Ganga River Basin Management Plan - 2015

Extended Summary

January 2015

by

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

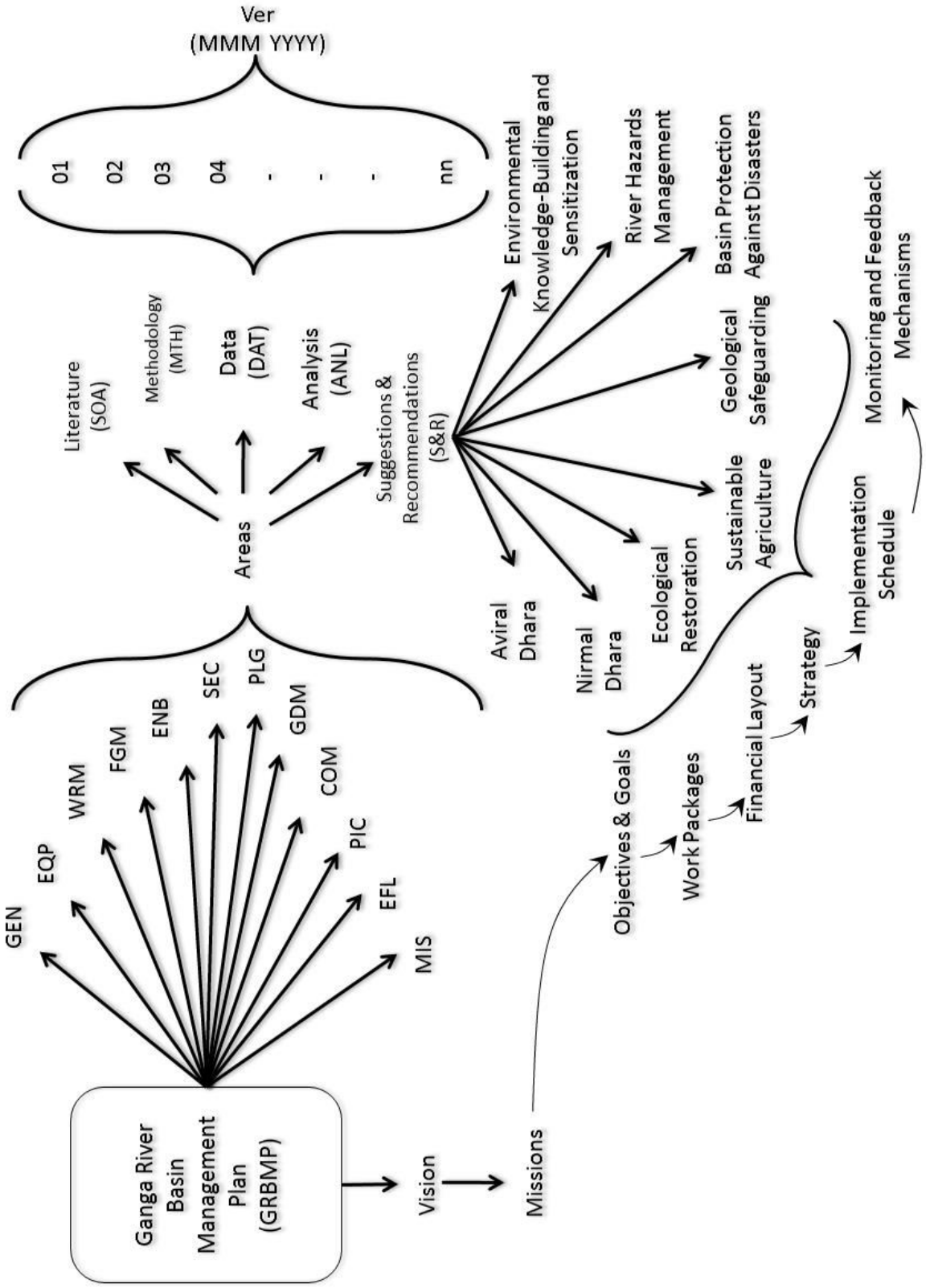
IIT Bombay | **IIT Delhi** | **IIT Guwahati** | **IIT Kanpur** | **IIT Kharagpur** | **IIT Madras** | **IIT Roorkee**

In Collaboration with

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

NIH Roorkee | **ISI Kolkata** | **Allahabad University** | **WWF India**

GRBMP Work Structure



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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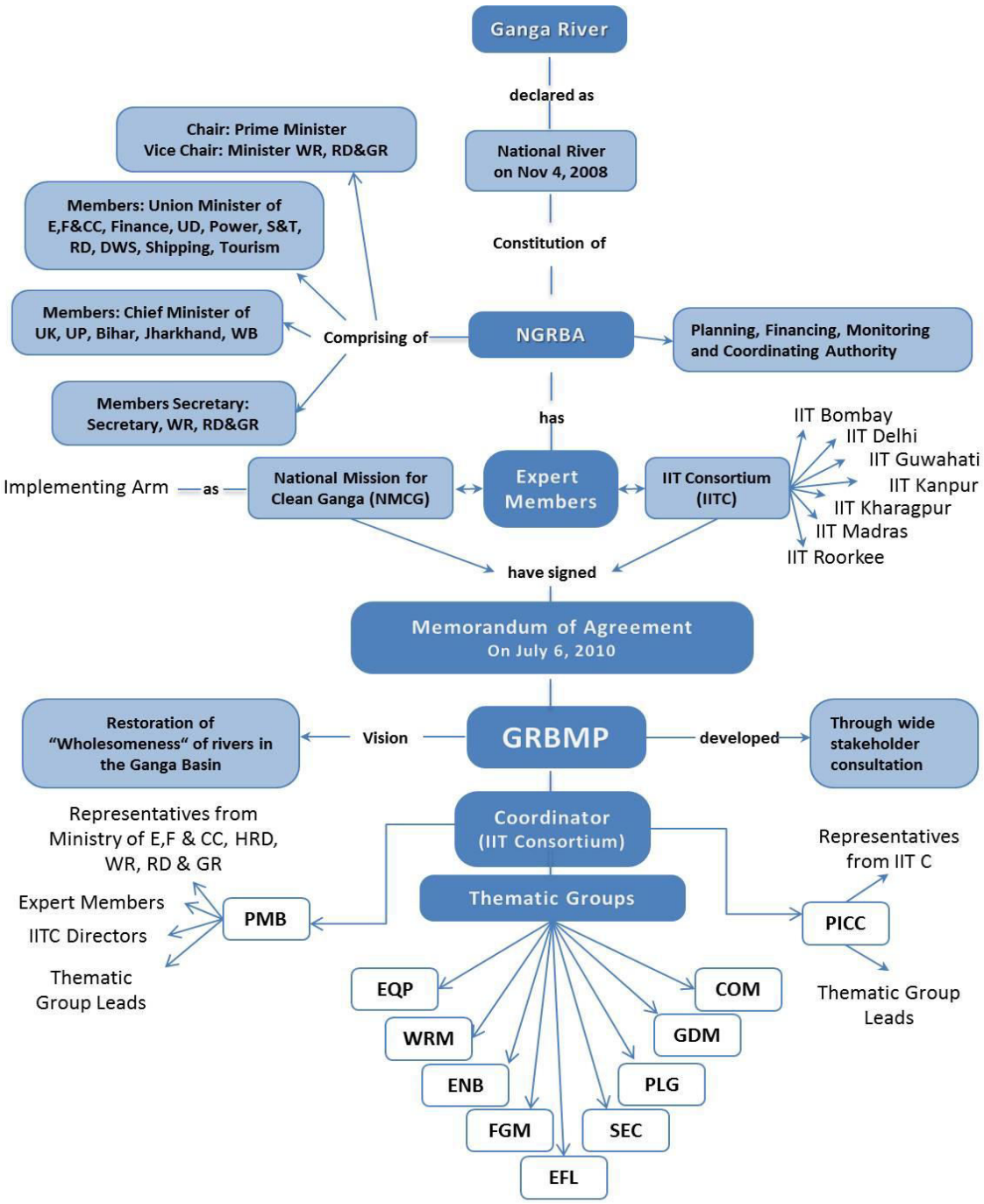
Organizational Structure for Preparing GRBMP



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
WRM: Water Resources Management
ENB: Ecology and Biodiversity
FGM: Fluvial Geomorphology
EFL: Environmental Flows
SEC: Socio Economic and Cultural
PLG: Policy Law and Governance
GDM: Geospatial Database Management
COM: Communication

Project Management Board [PMB]

Expert Members:

- Sri Swami Avimukteshwaranand Saraswati
- Dr Madhav A Chitale
- Dr Bharat Jhunjhunwala

Project Implementation and Coordination Committee [PICC]

Representatives from IIT Consortium:

- Dr Shyam Asolekar, IIT Bombay
- Dr A K Mittal, IIT Delhi
- Dr Mohammad Jawed, IIT Guwahati
- Dr Vinod Tare, IIT Kanpur
- Dr D J Sen, IIT Kharagpur
- Dr Ligy Philip, IIT Madras
- Dr I M Mishra, IIT Roorkee

Thematic Group Leads:

- Dr Purnendu Bose, Environmental Quality and Pollution (EQP)
- Dr A K Gosain, Water Resources Management (WRM)
- Dr R P Mathur, Ecology and Biodiversity (ENB)
- Dr Rajiv Sinha, Fluvial Geomorphology (FGM)
- Dr Vinod Tare, Environmental Flows (EFL)
- Dr S P Singh, Socio Economic and Cultural (SEC)
- Dr N C Narayanan and Dr Indrajit Dube, Policy Law and Governance (PLG)
- Dr Harish Karnick, Geospatial Database Management (GDM)
- Dr T V Prabhakar, Communication (COM)

Composition of Thematic Groups

1. Environmental Quality and Pollution (EQP)

Lead: Purnendu Bose, IIT Kanpur

Members: Shyam R Asolekar, Suparna Mukherjee (IIT Bombay); A K Mittal, A K Nema, Arun Kumar, T R Sreekrishanan (IIT Delhi); Ajay Kalmhad (IIT Guwahati); Saumyen Guha, Vinod Tare (IIT Kanpur); A K Gupta, M M Ghangrekar, Sudha Goel (IIT Kharagpur); Ligy Philip, Mukesh Doble, R Ravi Krishna, S M Shivnagendra (IIT Madras); A A Kazmi, B R Gurjar, Himanshu Joshi, Indu Mehrotra, I M Mishra, Vivek Kumar (IIT Roorkee); Anirban Gupta (BESU Shibpur); P K Singh (IIT BHU); Rakesh Kumar (NEERI Nagpur); S K Patidar (NIT Kurukshetra); Sanmit Ahuja (ETI Dynamics, New Delhi)

2. Water Resources Management (WRM)

Lead: A K Gosain, IIT Delhi

Members: Rakesh Khosa, R Maheswaran, B R Chahar, C T Dhanya, D R Kaushal (IIT Delhi); Subashisa Dutta, Suresh Kartha (IIT Guwahati); Shivam Tripathi, Gautam Rai, Vinod Tare (IIT Kanpur); Anirban Dhar, D J Sen (IIT Kharagpur); B S Murty, Balaji Narasimhan (IIT Mdras); C S P Ojha, P Perumal (IIT Roorkee); S K Jain (NIH, Roorkee); Pranab Mohapatra (IIT Gandhi Nagar); Sandhya Rao (INRM, New Delhi)

3. Fluvial Geomorphology (FGM)

Lead: Rajiv Sinha, IIT Kanpur

Members: Vinod Tare (IIT Kanpur); Vikrant Jain (IIT Gandhi Nagar); J K Pati (Allahabad University); Kirteshwar Prasad, Ramesh Shukla (Patna University); Parthasarthi Ghosh, Soumendra Nath Sarkar, Tapan Chakarborty (ISI Kolkata); Kalyan Rudra (WBPCB); S K Tandon, Shashank Shekhar (University of Delhi); Saumitra Mukherjee (JNU Delhi)

4. Ecology and Biodiversity (ENB)

Lead: R P Mathur, IIT Kanpur

Members: A K Thakur, Vinod Tare (IIT Kanpur); Utpal Bora (IIT Guwahati); M D Behera (IIT Kharagpur); Naveen Navania, Partha Roy, Pruthi Vikas, R P Singh, Ramasre Prasad, Ranjana Pathania (IIT Roorkee); Sandeep Behera (WWF-India)

5. Socio Economic and Cultural (SEC)

Lead: S P Singh, IIT Roorkee

Members: Pushpa L Trivedi (IIT Bombay); Seema Sharma, V B Upadhyay (IIT Delhi); P M Prasad, Vinod Tare (IIT Kanpur); Bhagirath Behera, N C Nayak, Pulak Mishra, T N Mazumder (IIT Kharagpur); C Kumar, D K Nauriyal, Rajat Agrawal, Vinay Sharma (IIT Roorkee)

6. Policy Law and Governance (PLG)

Lead: N C Narayanan, IIT Bombay and Indrajit Dube, IIT Kharagpur

Members: Shyam Asolekar, Subodh Wagle (IIT Bombay); Mukesh Khare (IIT Delhi); Vinod Tare (IIT Kanpur); Deepa Dube, Uday Shankar (IIT Kharagpur); G N Kathpalia, Paritosh Tyagi (IDC, New Delhi)

7. Geo-Spatial Database Management (GDM)

Lead: Harish Karnick, IIT Kanpur

Members: N L Sharda, Smriti Sengupta (IIT Bombay); A K Gosain (IIT Delhi); Arnab Bhattacharya, Kritika Venkatramani, Rajiv Sinha, T V Prabhakar, Vinod Tare (IIT Kanpur)

8. Communication (COM)

Lead: T V Prabhakar, IIT Kanpur

Members: Purnendu Bose, Rajiv Sinha, Vinod Tare (IIT Kanpur)

9. Environmental Flows (EFL)

Lead: Vinod Tare, IIT Kanpur

Members: Shyam Asolekar (IIT Bombay); A K Gosain (IIT Delhi); P M Prasad, R P Mathur, Rajiv Sinha, Shivam Tripathi (IIT Kanpur); M D Behara (IIT Kharagpur); B S Murthy, N Balaji (IIT Madras); Pranab Mohaparta, Vikrant Jain (IIT Gandhinagar); S K Jain (NIH Roorkee); Nitin Kaushal (WWF-India, New Delhi); Sandeep Behera (NMCG, MoWR, RD & GR, New Delhi); A P Sharma K D Joshi (CIFRI, Barrackpore); Ravindra Kumar (SWaRA-UP); Ravi Chopra (PSI, Dehradoon); Paritosh Tyagi, (IDC, New Delhi)

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.

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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.

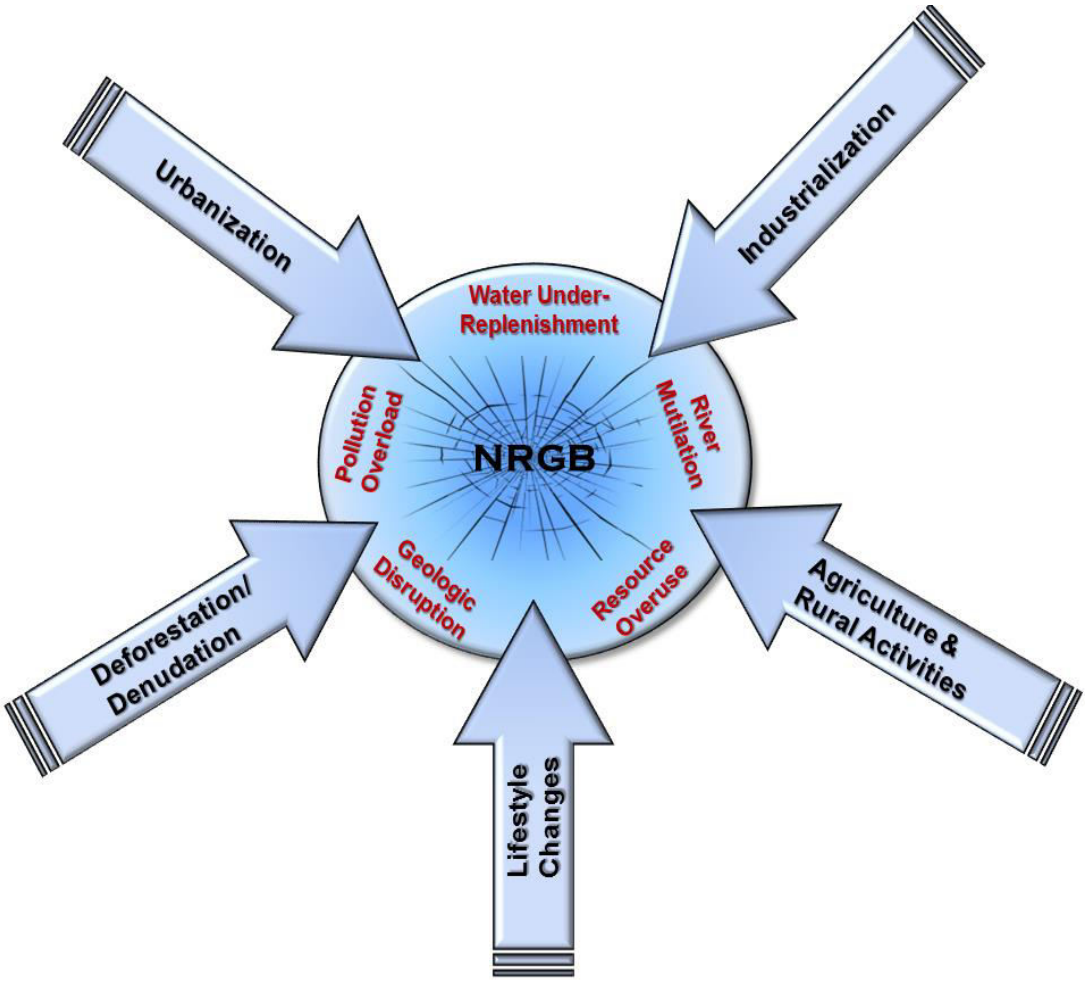

Figure 1: Major Adverse Impacts of Modern Anthropogenic Activities on NRGB

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.

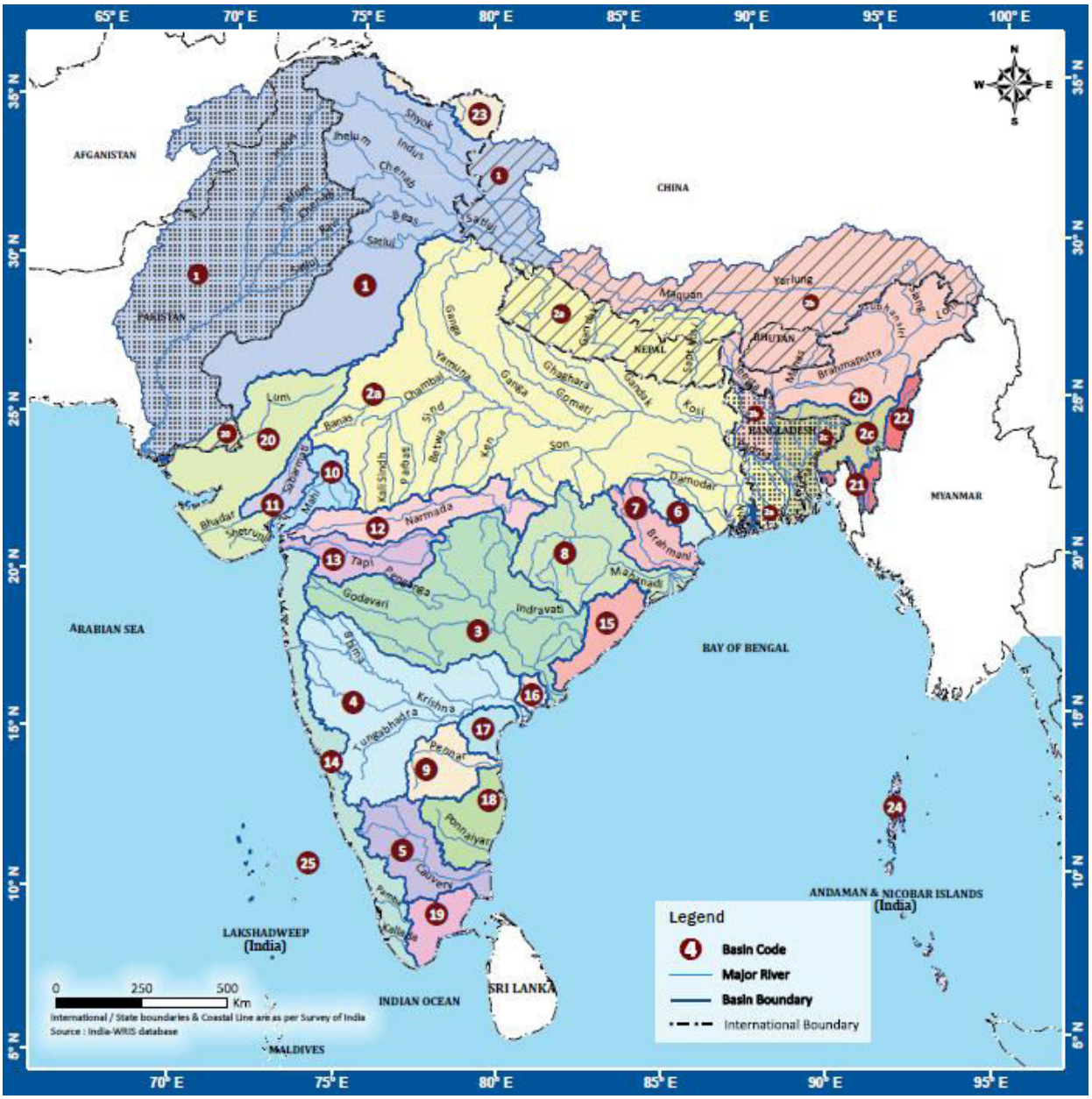

Figure 2: Main River Basins of India showing the Ganga River Basin (Yellow Region) Marked as "2a" [*India-WRIS, 2012*]

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.

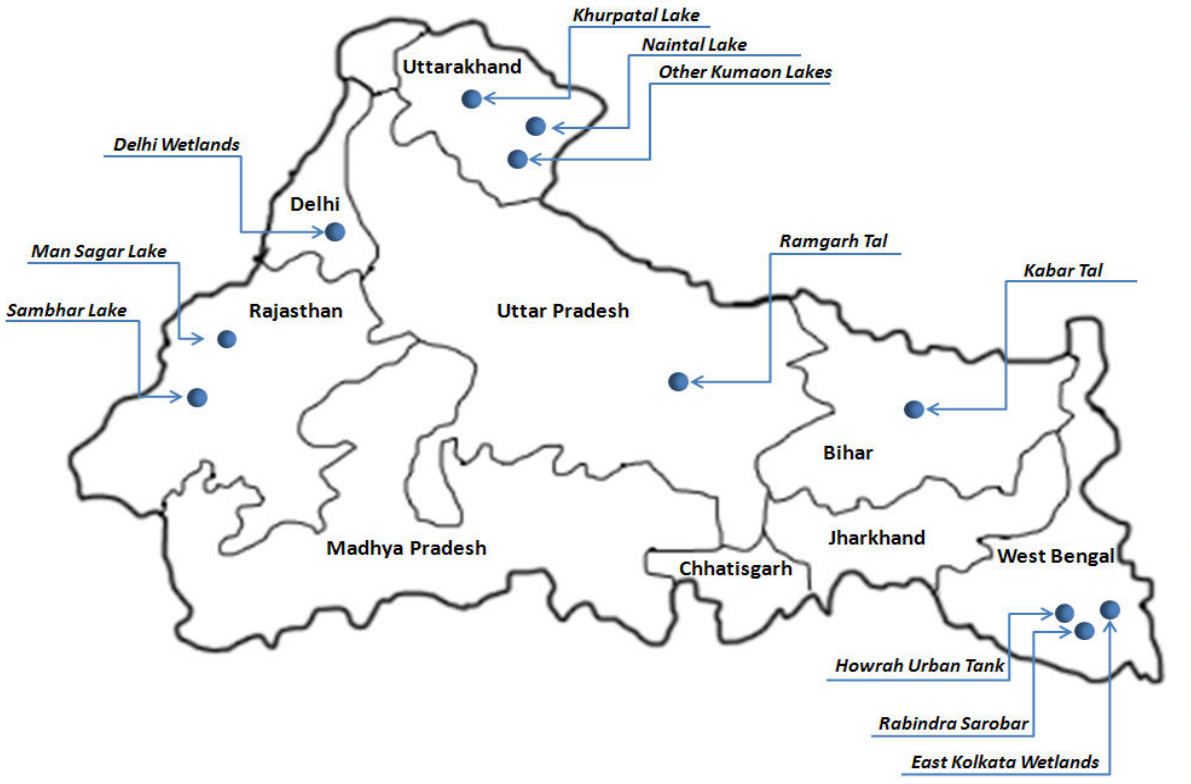

Figure 3: Major Lakes and Wetlands of NRGB [*Adapted from: Rainwaterharvesting, 2013*]

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.

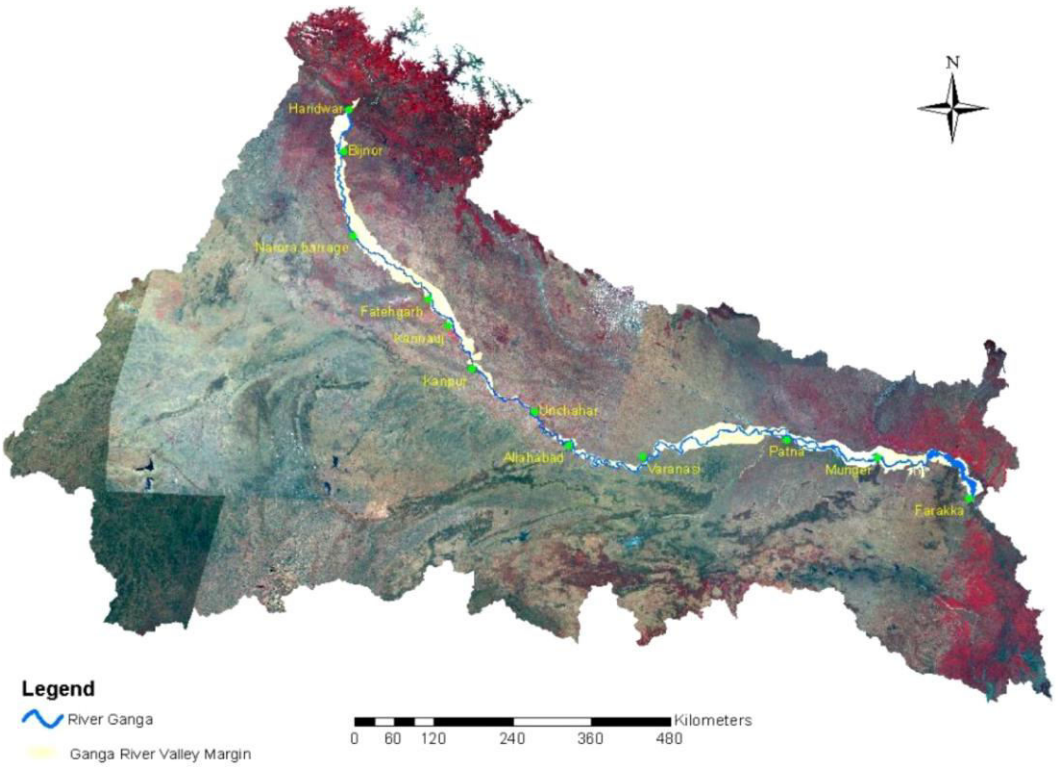

Figure 4: Geomorphic Map of Ganga River Valley

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.

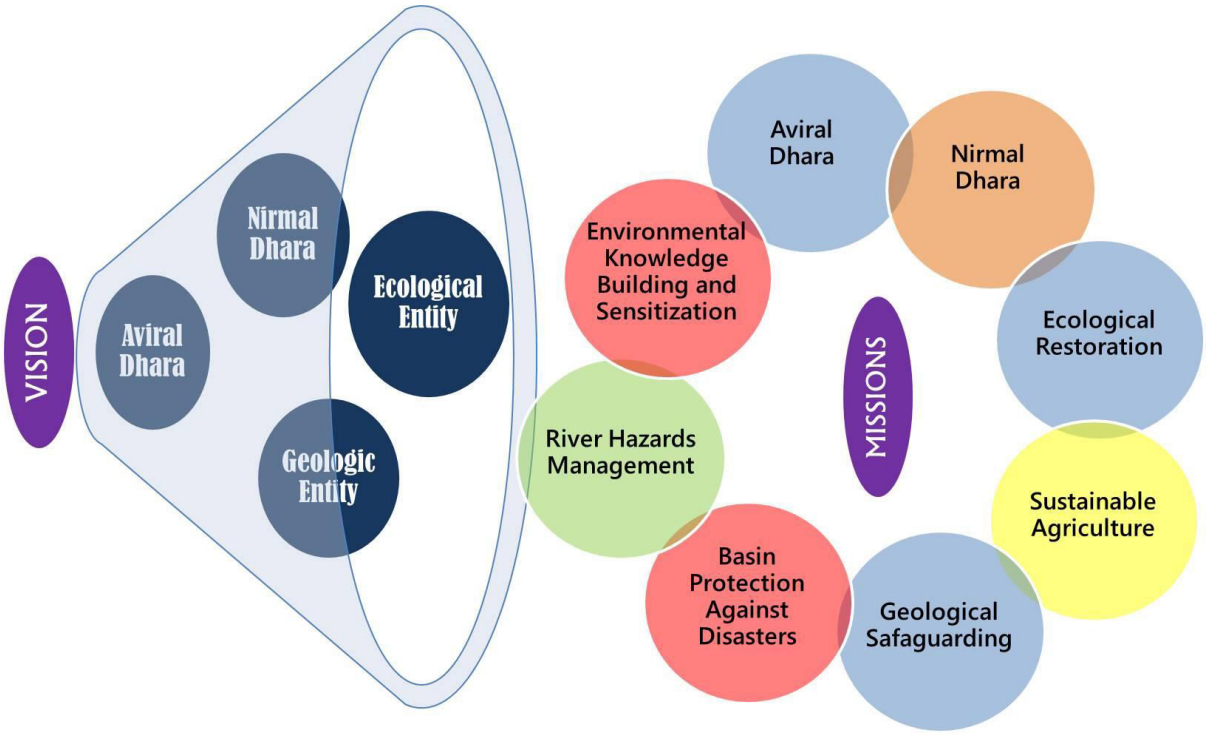

Figure 5: Target Missions to fulfill the Vision of a wholesome National River Ganga

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.

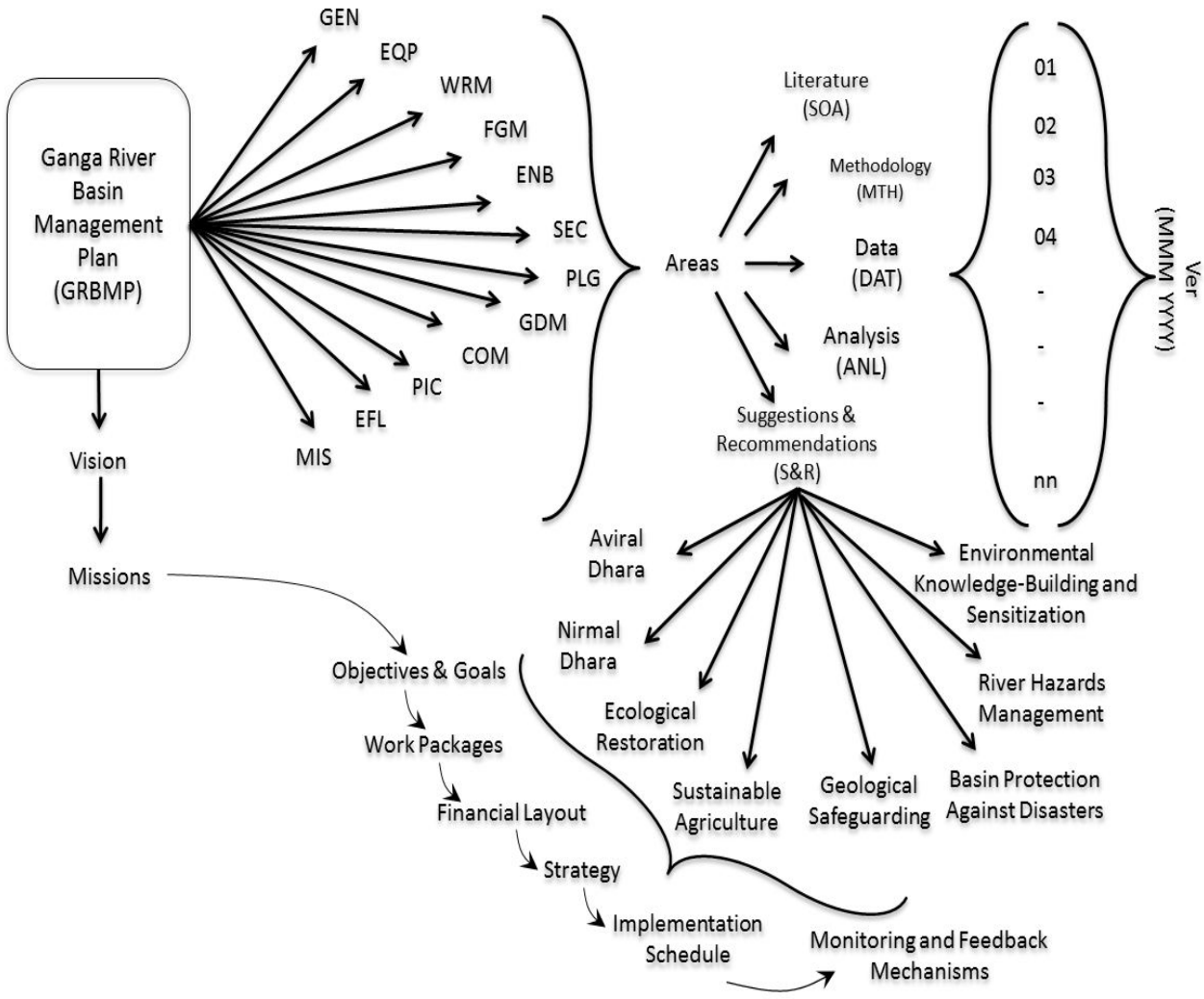

Figure 6: Flow Diagram of GRBMP Work Structure

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.

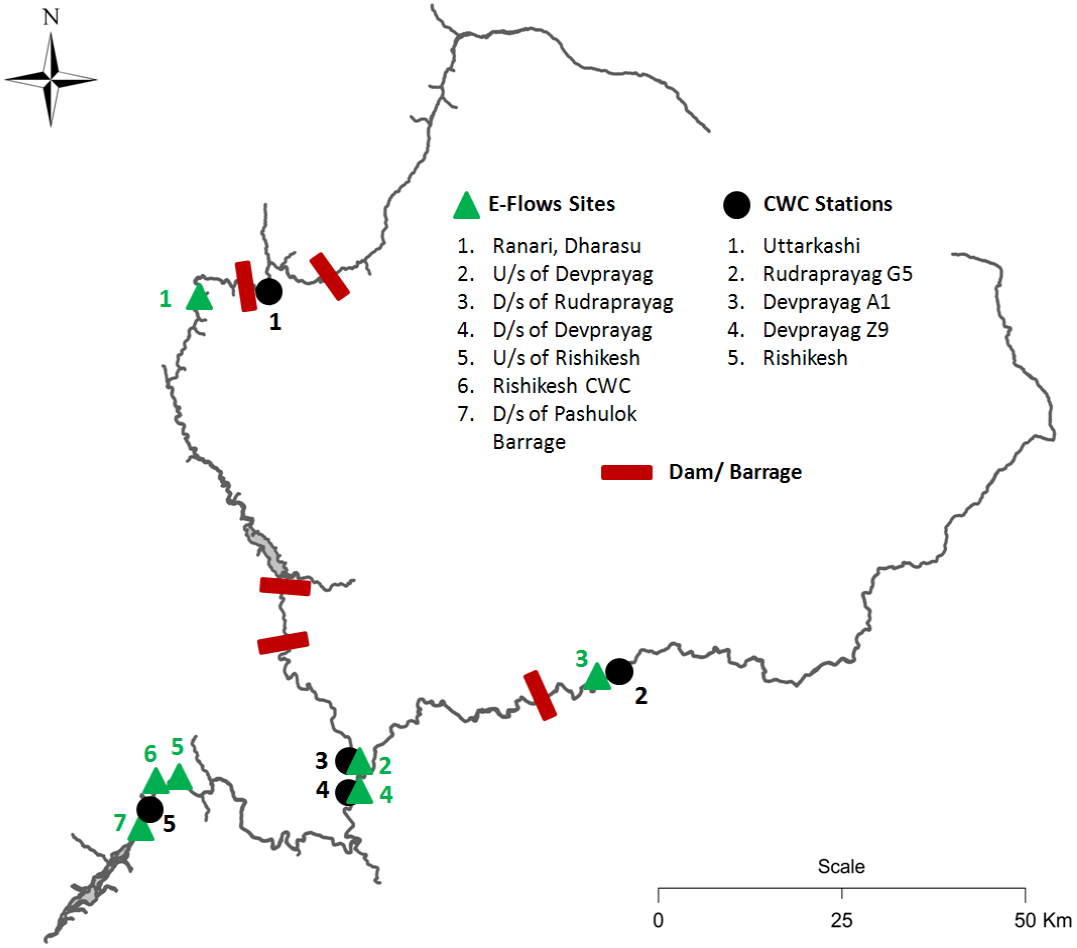

Figure 7: Location Map of E-Flows Sites in the Upper Ganga

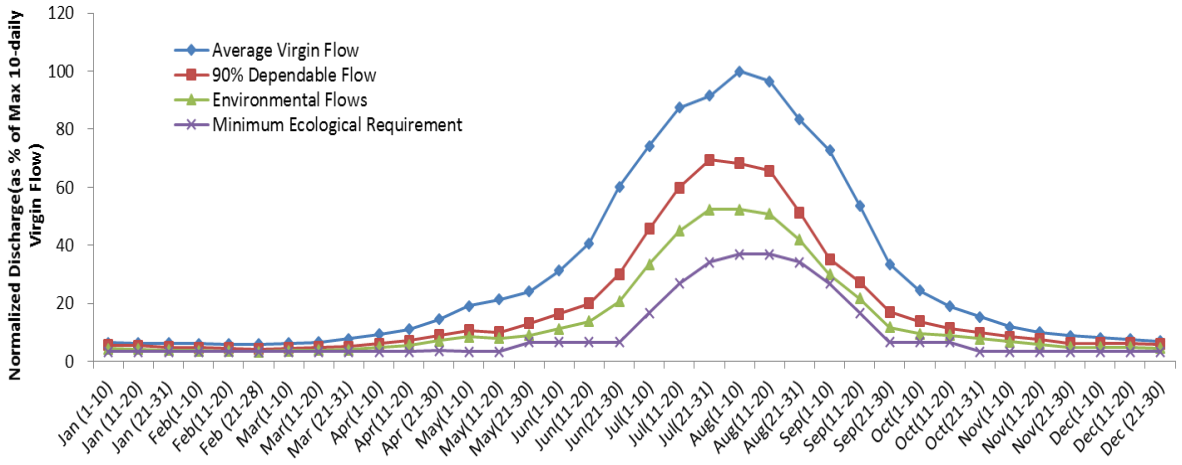

Figure 8: Computed 10-daily E-Flows at Ranari, Dharasu

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.

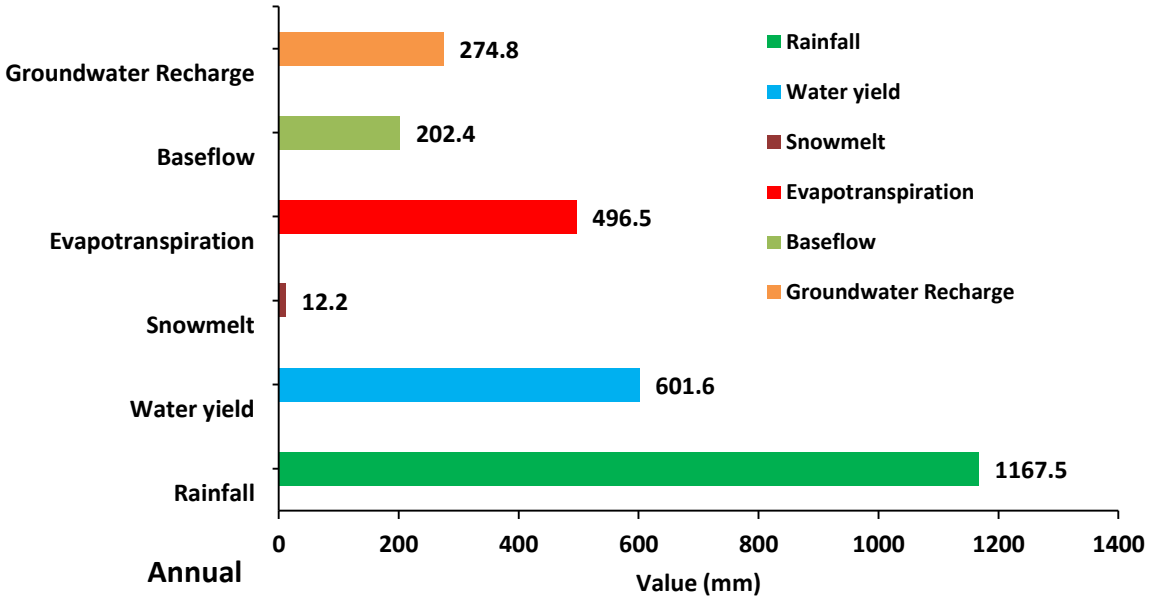

Figure 9: Average (1969-2006) Annual Water Balance of the Modeled Ganga Basin

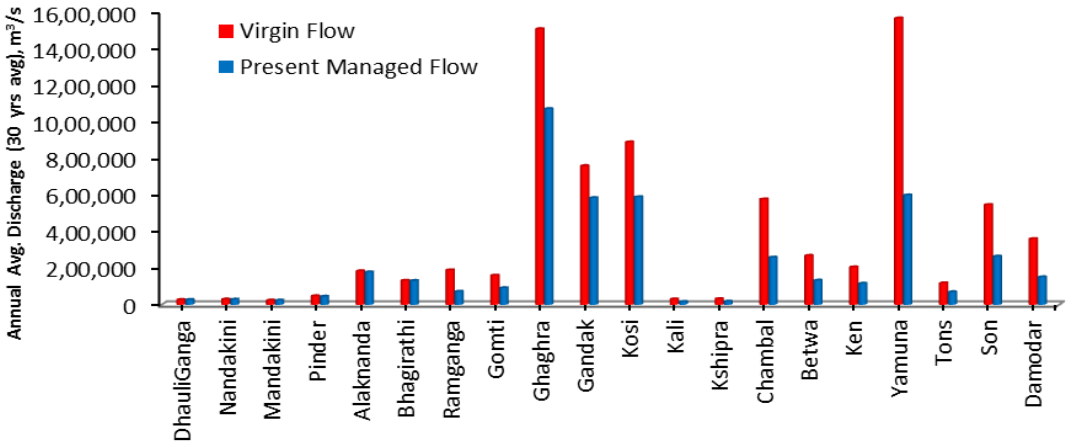

Figure 10: Annual Flow Contributions of Different Tributaries (sub-basins) to National River Ganga under Present Flow Conditions and under Virgin Flow Conditions

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.

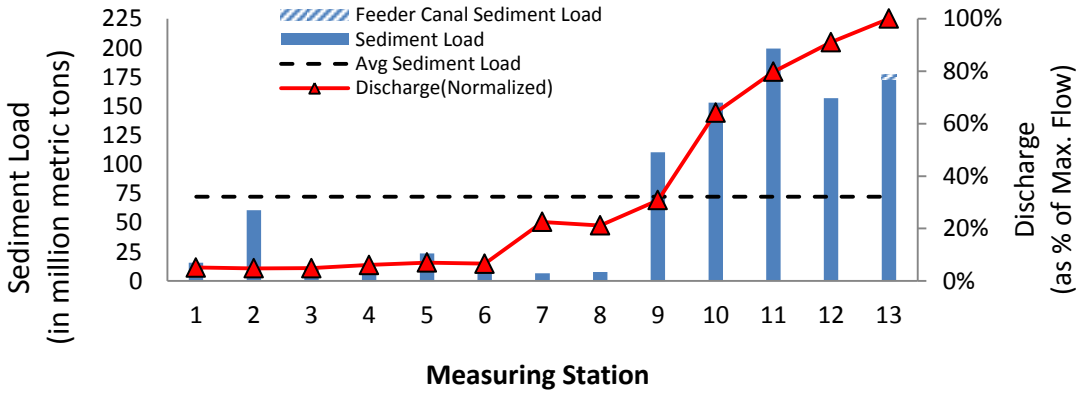

Figure 11: Comparison of the Annual Average Sediment Loads (for period 1999-2006) at Different Locations of National River Ganga

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.

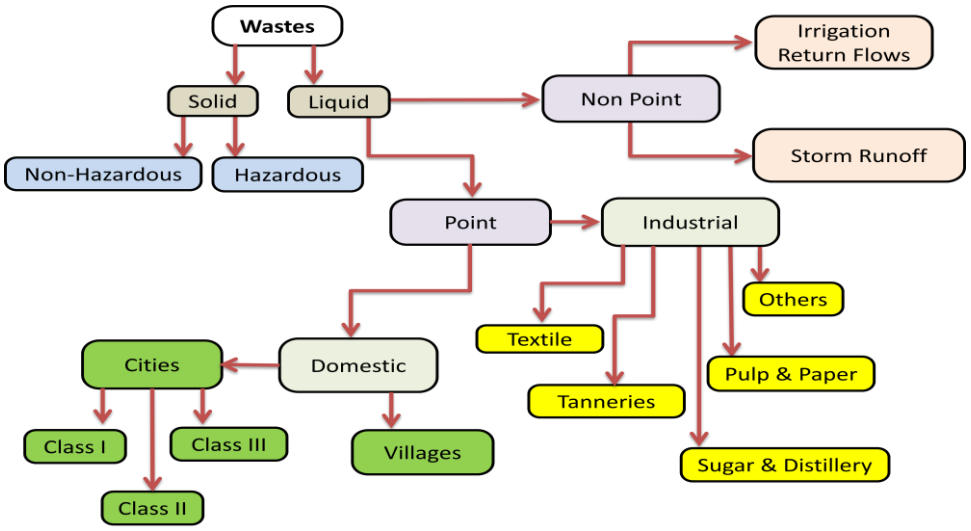

Figure 12: Types of Waste Generated in Ganga River Basin

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.

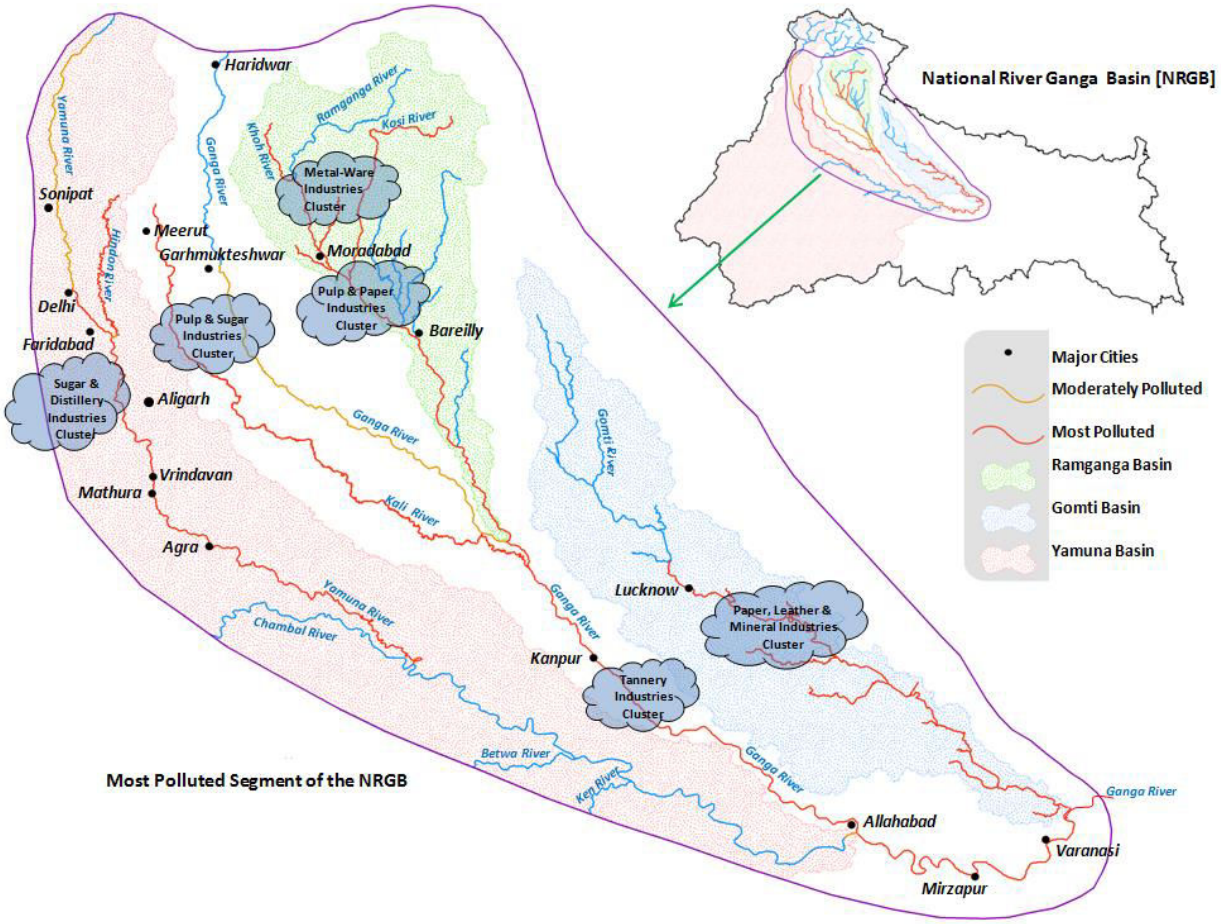

Figure 13: Most Polluted Stretches and their Pollution Sources in National River Ganga Basin

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.

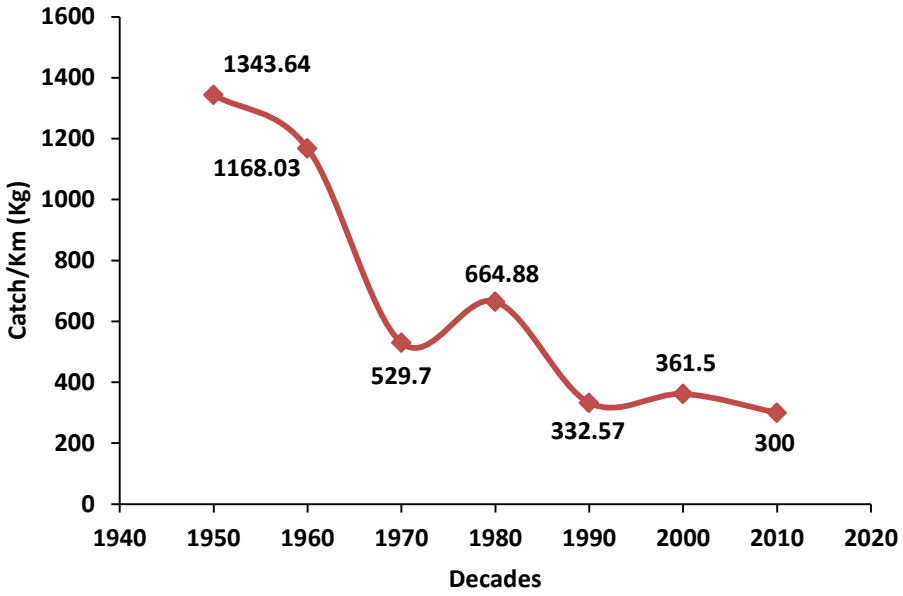

Figure 14: Decline of Fish Catch per km at Allahabad between 1950 to 2010

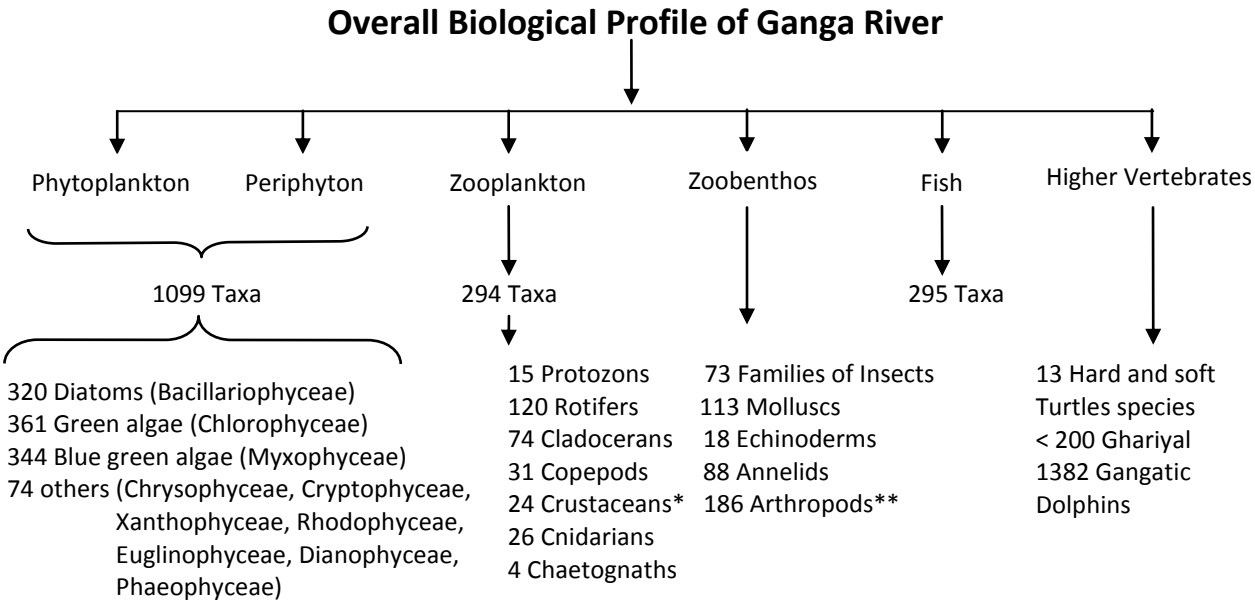

Figure 15: Biodiversity of River Ganga at a Glance

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.

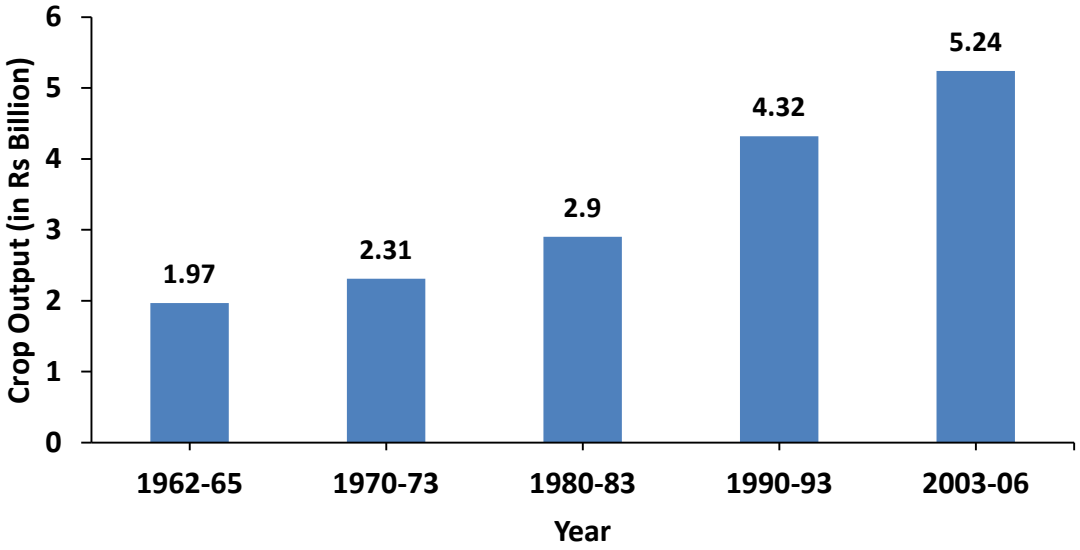

Figure 16: Average Crop Output Value per District in NRGB between 1962-65 and 2003-06

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.

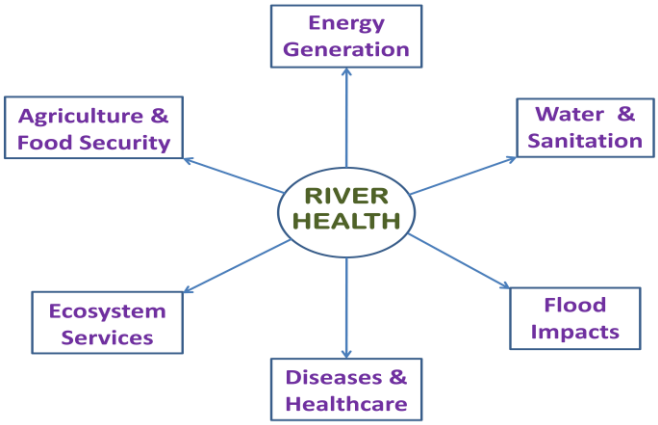

Figure 17: Major Sectors Likely to be Influenced by GRBMP Action Plan

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.

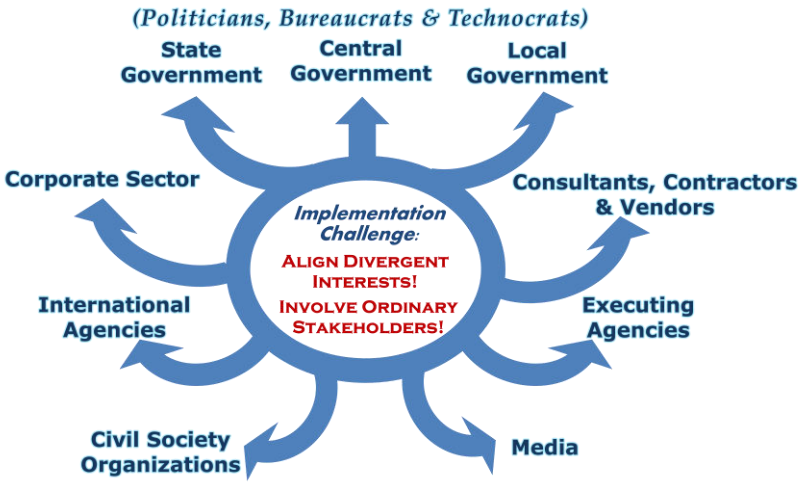

Figure 18: Implementation Challenges in Aligning Interests of Key Actors

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.