National Mission for Clean Ganga
Department of Water Resources, River Development &
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Government of India

सत्यमेव जयते

Closing the Loop Between Water, Soil and Aquatic Ecosystems

November 2025

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Centre for Ganga River Basin
Management and Studies
Indian Institute of Technology Kanpur

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NMCG is the implementation wing of National Ganga Council which was setup in October 2016 under the River Ganga Authority order 2016. Initially NMCG was registered as a society on 12th August 2011 under the Societies Registration Act 1860. It acted as implementation arm of National Ganga River Basin Authority (NGRBA) which was constituted under the provisions of the Environment (Protection) Act (EPA) 1986. NGRBA has since been dissolved with effect from the 7th October 2016, consequent to constitution of National Council for Rejuvenation, Protection and Management of River Ganga (referred to as National Ganga Council).

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this it is also responsible for introducing new technologies, innovations and solutions into India.

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A Unified Ecological Framework for Sustainable River Basin Management in India

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Preface

India is witnessing a fundamental shift in its water management paradigm. For decades, the dominant approach has been linear—extracting water, using it, and treating the resulting wastewater as a liability to be disposed of. While significant investments have been made in sewage treatment infrastructure and river pollution abatement, the symptoms of systemic ecological stress—chronic river pollution, groundwater depletion, and rapid soil degradation—persist. The limits of the "collect and dispose" model have been reached, making it evident that engineering solutions alone, divorced from ecological cycles, cannot sustain India's complex hydrological needs.

Yet, the disconnection between our water systems and our soil systems remains a critical gap. Modern urbanization has severed the ancient links where wastewater nutrients regenerated soils and wetlands buffered water cycles. This decoupling has created a dual crisis: water bodies are choking with excess nutrients leading to eutrophication, while agricultural soils are starving for organic carbon and fertility. The urgent need of the hour is not just treatment, but reconnection—transforming the linear wastewater pipeline into a circular resource loop that regenerates both water and land.

This document—Closing the Loop Between Water, Soil and Aquatic Ecosystems: A Unified Ecological Framework for Sustainable River Basin Management in India—is written to operationalize this paradigm shift. It proposes a scientifically grounded, "Long Loop" ecological cycle that integrates decentralized wastewater treatment, wetland rejuvenation, biomass management, and soil restoration into a single, cohesive operational strategy. It challenges the conventional dogma of "nutrient elimination," advocating instead for "managed eutrophication" through biomass harvesting—turning a pollution problem into an economic and agricultural resource.

The framework consolidates a comprehensive set of interventions: from the deployment of small-scale, decentralized STPs that feed local drains, to the systematic harvesting of aquatic biomass for compost and energy, and the safe return of stabilized biosolids to the soil. It is structured to guide district administrators, planners, and technical agencies in creating systems where urban waste becomes rural wealth, and where river rejuvenation is intrinsically linked to soil health and agricultural sustainability.

By embedding principles of circularity—where water is polished by nature, nutrients are returned to the earth, and aquifers are recharged through healthy soils—this framework empowers districts to move beyond mere compliance. It offers a pathway to build resilient, self-sustaining ecosystems that can withstand climate variability and support vibrant livelihoods.

This report is offered as a blueprint for a new ecological compact—one that merges the formerly separate domains of water management and soil conservation. It is our hope that this unified approach will inspire a new generation of river basin management in India, one that recognizes that the health of our rivers is inseparable from the health of our soils and the prosperity of our communities.

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1. Introduction: *The Need for a Paradigm Shift*

India's water sector is undergoing a fundamental transformation. The traditional model of "collect and dispose"—treating water as a linear commodity that is abstracted from rivers or aquifers, consumed, polluted, and discharged—has reached its ecological and operational limits. The symptoms of this failure are visible in:

- Chronic river pollution
- Groundwater decline
- Wetland degradation
- Soil nutrient exhaustion
- Eutrophication of lakes and ponds
- Frequent fish kills and algal blooms
- Increasing monsoon-flood / summer-drought extremes

India must replace the linear "wastewater disposal" paradigm with a circular "resource regeneration" paradigm. This document operationalizes that conclusion into a single, integrated ecological framework that:

- Connects water, soil, wetlands, biodiversity, and human systems.
- Aligns perfectly with the national DRMP (District River Management Plan) framework.
- Provides implementable pathways for restoring rivers, regenerating soils, stabilizing groundwater, and managing nutrient cycles.
- Links urban and rural water metabolism into a single hydrological system.

In doing so, it lays out **a unified blueprint** for river basin management that is technically sound, ecologically grounded, and socio-economically inclusive.

2. Understanding the Systemic Problem: *Why India's Waters Are in Crisis*

2.1 The Disconnection Between Water Cycles and Soil Cycles

Historically, India's hydrological systems were deeply integrated with soils:

- Rainwater infiltrated through vegetated surfaces.
- Water bodies fed groundwater, and groundwater fed streams.
- Floodplains regenerated nutrients seasonally.
- Waste products were biologically assimilated.

Urbanization, mechanization, and infrastructure expansion have severed these linkages. Impervious surfaces, piped systems, long-distance sewers, and the separation of wastewater from the landscape have disrupted the natural cycling of carbon, nitrogen, phosphorus, and water.

This decoupling has produced a double crisis:

- Water systems are polluted, depleted, and hydrologically unbalanced.
- Soils are nutrient-poor, carbon-poor, compacted, and hydrologically degraded.

2.2 The Linear Wastewater Paradigm and Its Failure

The classic city wastewater model is linear:

Source → Use → Sewer → STP → River Discharge

This model suffers from inherent structural flaws:

- Overdependence on large centralized STPs that require enormous energy, maintenance, and pumping infrastructure.
- Treatment far from the point of pollution, making local reuse impossible.
- No integration with wetlands, soils, or groundwater.
- Reliance on a pipe-to-river mentality that treats treated water as waste.

Even when STPs meet standards, the rivers continue to fail because the **ecological cycle remains broken**.

2.3 Attempting to Eliminate Eutrophication is Ecologically Impossible

The earlier engineering dogma sought to “eliminate nutrient discharge.” But India’s ecological reality makes this impossible:

- Tropical climate accelerates biological productivity.
- Birds, livestock, and wildlife contribute constant nutrient loads.
- Agricultural return flows introduce nitrogen and phosphorus.
- Sediments re-release nutrients during monsoon flush.
- Untreated waste from settlements and solid waste adds background loading.

Thus, trying to eliminate nutrients is futile. Instead, the strategy must shift to **controlled, managed eutrophication** through **periodic biomass harvesting**.

3. Core Principles of the New Ecological Framework

The integrated model operates on following **five foundational principles** that is aligned with the framework for preparing DRMP - District River Management Plan (cGanga & NMCG, 2025, A Comprehensive Framework for District River Management Plan (DRMP)).

3.1 Water Is Not a Disposable Commodity

Water must be retained within the landscape, cycled repeatedly, and reconnected with soils, vegetation, and groundwater.

3.2 Natural Systems are the Most Powerful Treatment Technologies

Sunlight, macrophytes, sediments, microbes, and hydrology collectively perform:

- Tertiary treatment
- Pathogen reduction
- Nutrient assimilation
- Oxygenation
- Pollutant breakdown

Engineered systems should complement—not replace—these functions.

3.3 Wastewater Contains Valuable Nutrients

Nitrogen, phosphorus, and organic carbon in wastewater and biosolids are essential for:

- Soil fertility
- Plant productivity
- Wetland health
- Microbial diversity
- Carbon sequestration

3.4 Biomass Is Not a Nuisance but an Ecological Service

Algae, hyacinth, and aquatic weeds are:

- Natural nutrient sinks
- Biological filters
- Water quality regulators
- Employment-generating resources

3.5 Soil Health = Water Health = River Health

Healthy soils:

- Store water
- Increase infiltration
- Reduce runoff
- Recharge groundwater
- Buffer droughts
- Moderate floods

Thus, the path to river restoration necessarily runs through soil regeneration.

4. The Long Loop: Integrating Water, Soil, Ecosystems, and Communities

This unified model conceptualizes water as part of a **closed, long-loop ecological cycle** that integrates:

- Wastewater treatment
- Natural water bodies
- Biosolids
- Biomass
- Soils
- Agriculture
- Groundwater
- Rivers

4.1 Step 1 — Decentralized Sewage Treatment Plants (d-STPs)

Small 1–5 MLD modular plants are set at:

- Confluences of local drains
- Edges of neighborhoods
- Near ponds and wetlands
- Peri-urban clusters

Benefits:

- Reduced pumping
- Local reuse enabled
- Lower cost and easier O&M
- Distributed risk profile
- Quick scale-up

4.2 Step 2 — Treated Water → Natural Drains

Instead of piping treated water long distances:

- Discharge into natural or ecological drains
- Maintain perennial flow
- Convert dry drains into living streams
- Improve oxygenation and self-purification

4.3 Step 3 — Drains Feed Ponds, Lakes, and Wetlands

This reconnects:

- Wastewater with local ecosystems
- Hydrology with ecology
- Villages with their water commons

Wetlands provide:

- Further treatment
- Nutrient uptake
- Buffering of flows
- Aquatic habitat
- Groundwater recharge

4.4 Step 4 — Wetlands as Nature's Polishing Units

Wetlands and ponds provide the final polishing:

- 70–90% pathogen reduction
- 40–60% nutrient uptake
- 60–80% suspended solids reduction
- DO restoration

4.5 Step 5 — Controlled Biomass Growth and Harvesting

When managed:

- Biomass acts as nutrient repository
- Seasonal harvesting removes nutrients
- Fish, birds, vegetation thrive
- Wetlands remain productive, not choked

4.6 Step 6 — Biomass → Compost / Biochar / Biogas

Harvested biomass becomes:

- Compost
- Vermicompost
- Biochar
- Biogas feed
- Handicraft fibre (hyacinth)

4.7 Step 7 — Biosolids Return to Land as Soil Amendment

When properly stabilized, biosolids:

- Add organic carbon
- Reduce fertilizer demand
- Improve soil texture and structure
- Increase water retention
- Enhance microbial diversity

4.8 Step 8 — Healthy Soils Recharge Aquifers

Carbon-rich, well-structured soils:

- Increase infiltration 2–6×
- Recharge shallow aquifers
- Reduce evaporation
- Buffer irrigation demand

4.9 Step 9 — Groundwater Sustains Baseflows

Sustained groundwater levels keep rivers flowing during dry seasons, restoring:

- Ecological continuity
- Fish movement
- Sediment transport
- Water quality

4.10 Step 10 — Restored Rivers Support Communities & Biodiversity

Rejuvenated river ecosystems:

- Provide clean water
- Support livelihoods
- Maintain ecological functions
- Enhance climate resilience

This long-loop metabolic cycle **regenerates both water and soil**.

5. Why Eutrophication Must Be Managed, Not Eliminated

5.1 The India Reality: Nutrient Inputs Are Natural

Nutrient formation in water bodies comes from:

- Bird droppings
- Livestock residues
- Plant decomposition
- Agricultural return flows
- Organic matter from settlements
- Sediment nutrient release
- Natural productivity in warm climates

Eutrophication is not a failure of treatment—it is natural.

5.2 The Ecological Objective: *Healthy, Productive Systems*

The goal is not to create sterile, nutrient-free water bodies.

The goal is to avoid:

- Toxic algal blooms
- Oxygen depletion
- Excessive weed growth
- Fish mortality

5.3 Biomass Harvesting as a Management Tool

Biomass harvesting functions as:

- Nutrient removal
- Oxygen stabilization
- Algal bloom control
- Sediment management
- Livelihood creation

5.4 Biomass-Based Economy

Aquatic biomass feeds a rural and peri-urban bioeconomy:

- Compost/vermicompost
- Mulching agents
- Biochar
- Geotextiles, mats, ropes

- Paper and pulp
- Handicrafts
- Briquettes

This creates **jobs where water meets people**.

6. Closing the Soil Loop: *Biosolids as a National Resource*

6.1 Soil Organic Carbon Decline

Indian soils are critically low in organic matter. SOC levels <1% are common; many soils have <0.5%. This causes:

- Low water retention
- High fertilizer requirement
- Low crop yield
- Rapid erosion
- Declining groundwater recharge

6.2 Biosolids Offer the Missing Carbon and Fertility

Stabilized STP biosolids contain:

- Nitrogen
- Phosphorus
- Micronutrients
- Organic carbon

These are precisely what soils lack.

6.3 Benefits in Agriculture

Biosolids:

- Reduce fertilizer use
- Improve soil texture
- Increase infiltration
- Enhance yields sustainably
- Promote microbial life

6.4 Rehabilitation of Degraded Land

Biosolids are ideal for:

- Barren lands
- Grazing commons
- Mining overburdens
- Urban greenbelts
- Roadside plantations

6.5 Managing Risks

With proper stabilization and source control:

- Pathogens are reduced
- Heavy metals remain within limits
- Salinity is regulated by monsoon cycles

7. The Unified Project Framework: Eight DRMP-Aligned Clusters

Cluster 1: Decentralized Wastewater Treatment Infrastructure
Modular STPs, sewer interception, soak-pit elimination.

Cluster 2: Waterbody Perennialisation
Treated water to drains, rivers, lakes, ponds; flow regulation.

Cluster 3: Wetland & Floodplain Restoration
Hydrological reconnection, buffer zones, aquatic habitat.

Cluster 4: Aquatic Biomass Harvesting & Blue-Green Livelihoods
Harvesters, SHGs, composting units, hyacinth economy.

Cluster 5: Biosolids and Soil Regeneration
Composting hubs, soil application protocols, land rehabilitation.

Cluster 6: Groundwater Recharge & Hydrological Restoration
Check-dams, recharge trenches, wetland percolation.

Cluster 7: Solid & Liquid Waste Integration
Preventing MSW inflow to drains, rural sanitation.

Cluster 8: Monitoring, Governance & Cyclic Planning
Digital dashboards, sensors, citizen science, 5-year DRMP cycle.

8. Governance Architecture

8.1 District Ganga Committee as the Nodal Body

All 8 clusters converge at the District Magistrate through:

- DRMP technical cell
- Line departments
- Community groups
- Academic partners

8.2 DRMP Cyclic Planning Framework

Every 5 years:

- Evaluate
- Update
- Reprioritize
- Integrate learnings

8.3 Digital DRMP Dashboard

Tracks:

- Water quality
- Biomass volume

- Biosolids movement
- Groundwater
- Project progress
- Ecological indicators

8.4 Community Involvement

Through:

- Jal Mitras
- School–college networks
- Fishing communities
- SHGs
- Farmers

9. Economic & Social Co-Benefits

9.1 Water Security

Perennial flows + groundwater recharge create year-round security.

9.2 Food Security

Biosolid application improves crop yields sustainably.

9.3 Employment

Biomass harvesting, composting, wetland management create jobs.

9.4 Climate Resilience

More vegetation, healthier soils, restored wetlands buffer against extreme events.

9.5 Public Health

Cleaner water bodies reduce vector-borne diseases.

10. Conclusion: The New Ecological Compact

This integrated master framework provides India with a **scientifically grounded, ecologically coherent, economically viable, socially inclusive** strategy for:

- Restoring rivers
- Regenerating soils
- Managing wastewater
- Controlling eutrophication
- Creating livelihoods
- Stabilizing groundwater
- Adapting to climate change

It merges two formerly separate domains—**water management** and **soil management**—into one **living, circular, biohydrogeochemical cycle**.

This is the future of DRMP. This is the future of India's river basin management. It is not just a new method—it is a new **ecological compact** between water, soil, ecosystems, and people.

DRMP Project Matrix (Summary Table)

Project Name	Scope	Key Benefits
Mechanical Biomass Harvesting	Harvesting in wetlands, large drains, lakes	Controls eutrophication, fast cleanup
Manual Biomass Harvesting Workforce	SHGs/youth groups	Employment, continuous maintenance
Biomass Composting Centers	Convert biomass to manure	Sustainable waste use
Hyacinth Livelihood Units	Women-led enterprises	Income generation
Algae-to-Biochar Pilots	Pyrolysis units	Soil improvement, carbon benefits
Floodplain Wetland Restoration + Biomass Cycle	Wetlands + periodic harvesting	Ecosystem health
Restore-First, Reuse-Later	Ponds/lakes as reuse sources	Cost-effective, hydrologically smart
Biomass Dashboard	Digital monitoring	Transparency and planning
Jal Mitra Network	Citizen science	Low-cost monitoring

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