; enforce ZLD/effluent compliance; reuse.	Industries / UPPCB
Wastewater & Sanitation	○ Sewage Generation vs STP Capacity: Gen ~5,500 vs installed 3,663.4 → deficit 1,836.6 (~33%...	Surface axis: untreated return flow is the dominant quality-failure pathway to river and aquifer; the STP gap removes usable surface water downstream.	Close the STP gap; intercept and treat before return.	Jal Nigam / Nagar Nigam
Dams & Reservoirs	○ Gross Reservoir Storage: 1.8 TMC	Surface/canal axis: storage buffers the season and feeds the canal command; storage or silting gaps push demand onto groundwater in the dry months.	Optimise storage operation; protect live capacity from silt.	Irrigation Dept.
Climate & Rainfall	☐ Average Annual Rainfall: 785.7 mm	Recharge axis: same annual mm now falls in ~45–50 days vs ~90–100, halving the infiltration window. Rural: hardened soil + flashier flow → runoff up, recharge sharply down despite a flat rainfall figure.	Plan to variability; bank wet-year surplus as recharge.	IMD / SWaRA
Climate Variability & Extremes	☐ Drought-Prone Area: 10.8	Three-channel temperature stress: surface evaporates faster; root-zone ET rises so the	Drought-proof through recharge banking and demand caps.	UPSDMA / Relief

		same yield needs more water; soil crusts so infiltration and recharge fall — simultaneously.		
Forests & Catchment	☐ Total Forest Cover: 104.7 sq km	Recharge/surface axis: catchment cover governs infiltration vs runoff; cover loss converts recharge into flood runoff and lowers dry-season surface flow.	Treat forest cover as recharge infrastructure; catchment treatment.	Forest Dept.
Ecology & Wetlands	○ Significant Water Bodies / Wetlands: Ganga-Yamuna riverine systems (Triveni Sangam, Prayag…	Recharge/surface axis: wetlands and water bodies are natural storage and recharge buffers; their loss removes flood-buffering and dry-season surface supply.	Protect and revive wetlands as storage; prevent encroachment.	Forest / Wetland Authority
Soil & Infiltration Capacity	○ Soil Type / Character: Middle-Ganga alluvial (loamy Bhangar + Khadar); usar/reh (Kanpur/Lu…	Recharge axis: soil sets the infiltration ceiling; under rising heat it hardens and crusts, throttling percolation to the root zone and the aquifer. Salinity (usar/reh) further removes usable water.	Soil-health management; reclaim usar/saline pockets.	Agriculture / Soil Cons.
Geology & Lithology	○ Geomorphic / Lithological Character: Middle Ganga-Yamuna doab; deep alluvium; recharge mas…	Recharge axis: deep alluvial lithology gives high storage and recharge capacity — the asset that over-draft is spending.	Match development to aquifer type; no over-draft of hard rock.	GSI / CGWB
Drinking Water	○ JJM Functional Tap Status: UP lagging; per-district on JJM dashboard	Recharge axis: the service-level gap drives private abstraction and exposure to contaminated or over-drawn layers, deepening the very stress it responds to.	Universalise safe piped supply; close JJM gap.	JJM / Jal Nigam
Population & Demography	○ Labour Force in Agriculture: 59.3 (state 2019)	Demand axis: population and consumption scale the baseline draw against a supply that temperature and rainfall-compression are already degrading — the demand blade of the closing scissors.	Demand management; right-size projected draw.	Planning Dept.

Climate stress on the water balance: rising temperature raises crop-water demand and evaporation while rainfall compression shortens the infiltration window — recharge falls as demand rises, against a growing population.

THE IMPACT. The Middle Ganga cluster carries the state's central paradox in its sharpest form. Its supply geology is the most recharge-capable in Uttar Pradesh — deep, well-recharged Gangetic alluvium running Kanpur–Lucknow–Prayagraj–Varanasi — yet its Falkenmark reading of 432 m³ per person is the lowest in the state: absolute scarcity. Its mean stage of 76.8% across fifteen districts sits, in aggregate, about 12.6 TMC below the sustainable line, and only one district is over-exploited. So the crisis is not aggregate over-draw.

It is extreme per-capita pressure concentrated in the cities — Lucknow, Kanpur, Prayagraj, Varanasi, on a rice–wheat doab — compounded by quality, with arsenic and nitrate in the urban-industrial belt and the Ganga's organic load, and hidden by aggregation, where a district average reads safe while the city block beneath it is over-drawn. The demand-and-delivery failure that runs through every node in this volume is, at the cluster scale, the C9 crisis: partial piped networks push the cities onto private borewells, the Atlas names Kanpur, Prayagraj and Varanasi for large-scale urban groundwater mining, and untreated urban wastewater degrades the shared aquifer and the river alike. This cluster holds four of the state's seven nodes; their concealment is its signature.

The issue, read across domains, is institutional rather than natural: the state's economic and administrative core sits in the worst per-capita water position on the best ground it has,

because no body reconciles the cities' concentrated draw with the region's ample recharge. The water is there; the institution that would match it to the demand is not.

THE REMEDY. Because the deficit is concentrated and institutional, the remedy is redistribution, quality repair and above all integration — not a blanket extraction cut, which would punish the rural districts for the cities' draw. Block-level measurement exposes the urban deficit the district average conceals; urban bodies extend piped supply and recharge inside the city footprint to move load off the shallow aquifer; the wastewater line intercepts the contamination; and a coordinating institution finally reconciles concentrated urban demand with the region's recharge capacity.

C9 is the operating-system core of the whole Atlas argument: the cluster where the disconnection thesis is not a metaphor but the literal diagnosis. The hands at the table are the urban bodies, the groundwater and data cells, the wastewater line — and, above them, a coordinating authority that does not yet exist. The metric is the city-block stage, not the district average; the target is the concentrated deficit closed by integration, not the countryside cut to cover the city.

AT THE TABLE — DOMAINS CONVENED

- ☐ **Urban water bodies** — piped supply, footprint recharge, load redistribution
- ☐ **Groundwater / data cells** — block-level truth
- ☐ **Wastewater line** — contamination interception
- ☐ **Coordinating authority** — reconcile urban draw with regional recharge

Groundwater trajectory — C9 Middle Ganga (stage GWRA-2024; no published cluster depth series)

Metric	T-20	T-10	T-5	T0	Δ / src
Depth (m bgl)	—	—	—	—	—

GW Stage (%)	—	—	—	**76.8**	GW RA-2024
T+5 [PRJ]	☐ Per-capita position worsening (FK 432, lowest in state); closed only by block measurement, piped supply and institutional integration.				

Aggregate stage 76.8% with one district over-exploited hides the real number: a Falkenmark of 432, absolute scarcity, on the best ground in the state. The deficit is institutional, concentrated in four city nodes — not natural.

THE VERDICT. C9 holds the best geology in the state and the worst per-capita water position — a deficit made by institution, not nature. It is the operating-system core of the whole argument: where 'a system-disconnection problem, not a scarcity problem' stops being a thesis and becomes the diagnosis.

C9 01

MIDDLE GANGA CLUSTER
THE SYNTHESIS VOLUME

V5 (REGENERATED) METHODOLOGY COMPLIANT

MIDDLE GANGA CLUSTER AT A GLANCE

THE CIVILISATIONAL CORRIDOR UNDER SEVERE STRESS.

Protect the living continuum. Rejuvenate rivers, aquifers and floodplains.

POPULATION (2023)	PER CAPITA WATER AVAILABILITY (2023)	GROUNDWATER EXTRACTION STAGE (T0) (GWRA-2024)	SURFACE WATER DEPENDENCE	SEWERAGE TREATMENT CAPACITY	DRINKING WATER SUPPLY COVERAGE (JJM, 2023)
~65.1 MILLION	~590 m³/person/year	76.8% SEMI-CRITICAL	~26%	~27%	~78%
Cluster Share: 15.9% (UP Total: ~21.0 M)	(UP Avg: ~865 m³) LOW STRESS	Cluster Avg (T0) GWRA-2024 (SRC-C9-001)	(Ganga Mainstem & Major Tributaries)	(Approx.)	Functional Household Tap Connections

GROUNDWATER EXTRACTION STAGE (T0): 76.8% SEMI-CRITICAL
Significant aquifer stress and declining water security.

GOVERNING METRIC GWRA-2024

CLUSTER AGGREGATION (C9–MIDDLE GANGA) GWRA-2024 (SRC-C9-001)

76.8%
SEMI-CRITICAL
Widespread aquifer stress across the cluster, masked by district averages.

THE AGGREGATION TRAP — THE CLUSTER HIDES THE CRISIS



OVERALL VERDICT: SEMI-CRITICAL
Widespread aquifer stress, polluted rivers and rapid urban expansion threaten the Ganga's long-term health.

THE ISSUE
- Over-extraction: 76.8% (T0) – Semi-Critical.
- Polluted Ganga mainstem and tributaries.
- Inadequate sewage treatment and reuse.
- Industrial and urban effluents degrading rivers and wetlands.
- Climate variability increasing flood and drought risk.

THE REMEDY
- Replenish aquifers through recharge zones, ponds and floodplains.
- Expand and upgrade STPs; ensure treated wastewater reuse.
- Strengthen pollution control in rivers and industrial clusters.
- Implement zoning and regulate encroachments.

THE VERDICT



OVERALL VERDICT: SEMI-CRITICAL
Aquifer stress, river pollution and unplanned growth jeopardize the civilisational corridor of the Ganga.

CRITICAL NEXT STEPS (0–2 YEARS)
- Scale recharge in floodplains and public spaces.
- Upgrade and expand sewage treatment capacity.
- Enforce industrial effluent norms and real-time monitoring.
- Rejuvenate riparian buffers and wetlands.

PRIMARY OWNERS (Lead)
State Water Resources Dept. · Uttar Pradesh Jal Nigam · Irrigation Dept. · Industries & Associations · District Administration

NODE SCORECARD (Impact Dimension Scores 1–10)

Water Security	Population Dependency	Economic Impact	Climate Sensitivity	Risk & Future Vulnerability
4.5	6.5	6.0	6.0	8.0

OVERALL IMPACT SCORE **6.2**

A sustainable water future for the Middle Ganga depends on clean rivers, healthy aquifers and responsible growth.

High Risk · Moderate Risk · Low Risk

C9-01

The Old System Beneath the New — Traditional Water Hydrology

Before the tubewell, the water of Uttar Pradesh was held by a different system — one built not to extract the aquifer but to slow the rain long enough for the ground to drink it. Tanks, talabs, ponds, field bunds and stepwells were the decentralised recharge infrastructure of the state: they caught the monsoon where it fell, spread it across the land, and let it percolate into the shallow aquifer rather than run off. Read through the water vector — the single question this Atlas asks of every domain, how does it act on the water — these structures were recharge works first and heritage second. Their decline is not a cultural footnote; it is part of the groundwater story, because the same decades that emptied the tanks filled the aquifer's place with the borewell, and the borewell takes from the ground what the tank used to give back to it.

The statewide signal is unambiguous. Tank-irrigated area in Uttar Pradesh fell from roughly 134,000 hectares in 2013–14 to about 64,000 hectares in 2015–16; tank irrigation now accounts for only about 0.5% of the state's irrigated area, against roughly 84% from wells and tubewells. The surface store that once buffered the aquifer has been all but abandoned, and the draw it used to prevent has been transferred underground. The Central Ground Water Board's 2021 situation analysis names the cause directly: large-scale encroachment of water bodies and their catchments has deepened the crisis. The traditional system did not fail of its own accord; it was built over, silted up, and left to the land mafia while the aquifer absorbed the difference.

C6 Bundelkhand — the Chandela and Bundela tanks

Bundelkhand holds the most documented traditional water system in the state, and it is the clearest proof of the thesis. On this hard granite craton, where about 85% of rainfall runs off and the rock will not bank water, the Chandela and Bundela dynasties built an estimated 8,000 tanks between roughly 800 and 1200 AD — earthen embankments 60 to 120 metres wide thrown across the rivulets between hills, halting the run-off the rock could not hold and

storing it on the surface where the aquifer could not. This was the correct hydrological answer to fracture geology: on rock that cannot store water below, you store it above. The settlement record at Charkhari in Mahoba lists about 962 talabs in the Chandela period, of which only 421 remain; Tikamgarh district alone still carries nearly 900. The structures evened out water availability across the year and let the region grow two crops on ground that now measures rain in disappointments.

The water vector, measured. Where the tanks have been restored, the aquifer responds. Tank-rejuvenation programmes in the Bundelkhand districts record groundwater recharge extending up to three kilometres downstream of a single restored tank and the refilling of private borewells used for drinking water — the decentralised-recharge function working exactly as it did a thousand years ago. The decline of these tanks parallels the groundwater decline; their revival reverses it. This is why C6's remedy is restoration, not relief: the surface store the rock demands already exists, decayed but recoverable.

The living proof — Jakhni, Banda (C6)

The clearest demonstration that the old system still works sits in the village of Jakhni in Banda, one of the most drought-broken districts of Bundelkhand. A settlement of barely 1,600 people, mostly farmers, rebuilt its own water on a single traditional principle — "khet par medh, medh par pedh," a bund on every field and a tree on every bund — raising field ridges to hold each field's own rain, desilting the old wells and reviving the ponds, with no government funding, no contractor and no machinery. The result is the water vector in its plainest form: by 2020 groundwater levels in Banda had risen by nearly 1.4 metres, and Jakhni today holds 33 wells, 25 hand pumps and six ponds that stay full through the year on recharged aquifers. The model was replicated across 470 villages in Banda district by 2018 and seeded a national programme of more than 1,000 "water villages." Jakhni proves the Bundelkhand remedy is not theoretical: the catchment can be rebuilt, locally, and the table comes back.

C5 Eastern and C9 Middle Ganga — the tank country and the vanishing urban ponds

The eastern and central Gangetic clusters were tank-and-pond country of a different kind — not the hill-embankment talab of the rock south but the level-plain pond and taal that dotted the alluvium, holding monsoon water on a high water table and recharging the shallow aquifer that the east still draws on. The Atlas records their decline most sharply at the urban scale, inside the C9 institutional core. Lucknow held 964 ponds in 1952; by 2006 the figure had fallen to 494, and the city has lost roughly 46% of its water bodies to reclamation and encroachment, many of the survivors now polluted with sewage. Read through the water vector, each filled pond is a recharge point removed from a city already drawing its shallow aquifer beyond what the district average admits — the urban concealment of C9 and the loss of the urban tank are the same process seen twice.

Coverage and honesty. A full per-district inventory of surviving versus lost traditional structures across all nine clusters is not yet assembled in the Atlas source register, and is marked GAP rather than estimated: the strong, traceable cases are Bundelkhand (C6) and the Lucknow urban water bodies (C9), with the statewide tank-irrigation collapse standing for the whole. The eastern plain's pond country (C5) and the western and Yamuna clusters almost certainly carry the same pattern, but the structure-by-structure evidence has not been harvested and is therefore not asserted here.

The Oorani logic — a transferable principle, not a UP structure

One framework from outside the state earns mention because it names the principle the whole section turns on. The Oorani — the decentralised village drinking-water pond of the South Indian dryland, and the tank cascades of the Karnataka kere, the Tamil eri and the Andhra cheruvu — embodies the same logic the Chandela tanks applied on rock and the plains ponds applied on alluvium: catch the rain locally, hold it on the surface, let it recharge the ground beneath the settlement that uses it. The Oorani is not a Uttar Pradesh structure and is not

claimed as one; it is cited as the clearest articulation of the transferable rule. Where the local water system was decentralised, surface-first and community-owned, the aquifer was held; where it was replaced by the centralised pipe and the private borewell, the aquifer fell. That principle, not any single structure, is what the state has to recover.

Source note

Chandela–Bundela tank counts and construction: Atal Bihari Vajpayee Institute / BIWAL baseline (2020); Bundelkhand settlement records (Charkhari, Mahoba). Tank-rejuvenation recharge outcomes: SRIJAN–Hindustan Unilever Foundation programme reports. Jakhni: district administration of Banda, WaterAid India, and national press. Statewide tank-irrigation area: UP irrigation statistics 2013–16. Lucknow water-body loss: Lucknow Municipal Corporation survey. Encroachment of water bodies statewide: CGWB, State of Ground Water in Uttar Pradesh (2021). Full per-cluster structure inventory: GAP — not yet harvested into the Atlas source register.

The Close — What Uttar Pradesh Is, in One Reading

Read node by node and cluster by cluster, Uttar Pradesh is not one water system experiencing one problem. It is a single territory carrying, simultaneously, the full range of water conditions the Indo-Gangetic plain can produce — from the most resilient to the most acute — and that simultaneity is its defining feature. A state that contained only one of these conditions could be governed by one rule. Uttar Pradesh contains all of them, and so the single most damaging thing that can be done to its water is to treat it as one problem.

The four crises are distinct and each has its own remedy. Recharge collapse in the hard-rock south is repaired by restoration, not relief — Bundelkhand cannot be tankered back to health, only its catchment can be rebuilt, as Jakhni proved. Extraction excess in the western plain and the Yamuna corridor is closed by managed demand, not new supply — the deficit is too

large for any source to fill, and it is driven by water-intensive cropping, free pumping power, and a canal that fails at the last mile. Quality failure in the east and in Awadh is met by safe water and contamination control, not more water — the abundance there is the disguise, and the contaminant is geogenic in the east but man-made in Awadh. And urban concealment along the Ganga cities is broken by measuring at the block, not the district, and by fixing the leaking pipe that forces the borewell open.

Against the four crises stands one asset — the Terai recharge front — whose value to the state is as a standard to protect, not a surplus to spend. And beneath all of it runs the single thread this volume exists to make visible: the water is one connected thing, and it is managed in disconnected pieces. The groundwater officer, the irrigation engineer, the agriculture department, the energy utility, the urban water body, the pollution-control authority and the forest department each hold one part of the same water, and they never share a table. The cluster map and the node frame exist to bring them to it — to make the invisible system visible, and to match each condition to the remedy that already works on its kind of ground.

That is the verdict of the Uttar Pradesh Atlas, carried here in one volume: not a scarcity to be endured but a disconnection to be repaired — condition by condition, city by city, system by system, on ground that, read correctly, can still be brought back.

The State Verdict — Every Unit at a Glance

The whole state in one table: each cluster and node, its crisis class, its headline metric, its grade and its primary lever. The state grade is D — not because every unit fails, but because the disconnection that produces the four crises is state-wide. Grades run A (secure) to D (critical).

Unit	Name	Crisis class	Headline metric	Grade	Primary lever
C1	Terai	Reserve / asset	Stage 60.7% · FK 1,063 · no district OE	A/B	Protect recharge front, forest, floodplain
C2	Western Extraction	Extraction excess (demand)	Stage 90.7% · ~79.8 TMC over line · 5 OE	D	Managed demand; canal last-mile; power tariff
C3	Upper Central	Silent depletion	Stage 71.6% · depth 13.71 m · FK 735	C	Prevention: meter, price power, recharge
C4	Awadh	Contamination beneath abundance	Stage 63.1% · NO□ 571 mg/L (Rae Bareli)	C	Fertiliser control; safe-source substitution
C5	Eastern Flood-Quality	Quality crisis	Stage 61.4% · As to 3,192 ppb · BOD 64.8	C	Switch metric to exceedance; safe water
C6	Bundelkhand	Hard-rock storage failure	Stage 73.0% · ~15% recharge · FK 852	D	Restoration: watershed, tanks (Jakhni model)
C7	Yamuna System	Extraction excess + dead river	Stage 81.0% · ~21.5 TMC over · Agra 117%	D	Discipline aquifer + revive river together
C8	Vindhyan Ecology-Energy	Coupled hard-rock nexus	Stage 60.4% · ~401 TMC surface store	B/C	Govern water-energy-mining-forest as nexus
C9	Middle Ganga	Institutional deficit	FK 432 (lowest) · ~12.6 TMC below line	D	Block measurement; piped supply; integration

N 1	Lucknow	Aggregation concealment	Block 107% vs district 66.5%	D	Block metric; piped supply; in-city recharge
N 2	Kanpur	Infrastructure concealment	OE + toxic (tannery effluent)	D	Separate supply from resource; meter, treat
N 3	Prayagraj	Spectacle concealment	Stage 72.7% · nitrate rising	C	Govern on stage+quality, not river volume
N 4	Varanasi	Wrong-metric concealment	Stage 88.3% · As >300 ppb · BOD 64.8	D	Switch to aquifer metric; safe-source supply
N 6	Gorakhpur	Excess + quality (inverse)	As to 311 ppb · ~45% wells unsafe	C	Drainage, treatment, public health
N 7	Meerut	Demand excess (urban)	Stage 76.9% · depth 12.41 m · NRW 65%	D	Cut NRW; demand discipline; recharge
N 8	Ghaziabad–Noida	Planned-modernity concealment	Ghaziabad 124% · GB Nagar 107%	D	Hard limits; piped supply to new build

STATE VERDICT. Grade D. Four structurally distinct crises — recharge collapse, extraction excess, quality failure and urban concealment — set against one asset, the Terai. The state is not uniformly short of water; it is uniformly mismanaged across a system read in disconnected pieces. The remedy is not one rule but four, matched to the four conditions, and an institution that finally brings the seven hands to one table.

References — Principal Data Sources

Every headline figure in this volume traces to the Atlas source register, which records its sources by domain. The principal agencies and datasets are listed below; the full source registry sits in the Atlas source register. Sources are grouped by the domain they primarily serve.

☐ **DACFW — Directorate of Economics & Stats** — Agri Statistics · https://desagri.gov.in

☐ **ICAR — Indian Council of Agri Research** — Agriculture / Irrigation · https://icar.org.in

☐ **CAG — Comptroller & Auditor General** — Audit / Governance · https://cag.gov.in

☐ **ZSI — Zoological Survey of India** — Biodiversity · https://zsi.gov.in

☐ **BSI — Botanical Survey of India** — Biodiversity · https://bsi.gov.in

☐ **India Biodiversity Portal** — Biodiversity Data · https://indiabiodiversity.org

☐ **NBA — National Biodiversity Authority** — Biodiversity Governance · https://nbaindia.org

☐ **RBI State Finance Publications** — Budget / Finance · https://rbi.org.in

☐ **Agmarknet — Ministry of Agriculture** — Crop / Agri Data · https://agmarknet.gov.in

☐ **NDMA — National Disaster Management Auth** — Disaster Management · https://ndma.gov.in

☐ **NADAMS — NRSC** — Drought Monitoring · https://nrsc.gov.in/Drought

☐ **WII — Wildlife Institute of India** — Ecology / Wildlife · https://wii.gov.in

☐ **NIDM — National Institute Disaster Mgmt** — Flood / Drought Data · https://nidm.gov.in

☐ **FSI — Forest Survey of India** — Forest Cover · https://fsi.nic.in

☐ **Bhuvan Portal — ISRO** — GIS / Satellite Data · https://bhuvan.nrsc.gov.in

☐ **GSI — Geological Survey of India** — Geology · https://gsi.gov.in

☐ **NGDR — National Geology Data Repository** — Geology Data Repository · https://ngdr.in

☐ **Bhukosh — GSI Geospatial Portal** — Geology GIS Data · https://bhukosh.gsi.gov.in

☐ **CGWB — Central Ground Water Board** — Groundwater · https://cgwb.gov.in

☐ **National Hydrology Project (NHP)** — Groundwater · https://nhp.mowr.gov.in

☐ **India-WRIS / NWIC** — Groundwater Data · https://indiawris.gov.in

☐ **NFHS — National Family Health Survey** — Health / Equity · https://rchiips.org

☐ **State Govt Dept** — Irrigation & Water Resources Dept UP · https://idup.gov.in

☐ **Bhuvan Thematic** — Land Use / Waterbodies · https://bhuvan-app1.nrsc.gov.in/thematic

☐ **PRS Legislative Research** — Policy Tracking · https://prsindia.org

☐ **IMD — India Meteorological Department** — Rainfall & Climate · https://imd.gov.in

☐ **RSIS — Ramsar Site Information Service** — Ramsar Sites · https://rsis.ramsar.org

☐ **NRSC — National Remote Sensing Centre** — Remote Sensing & GIS · https://nrsc.gov.in

☐ **India-WRIS WebGIS** — River Basin Data · https://indiawris.gov.in/wris

☐ **NITI Aayog — SDG Index & Reports** — SDG / Governance · https://niti.gov.in

☐ **Census of India** — Socioeconomics · https://censusindia.gov.in

☐ **MOSPI — Ministry of Statistics** — Statistics · https://mospi.gov.in

☐ **Central Water Commission (CWC)** — Surface Water & Rivers · https://cwc.gov.in

☐ **JJM — Jal Jeevan Mission** — Urban Water / Sanitation · https://jaljeevanmission.gov.in

☐ **AMRUT Mission** — Urban Water Data · https://amrut.gov.in

☐ **CPCB — Central Pollution Control Board** — Water Quality (Rivers) · https://cpcb.nic.in

☐ **NWMP — National Water Quality Monitoring** — Water Quality Data · https://cpcb.nic.in/nwmp-data

☐ **National Water Mission (NWM)** — Water Resources National DB · https://nwm.gov.in

☐ **NWIA — National Wetland Inventory (NRSC)** — Wetland Atlas · https://nrsc.gov.in

☐ **MoEFCC — Ministry of Environment** — Wetlands · https://moef.gov.in

Method note

Figures are graded by evidence quality: measured and published values carry the highest grade; collated and interpolated values carry explicit caveats; projections are marked as such. Where a value is genuinely absent it is marked GAP and never interpolated. Headline metrics match the Atlas source register (GWRA-2024 for groundwater); secondary or urban-hotspot figures appear only with a named location and an independent source.