Ganga River Basin Management Plan-2015

Volume 1: Extended Summary & Overview

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

VOLUME 1 OF 12

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NATIONAL MISSION FOR CLEAN GANGA (NMCG)

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).

www.nmcg.in

CENTRE FOR GANGA RIVER BASIN MANAGEMENT AND STUDIES (cGanga)

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.

www.cganga.org

ACKNOWLEDGEMENT

This document is a collective effort of a number of experts, institutions and organisations, in particular those who were instrumental in preparing the Ganga River Basin Management Plan which was submitted to the Government of India in 2015. Contributions to the photographs and images for this vision document by individuals are gratefully acknowledged.

SUGGESTED CITATION

GRBMP by cGanga and NMCG

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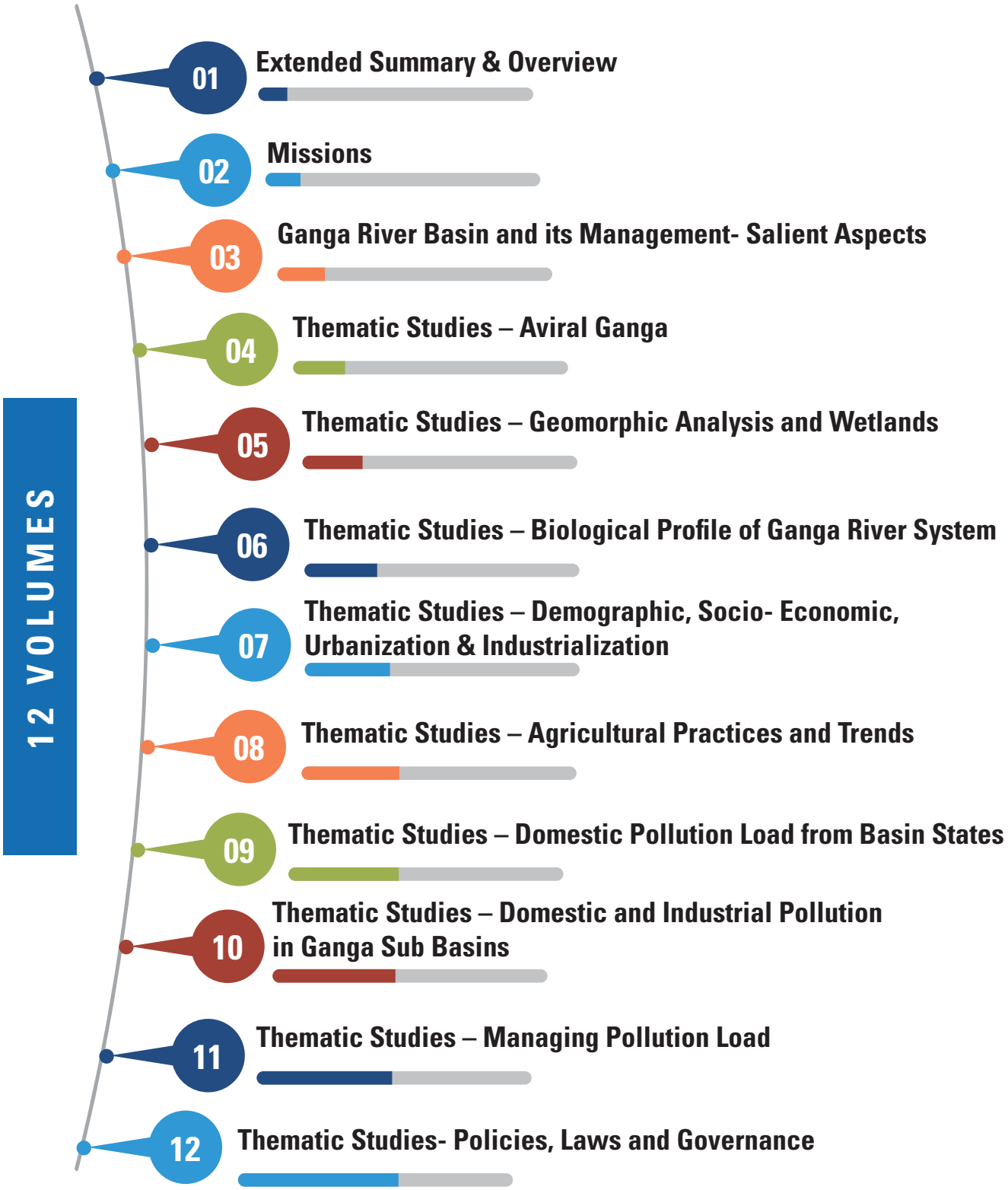

Ganga river in
Himalayas mountains

Extended Summary

January 2015

by

Consortium of 7 "Indian Institute of Technology"s (IITs)

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

In Collaboration with

IIT BHU | IIT Gandhinagar | CIFRI | NEERI | JNU | PU | NIT-K | DU

NIH Roorkee | ISI Kolkata | Allahabad University | WWF India

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government constituted the National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP). A Consortium of seven "Indian Institute of Technology"s (IITs) was given the responsibility of preparing the GRBMP by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. A Memorandum of Agreement (MoA) was therefore signed between the 7 IITs (IITs Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

The GRBMP is presented as a 3-tier set of documents. The three tiers comprise of: (i) Thematic Reports (TRs) providing inputs for different Missions, (ii) Mission Reports (MRs) documenting the requirements and actions for specific missions, and (iii) the Main Plan Document (MPD) synthesizing background information with the main conclusions and recommendations emanating from the Thematic and Mission Reports. It is hoped that this modular structure will make the Plan easier to comprehend and implement in a systematic manner.

There are two aspects to the development of GRBMP that deserve special mention. Firstly, the GRBMP is based mostly on secondary information obtained from governmental and other sources rather than on primary data collected by IIT Consortium. Likewise, most ideas and concepts used are not original but based on literature and other sources. Thus, on the whole, the GRBMP and its reports are an attempt to dig into the world's collective wisdom and distil relevant truths about the complex problem of Ganga River Basin Management and solutions thereof.

Secondly, many dedicated people spent hours discussing major concerns, issues and solutions to the problems addressed in GRBMP. Their dedication led to the preparation of a comprehensive GRBMP that hopes to articulate the

outcome of the dialog in a meaningful way. Thus, directly or indirectly, many people contributed significantly to the preparation of GRBMP. The GRBMP therefore truly is an outcome of collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team and of the associate organizations as well as many government departments and individuals.

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Abbreviations and Acronyms

1.	E-Flows	:	Environmental Flows.
2.	IITC	:	IIT Consortium.
3.	GRBMP	:	Ganga River Basin Management Plan.
4.	MND	:	Mission Nirmal Dhara.
5.	MoEF	:	Ministry of Environment and Forests.
6.	MoEFCC	:	Ministry of Environment and Forests & Climate Change.
7.	MoWR	:	Ministry of Water Resources.
8.	MoWRRDGR	:	Ministry of Water Resources, River Development & Ganga Rejuvenation.
9.	NGRBA	:	National Ganga River Basin Authority.
10.	NMCG	:	National Mission for Clean Ganga.
11.	NRGB	:	National River Ganga Basin.
12.	NRGBMC	:	National River Ganga Basin Management Commission.
13.	URMP	:	Urban River Management Plan.

1. Introduction

1.1. River Ganga in Indian Consciousness

River Ganga, along with her many tributaries, has been the source of physical and spiritual sustenance of Indian civilization for millennia. And all through the ages, Indians held the munificent River Ganga as a Divine Body. To the Indian mind, River Ganga is not only the holiest of rivers and purifier of mortal beings, but also a living Goddess – MOTHER GANGA! Her exalted status in Indian consciousness has been aptly encapsulated in the following words of Sri Krishna in Bhagavad Gita**:**

पवनः पवतामस्मि रामः शस्त्रभृतामहम् ।
झषाणां मकरश्चास्मि स्रोतसामस्मि जाह्नवी ॥

I am the wind among things of purification, and among warriors I am Rama, the hero supreme. Of the fishes in the sea I am Makara, the wonderful, and among all rivers the holy Ganges.

-Bhagavad Gita; Verse 31, Chapter 10

1.2. Deterioration of River Ganga

Despite being nationally revered, River Ganga has been deteriorating noticeably over a long time, at least since large scale water abstractions through canal systems began in the mid-nineteenth century. Her degradation gradually became multi-faceted and accelerated in recent decades, while attempts to keep the river clean through conventional pollution control methods have proved ineffective.

1.3. GRBMP's Goal

River Ganga was declared as India's National River by the Indian Government in 2008, thereby implying her well-being to be of prime national concern. Hence the main goal of GRBMP is to restore the wholesomeness of National River Ganga and her basin.

1.4. Functional Unity of the Ganga Basin

A river basin is the area of land from which the river provides the only exit route for surface flows. Functionally, a basin is a closely connected hydrological-ecological system. Hydrological connections include surface runoff, flooding, local/ regional evapotranspiration-precipitation cycles, and groundwater flow. Ecological links are many – from complex food webs to different types of biological agents. These linkages provide for extensive material transport and communication between the river and her basin. On account of the manifold hydrological-ecological connections, National River Ganga – besides being a prime source of material and spiritual resources on her own – is the key indicator of the health of her basin. Hence, the Ganga River Network was adopted in GRBMP as the primary environmental indicator of NRGB (National River Ganga Basin).

1.5. Importance of the Himalaya Mountains

The Himalayan glacier-fed head-streams of National River Ganga, as also her many Himalayan tributaries, bring in considerable water, sediment and nutrients into the river almost round-the-year, thus ensuring perennial life-giving flow in the river and fertility to her floodplains. The Himalayan connection thus plays a significant role in the basin dynamics.

1.6. Principle of Natural Resource Management in NRGB

The natural resources of NRGB are its abiotic or physical resources (mainly soil/silt, water, and the nutrients bound up with them) and its biotic resources (plants, animals and microbes). Together, these resources are invaluable for basin functioning, but they are interdependent through various physical and ecological processes prevalent in the basin. Proper understanding of the basin's resource dynamics is, therefore, pivotal in managing NRGB efficiently. Hence, unlike conventional basin management in India that considers mainly water resource management, GRBMP attempts to focus on comprehensive natural resource management in NRGB.

1.7. Philosophy

The philosophical basis of GRBMP is that NRGB is a common heritage which must be preserved in order to ensure its life-enhancing value. Hence, if the basin is degrading due to unrestrained anthropogenic activities, then we must curtail or regulate such activities as well as introduce specific measures for environmental restoration and strengthening of the basin.

1.8. Degradation Processes in NRGB and their Anthropogenic Causes

With proliferation and diversification of human activities having harmful environmental effects, National River Ganga and her basin have been degrading rapidly. The degradations are due to five main causes, viz.**:** (i) *over-use of natural resources of the basin*; (ii) *discharge of pollutants into terrestrial and aquatic environments*; (iii) *reduction in water-holding capacities and replenishment of water bodies*; (iv) *mutilation of rivers by piecemeal engineering operations*; and (v) *threats to geological processes in the basin*. The major human activities causing the above damages may also be clubbed under five main heads as shown in Figure 1, viz.**:** (i) *Industrialization*, (ii) *Urbanization*, (iii) *Lifestyle Changes*, (iv) *Agriculture & Other Rural Activities*, and (v) *Deforestation/ Denudation*. This broad grouping indicates the key factors underlying basin degradation; however, devising appropriate remedial interventions requires in-depth analysis of the problems.

1.9. Impact on Humans

The direct impact of NRGB's degradation on humans are the losses of "ecosystem services" namely, *provisioning services* (e.g. food, freshwater, fibres, energy), *regulating services* (e.g. flood attenuation, groundwater recharge, prevention of salt water intrusion), *supporting services* (e.g. nutrient recycling, soil formation, biodiversity maintenance), and *cultural services* (e.g. recreation, spiritual fulfilment). Even without quantitative valuation, it is certain that these losses are significant in NRGB.

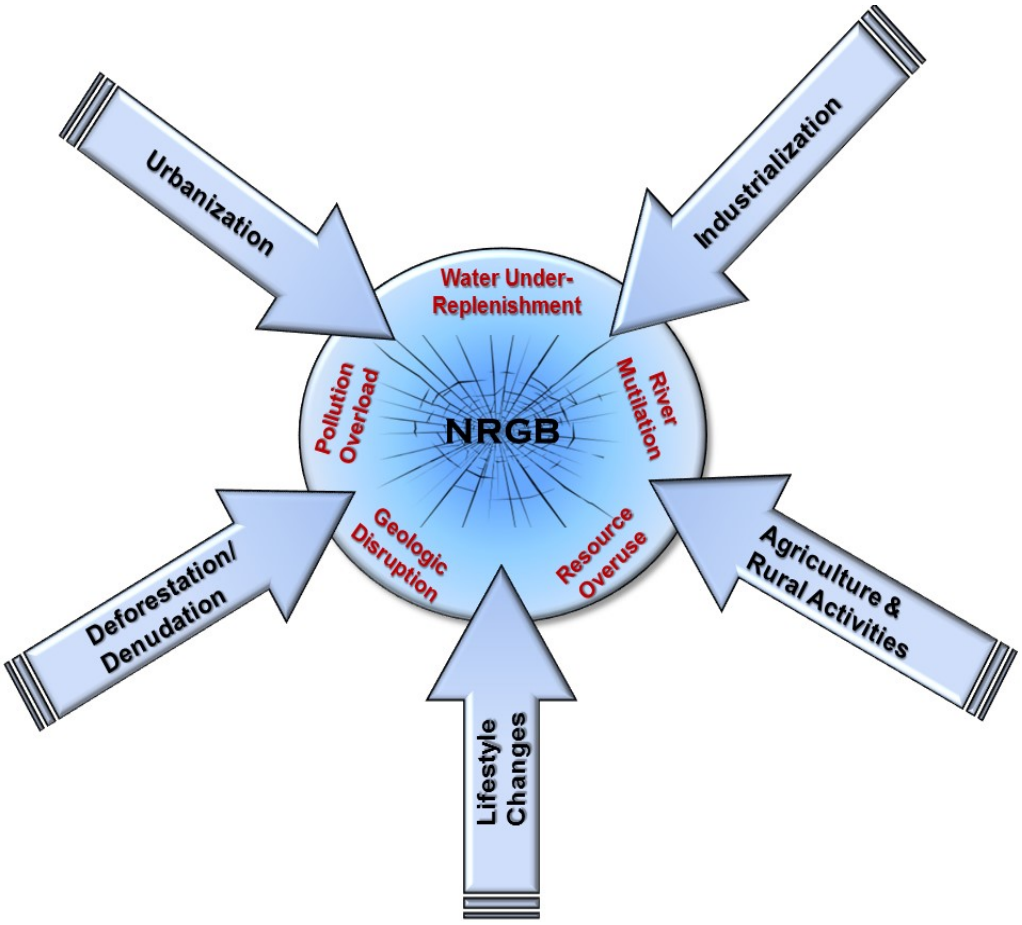

Figure 1: Major Adverse Impacts of Modern Anthropogenic Activities on NRGB

1.10. Scope for Interventions

Among the five main types of environmentally significant human activities stated above, the first three concern profit-making activities or activities of relatively affluent sections of society. Hence, it must be feasible to review these activities and modify them at some cost in order to minimize their adverse environmental impacts. Other activities – such as rural and agricultural activities – often concern basic needs and livelihoods of relatively poor or marginal sections of society, who may not be able to bear the cost of such interventions. But, in such cases too, suitable means must be devised to abate the negative impacts and ensure a wholesome environment in NRGB.

2. Key Features of National River Ganga Basin

2.1. River Network

National River Ganga (*see Figure 2*) originates in the Himalayas from several major head-streams namely, Alaknanda, Bhagirathi, Bhilangana, Dhauliganga, Mandakini, Nandakini and Pindar – which progressively join together on or before Devaprayag. Descending in the plains, the river flows approximately southeast and is joined by several large streams such as Ramganga, Yamuna, Kosi, Gandak, Gomti, Sone, Karamnasa and Ghaghra to become an immense river downstream of Allahabad. The river then flows through the Rajmahal hills and divides into two branches. The eastern branch – River Padma – flows southeast through Bangladesh to join the Brahmaputra and Meghna rivers before flowing into the sea. The south-flowing branch – River Hooghly – is joined by the Damodar and Mayurakshi before reaching the sea. The combined outfall of the two branches forms the world's largest delta (the "Sundarban Delta" covering about 60,000 sq.km.) stretching across Bangladesh and West Bengal. Overall, River Ganga is more than 2500 km long.

2.2. Basin Hydrology

The Ganga Basin, spread over four nations (India, Nepal, China and Bangladesh) covers an area of about 1,080,000 km^2, of which the NRGB, comprising about 80% of the total Ganga basin area, lies within India. The NRGB is the largest river basin of India, covering more than 26% of her geographical area. And out of India's total renewable water availability of 1,869 km^3/yr, NRGB's share is 525 km^3/yr. Thus, it is a large water-rich basin that supports about 43% of India's population.

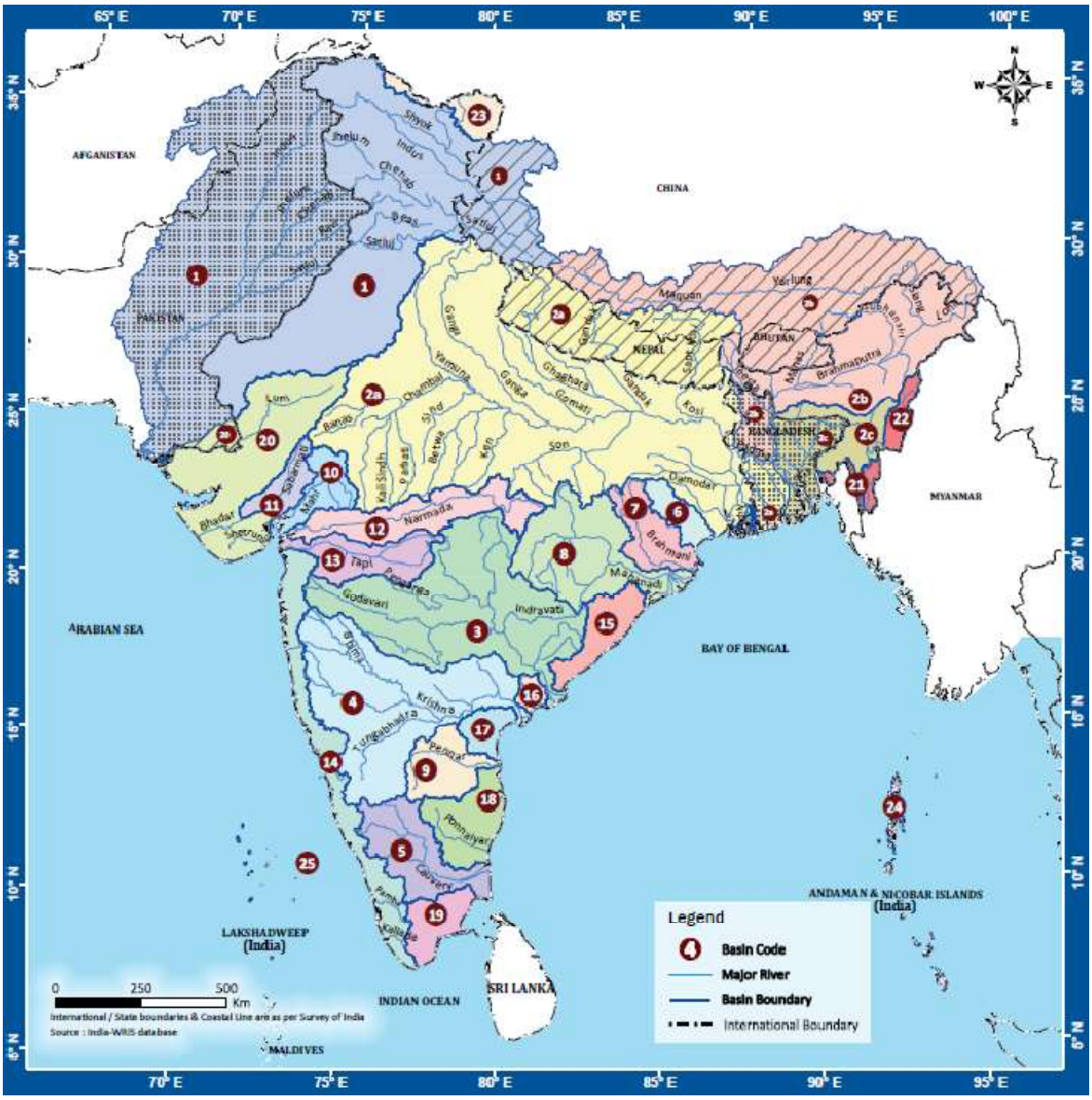

Figure 2: Main River Basins of India showing the Ganga River Basin (Yellow Region) Marked as "2a" [*India-WRIS, 2012*]

2.3. Defining River Ganga

River Ganga is defined herein as comprising of six main headstreams originating in the Himalayas, namely the Alaknanda, Dhauli Ganga, Nandakini, Pinder, Mandakini and Bhagirathi rivers starting from their feeding glaciers up to their respective confluences (together comprising the Upper Ganga segment), the subsequent main stem of the river downstream from Rishikesh to Varanasi (the Middle Ganga segment), and the final stretch from Varanasi to Ganga Sagar (the Lower Ganga segment).

2.4. Geology

NRGB is part of the tectonically active foreland basin of the Himalayan mountain range formed by collision of the Indian tectonic plate with the Eurasian plate more than fifty million years ago. Thus, much of NRGB consists of alluvial plains formed during the Tertiary and Quaternary periods by flood deposits of Himalayan and to some extent peninsular rivers. Due to ongoing tectonic processes resulting in high sediment erosion, the Ganga river network not only conveys water, but also transfers enormous amounts of sediments to the sea. The alluvial deposits of the basin constitute large and highly productive multi-aquifer systems in NRGB, which are a major storehouse of ground water. The soils of the basin are also largely alluvial, with mountain soils, terai soils and black soils towards the mountain ranges in the north and west of the basin.

2.5. Wetlands

There are many lakes, tanks and marshes in NRGB, vide Figure 3. They include large lakes as well as a large number of wetlands spread across the basin – in the mountainous Himalayan region, the Himalayan terai region, the Gangetic plains, and the coastal deltaic region – which together support diverse ecosystems in different geomorphic and climatic settings. Several of NRGB's wetlands are home to specialized flora and fauna as well as migratory species which fulfil crucial ecological and social functions.

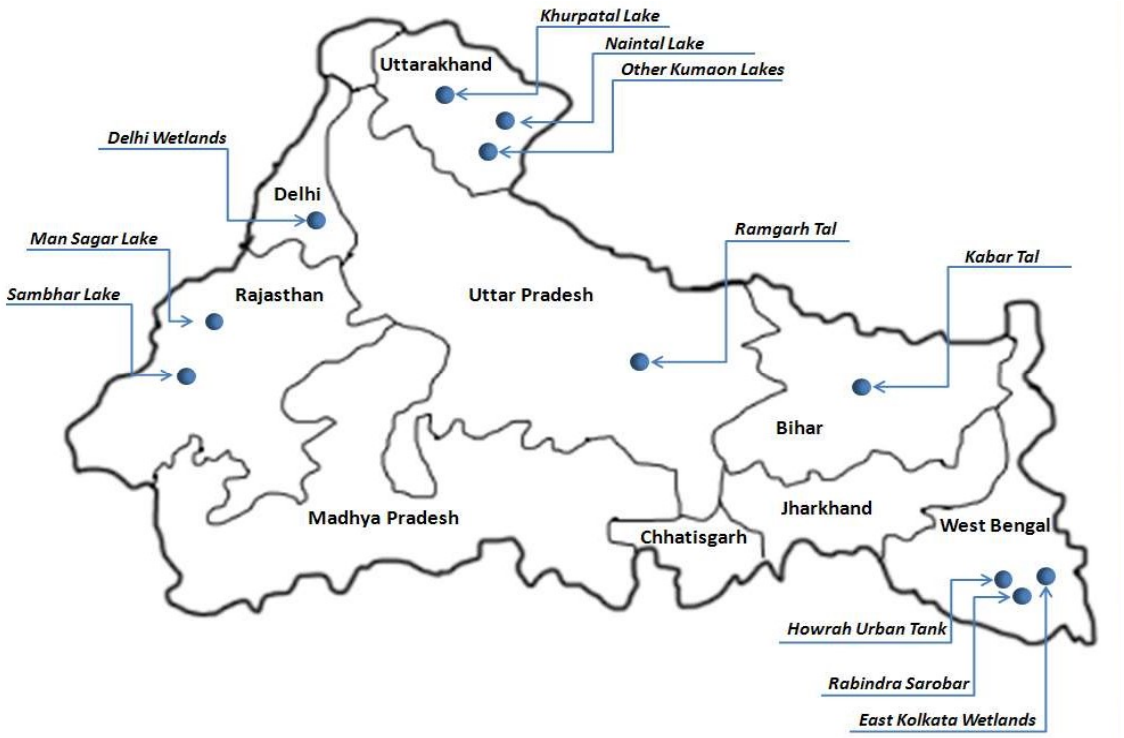

Figure 3: Major Lakes and Wetlands of NRGB [*Adapted from: Rainwater harvesting, 2013*]

2.6. Fluvial Geomorphology

National River Ganga's headstreams are fast-flowing mountainous rivers cutting through deep gorges and narrow valleys, the Middle Ganga stretch is multi-channel (braided) draining through relatively flat plains in the south, and the Lower Ganga segment tends to form a distributary system in the delta region. The fluvial pattern was affected by the geological evolution of NRGB. Near the Himalayan front, valley formation and incision were affected by both tectonic and climatic factors; strongly incised valley formation in the western and southern plains were controlled mainly by climatic factors; and fluvial geomorphology in the lower Ganga plains and the delta region were much influenced by sea level fluctuations, besides climate and tectonics. Detailed maps show significant diversity of valley widths and geomorphic features in different reaches of the river, which have strong implications for the hydrological regime and ecological health of NRGB. Figure 4 shows the valley map of the Middle and Lower Ganga stretches from Rishikesh to Farakka.

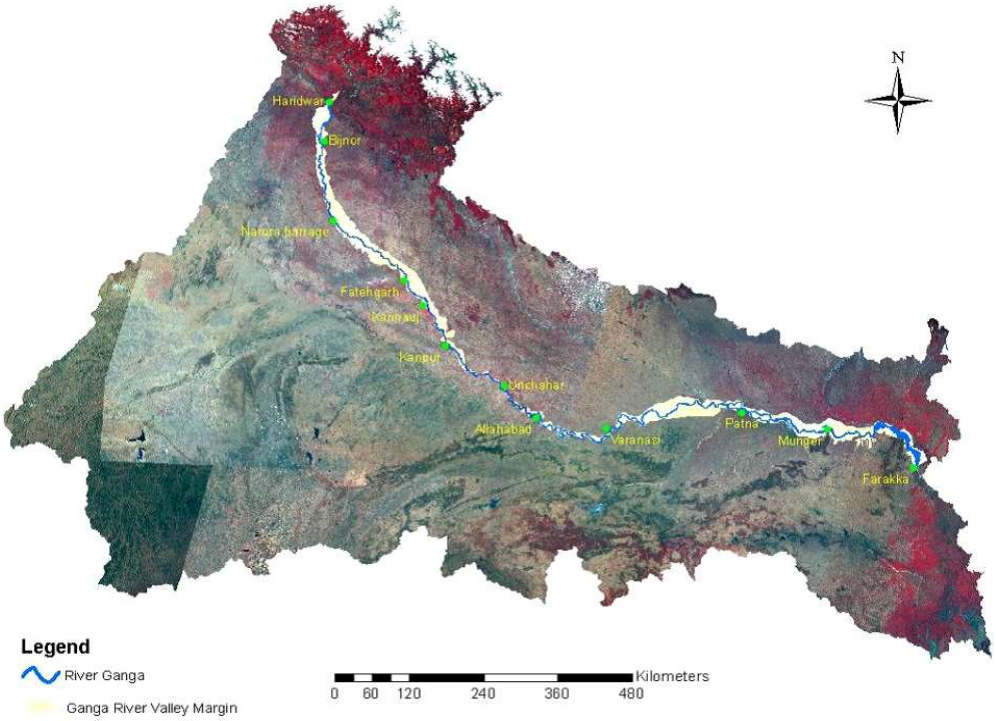

Figure 4: Geomorphic Map of Ganga River Valley

2.7. River Biodiversity

The biodiversity of National River Ganga uniquely synthesizes three different eco-regions of India situated along climatic gradients, namely the Himalayas, the Gangetic plains and the Deltaic region. The river's biodiversity comprises periphytons, phytoplanktons and macrophytes which are producers, and zooplanktons, zoobenthos, fish and higher aquatic vertebrates which are consumers of the food produced. Together, these micro- and macro-organisms, through their interplay with the abiotic environment, represent the ecological status of National River Ganga.

3. Vision, Mission, and Conceptual Framework

3.1. Vision of Ganga River

In order to preserve and invigorate National River Ganga, her essential character needs to be grasped in a holistic manner. After extensive research and consultations, the "wholesomeness of National River Ganga", viewed from

a dynamic perspective, was determined to be the sanctity of the river system imbibed in the four points stated below**:**

i. **"*Aviral Dhara*" (i.e. "Continuous Flow"):** The flow of water, sediments and other natural constituents of River Ganga are continuous and adequate over the entire length of the river throughout the year.

ii. **"*Nirmal Dhara*" (i.e."Unpolluted Flow"):** The flow in the Ganga River Network is bereft of manmade pollution; hence the river water quality should not be sullied by human activities.

iii. **Geologic Entity:** The Ganga River System is the earth's creations of ancient times, which may not be repairable if damaged.

iv. **Ecological Entity:** The Ganga River System is a delicately structured balance between various living species and the physical environment, achieved by nature over thousands of years and vulnerable to irreversible changes.

3.2. Objectives of GRBMP

Based on the above vision and societal needs, the main objectives of GRBMP are identified as the following:

a) Environmental Flows shall be maintained in all rivers and tributaries of Ganga River System to fulfil their geological, ecological, socio-economic and cultural functions.

b) Water quality in all rivers and tributaries of Ganga River System shall be consistent with their governing geological, ecological, socio-economic and cultural functions.

c) Water and other aquatic resources of the Ganga River System shall be used judiciously to enable sustainable development in the entire NRGB.

d) All existing, ongoing and planned anthropogenic activities in NRGB shall be reviewed or scrutinized in a transparent, inclusive manner (with consensus of all affected people and stakeholders) for the overall health of NRGB.

3.3. Formulation of Missions

Given the escalating impacts of human activities on NRGB, the above objectives guided the formulation of eight important areas where restorative

actions need to be carried out in Mission mode, viz.: "*Aviral Dhara*", "*Nirmal Dhara*", "*Ecological Restoration*", "*Sustainable Agriculture*", "*Geological Safeguarding*", "*Basin Protection Against Disasters*", "*River Hazard Management*" and "*Environmental Knowledge-Building and Sensitization*". The Vision and Missions of GRBMP are depicted in Figure 5.

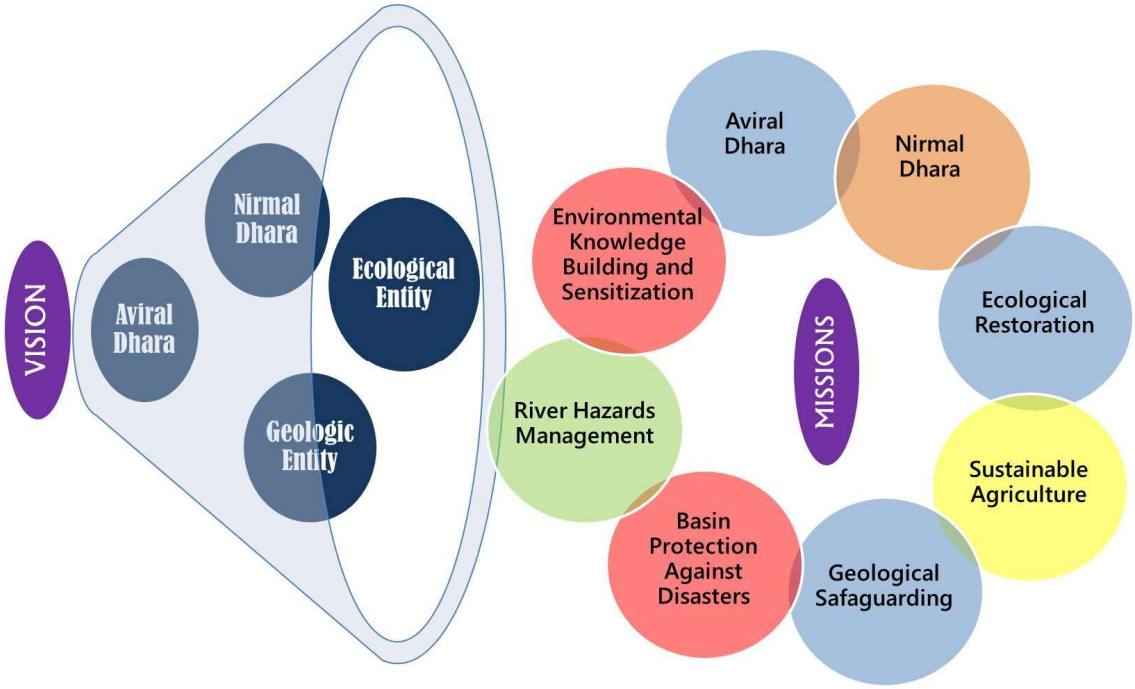

Figure 5: Target Missions to fulfill the Vision of a wholesome National River Ganga

3.4. Conceptual Framework

Based on the above Vision and the awareness of social needs, the main objective of GRBMP was identified as the formulation of policy frameworks (or "Action Plans") in the background of ongoing anthropogenic activities in NRGB. The basic approach in this framework action plan is: "*Apply modern science and technology in conjunction with traditional wisdom*", viz.:

पारंपरिक ज्ञान के साथ आधुनिक विज्ञान और नई
प्रौद्योगिकी को प्रयोग मे लाना
ज्ञान धारा + जन ज्ञान

3.5. Work Structure

The task of analysing and preparing the GRBMP was broken up from the whole to the parts into several thematic groups as follows**:** Environmental Quality and Pollution (EQP), Water Resources Management (WRM), Fluvial Geomorphology (FGM), Ecology and Biodiversity (ENB), Socio-economic and Socio-Cultural (SEC), Policy, Law and Governance (PLG), Geo-Spatial Database Management (GDM), and Communication (COM), plus a cross-thematic group on Environmental Flows (*or E-flows*), vide Figure 6.

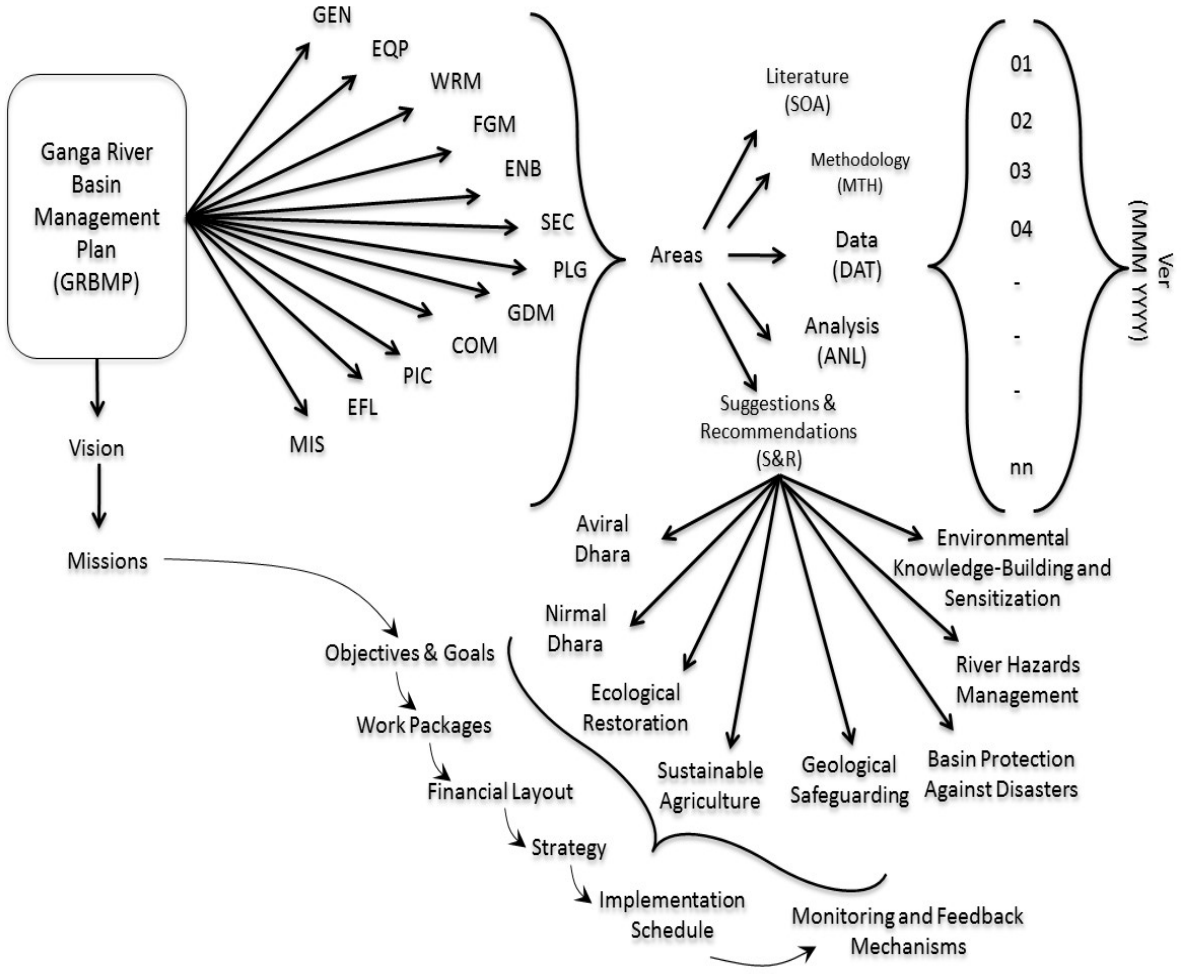

Figure 6: Flow Diagram of GRBMP Work Structure

4. Mission Summaries

4.1. Mission 1 – Aviral Dhara

4.1.1 Importance of Aviral Dhara: Aviral Dhara – or the continuous flow of water, sediments and other natural constituents – in National River Ganga was achieved through long-term balance between various dynamic parameters such as water and sediment flow rates, influent/ effluent seepage rates, and terrain gradient. Modern anthropogenic activities have violated the balance by**:** (a) erecting dams and barrages that snap a river's longitudinal connectivity and alter its flow regime, and (b) by significant water withdrawals, debris disposal, and altered water recharge rates. Hence the river network has become emaciated, as reflected in the loss of river biodiversity and the strain on goods and services emanating from it. Thus there is urgent need to restore Aviral Dhara throughout the river network.

4.1.2 Water Storage and Demand Control: Both longitudinal connectivity and adequate flows in rivers are essential to maintain Aviral Dhara. But having adequate river flows depends on the basin's overall water status. While information is limited, available data show that anthropogenic water use has been increasing rapidly in the basin, probably beyond its renewal capacity. Hence, (i) water availability in the basin must be increased through increased storage, (preferably by "distributed storage" in water bodies and aquifers); and (ii) water demands must be reduced through more efficient water use. These issues call for technical interventions as well as changes in policies on NRGB's water resource management.

4.1.3 Dams, Barrages and E-Flows: The Ganga river network is intercepted by numerous dams and barrages, and many new projects have been planned. But dams and barrages affect river morphology, stability and ecological balance, fertility of the river and its floodplains, nature of flood events, human health, and basin performance. Hence dams and barrages must permit longitudinal connectivity and allow E-Flows (Environmental Flows) in rivers. Towards this end, a method for ensuring longitudinal river connectivity with E-Flows passage through dams/barrages is suggested. A comprehensive set of criteria has also been proposed to define environmental clearance requirements for

dams/ barrages based on 4 categories of their environmental impacts. For dams, barrages, canal outlets, weirs and other structures that alter river flow regimes, the maintenance of E-flows (with commensurate sediment loads) is essential. Hence, a reliable method for estimating E-Flows for specific river stretches was also developed and demonstrated for select locations in the Upper Ganga basin (see Figure 7) where undisturbed river flows before the construction of dams, etc., are known. Illustrative results for computed E-Flows at one such site (Ranari, Dharasu) are shown in Figure 8.

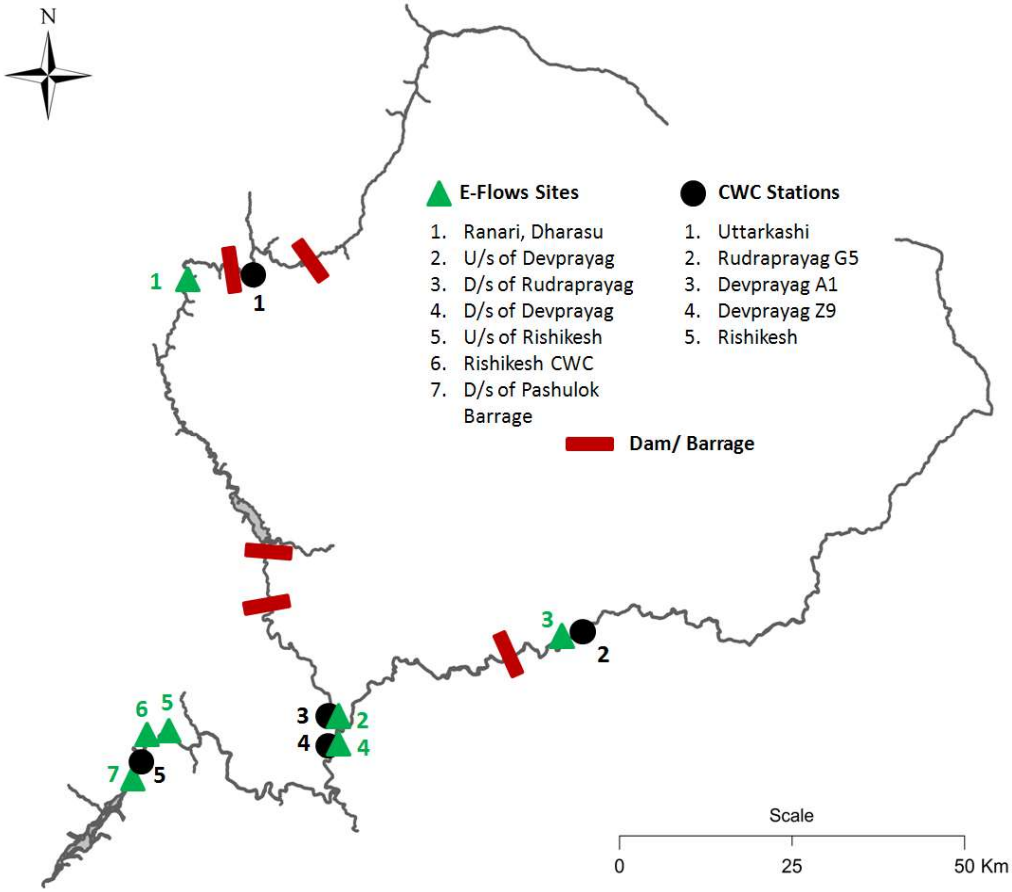

Figure 7: Location Map of E-Flows Sites in the Upper Ganga

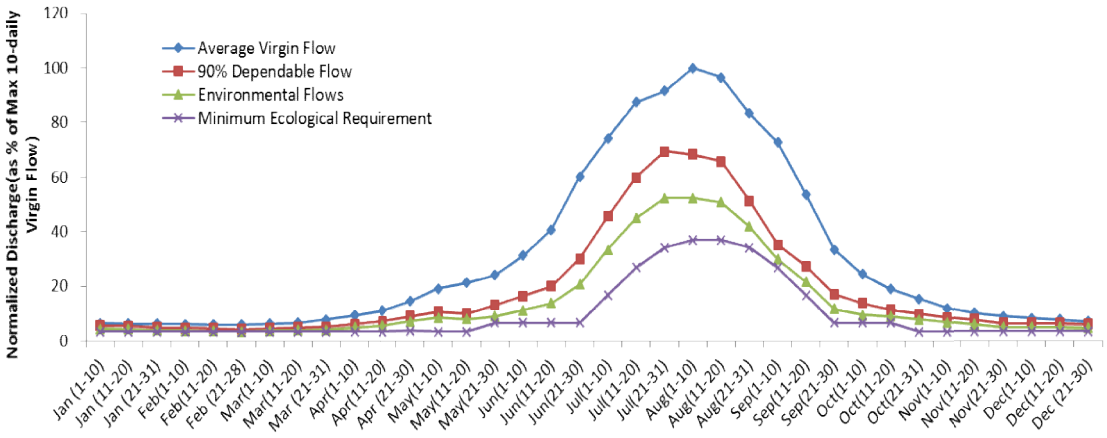

Figure 8: Computed 10-daily E-Flows at Ranari, Dharasu

4.1.4 Hydrological Modeling of NRGB: Dynamic modeling of surface flows in the combined Ganga basin area of India and Nepal was carried out using SWAT model. Raw data used included static spatial data, dynamic hydro-meteorological data, and water demand and abstraction data. Model simulation was carried out for the period 1969–2006, and the results were calibrated with river discharges. Groundwater modelling was carried out using MODFLOW computer model for the alluvium part of the basin. Modeling efforts were constrained by limitations of data of precipitation, canal water diversions, irrigation practices, nearly half of the 206 dams/ reservoirs, etc., besides limitations on quality of data for land use, groundwater abstractions, etc. The summary model outcome, vide Figure 9, shows that streamflow and evapotranspiration are the two main components of water outgo from the modeled basin area, with evapotranspiration being about 41-42% of precipitation. Model estimates of “virgin flows” and “present managed flows” in major rivers of the network are presented, vide Figure 10.

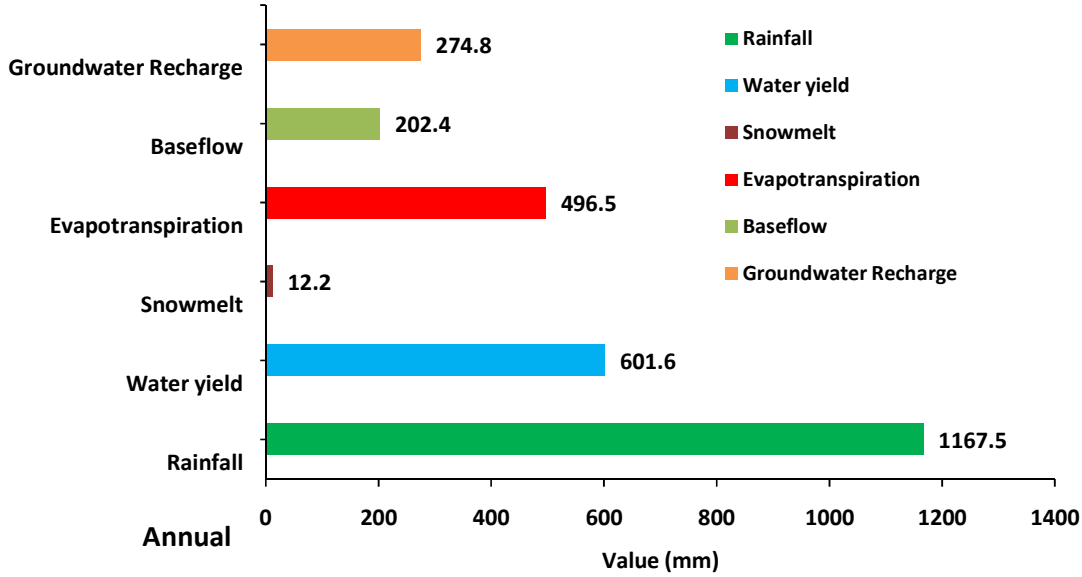

Figure 9: Average (1969-2006) Annual Water Balance of the Modeled Ganga Basin

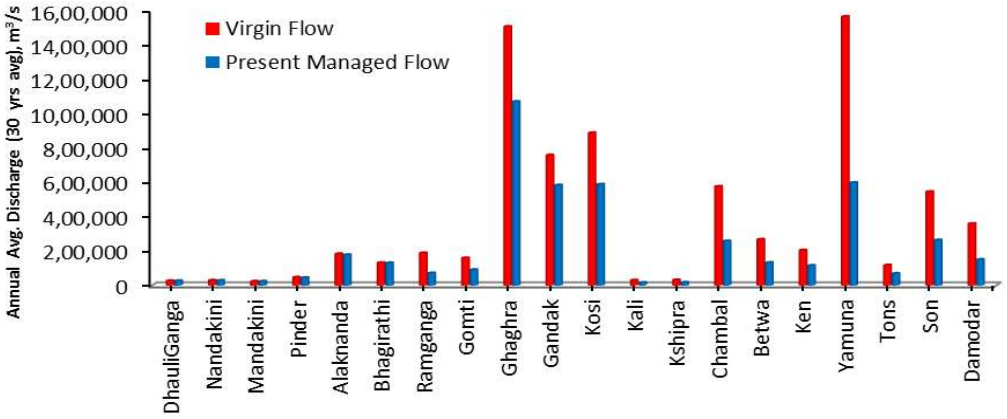

Figure 10: Annual Flow Contributions of Different Tributaries (sub-basins) to National River Ganga under Present Flow Conditions and under Virgin Flow Conditions

4.1.5 Sediment Resources of National River Ganga: Water-borne sediments play a vital role in the dynamics and ecology of the Ganga River Network, but their nutrient value is unknown. A reliable sediment budget of the basin is also unavailable, but the river's suspended sediment load is generally reported at between 500 to 800 million T/yr, and the total sediment load at about 2400 million T/yr – which are very high for any world river. Based on available data, the average annual and seasonal suspended sediment loads at different stations on National River Ganga were computed, vide Figure 11. Surprisingly, the average suspended sediment load at Farakka during the period 1999–2006

was found to be only 177 million T/year – much less than earlier estimates. The sediment load also showed major spatial variations, suggesting different aggrading and degrading river reaches.

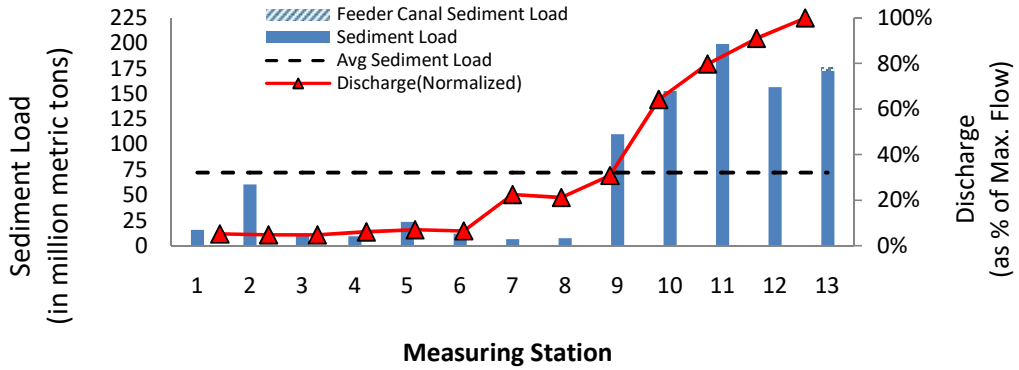

Figure 11: Comparison of the Annual Average Sediment Loads (for period 1999-2006) at Different Locations of National River Ganga

4.1.6 Recommended Actions: The main actions recommended are**:** (1) Determination of NRGB's hydrological status more accurately and in greater detail. (2) Preparation of water resources plan for NRGB with emphasis on wetlands, forests and distributed groundwater and surface water storages rather than large reservoirs storages. (3) Increase in anthropogenic water use efficiency through**:** (i) realistic pricing of fresh water; (ii) incentives, technical assistance, and allocation of water rights and entitlements to consumers; and (iii) reuse and recycling of water. (4) Governmental policy shift to bring NRGB's waters under natural resource management, with emphasis on resource preservation, stakeholder control, expert guidance and regulation. (5) Ensuring longitudinal river connectivity and E-Flows at dams, barrages and other manmade interferences, and adoption of new criteria for approving such projects. (6) Control of water withdrawals in water-depleting regions. (7) Assessment and monitoring of sediment resources of the network including the quantity, quality and nutrient value of sediments trapped behind dams. (8) Research to determine ecological limits, thresholds and interconnections of NRGB's water resources, and river flow health assessments within the framework of ecohydrology.

4.2. Mission 2 – Nirmal Dhara

4.2.1 Importance of Nirmal Dhara: Ganga river's water quality had been acclaimed in ancient times. Its life-giving and healing qualities are evident from the following description in Rajanirghanta (~300 AD) meaning *"The qualities of Ganga water are: Coolness, sweetness, transparency, high tonic property, wholesomeness, potability, ability to remove evils, ability to resuscitate from swoon caused by dehydration, digestive property and ability to retain wisdom*"**:**

अस्या जलस्य गुणाः शीतत्वम्, स्वादुत्वम, स्वछत्वम, अत्यन्तरुच्यत्वम्, पथ्तत्वम्, पावनत्वम्,
पापहारित्वम्, तृष्णामोहध्वंसत्वम्, दीपनत्वम्, प्रज्ञाधारित्वंच, इति राजनिर्घण्टः

In modern times, however, the Ganga River System's water quality has been significantly affected by disposal of anthropogenic wastes into the rivers which has caused enormous harm to river biota and the ecosystem goods and services of the river network. This underscores the necessity for restoring unpolluted flows in the river system.

4.2.2 Type of Anthropogenic Wastes: Anthropogenic wastes disposed in the Ganga River System, graphically shown in Figure 12, include both solid and liquid wastes of hazardous and non-hazardous types generated from domestic, industrial and agricultural sources. Liquid wastes from large urban centres and industries are major point sources of pollution, while surface runoff containing agrochemicals and entrained solid wastes are some major non-point pollution sources.

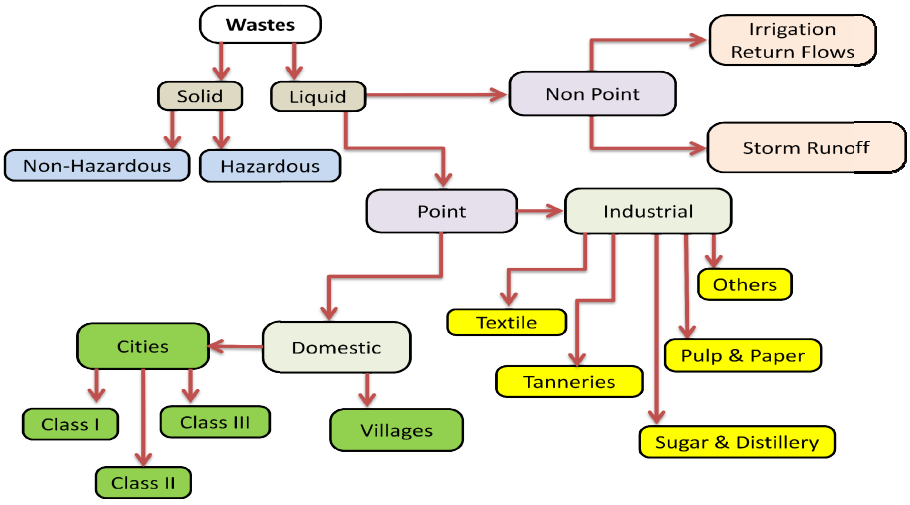

Figure 12: Types of Waste Generated in Ganga River Basin

4.2.3 Measures Needed to Achieve Nirmal Dhara: To check river pollution in the Ganga River Network, it is necessary to**:** (A) Prohibit major pollutant ingresses into rivers (hence adopting ZLD or Zero Liquid Discharge) by discharge of sewage (either treated or untreated) from Class I towns; discharge of industrial effluents (either treated or untreated) from any large, medium or cluster of small industries; direct injection of sewage and industrial effluents (either treated or untreated) into the subsurface; disposal of un-burnt and partially burnt corpses and animal carcasses in rivers; open defecation and dumping of municipal/industrial solid wastes or sludge in any river or its active flood plain; and construction of new residential, commercial or industrial structures in river flood plains. (B) Restrict other pollutant discharges by discharge of sewage (either treated or untreated) from Class II and smaller towns and villages; disposal of sewage or industrial treatment sludges except in secure landfills/hazardous waste sites; discharge of industrial effluents (either treated or untreated) from small scale industry; disposal and/or discharge of mining and construction debris in any river or its floodplains; river bed farming and agricultural activities in active flood plains; ritual immersion of idols; and floral and other offerings in rivers, washing of clothes, vehicles, etc., in rivers, and usage of agrochemicals in NRGB.

4.2.4 Recommended Actions: In keeping with the above requirements, the main recommendations are grouped under the following heads: (1) Management of Solid and Liquid Wastes Generated from Domestic/ Commercial Sources; (2) Riverfront Development, Floodplain Management and Rejuvenation of Water Bodies; (3) Management of Solid and Liquid Waste Generated from Industrial Sources; and (4) Management of Polluted Agricultural Runoff. Effective co-ordination of these activities is envisaged through a high-level constitutional body tentatively named the 'National River Ganga Basin Management Commission' (NRGBMC), pending whose formation the NMCG or some other dedicated government body may coordinate the activities. Project planning for urban works should begin with preparation of detailed Urban River Management Plans (URMP) for Class I towns, and subsequently also for Class II and Class III towns. The URMPs should be followed by preparation of DPRs, following which funds should be allocated for project implementation. Fund allocation should be prioritized for projects designed to prevent direct discharge of large quantities of liquid waste into the

River System (Priority Level I), followed by projects designed to prevent direct discharge of large quantities of solid waste into the River System (Priority Level II), followed by projects concerning river-frame development and restoration of floodplain in urban areas along the Ganga River System (Priority Level III). Other projects under Mission Nirmal Dhara (MND) may be executed at still lower priority depending on availability of funds.

4.2.5 Implementation Scheme: Financing of the above projects may be obtained from central/state governments, local revenue, corporate and private donations and grants, low cost debt from international organizations, commercial debts from banks and private equity. Category A and Category B projects are recommended for execution through the PPP route (such as the DBFO model) with initial investment from the service provider, while Category C projects may be executed by the concerned industries themselves and through SPVs for industrial clusters. Category D projects may be synergistically executed with other government projects as per actions required under other Missions of GRBMP. It is also recommended that the most polluted reaches of the river network be first targeted under MND. Thus, several major towns have been identified for priority action regarding sewage management on River Yamuna (Delhi, Faridabad, Vrindavan, Mathura and Agra), Ramganga (Moradabad), Gomti (Lucknow), and Ganga (Haridwar, Garhmukhteshwar, Kanpur, Allahabad and Varanasi), as shown in Figure 13. For overall implementation of MND recommendations in NRGB, financial work packages have been estimated for different categories of projects. Appropriate monitoring and feedback mechanism has also been suggested for sustainability of the projects.

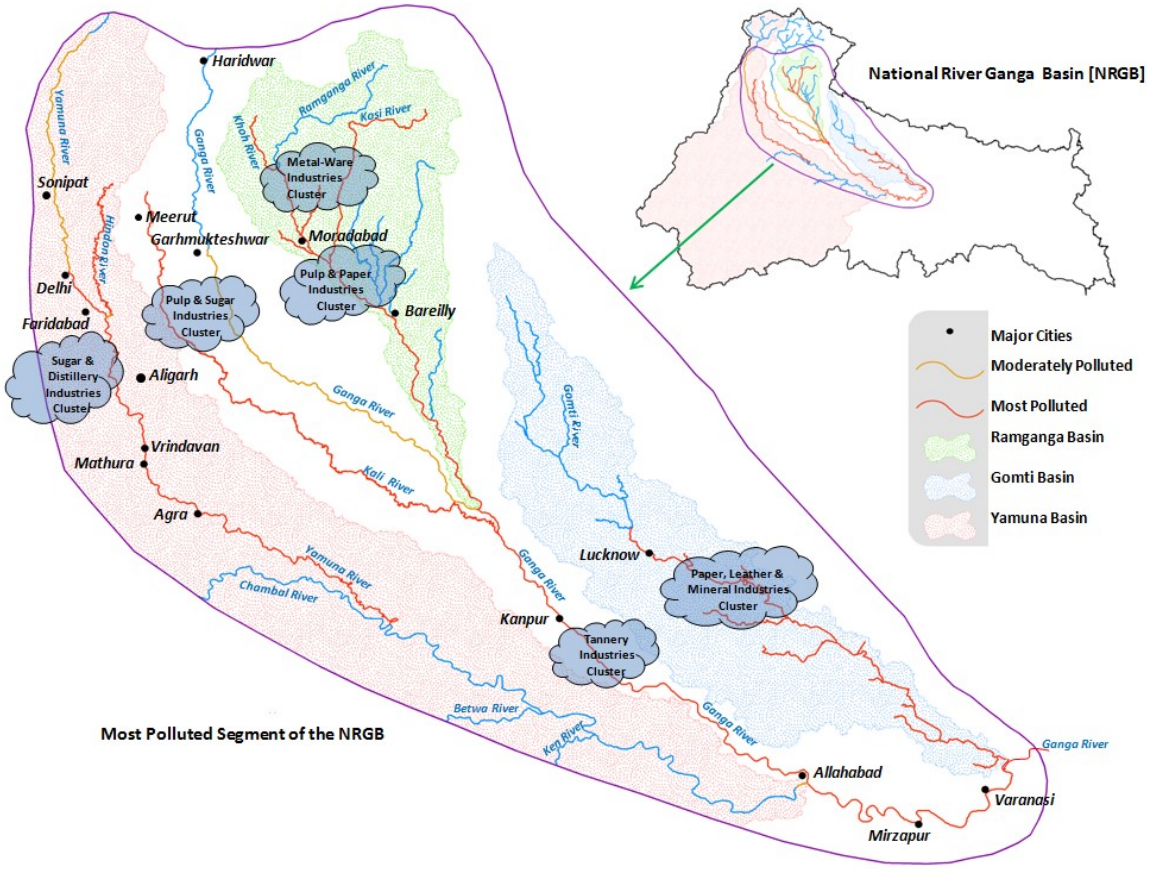

Figure 13: Most Polluted Stretches and their Pollution Sources in National River Ganga Basin

4.3. Mission 3 – Ecological Restoration

4.3.1 Need for Ecological Restoration: Ecological restoration of National River Ganga is urgently needed since river biodiversity is being rapidly lost. A rough idea of the loss of species biodiversity in the river is evident from the progressive loss of fish catch at Allahabad since 1950, vide Figure 14. In general, the biodiversity of River Ganga is unique, as it synthesizes three major eco-regions of India situated along different climatic gradients, namely: the Himalayan mountainous region in the upper reach, the Gangetic plains in the middle reach, and the estuarine region (including the Hooghly-Matlah delta) in the lower reach. The overall biological profile of River Ganga is depicted in Figure 15.

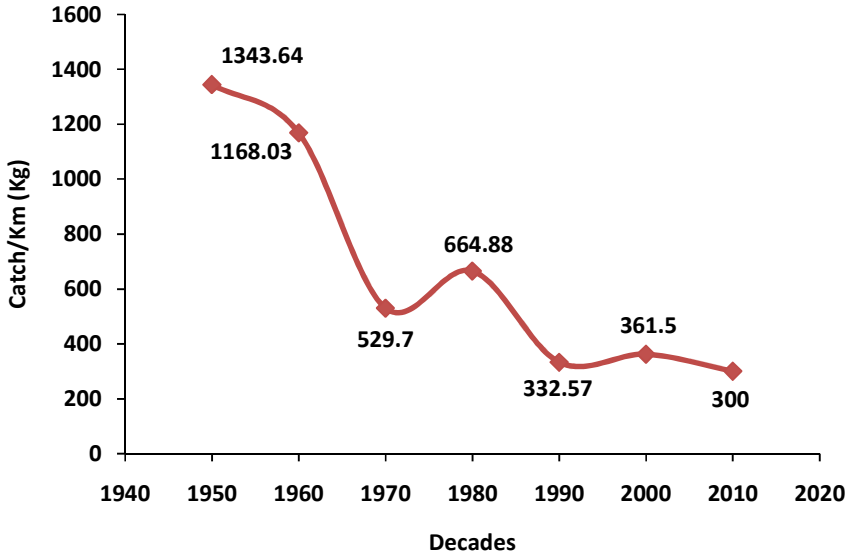

Figure 14: Decline of Fish Catch per km at Allahabad between 1950 to 2010

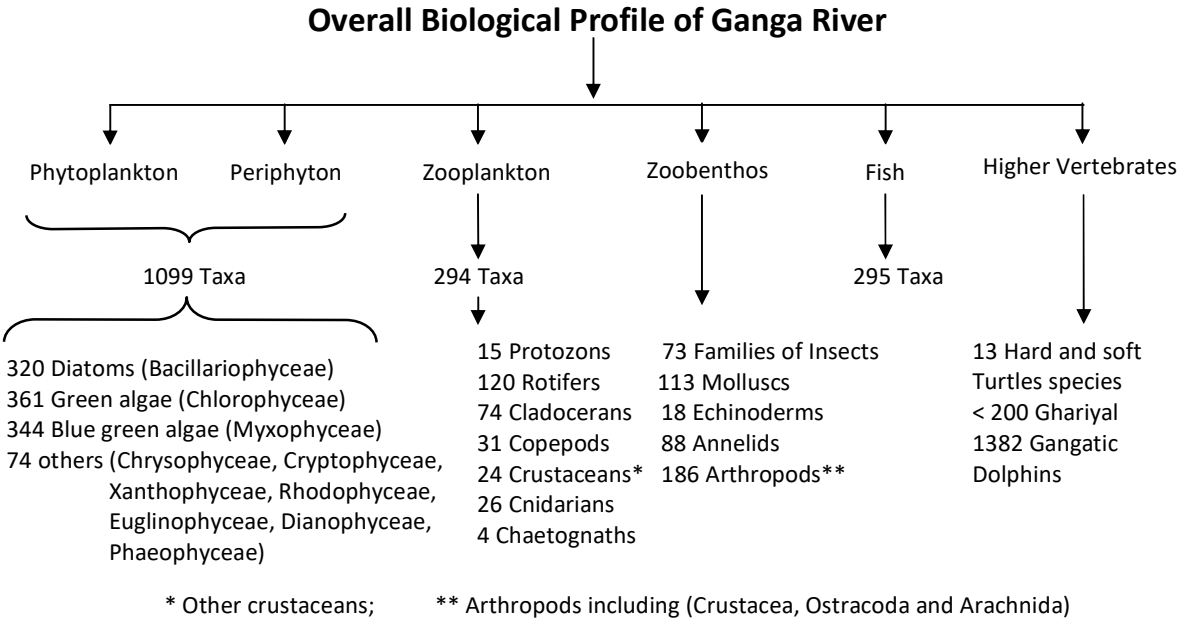

Figure 15: Biodiversity of River Ganga at a Glance

4.3.2 Threats to River Biodiversity: Eight main factors affecting the habitat of aquatic species of National River Ganga and causing loss of her biodiversity were identified, viz.**:** (i) Habitat Fragmentation by dams and barrages; (ii) Habitat Shrinkage due to increased water diversions and withdrawals from rivers; (iii) Habitat Alterations by gravel and sand mining from river beds and construction of embankments, levees, guide walls, etc.; (iv) Habitat Pollution

by influx of municipal, industrial and agricultural wastes; (v) Habitat Invasion by alien river species; (vi) Habitat Encroachment by constructions in floodplains and river bed farming; (vii) Habitat Disturbances by plying of noisy vessels, dredging, etc.; and (viii) Habitat Malnutrition by the trapping of nutrient-rich sediments behind dams and other structures.

4.3.3 Recommended Actions: Given the above threat factors, the measures recommended are**:** (1) Restoration of longitudinal connectivity along with E-flows at dams, barrages and other obstructions. (2) Maintenance of lateral connectivity across floodplains. (3) Restoration of unpolluted river flows. (4) Restrictions on river bed farming and gravel-and sand-mining from river beds. (5) Restrictions on plying of noisy vessels, dredging, and bed and bank modifications. (6) Control of alien species invasions, overfishing and fishing during spawning seasons. (7) River nutrient assessment and release of sediments trapped behind dams/barrages into downstream river reaches. (8) Long-term bio-monitoring of the Ganga river network. (9) Synergising actions under this mission with the Dolphin Conservation Action Plan – 2010. (10) Comprehensive research on the ecological dynamics of the Ganga River System.

4.4. Mission 4 – Sustainable Agriculture

4.4.1 Importance of Sustainable Agriculture: Modern agricultural practices have been major causes of soil degradation and fertility loss, pollution of water bodies, and natural resource depletion in NRGB. Hence transition to sustainable agriculture is urgently needed to maintain NRGB's ecosystem services. Arable land is the major constraint for agricultural growth in NRGB and water availability is a second major constraint. Yet, agricultural growth in NRGB almost quadrupled in forty years since the 1960s by adopting high-yield crops with high inputs of fertilizer and water, vide Figure 16. But intensive conventional agricultural practices with abundant use of water, agrochemicals, soil tillage, and mono-cropping practices have increased soil erosion and degradation, depleted soil nutrients and soil biodiversity, dwindled the basin's waters, and polluted its ecosystems. Hence urgent reforms are needed to combat these negatives with practicable measures.

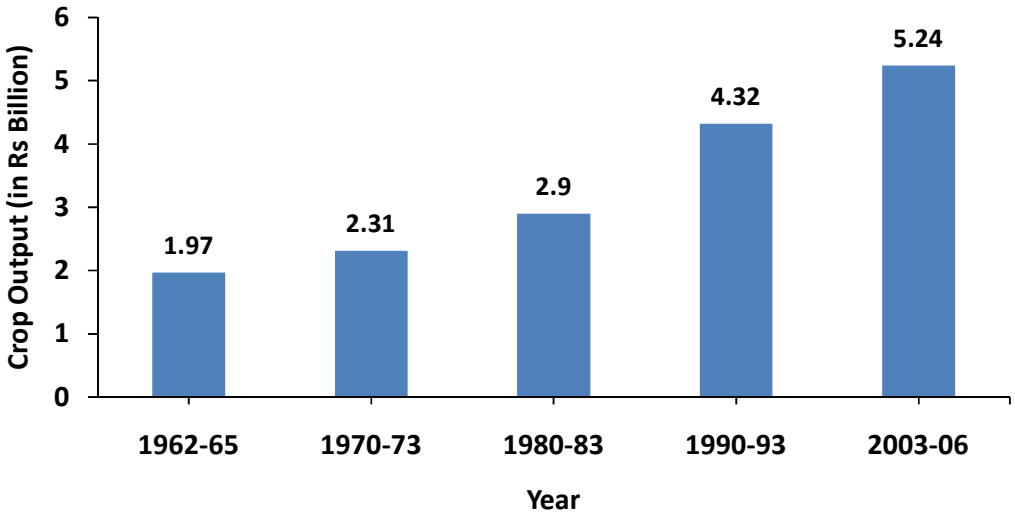

Figure 16: Average Crop Output Value per District in NRGB between 1962-65 and 2003-06

4.4.2 Recommended Actions: The main reforms recommended to minimize negative environmental impacts on NRGB while maintaining agricultural productivity and economic viability are identified as**:** (1) Adoption of Conservation Agriculture (involving no tillage, crop diversification, and permanent organic soil cover), especially in degrading lands, to enhance long-term soil fertility and agricultural output. (2) Promotion of Organic Farming where essential and/or economically feasible. (3) Economically beneficial improvements in water and nutrient application techniques in rice cultivation, especially by SRI (i.e. System of Rice Intensification) and Urea Deep Placement. (4) Promoting other established resource conservation technologies where feasible. (5) Promoting regional (landscape-scale) resource conservation steps to counter monotonous agro-ecosystem impacts. (6) Infusing experimentation, adaptability and flexibility in NRGB's agricultural practices to synthesize traditional knowledge with ongoing and future scientific discoveries. (7) Devising appropriate policy measures to implement the above recommendations within the existing socio-cultural, economic and institutional framework prevalent in different regions of NRGB.

4.5. Mission 5 – Geological Safeguarding

4.5.1 Importance of Geological Safeguarding: Geologically, river networks tend to achieve equilibrium between tectonic uplift and erosional phenomena

in the basins, but both factors have come under significant anthropogenic influence in modern times. Hence geological safeguarding and geomorphological upkeep of the basin are of key importance for the integrity and functional stability of NRGB. The identified geological vulnerabilities of NRGB include disruptive underground activities such as excavations, explosions, tunneling, mining, fracking, and over-withdrawal of ground-water from confined and semi-confined aquifers, as well as over-ground activities such as the operation of large reservoirs. Anthropogenic geomorphological damages are identified to be primarily due to harmful land-uses that enhance erosional stresses.

4.5.2 Recommended Actions: The recommended actions are**:** (1) Control/ restriction of geologically hazardous activities including deep groundwater withdrawals, underground excavations, explosions, tunnelling, mining, fracking, and operation of large reservoirs. (2) Region-specific restrictions on geo-morphologically harmful land-use practices such as deforestation and construction activities on hill slopes and in floodplains, excessive agricultural tillage, sand and gravel mining from river beds, and river bank modifications. (3) Drainage improvement of low-lying areas and stabilization of disturbed areas. (4) Mapping river migration zones, and continuous geological monitoring of NRGB.

4.6. Mission 6 – Basin Protection Against Disasters

4.6.1 Importance of Basin Protection Against Disasters: NRGB is prone to catastrophic natural disasters that can significantly harm the basin's ecosystems, and such disasters have been highly accentuated by modern anthropogenic activities. Hence special measures are needed to protect the basin against natural disasters. But out of many natural disasters that affect human communities, and apart from *Earthquakes* which is covered under Mission Geological Safeguarding, the major natural disasters of real concern for the basin's ecosystems are few, viz.**:** *Extreme Floods*, *Extreme Droughts*, *Forest Fires*, *Tropical Cyclones*, *Landslides*, and *Epidemics and Biological Invasions*.

4.6.2 Recommended Actions: The main recommendations are**:** (1) Routine hydro-meteorological and biological events – often perceived as disasters – are usually beneficial for the basin; hence they should not be countered. (2) To withstand catastrophic disasters, ecosystems need strengthening by preserving wetlands, promoting mixed indigenous forests and vegetation, and curbing land-use disturbances and encroachments by humans. (3) Extreme Floods are typical of sediment-charged Himalayan rivers of NRGB, to combat which floodplain regulations and vegetative measures are preferable to embankments/ levees, since the latter create perched rivers and increase the flood damage potential; but upstream dams (with longitudinal connectivity and environmental flows) may prove beneficial if sediment trapped behind dams can be transferred to downstream floodplains. (4) NRGB's ecosystems have evolved over time against certain fire and biological regimes; hence the ecology of Forest Fires and of Epidemics & Biological Invasions in NRGB's ecosystems needs to be studied extensively. Until then, active interventions to counter such events should be limited to checking harmful anthropogenic activities. (5) Landslides in the Upper Ganga Basin and other hilly regions are aggravated by deforestation, road and building constructions, and unsafe debris disposal, which need to be strongly checked. (6) Early rejuvenation of disaster-struck ecosystems should be aided by re-introducing indigenous species resistant to the specific disaster types and re-creating an enabling physical environment.

4.7. Mission 7 – River Hazards Management

4.7.1 Importance of River Hazards Management: Several river-related disasters in India in recent years bear testimony to the fact that human disturbances have increased the intensity of these disasters and vulnerability of communities towards these. Hence it is necessary to identify hazards related to anthropogenic disturbances on rivers and to formulate suitable means to reduce the risk. Now flood control strategies in most river basins in India are primarily embankment based. But manmade structures have influenced the natural flow regime of rivers and modified the flood intensity, frequency and pattern. Moreover, many Himalayan rivers are highly sediment charged, and the rising riverbed and reduction in carrying capacity due to extensive

sediment deposition in upstream reaches of a barrage has been a major problem. The engineering assumption that jacketing the river would increase the velocity and lead to scouring has instead resulted in silting of river beds and increased water logging and soil salinity in adjoining floodplains. The construction of protective levees and dykes, plus the large sediment flux from Himalayan catchments, has further complicated the flooding problem. In many cases, large areas have been inundated due to breaches in embankments coupled with rapid shifting of rivers. Unplanned roads and bunds have also caused severe drainage.

4.7.2 Recommended Actions: The main recommendations are**:** (1) Basin scale flood-risk maps should be prepared based on scientific data and reasoning, and they can be linked to an online data base and flood warning system. (2) Drainage improvement and land reclamation in low-lying areas should be taken up systematically and urgently given successful case histories from different parts of the world. (3) Assessment of soil salinity and its mitigation strategy are important; the latter may include the use of salinity resistant crops and soil improvement practices. (4) Alternatives to embankments for flood management with emphasis on 'living with the floods' concept must be emphasized; this may include floodplain zoning and other non-structural approaches. There is also an urgent need for academia, governmental organizations, NGOs, social institutions and the society at large to work together for this. (5) Research needed on sediment dynamics and its application in river management projects for designing sustainable river management strategies. The Kosi basin could be taken up as a case study since the Kosi is one of the highest sediment load carrying rivers in Ganga basin and it is also flood-prone. (6) Some pilot projects may be undertaken in partnership with state governments, e.g.**:** (a) Reactivation of paleochannels in the Kosi basin and design of flood spillway; (b) Improving drainage congestion caused by unplanned rail/road network by providing additional culverts and pathways in several parts of UP and Bihar; (c) Designing canals to drain water from permanently waterlogged areas; (d) Initiation of flood awareness programme and educating people to move away from flood-prone areas; and (e) Developing reliable flood forecasting system for specific river basins through modeling, and better communication systems for timely action.

4.8. Mission 8 – Environmental Knowledge-Building and Sensitization

4.8.1 Importance of Environmental Knowledge-Building and Sensitization: Basin planning and management combine diverse natural resources (water resources, land resources, biological resources, etc.) and processes (river dynamics, geological phenomena, atmospheric processes, etc.) with traditional wisdom and grassroots knowledge. Hence it is necessary to build a comprehensive data bank to enable meaningful analyses and obtain quantitative indicators of NRGB's status. Moreover, since NRGB's welfare needs the co-operation and help of both formal and informal sectors of society, the data bank – along with community-specific educational material and programmes on NRGB's environment – should be accessible to citizens to enable their participation in the NRGB's upkeep.

4.8.2 Recommended Actions: The main recommendations are**:** (1) Establishment of a comprehensive Data Bank by continuous collection, processing and storage of information on the basin's natural resources, anthropogenic activities, and environmental monitoring of basin; (2) Preparation of secondary results (representative parameters, charts, tables, etc.) based on primary data; (3) Preparation of documents and materials for easy understanding by non-specialized people; (4) Keeping all the above information in open domain for easy access by interested individuals and institutions; and (5) Conducting educational workshops and campaigns with stakeholders and interested citizens to enable their sensitization and comprehensive understanding of basin processes; and (6) Conducting ground-level monitoring and field researches of NRGB's environment with stakeholder participation.

5. Recommendations for Implementation

5.1 Specific Actions

On assessing the significant impacts on NRGB under different Missions, specific anthropogenic activities that should be immediately *Prohibited*, *Restricted* or

Promoted have been identified and listed. Their implementation and future development would require the coordinated efforts and co-operation of government and nongovernment institutions, key stakeholders and civil society. It is envisaged that only a dedicated, knowledge-based, empowered and stakeholder-involving agency would be able to pool in the collective knowledge and resources for environmental rejuvenation of NRGB.

5.2 Envisaged Consequences

The most direct and immediate result of implementing the desired measures would be on the health of the Ganga River System (in terms of Quantity, Quality & Biodiversity of the river's waters). On issues of socio-economic importance, the changes are likely to reflect immediately on Water & Sanitation, Disease & Health, Flood Impacts, Agriculture & Food Security, Energy Generation, and Ecosystem Services (such as aquatic foods and fish catches, cultural, religious & recreational activities) as shown in Figure 17. While implementation of the proposed measures will incur costs, it is envisaged that they will have significant net positive gains for the region in the foreseeable future.

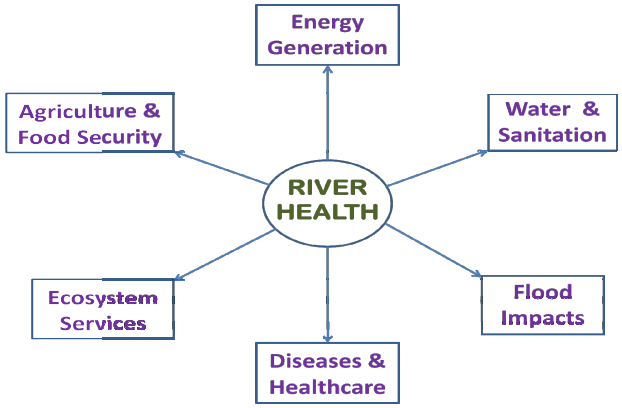

Figure 17: Major Sectors Likely to be Influenced by GRBMP Action Plan

5.3 Implementation Mechanism

The implementation, monitoring, review and evaluation of the basin's problems and interventions on a long-term basis are recommended through an independent Commission. The implementation challenge lies in aligning divergent interests of key social actors with involvement of ordinary stake holders as shown in Figure 18. Moreover, since rivers are prima facie inter-

state subjects as per the Constitution, the said Commission would need adequate resources and authority (under relevant provisions of the Constitution) to coordinate and oversee the activities of multiple sectoral organizations and informal sectors of society insofar as they affect National River Ganga. GRBMP, therefore, includes the functional requirements of a Commission that needs to be established by an Act of Parliament, to enable an enduring mechanism for sustainable growth in the National River Ganga Basin.

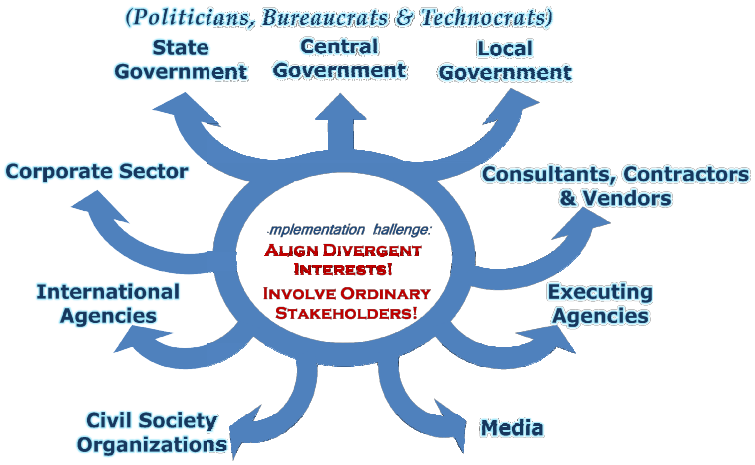

Figure 18: Implementation Challenges in Aligning Interests of Key Actors

6. GRBMP Documentation

The GRBMP is presented as a 3-tier set of documents. The three tiers comprise of: (i) Thematic Reports providing inputs for different Missions, (ii) Mission Reports documenting the requirements and actions for specific missions, and (iii) the main GRBMP Report synthesizing background information with the main conclusions and recommendations of Thematic and Mission Reports. It is hoped that this modular structure will make the Plan easier to comprehend and implement in a systematic manner.

Main Plan Document

January 2015

by

Consortium of 7 "Indian Institute of Technology"s (IITs)

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

In Collaboration with

IIT BHU | IIT Gandhinagar | CIFRI | NEERI | JNU | PU | NIT-K | DU

NIH Roorkee | ISI Kolkata | Allahabad University | WWF India

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government constituted the National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP). A Consortium of seven "Indian Institute of Technology"s (IITs) was given the responsibility of preparing the GRBMP by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. A Memorandum of Agreement (MoA) was therefore signed between the 7 IITs (IITs Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This is the Main Plan Document (MPD) that briefly describes (i) river Ganga in basin perspective, (ii) management of resources in Ganga Basin, (iii) philosophy of GRBMP, (iv) issues and concerns of the NRGB Environment, (v) suggestions and recommendations in the form of various Missions, and (vi) a framework for effective implementation of the recommendations. The MPD is complemented by eight Mission Reports (MR) and many Thematic Reports (TR) prepared by the Consortium of IITs to describe the strategy, information, methodology, analysis, suggestions and recommendations pertinent to the GRBMP.

There are two aspects to the development of GRBMP that deserve special mention. Firstly, the GRBMP is based mostly on secondary information obtained from governmental and other sources rather than on primary data collected by IIT Consortium. Likewise, most ideas and concepts used are not original but based on literature and other sources. Thus, on the whole, the GRBMP and its reports are an attempt to dig into the world's collective wisdom and distil relevant truths about the complex problem of Ganga River Basin Management and solutions thereof.

Secondly, many dedicated people spent hours discussing major concerns, issues and solutions to the problems addressed in GRBMP. Their dedication led to the preparation of a comprehensive GRBMP that hopes to articulate the outcome of the dialog in a meaningful way. Thus, directly or indirectly, many people contributed significantly to the preparation of GRBMP. The GRBMP therefore truly is an outcome of collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team and of the associate organizations as well as many government departments and individuals.

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Abbreviations and Acronyms

1.	CGWB	:	Central Ground Water Board.
2.	CWC	:	Central Water Commission.
3.	DBFO	:	Design-Build-Finance-Operate.
4.	DPR	:	Detailed Project Report.
5.	E-Flows	:	Environmental Flows.
6.	IITC	:	IIT Consortium.
7.	FAO	:	Food and Agricultural Organization.
8.	GRBMP	:	Ganga River Basin Management Plan.
9.	MND	:	Mission Nirmal Dhara.
10.	MoEF	:	Ministry of Environment and Forests.
11.	MoEFCC	:	Ministry of Environment and Forests & Climate Change.
12.	MoWR	:	Ministry of Water Resources.
13.	MoWRRD&GR	:	Ministry of Water Resources, River Development & Ganga Rejuvenation.
14.	NGO	:	Non-Governmental Organization.
15.	NGRBA	:	National Ganga River Basin Authority.
16.	NIH	:	National Institute of Hydrology (India).
17.	NMCG	:	National Mission for Clean Ganga.
18.	NRGB	:	National River Ganga Basin.
19.	NRGBMC	:	National River Ganga Basin Management Commission.
20.	PPP	:	Public-Private Partnership.
21.	SPV	:	Special Purpose Vehicle.
22.	SRI	:	System of Rice Intensification.
23.	UNEP	:	United Nations Environment Programme.
24.	URMP	:	Urban River Management Plan.

Executive Summary

1. Introduction

1.1 River Ganga in Indian Consciousness: River Ganga, along with her many tributaries, has been the source of physical and spiritual sustenance of Indian civilization for millennia. And all through the ages, Indians held the munificent River Ganga as a Divine Body. To the Indian mind, River Ganga is not only the holiest of rivers and purifier of mortal beings, but also a living Goddess – MOTHER GANGA!

1.2 Deterioration of River Ganga: Despite being nationally revered, River Ganga has been deteriorating noticeably over a long time, at least since large scale water abstractions through canal systems began in the mid-nineteenth century. But her degradation gradually became multi-faceted and accelerated in recent decades, while attempts to keep the river clean through conventional pollution control methods have proved ineffective.

1.3 GRBMP's Goal: River Ganga was declared as India's National River by the Government in 2008, thereby implying her well-being to be of prime national concern. Hence the main goal of GRBMP is to restore the wholesomeness of National River Ganga and her basin.

1.4 Functional Unity of the Ganga Basin: A river basin is the area of land from which the river provides the only exit route for surface flows. Functionally, a basin is a closely-connected hydrological-ecological system. Hydrological connections include surface runoff, flooding, local/ regional evapotranspiration-precipitation cycles, and groundwater flow. Ecological links are many – from complex food webs to different types of biological agents. These linkages provide for extensive material transport and communication between the river and her basin. On account of the manifold hydrological-ecological connections, National River Ganga – besides being a prime source of material and spiritual resources on her own – is the key indicator of the health of her basin. Hence, GRBMP adopts the Ganga River Network as the primary environmental indicator of NRGB (National River Ganga Basin).

1.5 Importance of the Himalaya Mountains: The Himalayan glacier-fed head-streams of National River Ganga, as also her many Himalayan tributaries, bring in considerable water, sediment and nutrients into the river almost round-the-year, thus ensuring perennial life-giving flow in the river and fertility to her floodplains. The Himalayan connection thus plays a significant role in the basin dynamics.

1.6 Natural Resource Management in NRGB: The natural resources of NRGB are its abiotic or physical resources (mainly soil/silt, water, and the nutrients bound up with them) and its biotic resources (plants, animals and microbes). These resources are interdependent through various ecological processes linking them with one another. Proper understanding of the basin's resource dynamics is, therefore, pivotal in managing NRGB efficiently. Unlike conventional basin management in India that consider mainly water resource management, GRBMP attempts to focus on comprehensive natural resource management in NRGB.

1.7 Philosophy: The philosophical basis of GRBMP is that NRGB is a common heritage which must be preserved in order to ensure its life-enhancing value. Hence, if the basin is degrading due to unrestrained anthropogenic activities, then we must curtail or regulate such activities as well as introduce specific measures for environmental restoration and strengthening of the basin.

1.8 Degradation Processes in NRGB and their Anthropogenic Causes: With proliferation and diversification of human activities having harmful environmental effects, National River Ganga and her basin have been degrading rapidly. The degradations are due to five main causes, viz.**:** (i) *over-use of natural resources of the basin*; (ii) *discharge of pollutants into terrestrial and aquatic environments*; (iii) *reduction in water-holding capacities and replenishment of water bodies*; (iv) *mutilation of rivers by piecemeal engineering operations*; and (v) *threats to geological processes in the basin*. The major human activities causing the above damages may also be clubbed under five main heads, viz.**:** (i) *Industrialization*, (ii) *Urbanization*, (iii) *Lifestyle Changes*, (iv) *Agriculture & Other Rural Activities*, and (v) *Deforestation/ Denudation*. This broad grouping indicates the key factors underlying basin

degradation; however, devising appropriate remedial interventions requires in-depth analysis of the problems.

1.9 Impact on Humans: The direct impact of NRGB's degradation on humans are the losses of "ecosystem services" namely, *provisioning services* (e.g. food, freshwater, fibres, energy), *regulating services* (e.g. flood attenuation, groundwater recharge, prevention of salt water intrusion), *supporting services* (e.g. nutrient recycling, soil formation, biodiversity maintenance), and *cultural services* (e.g. recreation, spiritual fulfilment). Even without quantitative valuation, it is certain that these losses are significant in NRGB.

1.10 Scope for Interventions: Among the five main types of environmentally significant human activities stated above, the first three concern profit-making activities or activities of relatively affluent sections of society. Hence, it must be feasible to review these activities and modify them at some cost in order to minimize their adverse environmental impacts. Other activities – such as rural and agricultural activities – often concern basic needs and livelihoods of relatively poor or marginal sections of society, who may not be able to bear the cost of such interventions. But, in such cases too, suitable means must be devised to abate the negative impacts and ensure a wholesome environment in NRGB.

2. Key Features of National River Ganga Basin

2.1 River Network: National River Ganga originates in the Himalayas with several major head-streams – Alaknanda, Bhagirathi, Bhilangana, Dhauliganga, Mandakini, Nandakini and Pindar, which progressively join together on or before Devaprayag. Descending in the plains, the river flows approximately southeast and is joined by several large streams such as Ramganga, Yamuna, Kosi, Gandak, Gomti, Sone, Karamnasa and Ghaghra to become an immense river in the plains below Allahabad. The river then flows through the Rajmahal hills and divides into two streams. The eastern branch – River Padma – flows southeast through Bangladesh to join the Brahmaputra and Meghna rivers before flowing into the sea. The south-flowing branch – River Hooghly – is joined by Rivers Damodar and Mayurakshi before reaching the sea. The combined outfalls of the two branches together form the world's largest delta

(the "Sundarban Delta" covering about 60,000 sq.km.) stretching across Bangladesh and West Bengal. Overall, River Ganga is more than 2500 km long.

2.2 Hydrology: The Ganga Basin, spread over four nations (India, Nepal, China and Bangladesh) covers an area of about 1,080,000 km^2, of which about 80% lies within India. NRGB is the largest river basin of India, covering more than 26% of her geographical area. And out of the total water availability of 1,869 km^3/yr in India, NRGB's share is 525 km^3/yr. Thus, it is a large water-rich basin that supports about 43% of India's population.

2.3 Defining River Ganga: River Ganga is defined herein as comprising of six main headstreams originating in the Himalayas, namely the Alaknanda, Dhauli Ganga, Nandakini, Pinder, Mandakini and Bhagirathi rivers starting from their feeding glaciers up to their respective confluences (together comprising the Upper Ganga segment), the subsequent main stem of the river downstream from Rishikesh to Varanasi (the Middle Ganga segment), and the final stretch from Varanasi to Ganga Sagar (the Lower Ganga segment).

2.4 Geology: NRGB is part of the tectonically active foreland basin of the Himalayan mountain range formed by collision of the Indian tectonic plate with the Eurasian plate more than fifty million years ago. Thus, much of NRGB consists of alluvial plains formed during the Tertiary and Quaternary periods by flood deposits of Himalayan rivers. The Ganga river network not only conveys water, but also transfers enormous amounts of eroded Himalayan sediments to the sea. The alluvial deposits of the basin constitute large and highly productive multi-aquifer systems in NRGB, which are a major storehouse of ground water. The soils of the basin are also largely alluvial, with mountain soils, terai soils and black soils towards the mountain ranges in the north and west of the basin.

2.5 Wetlands: There are many lakes, tanks and marshes in NRGB. Besides big lakes, NRGB has a large number and variety of wetlands spread across the basin – in the mountainous Himalayan region, the Himalayan terai region, the Gangetic plains, and the coastal deltaic region – which together support numerous and diverse ecosystems in different geo-climatic settings. Several of NRGB's wetlands are home to specialized flora and fauna as well as migratory species, which fulfil crucial ecological and social functions.

2.6 Fluvial Geomorphology: National River Ganga's headstreams are fast-flowing mountainous rivers cutting through deep gorges and narrow valleys, whereas the Middle Ganga stretch meanders through relatively flat plains, and the Lower Ganga segment tends to be braided in the delta region. The fluvial pattern was affected by the geological evolution of NRGB. Near the Himalayan front, valley formation and incision were affected by both tectonic and climatic factors; strongly incised valley formation in the western and southern plains were controlled mainly by climatic factors; and fluvial morphologies in the lower Ganga plains and delta were much influenced by sea level fluctuations besides climate and tectonics. Detailed maps show significant diversity of valley widths and geomorphic features in different reaches of the river, which have strong implications for the hydrological regime and ecological health of NRGB.

2.7 River Biodiversity: The biodiversity of National River Ganga uniquely synthesizes three different eco-regions of India situated along climatic gradients, namely the Himalayas, the Gangetic plains and the Delta region. The river's biodiversity comprises periphytons, phytoplanktons and macrophytes which are producers, and zooplanktons, zoobenthos, fish and higher aquatic vertebrates which are are consumers of the food produced. Together, these micro- and macro-organisms, through their interplay with the abiotic environment, represent the ecological status of National River Ganga.

3. Vision, Mission, and Conceptual Framework

3.1 Vision of Ganga River: In order to preserve and invigorate National River Ganga, her essential character needs to be grasped in a holistic manner. After extensive research and consultations, the "wholesomeness of National River Ganga", viewed from a dynamic perspective, was determined to be the sanctity of the river system imbibed in the four points stated below**:**

i. **"*Aviral Dhara*" (i.e. "Continuous Flow"):** The flow of water, sediments and other natural constituents of River Ganga are continuous and adequate over the entire length of the river throughout the year.

ii. **"*Nirmal Dhara*" (i.e. "Unpolluted Flow"):** The flow in the Ganga River Network is bereft of manmade pollution; hence the river water quality should not be sullied by human activities.

iii. **Geologic Entity:** The Ganga River System is the earth's creations of ancient times, which may not be reparable if damaged.

iv. **Ecological Entity:** The Ganga River System is a delicately structured balance between various living species and the physical environment, achieved by nature over thousands of years and vulnerable to irreversible changes.

3.2 Objectives of GRBMP: Based on the above vision and the awareness of social needs, the main objectives of GRBMP are identified as the following:

a) Environmental Flows shall be maintained in all rivers and tributaries of the Ganga River System to fulfil their geological, ecological, socio-economic and cultural functions.

b) Water quality in all rivers and tributaries of the Ganga River System shall be consistent with their governing geological, ecological, socio-economic and cultural functions.

c) Water and other aquatic resources of the Ganga River System shall be used judiciously to enable sustainable development in the entire NRGB.

d) All existing, ongoing and planned anthropogenic activities in NRGB shall be reviewed or scrutinized in a transparent, inclusive manner (with consensus of all affected people and stakeholders) for the overall health of NRGB.

3.3 Formulation of Missions: Given the escalating impacts of human activities on NRGB, the above objectives guided the formulation of eight important areas where restorative actions need to be carried out in Mission mode, viz.**:** "*Aviral Dhara*", "*Nirmal Dhara*", "*Ecological Restoration*", "*Sustainable Agriculture*", "*Geological Safeguarding*", "*Basin Protection Against Disasters*", "*River Hazard Management*" and "*Environmental Knowledge-Building and Sensitization*".

3.4 Conceptual Framework: Based on the above Vision and the awareness of social needs, the main objective of GRBMP was identified as the formulation of policy frameworks (or "Action Plans") for ongoing anthropogenic activities in NRGB. The basic approach in this framework action plan is "*Apply modern science and technology in conjunction with traditional wisdom*".

3.5 Work Structure: The task of analysing and preparing the GRBMP was broken up from the whole to its parts into several thematic groups as follows**:** Environmental Quality and Pollution (EQP), Water Resources Management (WRM), Fluvial Geomorphology (FGM), Ecology and Biodiversity (ENB), Socio-economic and Socio-Cultural (SEC), Policy, Law and Governance (PLG), Geo-Spatial Database Management (GDM), and Communication (COM), plus a cross-thematic group on Environmental Flows (or E-flows).

4. Mission Summaries

4.1 Mission 1 – Aviral Dhara: NRGB's present water status is poorly understood, but a broad review indicates declining water status in the river network due to large-scale water withdrawals from the basin's rivers and aquifers over many decades. Besides, the river network is extensively intercepted by dams and barrages into disjointed channel stretches with highly altered water, sediment and nutrient flows, thereby affecting river morphology and ecology considerably. The depleted water status of NRGB is borne out by hydrological modelling. The computed sediment loads are also found to be much less than previous estimates. The main recommendations are**:** (1) Determination of NRGB's hydrological status more accurately and in greater detail. (2) Preparing a water resources plan for NRGB with emphasis on wetlands, forests and distributed groundwater and surface water storages rather than large impounded reservoirs. (3) Increase in water use efficiency through realistic pricing of fresh water, incentives, technical assistance, allocation of water rights and entitlements, and reuse and recycling of water. (4) Governmental policy shift to bring NRGB's water resources under natural resource management, with emphasis on resource preservation, stakeholder control, expert guidance and regulation. (5) Ensuring longitudinal river connectivity and environmental flows (of water, sediments and other natural constituents) at dams, barrages and other manmade interferences, and

adoption of new criteria for approving such projects. (6) Control of water withdrawals in water-depleting regions. (7) Assessment and monitoring of sediment resources of the network including assessment of quantity, quality and nutrient value of sediments trapped behind dams. (8) Research to determine the ecological limits, thresholds and interconnections of water resources in NRGB, and river flow health assessments within the framework of ecohydrology.

4.2 Mission 2 – Nirmal Dhara: In modern times, the Ganga River System's water quality has been significantly polluted by disposal of anthropogenic wastes into the rivers. The wastes include both solid and liquid wastes of hazardous and non-hazardous types generated mostly from domestic, industrial and agricultural sources. Liquid wastes from large urban centres and industries are major point sources of pollution, while surface runoff containing agrochemicals and entrained solid wastes are some major non-point pollution sources.

To check river pollution, it is necessary to**:** (A) Completely prohibit major pollutant discharges into rivers by discharge of sewage (either treated or untreated) from Class I towns; discharge of industrial effluents (either treated or untreated) from any large, medium or cluster of small industries; direct injection of sewage and industrial effluents (either treated or untreated) into the subsurface; disposal of un-burnt and partially burnt corpses and animal carcasses in rivers; open defecation and dumping of municipal/industrial solid wastes or sludge in any river or its active flood plain; and construction of new residential, commercial or industrial structures in river flood plains. (B) Restrict other pollutant discharges by discharge of sewage (either treated or untreated) from Class II and smaller towns and villages; disposal of sewage or industrial treatment sludges except in secure landfills/hazardous waste sites; discharge of industrial effluents (either treated or untreated) from small scale industry; disposal and/or discharge of mining and construction debris in any river or its floodplains; river bed farming and agricultural activities in the active flood plain; ritual immersion of idols, floral and other offerings , and washing of clothes, vehicles, etc., in rivers; and usage of agrochemicals in NRGB.

In keeping with the above requirements, the main recommendations are grouped under the following heads: (1) Management of Solid and Liquid Wastes Generated from Domestic/Commercial Sources; (2) Riverfront Development, Floodplain Management and Rejuvenation of Water Bodies; (3) Management of Solid and Liquid Waste Generated from Industrial Sources; and (4) Management of Polluted Agricultural Runoff. Effective co-ordination of these activities is envisaged through a high-level constitutional body tentatively named the 'National River Ganga Basin Management Commission' (NRGBMC), pending whose formation the NMCG or some other dedicated government body may coordinate the activities.

Project planning for urban works should begin with preparation of detailed Urban River Management Plans (URMP) for Class I towns, and subsequently also for Class II and Class III towns. The URMPs should be followed by preparation of DPRs, following which funds should be allocated for project implementation. Fund allocation should be prioritized for projects designed to prevent direct discharge of large quantities of liquid waste into the River System (Priority Level I), followed by projects designed to prevent direct discharge of large quantities of solid waste into the River System (Priority Level II), followed by projects concerning river-frame development and restoration of floodplain in urban areas along the Ganga River System (Priority Level III). Other projects under Mission Nirmal Dhara may be executed at still lower priority depending on availability of funds.

Financing of the above projects may be obtained from central/state governments, local revenue, corporate and private donations and grants, low cost debt from multinational organizations, commercial debts from banks and private equity. Category A and Category B projects are recommended for execution through the PPP route (such as the DBFO model) with initial investment from the service provider, while Category C projects may be executed by the concerned industries themselves and through SPVs for industrial clusters. Category D projects may be synergistically executed with other government projects as per actions desired under other Missions of GRBMP.

4.3 Mission 3 – Ecological Restoration: Ecological restoration of National River Ganga is urgently needed since river biodiversity is being rapidly lost. Eight main factors affecting the river habitat are identified for causing this loss**:** (i) Habitat Fragmentation by dams and barrages; (ii) Habitat Shrinkage due to increased water diversions and withdrawals; (iii) Habitat Alterations by sand mining and constructing embankments, levees, guide walls, etc.; (iv) Habitat Pollution by influx of municipal, industrial and agricultural wastes; (v) Habitat Invasion by alien river species; (vi) Habitat Encroachment by constructions in floodplains and river bed farming; (vii) Habitat Disturbances by plying of noisy vessels, dredging, etc.; and (viii) Habitat Malnutrition by the trapping of nutrient-rich sediments behind dams. Hence, the measures recommended are**:** (1) Restoration of longitudinal connectivity along with E-flows across dams/ barrages; (2) Maintenance of lateral connectivity across floodplains; (3) Restoration of unpolluted river flows; (4) Restrictions on river bed farming, gravel and sand mining, plying of vessels, dredging, and bed and bank modifications; (5) Control of alien species invasions, overfishing and fishing during spawning seasons; (6) River nutrient assessment and release of dammed sediments into the river; bio-monitoring of Ganga river network; and (7) Synergising the above actions with the Dolphin Conservation Action Plan – 2010; and comprehensive research on the ecological dynamics of the Ganga River System.

4.4 Mission 4 – Sustainable Agriculture: Modern agricultural practices have been major causes of soil degradation and fertility loss, pollution of water bodies, and natural resource depletion in NRGB. Hence transition to sustainable agriculture is urgently needed to maintain NRGB's ecosystem services. Though arable land is the major constraint for agricultural growth in NRGB, the growth almost quadrupled in forty years since the 1960s by adopting high-yield crops with high fertilizer and water inputs. But extensive use of water, chemical fertilizers and pesticides, soil tillage, and mono-cropping have increased soil erosion and degradation, depleted soil nutrients and biodiversity, dwindled the basin's waters, and polluted its ecosystems. The main agricultural reforms recommended in NRGB are therefore identified as**:** (1) Adoption of Conservation Agriculture (involving no tillage, crop diversification, and permanent organic soil cover) to enhance long-term soil fertility and agricultural output, especially in degrading lands. (2) Promotion of

Organic Farming where economically feasible. (3) Improved water and nutrient management techniques, especially System of Rice Intensification and Urea Deep Placement, in rice cultivation. (4) Promoting other known resource conservation technologies. (5) Promoting regional (landscape-scale) resource conservation steps to mollify agroecosystem impacts. (6) Infusing experimentation, adaptability and flexibility in NRGB's agricultural practices. (7) Devising appropriate policy measures to achieve the above goals within the existing socio-cultural, economic and institutional framework.

4.5 Mission 5 – Geological Safeguarding: Geologically, river networks tend to achieve equilibrium between tectonic uplift and erosional phenomena in river basins, but both factors have come under significant anthropogenic influence in modern times. Hence geological safeguarding with geomorphological upkeep of the basin is of key importance. The identified geological vulnerabilities of NRGB include disruptive underground activities such as excavations, explosions, tunneling, mining, fracking, and over-withdrawal of ground-water from confined and semi-confined aquifers, as well as over-ground activities such as the operation of large reservoirs. Anthropogenic geomorphological damages are identified to be primarily due to harmful land-uses that enhance erosional stresses. The recommended actions include control/ restriction of geologically hazardous activities and geo-morphologically damaging land-use practices, drainage improvement and stabilization of disturbed areas, mapping river migration zones, and continuous geological monitoring of the NRGB and her dynamic rivers.

4.6 Mission 6 – Basin Protection Against Disasters: NRGB is prone to catastrophic natural disasters that can significantly harm the basin ecosystems, and such disasters have been highly accentuated by modern anthropogenic activities. Hence special measures are needed to protect the basin. The major disasters of concern are *Extreme Floods*, *Extreme Droughts*, *Forest Fires*, *Tropical Cyclones*, *Landslides*, and *Epidemics and Biological Invasions*. The main recommendations are**:** (1) Routine hydro-meteorological and biological events often perceived as disasters are usually beneficial for the basin and hence should not be countered. (2) Ecosystems generally need strengthening against catastrophic disasters by preservation of wetlands, promotion of mixed indigenous forests and vegetation resistant to the specific disaster-type, and

minimal land-use disturbances and encroachments by humans. (3) Extreme Floods are characteristic of the highly sediment-charged Himalayan rivers of NRGB, to combat which floodplain regulations and vegetative measures are preferable to embankments/ levees, but upstream dams (designed with river connectivity and environmental flows) can also prove beneficial if sediments trapped behind dams can be transferred to downstream floodplains. (4) The ecology of Forest Fires and of Epidemics and Biological Invasions in NRGB's ecosystems needs to be studied extensively; until then, active interventions should be limited to checking harmful anthropogenic activities. (5) Landslides in the Upper Ganga Basin are aggravated by deforestation, road and building constructions, and unsafe debris disposal, which need to be strongly checked. (6) Early rejuvenation of a disaster-struck ecosystem should be aided by re-introducing indigenous species in affected zones and re-creating an enabling physical environment.

4.7 Mission 7 – River Hazards Management: Rivers draining the Ganga basin are prone to two major river hazards – river dynamics and floods – and these are intricately interrelated. However, anthropogenic disturbance along the rivers such as landuse/ landcover changes, interventions such as barrages and dams, developmental projects such as rail/road networks, and even flood-control embankments have increased river hazards manifold. The objective of Mission "River Hazards" is to identify river hazards related to anthropogenic disturbances and to formulate suitable means to reduce the risk. River dynamics is a natural phenomenon primarily driven by channel instability caused by extrinsic factors such as tectonics or intrinsic factors such as excessive sedimentation and local slope variability. However, the frequency of migration events has been severely affected by anthropogenic disturbance along the rivers resulting in sudden and disastrous migrations affecting large populations. For instance, the large–scale avulsion of the Kosi in August 2008 during which the river shifted by ~120 km in its middle reaches occurred due to a breach in the embankment 12 km upstream of the barrage. Similarly, several smaller rivers in north Bihar have documented avulsion histories that has increased manifold since the construction of embankments. Flooding is the other disastrous river hazard in alluvial plains of the Ganga system, particularly in the eastern parts. Flood control strategies in most river basins in India are primarily embankment-based which have not only influenced the natural flow

regimes of rivers and modified the flood intensity, frequency and pattern, but have also created a false sense of security amongst people living in the region. The construction of barrages and other interventions has aggravated the problem further. Many Himalayan Rivers are highly sediment-charged and a major problem has been the rising river bed and reduction in carrying capacity due to extensive sediment deposition in reaches upstream of the barrage. Besides, unplanned roads and bunds have resulted in severe drainage congestion and channel disconnectivity thereby increasing the inundation period significantly. Hence it is time to move from 'river control' to 'river management' that necessitates the appreciation of the role of geomorphology. Further, the impact of engineering structures on river systems must be assessed primarily focusing on natural equilibrium and assessment of degradation due to anthropogenic factors such as geomorphic assessment of rivers and impact on ecosystems. Some specific recommendations are**:** (1) Preparation of basin scale flood-risk maps based on scientific data and reasoning such GIS based, interactive maps based on historical data analysis as well as modeling approaches linked to an online data base and flood warning system. (2) Urgent drainage improvement and land reclamation in low-lying areas. (3) Assessment of soil salinity and mitigation strategy, including the use of salinity resistant crops as well as soil improvement practices. (4) Alternatives to embankments for flood management with an emphasis on 'living with the floods' concept such as floodplain zoning and other non-structural approaches. (5) Research on sediment dynamics and its application in river management projects for designing sustainable river hazard management strategies.

4.8 Mission 8 – Environmental Knowledge-Building and Sensitization: Since basin planning and management combine diverse natural resources (water resources, soil resources, biological resources, etc.) and processes (river dynamics, geological phenomena, atmospheric processes, etc.) with traditional wisdom and grassroots knowledge, it is necessary to build a comprehensive data bank to enable meaningful analyses and obtain quantitative indicators of NRGB's status. Moreover, since NRGB's welfare needs the co-operation and help of both formal and informal sectors of society, the data bank – along with community-specific educational material and programmes on NRGB's environment – should be accessible to citizens to enable their participation in NRGB's upkeep. The main recommendations are**:** (1) Establishment of a

comprehensive Data Bank by continuous collection, processing and storage of information on natural resources, anthropogenic activities, and environmental monitoring of the basin; (2) Preparation of secondary results (charts, tables, etc.) based on primary data; (3) Preparation of documents and materials for easy understanding by non-specialized people; (4) Keeping all the above information in open domain for easy access by interested individuals and institutions; and (5) Conducting workshops and educational campaigns with stakeholders and interested citizens to enable their comprehensive understanding and sensitization of basin processes.

5. Recommendations for Implementation

5.1 Specific Actions: On assessing the significant impacts on NRGB under different Missions, specific anthropogenic activities that should be immediately *Prohibited*, *Restricted* or *Promoted* have been identified and listed. Their implementation and future development would require the coordinated efforts and co-operation of government and nongovernment institutions, key stakeholders and civil society. It is envisaged that only a dedicated, knowledge-based, empowered and stakeholder-involving agency would be able to pool in the collective knowledge and resources for the rejuvenation of NRGB.

5.2 Envisaged Consequences: The most direct and immediate result of implementing the desired measures would be on the health of the Ganga River System (in terms of Quantity, Quality & Biodiversity of the river's waters). On issues of socio-economic importance, the changes are likely to reflect immediately on Water & Sanitation, Disease & Health, Flood Impacts, Agriculture & Food Security, Energy Generation, and Ecosystem Services (such as aquatic foods and fish catches, cultural, religious & recreational activities). While implementation of the proposed measures will incur costs, it is envisaged that they will have significant net positive gains for the region in the foreseeable future.

5.3 Implementation Mechanism: The implementation, monitoring, review and evaluation of environmental problems and interventions on a long-term basis are recommended through an independent Commission. Moreover, since rivers are *prima facie* inter-state subjects as per the Constitution, the said

Commission would need adequate resources and authority (under relevant provisions of the Constitution) to coordinate and oversee the activities of multiple sectoral organizations and informal sectors of society insofar as they affect National River Ganga. GRBMP, therefore, includes the functional requirements of a Commission that needs to be established by an Act of Parliament, to enable an enduring mechanism for sustainable growth in the National River Ganga Basin.

6. GRBMP Documentation

The GRBMP is presented as a 3-tier set of documents. The three tiers comprise of: (i) Thematic Reports providing inputs for the overall Plan and its different Missions, (ii) Mission Reports documenting the requirements and actions for specific missions, and (iii) the main GRBMP Report synthesizing background information with the main conclusions and recommendations emanating from the Thematic and Mission Reports. It is hoped that this modular structure will make the Plan easier to comprehend and implement in a systematic manner.

1. Introduction

1.1. River Ganga in Basin Perspective

Indian civilization grew up under the care of River Ganga for thousands of years, nourished for generations by her generous bounties. The Ganga river – along with her many tributaries – provided material, spiritual and cultural sustenance to millions of people who lived in and around her basin. And all through the ages, Indians held the munificent River Ganga as a Divine Body who descends from the heights of the Himalayas and winds her way down to the sea, distributing her blessings to all and sundry. To the Indian mind, River Ganga is not only the holiest of rivers and purifier of mortal beings, but also a living goddess! Very aptly is she personified in Indian consciousness as "MOTHER GANGA". And her elevated status in Indian consciousness is encapsulated in the following words in Bhagavad Gita**:**

पवनः पवतामस्मि रामः शस्त्रभृतामहम् ।
झषाणां मकरश्चास्मि स्रोतसामस्मि जाह्नवी ॥

(*I am the wind among things of purification, and among warriors I am Rama, the hero supreme. Of the fishes in the sea I am Makara, the wonderful, and among all rivers the holy Ganges. – Bhagavad Gita; Verse 31, Chapter 10*)

Since ages, the religious and cultural pre-eminence of River Ganga in the Indian ethos testifies to her centrality in Indian civilization. This significance is so lasting that, even today, River Ganga remains the physical and spiritual lifeline of India. It is fitting, therefore, that Ganga was declared as India's **National River** by the Indian government in 2008. But this declaration was only the beginning of a promise. For national concern about environmental degradation of River Ganga had also become serious by then, leading to a strong urge to save her from wanton destruction. It was against this backdrop that a "Consortium of Seven IITs" was assigned the task of preparing a Management Plan to restore and preserve National River Ganga and her basin. This Plan – the Ganga River Basin Management Plan (GRBMP in short) – is presented here.

The physical environment of the National River Ganga Basin (hereinafter referred to as "NRGB") is governed by a complex combination of natural and manmade processes which have been changing and evolving over time. With

human activities multiplying and diversifying in the industrial age, the resulting environmental consequences have also been pronounced in recent times. Specifically, aquatic bodies – which govern human life and ecology of the area to a large extent – are perceived by many to have already degraded to a near-critical state. Thus, GRBMP focuses on the aquatic environment of the basin and the major factors affecting it – especially diverse anthropogenic activities, and seeks ways and means to strengthen the basin environment against identifiable adverse impacts. The attempt is to assess the critical issues at stake and formulate a comprehensive plan to safeguard the basin environment in the foreseeable future. For, only thus can we secure the environmental foundation of NRGB for the good of one and all.

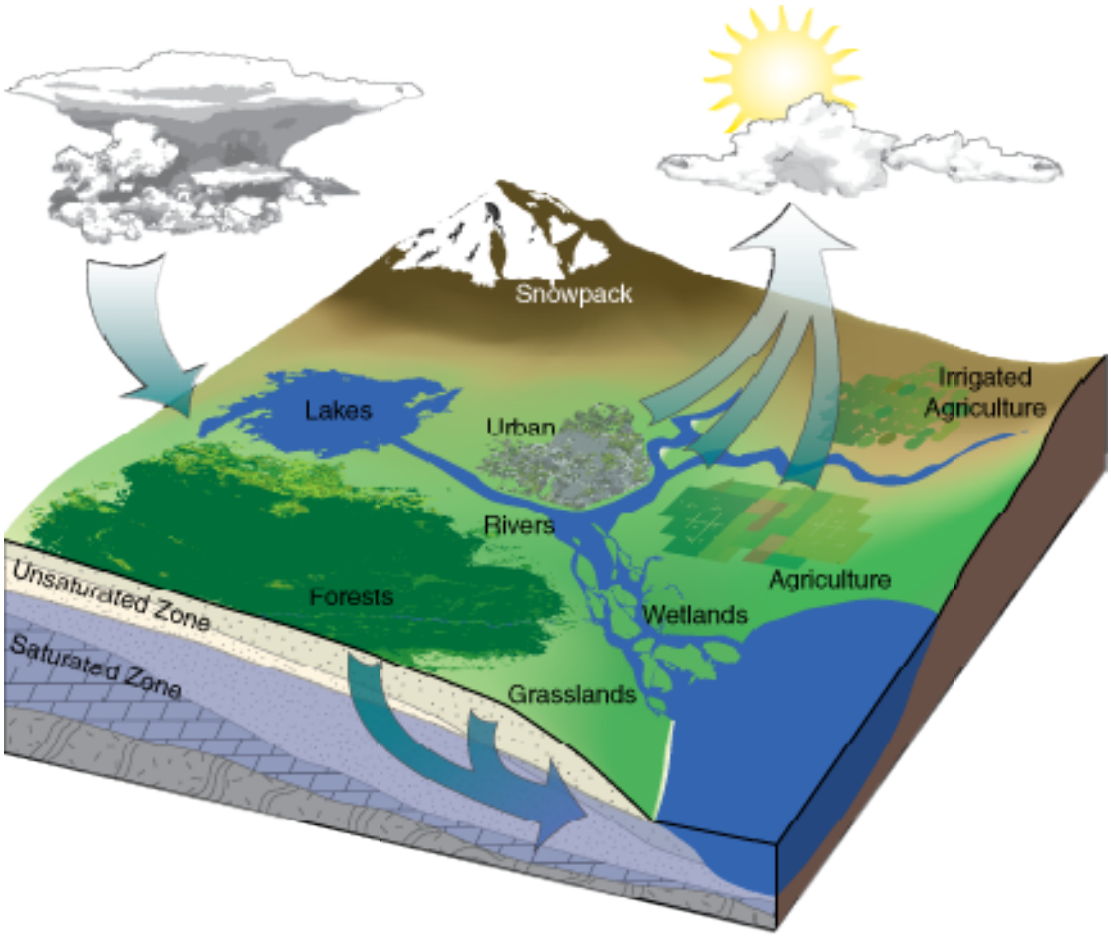


Figure 1.1: Illustrative Sketch of Inland Terrestrial Environments [*MSU, 2013*]

[Note**:** All lakes may not be of "drainage-type"– i.e. drained by rivers – as shown above; on the other hand, big lakes usually have streams conveying surface runoff into them.]

Human civilization has always considered its aquatic resources as assets rather than as liabilities – hence the term "*water resource*", though aquatic resources are much more than water. Now, natural waters – intimately bound up with other environmental goods – are an essential need for human settlements and the ecology of a river basin. The general hydrological features of a river basin can be seen in Figure 1.1. In NRGB, the water resources may be grouped under three main heads, viz. surface water courses (rivers, streams, and rivulets, gullies or "nala"s), surface water bodies (lakes, ponds, marshlands, icecaps, snow-packs), and groundwater (water table and deep ground- water). Among these three groups, groundwater has been in rapidly increasing use for the last five or six decades (since the advent of economic tube-well technologies), while surface sources have been widely used by people since millennia – with rivers and streams fulfilling major water needs in much of NRGB. This is partly due to poor rainfall over long dry periods of 8 to 9 months a year, with limited surface storages in the basin; but it is also because River Ganga flows perennially, its head-streams and Himalayan tributaries being fed by snowmelt and ice-melt almost round the year (*see Box 1.1*). It should be also noted here that, apart from water, the Himalayan tributaries probably also bring valuable minerals from glacial and mountain rocks in their upper reaches, thereby providing long-term fertility to the basin [*Diamond, 2005*]. Historically, therefore, the Ganga river system has been the mainstay of civilization and ecology in the Ganga basin.

Box 1.1

The Himalayan (Mountain) Range has a total area of 33,050 km^2 of glaciers … with a total ice volume of ca 3,421 km^3, (approx.) which provides important short and long-term water storage facilities. … Water from both permanent snow and ice and seasonal snow is released by melting … In the 'shoulder seasons', before and after precipitation from the summer monsoon, snow and ice melt contribute about 70% of the flow of the main Ganges river. – [*Eriksson et al., 2009*]

Snow and glacier melt contribute 29% to the annual flow at Devprayag. … Besides Gangotri (glacier), other glaciers in the headwaters region of Alaknanda, Yamuna, Ghaghara, Kosi, etc. also contribute to the flow in the Ganga. – [*Jain, 2008*]

In surveying the above hydrological setup of NRGB, it is easily seen that, while the basin waters come under three major types of water resource, the various water bodies are not independent but are hydraulically connected in most of the alluvial basin by groundwater flow as shown in Figure 1.2. Thus, while both surface and ground water reservoirs may be replenished by monsoon rains, the productivity of surface water sources during long dry non-monsoon periods depends much on the contemporary state of water table aquifers – water-filled aquifers boost their productivity, while depleted aquifers suck out the surface waters. But, groundwater apart, there are other hydrological connections also within the basin – such as surface runoff, river flooding, and regional evapotranspiration-precipitation cycles. Simultaneously with these hydrological linkages, there are dynamic ecological connections also within a basin – from complex food webs to different types of active biological agents. Thus, functionally, a basin is a closely-connected hydrological-ecological system, in which the hydrological-ecological linkages provide for extensive material transport and communication between the river and her basin. Directly and indirectly, therefore, National River Ganga (along with her tributaries and distributaries), is not only a major source of the region's resource needs but also a definitive indication of the health of the basin as a whole. Hence, GRBMP adopts the Ganga River Network as the primary environmental indicator of NRGB.

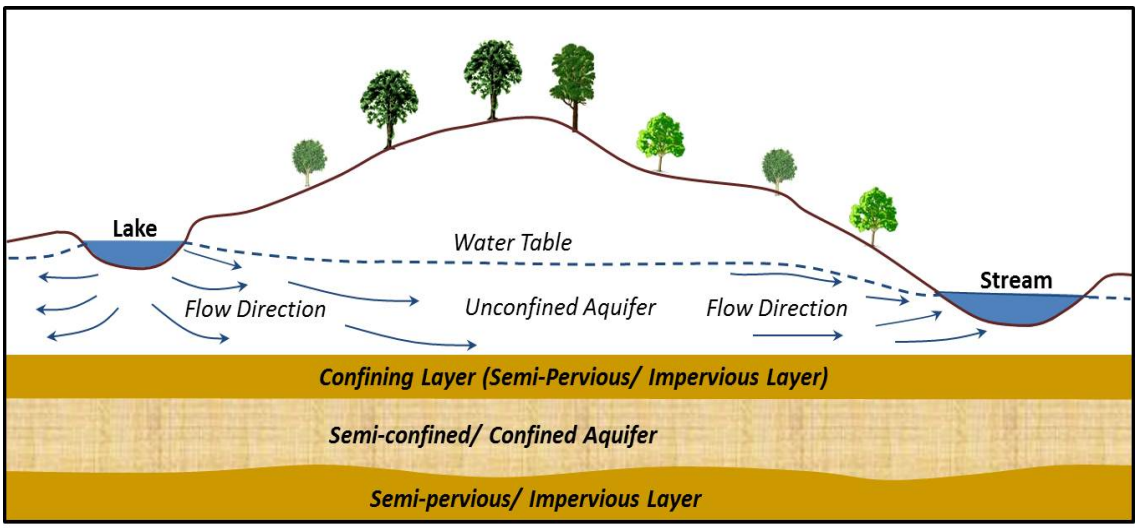


Figure 1.2: Schematic of Hydraulic Connectivity through Groundwater in NRGB

1.2. Resource Management in Ganga Basin

The natural resources of a river basin are essentially covered by the term “land resources”, viz.**:** *"Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)*" [*FAO, 1995*]. The physical attributes of land, in fact, comprise the fundamental basis of all terrestrial life, apart from external inputs like air and energy (mainly sunlight). They are also the most important ingredients needed by human communities to sustain and develop their lives.

The essential physical resources of river basins are soil and water, along with a multitude of minerals and compounds often bound up with them. Specific substances foreign to a basin may sometimes be imported into the basin by biotic processes (through biological agents) or abiotic processes (through physical agents such as wind) or even by cosmic events (such as asteroid strikes and meteoric showers), which add to the physical resource base of a basin. The biotic resources of a basin consist of plants, animals, micro-organisms and their outputs. Now, for a given environmental setting, since biota evolve over time to achieve a stable balance, it is prudent to assess the natural resources of a river basin in terms of its constituent ecosystems – rivers, wetlands, forests, grasslands, agro-ecosystems, etc. However, with significant human activity in ecosystems (as in agro-ecosystems and urban ecosystems), the complexity of human-technology-environment systems renders integrated environmental resources management a rather intricate problem [*Pahl-Wostl, 2007*].

While integrated management of natural resources in NRGB may be daunting, an attempt needs to be made to include major physical and biotic resources (such as soil/ silt, water, nutrients, microbes, plants and animals) in the basin’s resource inventory instead of considering only select resources as in

conventional basin management [*Pegram, et al., 2013*]. A compelling case for this is evident from the opening lines of the 2012 National Water Policy of the Indian government: "*A scarce natural resource, water is fundamental to life, livelihood, food security and sustainable development. India has more than 18% of the world's population, but has only 4% of world's renewable water resources and 2.4% of world's land area*" [*MoWR, 2012*]. The figures – often quoted in government documents to underscore the population pressure on India's water resources – have promoted increasing national emphasis on conserving water. However, what the figures also tell loud and clear is that the population pressure on land in India may be much more than that on water**:** in terms of world averages, the population pressure on land is nearly 67% higher than that on water! If soil be considered as proportional to land area, then evidently soil is a much more scarce resource than water in India. The corresponding figures for NRGB (discussed in the next chapter) are even more adversely skewed against soil, suggesting that soil is a more critical natural resource than water in NRGB.

Among the basin's main physical resources – soil and water – soil is actually a cluster of resources consisting of various minerals and organic compounds, besides also containing water and air. Formation of mature soils – from the weathering of parent material (rocks) to chemical decomposition and transformation – is a drawn-out process that may take hundreds or thousands of years [*Jenny, 1994; Wikipedia, 2014*]. But, once formed, soils can be much more durable. In contrast to soil, water is a highly variable resource. Inter-year fluctuations apart, it broadly follows an annual cycle of replenishment (through atmospheric precipitation) and losses (through river and groundwater flows, evaporation, and biological consumption). Thus, while changes in a basin's water resource status can be rapid and hence easily detectable, those of soils are slow and often go unnoticed, leading to long-term challenges of remedying degraded soils. It should be noted here that soil and water are also affected by each other through both biotic processes (like biotic soil mineralisation and transpiration by plants) and abiotic processes (like runoff and infiltration processes being affected by soil types and soil erosion, disintegration, hydration and hydrolysis being affected by water). And human-induced changes – even in uninhabited ecosystems like rivers, dense forests and high-altitude mountains – could impact a basin's physical resources in unforeseen

ways, injecting immense complexities in a basin's resource dynamics. While quantitative analyses of natural resource dynamics in GRBMP were not possible, an attempt has been made to induct interactive resource considerations in framing the Plan.

1.3. Philosophy of GRBMP

This Plan rests on the premise that the NRGB environment is a common human heritage which – depending on its status – can be either life-enhancing or life-damaging, and that the latter can be a long-term feature whereas the life-enhancing prospect tends to be delicately balanced and tenuous. Now, as a common heritage, it is undeniably our common goal that the environment should be life-enhancing; hence we must intervene to salvage the environment whenever it threatens to become harmful. Moreover, if the reasons for environmental changes are only partly known (e.g. when they are caused by complex biotic or earth processes), then suitable interventions may need to be devised experimentally along with efforts to better understand such processes; but, if the environmental degradation is due to unrestrained anthropogenic activities, then the interventions will have to: (i) curtail or regulate such activities, and (ii) introduce specific measures for environmental restoration and strengthening.

The above premise underlying the recommendations proposed herein should clear the way for judging the merit of the proposals in an unbiased manner. Conventionally, in debates pitting "Environment versus Development", Development is considered in economic terms whereas Environment is not assigned any economic value. To make a meaningful comparison, environmental positives must be considered as common human capital and environmental negatives as common human liabilities, where environmental positives and negatives (or, ecosystem gains and losses) include the build-up and/or depletion of valuable resources and wastes. Since basin-wide environmental positives and negatives have been relatively stable during past generations, they are often taken for granted, i.e. without considering their economic importance. Their proper economic valuation in NRGB requires complex and futuristic analysis of an intricate environmental system, which would need a time-span well beyond the timeframe envisioned for preparing

this GRBMP. However, to give an idea of the economic value of river basin environments, some estimates for the Murray-Darling Basin and the Yarra Valley in Australia have been given in Appendix I.

1.4. Issues and Concerns of the NRGB Environment

Various anthropogenic factors have contributed directly to the degradation of NRGB's aquatic environment in recent times. Broadly, five major types of degradation factors are noticeable: (i) over-extraction of natural resources from the basin to meet increasing human demands; (ii) discharge of pollutants in the basin, causing deterioration in the quality of land and natural waters; (iii) reduction in the rate of replenishment and water-holding capacities of natural reservoirs (i.e. of both surface and ground water bodies); (iv) mutilation of rivers by piecemeal engineering operations; and (v) possible threats to geological processes governing the basin. Some environmental changes (such as change in rainfall patterns) may also have been produced by anthropogenic activities – either local or external/global. However, since such issues are often inadequately understood and/or not locally amendable, they are excluded from the scope of this phase of GRBMP.

The major human activities affecting the aquatic environment of NRGB in modern times, and the reasons for their adverse effects, are broadly identified as follows:

1) **Industrialization**: (i) Over-withdrawal of resources (especially fresh water from surface and ground water sources); (ii) discharge and dumping of industrial wastes and leakage of industrial pollutants into the environment.
2) **Urbanization**: (i) Over-withdrawal of fresh water from surface and ground water sources for domestic, commercial and public activities; (ii) discharge of urban wastes and pollutants (including eroded soils and construction debris) into the environment; (iii) reduction of surface and groundwater recharges; and (iv) changes in geomorphological parameters governing basin hydrology due to land-use changes.
3) **Lifestyle Changes**: (i) Over-withdrawal of resources (especially fresh water from surface and ground water sources); (ii) discharge of emerging contaminants into the aquatic environment.

4) **Agricultural and Other Rural Activities**: (i) Over-use of resources (including fresh water from surface and ground water sources and other soil resources); and (ii) discharge of agricultural and rural wastes (including chemical fertilizers and pesticides) in the basin.

5) **Deforestation/ Denudation Activities**: Loss of vegetal cover due to deforestation, overgrazing, etc. resulting in rapid surface runoff; hence: (i) reduced groundwater recharge, (ii) increased runoff and soil erosion, with eroded soil eventually depositing in water courses and water bodies, and (iii) changes in geomorphological parameters governing basin functioning.

In addition to the environmental effects listed above, piecemeal river-based projects (for hydropower, water supply, flood control, etc.) often directly infringe on river functioning, thereby producing complex, basin-wide environmental repercussions. Finally, various modern anthropogenic activities may also pose threats to geological formations governing the basin. Such activities include the depletion of deep aquifers, reservoir operation, constructions on fragile slopes, underground tunneling, excavations and mining, and hydraulic fracturing of rocks. Likewise, land-use/ land-cover changes due to urban/ industrial/ infrastructure projects may affect the natural drainage pattern or cause other morphological changes, with consequent adverse effects on the basin. Since geological damages may be compounded by natural earth processes and are, moreover, not easily detected before they reach alarming proportions, these issues may need special precautions and long-term monitoring. The major disruptive modern activities and the consequent degradation factors are schematically shown in Figure 1.3.

The impact of environmental damages in NRGB on human beings may be gauged in terms of "ecosystem service" losses, which are losses of the many benefits that we normally derive from our environment (and which we often take for granted). "Ecosystem services" are commonly categorized as: (i) provisioning services or products which are visible and tradable items such as food, freshwater, fibres, and energy; (ii) regulating services e.g. flood attenuation, groundwater recharge, prevention of salt water intrusion; (iii) supporting services e.g. nutrient recycling, soil formation, biodiversity maintenance; and (iv) cultural services e.g. recreation, spiritual fulfillment [*UN*-

Water, 2013; Smith and Barchiesi, 2009]. Even without quantitative economic evaluation of the basin's ecosystem services, it is fairly evident that all the four ecosystem service categories have been significantly affected in the NRGB, calling for urgent need to repair the environment.

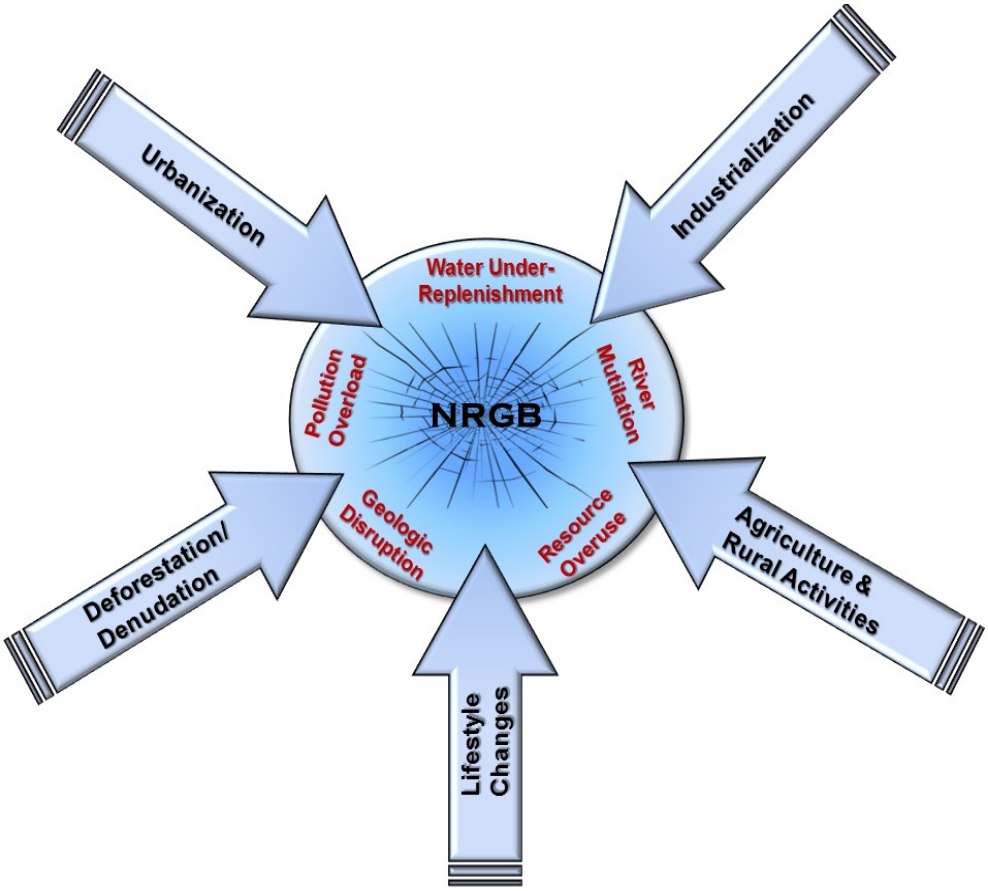


Figure 1.3: Major Adverse Impacts of Anthropogenic Activities on the NRGB Environment

Among the five main types of environmentally significant human activities stated above, the first three are related predominantly to profitable activities or activities of relatively affluent sections of society. It must be eminently feasible to review these activities and modify them – even if they incur some costs – in order to minimize their adverse environmental impacts, for which damages must otherwise be borne later. On the other hand, some activities (such as the fourth category above) often concern basic needs and livelihoods of relatively poor or marginal sections of society, and attempts to modify them significantly can cause social and financial distress. However, in such cases too, if the environmental impacts are significantly adverse, then suitable means

must be devised to abate the negative impacts and ensure a wholesome environment in the NRGB. The GRBMP attempts to provide a viable roadmap to mitigate such adverse impacts in the foreseeable future, and thereby enable human communities to flourish and life to thrive in its myriad forms in the NRGB.

2. Key Features of National River Ganga Basin

2.1. The Ganga River Network

The Ganga river network [*India-WRIS, 2012; Wikipedia, 2013; Indianetzone, 2014*] is depicted in Figures 2.1a and 2.1b. River Ganga originates in the Himalayas at the confluence of Rivers Alaknanda and Bhagirathi at Devprayag. However, before this confluence, the Alaknanda herself had merged with four major Himalayan rivers namely, Rivers Dhauliganga (at Vishnuprayag), Pindar (at Karnaprayag), Nandakini (at Nandprayag), and Mandakini (at Rudraprayag), while River Bhilangana had joined the Bhagirathi (near Tehri). Thus, River Ganga may be considered to originate from several Himalayan head-streams, although the Bhagirathi river is traditionally considered to be her source stream.

After Devaprayag, River Ganga emerges at the pilgrimage town of Haridwar in the Sivalik Hills, then changes course from southwest to southeast, and flows through the northern plains of India. In the plains, she is joined by several tributaries, most notably the Ramganga river, while following a curving course of about 800 km, before merging with the Yamuna river at Sangam near Allahabad. Before Sangam, River Yamuna, which also originates in the Himalayas, was joined by several large rivers from the north and west (such as the Tons, Hindon, Chambal, Betwa and Ken rivers), and carries more flow than Ganga herself in present times. According to ancient Hindu texts, Sangam was the confluence of three rivers – Ganga, Yamuna and Saraswati, but the latter river is non-existent today.

Subsequent to Sangam, several large tributaries such as the Kosi, Gandak, Gomti, Sone, Karamnasa and Ghaghra join the Ganga to form an immense river in the plains below Allahabad. From Bhagalpur in Bihar, the river moves across

the Rajmahal Hills and begins to run southwards. Thereafter, as she enters West Bengal, she divides into two major streams. The eastern stream, known as River Padma, flows southeast through Bangladesh to join the Brahmaputra and Meghna rivers, while the right-hand distributary of the Ganga, known as the Bhagirathi flows south. The Bhagirathi river is soon joined by River Jalangi, and, from thereon, known as River Hooghly. The southward flowing Hooghly is joined by Rivers Damodar and Mayurakshi before reaching the sea near Sagar Island. The combined outfalls of Ganga, Bramhaputra and Meghna rivers in Bay of Bengal together form the world's largest delta (the "Ganges Delta" or "Sundarban Delta" covering about 60,000 sq.km.) stretching across Bangladesh and West Bengal. Overall, River Ganga is more than 2500 km long, and perhaps longer than 2600 km depending on which streams are considered as her originating and terminating streams.

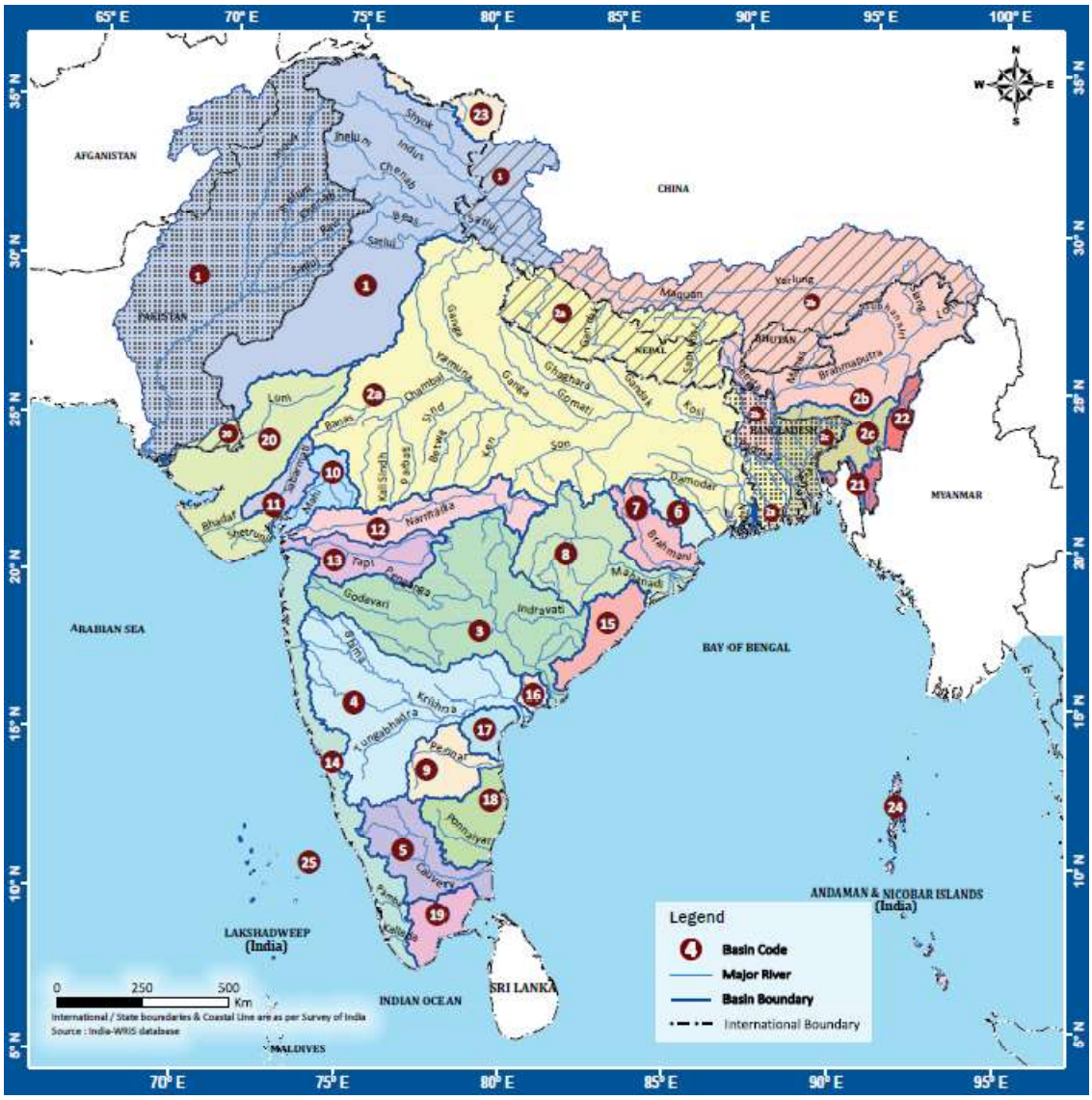


Figure 2.1a: Main River Basins of India: The Ganga River Basin is the Yellow Region Marked as "2a" [India-WRIS, 2012]

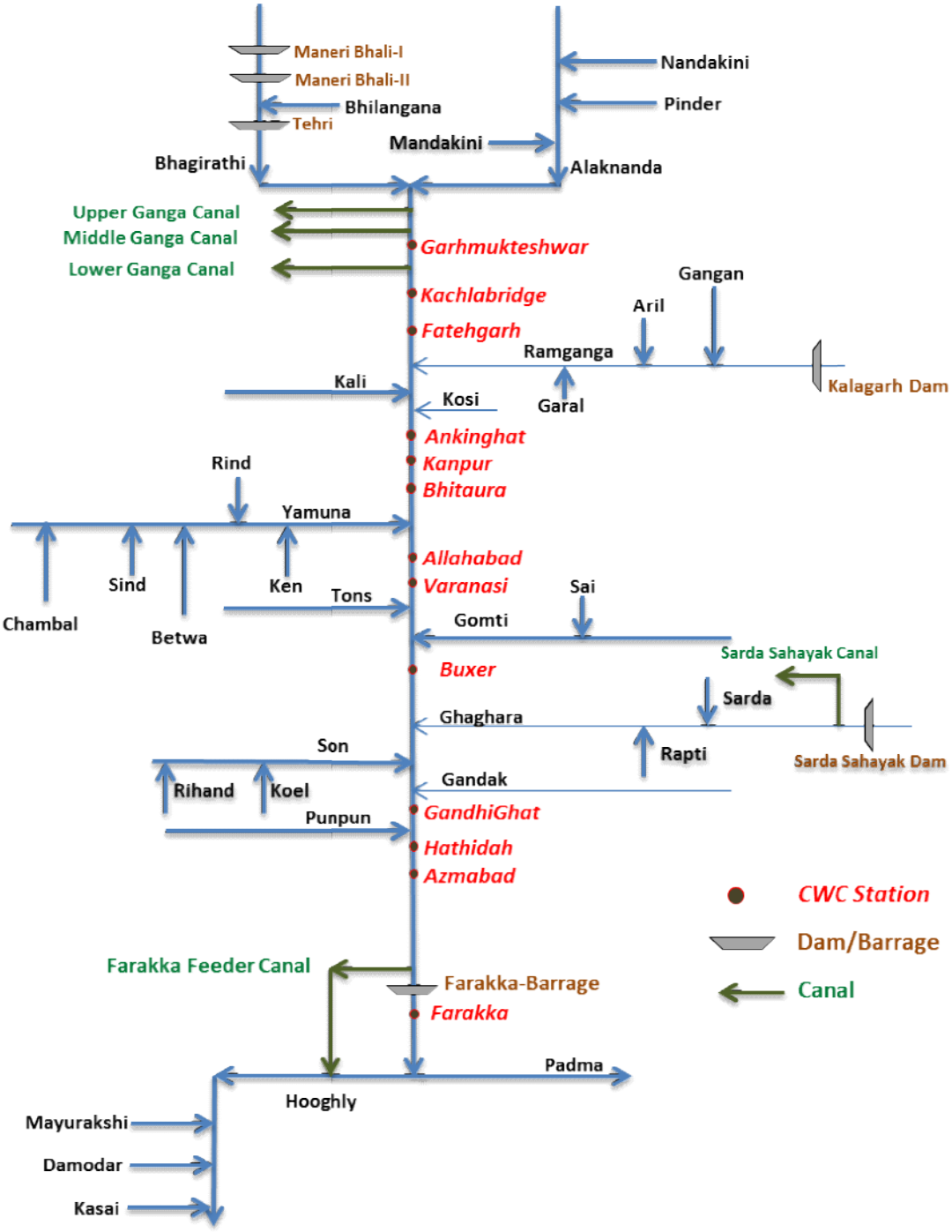


Figure 2.1b: Line diagram of River Ganga and her major tributaries [MoWR, 2014]

2.2. Water Resources

The Ganga basin, spread over four nations (India, Nepal, China and Bangladesh) covers an area of about 1,080,000 km^2 of which the major part – the NRGB – of about 862,000 km^2 lies within India [*Jain et al., 2007; MoWR, 2014; Wikipedia, 2013*]. NRGB is the largest river basin of India, covering more than 26% of her geographical area (see Figure 2.1a). The region gets significant annual rainfall (apart from snowfall in higher reaches) averaging 1060 mm/yr, but rainfall varies considerably over the catchment**:** it is much higher towards NRGB's eastern and northern ends than towards the west (see Figure 2.2a). As per government data [*CWC, 2010; MoWR, 2002*], out of the total surface and ground water availability of 1,869 km^3/yr in India, the total water availability of NRGB is 525 km^3/yr. Within India, only the combined Brahmaputra-Barak basin has a higher water availability of 585.6 km^3/yr, but much of the "available water" in the latter cannot be tapped, often causing devastating floods in some of the riparian states. Thus, the total surface water that can be utilized in NRGB (250 km^3/yr as per government estimate) is much higher than that of any other Indian basin, making it her most water-rich basin (see Figure 2.2b). And it supports a staggering 43% of the Indian population [IITC, 2011b]. Thus, the basin's per capita water availability is about 65% of the national average, and its per capita land availability is about 60% of the national average.

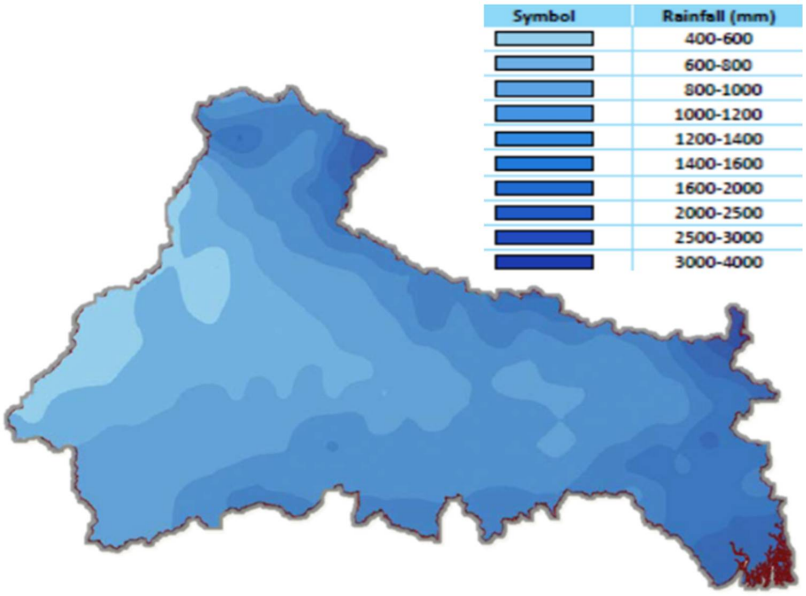


Figure 2.2a: Average Annual Rainfall in NRGB [from India-WRIS, 2012]

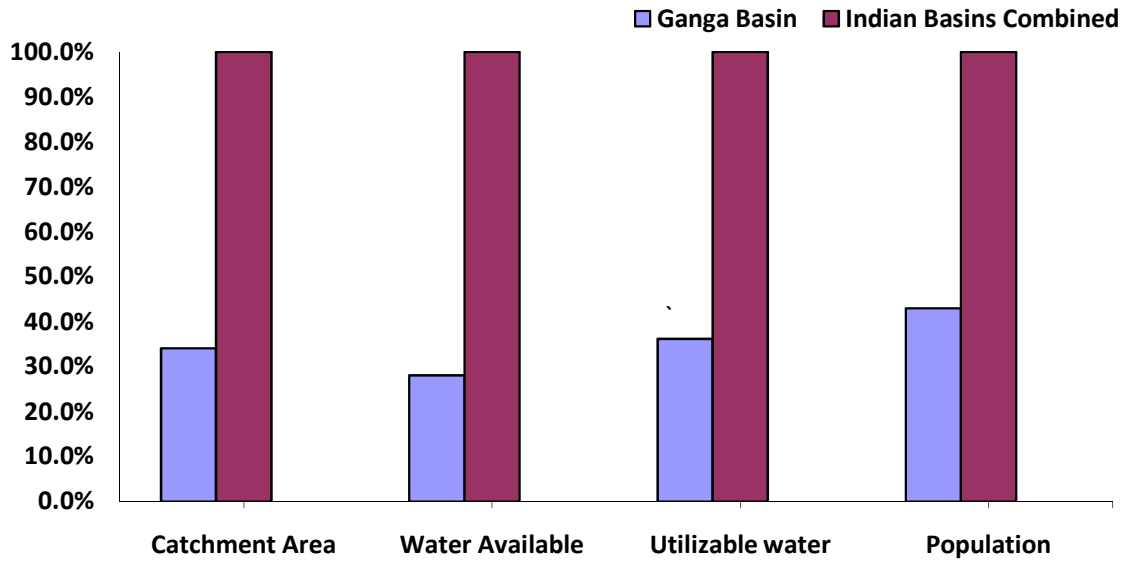


Figure 2.2b: Hydrological Importance of NRGB relative to All Indian Basins Combined

2.3. Geology

The Ganga basin covers a diverse landscape stretching from the Himalayan mountains in the north and north-east to the Aravali range in the north-west, the Vindhya range and Chotanagpur plateau in the south-west, and the sea in the south (see Figure 2.3a), while on the south-eastern side it merges with the Brahmaputra and Meghna river basins of North-East India and Bangladesh. Geologically, NRGB is part of the a tectonically active foreland basin of the Himalayan mountain range formed by collision of the northeast moving Indian tectonic plate with the Eurasian plate and its subduction under the latter, a process that occurred some fifty to seventy million years ago (although some recent research suggests that the Himalayas may be as old as five hundred million years, vide *Gehrels, 2003*). The former seabed south of the Himalayas then got gradually filled with sediments eroded from Himalayan rocks. Thus much of the NRGB – and the Indo-Gangetic plains in general – came to consist largely of alluvial plains formed during the Tertiary and Quaternary periods by flood deposits of Himalayan rivers [*Wadia, 1965; Wikipedia, 2013*]. Alluvial deposits of up to or more than 1 km thick, interspersed with semi-confining or confining strata, span across much of the basin, with the deposits being far thinner near the Vindhya mountains. Overall, they constitute large and highly productive multi-aquifer systems (see Figure 2.3b), which provide for

significant ground water resources in the basin [*CGWB, 2009; CGWB, 2012; CWC, 2010*]. Due to the alluvium deposited over the ages, the soils of the basin (see Figure 2.3c) are also mostly alluvial, with mountain soils, terai soils, red soils and black soils towards the mountain ranges [*Bhattacharyya et al., 2013*].

The major Himalayan rivers of NRGB are thought to have preceded the rise of the Himalayan mountains from the sea [*Wadia, 1965*]. At present, the rivers in the upper and middle Ganga plains occupy narrow valleys separated by large interfluves. Near the Himalayan front, valley formation and incision were affected by both tectonic and climatic factors, whereas the strongly incised valley formation in the western and southern plains are believed to have been controlled mainly by climatic factors. In contrast, the fluvial morphologies in the lower Ganga plains and the deltaic region were influenced significantly by sea level fluctuations, besides climate and tectonics [*Sinha et al., 2005*]. It may be noted here that the Himalayan rivers of the Ganga River Network are not only water conveyance systems, but also conduits for large amounts of sediment transfer from the Himalayas to the river basin (by flooding) and to the Gangetic delta and the sea. To quote Tandon *et al*. [*2008*], the "Ganga river system ranks 18^{th} worldwide in terms of its basin area (980,000 km^2) and 2^{nd} in terms of the total suspended load (524 MT/yr)." Other estimates cite even higher figures of suspended load at about 729 million T/yr [Wasson, 2003]. The total sediment load of the river is also very high – estimated at 2.4 Billion T/yr [IITC, 2012b]. The high sediment loads of the Ganga and Brahmaputra rivers, much of which come from eroded Himalayan sediments, are believed to be instrumental in having formed and maintained the large Sunderaban delta.

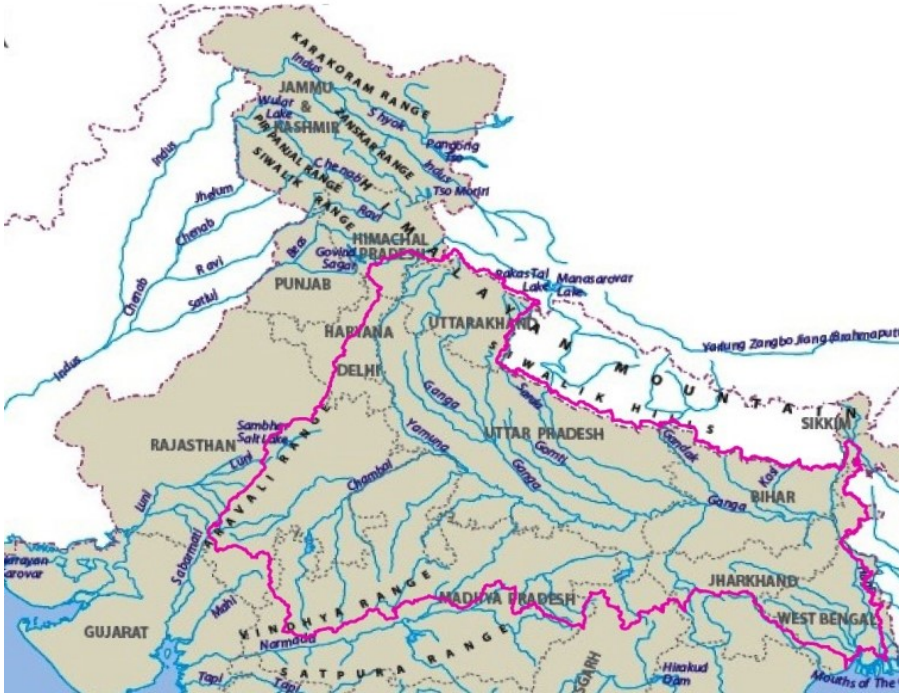


Figure 2.3a: Mountain Ranges in the Ganga Basin [Adapted from MapsofIndia.com, 2014a]

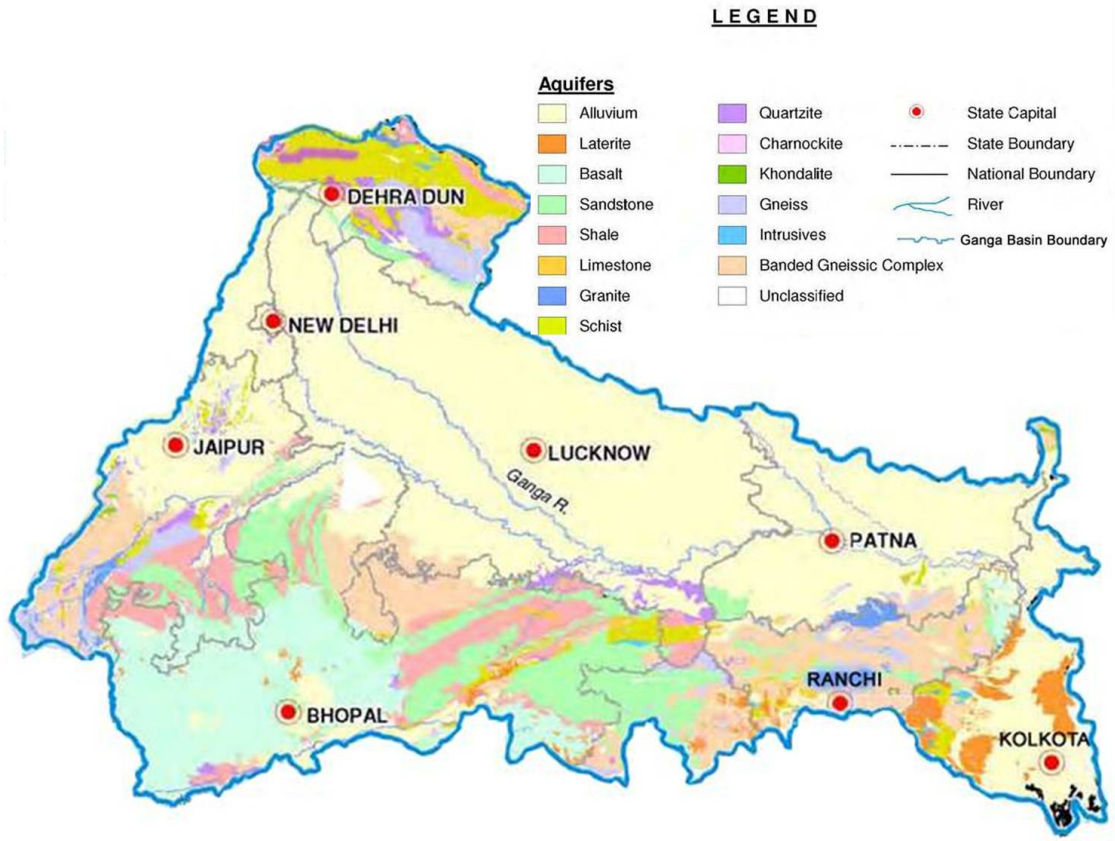


Figure 2.3b: Aquifer Systems of NRGB [Adapted from: CGWB, 2012]

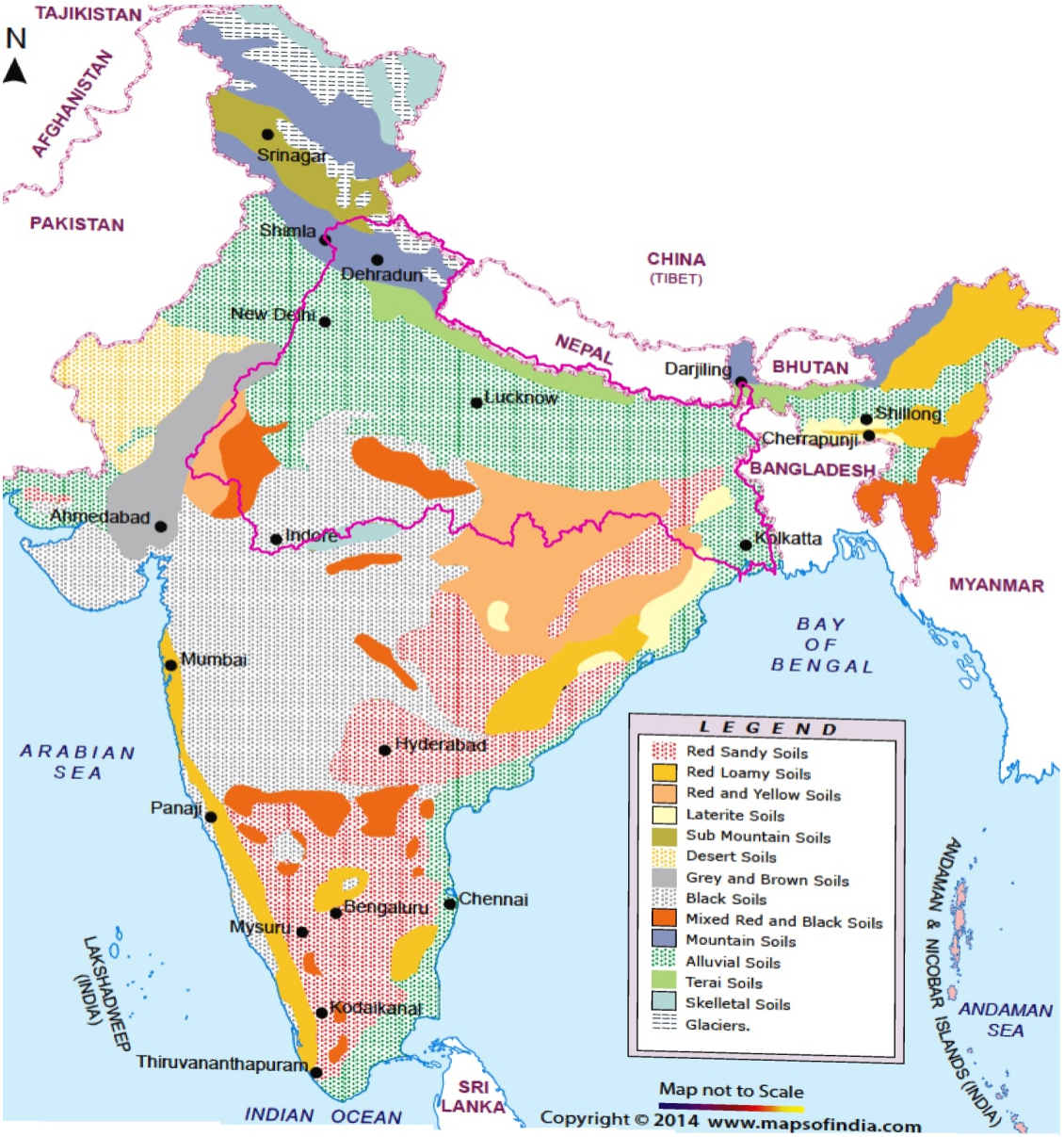
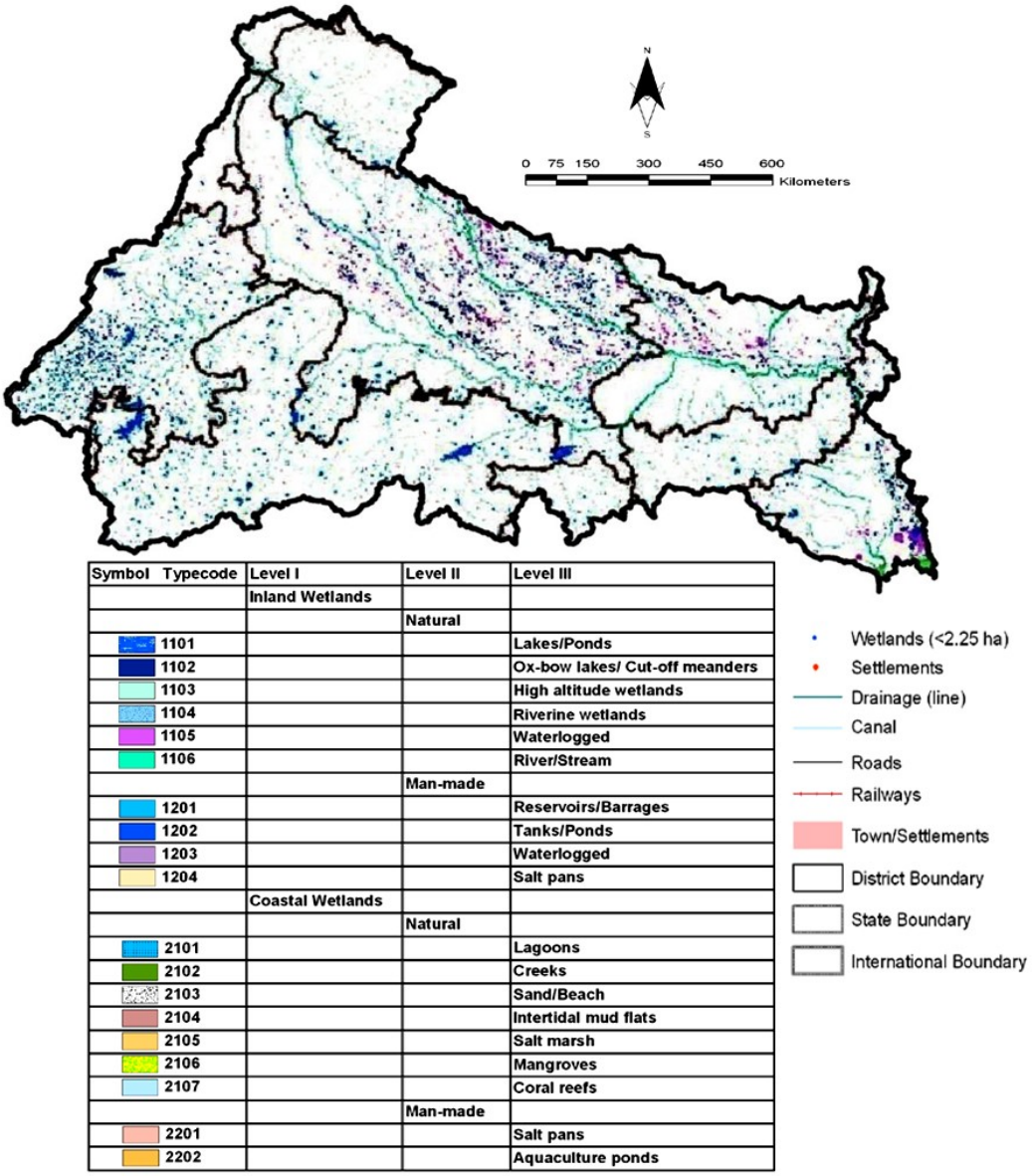


Figure 2.3c: Soil Map of NRGB [Adapted from: MapsofIndia.com, 2014b]

2.4. Wetlands

There are many lakes, tanks and marshes in NRGB. Figure 2.4a shows the many surface water bodies of NRGB including manmade reservoirs. Figure 2.4b shows some major fresh water and saline lakes of NRGB. But besides big lakes, NRGB has a large number and variety of wetlands spread across the basin – in the mountainous Himalayan region, the Himalayan terai region, the Gangetic plains, and the coastal deltaic region – which together support a large and

diverse ecological system in different geophysical settings. Several of NRGB's wetlands are home to specialized flora and fauna as well as migratory species, which fulfill crucial ecological and social functions such as nutrient recycling, water purification, flood attenuation, ground water recharge, and buffering of shorelines against erosion, besides providing water, fish, fodder and recreation to society [*Prasad et al., 2002*].



Symbol Typecode	Level I	Level II	Level III
	Inland Wetlands		
		Natural	
1101			Lakes/Ponds
1102			Ox-bow lakes/ Cut-off meanders
1103			High altitude wetlands
1104			Riverine wetlands
1105			Waterlogged
1106			River/Stream
		Man-made	
1201			Reservoirs/Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
	Coastal Wetlands		
		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt marsh
2106			Mangroves
2107			Coral reefs
		Man-made	
2201			Salt pans
2202			Aquaculture ponds

Figure 2.4a: Significant Surface Water Bodies of NRGB [Adapted from: SAC, 2011]

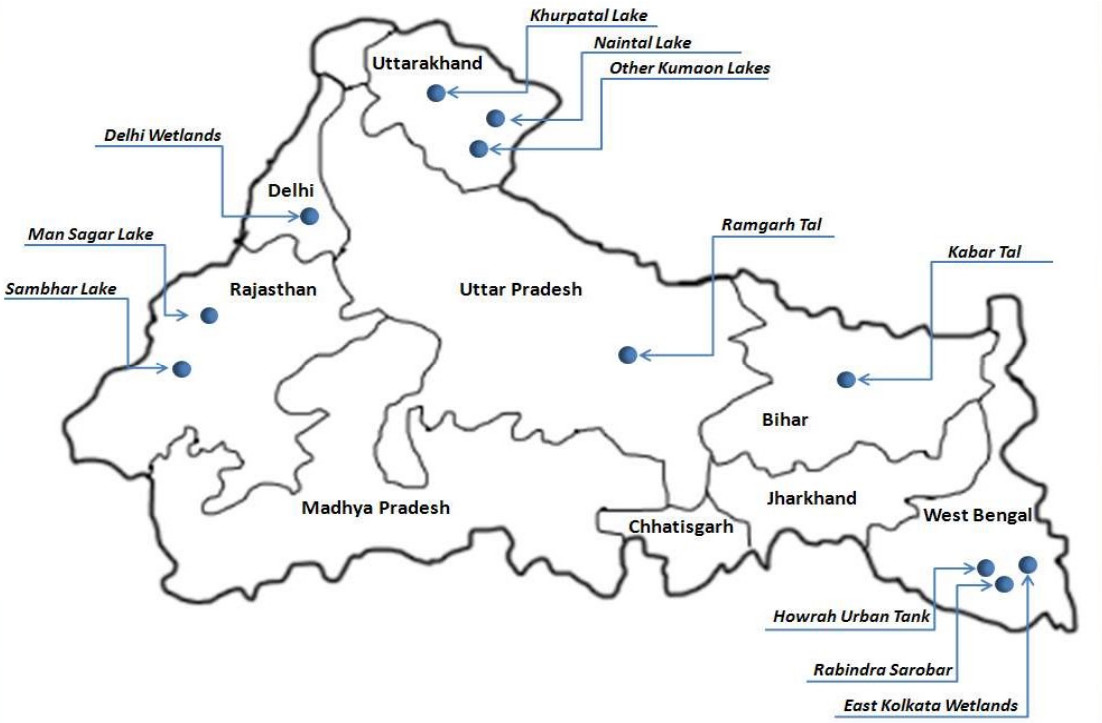


Figure 2.4b: Major Lakes and Wetlands of NRGB [Adapted from: Rainwaterharvesting, 2013]

2.5. Geomorphology of National River Ganga

In keeping the primary focus of NRGB on River Ganga, it is essential to delineate the river morphology clearly. River Ganga is defined herein as comprising of six main head-streams originating in the Himalayas, namely the Alaknanda, Dhauli Ganga, Nandakini, Pinder, Mandakini and Bhagirathi rivers starting from their feeding glaciers up to their respective confluences at Vishnuprayag, Nandaprayag, Karnaprayag, Rudraprayag, Devprayag and Rishikesh (together comprising the Upper Ganga segment), the subsequent main stem of the river downstream from Rishikesh to Varanasi (the Middle Ganga segment) and the final stretch from Varanasi to Ganga Sagar (the Lower Ganga segment). Among these segments, the headstreams are fast-flowing mountainous rivers cutting through deep gorges and narrow valleys, whereas the Middle Ganga stretch meanders through relatively flat plains, with annual floods often covering vast expanses on both sides of the river. The lowermost part of the Lower Ganga segment tends to be braided, especially in the delta region near the Bay of Bengal where sea tides affect the river flow.

Since the most dynamic and vulnerable regions of a river include its active floodplains, a river's active floodplain needs to be included in the defining river space. In fact, the entire river valley (including the active floodplain) is a sensitive geomorphic-ecological river space. Based on remote sensing data and other inputs, the active floodplain of the Middle and Lower Ganga stretches from Rishikesh to Farakka has been mapped as shown in Figure 2.5a [IITC, 2010b]. Likewise, the valley margins for the same stretches are shown in Figure 2.5b [IITC, 2011d]. Detailed maps given in the report show significant diversity of valley widths and geomorphic features in different reaches of the river, which have strong implications for the hydrological regime, water resource management, and ecological health of NRGB.

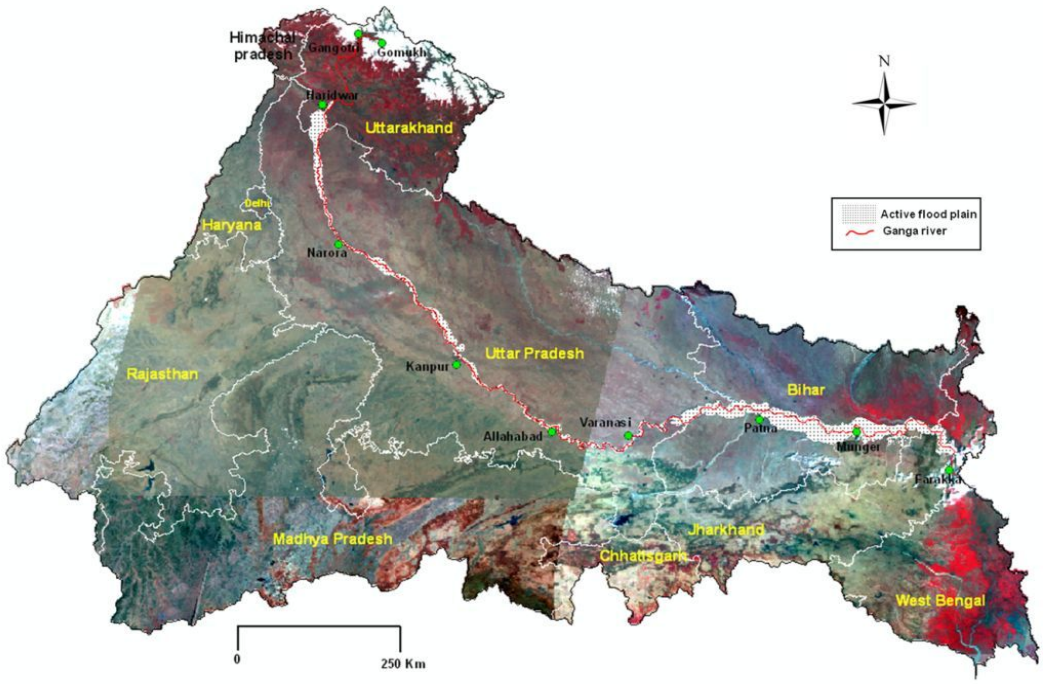


Figure 2.5a: Map of Ganga River with its Active Floodplain [based on AWIFS data]

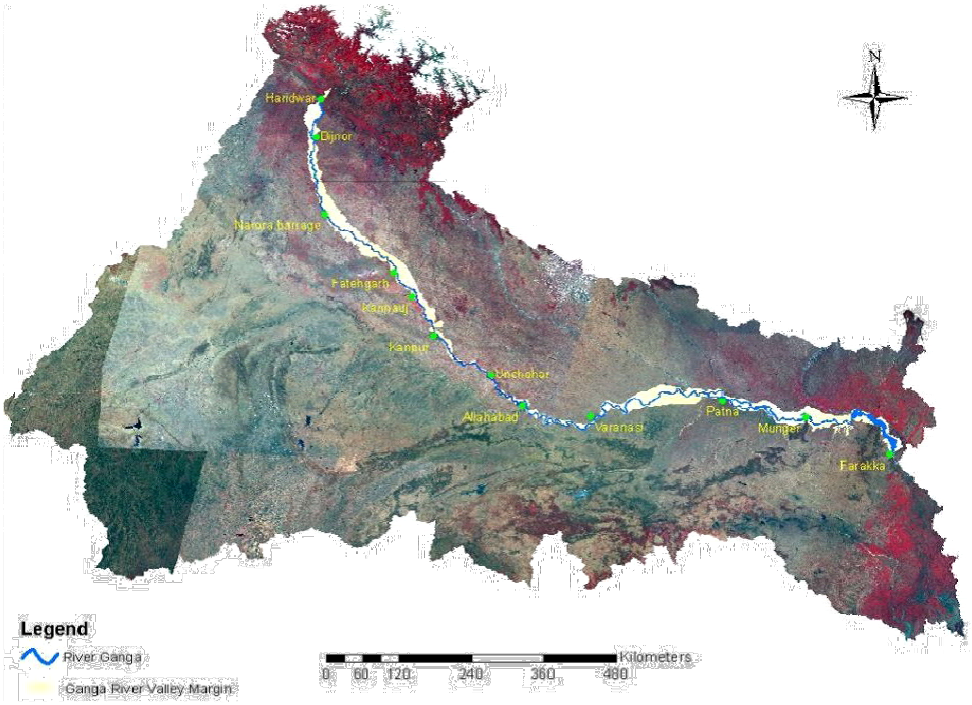


Figure 2.5b: Geomorphic Map of Ganga River Valley

2.6. Biodiversity of National River Ganga

The biodiversity of National River Ganga is unique as it synthesizes three very different eco-regions of India situated along climatic gradients, namely the Himalayas, the Gangetic plains and the Deltaic regions [IITC, 2011c; IITC, 2012c]. The distribution of flora and fauna being largely dependent on the substrate, habitat and trophic status, the presence or absence of a particular family, genus or species is indicative of the conditions prevailing in the eco-region. The biodiversity in the Ganga river may be grouped under seven heads, viz.: (i) Phytoplanktons (tiny free-floating living organisms that drift with the water); (ii) Periphytons (algal community that grows attached on the substratum along with phytoplanktons, comprise 1176 Taxa of attached and free-floating algal forms and constitute the main autotrophic base of the food chain in the Ganga ecosystem); (iii) Zooplanktons (comprising 294 Taxa of largely macroscopic or assemblage of microscopic free-floating animals); (iv) Zoobenthos (comprising 73 families of insects including higher forms that group under rocks and boulders spending part of their life as larvae and those which live and grow on soft substrate); (v) Fish (of 281 species plus 13 Chondrichthyes species); (vi) Higher aquatic vertebrates (comprising Reptiles,

and Mammals that include 13 species of hard and soft turtles, gharial and crocodiles besides the Gangetic dolphin and porpoise); and (vii) Macrophytes (which are higher forms of plants that grow free floating or submerged in water bodies). Among these, periphytons, phytoplanktons and macrophytes are producers while zooplanktons, zoobenthos, fish and higher aquatic vertebrates are consumers of the food produced. Together, these micro- and macro-organisms, through their interplay with the abiotic environment, represent the ecological status of National River Ganga.

3. Philosophy, Vision and Conceptual Framework

3.1 Vision

National River Ganga, which epitomizes the environmental status of the National River Ganga Basin, and around which human civilization flourished over millennia, has been flowing ceaselessly since primeval times. In order to preserve and invigorate National River Ganga, her essential character needs to be grasped in a holistic manner. After extensive research and consultations, the "wholesomeness of National River Ganga", viewed from a dynamic perspective, was determined to be the sanctity of the river system imbibed in four points stated below [IITC, 2012a]. Out of these, the first two points are based on ancient Indian concepts – a testimony to our ancient wisdom, while the latter two points derive from modern scientific knowledge and understanding**:**

1. **"*Aviral Dhara*" (meaning "Continuous Flow"):** The flow of water, sediments and other natural constituents of River Ganga are continuous and adequate over the entire length of the river throughout the year.
2. **"*Nirmal Dhara*" (meaning "Unpolluted Flow"):** The flow in the Ganga River Network is bereft of manmade pollution; hence the river water quality should not be adversely affected by human activities.
3. **Geologic Entity:** The Ganga River System is a heritage of past geological ages, i.e. they are the earth's creations of ancient times, which may not be reparable if damaged.

4. **<u>Ecological Entity</u>:** The Ganga River System is a delicately structured balance between various living species and the physical environment, achieved by nature over thousands of years and vulnerable to irreversible changes.

In the background of escalating impacts of human activities on the NRGB environment, the above four points have guided the formulation of eight important missions of GRBMP, viz.**:** "*Aviral Dhara*", "*Nirmal Dhara*", "*Ecological Restoration*", "*Sustainable Agriculture*", "*Geological Safeguarding*", "*Basin Protection Against Disasters*", "*River Hazards Management*", and "*Environmental Knowledge-Building and Sensitization*". These missions cover the most important areas where focused actions are needed to restore the wholesomeness of National River Ganga. The desired interventions of each mission are discussed in separate mission reports and their summaries are presented in the following chapter.

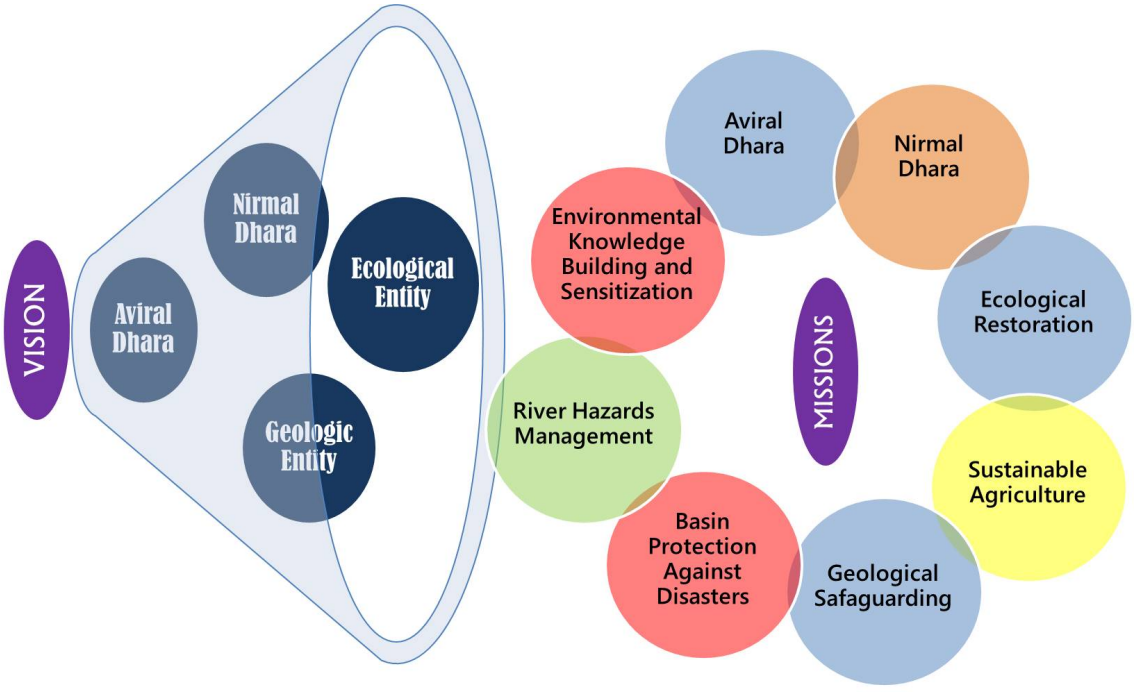


Figure 3.1: Target Missions to achieve Vision of a wholesome National River Ganga

3.2 Guiding Principles

The guiding principles for this Plan as decided upon by IIT Consortium is summarized as follows [IITC, 2012a]**:**

- Apply modern science and technology in conjunction with traditional wisdom**:**

पारंपरिक ज्ञान के साथ आधुनिक विज्ञान और नई प्रौद्योगिकी को प्रयोग मे लाना

ज्ञान धारा + जन ज्ञान

- Precautionary principles must apply wherever knowledge gaps and uncertainties exist.
- Multi-disciplinary inputs needed, from both experts and non-experts.
- Keep flexibility to cater to future needs and changing contexts.
- Clearly articulate choices and trade-offs involved.
- Need to manage parts of basin with heavy interventions (highly altered) differently from parts with mild interventions (near pristine).
- Avoid and eliminate all anthropogenic pollution.
- Consider surface and ground water together.
- Existing water uses to be protected, but without perpetuating existing inequities.
- Create broad public acceptance of the Plan.
- Create structures to monitor and regulate implementation of the Plan.

3.3 Conceptual Framework

Based on the above vision and the awareness of social needs, the main objectives of GRBMP are identified as the following [IITC, 2012a]**:**

a) Environmental Flows shall be maintained in all rivers and tributaries of Ganga River System to fulfill their geological, ecological, socio-economic and cultural functions.

b) Water quality in all rivers and tributaries of Ganga River System shall be consistent with their governing geological, ecological, socio-economic and cultural functions.

c) Water and other aquatic resources of the Ganga River System shall be used judiciously to enable sustainable development in the entire NRGB.

d) All existing, ongoing and planned anthropogenic activities in NRGB shall be reviewed or scrutinized in a transparent and inclusive manner (with broad consensus of all affected people and stakeholders) for the overall health of NRGB.

With the above objectives in mind, the GRBMP is formulating policy frameworks (or "Action Plans") with built-in feedback mechanism for a range of anthropogenic activities in NRGB. To fulfill these objectives, the need to set up a permanent nodal agency was also felt to implement the Action Plans and other needed measures in NRGB on a long-term basis. The nodal agency is envisioned as an independent Commission for NRGB proposed to be set up by an Act of Parliament. The basic approach in this framework action plan isas per the guiding principles stated previously.

While recognizing the NRGB environment with its diverse features and processes as an integrated whole, the task of analyzing and preparing the GRBMP was broken up from the whole to the parts into several thematic groups as follows**:**

- Environmental Quality and Pollution (EQP)
- Water Resources Management (WRM)
- Fluvial Geomorphology (FGM)
- Ecology and Biodiversity (ENB)
- Socio-economic and Socio-Cultural (SEC)
- Policy, Law and Governance (PLG)
- Geo-Spatial Database Management (GDM)
- Communication (COM)

In addition, two cross-thematic groups were also set up – one on Environmental Flows (*or E-flows*), and the other on Environmental Valuation. However, it was subsequently realized that the latter theme would require extensive research and primary data collection, which may go well beyond the time frame envisioned for preparing the GRBMP. Figure 3.2 below shows the work structure relating the Thematic Groups to develop the GRBMP Missions and the GRBMP as a whole. Based on these works, the major conclusions and

recommendations (actionable points) of GRBMP are presented in the next two sections.

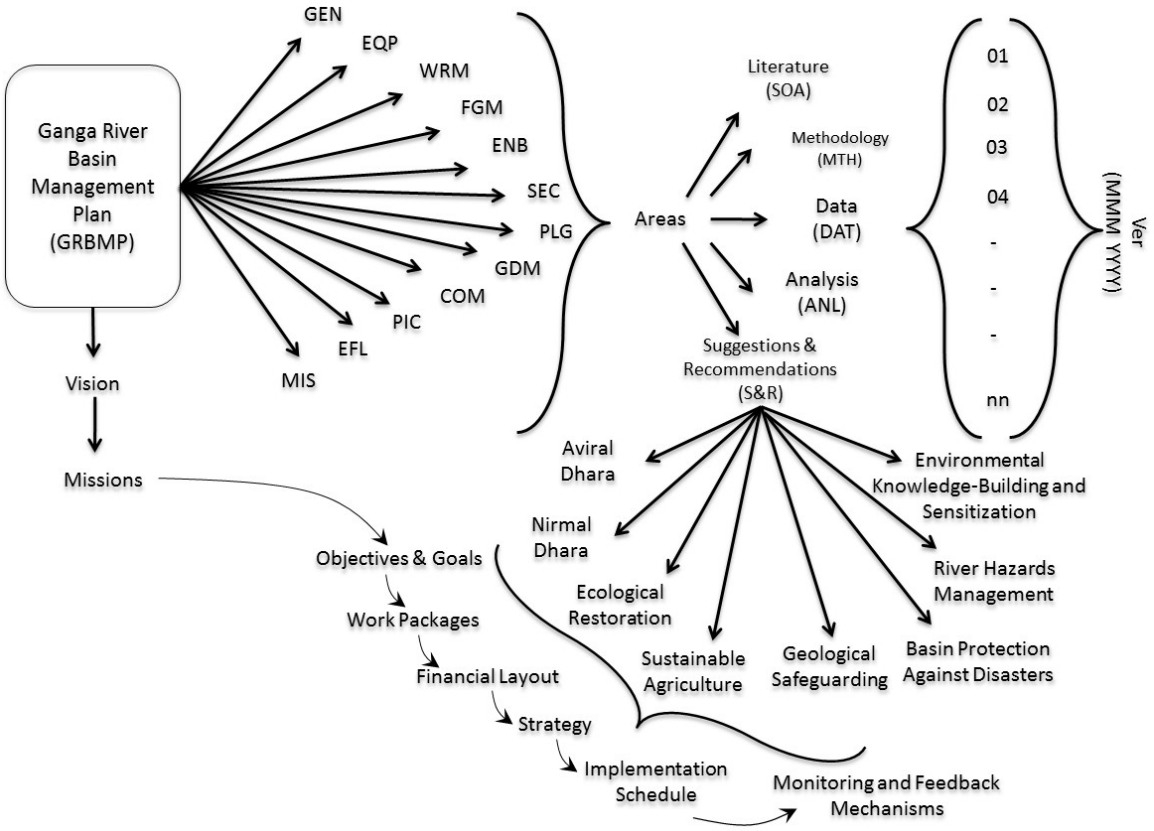


Figure 3.2: Flow Diagram of GRBMP Work Structure

4. GRBMP Missions

The main aspects of NRGB that need focused interventions were identified for action in mission mode under eight heads as discussed in the previous section, viz. *Aviral Dhara*, *Nirmal Dhara*, *Ecological Restoration*, *Sustainable Agriculture*, *Geological Safeguarding*, *Basin Protection Against Disasters*, *River Hazards Management*, and *Environmental Knowledge Building and Sensitization*. The main issues of concern, reasons for degeneration and recommended actions for each mission have been fully presented in the respective mission reports. The important findings of the missions are presented in the following sections to enable an integrated plan of action in GRBMP.

4.1. Mission 1 – Aviral Dhara

4.1.1 **Introduction:** The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Now Aviral Dhara – or the continuous flow of water, sediments and other natural constituents – in National River Ganga was achieved through long-term balance between various dynamic parameters such as water, sediment and influent/ effluent seepage flow rates and terrain gradient. Modern anthropogenic activities have violated the balance by**:** (a) erecting dams and barrages that snap a river's longitudinal connectivity and alter its flow regime, and (b) by significant water withdrawals, debris disposal, and altered water recharge/extraction rates. Hence the river network has become emaciated, as reflected in the loss of river biodiversity and the strain on goods and services emanating from it. Thus there is urgent need to restore Aviral Dhara throughout the river network.

4.1.2 **Water Storage and Demand Control:** Both longitudinal connectivity and adequate flows in rivers are essential to maintain Aviral Dhara. But having adequate river flows depends on the basin's overall water status. While information is limited, available data show that anthropogenic water use has been increasing rapidly in the basin, probably beyond its renewal capacity. Hence, (i) water availability in the basin must be increased through increased storage, (preferably by "distributed storage" in water bodies and aquifers); and (ii) water demands must be reduced through more efficient water use. These issues call for technical interventions as well as changes in policies on NRGB's water resource management.

4.1.3 **Dams, Barrages and E-Flows:** The Ganga river network is intercepted by numerous dams and barrages, and many new projects have been planned. But dams and barrages affect river morphology, stability and ecological balance, fertility of the river and its floodplains, nature of

flood events, human health, and basin performance. Hence dams and barrages must permit longitudinal connectivity and allow E-Flows (Environmental Flows) in rivers. Towards this end, a method for ensuring connectivity with E-Flows passage through dams/barrages is suggested, and a comprehensive set of criteria has been proposed to define environmental clearance requirements for dams/ barrages based on 4 categories of their environmental impacts. For dams, barrages, canal outlets, weirs and other structures that alter river flow regimes, the maintenance of E-flows (with commensurate sediment loads) is essential. Hence, a reliable method for estimating E-Flows for specific river stretches was also developed and demonstrated for select locations in the Upper Ganga basin (see Figure 4.1) where undisturbed river flows before the construction of dams, etc., are known. Illustrative results for computed E-Flows at one such site (Ranari, Dharasu) are shown, vide Figure 4.2.

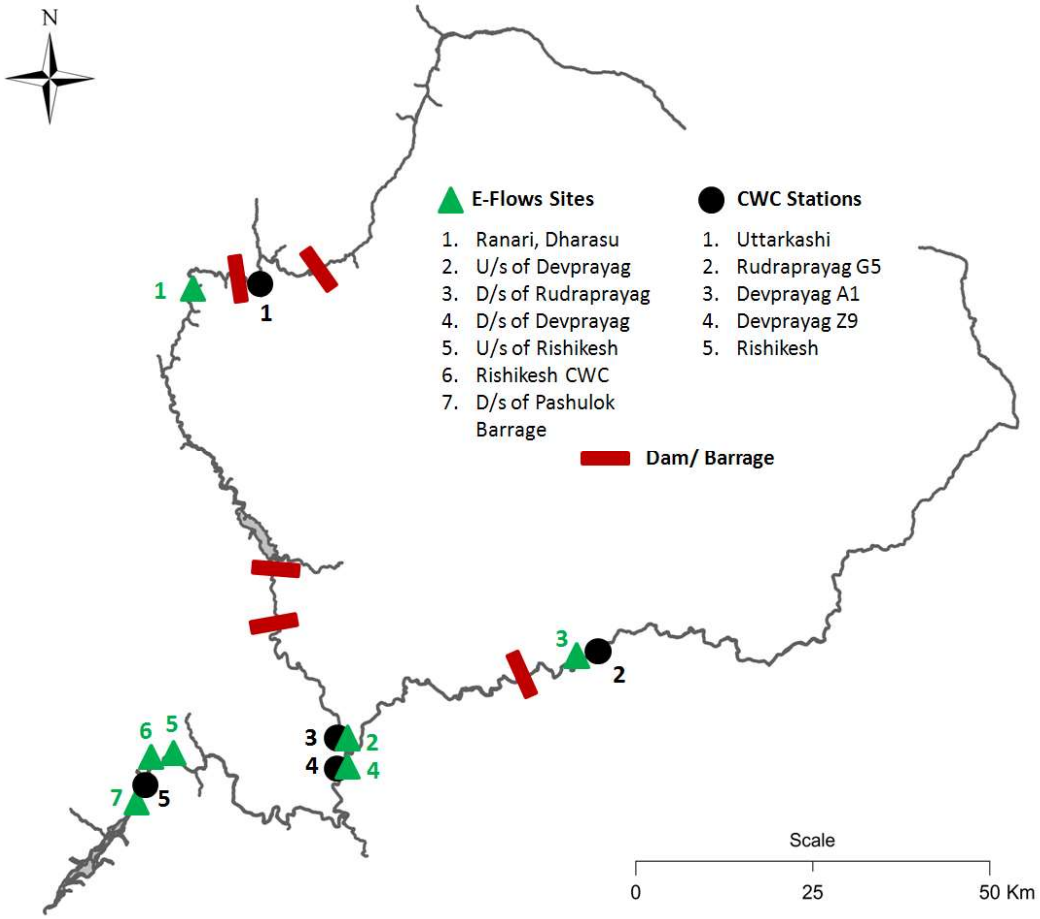


Figure 4.1: Location Map of E-Flows Sites in the Upper Ganga

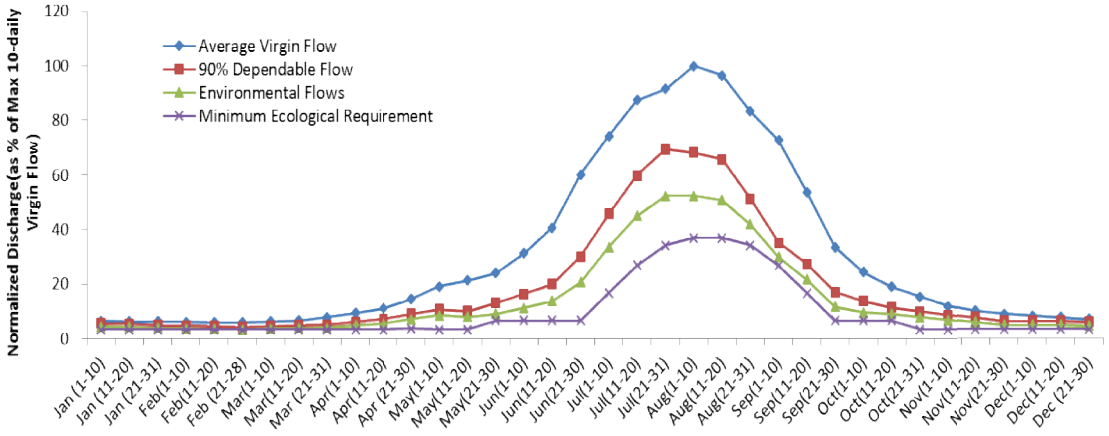


Figure 4.2: Computed 10-daily E-Flows at Ranari, Dharasu

4.1.4 Hydrological Modeling of NRGB: Dynamic modeling of surface flows in the combined Ganga basin area of NRGB and Nepal was carried out using SWAT model. Raw data used included static spatial data, dynamic hydro-meteorological data, and water demand and abstraction data. Model simulation was carried out for the period 1969–2006, and the results were calibrated with river discharges. Groundwater modelling was carried out using MODFLOW computer model for the alluvium part of the basin. Modeling efforts were constrained by limitations of data of precipitation, canal water diversions, irrigation practices, nearly half of the 206 dams/ reservoirs, etc., besides limitations on quality of data for land use, groundwater abstractions, etc. The summary model outcome, vide Figure 4.3, shows that stream-flow and evapotranspiration are the two main components of water outgo from the modeled basin area, with evapotranspiration being about 41-42% of precipitation. Model estimates of “virgin flows” and “present managed flows” in major rivers of the network are presented, vide Figure 4.4.

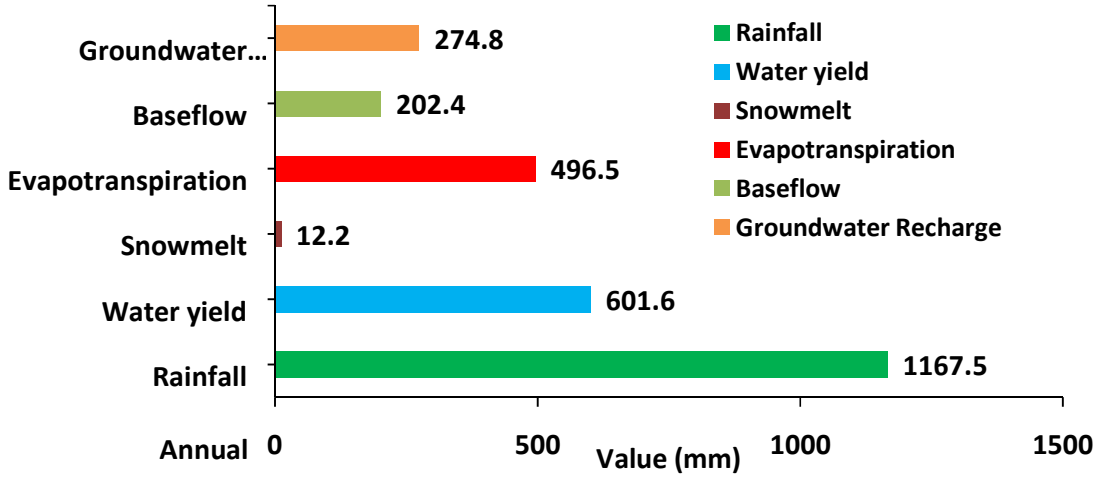


Figure 4.3: Average (1969-2006) Annual Water Balance of the Modeled Ganga Basin

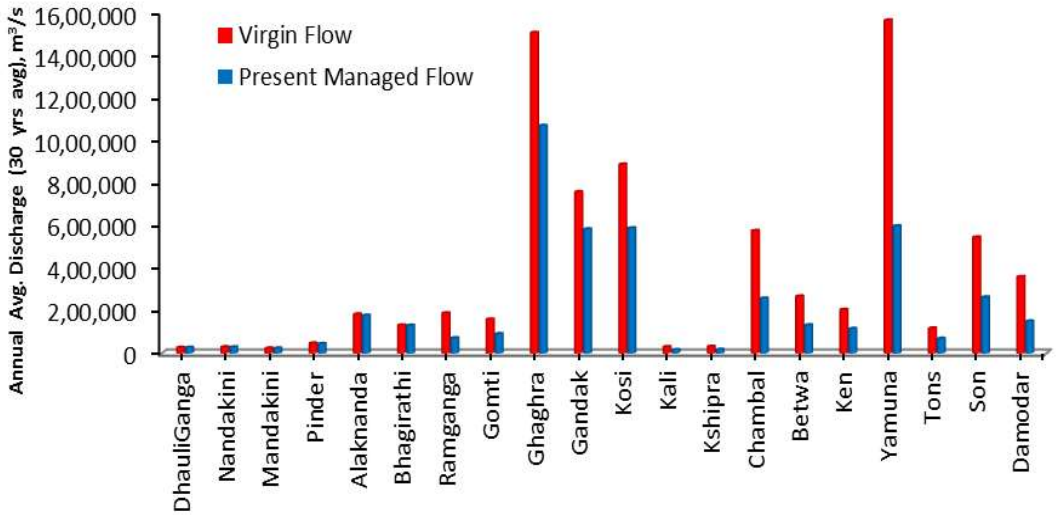


Figure 4.4: Annual Flow Contributions of Different Tributaries (sub-basins) to National River Ganga under Present Flow Conditions and under Virgin Flow Conditions

4.1.5 Sediment Resources: Water-borne sediments play a vital role in the dynamics and ecology of the Ganga River Network, but their nutrient value is unknown. A reliable sediment budget of the basin is also unavailable, but the river's suspended sediment load is generally reported at between 500 to 800 million T/yr and the total sediment load

at about 2400 million T/yr – which are very high for any world river. Based on available data, the average annual and seasonal sediment loads at different stations on National River Ganga were computed, vide Figure 4.5. Surprisingly, the average suspended sediment load at Farakka during the period 1999–2006 was found to be only 177 million T/year – much less than earlier estimates. The sediment load also showed major spatial variations, suggesting different aggrading and degrading river reaches.

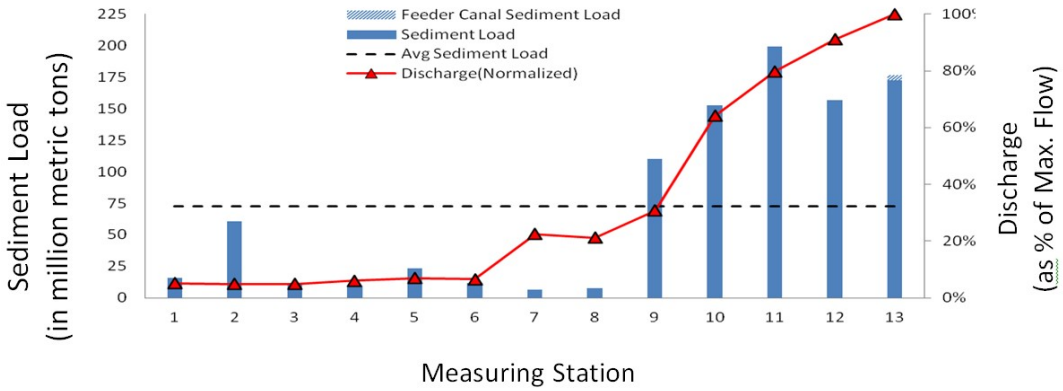


Figure 4.5: Comparison of the Annual Average Sediment Loads (for period 1999-2006) at Different Locations of National River Ganga

4.1.6 Recommended Actions: The main actions recommended are**:** (1) Determination of NRGB's hydrological status more accurately and in greater detail. (2) Preparation of water resources plan for NRGB with emphasis on wetlands, forests and distributed groundwater and surface water storages rather than large reservoirs storages. (3) Increase in anthropogenic water use efficiency through**:** (i) realistic pricing of fresh water; (ii) incentives, technical assistance, and allocation of water rights and entitlements to consumers; and (iii) reuse and recycling of water. (4)

Governmental policy shift to bring NRGB's waters under natural resource management, with emphasis on resource preservation, stakeholder control, expert guidance and regulation. (5) Ensuring longitudinal river connectivity and E-Flows at dams, barrages and other manmade interferences, and adoption of new criteria for approving such projects. (6) Control of water withdrawals in water-depleting regions. (7) Assessment and monitoring of sediment resources of the network including the quantity, quality and nutrient value of sediments trapped behind dams. (8) Research to determine ecological limits, thresholds and interconnections of NRGB's water resources, and river flow health assessments within the framework of ecohydrology.

4.2. Mission 2 – Nirmal Dhara

4.2.1 **Introduction:** The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Ganga river's water quality had been acclaimed in ancient times, Its life-giving and healing qualities being described in Rajanirghanta (~300 AD) thus (*"The qualities of Ganga water are: Coolness, sweetness, transparency, high tonic property, wholesomeness, potability, ability to remove evils, ability to resuscitate from swoon caused by dehydration, digestive property and ability to retain wisdom*")**:**

अस्या जलस्य गुणाः शीतत्वम्, स्वादुत्वम, स्वछत्वम, अत्यन्तरुच्यत्वम्, पथ्तत्वम्, पावनत्वम्,
पापहारित्वम्, तृष्णामोहध्वंसत्वम्, दीपनत्वम्, प्रज्ञाधारित्वंच, इति राजनिर्घण्टः

In modern times, however, her water quality has been significantly affected by disposal of anthropogenic wastes into rivers, which has caused enormous harm to river biodiversity and the ecosystem goods and services provided by the river system. This underscores the necessity for restoring unpolluted flows in the Ganga River System.

4.2.2 Type of Wastes: Anthropogenic wastes disposed in the Ganga River System, graphically shown in Figure 4.6, include both solid and liquid wastes of hazardous and non-hazardous types generated from domestic, industrial and agricultural sources. Liquid wastes from large urban centres and industries are major point sources of pollution, while surface runoff containing agrochemicals and entrained solid wastes are some major non-point pollution sources.

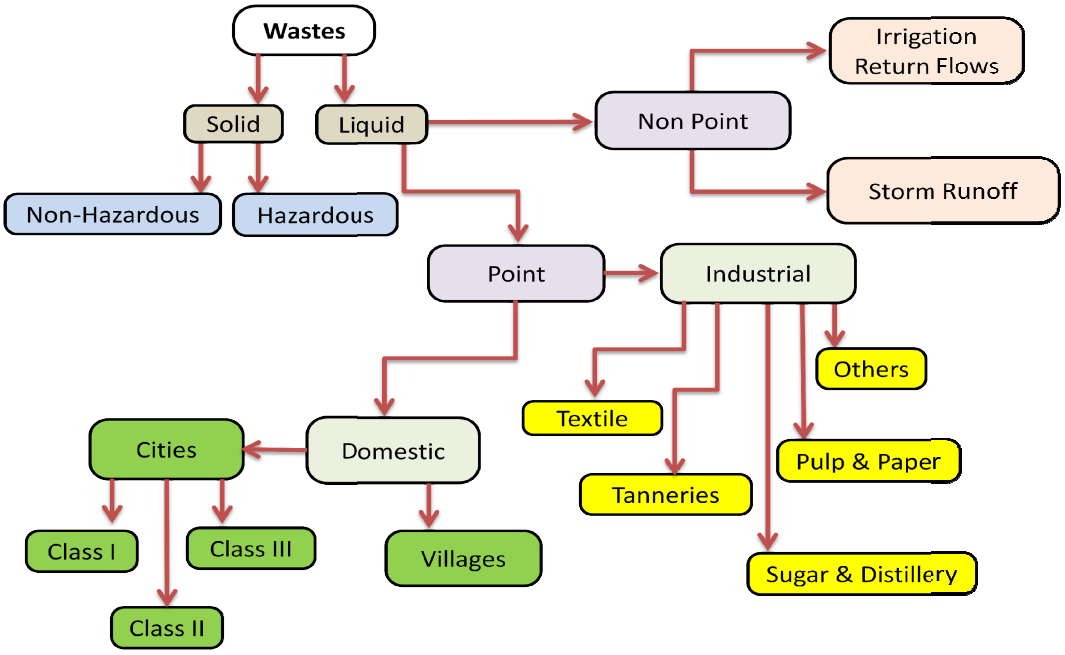


Figure 4.6: Types of Waste Generated in Ganga River Basin

4.2.3 Measures Needed to Achieve Nirmal Dhara: To check river pollution in the Ganga River Network, it is necessary to: (A) Prohibit major pollutant ingresses into rivers (hence adopting ZLD or Zero Liquid Discharge) by discharge of sewage (either treated or untreated) from Class I towns; discharge of industrial effluents (either treated or untreated) from any large, medium or cluster of small industries; direct injection of sewage and industrial effluents (either treated or untreated) into the subsurface; disposal of un-burnt and partially burnt corpses and animal carcasses in rivers; open defecation and dumping of municipal/industrial solid wastes or sludge in any river or its active flood plain; and construction of new residential, commercial or industrial structures in river flood plains. (B) Restrict other pollutant discharges by discharge of sewage (either treated or untreated) from Class II and smaller towns and villages;

disposal of sewage or industrial treatment sludges except in secure landfills/hazardous waste sites; discharge of industrial effluents (either treated or untreated) from small scale industry; disposal and/or discharge of mining and construction debris in any river or its floodplains; river bed farming and agricultural activities in the active flood plain; ritual immersion of idols; and floral and other offerings in rivers, washing of clothes, vehicles, etc., in rivers, and usage of agrochemicals in NRGB.

4.2.4 **Recommended Actions:** In keeping with the above requirements, the main recommendations are grouped under the following heads: (1) Management of Solid and Liquid Wastes Generated from Domestic/ Commercial Sources; (2) Riverfront Development, Floodplain Management and Rejuvenation of Water Bodies; (3) Management of Solid and Liquid Waste Generated from Industrial Sources; and (4) Management of Polluted Agricultural Runoff. Effective co-ordination of these activities is envisaged through a high-level constitutional body tentatively named the 'National River Ganga Basin Management Commission' (NRGBMC), pending whose formation the NMCG or some other dedicated government body may coordinate the activities. Project planning for urban works should begin with preparation of detailed Urban River Management Plans (URMP) for Class I towns, and subsequently also for Class II and Class III towns. The URMPs should be followed by preparation of DPRs, following which funds should be allocated for project implementation. Fund allocation should be prioritized for projects designed to prevent direct discharge of large quantities of liquid waste into the River System (Priority Level I), followed by projects designed to prevent direct discharge of large quantities of solid waste into the River System (Priority Level II), followed by projects concerning river-frame development and restoration of floodplain in urban areas along the Ganga River System (Priority Level III). Other projects under Mission Nirmal Dhara may be executed at still lower priority depending on availability of funds.

4.2.5 Implementation Scheme: Financing of the above projects may be obtained from central/state governments, local revenue, corporate and private donations and grants, low cost debt from multinational organizations, commercial debts from banks and private equity. Category A and Category B projects are recommended for execution through the PPP route (such as the DBFO model) with initial investment from the service provider, while Category C projects may be executed by the concerned industries themselves and through SPVs for industrial clusters. Category D projects may be synergistically executed with other government projects as per actions desired under other Missions of GRBMP. It is also recommended that the most polluted reaches of the river network be first targeted under MND. Thus, several major towns have been identified for priority action regarding sewage management on River Yamuna (Delhi, Faridabad, Vrindavan, Mathura and Agra), Ramganga (Moradabad), Gomti (Lucknow), and Ganga (Haridwar, Garhmukhteshwar, Kanpur, Allahabad and Varanasi), as shown in Figure 4.7. For overall implementation of MND recommendations in NRGB, financial work packages have been estimated for different categories of projects. Appropriate monitoring and feedback mechanism has also been suggested for sustainability of the projects.

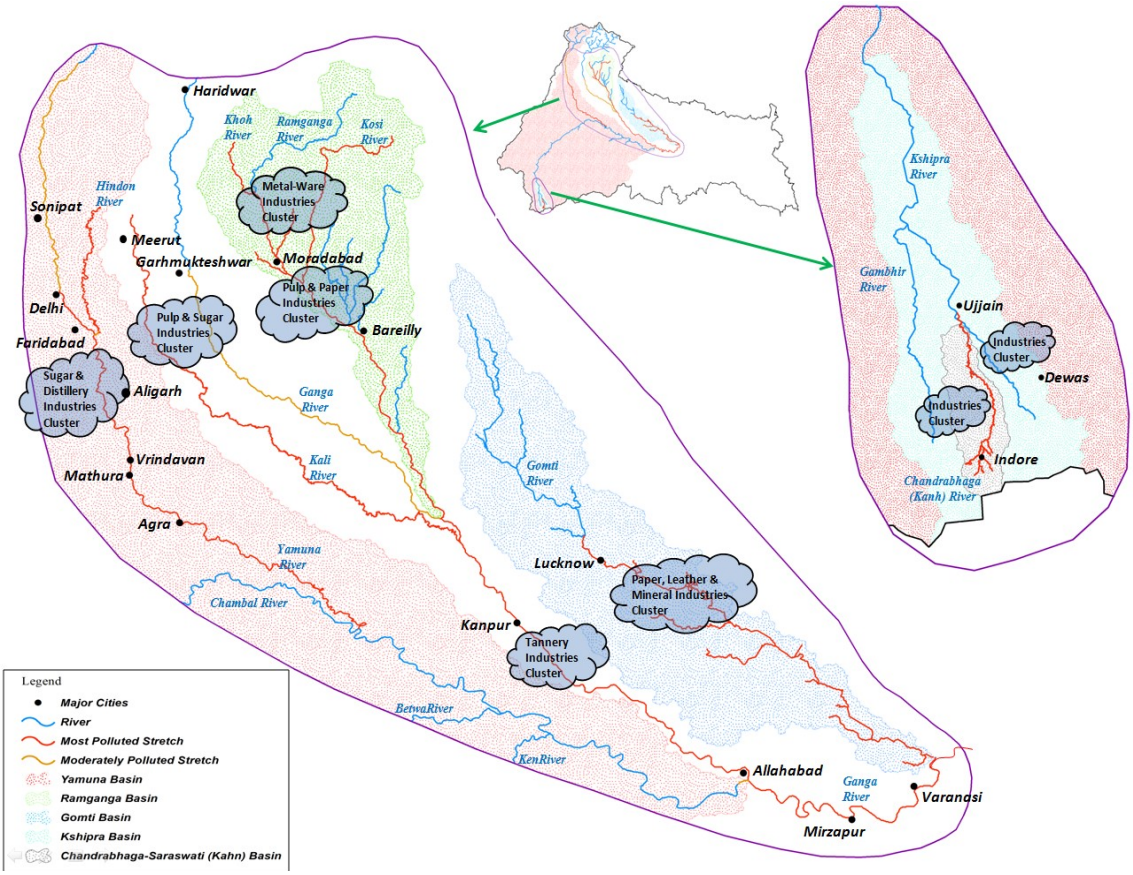


Figure 4.7: Most Polluted Stretches and their Pollution Sources in National River Ganga Basin

4.3. Mission 3 – Ecological Restoration

4.3.1 Introduction: The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Ecological restoration of National River Ganga is urgently needed since river biodiversity is being rapidly lost. A rough idea of the loss of species biodiversity in the river is evident from the progressive loss of fish catch at Allahabad since 1950, vide Figure 4.8. In general, the biodiversity of River Ganga is unique, as it synthesizes three major eco-regions of India situated along different climatic gradients, namely: the Himalayan mountainous region in the upper reach, the Gangetic plains in the middle reach, and the estuarine region

(including the Hooghly-Matlah delta) in the lower reach. The overall biological profile of River Ganga is depicted in Figure 4.9.

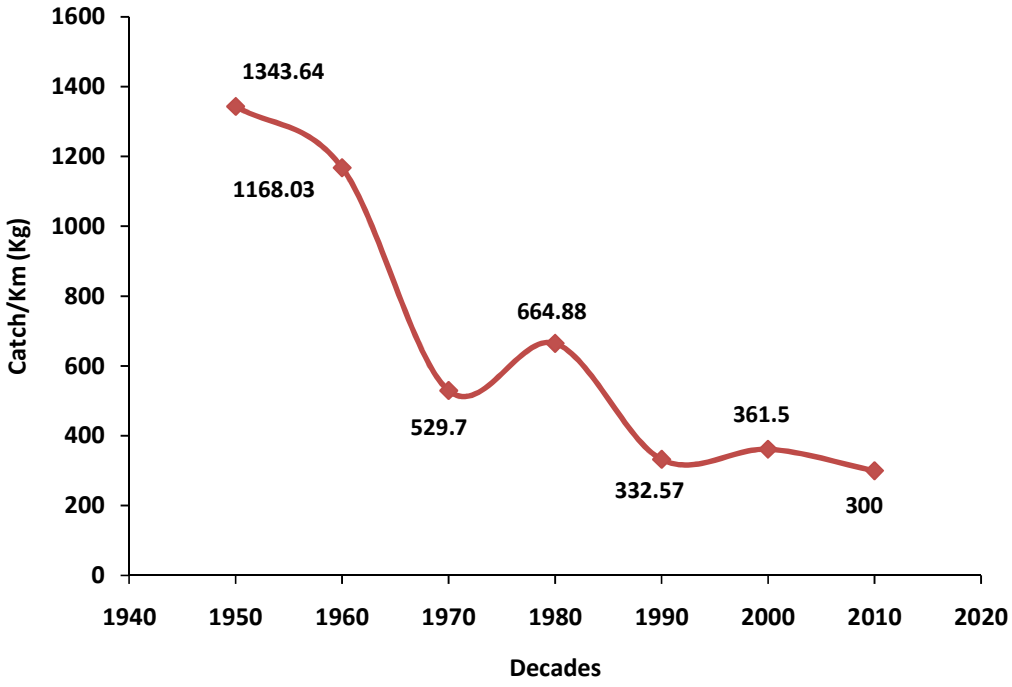


Figure 4.8: Decline of Fish Catch per km at Allahabad between 1950 to 2010 [IITC, 2014]

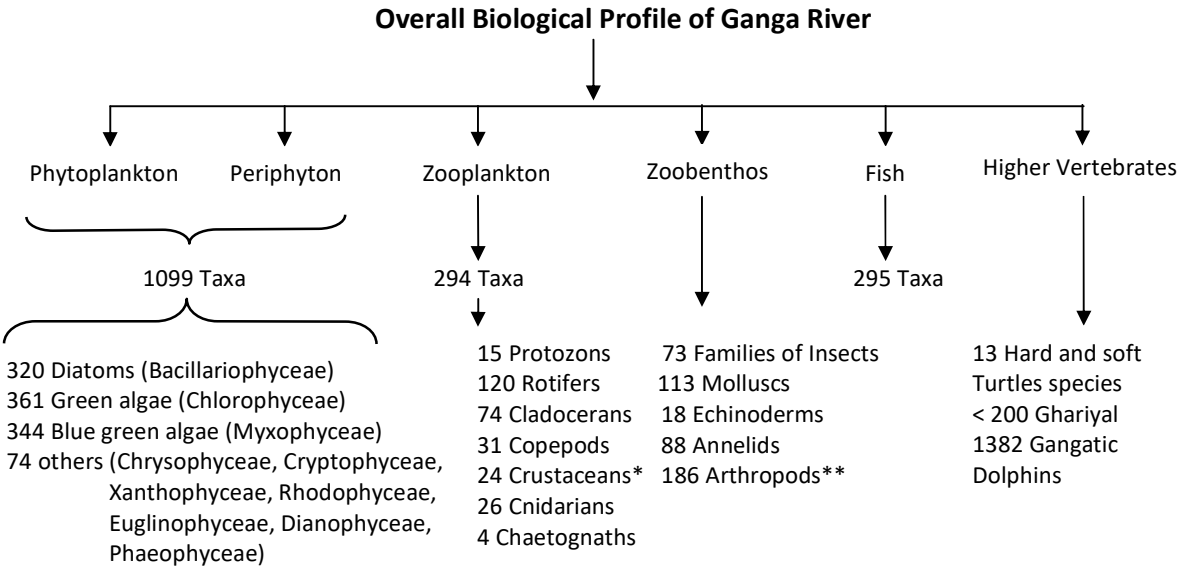


Figure 4.9: Biodiversity of River Ganga at a Glance

4.3.2 Threats to River Biodiversity: Eight main factors affecting the habitat of aquatic species of National River Ganga and causing loss of her biodiversity were identified, viz.**:** (i) Habitat Fragmentation by dams and barrages; (ii) Habitat Shrinkage due to increased water diversions and withdrawals from rivers; (iii) Habitat Alterations by gravel and sand mining from river beds and construction of embankments, levees, guide walls, etc.; (iv) Habitat Pollution by influx of municipal, industrial and agricultural wastes; (v) Habitat Invasion by alien river species; (vi) Habitat Encroachment by constructions in floodplains and river bed farming; (vii) Habitat Disturbances by plying of noisy vessels, dredging, etc.; and (viii) Habitat Malnutrition by the trapping of nutrient-rich sediments behind dams.

4.3.3 Recommended Actions: Given the above threat factors, the measures recommended are**:** (1) Restoration of longitudinal connectivity along with E-flows at dams, barrages and other obstructions. (2) Maintenance of lateral connectivity across floodplains. (3) Restoration of unpolluted river flows. (4) Restrictions on river bed farming and gravel- and sand-mining from river beds. (5) Restrictions on plying of noisy vessels, dredging, and bed and bank modifications. (6) Control of alien species invasions, overfishing and fishing during spawning seasons. (7) River nutrient assessment and release of sediments trapped in dammed reservoirs into downstream river reaches. (8) Long-term bio-monitoring of the Ganga river network. (9) Synergising actions under this mission with the Dolphin Conservation Action Plan – 2010. (10) Comprehensive research on the ecological dynamics of the Ganga River System.

4.4 Mission 4 – Sustainable Agriculture

4.4.1 Introduction: The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Modern agricultural practices have been major causes of soil degradation and fertility loss, pollution of water bodies, and natural resource depletion in NRGB. Hence transition to sustainable agriculture is urgently needed to maintain NRGB's

ecosystem services. Arable land is the major constraint for agricultural growth in NRGB and water availability is a second major constraint. Yet, agricultural growth in NRGB almost quadrupled in forty years since the 1960s by adopting high-yield crops with high inputs of fertilizer and water, vide Figure 4.10. But intensive conventional agricultural practices with abundant use of water, agrochemicals, soil tillage, and mono-cropping practices have increased soil erosion and degradation, depleted soil nutrients and soil biodiversity, dwindled the basin's waters, and polluted its ecosystems. Hence urgent reforms are needed to combat these negatives with practicable measures.

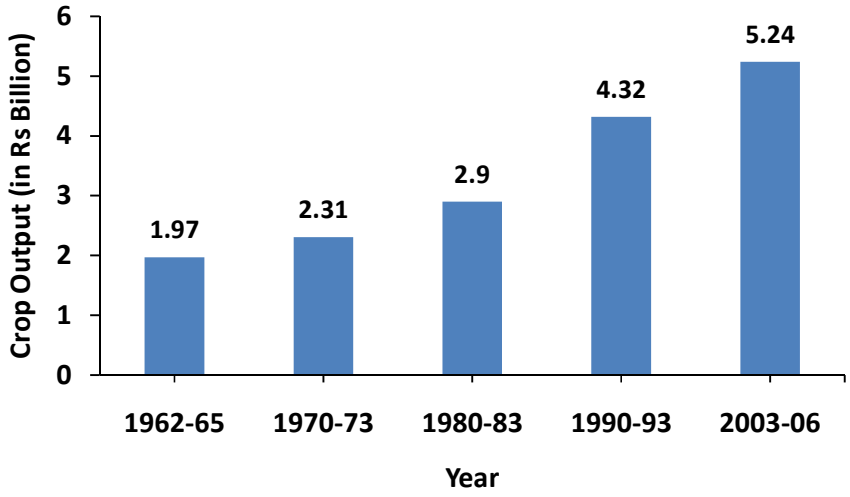


Figure 4.10: Average Crop Output Value per District in NRGB between 1962-65 and 2003-06

4.4.2 Recommended Actions: The main reforms recommended to minimize negative environmental impacts on NRGB while maintaining agricultural productivity and economic viability are identified as: (1) Adoption of Conservation Agriculture (involving no tillage, crop diversification, and permanent organic soil cover), especially in degrading lands, to enhance long-term soil fertility and agricultural output. (2) Promotion of Organic Farming where essential and/or economically feasible. (3) Economically beneficial improvements in water and nutrient application techniques in rice cultivation, especially by SRI (i.e. System of Rice Intensification) and Urea Deep Placement. (4) Promoting other established resource

conservation technologies where feasible. (5) Promoting regional (landscape-scale) resource conservation steps to counter monotonous agroecosystem impacts. (6) Infusing experimentation, adaptability and flexibility in NRGB's agricultural practices to synthesize traditional knowledge with ongoing and future scientific discoveries. (7) Devising appropriate policy measures to implement the above recommendations within the existing socio-cultural, economic and institutional framework prevalent in different regions of NRGB.

4.5 Mission 5 – Geological Safeguarding

4.5.1 **Introduction:** The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Geologically, river networks tend to achieve equilibrium between tectonic uplift and erosional phenomena in the basins, but both factors have come under significant anthropogenic influence in modern times. Hence geological safeguarding and geomorphological upkeep of the basin are of key importance for the integrity and functional stability of NRGB. The identified geological vulnerabilities of NRGB include disruptive underground activities such as excavations, explosions, tunneling, mining, fracking, and over-withdrawal of ground-water from confined and semi-confined aquifers, as well as over-ground activities such as the operation of large reservoirs. Anthropogenic geomorphological damages are identified to be primarily due to harmful land-uses that enhance erosional stresses.

4.5.2 **Recommended Actions:** The recommended actions are**:** (1) Control/ restriction of geologically hazardous activities including deep groundwater withdrawals, underground excavations, explosions, tunnelling, mining, fracking, and operation of large reservoirs. (2) Region-specific restrictions on geo-morphologically harmful land-use practices such as deforestation and construction activities on hill slopes and in floodplains, excessive agricultural tillage, sand and gravel mining from river beds, and river bank modifications. (3) Drainage improvement

of low-lying areas and stabilization of disturbed areas. (4) Mapping river migration zones, and continuous geological monitoring of NRGB.

4.6 Mission 6 – Basin Protection Against Disasters

4.6.1 **Introduction:** The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. NRGB is prone to catastrophic natural disasters that can significantly harm the basin's ecosystems, and such disasters have been highly accentuated by modern anthropogenic activities. Hence special measures are needed to protect the basin against natural disasters. But out of many natural disasters that affect human communities, and apart from *Earthquakes* which are covered under Mission Geological Safeguarding, the major natural disasters of real concern for the basin's ecosystems are few, viz.**:** *Extreme Floods*, *Extreme Droughts*, *Forest Fires*, *Tropical Cyclones*, *Landslides*, and *Epidemics and Biological Invasions*.

4.6.2 **Recommended Actions:** The main recommendations are**:** (1) Routine hydro-meteorological and biological events – often perceived as disasters – are usually beneficial for the basin; hence they should not be countered. (2) To withstand catastrophic disasters, ecosystems need strengthening by preserving wetlands, promoting mixed indigenous forests and vegetation, and curbing land-use disturbances and encroachments by humans. (3) Extreme Floods are typical of sediment-charged Himalayan rivers of NRGB, to combat which floodplain regulations and vegetative measures are preferable to embankments/ levees, since the latter create perched rivers and increase the flood damage potential; but upstream dams (with longitudinal connectivity and environmental flows) may prove beneficial if sediment trapped behind dams can be transferred to downstream floodplains. (4) NRGB's ecosystems have evolved over time against certain fire and biological regimes; hence the ecology of Forest Fires and of Epidemics & Biological Invasions in NRGB's ecosystems needs to be studied extensively. Until then, active interventions to counter such events should be limited to

checking harmful anthropogenic activities. (5) Landslides in the Upper Ganga Basin and other hilly regions are aggravated by deforestation, road and building constructions, and unsafe debris disposal, which need to be strongly checked. (6) Early rejuvenation of disaster-struck ecosystems should be aided by re-introducing indigenous species resistant to the specific disaster types and re-creating an enabling physical environment.

4.7 Mission 7 – River Hazards Management

4.7.1 Introduction: The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Several river-related disasters in India in recent years bear testimony to the fact that human disturbances have increased the intensity of these disasters and vulnerability of communities towards these. Hence it is necessary to identify hazards related to anthropogenic disturbances on rivers and to formulate suitable means to reduce the risk. Now flood control strategies in most river basins in India are primarily embankment based. But manmade structures have influenced the natural flow regime of rivers and modified the flood intensity, frequency and pattern. Moreover, many Himalayan rivers are highly sediment charged, and the rising riverbed and reduction in carrying capacity due to extensive sediment deposition in upstream reaches of a barrage has been a major problem. The engineering assumption that jacketing the river would increase the velocity and lead to scouring has instead resulted in silting of river beds and increased water logging and soil salinity in adjoining floodplains. The construction of protective levees and dykes, plus the large sediment flux from Himalayan catchments, has further complicated the flooding problem. In many cases, large areas have been inundated due to breaches in embankments coupled with rapid shifting of rivers. Unplanned roads and bunds have also caused severe drainage.

4.7.2 Recommended Actions: The main recommendations are**:** (1) Preparation of basin scale flood-risk maps based on scientific data and reasoning, and linked to an online data base and flood warning system. (2) Drainage improvement and land reclamation in low-lying areas to be taken up systematically and urgently, given successful case histories from different parts of the world. (3) Assessment of soil salinity and its mitigation strategy including the use of salinity resistant crops and soil improvement practices. (4) Alternatives to embankments for flood management with emphasis on 'living with the floods' concept, which may include floodplain zoning and other non-structural approaches. and an urgent need for people from academia, governmental organizations, NGOs, social institutions and the society at large to work together for this. (5) Research on sediment dynamics and its application in river management projects for designing sustainable river management strategies. The Kosi basin could be taken up as a case study. (6) Some pilot projects undertaken in partnership with state governments, e.g.**:** (a) Reactivation of paleochannels in the Kosi basin and design of flood spillway; (b) Improving drainage congestion caused by unplanned rail/road network by providing additional culverts and pathways in several parts of UP and Bihar; (c) Designing canals to drain water from permanently waterlogged areas; (d) Initiation of flood awareness programme and educating people to move away from flood-prone areas; and (e) Developing reliable flood forecasting system for specific river basins through modeling, and better communication systems for timely action.

4.8 Mission 8 – Environmental Knowledge-Building and Sensitization

4.8.1 Introduction: The Ganga River Network was adopted as the primary indicator of health of the National River Ganga Basin (NRGB) in GRBMP, and human-technology-environment aspects were factored in to assess the basin's resource dynamics. Basin planning and management combine diverse natural resources (water resources, land resources, biological resources, etc.) and processes (river dynamics, geological phenomena, atmospheric processes, etc.) with traditional wisdom and

grassroots knowledge. Hence it is necessary to build a comprehensive data bank to enable meaningful analyses and obtain quantitative indicators of NRGB's status. Moreover, since NRGB's welfare needs the co-operation and help of both formal and informal sectors of society, the data bank – along with community-specific educational material and programmes on NRGB's environment – should be accessible to citizens to enable their participation in the NRGB's upkeep.

4.8.2 Recommended Actions: The main recommendations are**:** (1) Establishment of a comprehensive Data Bank by continuous collection, processing and storage of information on the basin's natural resources, anthropogenic activities, and environmental monitoring of basin; (2) Preparation of secondary results (representative parameters, charts, tables, etc.) based on primary data; (3) Preparation of documents and materials for easy understanding by non-specialized people; (4) Keeping all the above information in open domain for easy access by interested individuals and institutions; (5) Conducting educational workshops and campaigns with stakeholders and interested citizens to enable their sensitization and comprehensive understanding of basin processes; and (6) Conducting ground-level monitoring and field researches of NRGB's environment with stakeholder participation.

5. Implementation of GRBMP Recommendations

5.1. Principles of Usage of Water in National River Ganga Basin

(1) The usage of water shall be posterior to nature and ecology.

(2) The usage of water for society shall have sequential priority from 'basic human needs' to 'livelihoods' to 'developmental activities'.

(3) Within each priority, water usage shall be institutionalized on the principles of equity, resource conservation and protection.

5.2. Prohibition of Environmentally Ruinous Activities in NRGB

S No	Activity Prohibited	Explanatory Note
1.	Engineered diversion and/or storage of water in any river unless E-flows are maintained in the immediate downstream of the diversion/storage.	*"E–Flows" are the flow regimes needed to maintain the ecological integrity of a river and the goods and services provided by it. It is computed by the Building Block Method or other standard holistic methods.*
2.	Discontinuity in flow in any river due to engineered diversion/ storage in the river.	*This measure conforms to the "Continuous Flow" ("Aviral Dhara") criterion of Vision.*
3.*	Discharge of sewage (either treated or untreated) from Class I towns, either directly or indirectly, into any river.	*This measure conforms to Unpolluted Flow ("Nirmal Dhara") criterion, since even treated sewage as per existing norms carries significant disease-causing pathogens* [IITC, 2010a]
4.*	Discharge of industrial effluents (either treated or untreated) from any large or medium industry or cluster of small industries, directly or indirectly, into any river.	*This measure conforms to the "Unpolluted Flow" ("Nirmal Dhara") criterion, since even treated effluents often contain significant amounts of recalcitrant, slow-degrading pollutants.*
5.**	Direct injection of sewage or industrial effluents (either treated or untreated) into the subsurface.	*This measure fulfills the "Unpolluted Flow" criterion by protecting groundwater from pathogens and recalcitrant pollutants.*
6.	Disposal of un-burnt or partially burnt corpses and carcasses of animals in any river or riverbank or natural water body.	*These measures conform to the "Unpolluted Flow" ("Nirmal Dhara") criterion by protecting rivers and water bodies from significant pollution sources.*
7.	Defecation and dumping of municipal or industrial solid wastes or sludge in any river, riverbank, active floodplain of river, or natural water body.	
8.	Construction of new permanent structures for residential, commercial or industrial use in the active flood plain of any river.	*This action conforms to the Vision criterion of geological and ecological integrity of river space.*

* Measures 3 and 4 are intended to curtail the present practice of discharging "treated" wastewater into rivers, since these wastewaters are only partially treated, and are therefore polluting. If they are fully treated, then they can be readily reused or used in place of fresh water. Thus, complete treatment of the wastewater serves a dual purpose of preventing pollution and saving on fresh water usage. The technological and financial viabilities of complete treatment have been explained in Mission Nirmal Dhara.

** Measure 5 envisages that, if treated wastewaters seep through the soil into the water table, they can be purified by slow filtration and biochemical processes in the soil but not if they are injected directly into groundwater. Hence, the treated wastewater should be held in an unlined water body to allow for seepage into the soil. Moreover, the ponds/lagoons into which treated wastewater is discharged should be in an accessible place for ready inspection or monitoring at any time.

5.3. Restriction of Environmentally Harmful Activities in National River Ganga Basin

The following anthropogenic activities are potentially damaging for the NRGB environment. Their allowance, prohibition or regulation should be based on their actual environmental impacts assessed in specific situations as also their social and economic implications.

1. Discharge of sewage (either treated or untreated) from Class II Towns and smaller towns and villages, directly or indirectly, into rivers.
2. Disposal of industrial/ municipal solid wastes and sludge (from treatment of sewage or effluents) to be restricted everywhere except in secure landfill/ hazardous-waste sites.
3. Discharge of industrial effluents (either treated or untreated) from small scale industrial units into rivers.
4. Disposal and/or discharge of mining and construction debris in any river's flood plain, river bank or in the river itself.
5. Construction of bridges and associated roads, jetties, ghats, ports and permanent hydraulic structures (*for water storage, diversion or control, or channelization*) in rivers.
6. Permanent constructions in floodplains that affect lateral connectivity and/or hamper flood drainage.

7. Withdrawal of ground water by electric/diesel operated shallow or deep tube wells.
8. Sand mining, dredging, stone crushing, sediment removal, and mining of other materials from river beds.
9. Plying of noisy vessels, dredging, and river bed and bank modifications.
10. Agricultural activities in river beds and active flood plains of rivers.
11. Commercial fishing or aquaculture in rivers.
12. Ritual immersion of idols, and floral and other offerings in rivers.
13. Washing of clothes, vehicles, etc. in rivers.
14. Deforestation of hill slopes, notified forests and other sensitive areas.
15. Hazardous or harmful emissions that can directly or indirectly affect terrestrial waters (such as sulfur/ nitrous oxides, pulverized fuel ash or 'flyash', etc).
16. Use of chemical fertilizers and pesticides in agriculture, horticulture, aquaculture, forestry, etc.
17. Sale and use of pharmaceutical, cosmetic, personal care and other products of domestic or institutional consumption that contribute harmful pollutants into the aquatic environment.
18. Any activity that can lead to geologically disruptive phenomena such as heightened seismic activity, ground subsidence, slope instabilities, landslides, and leaching/ erosion of contaminants into water bodies.
19. Cattle grazing on semi-barren hill slopes or in over-grazed areas.
20. Use of levees or embankments as major flood control devices in sediment-charged Himalayan rivers.
21. Road and building constructions and haphazard debris disposal in mountainous regions and forests.

5.4. Promotion of Environmentally Beneficial Activities in National River Ganga Basin

The following activities and interventions shall be promoted through both public and private mobilization to improve and invigorate the NRGB environment.

1. Reuse and/or recycle of domestic and industrial wastewaters (after due treatment) and use of products derived from sewage sludge, with appropriate mechanism for commercial use/ reuse wherever possible. Such mechanism may include higher pricing for fresh water over recycled water and for chemical fertilizers over organic fertilizers.
2. Development of much-needed pollution-controlling infrastructure, such as sanitation, sewerage and sewage treatment facilities for residential areas, industrial effluent treatment plants, and secure solid waste and hazardous waste landfill sites.
3. Facilities for environmentally safe cremation/burial of corpses and disposal of animal carcasses.
4. Ground water recharge with unpolluted water (*including use of kharif canals, paleo-channels, 'nalas', check dams, unlined ponds and lagoons, etc.*) to raise groundwater levels where needed and enhance river base flows.
5. Increasing water availability in basin through wetlands, forests and distributed surface and ground water storages.
6. Realistic pricing of fresh water with incentives, technical assistance and allocation of water rights and entitlements to promote efficient water usage.
7. Higher efficiencies in irrigation water use (through appropriate irrigation and farm management techniques, rationalization of cropping patterns, recycling of return flows, etc.) for agriculture, horticulture and fodder cultivation.
8. Higher efficiencies in institutional, commercial, industrial, domestic, municipal and community water uses through minimization of losses, wastage control and provision of adequate water treatment facilities.

9. Long-term bio-monitoring of the Ganga River Network.
10. Nutrient assessment of river reaches and reservoir-trapped sediments, and release of dammed sediments into downstream reaches and floodplains.
11. Afforestation/ grassland development of degraded forests/ grasslands, wastelands and denuded hill slopes (for control of surface runoff and soil erosion, slope stabilization and enhanced groundwater recharge).
12. Appropriate measures for flood mitigation in floodplains.
13. Protection of breeding areas and natural habitats of indigenous and migratory species (including fishes, birds, reptiles, amphibians and mammals), and preventing the spread of exotic species in rivers and water bodies.
14. Eco-friendly tourism, pilgrimage and recreational activities in rivers and riverbanks.
15. Removal of slum clusters and other human encroachments from active flood plains of rivers, and the use of the flood plains for development of water-recharge structures and ecological parks.
16. Promotion of Conservation Agriculture (especially in degrading farmlands) and of agricultural resource conservation methods such as micro-irrigation, SRI, Urea Deep Placement, Raised Bed Planting, Laser Land Levelling, etc.
17. Exploring alternate farming systems with use of bio-fertilizers and bio-pesticides (in place of chemical fertilizers and chemical pesticides), reduced soil tillage and nutrient washout in agriculture, horticulture, aquaculture, forestry, etc., to protect groundwater from agricultural pollutants.
18. Promoting landscape-scale agricultural systems to mitigate concentrated agroecosystem impacts.
19. Strengthening of ecosystems by preserving wetlands, promoting mixed indigenous forests and vegetation, and curbing land-use disturbances and encroachments by humans
20. Drainage improvement and land reclamation in low-lying areas to mitigate floods.

21. Promotion of integrated natural resource management instead of single-resource focus in all infrastructural and developmental projects in NRGB.
22. Regular collection, compilation and dissemination of environmental data of NRGB (including hydrological, geological, meteorological, land-use and pollution data) and maintenance of a historical database in public domain for ready access by any person/ agency.
23. Continuous ground-level monitoring through competent non-profit/ for-profit agencies of**:** (i) NRGB's environmental status, and (ii) implementation of Prohibited, Restricted and Promotional Activities.
24. Conduct regular educational programs – through competent non-profit/ for-profit agencies and institutions – for**:** (i) public awareness of NRGB's environmental problems and their remediation, and (ii) developing a healthy civic sense of environmental proprieties.
25. Periodic review of "GRBMP Action Plans and Their Implementation" with feedback from all concerned individuals and agencies including rural and urban local bodies.

Note**:** The last 3-4 measures are not intended to duplicate the works being done by specific government departments. Rather, they are aimed at enabling comprehensive environmental management of the NRGB by**:** (i) pooling the knowledge and efforts of government, private sector, academia, experts and common people, and (ii) environmental capacity building through the spread of scientific understanding and technical competence in both formal and informal sectors of society.

5.5. Envisaged Consequences of GRBMP Recommendations

The most direct and immediate result of implementing the above measures would be on the health of the Ganga River System (in terms of Quantity, Quality & Biodiversity of the river's waters). On issues of national and socio-economic importance, the changes (positives and negatives) are likely to reflect immediately on various sectors, especially on Water & Sanitation, Disease & Health, Flood Impacts, Agriculture & Food Security, Energy Generation, and Ecosystem Services (such as aquatic foods and fish catches, cultural, religious & recreational activities), vide Fig. 5.1. While implementation

of the proposed measures will incur costs, it is envisaged that they will have significant net positive gains for the region in the foreseeable future.

Figure 5.1: Major Sectors Likely to be Influenced by GRBMP Action Plan

5.6. Implementation Mechanism

As evident from the above, a long-term program for implementation, monitoring, review and evaluation of environmental problems and interventions pertinent to NRGB are needed. Since these measures cover a wide variety of activities involving continuous monitoring and feedback from diverse sources, institutions and individuals, an independent agency is essential to conduct these activities in a coordinated manner. The challenge in implementation is to align and/or co-ordinate the interests of different actors (keeping in mind their resident times) along with involvement of ordinary stakeholders for achieving a wholesome Ganga river, as illustrated in Figure 5.2. It is therefore proposed that a nodal agency, tentatively termed "National River Ganga Basin Management Commission" (NRGBMC), with adequate resources and authority be set up to ensure the environmental health of NRGB. The NRGBMC is proposed to be set up by an Act of Parliament

as per Appendix III giving the tentative draft of a Bill [IITC, 2013]. The NRGBMC should comprise Legal Luminaries, Technical Experts, Government Functionaries and Civil Society Members.

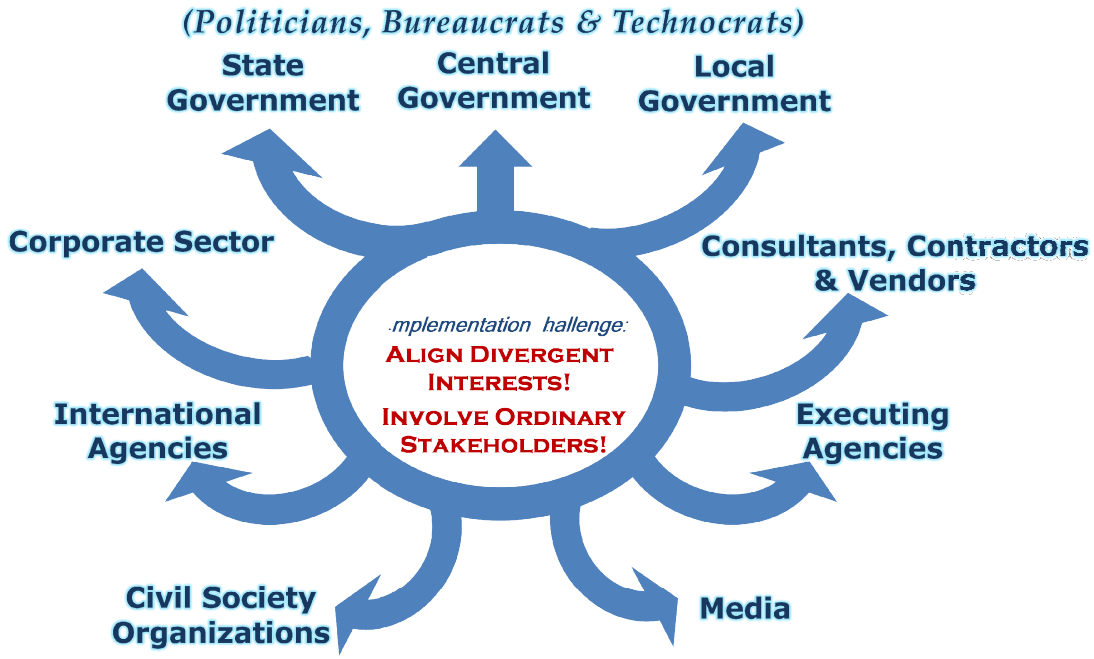


Figure 5.2: Implementation Challenges in Aligning Interests of Key Actors

The main task of the NRGBMC may be summarily stated as follows:

(1) The NRGBMC should take all measures necessary for the environmental conservation and development of National River Ganga Basin in a transparent and inclusive manner.

(2) Such measures shall include the following:

(a) Ensuring that E-flows are maintained in all rivers of the Ganga River Network at different locations and in different seasons.

(b) Protecting the geology and ecology of the National River Ganga Basin.

(c) Using of floodplains in appropriate manner, and after ensuring Environmental Impact Assessment for approval of major projects in flood plains.

(d) Ensuring both short-term and long-term measures for conservation and improvement of aquatic resources in National River Ganga Basin.

(e) Monitoring, review and dissemination of the National River Ganga Basin's environmental status in the public domain.

Note**:** All actionable measures of the GRBMP may not be implementable at one go, and the monitoring and review of environmental actions have to be a continuous process. The Technical Reports, Database and Action Plans of GRBMP can be taken as a starting point for the proposed NRGBMC.

5.7. Legislation for NRGBMC

The need for a new legislation and the constitutional provisions enabling the establishment of a new legislation for NRGBMC have been discussed in IIT-GRBMP Thematic Report titled "Mapping of Legislations Applicable to the Ganga River Basin" [IITC, 2011a]. Some of its conclusions are briefly recounted below as background to the proposed legislation.

5.7.1. Comprehensive Legislation for Management of NRGB

India has failed to develop its water resources through integrated river basin development, and inter-State conflicts over rivers have become common. But the Constitution has provisions enabling the Union to regulate interstate rivers in public interest. The Constitution gives full control over waters of a river to a State (List II entry 17), but the State's rights are subject to any law made by Parliament for the regulation and development of interstate rivers to the extent the control of the Union is declared by Parliament by law to be expedient in public interest (List I entry 56). This means that Parliament can make a law taking over the regulation, development and management of an interstate river for the common benefit of the States in national interest. The prevailing condition of National River Ganga warrants the immediate attention of law-makers for such a law.

For enacting the proposed law, it is important to locate subject matters in List II which may be seen as being in conflict with entry 56 of List I. Article 246 (1) confers exclusive jurisdiction on the centre to enact laws on subject matters enlisted in List I, whereas clause 2 of Article 246 grants such exclusivity to the states to enact law on subject matters enlisted in List II. Now Entry 56 of List I provides for "regulation and development of inter-state river and river valleys to the extent to which such regulation and development under the control of

Union is declared by Parliament by law to be expedient in the public interest." Thus, the matter of regulation and development of interstate rivers may not be in conflict with the legislative power of the states if the law refrains from impinging on matters within the competence of state legislatures.

The provisions of various existing legislations (enacted by the centre and states) indirectly affecting rivers and river basins relate to subjects on water, sanitation, irrigation, agriculture, pollution, fishing, ecology and biodiversity, environment, etc. Under most of these legislations, Authorities perform the necessary functions stated under the law, but interestingly no authorities are entitled to play a role in prevention of river pollution. In fact, no concerted effort has been made till date on the legislative front against exploitation of rivers in various ways. Many issues concerning river management do not fall within the present legislative frame, such as maintenance of environmental flows, protection of a river basin's ecology and biodiversity, maintenance of ground water table, consolidated plans for diversion of river waters in different stretches, discharge of sewage, obstructions to river flows and loss of connectivity, use of floodplains and active floodplains, etc. It is desirable, therefore, to adopt an integrated river basin management plan approach that focuses on maintenance and restoration of wholesomeness of rivers of the Ganga basin. Accordingly, the proposed Ganga River Basin Management Act should aim to prohibit and regulate activities that affect the wholesomeness of rivers, and establish authorities or institutions to regulate the activities thereon.

5.7.2. Objective of NRGBMC

The NRGBMC is intended to serve as a custodian of National River Ganga Basin (NRGB) and work for its upkeep and improvement on the premise that health of National River Ganga is a key indicator of the health of NRGB as a whole.

5.7.3. Functions of NRGBMC

The Commission is envisaged to fulfil the following functions**:**

Information and Communication:

- Procure primary and secondary data (both environment-related data as well as socio-economic, cultural, developmental and other data of NRGB) from government and non-government data collection agencies, and pre-process the data for possible errors and inconsistencies.
- Compile the above data along with those obtained by NRGBMC itself through environmental monitoring, and process them to obtain suitable representations in the form of maps, charts, parametric values, etc.
- Compile all useful environmental reports obtained from various sources in easily usable formats.
- Store all data and reports (soft- and hard-copies) in easily retrievable systems and make them accessible to interested users.

Environmental Monitoring and Impact Assessments:

- Conduct regular field measurements of environment–related data in NRGB for such information that are not regularly collected or available from other agencies. The data may be procured through the NRGBMC's in-house facilities and through outsourced works to technical and non-technical organizations and individuals (such as local governance bodies, schools, colleges, NGOs, community organizations, etc.)
- Conduct random field measurements of environment–related data of NRGB for specific or sporadic needs (such as to cross-check existing data or fill up gaps in data). The data may be procured through the NRGBMC's in-house facilities and through outsourced works as above.
- Pre-process all data collected for subsequent archiving and use.
- Conduct Environmental Impact Assessments of on-going and future developmental and infrastructural projects in NRGB as and when the need arises.

- Monitor developmental and infrastructural projects in NRGB for which EIA or preliminary environmental approval was granted by Commission.
- Assist in field measurements and monitoring that may be needed for investigation purposes.

Investigation:

- Investigate issues regarding non-implementation of measures relating to specified prohibition, restriction, conservation and promotion of activities.
- Investigate issues regarding non-compliance of policy decisions and guidelines issued by NRGBMC for environmental preservation of the National River Ganga Basin.
- Investigate issues regarding continuance of existing practices in contravention of NRGBMC's strictures.

Research and Development:

- Evaluate national and international research reports on river basins for their pertinence to the NRGB environment.
- Conduct need-based applied research as may be possible by NRGBMC.
- Identify other major research needs of NRGB for communicating to the government.
- Conduct economic, sociological and cultural analyses pertinent to NRGBMC data bank as well as other information procured from government or other sources.
- Review the impacts of anthropogenic activities in NRGB from time to time.

Policy and Governance:

- Review governmental Policies and Plans (existing and under consideration)
- Frame suitable Policies to ensure that the environmental needs of NRGB are met.
- Formulate good governance guidelines.

Advocacy and Sensitization:

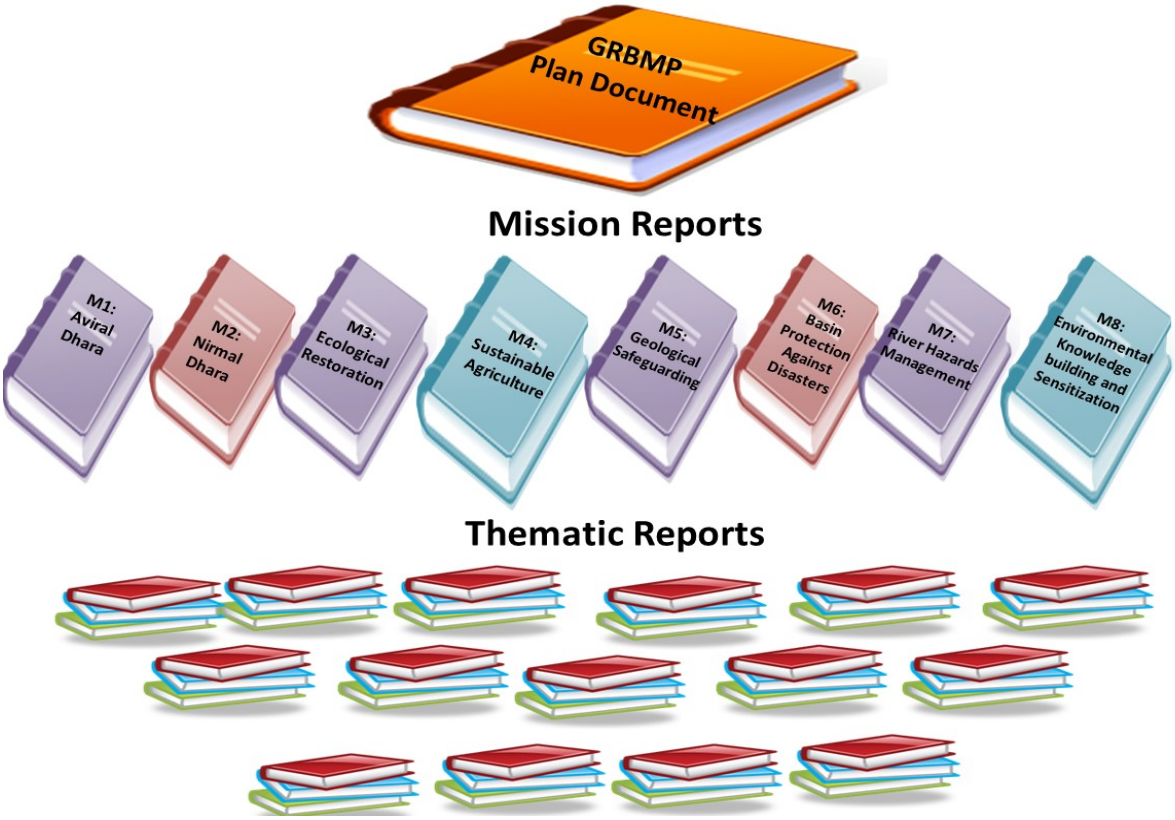
- Promote overall awareness of NRGB's environment and how NRGBMC's measures help in safeguarding and restoring it.
- Educate stakeholders (from rural communities to school students and special interest groups) on comprehensive understanding of complex environmental processes and their interaction with anthropogenic activities. This will involve preparing special educational material, training of field educators, and conducting regular educational programs and feedback from various types of stakeholders.
- Conduct advanced interactive programmes with stakeholders and experts through Seminars, Workshops, etc.
- Conduct special campaigns to sensitize and motivate people to participate in improving the health of NRGB.

5.7.4. NRGB Fund Generated by NRGBMC

The NRGBMC must be empowered to**:** (i) impose penalties/ damages on individuals and agencies for any violation of its norms and guidelines on restrictions and prohibitions of environmentally harmful activities in the NRGB, and (ii) reward individuals and agencies who contribute exceptionally to the health of NRGB either by their reformative actions or by their watchdog/ investigative actions in conformity with NRGBMC's goals and guidelines. All penalties and damages should be deposited in a specific fund with the Central Government. The said fund should be utilized by the Government on the recommendation and consent of the NRGBMC for environmental improvement of NRGB and to reward individuals and agencies who have made exceptional contributions for the health of NRGB.

6. GRBMP Documentation

The GRBMP is presented as a 3-tier set of documents. The three tiers comprise of: (i) Thematic Reports providing inputs for different Missions, (ii) Mission Reports documenting the requirements and actions for specific missions, and (iii) the main GRBMP Report synthesizing background information with the main conclusions and recommendations emanating from the Thematic and Mission Reports. It is hoped that this modular structure will make the Plan easier to comprehend and implement in a systematic manner.



Glossary of Technical Terms

The following technical terms have been used in this document. They may be defined as follows (in a simplified manner where possible for ease of understanding)**:**

(a) "**Active Flood Plain**" is the area on the two sides of a river that gets inundated by a flood having a mean recurrence interval of 2.33 years.

(b) "**Afforestation**" is the planting of trees to restore or re-establish forest cover.

(c) "**Aviral Dhara**" or "**Continuous Flow**" (in a river or stream) means continuity of flow in both time and space, including connectivity of flow throughout the river.

(d) "**Basin**" means the entire catchment (*of a water body or water course*) including the soil, water, vegetation and other natural resources in the area.

(e) "**Catchment**" (or "**Drainage Basin**") is the entire land area whose runoff from rain, snow or ice drains into a water body or a water course (before the water course joins another river or discharges into a water body.)

(f) "**Connectivity**" (of a river) means continuity of flow in the three directions, viz. longitudinal connectivity (along the length of the river), lateral connectivity (across the width of river), and vertical connectivity (below the water surface in vertical direction).

(g) "**Deforestation**" means removal or reduction of forest cover, especially when caused by anthropogenic activities.

(h) "**Degraded Forest**" means a forest having loss or reduction of native forest cover and/or vegetation density.

(i) "**Direct Injection**" (of water) means injection or introduction (of water) directly into subsurface waters through natural or artificial crevices, faults, channels or conduits without the natural passage through porous soil strata.

(j) "**Ecological Park**" is a protected area for conservation of native, endangered species.

(k) "**Ecology**" is the totality of relations between organisms and their environment. It includes the composition, distribution, amount, number and changing states of organisms within and among ecosystems.

(l) "**Ecosystem**" is a community of organisms and their physical environment, considered to function together as a unit, and characterized by a flow of energy that leads to trophic (or nutritional) structure and material cycling.

(m) "**E-Flows**" means Environmental Flows (*defined later*).

(n) "**Embankment**" is a raised wall of earth, stone or other material to hold back water within a water body or water course; it includes levees constructed on either side of a river as a flood protection measure.

(o) "**Engineered Diversion**" means a structure or device constructed or installed to transfer (part of) the river water into a canal or other engineering structure.

(p) "**Environmental Flows**" (*or* "***E-Flows***") are the regime of flows required to maintain the ecological integrity of a river and the goods and services provided by it, computed by Building Block Method (or other standard holistic methods).

(q) "**Flood**" means the overflowing of water from a water course or water body that inundates normally dry land.

(r) "**Flood Plain**" is the land area susceptible to inundation by flood waters.

(s) "**Flood Routing Channel**" is a channel designed to carry the excess water of a water course during high flows.

(t) "**Geologic Entity**" is an entity formed by ancient earth processes over geologic ages (hence over long periods of time, usually millions of years).

(u) "**Ground Water Recharge**" is replenishment (in part or wholly) of water depleted from ground water reservoirs.

(v) "**Hydrologic Cycle**" is the natural cyclic movement of water on earth (from oceans to the atmosphere by evaporation, then onto land by rain and snow, and back to the oceans by flow through rivers).

(w) "**Irrigation Return Flow**" means the return of unconsumed water from irrigation applications to the water source from which they were taken. The source is usually a natural water course, water body or groundwater.

(x) "**National River Ganga**" is the entire length of six head-streams in the state of Uttarakhand namely, Rivers Alaknanda, Dhauli Ganga, Nandakini, Pinder, Mandakani and Bhagirathi (starting from their originating glaciers up to their respective confluences at Vishnuprayag, Nandaprayag, Karnaprayag, Rudraprayag and Devprayag) as also the main stem of the river thereafter up to Ganga Sagar.

(y) "**Nirmal Dhara**" or "**Un-polluted Flow**" means flow in a river or stream that is not polluted by anthropogenic activities.

(z) "**Paleo-Channel**" is the remnant of an extinct river or stream that got filled with sediments deposited in later periods.

(aa) "**Water Body**" (or "**Surface Water Body**") is a depression on land or a lowland area that usually holds water or remains saturated through most of the year, such as a lake, tank, pond, marsh or swamp.

(bb) "**Water Course**" (or "**Surface Water Course**") is an overland channel (natural or manmade) through which water flows such as a river, stream, rivulet ("nala") or canal.

(cc) "**Watershed**" is same as Drainage Basin. [*Note*: The term "**watershed**" is also used to mean a "drainage divide" as per British usage, i.e. it is a ridge of high land dividing two areas that are drained by different rivers or water bodies.]

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Appendix I

Environmental Valuation: Examples from Australia

Economic Value of Ramsar-listed Wetlands in the Murray-Darling Basin, Australia.

The annual revenue generated in the Murray Darling Basin (MDB) was of the order of $15 billion in 2006. The basin is home to about 30,000 wetlands (including 16 Ramsar-listed sites spread over 630,000 hectares). A detailed analysis of one of the Ramsar sites – the Hattah Lakes – by the Australian Conservation Foundation (ACF) in 2010 showed that it generates large annual revenue from its ecosystem services (even excluding tourism and recreation). Extending the result to all 16 Ramsar wetlands of the basin, ACF estimated the total ecosystem benefits of the 16 wetlands at $2.1 billion as follows:

Ecosystem service		**$/hectare/yr**
Water filtration**:**	Includes retention, removal and transformation of excessive nutrients and sediment (representing the avoided cost of investment in a water filtration plant that would be required were the wetland not to exist.)	$2,900
Flood Control**:**	Controls excessive flows of water during flood events, thus avoiding downstream damage.	$204
Water Storage**:**	Water is stored within a wetland in times of high water flows and future flows are regulated and balanced out through drier times, reducing investment in additional weirs.	$14
Habitat Provision**:**	Habitat for birds and animals that provide insect predation and pollination services to surrounding farms.	$217
Other**:**	Carbon storage and groundwater recharge.	(*Not Valued*)
	TOTAL VALUE PER HECTARE:	$3,335
	AREA IN HECTARES OF RAMSAR WETLANDS:	630,000
	TOTAL VALUE OF ECOSYSTEM SERVICES (per annum):	**$2.1 billion p.a.**

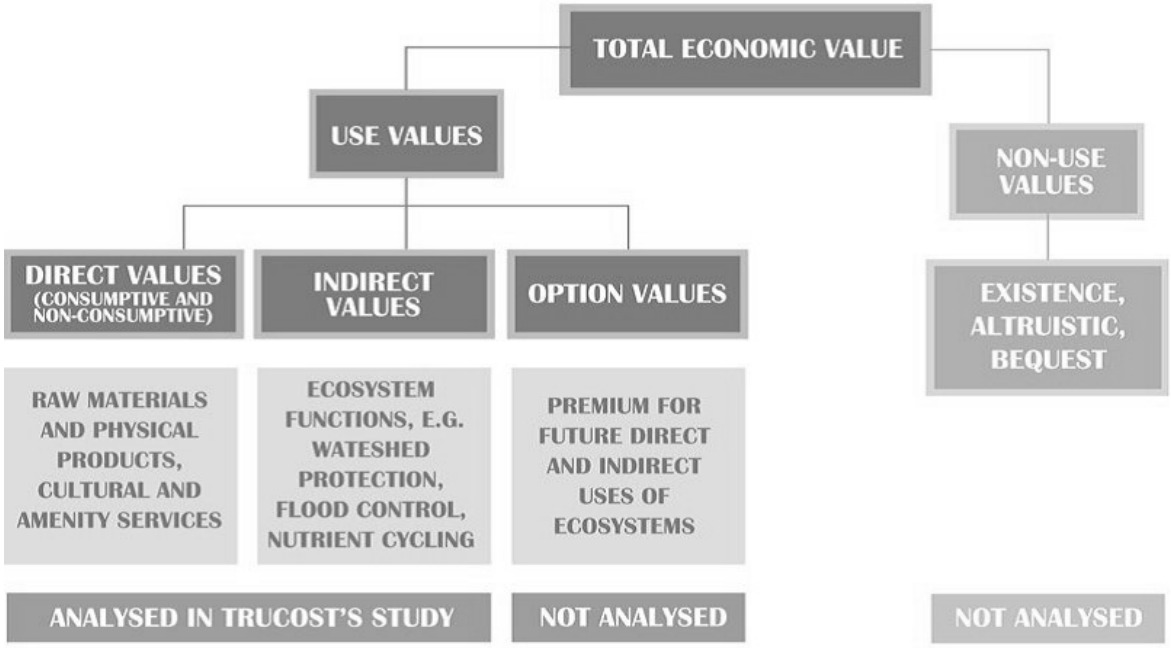
Clearly, without the MDB wetlands and rivers, the great productive base of our agrarian economy would not exist. Without water stored, filtered and

delivered through our rivers and wetlands, rural towns could not have drinking water, irrigators could not grow their crops and pastoralists could not water their animals. [*Adapted from: O'Connor, 2010*]

Economic Value of Yarra Valley Water supplied to Melbourne, Australia.

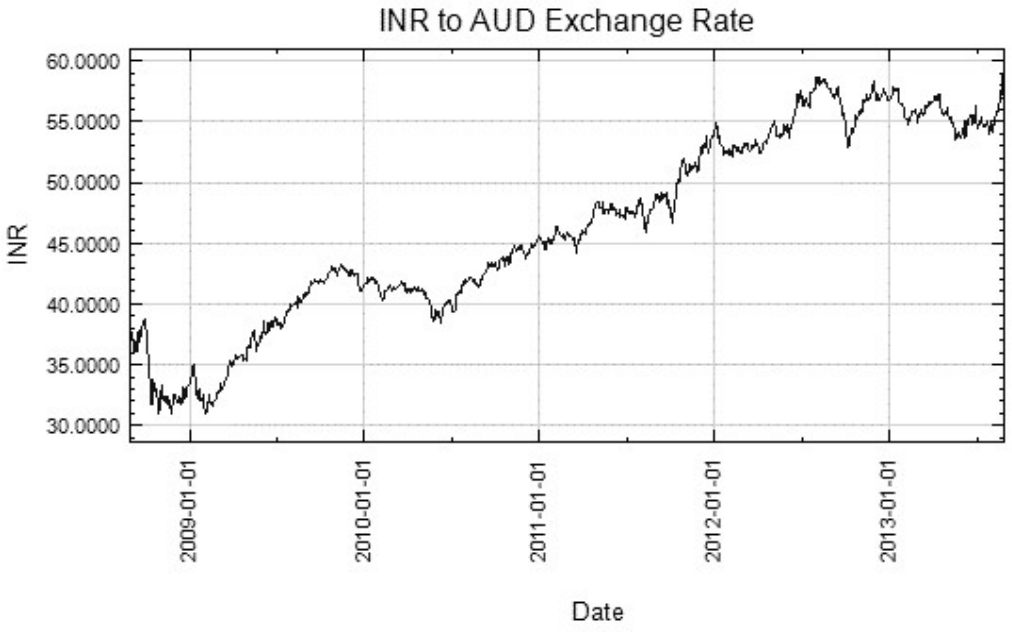
The Murray-Darling Basin (MDB) is the catchment for Murray and Darling rivers and their many tributaries, covering over one million km^2 or 14% of Australia, and generating one-third of Australia's food supply and 39% of national income from agriculture. The MDB Authority consulted on a MDB Plan that aims to restore the system to a state that enables it to avoid lasting damage to rivers, wetlands, forests and soils. The plan provides an integrated and strategic framework that includes sustainable diversion limits to restore regular flows, thereby improving the capacity of rivers and floodplains to provide "ecosystem services" such as increased carbon and nutrient recycling; groundwater replenishment; significant reduction in the economic losses associated with algal blooms and salinity; and growth in recreation and tourism industries generated by healthy rivers.

The Yarra River catchment – located adjacent to and south-east of MDB – covers over 4,000 km^2 and supplies around 70% of Melbourne's drinking water in 2011-12. Some 4,771,000 m^3 of water were released in the Yarra River in 2011-12 to improve the habitat for aquatic animals; support fish species; increase flood tolerant vegetation; maintain the shape of the river channel; and avoid a decline in water quality. Yarra Valley Water (YVW) commissioned Trucost Plc to estimate the "value of water". Trucost analysed the total value of water in the region to enable YVW to continue to provide sustainable and economically-efficient water management … rather than incurring the costs of damages later. In its analysis, Trucost included the UN System of Environmental-Economic Accounting for Water as a conceptual framework to highlight the Total Economic Value (recommended by FAO) based on different types of uses drawn from them, as depicted below. The study estimated the direct and indirect use values of water abstracted and distributed by YVW. Option and non-use values were not included in valuations due to limitations in quantifying them. Values were calculated in Australian Dollars (AUD) and adjusted for inflation to 2012 prices [*1 AUD ≈ Rs. 52 to 58/- in 2012, vide chart shown at the end of this section*].



Key findings**:** The analysis revealed that the indirect use value of water required to supply Melbourne amounts to an estimated AUD 5.85/m^3 (as against the domestic and commercial supply price of AUD 1.90–1.91/m^3). Variability in water scarcity over time contributed to wide fluctuations in indirect use values year on year. The value of water to Melbourne ranged from AUD 1.66/m^3 in 2010-11, when water was relatively abundant, to AUD 8.97/m^3 in the most water-scarce year analysed. The hydrological function had the highest indirect use value of the ecosystem functions analysed (AUD 4.85/m^3); of this, groundwater recharge had a far more significant value than freshwater replenishment due to limited groundwater availability in the Yarra valley. [*Adapted from: van Ast, 2013*]

Indian Rupee (INR) to Australian Dollar (AUD) exchange rates. [*Accessed 27-8-13 from: http://www.indexmundi.com/xrates/graph.aspx?c1=INR&c2=AUD&days=1825*]



Source: United States Federal Reserve Bank of New York

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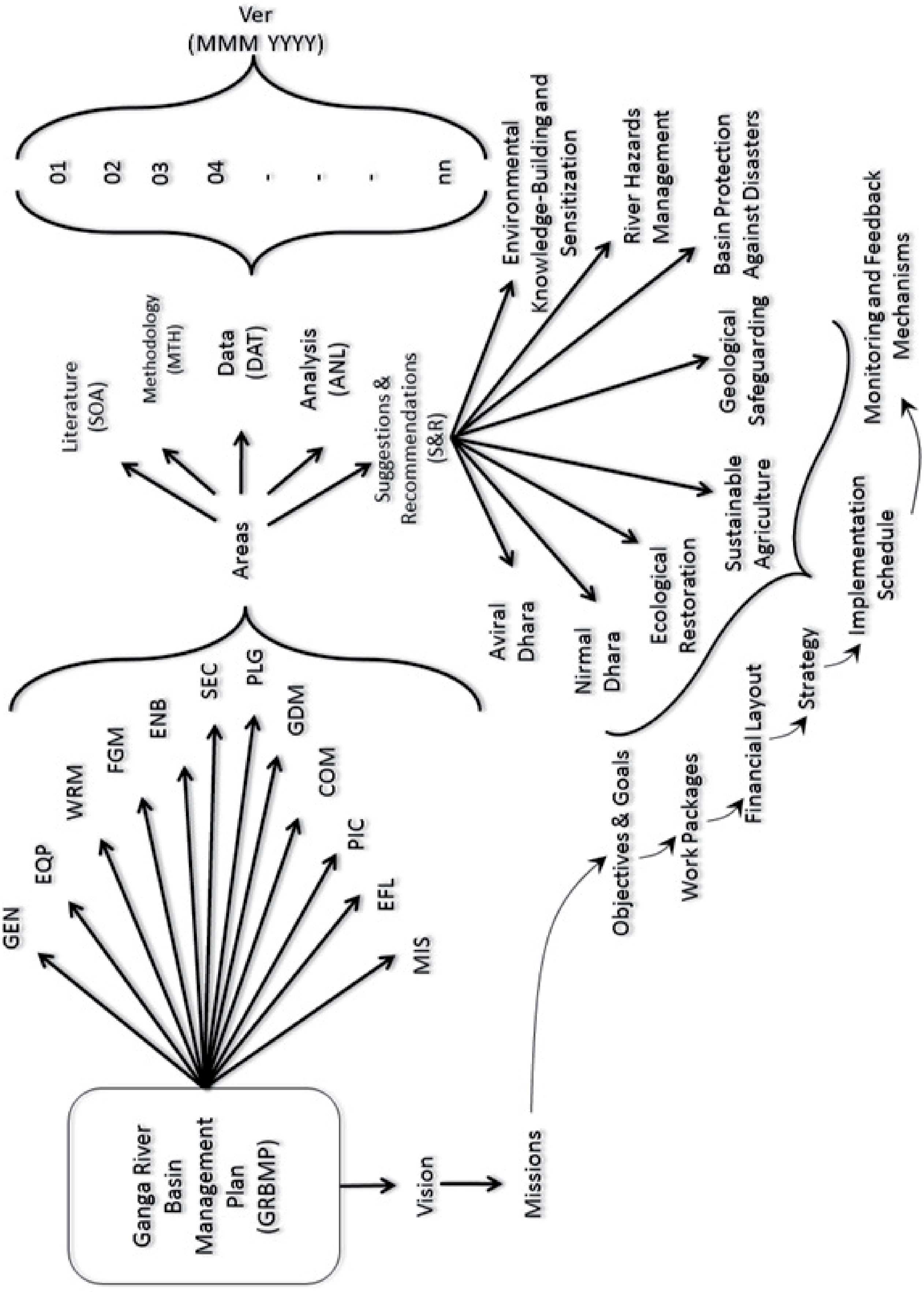
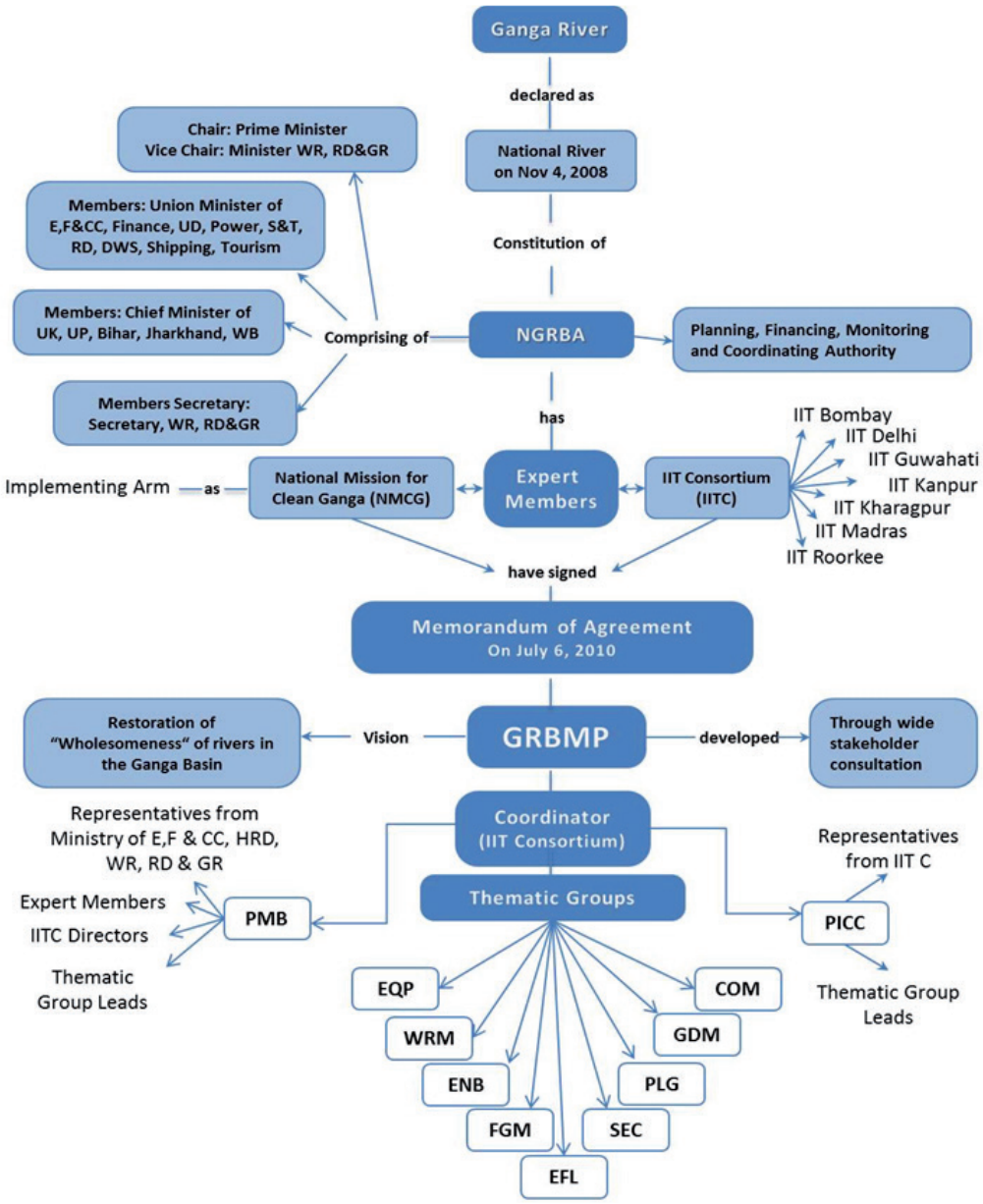


GRBMP WORK STRUCTURE

ORGANIZATIONAL STRUCTURE FOR PREPARING GRBMP



NGRBA: National Ganga River Basin Authority
NMCG: National Mission for Clean Ganga
MoEF: Ministry of Environment and Forests
MHRD: Ministry of Human Resource and Development
MoWR, RD&GR: Ministry of Water Resources, River Development and Ganga Rejuvenation
GRBMP: Ganga River Basin Management Plan
IITC: IIT Consortium
PMB: Project Management Board
PICC: Project Implementation and Coordination Committee

EQP: Environmental Quality and Pollution
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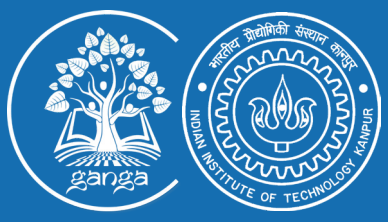

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