Ganga River Basin Management Plan - 2015

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

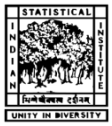
JNU

PU

NIT-K

DU

NIH Roorkee

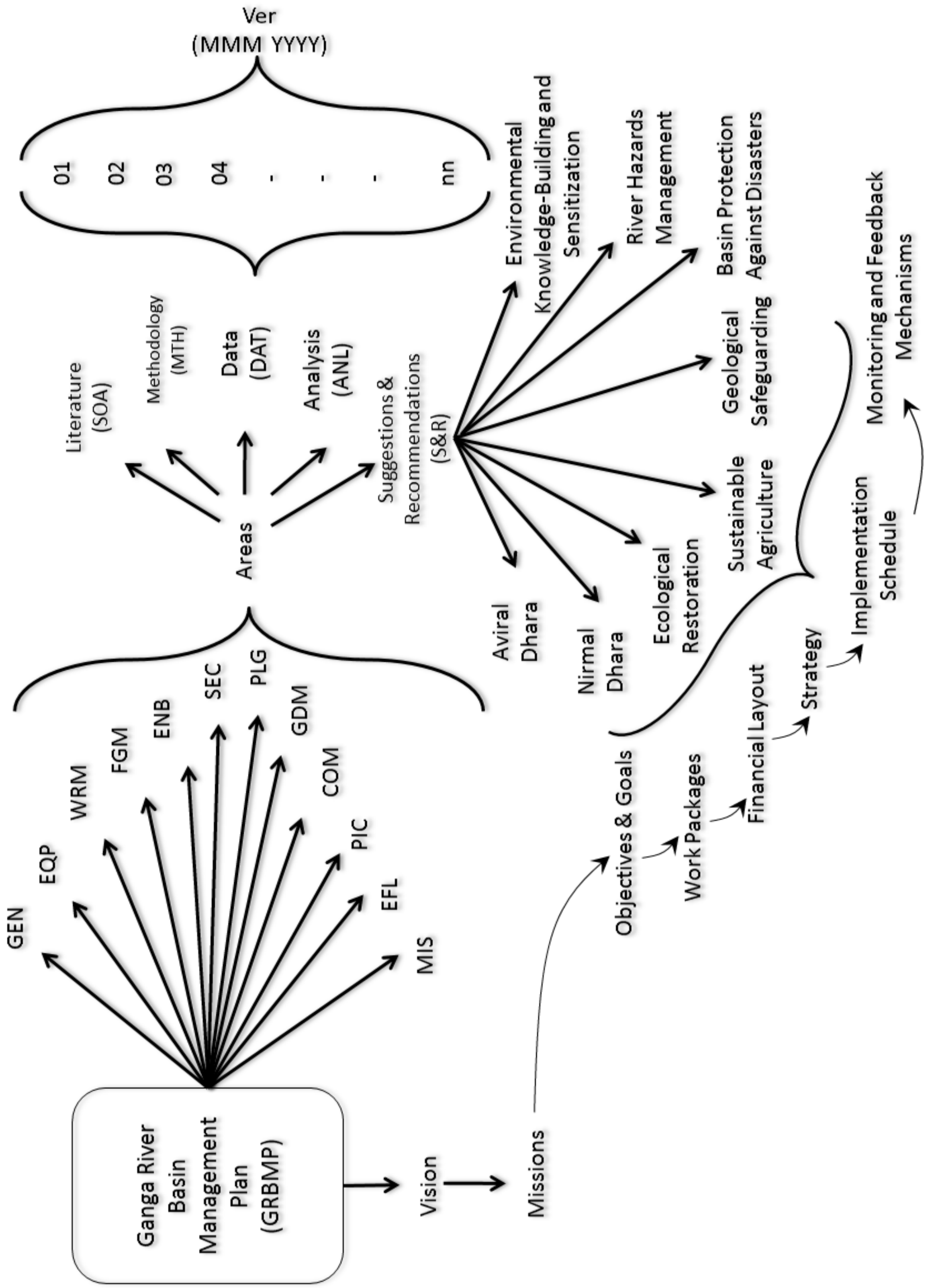


ISI Kolkata

Allahabad University

WWF India

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, NewDelhi. 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.

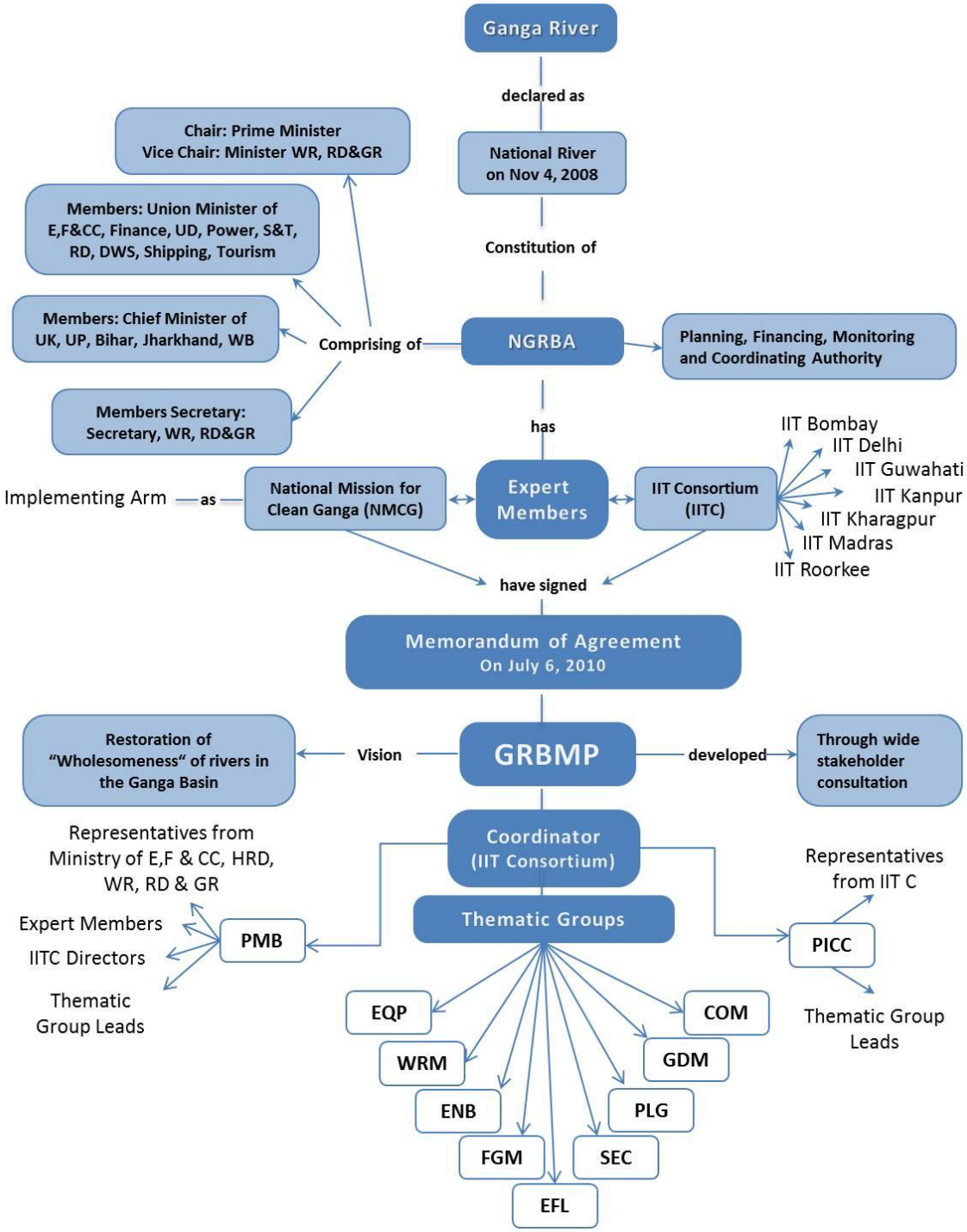
Secondly, many dedicated people spent hours discussing major concerns, issues and solutions to the problems addressed in GRBMP. Their dedication led to the preparation of a comprehensive GRBMP that hopes to articulate the outcome of the dialog in a meaningful way. Thus, directly or indirectly, many people contributed significantly to the preparation of GRBMP. The GRBMP therefore truly is an outcomeof 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.

Dr Vinod Tare
Professor and Coordinator, GRBMP
IIT Kanpur

Authors

Vinod Tare (vinod@iitk.ac.in), Purnendu Bose (pbose@iitk.ac.in) and Gautam Roy (gautamwho@gmail.com)

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

Contents

List of Figures

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 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 involving them. 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 from the basin*; (ii) *discharge of pollutants into terrestrial and aquatic environments*; (iii) *reduction in water-holding capacities and replenishment rates 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.

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 RiverGanga 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. The 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, 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 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.

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 regions. 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 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*".

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 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*).

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 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: 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. 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) 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; and floral and other offerings in rivers, 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 this loss**:** (i) Habitat Fragmentation by dams and barrages; (ii) Habitat Shrinkage due to

increased water diversions and withdrawals; (iii) Habitat Alterations by 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**:** restoration of longitudinal connectivity along with E-flows across dams/ barrages; maintenance of lateral connectivity across floodplains; restoration of unpolluted river flows; restrictions on river bed farming, gravel and sand mining, plying of vessels, dredging, and bed and bank modifications; control of alien species invasions, overfishing and fishing during spawning seasons; river nutrient assessment and release of dammed sediments into the river; bio-monitoring of Ganga river network; synergising 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 and geomorphological upkeep of the basin are 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 disturbed areas' stabilization, mapping river migration zones, and continuous geological monitoring of the NRGB and her dynamic rivers.

4.6 Mission 6 – Basin Protection AgainstDisasters: 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*, *ExtremeDroughts*, *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 actually 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, and 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 the hazards related to anthropogenic disturbances on the rivers 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 tectonics or intrinsic factors such as excessive sedimentation and local slope variability – by which rivers adjust their profiles and equilibrium. However, the frequency of migration events has been severely affected by anthropogenic disturbance along the rivers resulting into a sudden and disastrous migration affecting a large population. 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 natural phenomena in alluvial plains of the Ganga system particularly in the eastern parts regarded as one of the worst flood-affected regions in the world. An excess of 2700 billions of rupees have been spent on the flood protection measures in India but the flood damages and flood-affected areas are still on rise. The flood protection measures have largely failed and one of the important reasons for this has been that floods have long been considered as purely hydrological phenomenon. Flood control strategies

in most river basins in India are primarily embankment-based which have not only influenced the natural flow regime of the rivers and have 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 owing to extensive sediment deposition in the reaches upstream of the barrage. The obstruction of great volumes of water due to construction of a series of protective levees and dykes has complicated the flooding problem in these rivers. Apart from embankments along the river, unplanned roads and bunds have resulted in severe drainage congestion and channel disconnectivity thereby increasing the inundation period significantly. We emphasize that 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; this may include geomorphic assessment of rivers as well as impact on ecosystem. 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 must be emphasized; this may include floodplain zoning and other non-structural approaches. (5) Sediment dynamics and its application in river management projects form very important areas of future research 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, land 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 the 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 environmental rejuvenation of NRGB.

5.2 Implementation Mechanism: The implementation, monitoring, review and evaluation of environmental problems and interventions on a long-term basis are therefore 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 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 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 withher 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 windsher way down to the sea, distributing her blessings to all and sundry. To the Indian mind, River Ganga is not only the holiest of riversand 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,RiverGanga 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 thata"Consortium of Seven IITs"was assigned the task of preparing a Management Plan torestore and preserveNational River Ganga and her basin. This Plan – the Ganga River Basin Management Plan (GRBMP in short) – ispresented 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 toa near-critical state. Thus, GRBMP focuses on the aquatic environment of the basin and the major factors affecting it – especiallydiverse 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 safeguardthe basin environment in the foreseeable future. For, only thus can we secure the environmental foundation of NRGB for the good of one and all.

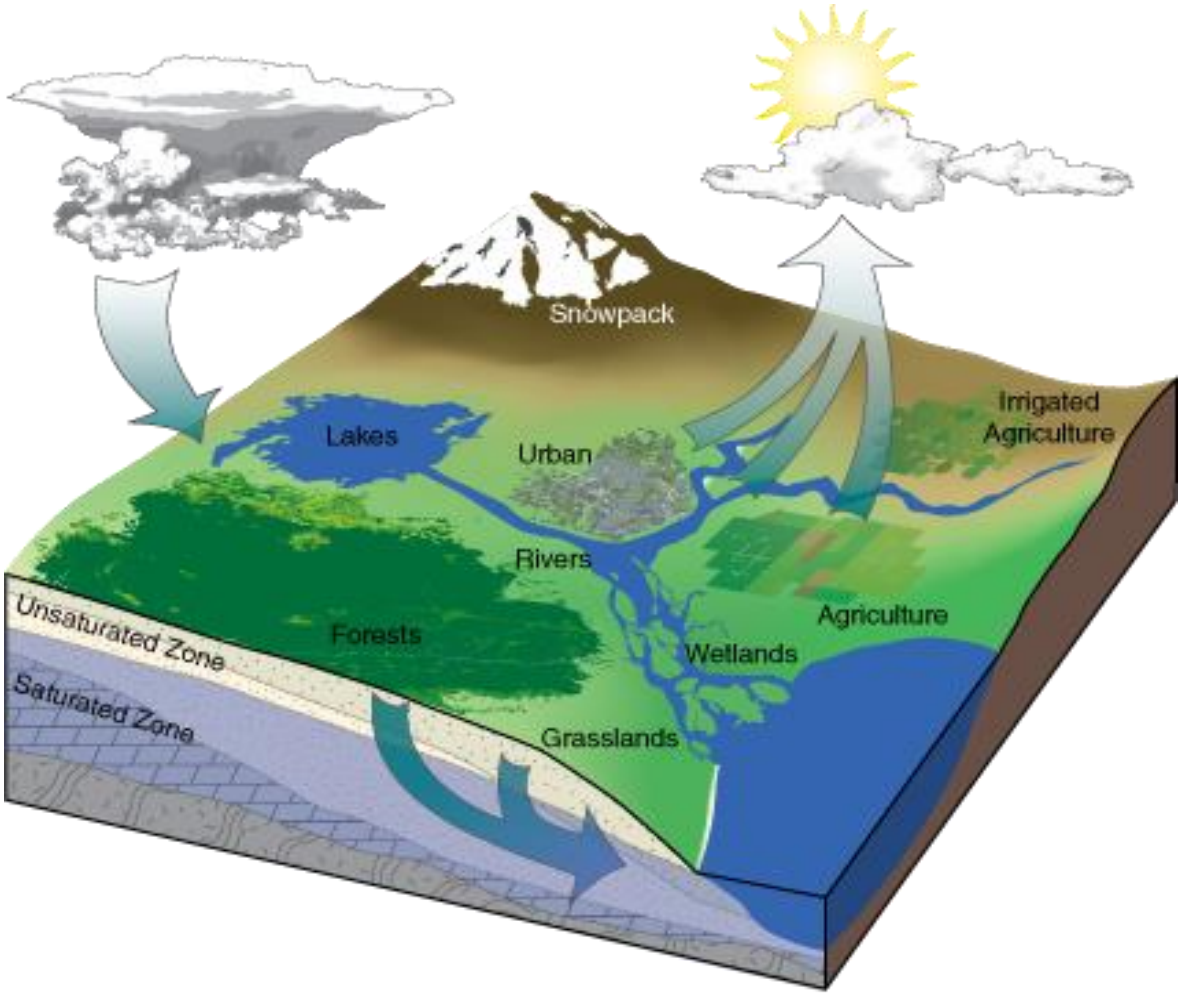


Figure 1.1: Illustrative Sketch of Inland Terrestrial Environments [*MSU, 2013*]

[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 groupedunder 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, withlimited 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 waterscome underthree major types of water resource, thevarious 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 connectionsalso within the basin– such as surface runoff, river flooding, and regional evapotranspiration-precipitation cycles.Simultaneous 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.

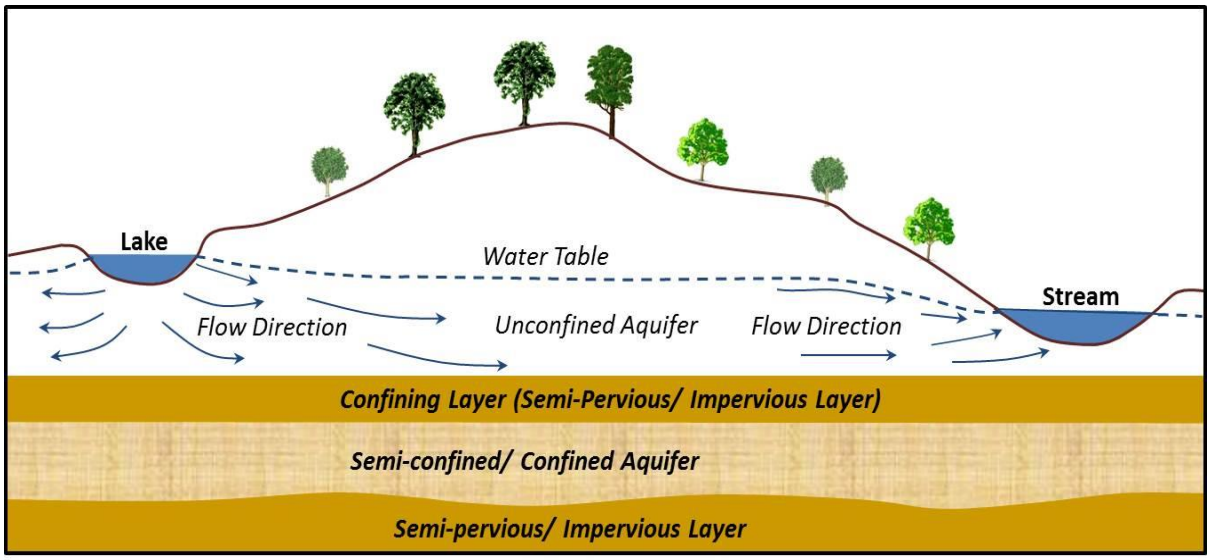


Figure 1.2: Schematic of Hydraulic Connectivity through Groundwater in NRGB

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). Theyare also the most important ingredients needed byhuman communities to sustain and develop their lives.

The essential physical resourcesof 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 ratherintricate problem[*Pahl-Wostl, 2007*].

While integrated management of natural resources in NRGB may be daunting, an attempt needs tobe 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 resourcesas in

conventional basin management [*Pegram, et al., 2013*]. A compelling case for this is evidentfrom 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 muchmore scarce resource than water in India. The corresponding figures for NRGB (discussed in the next chapter) are even more adversely skewed against soil, suggesting thatsoil is a more criticalnatural resource than water in NRGB.

Among the basin's mainphysicalresources– 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 – isa drawn-out process that may take hundreds or thousands of years [*Jenny, 1994; Wikipedia, 2014*].But,once formed, soilscan be muchmore durable. In contrast to soil, water is ahighly variable resource.Inter-year fluctuations apart, Itbroadly follows an annual cycle of replenishment (throughatmospheric 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 easilydetectable, those of soils are slow and often go unnoticed, leading to long-term challengesof 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). Andhuman-induced changes – even in uninhabited ecosystemslike 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 were not possible in GRBMP, an attempt has been made to induct interactive resource considerations in framing thePlan.

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 thedegradation of NRGB's aquatic environment in recent times. Broadly, fivemajor types of degradationfactors are noticeable: (i) over-extraction of natural resources from the basin for increasinghuman demands; (ii) discharge of pollutants in the basin, causing deteriorationin 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 thisphase of GRBMP.

The major human activities affecting the aquatic environment ofNRGB 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 industrialpollutants 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 wastesand 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) **LifestyleChanges**: (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-useof 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 theyreach 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.

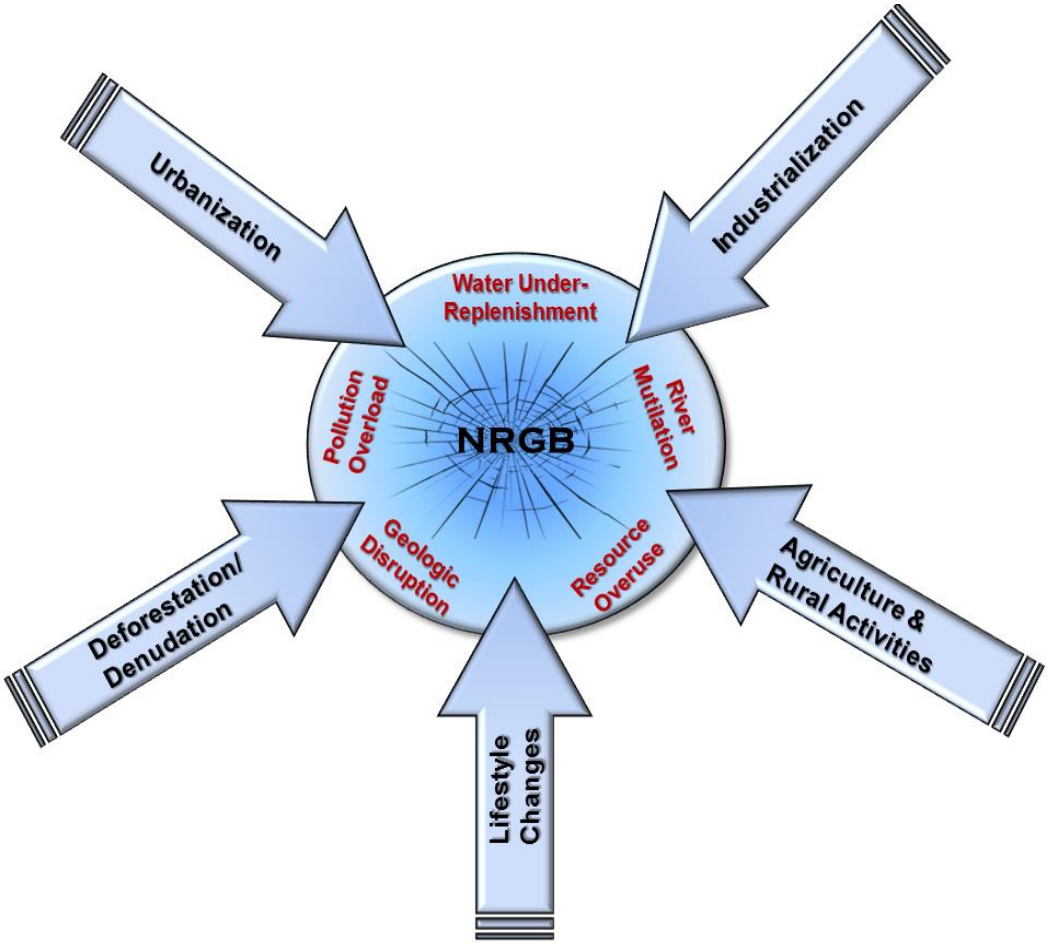


Figure 1.3: Major Adverse Impacts of Anthropogenic Activities on the NRGB Environment

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 riveris 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, severallarge 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.

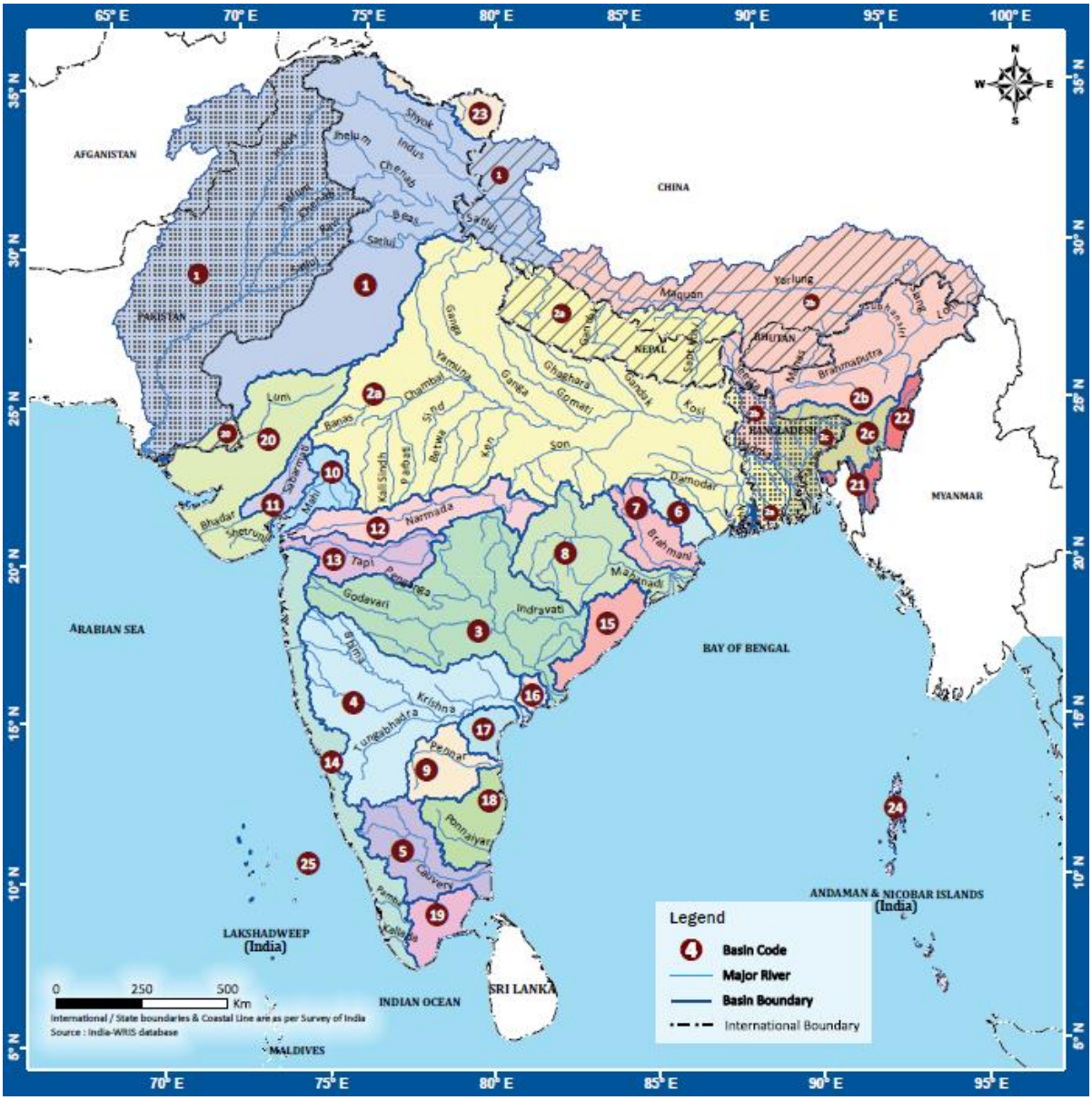


Figure 2.1a: Main River Basins of India: The Ganga River Basin is the Yellow Region Marked as "2a" [*India-WRIS, 2012*]

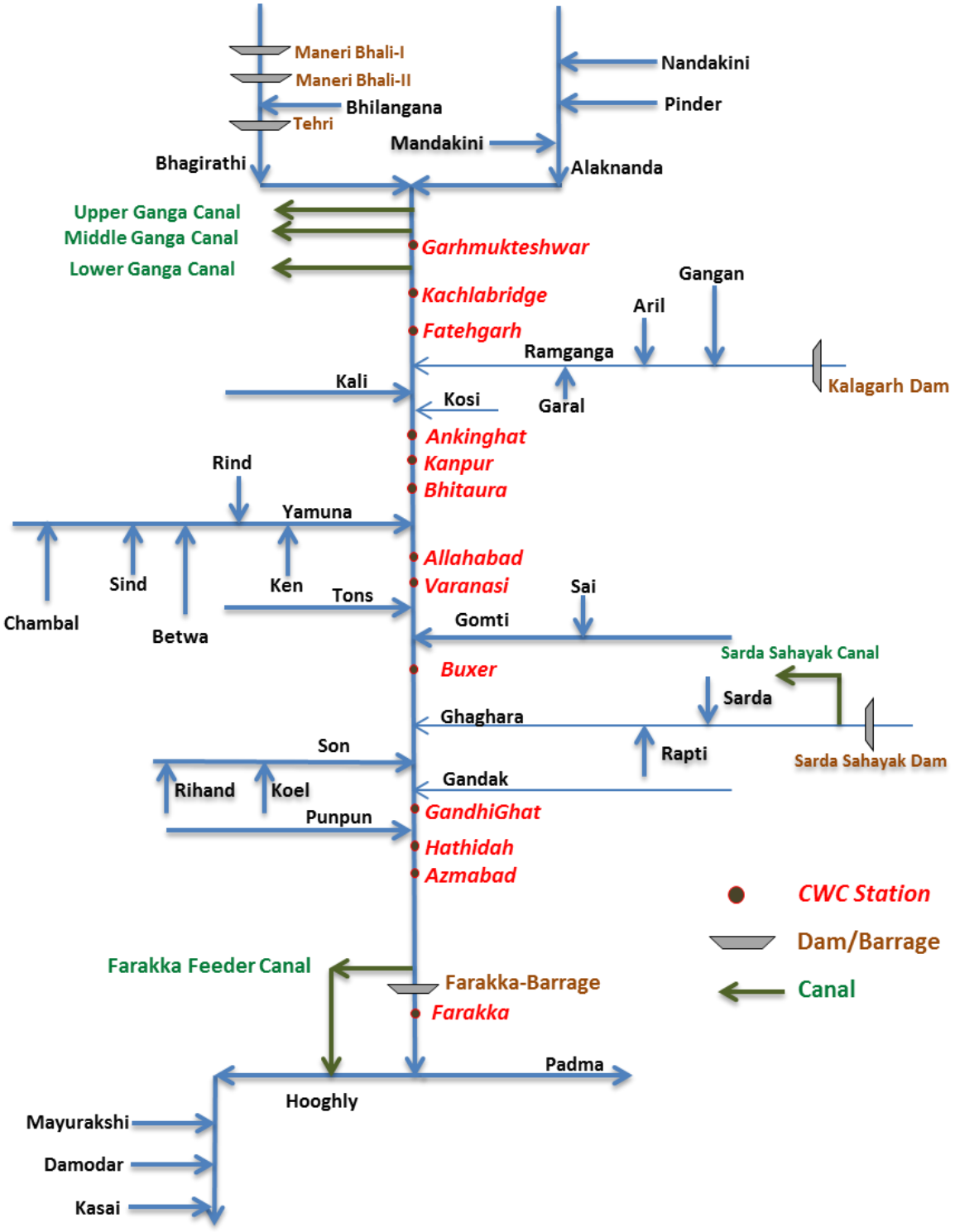


Figure 2.1b: Line diagram of River Ganga and her major tributaries [*MoWR, 2014*]

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 [*Wikipedia, 2013; Jain et al., 2007; MoWR, 2014*]. 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 mostwater-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.

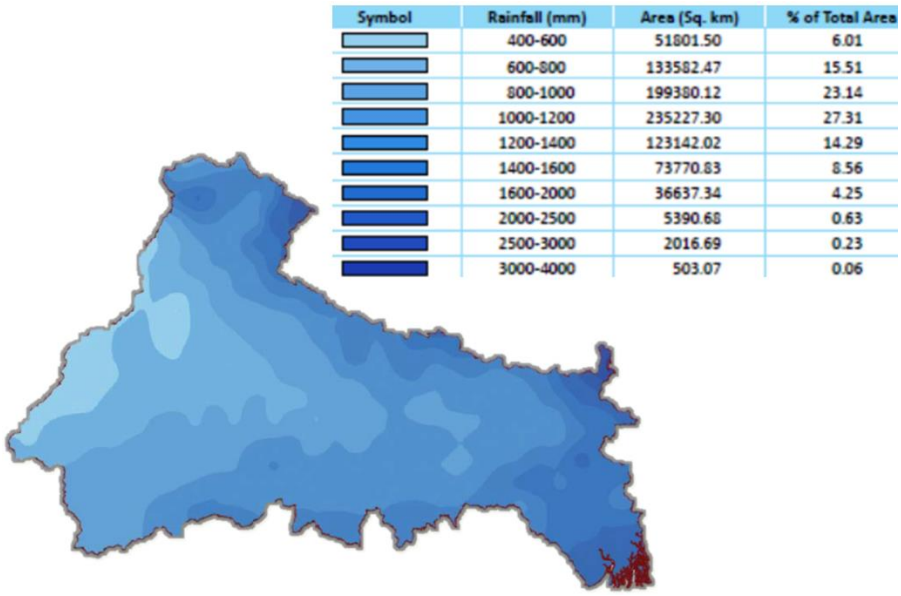


Figure 2.2a: Average Annual Rainfall during 1971–2005 in NRGB [*India-WRIS, 2012*]

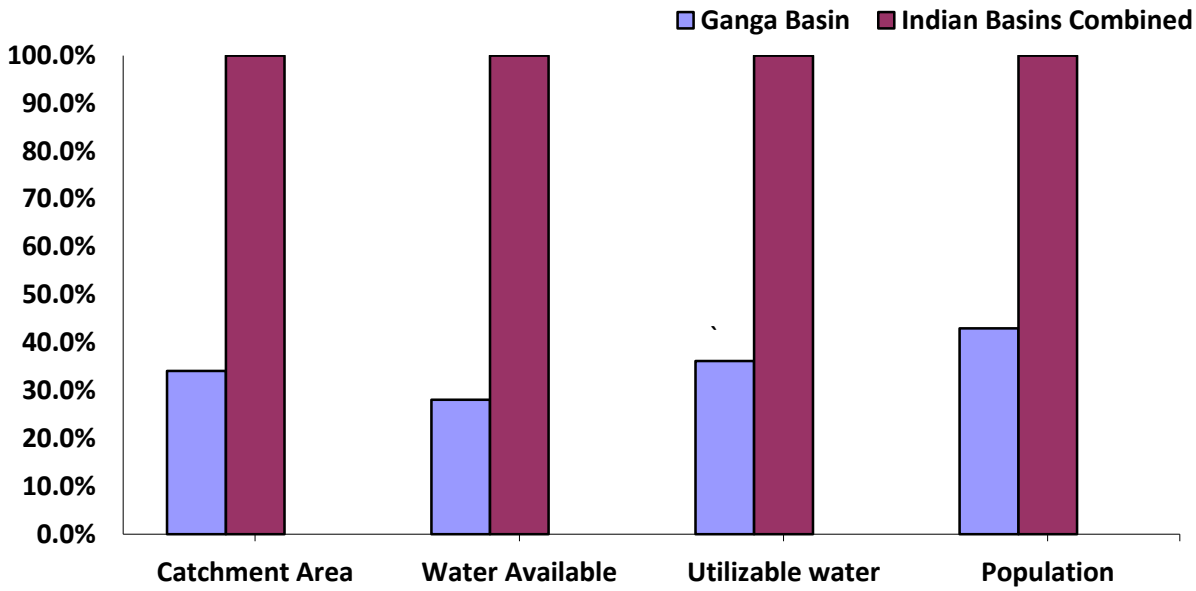


Figure 2.2b: Hydrological Importance of NRGB relative to All Indian Basins Combined

2.3. Geology

The Ganga basin covers a diverse landsacpe 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, NRGBis part of the a tectonically active foreland basin of the Himalayan mountain rangeformed by collision of the northeast moving Indian tectonic plate with the Eurasian plate and its subduction under the latter, a process that occurredsomefifty 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 erodedfrom Himalayan rocks. Thus much of the NRGB –andthe Indo-Gangetic plainsin general –cameto consist largely of alluvial plains formed during the Tertiary and Quaternary periods by flood deposits of Himalayan rivers [*Wadia, 1965; Wikipedia, 2013*]. Alluvial deposits ofup 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 thinnernear the Vindhya mountains. Overall, they constitute large and highly productive multi-aquifer systems (*seeFigure 2.3b*),whichprovide for significant

ground water resourcesin the basin [*CGWB, 2009; CGWB, 2012; CWC, 2010*].Due to the alluvium deposited over the ages. the soils of the basin (*seeFigure 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 18th worldwide in terms of its basin area (980,000 km^2) and 2nd 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.

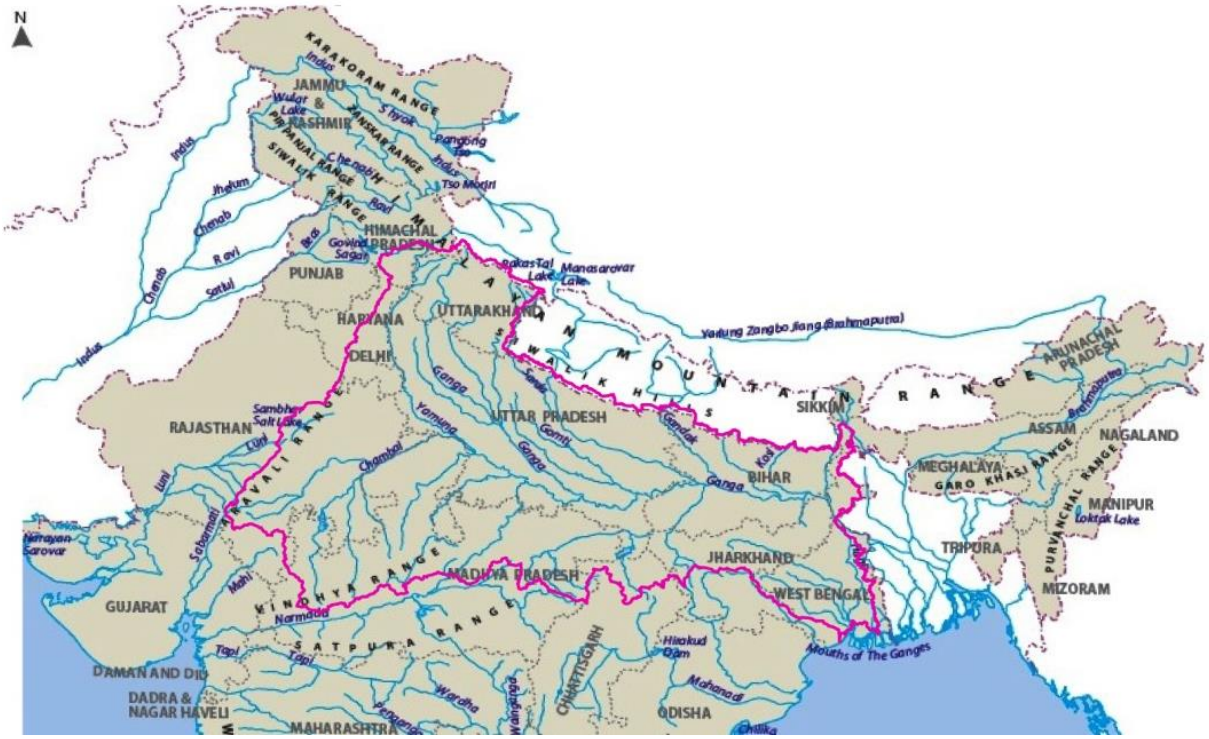


Figure 2.3a: Mountain Ranges in the Ganga Basin [Adapted from *MapsofIndia.com, 2014a*]

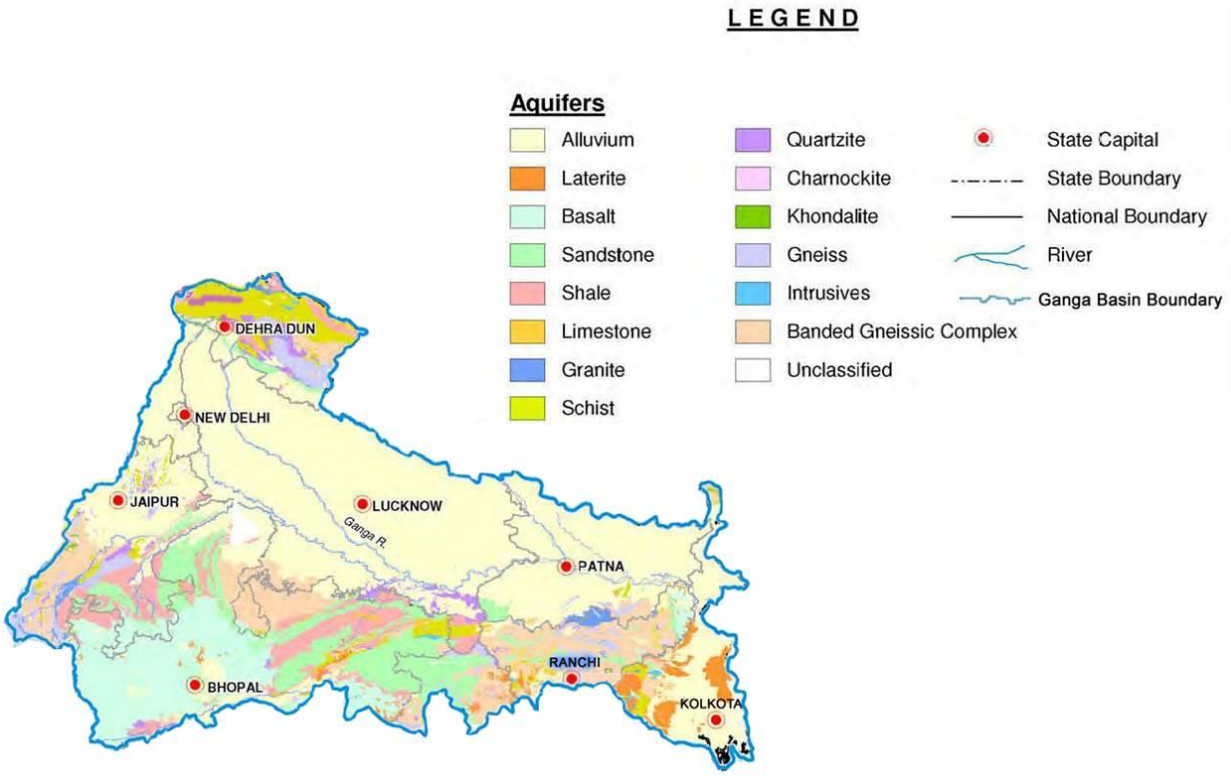


Figure 2.3b:Aquifer Systems of NRGB [*Adapted from: CGWB, 2012*]

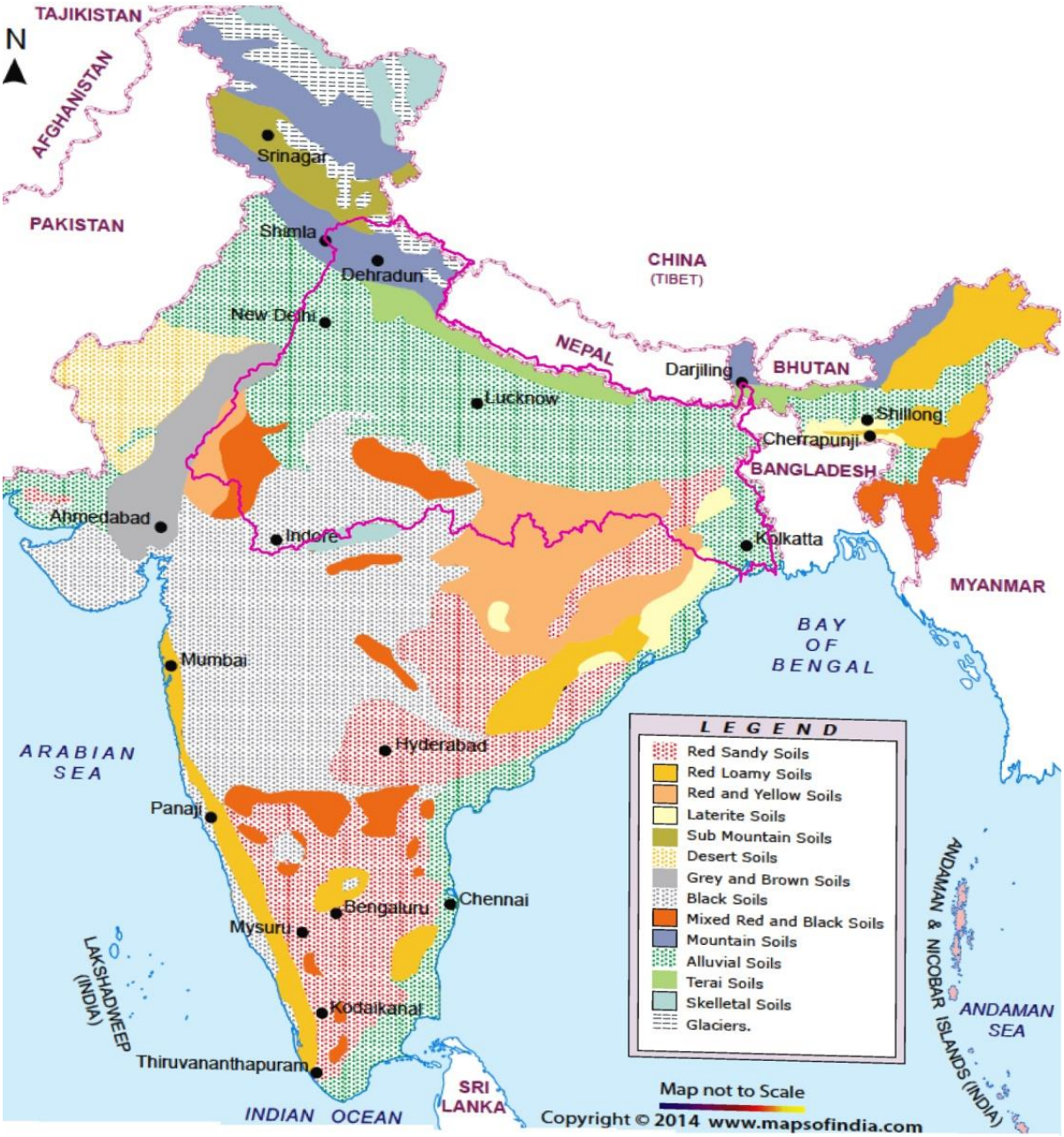
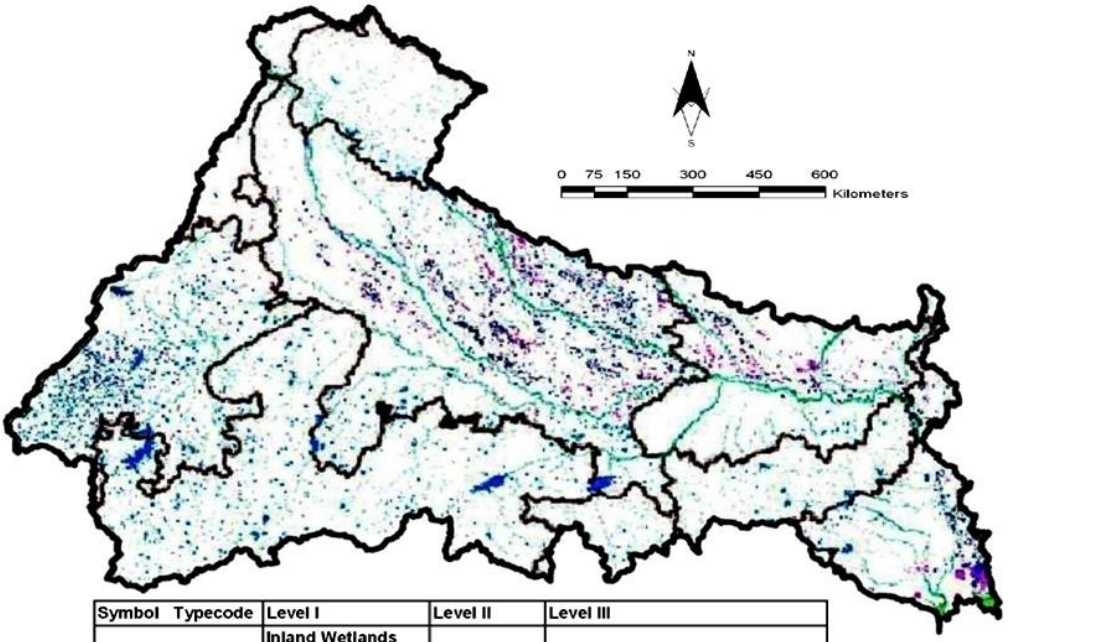


Figure 2.3c: Soil Map of NRGB [*Adapted from: MapsofIndia.com, 2014b*]

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 somemajor 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*]

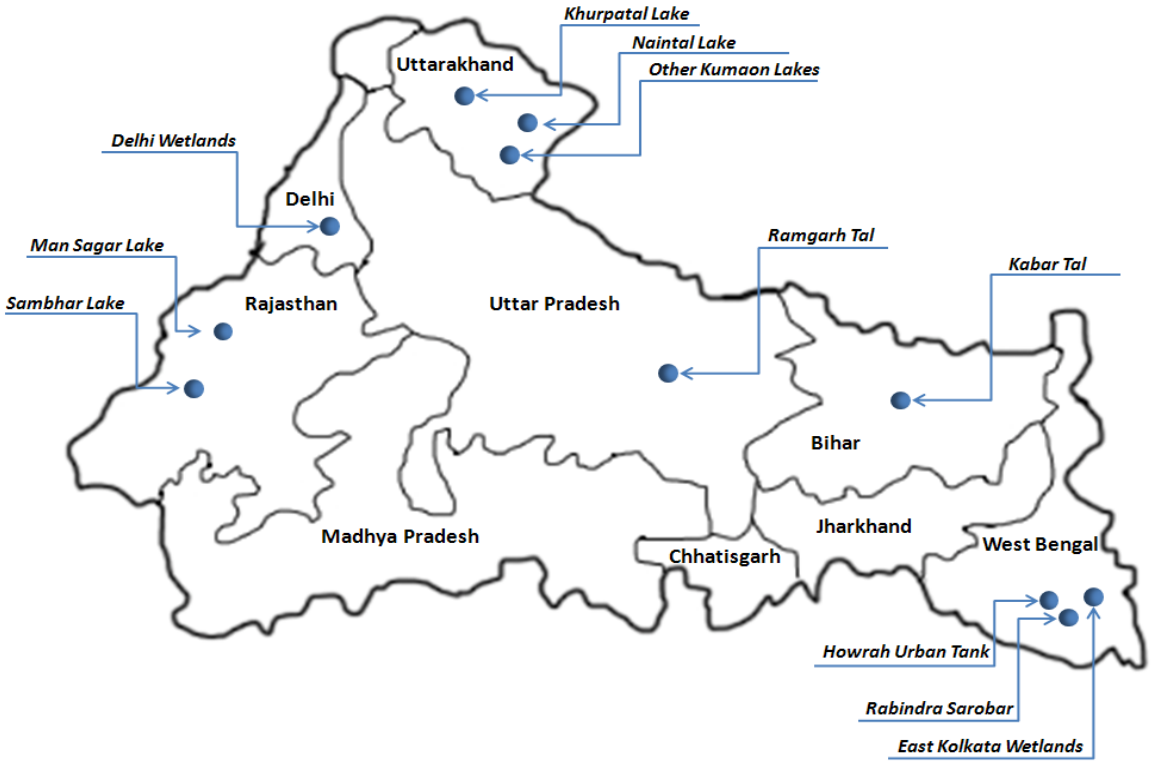


Figure 2.4b: Major Lakesand Wetlands of NRGB [*Adapted from: Rainwater--harvesting, 2013*]

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-ecologicalriver space. Based on remote sensing data and other inputs, the active floodplain of the Middle and Lower Ganga stretchesfrom 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.

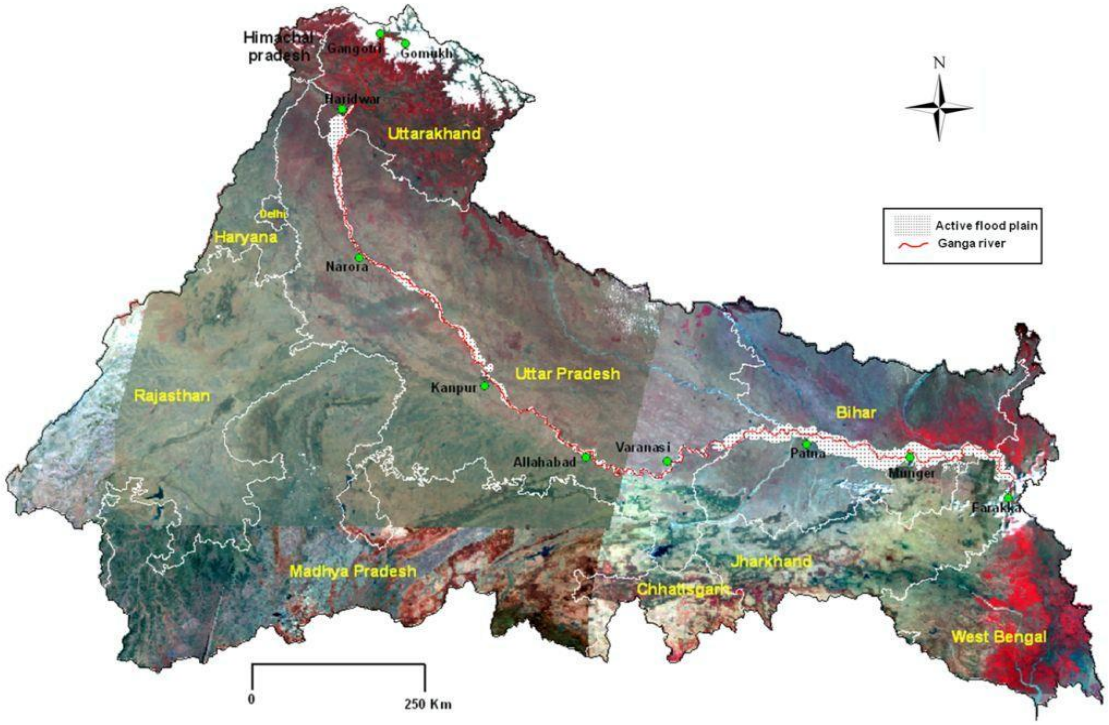


Figure 2.5a: Map of Ganga River with its Active Floodplain [*based on AWIFS data*]

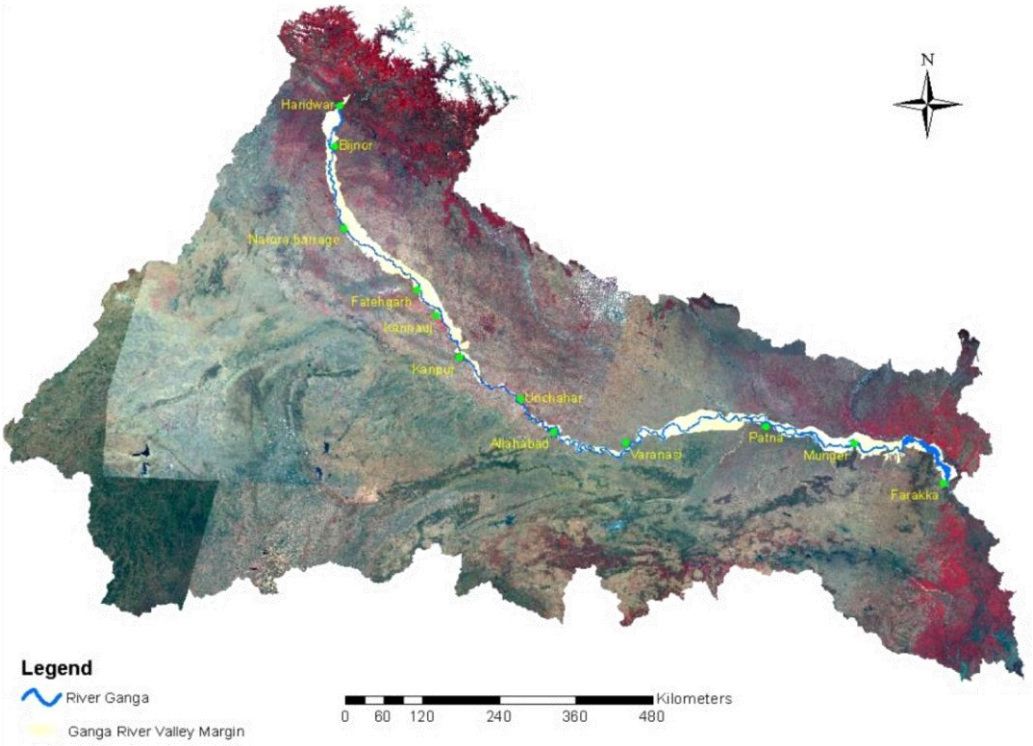


Figure 2.5b: Geomorphic Map of Ganga River Valley

2.6. Biodiversity of National River Ganga

The biodiversity of National River Gangais 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 sevenheads, viz.: (i) Phytoplanktons (tiny free-floating living organisms that drift with the water); (ii)Periphytons (algal community grows attached on the substratum along with phytoplanktons, comprise1176 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 281species 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 as 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 (significantly) 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. **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.

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.

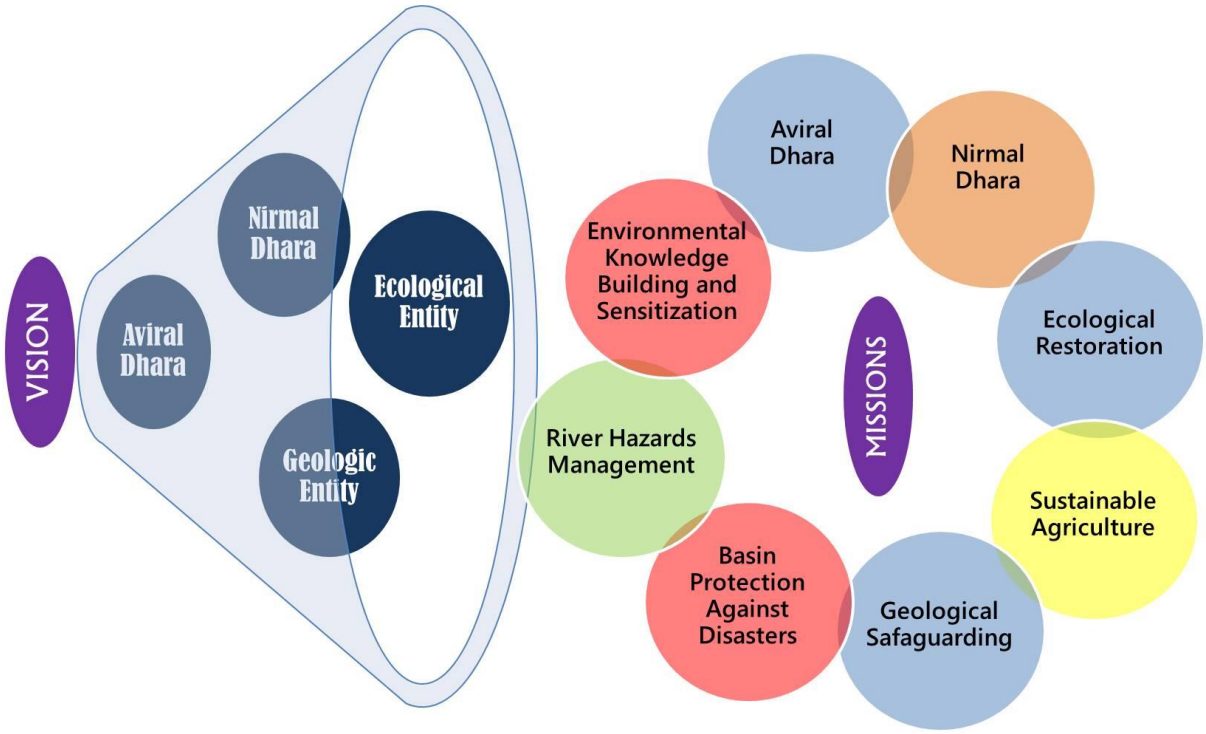


Figure 3.1: Target Missions to achieve Vision of a wholesome National River Ganga

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 NRGBshall be reviewed or scrutinized in a transparent and inclusive manner (with broad consensus of all affected people and stakeholders) for the overall health ofNRGB.

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.

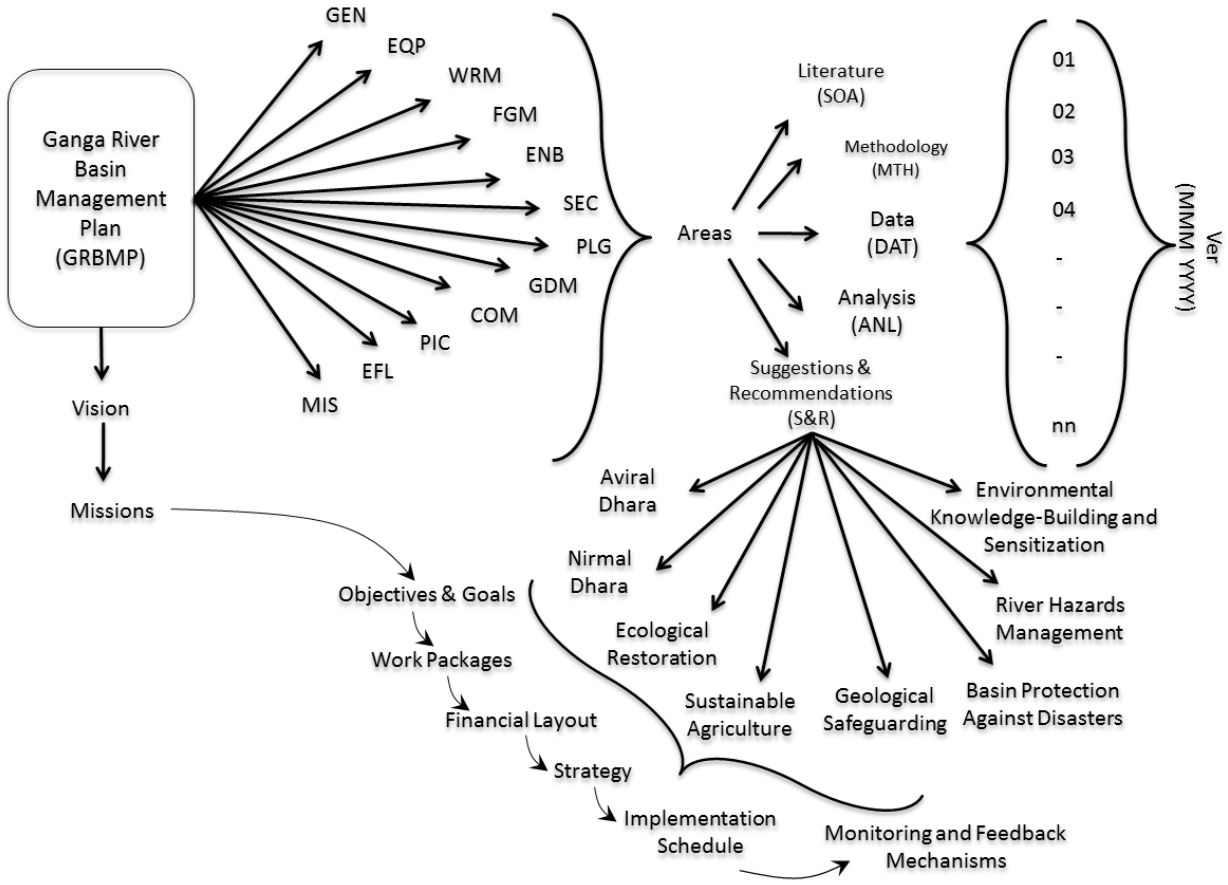


Figure 3.2: Flow Diagram of GRBMP Work Structure

4. GRBMP Missions

The main aspects of NRGB's 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 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 in a condensed form 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 anthropo-genic

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.

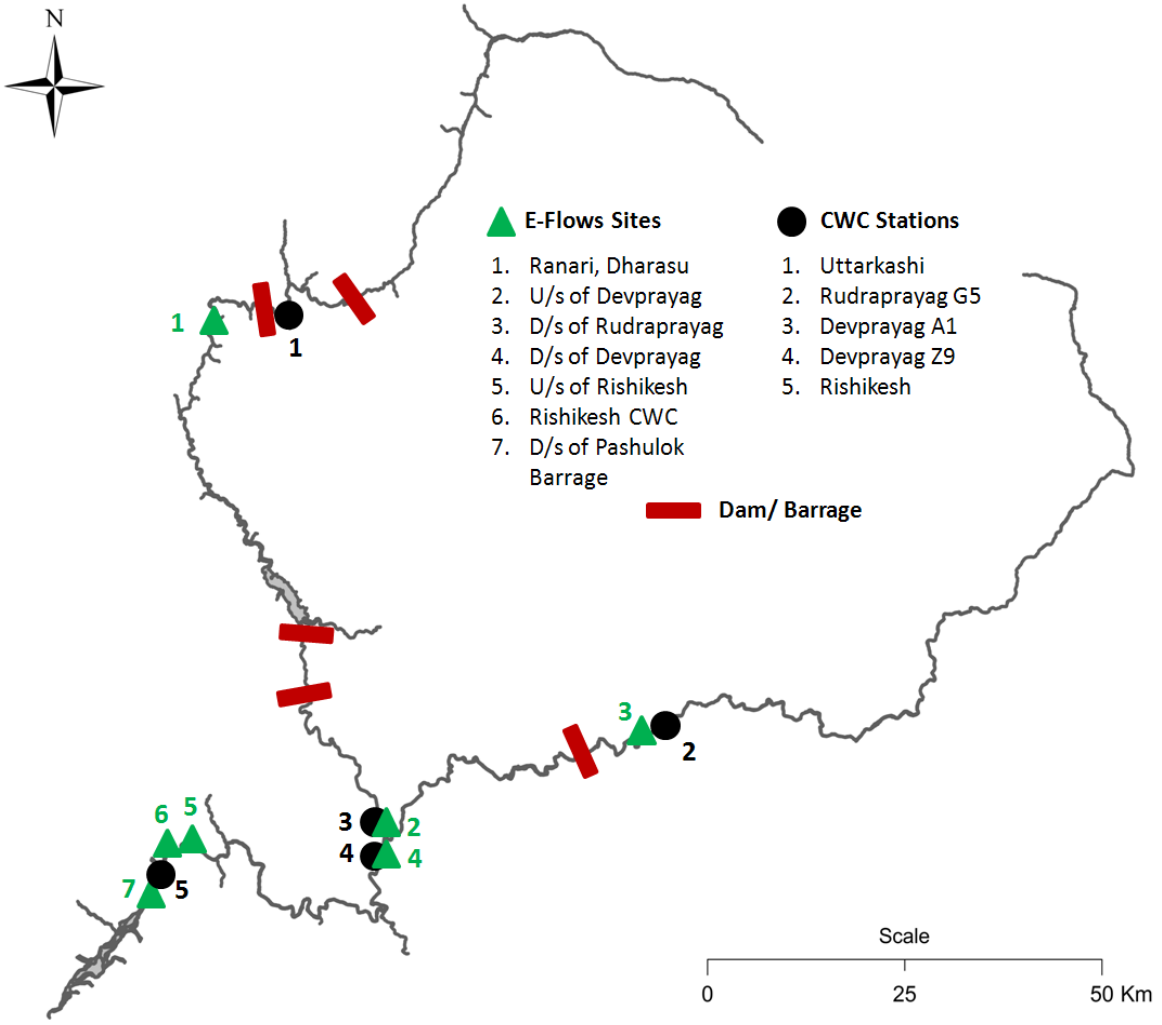


Figure 4.1: Location Map of E-Flows Sites in the Upper Ganga.

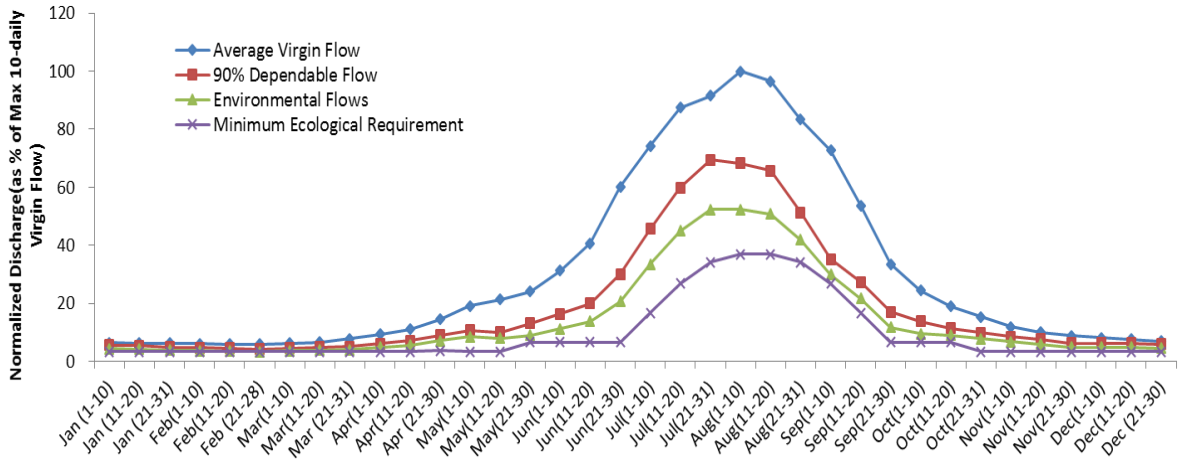


Figure 4.2: Computed 10-daily E-Flows at Ranari, Dharasu.

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 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 4.4.

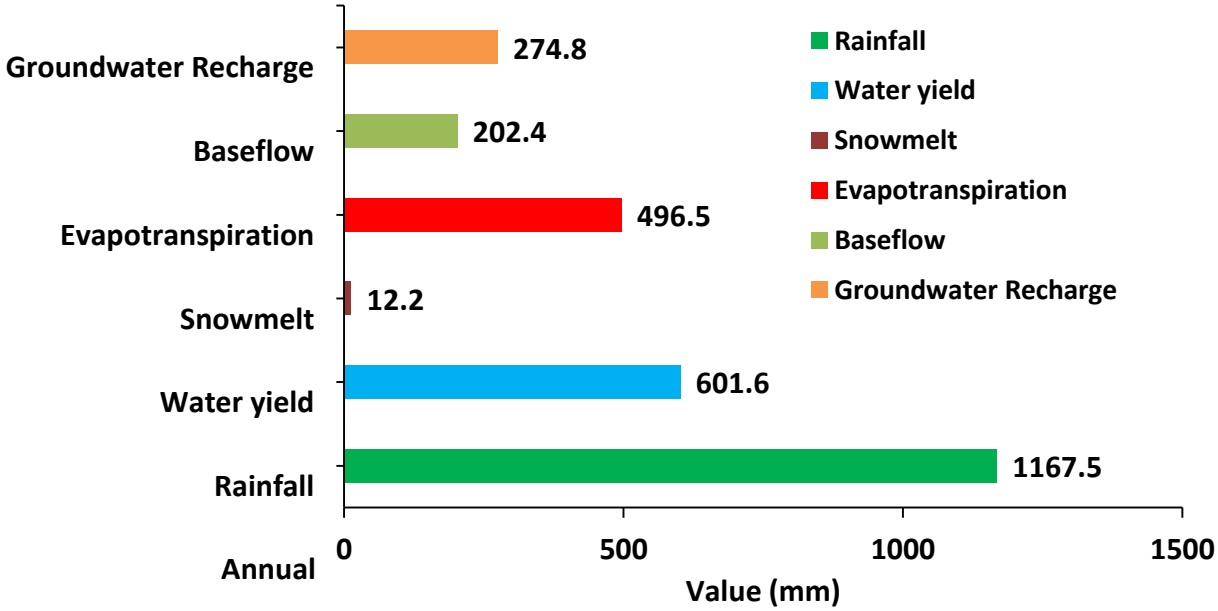


Figure 4.3: Average (1969-2006) Annual Water Balance of the Modeled Ganga Basin.

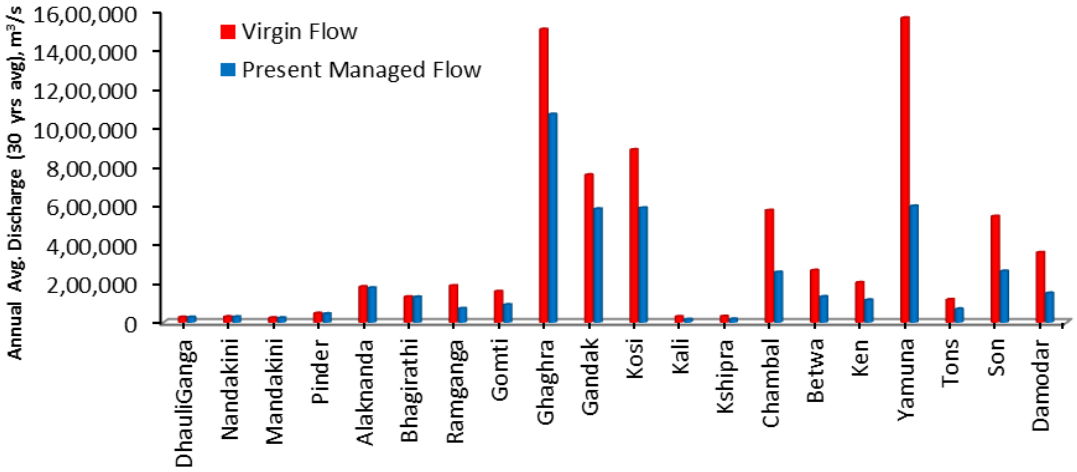


Figure 4.4: Annual Flow Contributions of Different Tributaries (sub-basins) to National River Ganga under Present Flow Conditions and under Virgin Flow Conditions.

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.

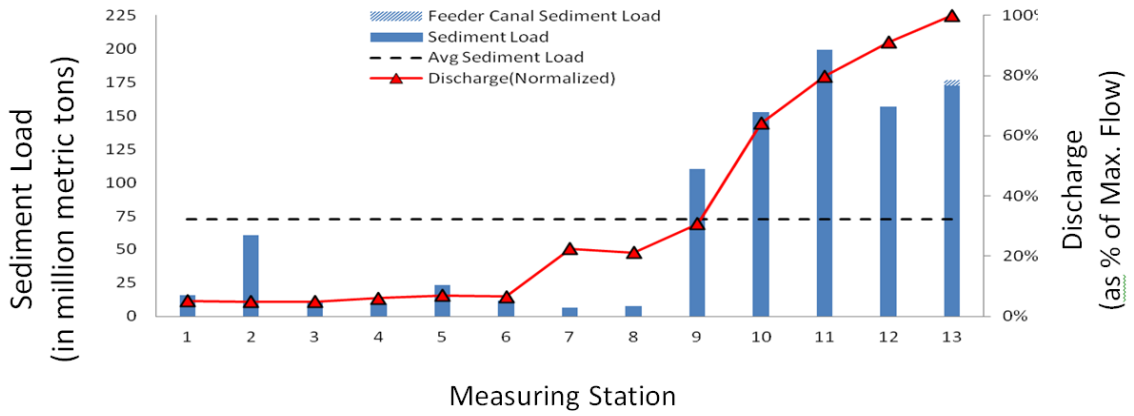


Figure 4.5: Comparison of the Annual Average Sediment Loads (for period 1999-2006) atDifferent Locations of National River Ganga

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 affecetd 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.

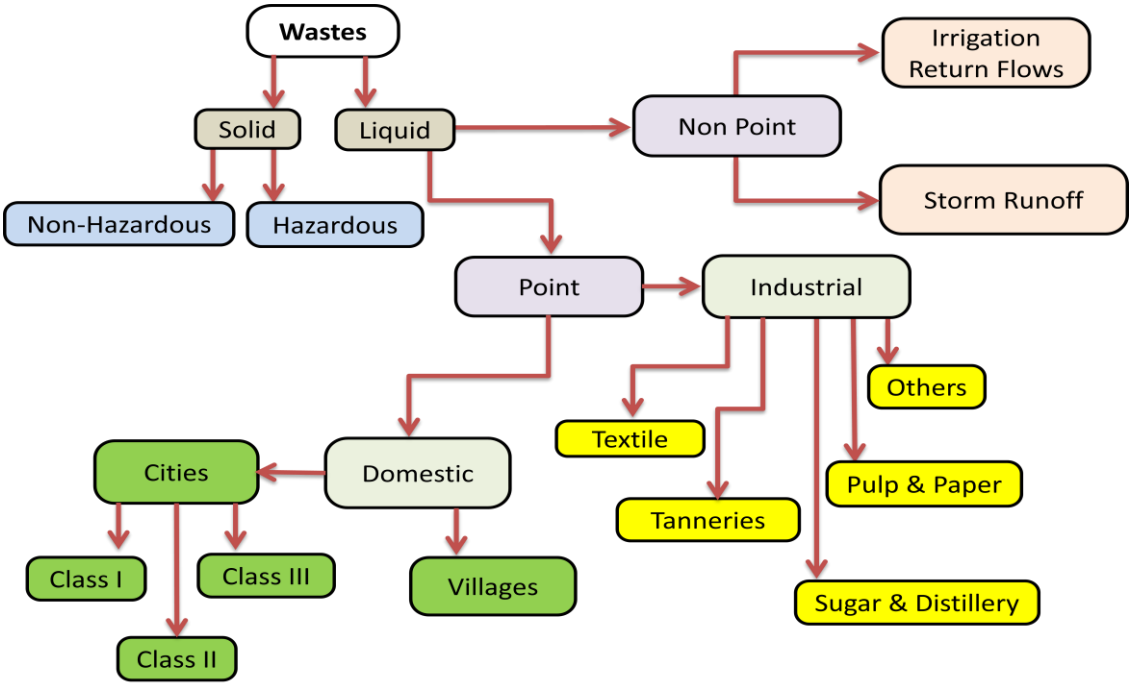


Figure 4.6: Types of Waste Generated in Ganga River Basin

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.

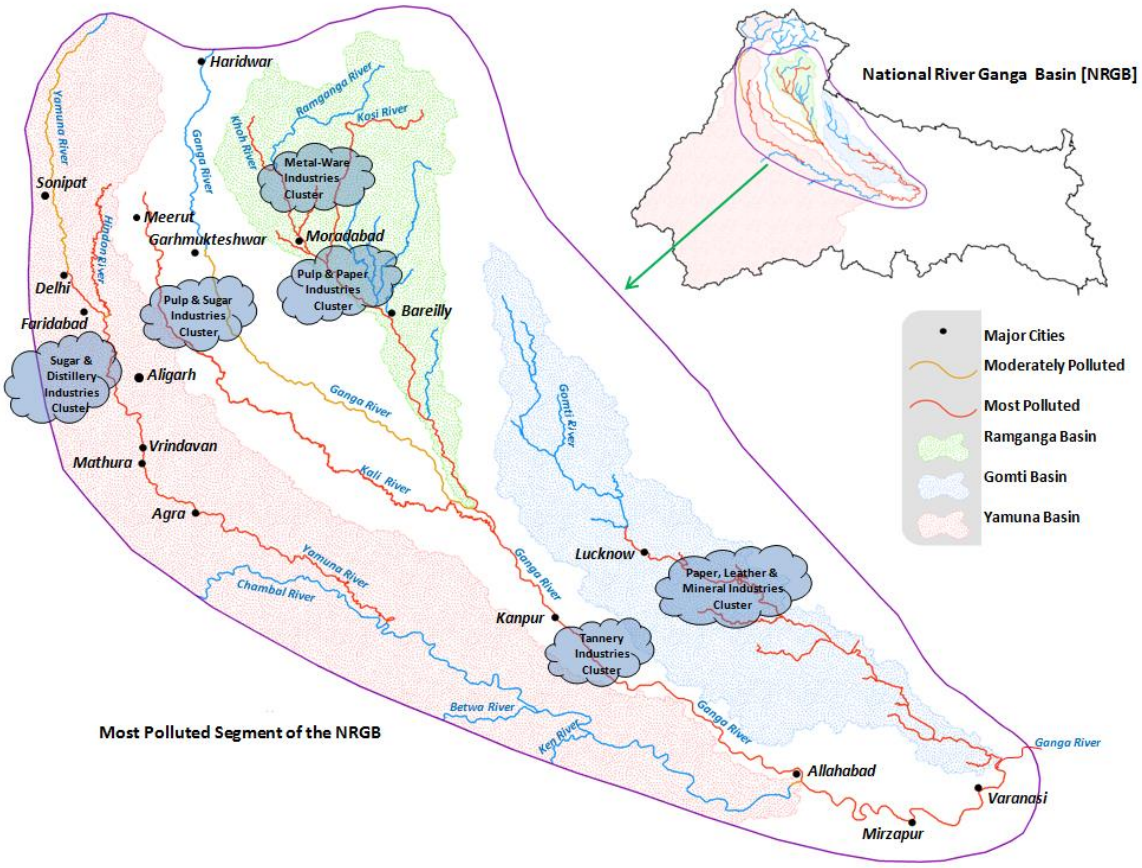


Figure 4.7: Most Polluted Stretches and their Pollution Sources in National River GangaBasin

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.

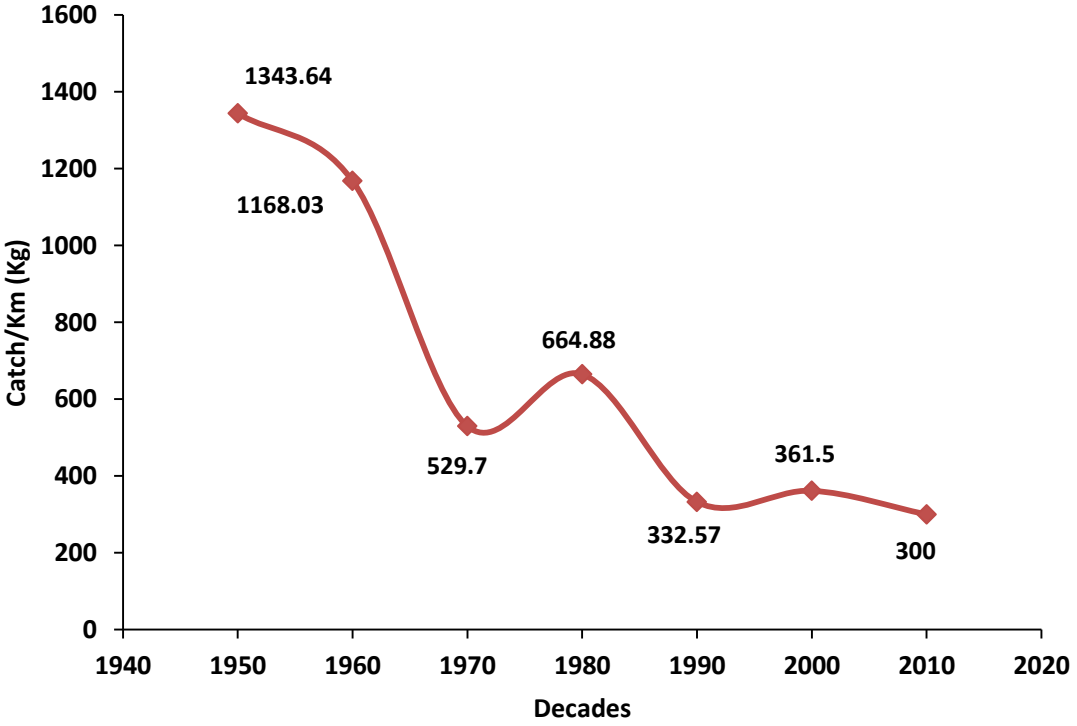


Figure 4.8: Decline of Fish Catch per km at Allahabad between 1950 to 2010 [IITC, 2014]

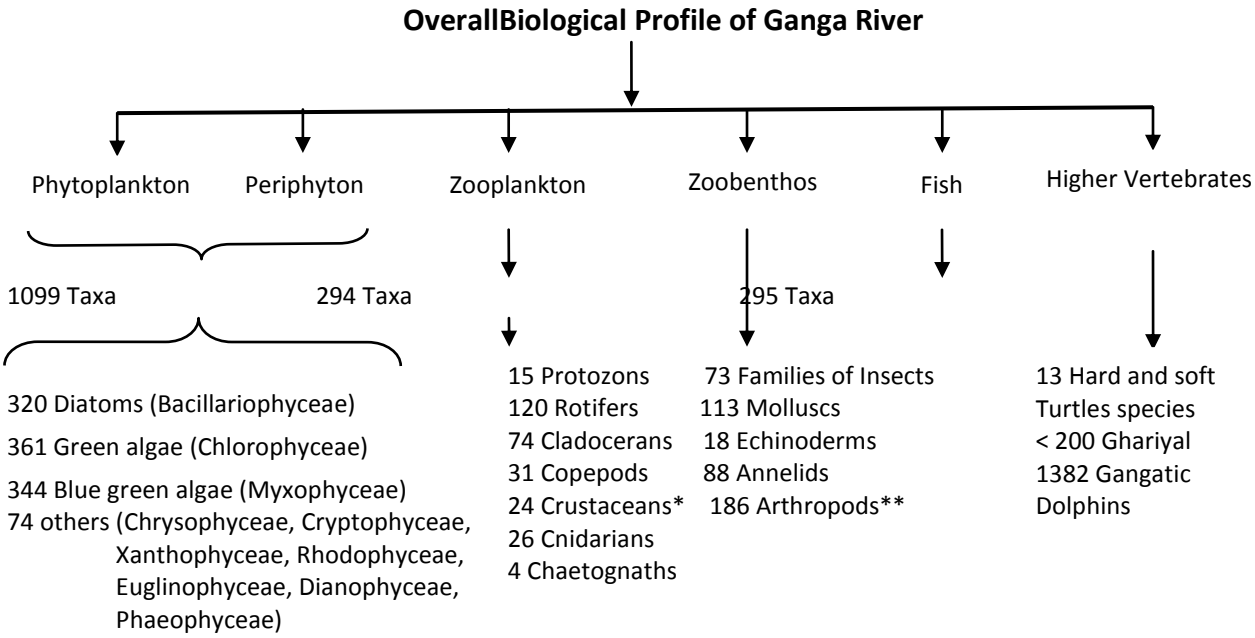


Figure 4.9: Biodiversity of River Ganga at a Glance.

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.

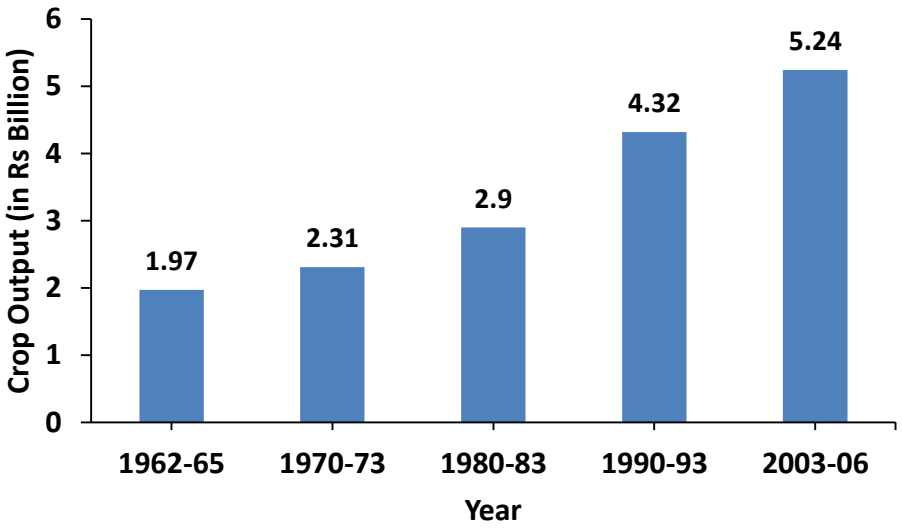


Figure 4.10: Average Crop Output Value per District in NRGB between 1962-65 and 2003-06

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 is covered under Mission Geological Safeguarding, the major natural disasters of real concern for the basin's ecosystems are few, viz.:*Extreme Floods*, *ExtremeDroughts*, *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) 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 people from 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 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. Hnece 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. Implementation of GRBMPRecommendations

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, resourceconservation 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 (Bigger) Block Method or other standard holistic methods.*
2.	Discontinuity in flow in any river due to engineered diversion/storage in the river.	*This measureconforms 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 measureconforms 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 measureconforms 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 frompathogens and recalcitrant pollutants.*

Table continued on next page … … … …

… … … … *Table continued from previous page*

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 areonly 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 beenexplained in Sections 4.2.1 to 4.2.4.

** Measure 5 envisages that, if treated wastewaters seep through the soil into the water table, they can bepurifiedby slow filtration and biochemical processesin the soil butnot if they areinjecteddirectly 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 inspecific situationsas 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. Unfettered plying of noisy vessels, dredging, and river bed and bank modifications.
10. Agricultural activities in river bedsandactive flood plainsof 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. Developmentof 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 raisegroundwaterlevels where neededand enhanceriver 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 controlof 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, amphibiansand mammals), and preventing the spread of exotic species in rivers and water bodies.
14. Eco-friendly tourism, pilgrimage and recreational activities in rivers andriverbanks.
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) 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 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 competentnon-profit/ for-profit agencies of**:** (i) NRGB'senvironmental 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'senvironmental problemsand their remediation, and (ii) developing a healthy civic sense of environmental proprieties.
25. Periodic reviewof "GRBMPAction Plans and Their Implementation"with feedback from all concerned individuals and agencies including rural and urban local bodies.

Note**:** Measures 13, 14 and 15 are not intended to duplicate the works being done byspecific 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. 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. It is therefore proposedthat 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 aBill [IITC, 2013]. TheNRGBMC should comprise Legal Luminaries, Technical Experts, Government Functionaries and Civil Society Members.

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

(1) The NRGBMCshould 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 aquaticresources in National River Ganga Basin.

(e) Monitoring, review and dissemination of the National River Ganga Basin'senvironmental 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 this GRBMP (under finalization) can be taken as a starting point for the proposed NRGBMC.

5.6. Legislation for NRGBMC

The need for a new legislation and the constitutional provisions enabling the establishment of 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.

5.6.1. 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 RiverGanga warrantsthe 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 riverbasin'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.

5.6.2. 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.

5.6.3. 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.

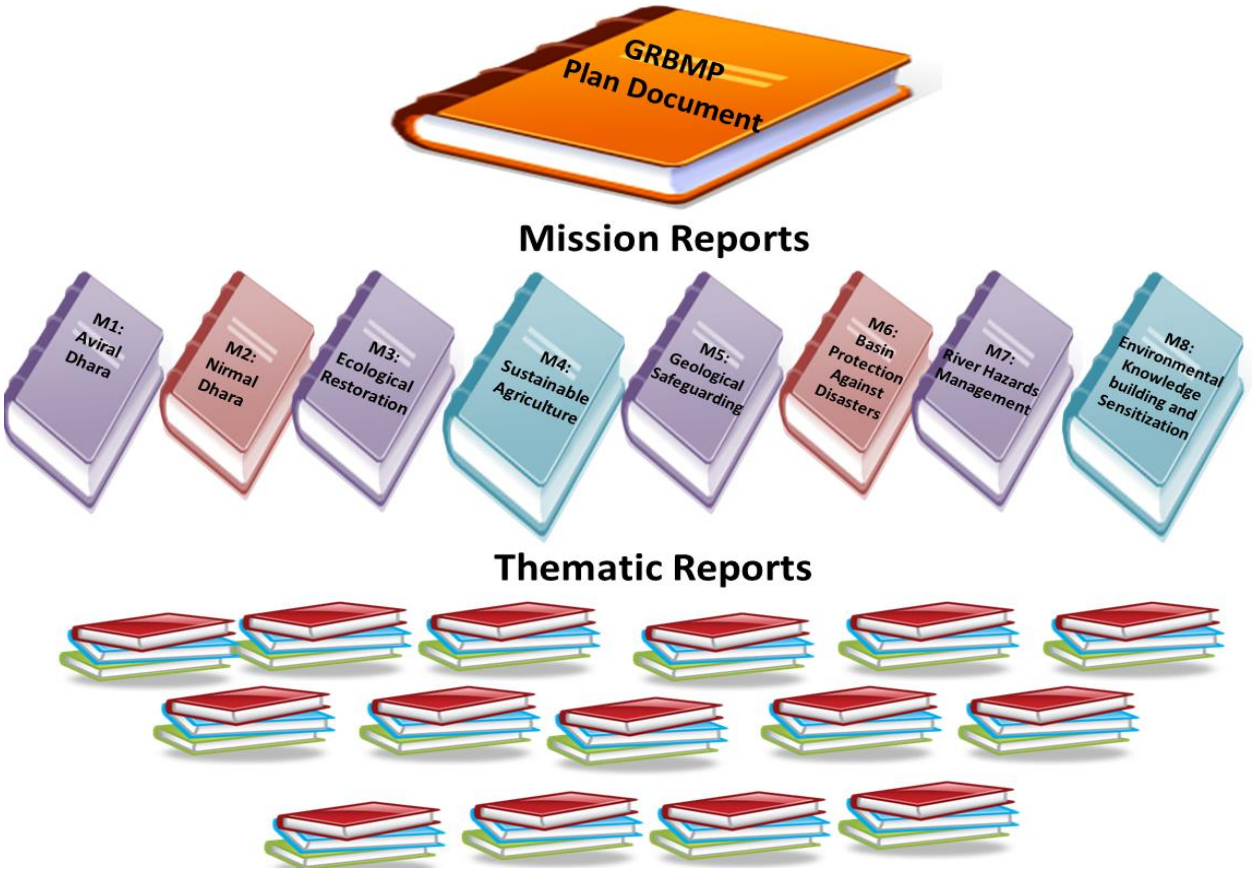
- Educate stakeholders (from rural communities to school students and special interest groups) on comprehensive understanding of complex environmental processes and their interaction with anthropogenic activities. This will involve preparing special educational material, training of field educators, 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.

5.6.4. 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***")arethe 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.]

References

1. Bhattacharyya, T.*et al*. [2013], "*Soils of India: historical perspective, classification and recent advances*", Current Science, Vol. 104 (10), May 2013.
2. CGWB (Central Ground Water Board, MoWR, GOI) [2009], "*Methodology for Assessment of Development Potential of Deeper Aquifers*".
3. CGWB (Central Ground Water Board,MoWR, GOI) [2012], "*Aquifer Systems of India*".
4. CWC (Central Water Commission) [2010], "*Water and Related Statistics*". [*Accessed May 09, 2013 from*:www.cwc.nic.in/ISO_DATA_Bank/W&RelatedStatatics_2010.pdf].
5. CWC (Central Water Commission) [2013], "*Water and Related Statistics*". [*Accessed September 05, 2014 from*:http://www.cwc.nic.in/main/downloads/Water%20and%20Related%20Statistics-2013.pdf].
6. Diamond, J. [2005], "*Collapse: How Societies to Choose to Fail or Succeed*", Viking, NY.
7. Eriksson, M. et al. [2009], "*The Changing Himalayas – Impact of Climate Change on water Resources and Livelihoods in the Greater Himalayas*" , Intl. Centre for Integrated Mountain Development (ICIMOD), Kathmandu. [*Accessed March 19, 2013 from:* http://www.worldwatercouncil.org/fileadmin/world_water_council/documents_old/Library/Publications_and_reports/Climate_Change/PersPap_01._The_ChangingHimalayas .pdf]
8. FAO (Food and Agricultural Organization of the United Nations) [1995], "*Planning for sustainable use of land resources: Towards a new approach*", FAO Land And Water Bulletin – 2, Food and Agricultural Organisation, Rome.
9. Gehrels, G. E. et al. [2003],"*Initiation of the Himalayan Orogen as an Early Paleozoic Thin-skinned Thrust Belt",* GSA Today, 13, 4–9, 2003. [*Accessed summary information Sept.16, 2013 from:* http://www.nature.com/news/2003/031002/full/news030929-6.html]
10. IITC [2010a]: "Sewage Treatment in Class I Towns: Recommendation and Guidelines; 003_GBP_IIT_EQP_S&R_02_Ver 1_Dec 2010".

11. IITC [2010b]: "Active Floodplain Mapping: Defining the River Space; 005_GBP_IIT_FGM_DAT_01_Ver 1_Dec 2010".
12. IITC [2011a]: "Mapping of Legislations Applicable to the Ganga River Basin; 011_GBP_IIT_PLG_DAT_01_Ver 1_Dec 2011".
13. IITC [2011b]: "Agriculture in the Ganga River Basin: An Overview; 015_GBP_IIT_SEC_ANL_01_Ver 1_Dec 2011".
14. IITC [2011c]: "Floral and Faunal Diversity of Upper Ganga; 020_GBP_IIT_ENB_DAT_01_Ver_Dec 2011".
15. IITC [2011d]: "Delineation of Valley Margin and Geomorphic Mapping along the Ganga River Basin and the Yamuna Sub-basin; 021_GBP_IIT_FGM_DAT_02_Ver 1_Dec 2011".
16. IITC [2012a]: "Ganga River Basin Environment Management Plan: Vision, Conceptual Framework and Guiding Principles", April 2012.
17. IITC [2012b]: "Floral and Faunal Diversity of River Alaknanda; 032_GBP_IIT_ENB_DAT_11_Ver 1_Jun 2012".
18. IITC [2012c]: "Status of Higher Aquatic Vertebrates in Ganga River Basin; 027_GBP_IIT_ENB_DAT_05_Ver 1_Jun 2012".
19. IITC [2013]: "Implementation Mechanism for Ganga River Basin Management Plan; 040_GBP_IIT_PLG_S&R_01_Ver 1_Dec 2013".
20. IITC [2014]: "Measures for Ecological Revival of River Ganga; 054_GBP_IIT_ENB_DAT_14_Ver 1_May 2014".
21. Indianetzone [2014], "*Ganges River Tributaries*." [*Accessed April 28, 2014 from*: http://www.indianetzone.com/29/tributaries_ganges_indian_river.htm].
22. India-WRIS (MoWR, GOI) [2014], "*River Basin Atlas of India – 2012*", RRSC-West, NRSC, ISRO, Jodhpur, India, 2012.
23. Jain, SK [2008], "*Impact of retreat of Gangotri glacier on the flow of Ganga River*", Current Science, Vol.95, No.8, Oct. 2008.
24. Jain, SK, PK Agarwal and VP Singh [2007], "*Hydrology and Water Resources of India*", Springer (Netherlands), 2007.
25. Jenny, H. [1994], "*Factors of soil formation: a system of quantitative pedology*", Dover Publication, 1994. [*Accessed May 28, 2014 from:* http://www.soilandhealth.org/01aglibrary/010159.Jenny.pdf.]
26. Maps of India [2014(a)], "*India Hill Ranges and Rivers*". [*Accessed May 30, 2014 from*: http://www.mapsofindia.com/maps/india/hillranges.htm.]

27. Maps of India [2014(b)], "*India Soil Map*". [*Accessed May 30, 2014 from*: http://www.mapsofindia.com/maps/india/soilsofindia.htm#.]

28. MoWR (Min. of Water Resources, GOI) [2002], "*National Water Policy 2002*". [*Accessed May 09, 2013 from*: http://wrmin.nic.in/writereaddata/linkimages/nwp20025617515534.pdf]

29. MoWR [2012], "*Draft National Water Policy 2012*". [*Accessed May 09, 2013 from*: http://wrmin.nic.in/writereaddata/linkimages/nwp20025617515534.pdf]

30. MoWR (Ministry of Water Resources, GOI) [2014], "*Ganga Basin – Version 2.0*".

31. MSU (Michigan State University) [2013],"Hydrogeology",.[*Accessed March 14, 2013 from*: http://hydrogeology.glg.msu.edu/wordpress/wp-content/uploads/2008/1/ ILHM_conceptual_diagram_3D.png.]

32. O'Connor, S [2010], "*Socioeconomics and the Murray Darling Basin: water allocation and economic viability*", Australian Conservation Foundation. [*Accessed July 30, 2013 from*: http://www.acfonline.org.au/sites/default/files/resources/ Basin_Plan_economic_analysis_20-10-10_0.pdf]

33. Pahl-Wostl, C. [2007], "*The implications of complexity for integrated resources management*", Environmental Modelling & Software, 22, Issue 5,May 2007, pp 561-569.

34. Prasad, S.N. et al. [2002], "*Conservation of Wetlands of India – A Review*", Tropical Ecology, 43(1): pp 173-186, 2002. [*Accessed February 21, 2013 from*:http://www.ces.iisc.ernet.in/energy/water/paper/Conservation_of_ wetlands_of_India.pdf]

35. Pegram, G. et al. [2013], "*River Basin Planning: Principles, Procedures and Approaches for Strategic Basin Planning*", UNESCO, Paris.

36. Rainwaterharvesting [2013], "*Database on Threatened Lakes.*" [*Accessed Feb.21, 2013 from*: http://www.rainwaterharvesting.org/public_interest.htm.]

37. SAC (Space Application Centre, ISRO) [2011], "*National Wetland Atlas*", Ahmedabad. [*Accessed May 10, 2013 from*: http://www.indiawaterportal.org/sites/ indiawaterportal.org/files/NWIA_National_atlas.pdf.]

38. Sadoff, C.W. and Muller, M. (Global Water Partnership) [2009], "*Better Water Resources Management*". [*Accessed March 19, 2013 from*:

http://www.worldwatercouncil.org/fileadmin/world_water_council/documents_old/Library/Publications_and_reports/Climate_Change/PersPap_04._Planning_Better_WRM.pdf]

39. Sinha, R. et al. [2005], "Late Quaternary geology and alluvial stratigraphy of the Ganga basin", Himalayan Geol., Vol. 26(1).
40. Smith, D.M. and Barchiesi, S. [2009], "Environment as infrastructure: Resilience to climate change impacts on water through investments in nature", Intl. Union for Conservation of Nature, Switzerland. [*Accessed March 19, 2013from*: http://www.worldwatercouncil.org/fileadmin/world_water_council/documents_old/Library/Publications_and_reports/Climate_Change/PersPap_02._Environment_as_Infrastructure.pdf].
41. Tandon, *et al*. [2008], "*Late Quaternary Evolution of the Ganga Plains: Myths and Misconceptions, Recent Developments and Future Directions*", Golden Jubilee Memoir of GSI, No.66.
42. UN-Water (UN-Water Task Force on Water Security) [2013], "Water Security & the Global Water Agenda", United Nations University, Ontario. [*Accessed April 01, 2013 from*: http://www.unwater.org/downloads/watersecurity_analyticalbrief.pdf.]
43. van Ast, L. et al. [2013], "*White Paper: Valuing Water to Drive More Effective Decisions*", Trucost, April 2013. [*Accessed July 02, 2013 from*: http://www.trucost.com/published-research/95/white-paper-valuing-water-to-drive-more-effective-decisions]
44. Wadia, D.N. [1965], "*The Himalaya Mountains – Their Age, Origin and Sub-crustal Relations*", Himalayan Journal, V.26. [*Accessed September 11, 2013 from*: http://www.himalayanclub.org/journal/the-himalaya-mountains-their-age-origin-and-sub-crustal-relations/.]
45. Wasson, R.J. [2003], "*A Sediment Budget for the Ganga-Brahmaputra Catchment,*" Current Science, Vol. 84, No. 8, pp 1041–1047.
46. Wikipedia [2013],"*Himalyas*" and "*Ganges*", 2013. [*Accessed May 10, 2013 from*: http://en.wikipedia.org/wiki/Himalayas andhttp://en.wikipedia.org/wiki/Ganges.]
47. Wikipedia[2014], "*Soils*". [Accessed May 28, 2014 from: http://en.wikipedia.org/wiki/Soil.]

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.**

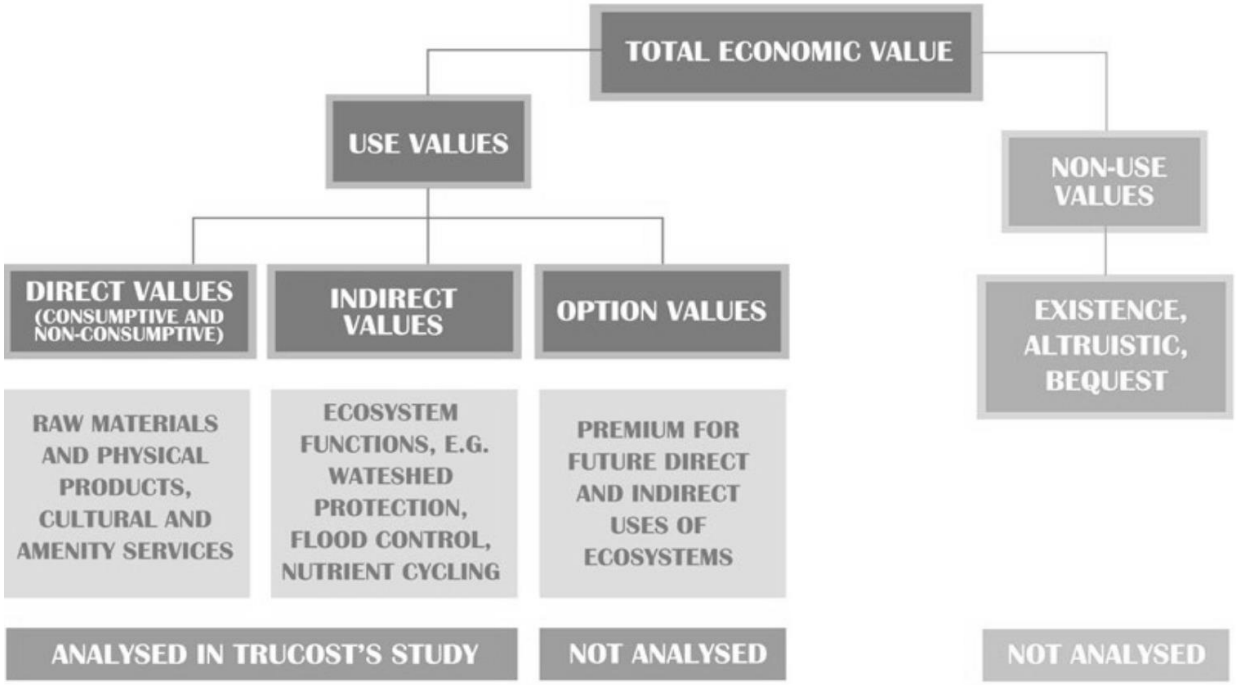
Clearly, without the MDB wetlands and rivers, the great productive base of our agrarian economy would not exist. Without water stored, filtered and

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.

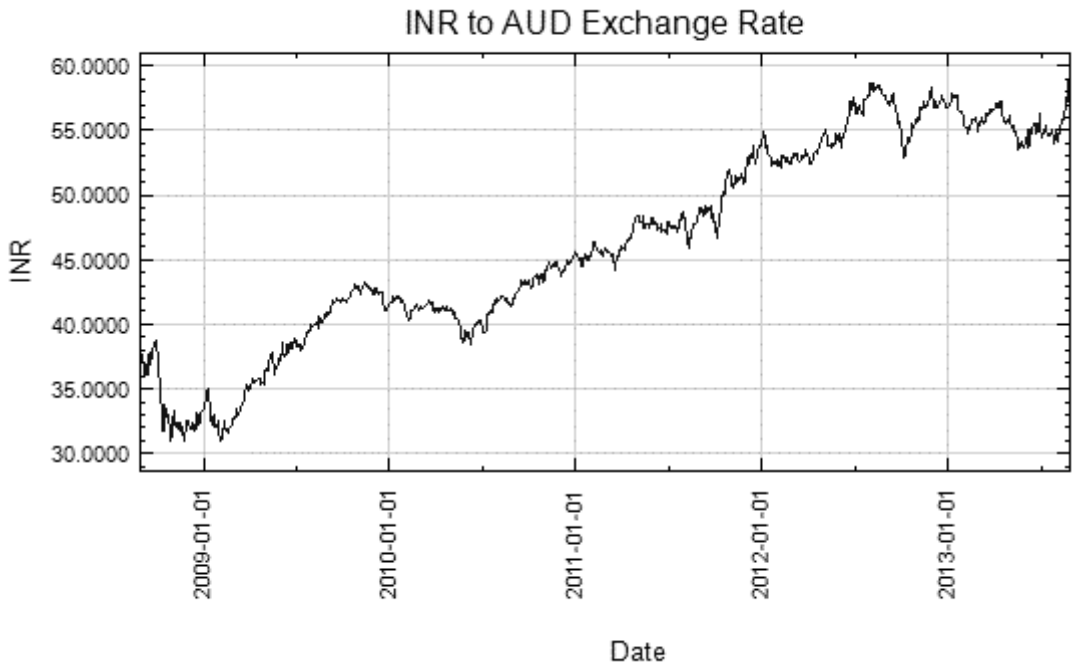
The Murray-Darling Basin (MDB) is the catchment for Murray and Darling rivers and their many tributaries, covering over one million km^2 or 14% of Australia, and generating one-third of Australia's food supply and 39% of national income from agriculture. The MDB Authority consulted on a MDB Plan that 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 – coversover 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 shownat 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 AUD5.85/m^3 (as against the domestic and commercial supply price of AUD1.90–1.91/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 AUD1.66/m^3 in 2010-11, when water was relatively abundant, to AUD8.97/m^3 in the most water-scarce year analysed. The hydrological function had the highest indirect use value of the ecosystem functions analysed (AUD4.85/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

Appendix II

List of GRBMP Reports

S No	Title
1	GRBMP: Vision, Conceptual Framework, and Guiding Principles
2	Mission 1: Aviral Dhara
3	Mission 2: Nirmal Dhara
4	Mission 3: Ecological Restoration
5	Mission 4: Sustainable Agriculture
6	Mission 5: Geological Safeguarding
7	Mission 6: Basin Protection Against Disasters
8	Mission 7: River Hazards Management
9	Mission 8: Environmental Knowledge Building and Sensitization
10	GRBMP – 2015: Main Plan Document

Thematic Reports

S No	Title	Report Code
1	River Ganga at a Glance: Identification of Issues and Priority Actions for Restoration	001_GBP_IIT_GEN_DAT_01_Ver 1_Dec 2010
2	Guidelines for the Preparation of Urban River Management Plan (URMP) for Class I Towns in Ganga River Basin	002_GBP_IIT_EQP_S&R_01_Ver 1_Dec 2010
3	Sewage Treatment in Class I Towns: Recommendation and Guidelines	003_GBP_IIT_EQP_S&R_02_Ver 1_Dec 2010
4	Guidelines for Implementation of Sewage Collection, Diversion, Pumping, Treatment, and Reuse (Sewage CDPTR) Infrastructure in Class I Towns	004_GBP_IIT_EQP_S&R_03_Ver 1_Dec 2010
5	Active Floodplain Mapping: Defining the River Space	005_GBP_IIT_FGM_DAT_01_Ver 1_Dec 2010
6	Strength, Weakness, Opportunity and Threat (SWOT) Analysis of Ganga Action Plan (GAP)	006_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2011
7	Assessment of Public Consultation Process for Environmental Clearance of Hydropower Projects in Upper Ganga Segment	007_GBP_IIT_PLG_ANL_01_Ver 1_Dec 2011
8	Mapping of Policy Instruments and Governance Agencies for Environmental Clearance of Hydropower Projects in Upper Ganga Segment	008_GBP_IIT_PLG_ANL_02_Ver 1_Dec 2011

S No	Title	Report Code
9	Policy and Governance: Perspective and Analytical Framework for Management of Urban Sewage	009_GBP_IIT_PLG_ANL_03_Ver 1_Dec 2011
10	Prevention of River Pollution by Urban Sewage: Recommendations from Policy and Governance Perspective based on a Model Case Study	010_GBP_IIT_PLG_ANL_04_Ver 1_Dec 2011
11	Mapping of Legislations Applicable to the Ganga River Basin	011_GBP_IIT_PLG_DAT_01_Ver 1_Dec 2011
12	Review of Wastewater Reuse Projects Worldwide: Collation of Selected International Case Studies and Experiences	012_GBP_IIT_EQP_SOA_01_Ver 1_Dec 2011
13	Emerging Contaminants in Ganga River Basin with Special Emphasis on Pesticides	013_GBP_IIT_EQP_SOA_02_Ver 1_Dec 2011
14	Pulp and Paper Industries in Ganga River Basin: Achieving Zero Liquid Discharge	014_GBP_IIT_EQP_S&R_04_Ver 1_Dec 2011
15	Agriculture in the Ganga River Basin: An Overview	015_GBP_IIT_SEC_ANL_01_Ver 1_Dec 2011
16	Trends in Agriculture and Agriculture Practices in Upper Ganga Basin (Uttarakhand)	016_GBP_IIT_SEC_ANL_02_Ver 1_Dec 2011
17	Trends in Agriculture and Agriculture Practices in Middle Ganga Basin (Uttar Pradesh)	017_GBP_IIT_SEC_ANL_03_Ver 1_Dec 2011
18	Trends in Agriculture and Agriculture Practices in Lower Ganga Basin (Bihar)	018_GBP_IIT_SEC_ANL_04_Ver 1_Dec 2011
19	Trends in Agriculture and Agriculture Practices in Lower Ganga Basin (West Bengal)	019_GBP_IIT_SEC_ANL_05_Ver 1_Dec 2011
20	Floral and Faunal Diversity of Upper Ganga	020_GBP_IIT_ENB_DAT_01_Ver_Dec 2011
21	Delineation of Valley Margin and Geomorphic Mapping along the Ganga River Basin and the Yamuna Sub-basin	021_GBP_IIT_FGM_DAT_02_Ver 1_Dec 2011
22	Environmental Flows: State-of-the-Art with special reference to Rivers in the Ganga River Basin	022_GBP_IIT_EFL_SOA_01_Ver 1_Dec 2011
23	Water Quality in the Ganga River and Efficacy of Sewage Treatment Processes in Coliform Removal: A Case for Adopting Tertiary Treatment	023_GBP_IIT_EQP_ANL_01_Ver 1_June 2012

S No	Title	Report Code
24	Floral and Faunal Diversity of Middle Ganga	024_GBP_IIT_ENB_DAT_02_Ver 1_Jun 2012
25	Floral and Faunal Diversity of Lower Ganga: Part A – Varanasi to Farakka	025_GBP_IIT_ENB_DAT_03_Ver 1_Jun 2012
26	Floral and Faunal Diversity of Lower Ganga: Part B – Farakka to Ganga Sagar	026_GBP_IIT_ENB_DAT_04_Ver 1_Jun 2012
27	Status of Higher Aquatic Vertebrates in Ganga River Basin	027_GBP_IIT_ENB_DAT_05_Ver 1_Jun 2012
28	Hilsa: An assessment in lower Ganga River Basin	028_GBP_IIT_ENB_DAT_06_Ver 1_Jun 2012
29	Status of Fish and Fisheries of River Ganga	029_GBP_IIT_ENB_DAT_07_Ver 1_Jun 2012
30	Wetlands in Ganga River Basin	030_GBP_IIT_ENB_DAT_08_Ver 1_Jun 2012
31	Riparian Vegetation in Ganga River Basin	031_GBP_IIT_ENB_DAT_09_Ver 1_Jun 2012
32	Floral and Faunal Diversity of River Alaknanda	032_GBP_IIT_ENB_DAT_10_Ver 1_Jun 2012
33	Floral and Faunal Diversity of River Yamuna	033_GBP_IIT_ENB_DAT_11_Ver 1_Jun 2012
34	Floral and Faunal Diversity of River Ram Ganga	034_GBP_IIT_ENB_DAT_12_Ver 1_Jun 2012
35	River Style Framework for the Ganga River	035_GBP_IIT_ FGM_DAT_03_Ver 1_July 2012
36	The Status of Sundari (H. fomes) an indicators species in the Sunderbans	036_GBP_IIT_ENB_DAT_13_Ver 1_Sep 2012
37	Stream Power Distribution Pattern for the Ganga River to Determine the Effects of River Energy and Sediment Supply on Channel Morphology	037_GBP_IIT_ FGM_DAT_04_Ver 1_Oct 2013
38	Pattern of Antibiotic Resistance in Bacteria from Three Different Aquatic Environments over Three Seasons	038_GBP_IIT_ EQP_DAT_01_Ver 1_Nov 2013
39	Assessment of Some Aspects of Provisioning Sewerage Systems	039_GBP_IIT_EQP_S&R_05_Ver 1_Dec 2013
40	Implementation Mechanism for Ganga River Basin Management Plan	040_GBP_IIT_PLG_S&R_01_Ver 1_Dec 2013
41	Cremation Practices: Analysis and Recommendations	041_GBP_IIT_EQP_S&R_06_Ver 1_Dec 2013
42	Sanitation in India: A Review of Current Scenario	042_GBP_IIT_EQP_DAT_02_Ver 1_Dec 2013
43	Sanitation in India: Recommendations for Optimal Practices	043_GBP_IIT_EQP_S&R_07_Ver 1_Dec 2013
44	State of Health in the Ganga River Basin	044_GBP_IIT_SEC_ANL_06_Ver 1_Dec 2013

S No	Title	Report Code
45	Cultural-Religious Aspects of Ganga Basin	045_GBP_IIT_SEC_ANL_07_Ver 1_Dec 2013
46	Demographic and Socio-Economic Analysis in Upper Ganga Basin (Uttarakhand)	046_GBP_IIT_SEC_ANL_08_Ver 1_Dec 2013
47	Demographic and Socio-Economic Analysis in Middle Ganga Basin (Uttar Pradesh)	047_GBP_IIT_SEC_ANL_09_Ver 1_Dec 2013
48	Demographic and Socio-Economic Analysis in Lower Ganga Basin - I (Bihar)	048_GBP_IIT_SEC_ANL_10_Ver 1_Dec 2013
49	Demographic and Socio-Economic Analysis in Lower Ganga Basin - II (West Bengal)	049_GBP_IIT_SEC_ANL_11_Ver 1_Dec 2013
50	Status of Urbanization and Industrialization in Uttarakhand	050_GBP_IIT_SEC_ANL_12_Ver 1_Dec 2013
51	Status of Urbanization and Industrialization in Uttar Pradesh	051_GBP_IIT_SEC_ANL_13_Ver 1_Dec 2013
52	Status of Urbanization and Industrialization in Bihar	052_GBP_IIT_SEC_ANL_14_Ver 1_Dec 2013
53	Status of Urbanization and Industrialization in West Bengal	053_GBP_IIT_SEC_ANL_15_Ver 1_Dec 2013
54	Measures for Ecological Revival of River Ganga	054_GBP_IIT_ENB_DAT_14_Ver 1_May 2014
55	Reform Imperatives for Agricultural Sustainability in Ganga Basin	055_GBP_IIT_SEC_ANL_16_Ver 1_May 2014
56	Hydrological Flow Health Assessment of the River Ganga	056_GBP_IIT_ WRM_ANL_01_Ver 1_Jun 2014
57	Surface and Groundwater Modelling of the Ganga river basin	057_GBP_IIT_ WRM_ANL_02_Ver 1_Aug 2014
58	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Urrarakhand	058_GBP_IIT_EQP_S&R_08_Ver 1_Dec 2014
59	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Haryana	059_GBP_IIT_EQP_S&R_09_Ver 1_Dec 2014
60	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Uttar Pradesh	060_GBP_IIT_EQP_S&R_10_Ver 1_Dec 2014
61	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Rajasthan	061_GBP_IIT_EQP_S&R_11_Ver 1_Dec 2014
62	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Bihar	062_GBP_IIT_EQP_S&R_12_Ver 1_Dec 2014

S No	Title	Report Code
63	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Madhya Pradesh	063_GBP_IIT_EQP_S&R_13_Ver 1_Dec 2014
64	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: West Bengal	064_GBP_IIT_EQP_S&R_14_Ver 1_Dec 2014
65	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Yamuna Sub-Basin	065_GBP_IIT_EQP_S&R_15_Ver 1_Dec 2014
66	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Ramganga, Kali and Gomati Sub-Basin	066_GBP_IIT_EQP_S&R_16_Ver 1_Dec 2014
67	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Gandak and Kosi Sub-Basin	067_GBP_IIT_EQP_S&R_17_Ver 1_Dec 2014
68	Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Hooghly Sub-Basin	068_GBP_IIT_EQP_S&R_18_Ver 1_Dec 2014
69	Policy and Governance Trends in Urban Water and Sanitation Sector in India	069_GBP_IIT_PLG_ANL_05_Ver 1_Dec 2014
70	Assessment of Potential Institutional Models for Sewage Treatment in Ganga Basin and the Way Forward	070_GBP_IIT_PLG_ANL_06_Ver 1_Dec 2014
71	M Tech Thesis: Assessment of Provisioning an Appropriate Solid Waste Management Approach in Urban Agglomerations in Ganga River Basin	071_GBP_IIT_EQP_S&R_19_Ver 1_Dec 2014
72	M Tech Thesis, 2014: Assessment of Approaches for Eliminating Use of Fresh Water in Tanneries at Jajmau, Kanpur	072_GBP_IIT_EQP_S&R_20_Ver 1_Dec 2014
73	Assessment of E Flows at Some Select Sites in Upper Ganga Segment	073_GBP_IIT_EFL_ANL_01_Ver 1_Dec 2014

Appendix III

Summaries of IITC GRBMP Thematic Reports

River Ganga at a Glance: Identification of Issues and Priority Actions for Restoration

Report Code:001_GBP_IIT_GEN_DAT_01_Ver 1_Dec 2010

River Ganga's origin and subsequent course in the plains are described. The Ganga River System is reviewed in three distinct fluvial segments. The Upper Ganga Segment from Gaumukh to Haridwar is described and essential environmental actions needed are defined, especially with regard to the effect of hydropower projects and tourism on the river ecosystem. In the Middle Ganga Segment up to Varanasi, the chief environmental measures needed are found to be complete stoppage of discharge of industrial and domestic wastewaters (and hence their recycling), and the creation of a dolphin protection zone below Garmukhteswar. The Lower Ganga Segment up to Ganga Sagar needs similar pollution control measures as in Middle Ganga, besides detailed hydrological and geo-morphological studies to deal with the high silt loads.

Guidelines for the Preparation of Urban River Management Plan (URMP) for Class I Towns in Ganga River Basin

Report Code: 002_GBP_IIT_EQP_S&R_01_Ver 1_Dec 2010

Most Class I Towns of Ganga River Basin (GRB) are located near River Ganga or its tributaries, and their sewage, solid wastes, riverbank encroachments, etc. harm the rivers. Hence URMPs (Urban Renewal Management Plans) are needed for all Class I Towns of GRB over a 25-year planning horizon for wastewater management and riverbank protection. The URMPs, to be prepared immediately by individual towns, should include actionable items such as removal of encroachments and beautification of riverbanks, banning/ restriction of undesirable activities, sewage collection and diversion, pumping and treatment, and storage, transport and reuse of treated sewage and sludge. The URMPs should be implemented after approval by an expert committee of NGRBA, and funding for various work packages should be made available

through NGRBA by different ministries. Unlike other city development plans the URMPs will be river-centric and not city-centric, thereby preventing adverse urban impacts on rivers.

Sewage Treatment in Class I Towns: Recommendation and Guidelines

Report Code: 003_GBP_IIT_EQP_S&R_02_Ver 1_Dec 2010

Urban sewage is a major point source of pollution and also a source of recycled water. Adequate sewage treatment for reuse – either in centralized STPs (Sewage Treatment Plants) or small decentralized STPs – will minimize fresh water withdrawals. The costs, process quality, reliability, environmental factors, land requirements, etc. of different sewage treatment processes are compared. The treatment chain is considered in three stages – Preliminary Treatment, Primary and Secondary Treatment, and Tertiary Treatment. Technological options for the second stage treatment are considered, and for eight different treatment processes the unit treatment costs and footprint area of treatment plant are derived. A decision matrix table of costs and different treatment parameters is presented. Technological options for sludge management, flow measurement, and bio-assay tests (of treated effluent) are explained. The importance of reusing the treated water, and thereby enabling zero liquid discharge from treatment plants into the environment, is emphasized.

Guidelines for Implementation of Sewage Collection, Diversion, Pumping, Treatment, and Reuse (Sewage CDPTR) Infrastructure in Class I Towns

Report Code: 004_GBP_IIT_EQP_S&R_03_Ver 1_Dec 2010

Currently, sewer networks and pumping facilities are absent or partial, treatment plants malfunctioning or inadequate, and sludge disposal improper. ULBs (Urban Local Bodies) responsible for operating these facilities have different concerns besides financial and other constraints. The Sewage CDPTR Infrastructure for all Class I Towns of Ganga River Basin (GRB) needed are: (i) complete stoppage of sewage discharge into rivers, (ii) sewage treatment up to tertiary level, and (iii) reuse of treated sewage water for non-contact/ non-

potable purposes. Thus, all new Sewage Treatment Plants must treat up to tertiary level and existing plants upgraded to this level. All Sewage CDPTR Infrastructure should be funded by central and state governments and executed through private-public partnership adopting a DBFO (Design-Build-Finance-Operate) Model, wherein a ULB may contract a service provider for 5–15 years with annual payments against service rendered. Public monitoring of such facilities through independent NGOs, CSOs, etc. is required.

Active Floodplain Mapping: Defining the River Space

Report Code: 005_GBP_IIT_FGM_DAT_01_Ver 1_Dec 2010

The "valley" and "active floodplain" of a river defines the space that it occupies for performing its natural functions. "Floodplain" is an area that is inundated during flood. "Valley" is a wider topographic low occupied by the river and its floodpalin over a longer time. Standard hydrological criteria of defining "active floodplain" is the 2.33 year return flood. Floodplain is ecologically most sensitive and supports a wide variety of vegetation and life forms; its complete preservation is one of the prime indicators of good river health.

Landsat 4-5 TM (30 m resolution), ***IRS P6 AWIFS*** (56 m), ***SRTM*** data were processed in Arc GIS to generate critical parameters for identifying floodpain and valley; and were validated by cross consultation of *MODIS* and *Google Earth* flood times images.

In a basin scale, active floodplain of Ganga River can be divided into four stretches:

a. Hardiwar-Narora: As the river leaves its mountainous reaches it creates a wider (~ 28 km) floodplain that narrows (~10 km) downstream; reduces to ~5 km near the Narora barrage;
b. Narora-Kanpur: Widens (~28 km) again after its confluence with Ramganga, reduces to ~15 km upstream of Kanpur and narrowest (~1 km) downstream of Kanpur.
c. Kanpur-Buxar: Generally narrow; increasing to ~7.5 km near Allhabad; continues unchanged downstream
d. Buxar-Farakka: Floodplain is widest (~42 km) downstream of Munger; near Farakka it is ~26 km

Strength, Weakness, Opportunity and Threat (SWOT) Analysis of Ganga Action Plan (GAP)

Report Code: 006_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2011

This report is primarily aimed at presenting an analysis of the strengths, weaknesses, opportunities and threats (SWOT) of Ganga Action Plans (GAP I and GAP II) and is primarily based on the secondary data collected and literature review. The objective of this report is to consolidate—in a systematic manner—the available knowledge and insights in order to understand nuances and complexity involved in design, implementation and monitoring aspects of the Ganga Action Plan (GAP). Several issues such as delays in implementation of the program, confusion over funding, technological issues, operation and maintenance of the assets do not only indicate typical governance failures but also clarify the gaps in policy and program design. These gaps also highlight the weakness in program planning/implementation/monitoring/evaluation, center-state coordination, state-ULB coordination, etc. The issues such as multiplicity of institutions, especially at the local level and their conflicting/overlapping roles place the need for a deeper institutional analysis. Opaque implementation and low levels of citizen's participation pose broader challenges for the future design and intervention and demand greater transparency. It is equally important to nuance this as problems with respect of to Ganga according to its three important stretches viz., the upper, middle and lower stretches of its flow in order to design the future course of action. Each of its stretch is characterized by different types of problems, having different physical conditions as well as dynamics created by distinct political economy.

Assessment of Public Consultation Process for Environmental Clearance of Hydropower Projects in Upper Ganga Segment

Report Code: 007_GBP_IIT_PLG_ANL_01_Ver 1_Dec 2011

After analyzing the governance structure in the earlier report (Report Code: 010_GBP_IIT_PLG_ANL_02_Ver 1_Dec 2011), this report focuses on a specific aspect of governance – the Public Hearing and Consultation (PC) process which is mandatory for hydropower projects (HPPs) to ensure transparency, accountability and participation in the environmental clearance process. PC is an important vehicle in democratic environmental decision making by

developing an arena where the views and suggestions of public are incorporated. Eight case studies of HPPs sampled for rivers Bhagirathi and Alaknanda were undertaken to understand the issues in PC. There is no claim of representativeness of these samples since it forma only a small proportion of the HPPs in the region. However, the in-depth case studies illustrated issues in the microcosm, which is indicative of the macro issues. Understanding the inadequacies and serious lacunae in the process, detailed analysis is given in the report. Some important recommendations are summarised below:

1. The public consultation process must be mandatory even for projects of less than 25 MW;
2. Should ensure informed (all aspects of the project written in local language to be circulated) participation in gramsabhas with adequate time for interested people to express their concerns and the must be recorded in the report
3. Implementation of transparency related provisions by making it mandatory for the PC panel to be constituted a day before the meeting and oversee all such provisions;
4. Before the final EC decision, EAC should inform people about how their concerns and suggestions are incorporated in the EC recommendations by making necessary provision to strengthen each of the stakeholder's right to challenge the EAC decision.
5. The Secretary, MoEF will be responsible for ensuring preparation and timely submission of such compliance reports (in a prescribed format) and its dissemination to local people through the offices of DM and DJ, and also through the MoEF websites.

Mapping of Policy Instruments and Governance Agencies for Environmental Clearance of Hydropower Projects in Upper Ganga Segment

Report Code: 008_GBP_IIT_PLG_ANL_02_Ver 1_Dec 2011

While acknowledging the need for hydropower generation, the process of according environmental clearances to hydropower projects on the basis of EIA studies is an essential tool for safeguarding the ecological integrity and resulting livelihoods in the Upper Ganga basin. Though the State has taken

stringent provisions to make the EIA-EC practice mandatory for hydropower projects, various stakeholders (especially from civil society organisations) have expressed grievances about the lacunae in policy instruments and performance of governing agencies leading to violations in practice. The objective of this report is to systematically map the institutional structure (PIs and GAs) for environmental governance in India and to suggest suitable changes to it. The following are the major recommendations of this report:

1. Pre-environmental clearance based on EIA studies is to be made mandatory for projects of all capacity/types including micro-mini-projects and small-medium-large projects whether run-off-the river or otherwise. All of these project types are likely to cause significant impact on local environment which must be studied.
2. An independent authority having required technical competence and supported financially by a consortium of developers is to be established through MoEF. Such an agency should design and conduct feasibility studies and location specific EIAs, if not cumulative impact assessments under the regulation of MoEF. This proposition differs from the consultancy services development mandate of the government and hence, its merits and demerits are needed to be discussed in detail.
3. Independent professionals having required competence in their respective subjects and adequate environmental credentials should be appointed as EAC members and must be provided with adequate secretarial support to thoroughly appraise and evaluate findings of feasibility studies and EIAs, and to recommend for a clearance through a public proceeding.
4. To ensure transparency and accountability in the environmental clearance decision making process, it should be made mandatory for the concerned agencies to give speaking justifications of their decisions and to share the proceedings in public domain.
5. An independent authority should be established to monitor violations during post clearance construction activities and ensure proactive compliances from the developers.

Policy and Governance: Perspective and Analytical Framework for Management of Urban Sewage

Report Code: 009_GBP_IIT_PLG_ANL_03_Ver 1_Dec 2011

After the analysis of GAP (Report Code: 006_GBP_IIT_GEN_ANL_01_Ver 1_Dec 2011), an urgent need was felt to evolve and articulate a systematic, comprehensive, conceptually sound, and internally consistent perspective—and an analytical framework based on it—that is focused on the policies and governance. The 'Policy and Governance Perspective' and the analytical framework developed in this report are built on the foundation of some clearly defined basic concepts and terms. It also presents a conceptual schema—called as the 'Governance Grid'—which takes a comprehensive view of governance of an entire sector. The perspective then presents a comprehensive and conceptually coherent schema of the actual process of governance as it generally unfolds in reality. The schema begins with the ground-level problems in any sector and helps the analyst identify the core governance maladies of different types in the sector. To address these maladies, the analyst then can evolve recommendations for appropriate changes in—or creation of new—policy instruments and / or governing agencies. The perspective prompts an argument that such core governance maladies cannot be cured by technical, financial, or managerial 'fixes'. It also makes a note that all governance problems cannot be addressed using the policy and institutional 'fixes' either, as they cannot resolve such problems rooted in the 'political bottom-line'. In other words, the problems rooted in the adverse balance of political-economic powers acting against the goals set for the governance of the sector can be resolved only through political action by the sections of society supporting the goals set for governance.

Prevention of River Pollution by Urban Sewage: Recommendations from Policy and Governance Perspective based on a Model Case Study

Report Code: 010_GBP_IIT_PLG_ANL_04_Ver 1_Dec 2011

This report presents an analysis of the ground-level situation of the sewage conveyance and treatment systems in the Kanpur city in Uttar Pradesh. The

objective is to bring out important policy and governance related lacunas in the sector, causing continued release of partially treated or untreated sewage and faecal-matter in the river Ganga. This report broadly follows the template presented in the report titled: Policy and Governance Perspective and Analytical Framework for Management of Urban Sewage (Report Code: 009_GBP_IIT_PLG_ANL_03_Ver 1_Dec 2011) and begins with the background information on the city of Kanpur with the focus on the activities of the Ganga Action Plan (GAP) executed in two phases (GAP I and GAP II) in the city. The findings focus on different deficiencies in the performance of the sewage system in the city of Kanpur with the analysis of various Policy Instruments (PIs) and lacunas in the Governing Agencies (GAs). The major observation is the proposed weakening of the UP Jal Nigam (UPJN), the para-statal agency currently entirely responsible for carrying out the task related to sanitation. The proposal to shift most of these functions to ULBs through 74th Constitutional amendment act and in parallel encouraging private participation raises a number of questions like huge capacity gaps in ULBs to undertake such functions. The resistance from UPJN for the shift could also affect the smooth functioning of the future pollution abatement activities. The regulatory functions of SPCB are currently severely limited by political interference and resource constraints. It has been evident from the efforts hitherto that sufficient level of experimentation has not taken place for decentralized and in-situ sewage disposal techniques. There is a great need to incentivize such techniques as well as their production and market development if such experiments are to become successful. Such new techniques and practices could be used in the rapidly developing peri-urban areas of large urban agglomerations such as Kanpur as well as to smaller cities which do not have centralized systems for sewage collection, conveyance, treatment, and disposal/reuse. Incentivizing market development for recycling and reuse is another equally important area, especially for cities that are having centralized systems. The shortage of freshwater increasingly faced by the industries in many part of the country which have adequate financial strength to raise finance for undertaking reuse or purchasing treated sewage for industrial use. This potential need to be assessed and pilots should be undertaken at appropriate locations, especially in industrial towns after conducting feasibility assessment of such pilots. However the larger question is whether all the

sewage could be absorbed by this mode which again brings in the question of a variety of modes of disposal in the place of currently imagined centralized systems. Small towns would continue to face the financial crisis; even after successful introduction of reforms, primarily because of the smaller sizes of their local economies, which are almost stagnated. Such towns would need continued state support. More case studies are required to be undertaken in the framework of this report to identify the amendments and revisions in GAs and PIs, which would be needed to address these lacunas and distortions. This, in effect, would help us improve the governance of urban sanitation (or sewage) sector in different states along the banks of river Ganga and her tributaries.

Mapping of Legislations Applicable to the Ganga River Basin

Report Code: 011_GBP_IIT_PLG_DAT_01_Ver 1_Dec 2011

Using the Law as an instrument of the River Basin Management has never been within the agenda of state and central legislative authorities; possibly, because it was thought that river is a natural resource and could be exploited to the extent one wants and that river will restore its system back in the natural process.

Because of the above underline thought, there are several legislations [Acts], regulations, rules, order and by-laws enacted/frame, which either pertain to the activities within river basin or have incidental impact over the same. Most of these legislations were enacted to achieve certain specific goals wherein river basin management was never a prime objective. But certain provision of these legislations has been used to regulate the activities on the river bed i.e., water navigation; control pollution, establishment of burning ghat and water sharing etc.

No concerted efforts have been made till date in legislative front against the exploitation of river. Many issues concerning river management didn't fail within the present legislative frame; some of these are maintenance of e-flow; protection of basin's ecology & species; issues relating to the maintenance of ground water in nearby basin area; consolidated plans for diversion of the river water in different stages of rivers; discharge of sewage; obstructions on the

river bed; use of floodplain & constructions on it; matter regarding the amount of river water usage; the activities allowed within the river bed etc.

Review of Wastewater Reuse Projects Worldwide: Collation of Selected International Case Studies and Experiences

Report Code: 012_GBP_IIT_EQP_SOA_01_Ver 1_Dec 2011

Unlike most of the river basins worldwide, the practice of treated wastewater reuse is underdeveloped in the Ganga River Basin owing to mist of apprehensions as a result of misconceptions, lack of knowledge and public perception, unclear policies and lack of institutional capabilities. The report presents and reviews some selected case studies of operating wastewater reuse installations worldwide and their associated environmental and public health impacts, economics, community and public perception and participation in order to introduce new ideas and exchange experience for promotion of wastewater reuse in the Ganga River Basin. The plethora of successful case studies suggest that treated wastewater reuse is a plausible option as part of integrated water resources management in the Ganga River Basin. On following the case studies, the zero discharge municipality/city concept by integrating the reuse of highly reclaimed wastewater adopting tertiary-level advanced treatment for non-potable non-human contact uses, seasonal storage in surface reservoir for groundwater recharge and irrigation is recommended as part of the river basin management plan. Water quality standard or guidelines pertaining to wastewater reuse for each beneficial uses must be developed. Moreover, the risk involved, if any must be assessed for treated wastewater reuse schemes before implementation.

Emerging Contaminants in Ganga River Basin with Special Emphasis on Pesticides

Report Code: 013_GBP_IIT_EQP_SOA_02_Ver 1_Dec 2011

Pesticide contamination poses significant risks to the environment and non-target organisms include beneficial soil microorganisms, insects, plants, fish, birds and humans. A limited number of studies have been conducted in the last three decades in Ganga river basin where pesticide concentrations have been monitored in various environmental media. In general, total DDT and total HCH

concentrations have been reported at significant concentrations by most researchers. Major findings are:

- Water: Pesticide levels in water samples from the Ganga River basin ranged from non-detectable to a maximum total pesticide concentration of 13.1 micro-g/L in the city of Varanasi. Only four of the fifteen studies reviewed here showed total pesticide concentrations higher than the permissible levels of 1 micro-g/L.
- Sediments: Pesticide levels in sediments ranged from 0.05 ng/g to 240 ng/g.
- Fish: Significant and high pesticide levels have been reported in fish tissue with maximum total DDT concentration of 7.5 micro-g/g in cat fish and maximum total HCH concentration of 3.5 micro-g/g in cat fish. These results indicate that pesticides like DDT and HCH bioaccumulate to significant levels in fish tissue. Health risks associated with these levels of pesticides in food need to be examined in greater detail.

In order to control water pollution by these substances, domestic and industrial wastes (both solid and liquid) should not be discharged/ dumped into water bodies without proper treatment. Further, constant monitoring and analysis of the most commonly used pesticides in all environmental media is essential for a comprehensive risk assessment.

Pulp and Paper Industries in Ganga River Basin: Achieving Zero Liquid Discharge

Report Code: 014_GBP_IIT_EQP_S&R_04_Ver 1_Dec 2011

Pulp and Paper Mills, particularly agro-based ones, are a major source of pollution in Ganga river. These mills also consume considerable fresh water. The need for reduced water consumption through improved manufacturing processes and reuse of wastewater are highlighted. Benchmark water consumption figures are indicated for different type of mills. Feasibility of CETPs in place of individual ETPs was examined and found to be generally non-advantageous. For base year 2010, the costs of tertiary treatment needed to produce industry-grade water was worked out for different types of industries. It was found that for complete water recycling, the production costs could increase by about 17–19% for agro-based industries and by 4–6% for RCF-based industries. Practical means for achieving the Zero Liquid Discharge target

can be accomplished through a dedicated service provider operating the wastewater treatment and recycling facilities on Design, Build and Operate model.

Agriculture in the Ganga River Basin: An Overview

Report Code: 015_GBP_IIT_SEC_ANL_01_Ver 1_Dec 2011

This report examines the trends in: agriculture land-use and cropping patterns; size of land holdings; crop-diversification; sources of irrigation and status of ground water; use of fertilizers, pesticides, and other inputs; and agricultural production and productivity. For this purpose, the entire basin is divided into three stretches, namely, Upper Ganga Basin (Uttarakhand), Middle Ganga Basin (Uttar Pradesh) and Lower Ganga Basin (Bihar and West Bengal). The study finds that agricultural production in the basin has increased tremendously during last four decades, albeit at varying rates across the states. Net sown area (NSA has declined over time due to growing industrialization and urbanization, while gross irrigated area (GIA) and the uses of other inputs like fertilizer and modern agricultural equipments have increased over the period. Increase in irrigation facilities has resulted into adoption of more water intensive cropping pattern. Although there is a good network of canals, especially in Uttar Pradesh, nevertheless ground water has been the key sources of irrigation in the basin. For instance, it shares 73% of GIA in Uttar Pradesh and Uttarakhand (combined), 59% in West Bengal and 49% in Bihar and Jharkhand (combined). Chemicalization of agriculture has also increased over the period in the basin. West Bengal seems to have registered a tremendous growth in the use of chemical fertilizers from the level of only 5 kg/hectare during 1962-65 to a level of 226 kg/hectare during 2003-06. Uttar Pradesh also followed, more or less, the same level of growth throughout the period with a level of only 4 kg/hectare during 1962-65 to 205 kg/hectare during 2003-06. Comparatively, Bihar has registered a modest growth in the fertilizer consumption. Such an intensive use of fertilizer may lead to disposal of high levels of nitrogen and phosphorus as part of the agricultural runoff into surface water bodies.

Trends in Agriculture and Agriculture Practices in Upper Ganga Basin (Uttarakhand)

Report Code: 016_GBP_IIT_SEC_ANL_02_Ver 1_Dec 2011

This report examines the trends in agriculture and agriculture practices in Uttarakhand and their implications for the Ganga River basin. The study, among others, focuses on land use and cropping pattern, size of land holdings, input use, including irrigation and chemical fertilizers, crop diversification, production and profitability. It is observed that although, the Ganga and its tributaries flow across Uttarakhand, the use of river water in the agriculture is largely confined to the plain areas because possibility of development of irrigation system and adoption of modern input-intensive agriculture in hilly areas is quite limited due to physical, environmental and economic reasons. The study finds that net sown area (NSA) has declined in the recent years due to increasing land demand for non-agricultural uses, particularly for industrialization and urbanization. Further, increasing marginalization of land holdings may pose great threat to the sustainability and economic viability of the agriculture. In the plain areas, cropping pattern is limited to only three water intensive crops—sugarcane, wheat and rice. Huge quantity of water could be saved by changing the cropping pattern from these crops to the less water consuming crops. It is also observed that the use chemical fertilizer in agriculture, especially in plain areas has increased significantly. The study suggests that in order to maintain *aviral* and *nirmal dhara* in the Ganga River, a two-fold strategy is to be adopted: First, the government policy should be oriented towards making agriculture ecologically as well as economical sustainable which could be done through incentivizing the farmers to adopt alternative farming system, such as organic farming. Second, modern farm technology such as laser land leveling and water saving technology may be promoted for increasing the water use efficiency in agriculture. In order to improve the livelihood of farmers of hill regions, hill agriculture is to be diversified from traditional crops to high value and low volume products. Primary processing of these products can be done in the village itself and secondary and tertiary processing may be done in the industrial clusters.

Trends in Agriculture and Agriculture Practices in Middle Ganga Basin (Uttar Pradesh)

Report Code: 017_GBP_IIT_SEC_ANL_03_Ver 1_Dec 2011

This study examines land-use pattern, occupational structure, size of land holdings, cropping pattern, crop-wise production and yield, area under different sources of irrigation, irrigation intensity, cropping intensity, use of chemical fertilizer and pesticides, status of groundwater utilization, trends in value of agricultural output, costs and returns from major crops and agricultural profitability in Middle Ganga Basin (Uttar Pradesh) which is divided into five regions—North Upper Ganga Plains (NUGP), South Upper Ganga Plains (SUGP), Central region (CR), Southern region (SR) and Eastern Region (ER). The study finds that paddy, wheat, and sugarcane together shared 68.8 percent of total GCA, 83 percent of total GIA and 75 percent of chemical fertilizers consumption in the state. Out of these three crops, sugarcane and wheat continued to generate profits to the growers over the period, while paddy did not consistently provide profits to them. The study reveals that the existing cropping pattern and agricultural practices are economically and ecologically unsustainable. The excessive use of chemical fertilizers and pesticides degrade soil and water and become the major non-point source of pollution of river water. Exponential growth of tube-wells in the basin has seriously depleted the ground water tables and consequently the quality of water. The study suggests that there is strong need to the change the existing agricultural practices and to encourage the farmers to adopt sustainable agricultural practices. Rice-wheat-sugarcane system of farming would not be environmentally sustainable for a longer period. Price signals and market conditions are main determinants of diversification which can be influenced through appropriate agricultural price policy. Alternative agricultural practices (such as organic farming) are not only required to generate more income and employment in the rural areas on sustainable basis but also for improving river health and consequently health of human, animals, and plants. In order to encourage farmers to adopt organic farming, their net farm income may be insured at least for three years either though providing subsidized inputs or through direct transfer of subsidies. This transfer could be much lower than the environmental and health costs that the society bears due to chemicalization of agriculture and pollution of rivers. The government may

introduce a water credit system to encourage the farmers to make efficient use of irrigation water. Irrigation literacy of farmers should be improved through electronic and print media to optimize the water use in agriculture. Information database comprising information on rainfall, groundwater recharge and utilization, water demand for difference purposes, land use pattern, cropping intensity and cropping pattern, customary water rights, irrigation system and practices, etc. may be collected annually and made available on-line.

Trends in Agriculture and Agriculture Practices in Lower Ganga Basin (Bihar)

Report Code: 018_GBP_IIT_SEC_ANL_04_Ver 1_Dec 2011

Bihar has been an agrarian economy with 90 percent of its population living in rural areas.The current report mainly examines the status of the agriculture in the bank and non-bank districts of Bihar in order to see the impact of Ganga on agriculture. The study finds that over the years, the area sown more than once has shown declining trend in Bihar, even the cropping intensity is also on declining phase. The current fallow land has increased and net sown area has declined in non-bank districts. The marginal holdings (less than one ha) account for 89.5 percent of the total land holdings in Bihar in 2005-06. Another alarming finding is that average size of marginal holding is 0.24 ha in Bihar in 2005-06. Tube-well has emerged as the most dominating source of irrigation in Bihar. In 2005-06, Tube-wells irrigated 64.72 percent of the net irrigated area and 66.94 percent of the gross irrigated area. Consumption of chemical fertilizers has increased substantially in Bihar agriculture over the time period. The rise in consumption has been more in case of bank districts. The area under rice cultivation has declined gradually over the years, but the area under wheat is showing rising trend. Among the non-food grain crops, sugarcane and banana have shown increase in area as well as production over the years. Looking at the cost and returns in major crops in Bihar, sugarcane, wheat and masur are found to be the profitable crops for farmers in Bihar whereas maize and paddy are not profitable for the farmers. The human and animal absorption in agriculture is declining which has implications for employment and use of animal waste as input in agriculture.

Trends in Agriculture and Agriculture Practices in Lower Ganga Basin (West Bengal)

Report Code: 019_GBP_IIT_SEC_ANL_05_Ver 1_Dec 2011

The study tries to examine the nature and pattern of agricultural activities in West Bengal and their implications for the Ganga River basin. The broad objectives of the study are to examine (a) the agricultural land use and land holding patterns in the state; (b) the trend of growth of agricultural output according to major crops; (c) the sources of inputs used in agriculture with special reference to water and fertilizers. It is observed that over the years, with rise in population in the state, cropping intensity is on the rise and it is higher in the river-bank districts. Rise in cropping intensity without proper crop diversification may lead to unsustainable use of agricultural land indicating greater demand for fertilizers, pesticides and insecticides, water etc. Average operational holding in the state has decreased significantly over time and considerable portions of farmers are turned out to be marginal farmers. There has been a significant increase agriculture production in the state, thanks to the introduction of high-yielding boro rice cultivation, enabling farmers to grow multiple crops in a year. Amongst the traditional crops, the fertilizer consumption in rice and potato cultivation is very high. There is thus a need to introduce crop diversification, which would economize the use of all resources including chemical fertilizers. Over time, there has been increase in the use of surface and ground water, thereby creating serious implications in terms of ground water depletion and river ecosystem.

Floral and Faunal Diversity of Upper Ganga

Report Code: 020_GBP_IIT_ENB_DAT_01_Ver_Dec 2011

The Central Himalaya in the Uttarakhand offers unique topographical, climatic and environmental features. The diversity of life was reviewed in the upper stretch of river Ganga, Gangotri to Haridwar (294 km). This stretch was divided into three sub-stretches viz., Gangotri to Gangnani (36.9 km) (UG-1), Gangnani to Devprayag (152.76 km) (UG-2) and Devprayag to Haridwar (89.24 km) (UG-3) based on differences in physical, chemical, and biotic attributes. The biotic

components of the system are represented by of phytoplankton, periphyton, zooplankton and vertebrate population essentially consisting of fish.

The biotic component in the UG-1 stretch is represented by total 20 taxa of phytoplankton (Bacillariophyceae 17 sp.; Chlorophyceae 02 sp.; Xanthophyceae 01 sp.), 16 taxa of periphyton (Bacillariophyceae 16 taxa) and 25 taxa of zoobenthos (Ephemeroptera 06 sp.; Trichoptera 02 sp.; Diptera 10 sp.; Plecoptera 05 sp.; Coleoptera 02 sp.) as the dominant group. Zooplankton and fish are generally absent in the stretch while some workers reported brown Trout (*Salmo trutto fario*) in the stretch.

In UG-2 stretch the biota consist of 49 taxa of phytoplankton (Bacillariophyceae 28 sp.; Chlorophyceae 16 sp.; Cyanophyceae 04 sp.; Xanthophyceae 01 sp.), 119 taxa of periphyton (Bacillariophyceae 104 sp.; Chlorophyceae 11 sp.; Cyanophyceae 04 sp.), 30 taxa of zoobenthos (Ephemeroptera 8 sp.; Trichoptera 5 sp.; Diptera 8 sp.; Coleoptera 4 sp.; Hemiptera 1 sp.; Odonata 1 sp.; Plecoptera 3 sp.) and 36 taxa of fish (Cyprinidae 23 sp.; Balitoridae 6 sp.; Sisoridae 6 sp.; Schilbeidae 1 sp.). The most characteristic fish of this sub-stretch is Trout (*Schizothorax* sp. and *Schizothoraichthys* sp.). *Schizothorax richardsonii* is selected as a keystone species of this sub-stretch. Zooplankton is not conspicuous except the occasional presence of ciliates viz. *Colpidium* and *Paramecium* sp.

The biota in UG-3 stretch constituted 72 taxa of periphyton (Bacillariophyceae 61 sp.; Cyanophyceae 6 sp.; Chlorophyceae 5 sp.), 77 taxa of phytoplankton (Bacillariophyceae 52 sp.; Cyanophyceae 10 sp.; Chlorophyceae 12 sp.; Xanthophyceae 1 sp.; Euglenophyceae 2 sp.), 14 taxa of zoobenthos (Ephemeroptera 3 sp.; Trichoptera 2 sp.; Diptera 4 sp.; Coleoptera 3 sp.; Odonata 2 sp.; presence of Plecoptera sp.) and 42 taxa of fish. Cyprinidae is the most dominant family while the most critical species is *Tor* sp., which is restricted in the upper region of Rishikesh. This species is known to migrate against water current up to the river Nayar, where it is known to spawn and rear. Mahseer is not spotted now downstream of Rishikesh barrage. Nematodes and Molluscs also showed the presence in form of zoobenthos in both UG-2 and UG-3 stretch. Zooplankton in UG-3 is scanty consisting of ciliates.

Delineation of Valley Margin and Geomorphic Mapping along the Ganga River Basin and the Yamuna Sub-basin

Report Code: 021_GBP_IIT_FGM_DAT_02_Ver 1_Dec 2011

Maps of valley margin and geomorphic features within the channel belt and active floodplain of Ganga River is presented. **Valleys margins** mark the water divide for the river; lateral hydrological connectivity and recharge of the basin takes place only within the valley margin. The **geomorphic features** within the valley are direct reflection of the hydrological processes operative within the channel and the adjacent floodplain and provide the physical infrastructure of the ecological functions for the River. The satellite images and SRTM is the data source.

Valley width is not uniform and based on valley width, its orientation and position of the river within the valley (symmetrical, left/right margin) the river has been divided into 7 stretches. Maximum valley width varies from 11 to 39 km, while the minimum is 1 to13 km.

22 geomorphic elements have been mapped from Gomukh to Farakka. These include 6 types of in-channel bars, 4 types of secondary/floodplain channels, and 12 types of floodplain features including variety of abandoned bars, levees, floodplain lakes.

River remains narrow confined by Himalayan hills up to **Haridwar**; downstream of Haridwar it widens as it enters the plain and forms a braided stretch on a piedmont fan. Downstream of **Narora** the valley is wide with abandoned braid bars, but channel flow is very narrow due to Narora barrage. After **Fategarh** major tributaries join the river and it is incised at places. Between **Kanpur** and **Allahabad** the river is straight with abundant bars. South of **Dalamau** it becomes more stable, meandering. The sinuous course continues beyond **Varanasi** till Gomti and Gaghghara joins and Ganga starts braiding with large stabilised alluvial islands. Joining of large sediment-carrying tributaries (Gandak, Kosi, Mahananda) continues to feed Ganga and the river is characterised by numerous in-channel and abundant braid bars till **Farakka**.

Environmental Flows: State-of-the-Art with special reference to Rivers in the Ganga River Basin

Report Code: 022_GBP_IIT_EFL_SOA_01_Ver 1_Dec 2011

This report explained the concept of E-Flows and its rationale. If further did a thorough review of E-Flows work at a global level and also its relevance for Indian conditions, with special reference to Ganga river system. The concept of Environmental Flows (E-Flows) is defined in this repost, i.e.

"A regime of flow in a river or stream that describes the temporal and spatial variation in quantity and quality of water required for freshwater as well as estuarine systems to perform their natural ecological functions (including sediment transport) and support the spiritual, cultural and livelihood activities that depend on these ecosystems"

A comparative account of various set of E-Flows Assessment (EFA) methodologies has been tabulated to provide comprehensive information about EFA methodologies.

The report also reviewed various initiatives for assessment of E-Flows across the country. The notable among those ones included, the work of WQAA (Water Quality Assessment Authority, Ministry of Water Resources, Government of India) and the study on E-Flows assessment of Upper Ganga by WWF-India (World Wide Fund for Nature – India) and its partners.

The report took a concerted view that for assessment of E-Flows for Ganga river system, the Building Block Methodology (BBM) is the most appropriate methodology. The BBM is one of the holistic set of methodologies and is known for being flexible to accommodate critical local aspects, plus, this methodology works well in data-rich and data-deficient conditions.

Water Quality in the Ganga River and Efficacy of Sewage Treatment Processes in Coliform Removal: A Case for Adopting Tertiary Treatment

Report Code: 023_GBP_IIT_EQP_ANL_01_Ver 1_June 2012

Various intervention and treatment schemes under the Ganga Action Plan (GAP) have been implemented over the last few decades for abatement of pollution and maintaining the river water quality. The report is aimed at analyzing water quality trend of the entire course of the Ganga River since the

implementation of GAP and critically reviewing the efficacy of secondary-level sewage treatment technologies in removing microbial pollution and the performance of commonly adopted techniques for disinfection of secondarily-treated effluent. Water quality trend analysis suggests that the river is subjected to severely increasing microbial pollution despite insignificantly higher organic pollution. Lean river flow during most periods in a year due to prevailing climatic and monsoon characteristics in the basin further aggravate the situation. Secondary-level sewage treatment techniques adopted under GAP primarily target reduction in organic pollution and maintaining aesthetics, whereas the reduction in coliforms has been purely incidental. Present paradigm of wastewater treatment employing primary and secondary treatment is vastly ineffective and thereby disinfection of secondarily-treated effluent is bound to be unsatisfactory. The comprehensive analysis presented in the report suggests a case for adopting tertiary-level wastewater treatment with multiple-barrier disinfection approach employing ozonation followed by UV-treatment and/or chlorination in the Ganga River Basin.

Floral and Faunal Diversity of Middle Ganga

Report Code: 024_GBP_IIT_ENB_DAT_02_Ver 1_Jun 2012

The Ganga enters the plains at Haridwar and follows 800 km arching course and continues its journey south east. The stretch of Ganga from Haridwar (downstream of Bhimgoda barrage) down upto Varanasi has been referred as middle Ganga (MG). The stretch is divided into five substretches (a. MG-1 Haridwar to Bijnor; b. MG-2 Bijnor to Narora; c. MG-3 Narora to Fatehgarh; d. MG-4 Fatehgarh to Allahabad; e. MG-5 Allahabad to Varanasi). The multipurpose barrages constructed at Rishikesh, Haridwar, Bijnor and Narora where large abstractions of water for irrigation and generation of power takes place. The middle Ganga stretch also having major diversions as Upper, Madhya and Lower Ganga canal. The river bed is wide with extensive flood plains, meandering streams on sand and pebbles. The water temperatures are moderate and velocities low 20-30 cm/sec. The river consists of pools, riffles and run of the river. The water is clean up to Fatehgarh and thereafter receives large pollution load from the tributaries and urban areas specially Kannauj, Kanpur, Fatehpur, Allahabad and Varanasi.

The data of biota in the middle Ganga is very fragmentary. All components have not been reported in all stretches, MG-1 to MG-5. Phytoplankton is represented by total of 355 taxa (166 sp. of Bacillariophyceae, 113 sp. of Chlorophyceae, 56 sp. of Cyanophyceae, 9 sp. of Euglenophyceae, 9 sp. of Dinophyceae, 1 sp. of Xanthophyceae and 1 sp. of Chrysophyceae) are reported in the middle stretch from Haridwar to Varanasi. Periphyton consists of total 114 taxa (75 sp. of Bacillariophyceae, 23 sp. of Chlorophyceae, 12 sp. of Cyanophyceae, 2 sp. of Euglenophyceae and 2 sp. of Xanthophyceae) from MG-1, MG-3 and MG-4. In the middle stretch of Ganga river, zooplankton were represented by 11 sp. of Protozoans, 28 sp. of Rotifers, 2 sp. of Copepods, 18 sp. of Cladocerans and 4 miscellaneous taxa. Zoobenthos in the middle Ganga region was represented by 7 orders of Insecta, Annelida and Mollusca. Among the various group of organisms, the Insecta population was dominant in the entire middle stretch and represented by Diptera and Trichoptera. The middle stretch is very productive in fish resources and is represented by 126 species belonging to 27 families. Cyprinidae is the most dominating fish family in all substretches. Higher vertebrates in the stretch is represented by Ganga river dolphin (*Platanista gangetica*), gharials (*Gavialis gangeticus*), soft (*Aspideretes gangeticus*, *A. hurum*, *Chitra indica, Lissemys punctata, Hardella thurji, Geoclemys hamiltoni and Melanochelys trijuga*) and hard shell turtles (*Kachuga smithii, K. tecta, K. tentoria, K. dhongoka and K. kachuga*).

Floral and Faunal Diversity of Lower Ganga: Part A – Varanasi to Farakka

Report Code: 025_GBP_IIT_ENB_DAT_03_Ver 1_Jun 2012

The lower segment comprises a fresh water zone (Varanasi to Farakka) 701 km (LG-A). The LG-A spreads through three states Uttar Pradesh, Bihar and West Bengal and includes five important towns Varanasi, Buxar, Patna, Bhagalpur and Farakka. The stretch LG-A is characterized by the presence of number of tributaries and no obstruction and abstraction. The river bed of this region is sandy in nature with 80-90% sand and low percentage of silt and clay. But from Bhagalpur to Farakka, the sand contribution declines considerably with 54-69% sand and substantial increase in silt content. This stretch of lower Ganga supports good growth of biological communities due to the presence of

nutrients, higher temperature and clean water with high velocity. Good solar radiation also supports the primary productivity.

The biological profile of the Ganga in the stretch consists of phytoplankton, zooplankton, zoobenthos including macro-invertebrates, fish and higher vertebrates. Phytoplankton is represented by total of 270 taxa (91 sp. of Chlorophyceae, 81 sp. of Bacillariophyceae, 78 sp. of Cyanophyceae, 8 sp. of Euglenophyceae, 3 sp. of Chrysophyceae, 3 sp. of Xanthophyceae, 2 sp. of Dinophyceae, 2 sp. of Rhodophyceae, 1 sp. of Cryptophyceae, 1 sp. of Synurophyceae). Zooplankton comprises of Protozoans (8 sp.), Rotifers (26 sp.) and Crustaceans (5 sp. of Copepods and 13 sp. of Cladocerans). In this stretch all groups are represented though are low in specific composition. The stretch supports the zoobenthos *i.e.* Insects (43%), Annelids (21%) and Molluscs (36%). Nematodes are also reported in the stretch. Fish in the stretch is represented by total of 121 species belonging to 35 families. Thirty five commercially important fishes are included in the taxa along with six invasive species. Every third fish caught belongs to the family Cyprinidae. Beside the preponderance of fish species in this zone, an aquatic mammal, Gangetic dolphin *Platanista gangetica gangetica*, Indian Gangetic Gharials *Gavialis gengeticus*, Salt water crocodile *Crocodylus porosus* and number of fresh water turtles have been reported in this stretch.

Floral and Faunal Diversity of Lower Ganga: Part B – Farakka to Ganga Sagar

Report Code: 026_GBP_IIT_ENB_DAT_04_Ver 1_Jun 2012

Lower Ganga downstream of Farraka upto Gangasagar is named as LG-B (286 km). River Ganga bifurcates near Farakka into a major offshoot Padma, which flows further eastwards to Bangladesh and a minor offshoot Bhagirathi which flows southwards to Bay of Bengal through deltaic region of West Bengal. Below the confluence of river Jalangi with Bhagirathi, the river flows under the name of Hooghly, through Kolkata and Diamond Harbour and finally reaches its destination (Bay of Bengal). In lower reaches it joined by several tributaries like Ajay, Damodar, Roopnarayan, Haldi, Thakuran and river Matlah.

The Hooghly-Matlah estuarine system is the largest among the estuaries of Indian coast and is characterized by mixing of freshwater and regular tidal

influxes which create a steady gradient of marine to freshwater conditions. Tides facilitate transportation of sediments, replenishment of nutrients, flushing out of wastes and mixing of fresh and salt waters. LG-B has been further subdivided into four stretches as the distributional pattern of both salinity and biota clearly demarcated the different stretches of the estuary.

The biodiversity of the lower Ganga Basin is largely controlled by freshwater flux, nutrient inputs and changing environmental condition like salinity, rainfall and temperature. Salinity is the most important chemical factor which affects the diversity and abundance of the biota of this basin directly. Depending on the different groups of animals and plants found in the basin, the diversity can be differentiated between Phytoplankton, Zooplankton, Macrobenthos, Nekton, Macrofauna and Angiosperms. Phytoplankton distribution in the LG-B is represented by 641 algal species (Cyanophyceae 280 taxa; Chlorophyceae 206 taxa; Bacillariophyceae 115 taxa; Rhodophyceae 17 taxa; Dinophyceae 14 taxa; Xanthophyceae 4 taxa; Euglenophyceae 3 taxa; Phaeophyceae 2 taxa) under 169 genera. The dominant algae in lower Ganga is Cyanophyceae followed by Chlorophyceae. Most of the zooplankton studies are centered on Hooghly estuary. Studies on zooplankton communities from the upper stretches are very few. The zooplankton communities in lower Ganga basin are represented by members of Cnidaria (25 taxa), Rotifera (102 taxa), Copepod (26 taxa), Cladocerans (53 taxa) and larval forms of Decapods and Cyclopods. Only some species of Chaetognaths under two genera, namely, *Sagitta* and *Krohnnitta* are reported from the Hooghly-Matlah estuary. Macrobenthos and Macro-invertebrates constitute Annelida (90 taxa), Arthropoda (Total 476 taxa; 240 species of Crustaceans, 33 species of Arachnids, 201 species of insects and 2 species of Merostomata), Mollusca (Total 68 taxa) and Echinodermata (17 taxa). The Ichthyo-fauna is represented by 175 species, out of which 103 species, under 69 genera and 37 families are strictly estuarine in nature. The higher aqatic vertebrates of Hooghly-Matlah estuary is represented by turtles, crocodiles, mammals, dolphin and porpoises. Angiosperms are represented by more than 1175 plant species in 680 genera under 154 families in LG-B.

Status of Higher Aquatic Vertebrates in the Ganga River, India

Report Code: 027_GBP_IIT_ENB_DAT_05_Ver 1_Jun 2012

Besides 297 species of fish, river Ganga sustains twenty seven species of Reptiles including Gharial, Crocodile, Soft and Hard shell Turtles and Dolphin as aquatic vertebrates. Two species of river Dolphin (*Platanista gangetica gangetica*) and *P. gangeticaminor* are found in the Indian subcontinent. Ganga is the home of *P. gangetica gangetica*.

P. gangeticagangetica is exclusively riverine and occur in high densities where a river joins areas of eddy current. They prefer deep waters with sand/ silt bars. Once believed to be in tens of thousands are reduced to 1800 presently.

Dolphins are social animal and live in small groups associated with Crocodiles, Turtles and Wetland Birds. Adults remain in couples. Calving can occur anytime but peaks in Dec-Jan and March-May. Gestation lasts 10.5 months. Dolphin feed on several species of fish and invertebrates.

Three species of Gharial, Mugger and salt water Crocodile are reported. Gharial (*Gavialis gangeticus*) is endemic to India subcontinent. They are now becoming rare due to modifications of river morphology loss of nesting sites and flow regulation.

Gharials are thoroughly aquatic, prefer deep pools and high sand bars and good stock of fish. The mating season is Nov-Jan, egg laying takes place in dry season March-May. 30-50 eggs are deposited in holes dug in sand. Juveniles emerge in 90 days.

Five families of Turtles (Chelonians) are reported. In the Ganga river 12 species of fresh water hard and soft shelled Turtles belonging to *Kachuga* (5 sp.), *Aspideretes* (2 sp.) *Chitra indica*, *Lissemys punctata*, *Hardella thurjii*, are reported. Many of them are endangered and vulnerable. They prefer muddy banks with sand bars for basking, feeding and nesting. They lay egg in dry season which coincides with the Cucurbitaceous cropping in sandy banks.

Hilsa: An assessment in lower Ganga river basin, India

Report Code: 028_GBP_IIT_ENB_DAT_06_Ver 1_Jun 2012

The prized fish of Bengal *Hilsa* (*Tenualosa ilisha*) belongs to the Family Clupeidae, Subfamily Alosinae, grows in marine environment but migrates to

fresh water for breeding is anadromus in nature. It tolerates variations in salinity and travels over 1200 km in inland water for breeding upto Allahabad. The distribution in the sea coincides with Indian monsoon. They are fast swimmers and move near the surface in sea while in inland water prefer movement at depth (14-18 m). In the rivers they may rise upto 2 m on cool drizzling day.

The *Hilsa* fish is heterosexual. Breeding appears to be with monsoon in July, peaks in September-December. Second spawning is attributed to rise in temperature.

The construction of Farakka barrage has altered the behavior past 1975. *Hilsa* now travels upto Farakka barrage and breeds in the entire fresh water area and gradient stretches of Hooghly. Thus there has been considerable increase in population/ catch in this area. The average catch in Pre-Farakka period was 1457.1 tons. It has increased to 2126.2 tons (1975-1978) and 2135 tons (1984-1994).

Status of Fish and Fisheries of River Ganga

Report Code: 029_GBP_IIT_ENB_DAT_07_Ver 1_Jun 2012

River Ganga supports a large number of indigenous and exotic species of fishes. The fish population is constituted by large groups of carps and catfishes besides mullets, clupeids, feather back and other miscellaneous species. The fresh water population from Gangnani to Farakka is represented by 181 sp. under 89 genus and 37 families. The family Cyprinidae is conspicuous by large numbers and species richness. The Hooghly Matlah estuary is represented by 103 +72 species (72 sp. are common with fresh water), 69 genus and 37 families. The Chondrichthyes (cartilaginous fish) add up another 13 species. About 100 species have high commercial importance. These included Indian Major Carps (IMC), Catfishes, other Carps,Clupeids while *Hilsa*, *Polynemus*, *Liza*, *Pama* and *Harpodon*.

The Himalayan segment is characterized by the presence of Trouts and Mahseer. The substretch Gangotri to Gangnani is generally devoid of any fish through a few brown Trouts have been sighted. The middle Indogangetic plains and lower Ganga upto Farakka is represented by IMC and Catfishes. Some exotic fishes, common Carp (Cyprinus carpio) and Tilapia (*Oreochromis*

niloticus) have started competing with endemic species and have assumed a bigger role down stream of Allahabad.

There has been a remarkable reduction in the production capacity of fresh water fishes due to human indulgence, dams, withdrawal to large quantities of water and pollution due to domestic/ industrial wastes and indiscriminate fishing.

The total catch has gone down significantly. The catch composition has also changed. The IMC component has come down with increase in less economically important fishes and marginal increase in catfishes.

The catch and catch composition in the Hooghly Matlah region has also changed. The fresh water forms are now available upto Diamond Harbour. Change in salinity pattern has also significantly altered the fish composition and availability.

Hilsa is now restricted in the estuarine zone only and its migration has been stopped in fresh water zone beyond Farakka. *Hilsa* has completely disappeared from Bhagalpur, Patna, Varanasi and Allahabad.

Wetlands in Ganga River Basin

Report Code: 030_GBP_IIT_ENB_DAT_08_Ver 1_Jun 2012

Wetlands are areas transitional between terrestrial and aquatic ecosystem, where water table is usually at or near the surface. Ramsar convention (1971) has defined wetlands as areas of marsh, fen, peat land or water whether natural or artificial, permanent or temporary with static or flowing water, fresh, brackish or salt including areas of marine water the depth of which at low tide does not exceed 6 m.

Wetlands are repository of vital information and services. They provide maintenance of food web, habitat to aquatic flora and fauna, as well as to numerous birds, filtering of sediments and nutrients from surface water, controlling floods, recharging ground water, provide drinking water, fish, fodder, fuel and provide source of livelihood and recreation to local populace.

India has 58.2 million hectares of land including areas under cultivation for paddy. Fresh water wetlands alone support 20% of biodiversity in India. National Wetland Inventory and Association (NWIA) report 103882 ha area

under wetland in Uttrakhand, 124530 ha in Uttar Pradesh, 403209 ha in Bihar, 1107907 ha in West Bengal, the major states in the Ganga basin.

Uttrakhand has 58 wetlands covering 8532 ha in 3 districts Uttarkashi, Tehri Garhwal and Haridwar. In Uttar Pradesh a large number of lakes, ponds and channels in 17 districts of Ganga basin with cumulative area of 314775 ha in 25112 wetlands. The river and streams account for 57.7% and 13.6% in water logged areas of the total wetland. In Bihar 12 districts are related to Ganga basin including lakes/ponds and cut off meander river and water logged areas. The river and stream related constitute 81.9% and the rest in small lakes and ponds. Jharkhand with lone district of Sahibganj accounts for 555 wetlands with 16118 ha area. The river and stream related wetlands represent 65% and small lakes and ponds 17.75%. Wetlands in West Bengal are many in seven districts related to Bhagirathi and Hooghly river. Wetlands upto Maldah district (Farakka barrage) have been included in this report. The Maldah district has 123 wetlands with aggregated area of 4608 ha.

Much of the information on biodiversity in wetlands is not available, however some of them have been monitored *viz.* Banganga wetland, Jhilmil jheel, Tehri dam in Uttarakhand. Lake Bahsri (Farrukhabad). Samaspur bird sanctuary (Balia) and Narora dam in Uttar Pradesh.

The wetlands are threatened due to encroachment for agriculture and buildings, deforestation, pollution, overfishing, poaching of wild animals, introduction of exotic plants and animals. Protection and conservation is the need of the hour. Sound conservation methods are in place to achieve their continuation but a will to do is needed.

The Maldah district has 123 wetlands with aggregated area of 4608 ha have been included in this report.

Riparian Floral Diversity of Ganga River

Report Code: 031_GBP_IIT_ENB_DAT_09_Ver 1_Jun 2012

River bank vegetation ecologically termed as Riparian vegetation is highly dynamic linking terrestrial and aquatic habitat under the influence of water ways. Riparian plant habitats and communities are characterized by hydrophilic plants. They consist of macrophytes, native grasses, sedges, climbers, shrubs and trees. Water current plays decisive role in dispersal of

vegetative propagates. They fulfill the demands of timber, fuel, fodder, medicines and fruits of local populace. Riparian vegetation grows luxuriantly after floods when conditions promote growth.

Krishnamurthi *et al.* (1991) have identified 475 species downstream Rishikesh including 49 types of tress with 16 having medicinal value with herbs 67%, shrubs 12%, climbers 6%, trees 10%, sedges 2% and native grass 3%. The riparian flora in Gangotri to Narora constitutes main vegetation as *Primula*, *Stellaria*, *Elatostema*, *Geranium*, *Rhododendron*, *Juniperus* and *Salix*. *Cedrus deodara* borders the bed on both sides on the flood plain deposit. The important families are Poaceae, Asteraceae, Euphorbiaceae, Moraceae and Lamiaceae. The stretch Mirzapur to Farakka has 40 macrophytes. The genera represented include *Eclipta*, *Polygonum*, *Ipomea*, *Rumex*, *Saccharum*, *Scirpus* and *Tamarind*. The Bihar Diara lands harbor Acanthaceae, Polygonaceae, Apocynaceae, Asteraceae, Boraginaceae, Amaranthaceae, Euphorbiaceae and Lamiaceae. West Bengal, with humid conditions has 212 macrophytes including the families of Acanthaceae, Acoraceae, Aizoaceae and Amaranthaceae. The total angiosperms in the middle and lower Ganga include 154 families and 680 genera (235 taxa of trees, 280 taxa of shrubs, 660 taxa of herbs, 680 taxa of weeds, terrestrial 832 and cultivated 289 taxa). The canopy trees include Saal (*Shorea robusta*), Teak (Tectona grandis), Sheesham (*Dalbergia sissoo*), Mango (Mangifera indica), Neem (*Azadirachta indica*), Banyan (*Ficus benghalensis*), Peepal (*Ficus religiosa*), Jamun (*Syzygium cumini*), Mahua (*Madhuca longifolia*) and Simal (*Bombax* sp.).

Degradation and Strategies to conserve are elucidated.

Floral and Faunal Diversity in River Alaknanda

Report Code: 032_GBP_IIT_ENB_DAT_10_Ver 1_Jun 2012

The Alaknanda basin is characterized by hilly terrain, deep gorges and river valleys. The river originates at the water divide between Satopanth and Bhagirathi glacier (near Vasudhara falls) flows eastward joins Saraswati river at Mana and then flows downstream in south east direction to Joshimath where it meets Dhauliganga. It moves south west and meets river Bhagirathi at Devprayag. Several rivulets in the Garhwal region merge with Alaknanda at Panch Prayag i.e. Vishnuprayag (Dhauliganga), Nandaprayag (Nandakini)

Karanprayag (Pindar), Rudraprayag (Mandakini) and Devprayag (Bhagirathi). One hydro electric project is under operation and 36 others are proposed as Run of the River Projects (ROR).

Rapids are major habitat type followed by riffles and ponds. Mature cobbles, pebbles and boulders constitute the major substrate. Water is clear, cold with high velocities.

Alaknanda has been ecologically differentiated into two stretches **(A)** Mana to Vishnuprayag and **(B)** Vishnuprayag to Devprayag. The biodiversity of stretch A is generally unexplored attributed to very cold water and very high current. Diatoms (6 sp.), green algae (1 sp.) and blue green algae (1 sp.) however has been reported. No fish has been reported.

The stretch **(B)** has diatoms as dominant group with (145 sp.), green algae (11 sp.), blue green algae (6 sp.) as phytoplankton and Periphyton. Protozoans (8 sp.), Rotifers (2 sp.) and crustaceans (3 sp.) represented as zooplankton. Dipterans, Trichopterans and Ephemeropterans constitute the Zoobenthos. Forty three species of fish belonging to Cyprinidae (26 sp.), Sissoridae (7 sp.), Balitoridae (6 sp.), Cobitidae (3 sp.) and Ambyceptidae (1 sp.) families have been reported. Trout is the characteristic species while Snow Trout (*Schizothorax richardsonii*) has been identified as keystone sp.

Floral and Faunal Diversity in River Yamuna

Report Code: 033_GBP_IIT_ENB_DAT_11_Ver 1_Jun 2012

The river Yamuna, originates from Yamunotri glacier at Bandar Punch in the region of Simla at 6387 m (amsl) in the lower Himalayas. After flowing through the Shivaliks it emerges on the plains at Tajewala and flows down to south west to south through National Capital Region, Delhi to Mathura, Agra, Etawah and merges with Ganga at Allahabad traversing a distance of 1170 km. During its course the river joins Hindon, Chambal, Sind, Betwa, Ken and Paisuni.

The course of Yamuna has been differentiated into five sub stretches: Himalyan, (YR_1) origin to Tajewala (172 km); Upper stretches, (YR_2) Tajewala to Wazirabad barrage (224 km); Delhi stretch (YR_3) Wazirabad barrage to Okhla barrage (22 km); Eutrophic stretch, (YR_4), Okhla barrage to Chambal confluence (490 km); Diluted stretch, (YR_5), Chambal confluence to Ganga confluence (468 km).

The soils of Yamuna vary considerably as they have developed under different lithological, climatic, and pedogenetic conditions. River bed is primarily sandy.

The biodiversity of river Yamuna varies profoundly due to obstruction of water, large abstraction and indiscriminate addition of treated and untreated domestic and industrial wastes. The ecological condition in (YR_3), Delhi stretch is highly stressed. The poor conditions prevail upto Agra downstream.

The phytoplankton is represented by 218 sp. in the entire stretch with Chlorophyceae as dominant group (110 sp.), followed by diatoms, Bacillariophyceae (56 sp.) and blue green algae, Cyanophycea (37 sp.), Euglenophyceae (7 sp.) and others (8 sp.). They include sensitive and tolerant species. The Periphyton is more common and includes 394 sp. mostly in YR_1, YR_2 and YR_3. The Bacillariophycea, Chlorophyceae and Cyanophyceae constitute the major component of periphyton. The Zooplankton is constituted by Protozoans (97 sp.), Rotifers (105 sp.), Crustaceans (42 sp.) and many others including Gastropoda, Nematoda, Insecta and Annelida.

The Zoobenthos is represented by 3 orders of Arthropods, 9 orders of Insecta, 2 classes of Mollusca, 4 classes/subclasses of Annelida and 1 order of Nematoda.

The distribution and status of fish fauna reported 139 species belonging to 78 genus and 33 families. A total of 88 species belonging to 47 genus and 21 families have been recorded from YR1, while in YR2, 20 species belonging to 11 genus and 4 families have been reported. In YR_3 stretch 49 species belonging to 33 genus and 19 families have been reported. YR4 and YR5 stretch represented by 50 species, 35 genus, 19 families and 67 species, 51 genus, 23 families, respectively. Cyprinidae continued to throng the river followed by Bagridae, Sissoridae, Channidae and Siluridae. The catch is gradually getting reduced and composition changing drastically. The carps are being reduced and catfishes increased.

Floral and Faunal Diversity in River Ramganga

Report Code: 034_GBP_IIT_ENB_DAT_12_Ver 1_Jun 2012

The river Ramganga originates as two streams as Western and Eastern Ramganga and flows down in plains independently. Western Ramganga originates near Gairsain (Uttarakhand) of Doodha Toli ranges in the lower

Himalayas. The river flows down through Patli Dun of lower Shivalik and flows through Corbett National Park, Moradabad, Rampur, Bareilly, Badaun and Shahjahanpur and joins Ganga downstream of Farrukhabad. Eastern Ramganga merges with river Sarju at Rameshwar ghat and finally confluences with river Kali and joins Ganga at Farrukhabad adjacent and opposite Ramganga.

Phytoplankton constitutes the main producer component and comprise of three important classes Bacillariophyceae (26 sp.), Chlorophyceae (9 sp.), Cyanophyceae (11 sp.) and Xanthophyceae (1 sp.). The Periphyton is represented by Chlorophyceae (24.4-47.9%) and Bacillariophyceae (52.1-75.6%) of total population.

The Zooplankton constitutes Protozoans (5 sp.) and 24-44.7% of total population and the Rotifers (6 sp.) and Crustaceans (6 sp.) together constituting 59.1-76% of the total population.

The Zoobenthos is represented by seven orders of Insecta *viz.* Ephemeroptera, Diptera, Coleoptera, Trichoptera, Hemiptera, Plecoptera and Odonata.

The diversity of fish is rich and is supported by 49 sp. belonging to seven families under 22 genera. Family Cyprinidae is the most dominant group 28 sp. and 11 genera. The important fishes are game fishes Trout (*Schizothorax*) and Mahseer (*Tor* sp.) and *Labeo*, *Catla* and *Puntius*.

The variation in the number of genus and species under different families are mentioned as: Cyprinidae (11/28) > Balitoridae (2/8) > Sisoridae (4/5) > Cobitidae (2/4) > Channidae (1/2) > Belonidae and Mastacembelidae (1/1)*

River Style Framework for the Ganga River

Report Code: 035_GBP_IIT_ FGM_DAT_03_Ver 1_July 2012

The River Style framework is a holistic approach to provide a physical basis to describe and explain the distribution of river forms and processes within a catchment, and predict future river behavior. Various components and its sub-components i.e., valley setting, geomorphic units and bed material texture, plays decisive role to classify the river reach and its style. River restoration and management approaches with respect to river Ganga has been proposed on the basis of river characters and river style in the current report. The detailed methodology adapted (i.e., landscape/valley setting; channel confinement, floodplain boundation, land use/land cover association, channel and floodplain

material, etc.) to characterize the stretches of river Ganga and its ecological significance is also summarized. On the basis of the whole exercise ten river styles are documented in the stretch of river Ganga (Gangotri to Farakka). The characterized river style in the river not only used for geomorphic assessment but can also utilized in determining the E-flow at different points along the river.

The Status of Sundari (H. fomes) an indicators species in the Sunderbans

Report Code: 036_GBP_IIT_ENB_DAT_13_Ver 1_Sep 2012

The Sundarbans area of Hooghly Matlah estuary of the Ganga basin has assumed the name from the forests of Sundari (*Heritiera fomes*) and the exquisite and beautiful plants which look "Sundar" in Vernacular. The trees belong to Phylum Tracheophyta, Family Sterculiaceae. The forest covers an area of 14600 km^2. In India, portion of the forest is poor in growth due to high salinity and other biotic interactions and ecological succession. The mangrove is buttressed by trees 10-25 m tall with dense pneumatophores about 50 cm height. It prefers fresh water and is fast growing in low saline environment commonly found along tidal creeks, channels of coastal swamps. They regenerate through seeds. IUCN has categorized 'Sundari' as endangered and on the extinction threat. The *Heritiera* trees are useful due to hardness of wood and are used in boat building and other domestic uses including furniture.

The present status of 'Sundari' forests has reached due to drivers of change including past alterations, salinity increase, industrial pollution especially of oil and gas exploration, production and accidental release by large tankers. They cause defoliation and top drying. Increase in salinity is due to reduced water flow, reduction in periodic inundation, sediment and nutrient balance. Conservation and Management is necessitated by holistic management approach including vegetative propagation.

Stream Power Distribution Pattern for the Ganga River to Determine the Effects of River Energy and Sediment Supply on Channel Morphology

Report Code: 037_GBP_IIT_ FGM_DAT_04_Ver 1_Oct 2013

The stream power distribution pattern of all the rivers are characterised by various peaks. These peaks are the zone of the erosion processes and extensive sediment transport. In most of the cases these peaks lies in the Higher Himalayan area, which explains the high sediment supply from this region. There is significant decrease in stream power of all rivers from mountainous region to alluvial plain area. Sudden decrease of stream power is responsible for extensive deposition in the alluvial plains area. However, alluvial reaches of all the rivers are characterised by reach scale variability in stream power, which will explain the reach scale geomorphic variability in the Ganga river system.

Stream power distribution pattern in all the streams is mostly governed by local slope variability. Hydrological variation which is represented by tributary confluence doesn't have a major control on the stream power distribution pattern. However, downstream hydrological variability in the current model is based on the discharge-area relationship and mostly highlights the tributary confluence on hydrological fluxes. Improvement of data acquisition regarding downstream discharge variability through flow routing for the Ganga river and its tributaries will further improve stream power data of the Ganga river basin.

Pattern of Antibiotic Resistance in Bacteria from Three Different Aquatic Environments Over Three Seasons

Report Code: 038_GBP_IIT_ EQP_DAT_01_Ver 1_Nov 2013

Widespread and indiscriminate use of antibiotics has led to the development of antibiotic resistance in bacteria in various environments including aquatic systems. The objective of this study was to evaluate antibiotic resistance in bacteria from three different water sources: River Hooghly in Kolkata, River Kangsabati and groundwater from Kharagpur, West Bengal, and determine the impact of urban activity and seasonal variations on bacterial resistance. Water samples were collected during three seasons: post-monsoon, winter and

summer (September, January and May respectively) in 2012-2013 and along three transects across River Hooghly (9 sampling locations: both banks and mid-stream). A total of 163 Gram-negative bacteria were isolated from river Hooghly (n=138), river Kangsabati (n=13) and groundwater (n=12) based on standard differential, morphological and biochemical identification. Antibiotic susceptibility testing was done using 12 antibiotic discs. Depending on the zone of inhibition, isolates were characterized as resistant, sensitive and intermediate. Bacteria resistant to 3 or more antibiotics are termed multiple antibiotic resistant (MAR) bacteria. The percentages of MAR bacteria at the three sampling locations were found to be 71.01% (98/138) for River Hooghly, 15.38% (2/13) for river Kangsabati and 8.33% (1/12) for groundwater. Prevalence of MAR bacteria with respect to seasonal variation was found to be 73.58% in post-monsoon, 59.26% in winter and 53.57% in summer. In addition, antibiotic resistance index (ARI) was also calculated for each sampling station which indicates the level of exposure to antibiotics. All stations in Kolkata exhibited ARI values greater than the threshold value of 0.2. The maximum ARI value was as high as 0.63 in post-monsoon, River Hooghly, indicating greater exposure to antibiotics from wastewater discharges and runoff mainly from animal husbandry. On the other hand, ARI values for river Kangsabati and groundwater were lower than 0.2 for all three seasons and can be attributed to their non-urban environment and low impact of wastewater discharges. Considering % MAR and ARI values, there were significant differences with regards to seasons on the resistance pattern observed: post-monsoon > winter > summer. These results demonstrate the greater prevalence of MAR bacteria in large urban centers like Kolkata and the impact of seasons on their prevalence pattern.

Assessment of Some Aspects of Provisioning Sewerage Systems

Report Code: 039_GBP_IIT_EQP_S&R_05_Ver 1_Dec 2013

The main approach to achieve the ultimate objective of “Nirmal Dhara” has been to identify the type of polluting wastes, their sources of generation (point and non-point sources), and the techno-economic feasibility of collecting and treating them for their safe environmental discharge and/or possible recycle or reuse. An appropriate techno-commercial frame-work is a prerequisite for sustainable sanitation solutions in urban centres. The first step towards

developing such a framework is to have an assessment of provisioning sanitation systems in economic sense. Provisioning of sanitation systems yields certain benefits depending upon the choice of technologies and components, their designs, and efforts and investments made. Onsite sanitation systems like septic tanks, soak pits, etc. may appear to be low cost, less energy consuming, and simple, but may also pose serious concerns such as pollution of surface and ground waters. On the other hand sewerage system with provision of treating sewage up to tertiary level and using treated sewage for various beneficial uses may be considered very complex and unaffordable. Making a right decision is greatly facilitated if costs and benefits can be assessed.

This report aims at estimating the per capita expenditure on sewerage system with provision of reuse and recycle of water which can subsequently be compared with other options. The energy consumption and footprint are also important along with expenditure incurred and hence are also estimated separately. The study also aims at estimating the financial layout for provisioning sewerage infrastructure in all Class I and Class II towns of the Ganga River Basin (GRB) with the objective of recycling and reuse of sewage along with assessment of fresh water savings that could facilitate in management of Environmental Flows (E-Flows) in the rivers.

Comparison of the estimated sewage generation and dry weather flows reveals that treatment of sewage up to tertiary level or equivalent is essential if river water quality standards befitting the ecological needs are to be maintained. The cost of provisioning sewerage systems does not appear to be unaffordable on per capita per day basis considering the benefits and savings in water supply and health related expenditures.

Implementation Mechanism for Ganga River Basin Management Plan

Report Code: 040_GBP_IIT_PLG_S&R_01_Ver 1_Dec 2013

River Ganga, having been declared as the National River by the Government of India requires prompt and effective measures to contain further deterioration of the river and rejuvenation efforts. The proposed legislation is one such bold attempt towards a comprehensive and self-contained Act which provides for

regulation, conservation and development of the basin. It provides for the establishment of National River Ganga Basin Management Commission (NRGBMC) and National River Ganga Basin Tribunal (NRGBT) for effective and expeditious disposal of matters affecting the river basin with a view towards its restoration and conservation.The Ganga River Basin Management Plan (GRBMP) relates to diverse domains and therefore it is multi-dimensional. Based on inputs from a multi-specialty team, the Plan has identified need for wide ranging interventions – both technical and non-technical, in terms of among others, policies, programmes and infrastructure. The Plan recommendations are far reaching, transcend short-, medium- and long-terms and as regards implementation pertain to multiple agencies. Moreover, during the process of developing the Plan, one of the domains that have been investigated comprises legislative framework applicable in the Ganga River Basin, specifically for managing and harvesting of water resources, protection and conservation of river water quality, utilising the water courses for gainful applications, etc.

In this context, this brief report summarises findings of the investigations, available constitutional/legal provisions and institutional mechanisms, and attempts to develop justification for a new/alternate legislation and mechanism including the philosophy or premise of the proposed legislation. In addition, the report also includes as an annexure a draft bill for the proposed legislation which needs to be discussed and deliberated amongstdifferent stakeholders.

Cremation Practices: Analysis and Recommendations

Report Code: 041_GBP_IIT_EQP_S&R_06_Ver 1_Dec 2013

For a typical Indian city cremation grounds constitute part of the essential social infrastructure and their provision and maintenance are the responsibility of the respective urban local bodies. Further, in the context of the Ganga River Basin Management Plan (GRBMP) one of the main objectives of developing cremation grounds is to facilitate the poorest strata of the society and thereby prevent disposal of dead bodies into the rivers. From environmental conservation point of view, another objective would be to reduce pressure on

forest resources. In this respect, this report commences with a description of the sensitive subject of religious beliefs to help develop a perspective, then takes on issues related to technology, analyses lessons from successful initiatives in the past in selected towns. Based on the above considerations a set of recommendations for possible future initiatives are evolved which can be classified broadly into four categories viz., socio-religious aspects, institutional aspects, infrastructure requirements, and finally technological aspects.

Sanitation in India: A Review of Current Scenario

Report Code: 042_GBP_IIT_EQP_DAT_02_Ver 1_Dec 2013

There is considerable awareness about community water supply needs, but the problems of excreta and sewage disposal, i.e., sanitation, has received less attention in India. The effects of poor sanitation seep into every aspect of human life be it health, welfare, economy, dignity, empowerment or environment.

To meet the country's sanitation challenge there is an urgent need to focus on proper collection and treatment of excreta and sewage and to build and maintain appropriate toilets for all. Government has spent and is still spending a lot of money to improve the state of sanitation, but majority of systems have failed due to various reasons.

In this report the currently available sanitation solutions have been critically assessed and analyzed to determine their relative merits and demerits, especially with regard to Indian conditions and sensibilities. The minimum requirements of an effective sanitation system have also been identified.

Sanitation in India: Recommendations for Optimal Practices

Report Code: 043_GBP_IIT_EQP_S&R_07_Ver 1_Dec 2013

There is considerable awareness about community water supply needs, but the problems of excreta and sewage disposal, i.e., sanitation, has received less attention in India. The effects of poor sanitation seep into every aspect of human life be it health, welfare, economy, dignity, empowerment or environment.

To meet the country's sanitation challenge there is an urgent need to focus on

proper collection and treatment of excreta and sewage and to build and maintain appropriate toilets for all. Government has spent and is still spending a lot of money to improve the state of sanitation, but majority of systems have failed due to various reasons.

Through assessment and analysis of prevalent sanitation issues in various types of human settlements in the country, this report recommends workable sanitation models for various situations. For this purpose, urban sanitation and rural sanitation issues are analyzed separately. Areas of concern are identified and problems faced are discussed, followed by formulation of the recommendations.

Sanitation models suggested in this report for various situations have certain common characteristics. They allow people to defecate with dignity and a certain minimum extent of physical comfort. Further, these proposed models also incorporate methods for the safe disposal of the resultant excreta and sewage. In short, they provide both acceptable “front-end” and safe “back-end” solutions. These models completely discard the prevalent objectionable practices in the sanitation sector, i.e., manual scavenging, open defecation, conventional dry latrines, open drains, direct defecation into water bodies (cesspools) and soak pits in areas with high ground water table or rocky/impervious strata.

Finally, cost analysis of various sanitation models show that the cost of defecation and safe disposal of the resultant excreta and sewage ranges between Rs. 3.50 and Rs 5.50 per person per day, irrespective of the model adopted. Our country must be aware of this cost and willing to pay for it for a systemic solution to the sanitation problem.

State of Health in the Ganga River Basin

Report Code: 044_GBP_IIT_SEC_ANL_06_Ver 1_Dec 2013

This report presents the status of health along with morbidity, and public and private healthcare expenditure in the Ganga River Basin. With a growing population and urbanization in the Ganga basin, per capita availability of water and safe drinking water has declined significantly. The sewer discharge into river has many bacteria and Virus which causes diseases like Diarrhoea, Cholera, etc. Inadequate access to safe drinking water & sanitation facilities

and poor hygiene practices lead to ill-health of the people of the Ganga basin. It may also be mentioned that the existing public healthcare infrastructure is not adequate to meet the ever increasing healthcare requirement in the basin.

India spends a little over 4% of GDP on health. Public expenditure on health (both plan & non-plan and taking Cente and States together) consisted of 1.04% of GDP in 2011-12 (GOI, 2012). Private sector constitutes about 75% of total healthcare expenditure in India. This report has been divided into two major sections, one for aggregated analyses and another for district-wise analyses. Both the sections are further subdivided into three analytic parts, viz., first is service and education health infrastructure, second is issues related to drinking water, sanitation and health, and lastly health expenditure mainly public and private expenditure.

The mission "Nirmal Dhara" insist for reduction of sewage discharge and putting treated water into the sources. Huge amount of public and private expenditure on water-borne diseases could be saved if quality of water is improved by controlling pollution and reducing degradation of river and ground water. Also, less polluted water need less treatment and cost of water treatment.

Cultural-Religious Aspects of Ganga Basin

Report Code: 045_GBP_IIT_SEC_ANL_07_Ver 1_Dec 2013

The main objective of this report is to develop a clear understanding of the relationship between river Ganga and the Indian society in general and the people living along her banks in particular; assess significance of the river in their lives, attempt correlation of possible impacts of diverse rituals from water quality point of view and ultimately being centres of pilgrimage. Considering these religious aspects, pollution of Ganga water has tremendous socio-cultural consequences. The bank of river Ganga like Haridwar, Rishikesh, etc. locations help in driving the economy of the hill State of Uttarakhand and generate livelihood for a very large number of people. Evidently this contributes in framing the overall strategy for restoration of the river to its old glory. Apart from these aspects, it is one of the major area of revenue generation for the relatively new state of Uttarakhand and hence impetus

promotion of tourism is also violating the ecological, geographical and infrastructural limitations. Also, large growth in the number of pilgrims has led to unregulated growth of hotels, ashrams and dharamshalas which offer places for overnight stay to the weary tourists/ pilgrims/ visitors. There are issues related to town planning, land use, safety, access, supporting infrastructure, etc. which have not received the required level of attention, particularly in the fragile setting of the hilly region beyond Rishikesh. Increased construction activity in the region has led to high demand for building materials and this has led to unregulated and illegal mining of sand and boulders on the banks of the river. This has, in turn, made adverse impact on the river morphology and its interaction with the flora, fauna and the habitation along the banks.

Demographic and Socio-Economic Analysis in Upper Ganga Basin (Uttarakhand)

Report Code: 046_GBP_IIT_SEC_ANL_08_Ver 1_Dec 2013

This report includes the analysis of demographic, economic, social and health components for population within the Upper Ganga Basin (UGB) with primary focus on the state of Uttarakhand. In demographic aspects, population growth, density, composition and distribution are the factors studied. In economical aspect, the study of gross domestic product, per capita gross domestic product, trends in occupational structure, and rural households below poverty line are studied. In social and health aspects, literacy rate, access to three basic needs- electricity, toilet and safe drinking water, CDR (crude death rate), and child healthcare are studied. This report attempts to analyse the same with the existing data from secondary sources, viz. Census 2011.

On an average, population grew faster in the districts of plain region than the districts of hill region. Further, plain region has relatively higher proportion of urban population than hill region. Migration of people from the hilly region seems to be the main reason for the deceleration of population growth rates. During the last one decade, the state has made remarkable progress in terms of GSDP. From 2002 to 2009 there has not been any significant decline in the BPL households. Incidence of rural poverty is observed highest among the SC households. Literacy rates are higher in the hill districts than the plain districts. Moreover, hill districts have relatively higher number of schools under

government ownership while the plain districts have higher number of schools under private ownership. Access to three basic needs- electricity, toilet and safe drinking water has been much lower in rural areas than urban areas. Percentage of children suffering from diarrhea is lower in Kumaon region than the Garhwal Region. Further the percentage of children suffering from diarrhea is higher in plain region than the hill region. Moreover, higher percentage of children from rural areas suffered from diarrhea. The higher prevalence of diarrhea in plain districts of the state may possibly be attributed to the poor quality of groundwater, an important source of drinking water in these district.

Demographic and Socio-Economic Analysis in Middle Ganga Basin (Uttar Pradesh)

Report Code: 047_GBP_IIT_SEC_ANL_09_Ver 1_Dec 2013

This report includes the analysis of demographic, economic, social and health components for population within the Middle Ganga Basin (MGB) with primary focus on the state of Uttar Pradesh. In demographic aspects, population growth, density, composition, and distribution are the factors studied. In economical aspects, the study of gross domestic product, per capita gross domestic product, trends in occupational structure, and rural households below poverty line are studied. In social and health aspects, literacy rate, access to three basic needs- electricity, toilet and safe drinking water, CDR (crude death rate), and child healthcare are studied. This report attempts to analyse the same with the existing data from secondary sources, viz. Census 2011.

As of census 2011, Uttar Pradesh holds the position of being most populated state with 200 million people living there. The Southern Region (SR) reported the maximum decline in decadal growth-rate (7% point) and Northern upper Ganga Plain (NUGP) reported the lowest (3.7 % point). In NUGP, the dependency ratio among the districts along Ganga River was observed to be more than 70 percent during 2009-10. ER and NUGP have contributed maximum share to the primary sector of the state economy. Although ER has also contributed to the secondary sector in significant amount, NUGP accounts for the maximum share to the secondary sector in GSDP (marginally higher than that of the ER). An increase of more than 70 percent in literacy rate of the

state was observed during the last two decades from a level of 41 percent in 1991 to 70 percent in 2011. Male literacy rate (79%) in the state was about 34 percent higher compared to female literacy rate (59%) in 2011. Districts in ER namely Mirzapur, Sonbhadra, Allahabad, and Sant Ravidas Nagar had 20-25 percent households deprived of clean drinking water facility. Apart from some districts of ER, other districts, belonging to other regions along Ganga river, such as, Mainpuri, Fatehpur, Rae Bareli, Etah, Hathras also had less than 25 percent of total households having access to toilet facility during 2007-08.

Demographic and Socio-Economic Analysis in Lower Ganga Basin - I (Bihar)

Report Code: 048_GBP_IIT_SEC_ANL_10_Ver 1_Dec 2013

This report includes the analysis of demographic, economic, social and health components for population within the Lower Ganga Basin (LGB) with primary focus on the state of Bihar. In demographic aspects, population growth, density, composition, and distribution are the factors studied on LGB. In economical aspect, the study of gross domestic product, per capita gross domestic product, trends in occupational structure, and rural households below poverty line are studied. In social and health aspects, literacy rate, access to three basic needs- electricity, toilet and safe drinking water, CDR (crude death rate), and child healthcare are studied. This report attempts to analyse the same with the existing data from secondary sources, viz. Census 2011.

Bihar is characterized as the most densely inhabited state with population density of 1102 persons/ sq.km. However, about 90% of the state population resides in rural areas, giving the entire state the character of a ‘rural state’ and the general development deficit. Average state-wide sex ratio at 916 in 2011 is below the national average which is 940. During the last decade there has been a drop in the sex ratio. Male and female literacy rates have increased significantly but the gender gap is quite significant. Since 2004-05 the state has recorded high to very high growth in GSDP which is above the national growth rate.

Demographic and Socio-Economic Analysis in Lower Ganga Basin - II (West Bengal)

Report Code: 049_GBP_IIT_SEC_ANL_11_Ver 1_Dec 2013

This report includes the analysis of demographic, economic, social and health components for population within the Lower Ganga Basin (LGB) with primary focus on the state of Bihar. In demographic aspects, population growth, density, composition, and distribution are the factors studied on LGB. In economical aspects, the study of gross domestic product, per capita gross domestic product, trends in occupational structure, and rural households below poverty line are studied. In social and health aspects, literacy rate, access to three basic needs- electricity, toilet and safe drinking water, CDR (crude death rate), and child healthcare are studied. This report attempts to analyse the same with the existing data from secondary sources, viz. Census 2011.

Over the last 11 decades the population of the state has increased sharply by 540 % and stands at 9.13 Crore in 2011. The population density of West Bengal in 2011 has reached 1029/sq. km which is second highest after Bihar. However the national average in 2011 stands at 382/sq. km. Kolkata with 24,252 persons/sq. Km probably represents one of the most densely inhabited areas on the earth. There has been continuous decline in the share of primary sector in the GSDP while share of tertiary sector has continued to witness an increase. However, around 40% of the state's main workers are engaged directly in agriculture as cultivators or agricultural labourers. Except for Kolkata, access to safe drinking water through household tap is rather low. Access to sanitation (household / community latrine) is low at around 58%.

Status of Urbanization and Industrialization in Uttarakhand

Report Code: 050_GBP_IIT_SEC_ANL_12_Ver 1_Dec 2013

This report presents the trends in urbanization and industrialization in the state of Uttarakhand and analyses their implications for the GRBMP. During the last two decades, Uttarakhand witnessed relatively rapid urbanization and industrialization. However, urbanization in the state is primarily confined to the four districts in the plains, namely, Haridwar, US Nagar, Dehradun and Nainital, which together constituted about 85% of the urban population of the state.

While there has been a significant improvement in access to sanitation in urban areas, there is a large unmet demand in rural areas across the state. There are issues with the type of sanitation solutions, sustainability, operation and maintenance and lack of treatment facilities. Despite rapid economic growth in the state during the last decade, quality of employment appears to have deteriorated. A majority of people of the state migrate to other states in search of better employment opportunities.

Uttarakhand has emerged as one of the fastest growing states of India in the last decade, especially driven by growth of the secondary sector – manufacturing and construction activities. However, industrialization is mainly concentrated in the plains region of the state and the share of hill districts in the total investment has drastically declined.

Status of Urbanization and Industrialization in Uttar Pradesh

Report Code: 051_GBP_IIT_SEC_ANL_13_Ver 1_Dec 2013

This report presents the trends in urbanization and industrialization in the Middle Ganga River basin and analyzes their implications for the GRBMP.There are several anthropogenic and socio-economic factors associated with rapid and at times unregulated urbanization and industrialization that affect the quantity and quality of water resources.

Relatively higher level of urbanization in the districts of Northern Upper Ganga Plain (NUGP) and Southern Upper Ganga Plain (SUGP) have great implications for Ganga River. However, studies revealed that in 2011, about 38% rural household and 6.64% urban household in the state did not have any sewage connections. Industrialization may also grow at a faster rate, with some push from the government, with the objective of expanding the employment base of the state. It is recognized that a wide range of industries e.g., leather and leather products, distillery and breweries, chemicals, sugar, pulp & paper, metals and metal products, textiles, fertilizers, etc. are not resorting to proper treatment of effluent which further increase the pollution in tributaries and main stem of river Ganga.

Given the fact that the level of urbanization and industrialization is most fast paced in the NUGP followed by SUGP and CR (Central region), treatment and safe disposal of municipal solid waste, sewage and industrial effluents are far more pressing in these ever expanding regions. The confrontation system may be designed based upon the two fundamental principles: first, zero discharge into the river system, and second, recycling of waste water and solids for productive uses.

Status of Urbanization and Industrialization in Bihar

Report Code: 052_GBP_IIT_SEC_ANL_14_Ver 1_Dec 2013

This report presents the trends in urbanization and industrialization in the Lower Ganga River basin with a focus on the state of Bihar and analyzes their implications for the GRBMP.There are several anthropogenic and socio-economic factors associated with rapid and at times unregulated urbanization and industrialization that affect the quantity and quality of water resources.

Relatively significant urbanization is reported only in 4 of the 12 `bank districts'. Also, about a quarter of the urban population is found to reside in slums or slum like settlements. The number of factories constitute under 1.5% of the national and there are virtually no industries or industrial belts of national significance. The state has been characterised by significant deficit in governance, which is also contributing to lack of planning for the necessary infrastructure development. The deficit in pollution control is reflected in terms of weak implementation of the existing legal provisions and poor monitoring.

There is a need for growth of supporting infrastructure for agriculture and horticulture sectors, thereby facilitate exports from the state. Along with a strong infrastructure for development, an urgent need for infrastructures and services for sewage handling and solid waste management is also observed in all urban centres across the state.

Status of Urbanization and Industrialization in West Bengal

Report Code: 053_GBP_IIT_SEC_ANL_15_Ver 1_Dec 2013

This report presents the trends in urbanization and industrialization in the state of West Bengal and analyzes their implications for the GRBMP.There are several anthropogenic and socio-economic factors associated with rapid and at times unregulated urbanization and industrialization that affect the quantity and quality of water resources.

Despite the slow or significantly restricted industrial development in the last three decades or so, West Bengal has witnessed faster rise of urban centres and urban population. Studies reveal that West Bengal has the highest number of red category industries causing high pollution, followed by Maharashtra and Tamil Nadu. A majority of the registered manufacturing units in the state are located in four basin districts, viz. Howrah, 24-Parganas, Kolkata and East Midnapore.

It is evident in the present report that the state needs to reinvent and re-define its policy framework to attract investment towards industrial development and at the same time there is a major need for promotion of non-farm employment opportunities in the rural areas to control the pace of migration to urban areas. There is a need for growth of supporting infrastructure for agriculture and horticulture sectors thereby facilitate exports from the state. Along with a strong infrastructure for development, an urgent need of infrastructures and services for sewage handling and solid waste management is observed in all urban centres across the state.

Measure for Ecological Revival of River Ganga

Report Code: 054_GBP_IIT_ENB_DAT_14_Ver 1_May 2014

The biodiversity of the river Ganga is unique, as it synthesizes three major eco-regions of India situated along different climatic gradients - the Himalayan mountainous region, the Gangetic plains and the estuarine region including Hooghly-Maldah delta. Different geological and evolutionary history of these regions made the Ganga basin rich in biotic diversity. The river Ganga is home to a vast variety of living organisms, from simple microscopic flora and fauna to

a large assemblage of higher invertebrates (Arthropods, Annelids and Molluscs) and vertebrates (Fishes, Reptiles and Mammals).

The main problems of Ganga river basin arise by unsustainable use of water resources; obstruction in flows resulting in river fragmentation and loss of longitudinal connectivity on account of exploitation of its hydro-electric potential in the Himalayan segment; abstraction of large quantities of water for irrigation in plains; and ever increasing water pollution in the middle and lower segments. Due to lack of any definitive bio-monitoring program by the concerned agencies, the analysis in this area is mainly based on extrapolation, which affected the quality of available data.

The riverine ecosystem has been exploited for meeting human needs. Major threats to the Ganga basin are change in the flow regime, habitat alteration, emergence of invasive species, introduction, and proliferation of invasive species and pollution load. The additive nature of these is affecting/disturbing ecological integrity of Basin. Conspicuous declination has been observed in fish yield, fish catch, fish size and fish composition in the Ganga Basin due to combined effect of alteration in quality and quantity of flow.

Adequate space required for growth and migration of endemic flora and fauna can be facilitated by maintaining longitudinal and lateral connectivity of river through provisioning the environmental flow in all tributaries and main stem of Ganga. Legislation in River Act (proposed), fishing should come under regulated and restricted category to control the excessive exploitation of fish and their broods and juveniles. Rare, endangered and threatened species of flora and fauna need to be identified and conserved to maintain the ecological integrity of the Ganga basin. Appropriate bio-monitoring program with the community involvement need to start for tributaries and main stem. The protocol and procedure, required to control the population of invasive species like Common carp, - Grass carp, and Tilapia, need to be worked out through the concerted efforts of Central Inland Fishery Research Institute and other scientific bodies.

Reform Imperatives for Agricultural Sustainability in Ganga Basin

Report Code: 055_GBP_IIT_SEC_ANL_16_Ver 1_May 2014

Agriculture is the main source of livelihood of a majority of rural population in the Ganga River Basin. As per the National Sample Survey (NSS) 68th Round (2011-12), 62.37% of total workforce in Bihar, 52.41% in Uttar Pradesh, 48.96% in Uttarakhand and 39.23% in West Bengal directly depend on agriculture. The Ganga river, being a perennial source of water, facilitates both surface and groundwater irrigation in the basin. Since, the scope of bringing more area under cultivation is limited due to rising land demand for non-agricultural uses, such as, urbanization and industrialization, future requirement of agricultural commodities, including food, may be met by intensive use of land, water and other resources which would have some superfluous implications in terms of degradation of soil and water resources. Green revolution technology, though has made significant contribution to transform agriculture from the food-deficit economy to food-surplus one and could substantially raise farm production, productivity and income, it has no longer remained 'green' and its environmental and ecological consequences have now become quite obvious.

Despite economic benefit of the green revolution, the associated high input-intensive farm practices followed by farmers in the basin have caused depletion in the groundwater table, increase in input cost, deterioration in the quality of soil and water and increased credit requirement and consequently rising indebtedness among farmers. Therefore, basic issue for the GRBMP has been addressed in this study is, how to achieve ever-green and sustainable agricultural development without adversely affecting soil, water, ecology and environment.

The other approaches - need to be identified to develop the farming systems that widen livelihood opportunities; conserve soil, water, and other natural resources; protect environment, ecology and biodiversity; reduce farmer's dependence on external inputs, ensure food security, and improve human health and safety. A water credit system should be initiated to encourage farmers to make efficient use of irrigation water and save water for river ecosystem services. So far there is no clarity on who owns the ground water. It is, therefore, necessary to institute secure water rights to users and develop

water market and water pricing so that water-saving technologies may be encouraged. The minimum support price (MSP) program may be used as a policy instrument to achieve diversification of agriculture towards high value and low water consuming crops. There is also need to estimate the social cost of chemicalised farming and internalize its negative externalities.

Hydrological Flow Health Assessment of the River Ganga

Report Code: 056_GBP_IIT_ WRM_ANL_01_Ver 1_Jun 2014

Continuity in flow is a basic concern in Ganga river basin; a number of water resources projects (irrigation and hydropower projects) have rendered the river dry in several stretches. Hence a hydrologic health assessment of the Ganga River basin was undertaken based exclusively on hydrologic flow regime.

The hydrologic flow regime for the virgin state and the current managed state were obtained through calibrating the hydrologic model Soil and Water Assessment Tool (SWAT). The Flow health assessment was made for four scenarios 1) Virgin scenario 2) Currently managed scenario 3) Flow health due to improved irrigation efficiency and 4) Flow health due to implementation of projects such as run of the river hydroelectric projects that are envisaged.

In general, the study shows that the hydrologic flow health has been considerably affected at several stretches of the River Ganga due to the present state of water management. This report could be a first step to start a meaningful and effective dialogue between various stakeholders of the basin and agree upon a desired flow health to achieve in the different stretches of Ganga. This along with a study on the functional needs of the ecosystem along different stretches will help to arrive at an E-flow regime to be maintained along different stretches of Ganga during different times of the year.

Surface and Groundwater Modelling of the Ganga River Basin

Report Code: 057_GBP_IIT_ WRM_ANL_02_Ver 1_Aug 2014

A detailed modeling of surface water and ground water system of the Ganga basin was carried out as a part of preparing management plan for the basin. This report describes the modelling results.

The Soil and Water Assessment Tool (SWAT) model was adopted to simulate the surface water response of the Ganga basin. For this purpose, the study area was subdivided in 1045 sub-basins and modelling was carried out for each of these basins. The entire model was calibrated at 30 locations with the river discharge data obtained from CWC. The model results were comparable with the observed results on a monthly scale.

Similarly, the groundwater model was set up for the alluvium part of the entire Ganga basin using MODFLOW. The model was calibrated for a period of 4 years and the model results were found to be satisfactory. The Groundwater model was able to model the stream-aquifer interaction in a consistent manner.

In the next step, these two models were used to simulate different scenarios viz. virgin, future in order to understand the virgin conditions of the basin and the future state of the basin respectively. Scenarios have also been generated by introducing the enhancement in the irrigation efficiency with a view to restore the hydrological health of the basin.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Uttarakhand

Report Code: 058_GBP_IIT_EQP_S&R_08_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Uttarakhand. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of Uttrakhand has 8 Class I towns and 4 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 10.16 million. Uttarakhand is estimated to have a total surface water consumption of 184.71 MLD, along with utilization of 727.98 MLD groundwater. The amount of sewage generated in Uttarakhand is estimated to be 710.4 MLD. The total BOD, COD, and TKN loading from this sewage is estimated to be 238.7, 405.8 and 47.7 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Haryana

Report Code: 059_GBP_IIT_EQP_S&R_09_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Haryana. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of Haryana has 16 Class I towns and 3 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 25.35 million. Haryana is estimated to have a total surface water consumption of 577.3 MLD, along with utilization of 598.9 MLD groundwater. The amount of sewage generated in Haryana is estimated to be 1617.7 MLD. The total BOD, COD, and TKN loading from this sewage is estimated to be 154.62, 262.87 and 30.92 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Uttar Pradesh

Report Code: 060_GBP_IIT_EQP_S&R_10_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Uttar Pradesh . The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of Uttar Pradesh has 62 Class I towns and 43 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 200.95 million. Uttar Pradesh is estimated to have a total surface water consumption of 4366.6 MLD. The amount of sewage generated in Uttar Pradesh is estimated to be 4603.7 MLD. The total BOD, COD, and TKN loading from this sewage is estimated to be 878.98, 1422.46 and 178.35 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Rajasthan

Report Code: 061_GBP_IIT_EQP_S&R_11_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Rajasthan. The study was undertaken using the Census, 2011 data on the population. The

per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of Rajasthan has 19 Class I towns and 4 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 68.75 million. Rajasthan is estimated to have a total surface water consumption of 696.4 MLD, along with utilization of 405.6 MLD groundwater. The amount of sewage generated in Rajasthan is estimated to be 405 MLD. The total BOD, COD, and TKN loading from this sewage is estimated to be 215.34, 366.1 and 43.07 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Bihar

Report Code: 062_GBP_IIT_EQP_S&R_12_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Bihar. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of Bihar has 28 Class I towns and 23 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 104.48 million. The amount of sewage generated in Bihar is estimated to be 710.4 MLD. The total BOD, COD, and TKN loading from the sewage generated in Bihar is estimated to be 66.33, 102 and 36.92 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Madhya Pradesh

Report Code: 063_GBP_IIT_EQP_S&R_13_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Madhya Pradesh. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of Madhya Pradesh has 27 Class I towns and 10 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 73.64 million. Madhya Pradesh is estimated to have a total surface water consumption of 1074.3 MLD, along with utilization of 221.22 MLD groundwater. The amount of sewage generated in Madhya Pradesh is estimated to be 844.1 MLD. The total BOD, COD, and TKN loading from this sewage is estimated to be 343, 583.07 and 68.50 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: West Bengal

Report Code: 064_GBP_IIT_EQP_S&R_14_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in West Bengal. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

The state of West Bengal has 62 Class I towns and 15 Class II towns, which along with a number of Class III and Class IV towns have a combined population of 92.67 million. West Bengal is estimated to have a total surface water consumption of 184.71 MLD, along with utilization of 727.98 MLD groundwater. The amount of sewage generated in West Bengal is estimated to be 710.4 MLD. The total BOD, COD, and TKN loading from this sewage is estimated to be 238.7, 405.8 and 47.7 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Yamuna Sub-basin

Report Code: 065_GBP_IIT_EQP_S&R_15_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Yamuna

Sub-Basin. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

Major cities in the Yamuna sub-basin have a total population of 17.31 million. The sub-basin is estimated to have a total water consumption of 2919.05 MLD. The amount of sewage generated in the sub-basin is estimated at 2420.11 MLD, of which 1712.95 MLD remains untreated. The total BOD, COD and TKN loading from this sewage is estimated to be 462.56, 784.88 and 93.45 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Ramganga, Kali and Gomati Sub-Basin

Report Code: 066_GBP_IIT_EQP_S&R_16_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Ramganga, Kali and Gomti Sub-Basin. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities

and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

Major cities in the Ramganga, Kali, and Gomati sub-basin are Moradabad, Bareilly, Shahjhanpur, and Rampur, which have a total population of 2.5 million. The sub-basin is estimated to have a total surface water consumption of 370 MLD. The amount of sewage generated in the sub-basin is estimated at 341.98 MLD. The total BOD, COD and TKN loading from this sewage is estimated to be 39.79, 118.64 and 13.69 tonnes/day respectively.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Gandak and Kosi Sub-Basin

Report Code: 067_GBP_IIT_EQP_S&R_17_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Gandak and Kosi Sub-Basin. The study was undertaken using the Census, 2011 data on the population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

Assessment of Domestic Pollution Load from Urban Agglomeration in Ganga Basin: Hooghly Sub-Basin

Report Code: 068_GBP_IIT_EQP_S&R_18_Ver 1_Dec 2014

This report focuses on the inventory of water demand, water supply, sewage generation and collection, and estimation of the BOD/COD, Nitrogen and Phosphorous loads from urban centres (Class I and Class II towns) in Hooghly Sub-Basin. The study was undertaken using the Census, 2011 data on the

population. The per capita water supply and sewage generation information was taken from the CPHEEO manuals. Further, per capita contribution of phosphorus, nitrogen, BOD, and COD are calculated based on the guideline provided in various literatures. IIT Consortium team also performed field visits to many of these towns to collect some primary data and information available with Urban Local Bodies (ULBs) and some local agencies. An information sheet has been prepared for each of the Class I and Class II Towns. The information regarding existing sewage treatment facilities and plants are also included wherever such information was provided by the local bodies, state agencies and/or MOEF.

Major cities in the Hooghly sub-basin are Baidyabati, Chakdaha, Budge, and Bansberia, which have a total population of 0.43 million. The sub-basin has a total surface water consumption of 48.55 MLD. The amount of sewage generated in the sub-basin is estimated at 42.91 MLD. The total BOD, COD and TKN loading from this sewage is estimated to be 11.7, 19.9 and 2.3 tonnes/day respectively.

Policy and Governance Trends in Urban Water and Sanitation Sector in India

Report Code: 069_GBP_IIT_PLG_ANL_05_Ver 1_Dec 2014

Policy and Governance Trends in Urban Water and Sanitation Sector in India

This report discusses the crisis in public utilities leading to a downward spiral of deteriorating assets and declining productivity thus increasing operating costs and citizens' unwillingness to pay for the suboptimal services. This downward spiral has led to two strands of arguments in the realm of state failure: one that International Financial Institutions (IFIs) perceive the failure of public utilities from a financial viability point of view and the second argument comes from the political economy angle of the bureaucratic nexus with vested interests, inefficiency/rent seeking which also reflects the lack of accountability and transparency of public utilities. The varying arguments of 'state failure' called for privatization with a number of reasons put forward such as to improve quality, operating efficiency and system performance, etc. However, in privatization, the scale of investment needed in the UWSS is expected to be

substantial as the service provisioning under this sector is conceived as building, operating and maintaining centralized Sewage Treatment Plants (STPs) which involves capital and energy intensive technology solutions. A World Bank study showed that returns on infrastructure investment in developing countries, including water, fell far short of the cost of capital. The Return on Equity in the water and railroad sectors had negative average returns of -0.14% and 6.7% respectively, while the port and the energy sectors had positive returns of 6-8%. Thus there has been less direct privatization of water services since the 1990s, however, the commercialization trend continues through PPPs. There have been certain problems associated with PPPs as the risk of continue to remain high, the share of private investment will continue to be relatively small with substantial reliance on public funding. The report addresses these risks and issues in detail. The specific issues associated with PPPs in UWSS are escalated tariff rates, disconnections and marginalization, vested interests vying for high profits, problems emerging from cost cutting, public guarantees of private finances and profits, efficiency and efficacy of operation, commercialization of water, control of the resources and natural resource exploitation. The availability of grant funds and limited internal resources has resulted in easier and quicker acceptance of the PPP approach by local stakeholders, including political representatives. However, they lack technical and monitoring capacity to facilitate, implement and scale up PPPs. Hence, the commitment of ULBs to PPP projects is a tactical response with no attempts made to link the provision of public funding to tariff reforms in the sector essential for sustained asset management and service quality. There is no evidence of any assessment, either by private or public, of the conditions at the ground level considering population, demand supply gap or environmental impact before initiating the projects. After a discussion on the current investment demands and status of PPPs in UWSS, the report revisits the larger policy discussions and clarifies important proposals that support the need for heterodox institutional solutions in place of the singular imagination of centralized technological and institutional solution. Hence for PPPs to succeed, a huge effort is needed on behalf of government to improve its governance structure for planning, monitoring and regulating in order to complement the private participation as well as ensure compliance of the terms. Bringing transparency, accountability and participation of citizens are

needed to safeguard public concerns and to ensure larger acceptance of the citizens about the need, modalities and implications of the PPP model. This forms the background for better understanding of the suggested technological solutions like ZLD and institutional models like DBFO in the Ganga Basin.

Assessment of Potential Institutional Models for Sewage Treatment in Ganga Basin and the Way Forward

Report Code: 070_GBP_IIT_PLG_ANL_06_Ver 1_Dec 2014

In the background of larger discussions about state and private sector participation in UWSS, this report discusses the institutional options for wastewater treatment in Ganga basin. It undertakes a brief analysis of the failures of the currently practiced state-led model through a review of Ganga Action Plan (GAP) and the new institutional solutions that insulates itself from the larger governance maladies of the existing state-led institutional arrangements. The technological aspects studied in the report reflected on the question whether it would be possible to treat the entire sewage generated in the basin through centralized STPs through a huge network of sewer lines. The governance aspects show the lacunas and gaps in the existing pollution abatement laws, overlaps and conflicting jurisdictions of the government agencies and common reasons for administrative and other delays leading to bad design and implementation. Thus the next part of the report looks at the concerns of stakeholders (private sector provider, governing agencies and citizens) in PPP led model for sewage treatment. The report also looks at a case study from a similar initiative in the energy sector as no relevant case study is found in UWSS. The prominent challenges thus coming out from the case study and relevant for the wastewater sector are the technical, financial, social and political viability of a PPP model in the background of the socio-economic realities in the Ganga basin and a market for wastewater. The report at the end discusses the need for heterodox institutional options for wastewater treatment in India in the light of the limitations emerging from the state-led and PPP models. The report concludes with a table presenting the strengths and weaknesses of the three institutional models (state led, PPP and Community led) highlighting how the centralized state led model of UWSS has its advantages in terms of its democratic, representative and non-profit

features of an explicit and declared purpose of public interest. The limitations of the state in terms of questionable efficiency, capacity and limitations of infrastructure along with the lack of accountability and transparency has been most compelling reasons for the emergence of PPP led models of UWSS. However, this transition towards PPP of essential services has not been a smooth process where private companies have neither shown improved quality of services nor addressed many of the problems of the state led model. Thus an emerging recommendation is to search for a mix of institutional options involving state, community and private partnerships with decentralization, transparency, accountability and participation as guiding principles.

Assessment of Provisioning an Appropriate Solid Waste Management Approach in Urban Agglomerations in Ganga River Basin

Report Code: 071_GBP_IIT_EQP_S&R_19_Ver 1_Dec 2014

An appropriate frame work is a prerequisite to provide solutions for solid waste management in urban centres. The first and foremost step towards it is to have an assessment of having the management plan in economic sense. Dumping the solid waste as landfills may appear to be a very low cost solution and may have certain advantages in low lying areas, but it has very serious effects on land, agriculture, underground water and surface water bodies as well. So having a plan for complete treatment of solid waste with an approach towards minimal landfill and more recycling/reuse is the need of the hour. On the other hand achieving 100% collection efficiency and encouraging more recycling/reuse of solid waste with use of advanced treatment technologies may lead to resource recovery and also help in energy regeneration.

The present study aims at estimating the per capita expenditure on solid waste management with provision of segregation of the total solid waste generated, proper collection and conveyance of waste and subsequent recycling and treatment of different types of wastes. It is also important to note that energy consumption and footprint are also important along with expenditure incurred and hence are also estimated separately. The study also aims at estimating the financial layout for provisioning infrastructure for solid waste management in

all Class I and Class II towns of the Ganga River Basin (GRB) with the objective of recycling and reuse of non-biodegradable waste and minimizing landfill sites.

Results indicate that footprint for waste treatment is approximately 0.7m2 per person. The electrical energy consumption in complete solid waste management comes out to be 0.001 KW-h per person per day while the equivalent energy in the form of fuel consumption is 0.017KW-h per person per day for Class I towns and subsequent value for Class II towns is 0.016KW-h per person per day. The total per capita expenditure for having complete solid waste management system is estimated to be INR 1.15 per capita per day.

Proper solid waste management and more reuse/recycle is aesthetically good and have many other benefits as well. The cost of provisioning solid waste management systems does not appear to be unaffordable on per capita per day basis considering the benefits and savings in ensuring good quality of agricultural land availability, no groundwater or surface water hazards and hence, minimum health hazards.

Assessment of Approaches for Eliminating Use of Fresh Water in Tanneries at Jajmau, Kanpur

Report Code: 072_GBP_IIT_EQP_S&R_20_Ver 1_Dec 2014

Industrial development is vital for the economy of a country. However, it should not occur at the cost of the environment. A major contributor to the Indian exports is the leather and leather goods but at the same time it is one of the most polluting industries. Though a lot of money and effort has been spent towards the treatment facilities for tannery effluent, overall achievement has been limited and the treated effluent is often found not complying with the current effluent discharge standards, especially for total dissolved solids (TDS). Conventional practice of treatment has no provision for removal of TDS and thus the levels are often much higher than the discharge standard of 2100 mg/L. Subsequent use of partially treated or untreated effluent for agriculture or disposal in inland water bodies has very serious effects on the users of such resources. Encouraging more recycling/reuse of effluent with application of

advanced treatment technologies will limit the unsustainable exploitation of fresh water resources.

The present study aims at estimating the expenditure for reusable water inclusive of costs of complete segregation of effluents, proper collection and conveyance, complete treatment of effluent and distribution of treated effluent. Energy and land footprint are also important along with the expenditure incurred, and hence are also estimated separately. The study also aims at estimating the tariffs for recyclable water with the financial options available for provisioning infrastructure facilities with such high capital and operational expenditures.

The proposed approach is illustrated through a case study of Tanneries in Jajmau, Kanpur. Two options considered include zero discharge into water bodies using multi effect evaporator for recovery of salts from the reject of reverse osmosis (RO reject) process and controlled discharge of accumulated RO reject in lagoons during high flows in monsoons. Results indicate that the approximate land and energy footprint for CETP facilities with MEE and lagoon is 0.16 hectare per MLD & 18.82 MW-h per MLD per day and 2.08 hectare per MLD & 2.33 MW-h per MLD per day respectively. The approximate land and energy footprint considering common beam house (CBHF) facilities with MEE and Lagoon is 0.24 hectare per MLD and 25.94 MW-h per MLD per day & 2.17 hectare per MLD and 9.61 MWh per MLD per day. The approximate tariffs for recycled water with MEE and Lagoon (at 30% equity and 70% loan at 5% interest rate for 20 years) ₹ 290 per KL and ₹ 144 per KL respectively. The approximate tariffs of de-limed skins in CBHF facilities with MEE and Lagoon is ₹ 57 per sq. m. and ₹ 47 per sq. m. respectively.

Proper effluent treatment and reuse/recycle is aesthetically good and have many other benefits as well. The tariffs for recycled water though may appear high in comparison to existing freshwater tariffs but it is important that the cost of abatement is truly borne by the polluter and the over exploitation of the under-priced public resources for private financial gains is stopped.

Assessment of E Flows at Some Select Sites in Upper Ganga Segment

Report Code: 073_GBP_IIT_EFL_ANL_01_Ver 1_Dec 2014

The objective of the Environmental Flows (E-Flows) is to recognize the physical limit beyond which a water resource suffers irreversible damage to its ecosystem functions, and systematically balance the multiple water needs of society in a transparent and informed manner. This report focuses on the derivation of E-Flows on the basis of a novel concept devised by the IITC E-Flows group. The objective of the E-Flows is the survival and growth of the site specific fish species, called “key-stone” species. Through the analysis of virgin flow and biological requirement of site specific key-stone species, average virgin flow, 90% dependable flow, E-Flows, and Minimum Ecological Requirement (MER) are computed. Further, on the basis of the estimated quantities, river health classes are decided viz., Very Good, Marginal, and Poor. Any river with flow regime better than E-Flows is considered to be in good health. On the other side if flow regime is inferior thanthe MER, the river may be considered to be in poor health. The analysis was carried out on 7 sites in upper segment of the Ganga River Basin, where the interaction between the surface water with the ground water is considered negligible and information on virgin flows could be extracted with some degree of confidence.

Appendix IV

THE NATIONAL RIVER GANGA BASIN MANAGEMENT BILL, 2015

(An ACT to provide for Regulation, Conservation and Development of the National River Ganga Basin, and for the establishment of National River Ganga Basin Management Commission and National River Ganga Basin Tribunal for effective and expeditious disposal of matters affecting the River Basin with a view to restore and conserve the river basin and for matters connected therewith or incidental thereto)

WHEREAS, the river Ganga is declared as the National River of India on November 5, 2008 by the Government of India considering its unique position in Indian society and world's natural heritage.

AND WHEREAS, it shall be desirable to adopt an integrated river basin management approach that focuses on maintenance and restoration of wholesomeness of rivers of the Ganga Basin in public interest.

AND WHEREAS'Wholesomeness' in this context shall mean sanctity of the river system as imbibed in the following points:

a. Continuous Flow ("Aviral Dhara") in time and space including maintenance of connectivity of flow in the river systems.
b. Un-polluted Flow ("Nirmal Dhara") meaning that quality of river waters is not significantly affected by human activities.
c. Rivers as Geologic Entities that is, rivers as the earth's creations of ancient times (over geological ages), which may not be recoverable if damaged.
d. Rivers as Ecological Entities that is, rivers as delicately structured ecological balance between various living species and the physical environment achieved over thousands of years and vulnerable to irreversible change.

AND WHEREAS 'Public Interest' in this context shall mean welfare or wellbeing of all beings including the future generations.

AND WHEREAS, to attain the wholesomeness, it is mandated to adopt preventive and corrective approach, the Act shall prohibit, restrict and promote activities that directly or indirectly affect the wholesomeness of all rivers in the National River Ganga Basin.

AND WHEREAS, the Act shall establish appropriate authorities to achieve the objectives of the Act and matters related thereto.

AND WHEREAS the Act shall be enacted to realize fundamental right guaranteed under Article 21 and to give effect to provisions of the Directive Principles of State Policy under Articles 39(b), 48 A, 49 and the Fundamental Duties enshrine under Article 51A (f) and(g) of the Constitution of India.

AND WHEREAS, the Act shall be enacted by Parliament by invoking legislative power under Article 246 read with Entry 56 of the Union List of the Constitution of India.

CHAPTER I
PRELIMINARY

1. Short Title, Extent and Commencement

1) The Act may be called The National River Ganga Basin Management Act, 2012.
2) It shall extend to the whole National River Ganga Basin.
3) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint and different dates may be appointed for different States.

2. Definitions

In this Act, unless the context otherwise requires –

1) “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;
2) Afforestation means plantation of trees to restore or reestablish the forest cover;

3) Authority means any authority, board, corporation, council, department, institute, university or any other body corporate, established by or under any Central, State or Provincial Act in force in the territory of India and includes,

a. The Central Government,
b. The State Governments,
c. A Department of the Government,
d. Local authorities;

4) "Aviral Dhara" (in a river or stream) means continuity of flow in both time and space, including connectivity of flow throughout the river;
5) Basin includes land, water, vegetation and other natural resources on a catchment basis;
6) "Basin" means the entire catchment (of a water body or water course) including the soil, water, vegetation and other natural resources in the area;
7) "Catchment" (or "Catchment Area", or "Watershed", 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);
8) Class I town means a town whose population is greater than 100,000;
9) Class II town means a town whose population is greater than 50,000 and less than 100,000;
10) "Commercial fishing" means large-scale fishing for commercial purposes by nets, cyanide poisoning, or other modern fishing gear or methods.
11) Commission means National River Ganga Basin Management Commission;
12) "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).
13) "Deforestation" means removal or reduction of forest cover, especially when caused by anthropogenic activities;

14) “Degraded Forest” means a forest having loss or reduction of native forest cover and/ or vegetation density;
15) “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;
16) “Ecological Park” is a protected area for conservation of native and endangered species;
17) “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;
18) “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;
19) “E-Flows” means Environmental Flows;
20) “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;
21) “Engineered Diversion” means a structure or device constructed or installed to transfer the river water into a canal or other engineering structure;
22) “Environmental Flows” are the regime of flows including sediments and other natural constituents required to maintain the ecological integrity of a river and the goods and services provided by it, computed by Building (Bigger) Block Method;
23) “Flood” means the overflowing of water from a water course or water body that inundates normally dry land;
24) “Flood Plain” is the land area susceptible to inundation by flood waters;
25) “Flood Routing Channel” is a channel designed to carry the excess water of a water course during high flows;

26) “Geologic Entity” is an entity formed by ancient earth processes over geologic ages;
27) “Ghat” is a sloping or cliffed part of a riverbank, often with artificially constructed steps, used for providing easy human access to river water;
28) “Ground Water Recharge” is replenishment (in part or wholly) of water depleted from ground water reservoirs;
29) Hazardous Solid Waste (HSW) includes as provided in the Act;
30) “Hydrological Cycle” is the natural cycle of change through which water moves on earth;
31) Industrial Effluents includes as it is mentioned in the Act;
32) Kharif Canals means Irrigation canals used for crops grown in rainy season;
33) Landfills means a place used for disposal of solid waste on land;
34) Large Scale Industries provided in the Act;
35) Medium Scale Industries provided in the Act;
36) Municipal Solid Waste provided in the Act;
37) “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 including Prayag Raj;
38) “Nirmal Dhara” or “Un-polluted Flow” means flow in a river or stream that is not significantly polluted by anthropogenic activities;
39) “Paleo-Channel” is the remnant of an extinct river or stream that got filled with sediments deposited in later periods;
40) "person" includes—
    a. an individual;
    b. a Hindu undivided family;
    c. a company;
    d. a firm;
    e. an enterprise;

f. an association of persons or a body of individuals, whether incorporated or not, in India or outside India;
g. any corporation established by or under any Central, State or Provincial Act or a Government company as defined in section 617 of the Companies Act, 1956 (1 of 1956);
h. any body corporate incorporated by or under the laws of a country outside India;
i. a co-operative society registered under any law relating to cooperative societies;
j. a local authority;
k. every artificial juridical person, not falling within any of the preceding sub-clauses.

41) Ritual Bathing means taking dip in the water for religious or spiritual purposes;
42) River Bed Farming includes seasonal agriculture/farming on the river bed during low flows when the bed is exposed;
43) Rivers in National River Ganga Basin include, but is not restricted to, all major and minor tributaries of the National River Ganga within the basin;
44) River Bank means the land at the side of a river which retains the river in its natural channel, when there is the greatest flow of water;
45) River Bed means dried portion of the river, the place where the river run its course; when it fills with water.
46) River Port means a place on a waterway with facilities for loading and unloading ships;
47) River System means network of rivers rather than a single river;
48) Rivulets includes very small tributaries of a major river;
49) Sand Mining means large scale removal of river sand from the dried channel belt or a part of it;
50) Sewage means as provided in the Act;
51) Small Scale Industries as provided in the Act;
52) Solid Waste as provided in the Act;
53) Sludge as provided in the Act;

54) Tribunal means the National River Ganga Basin Management Tribunal;
55) "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;
56) "Water Course" (or "Surface Water Course") is an overland channel (natural or manmade) through which water flows, such as a river, stream, rivulet (or "nala") or canal;
57) Water Recharge Structures includes arrangements made for enhancement of sub surface flow and storages of water.

CHAPTER II
DUTY TO ENSURE RESPECT AND DIGNITY OF NATIONAL RIVER GANGA

3. Respect and Dignity

Every person shall ensure utmost respect and dignity for the National River Ganga and desist from activities prejudicial to her interests.

4. Duty of State and Citizen

It shall be the duty of the State and every other person to ensure the protection, preservation, conservation and maintenance of wholesomeness of National River Ganga.

CHAPTER III
USAGE OF WATER IN NATIONAL RIVER GANGA BASIN

5. Usage of water shall be determined in accordance with the following

1) The usage of water shall be posterior to nature and ecology.
2) The usage shall have sequential priority from 'water for life' to 'livelihoods' to 'developmental activities'.
3) There shall be institutional arrangements for usage of water based on principles of equity, resource-conservation, protection of water resources, and harmonization of water use.

CHAPTER IV
PROHIBITION AND RESTRICTION OF ACTIVITIES

6. Prohibition of Activities relating to the National River Ganga Basin

Notwithstanding anything contained in any law whatsoever, no person or authorityshall indulge in any activity relating to any of the following:

1) engineered diversion and/or storage of water in any river unless E-Flows are maintained in the immediate downstream of the diversion/storage; or
2) discontinuity in the flow due to engineered diversion/storage in any river; or
3) discharge of sewage (either treated or untreated) from Class I towns, either directly or indirectly, into any river; or
4) discharge of industrial effluents (either treated or untreated) from any large, medium or cluster of small industries, either directly or indirectly, into any river; or
5) direct injection of sewage and industrial effluents (either treated or untreated) into the subsurface; or
6) disposal of un-burnt and partially burnt corpses and animal carcasses in any river or riverbank; or
7) open defecation and dumping of municipal/industrial solid wastes or sludge in any river or its active flood plain; or
8) setting up of or continuation in dwellings or other encroachments in the river banks or its active river flood plains; or
9) construction of new permanent structures for residential, commercial and industrial purposes in the active flood plain of any river;

   Provided that construction of bridges and associated roads, jetties/ghats/ports and hydraulic structures for storage/ diversion/ control/ channelization of river waters shall not be thereby prohibited.
10) any other like activities as may be prescribed by the commission.

7. Restriction of Activities relating to the National River Ganga Basin

No person shall indulge in any of the following activities except in accordance with the rules and regulations as may be laid down in this regard from time to time.

1) discharge of sewage (either treated or untreated) from Class II town and smaller towns and villages, either directly or indirectly, into any river; or
2) disposal of sludge derived through treatment of sewage and industrial effluents except in secure landfills/hazardous waste sites; or
3) discharge of industrial effluents (either treated or untreated) from small scale industry into any river; or
4) disposal and/or discharge of mining and construction debris in any river's flood plain, river bank or the river itself; or
5) construction of bridges and associated roads, jetties, ghats, ports and permanent hydraulic structures for storage/diversion/control/channelization of waters in any rivers; or
6) withdrawal of ground water by electric/diesel operated shallow and deep tube wells; or
7) sand mining, stone crushing, sediment removal and mining of other minerals from the river bed of any river; or
8) dredging or any other excavation activity on river bed for any purposes threatening the balance of the natural environment; or
9) river bed farming and agricultural activities in the active flood plain of any river; or
10) commercial fishing or aqua culture in any river; or
11) ritual immersion of idols, and floral and other offerings in any river; or
12) wallowing of animals, washing of clothes, vehicles, etc., in any river; or
13) deforestation of hill slopes and notified forest and other sensitive areas; or

14) hazardous or harmful emissions into the atmosphere that can affect terrestrial waters directly or indirectly in any river; or
15) use of chemical fertilizers and pesticides in agriculture, horticulture, aquaculture, animal husbandry, forestry, etc. in any river; or
16) any activity that may lead to geologically disruptive phenomena such as heightened seismic activity, ground subsidence, and leaching or erosion of contaminants into water bodies; or
17) cattle grazing on erodible hill slopes and in over-grazed areas; or
18) any other like activities as may be prescribed by the commission.

CHAPTER V
CONSERVATION, DEVELOPMENT OF NATIONAL RIVER GANGA BASIN

8. Conservation and Development

1) The appropriate authority shall take all measures necessary for the conservation and development of the National River Ganga Basin.
2) Such conservation shall include measures relating to the following:

a. ensuring that E-Flows are maintained in all rivers at different locations and in different seasons;
b. protecting both geology and ecology in the river basin;
c. using of floodplains in environmentally safe manner, and after ensuring Environmental Impact Assessment for approval of flood plains projects;
d. ensuring both short-term and long-term measures for conservation and improvement of natural resources in National River Ganga Basin;
   Explanation - The term “appropriate authority” in this section and the subsequent one shall be taken to include the Central Government or State Government or such Local authorities responsible for implementation as the context indicates;
e. monitoring, review and dissemination of the National River Ganga Basin’s environmental status in the public domain.

9. Promotion of Activities relating to the National River Ganga Basin

The appropriate authority shall adopt special measures to promote the following activities in the National River Ganga Basin:

1) reuse and recycle of treated domestic and industrial sewage and use of products derived from sewage sludge, with mechanism for commercial use/ reuse where feasible;

2) measures including construction of sewer lines, provision of sanitation services, construction of wastewater treatment plants for municipal and industrial effluents, construction of secure solid waste landfills, hazardous waste landfills and other related facilities in the River Basin;

3) facilities for environmentally safe cremation/burial of corpses and measures for 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 increase ground water levels and enhance river base flows;

5) higher efficiencies in irrigation water use (through appropriate irrigation techniques, rationalization of cropping patterns, recycling of return flows, etc.) for agriculture, horticulture, fodder cultivation, etc;

6) 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;

7) afforestation and/or grassland development in degraded forest lands, wastelands and denuded hill slopes (for control of surface runoff and erosion, and for enhancing groundwater recharge);

8) activities related to flood control, including development of flood routing channels, embankments and other methods for controlling sediment flows and distribution;

9) protection of breeding areas and natural habitats of indigenous and migratory species of fishes, birds, reptiles, amphibians and mammals, and the prevention of the spread of exotic species;
10) eco-friendly tourism, pilgrimage, recreational and sporting activities in all rivers and riverbanks;
11) use of the riverbank and active flood plains of rivers for development of water-recharge structures and ecological parks;
12) use of bio-fertilizers and bio-pesticides (in place of chemical fertilizers and pesticides) in agriculture, horticulture, aquaculture, forestry, etc., to protect groundwater from agricultural pollutants;
13) any other like activities as may be prescribed by the commission.

CHAPTER VI
DUTIES OF CENTRAL AND STATE GOVERNMENTS

10. Duties of Central and State Governments

1) It shall be the duty of the Central Government to constitute the National River Ganga Basin Management Commission to carry out the provisions of the Act.
2) The Central and State Governments shall render all assistance and cooperation necessary for the effective implementation of the provisions of the Act.
3) The Central Government shall, in consultation with and concurrence of the Commission, make rules and regulations necessary for the effective implementation of the provisions of the Act.
4) In accordance with the directions of the Commission, the Central and the State governments, as the case may be, shall take necessary measures towards prohibition and restriction of activities in any river of the National River Ganga Basin as well as conservation and development of the basin.

CHAPTER VII
NATIONAL RIVER GANGA BASIN MANAGEMENT COMMISSION CONSTITUTION, POWER AND FUNCTIONS

11. Establishment of Commission

1) With effect from such date as the Central Government may by notification decide, there shall be established for the purposes of this Act, a Commission to be called the "National River Ganga Basin Management Commission" hereinafter referred to as the Commission.
2) The Commission shall be a body corporate by the name aforesaid having perpetual succession and a common seal with power, subject to the provisions of this Act, to acquire, hold and dispose of property, both movable and immovable and to contract and shall, by the same name, sue of be sued.
3) The Head Office of the Commission shall be at such place as the Central Government may decide from time to time.
4) The Commission may establish offices at other places in India.

12. Composition of Commission

1) The Commission shall consist of the following Members, namely:
   a. A Chairperson,
   b. A Retired or Sitting Judge of the High Court,
   c. Five Independent Members of Civil Society/Academia/Experts having expertise in requisite areas of river basin management.
2) The Chairperson shall be the Chief executive of the Commission and shall exercise such powers and perform such duties, as may be prescribed and he shall be responsible for the business of the Commission.
3) The Chairperson and other members of the Commission shall be persons of ability, integrity and standing and who have special knowledge of and such professional experience of not less than 15 years in scientific, technical, socio-economic, legal or other pertinent areas of river basin management.

13. Selection of Chairperson and other members of the Commission

1) The Chairperson and Independent Members shall be appointed by the Central Government from a panel of names recommended by a selection committee consisting of

a. The Prime Minister of India:	Chairperson
b. Leader of Opposition:	Member
c. Cabinet Secretary, Central Government:	Member Secretary

2) The Retired or Sitting Judge of the High Court shall be selected by the Chief Justice of India.
3) The term of the Selection Committee and the manner of selection of panel of names shall be such as may be prescribed by the Central Government by way of notification.
4) The Chairperson and every other member shall, before entering upon his office, make and subscribe to an oath of office for secrecy and maintain integrity in such form and manner as may be prescribed.

14. Term of Office of Chairpersons and Other Members

The term of office of the members shall be as follows:

1) The Chairperson and every other member shall hold office as such for a term of five years from the date on which he enters upon his office but shall not be eligible for reappointment.

   Provided that the Chairperson and other members shall not hold office as such after he has attained the age of 70 years.
2) A vacancy caused by the resignation or the removal of the Chairperson or any other member or by death or otherwise shall be filled by fresh appointment in accordance with the previous provisions.
3) The Chairperson and every other member shall, before entering upon his Office, make and subscribe to an oath of office and of secrecy in such form, manner and before such Commission as may be prescribed. In the event of the occurrence of a vacancy in the Office of the Chairperson by reason of his death, resignation or otherwise, the senior-most member shall act as the Chairperson till the new Chairperson enters upon his Office.

4) When the Chairperson is unable to discharge his function owing to absence, illness or any other cause, the senior-most member shall discharge the routine functions of the Chairperson till the date on which the Chairperson resumes his Office.
5) No person shall be appointed as Chairperson or member of the Commission who shall have direct or indirect interest in any business or commercial activity related to the River Basin.

15. Resignation, Removal and Suspension of Chairperson and other members

1) The Chairperson or any other member may, by notice in writing, address to the Central Government resign from Office.
   Provided that the Chairperson or any other member shall, unless he is permitted by the Central Government to relinquish his Office sooner, continue to hold Office until the expiry or three months from the date of receipt of such notice or until a person duly appointed as his successor enters upon his Office or until the expiry of his term of Office, whichever is the earliest.
2) Notwithstanding anything contained above, the Central Government may, by order, remove the Chairperson or any other member from his Office if such Chairperson or Members, as the case may be:
   a. Is or at any time has been, adjudged as an insolvent; or
   b. Has engaged at any time, during his term of office, in any paid employment; or
   c. Has been convicted of an offence which, in the opinion of the Central Government involved moral turpitude; or
   d. Has acquired such financial or other interest as his likely to affect prejudicially his functions of a member; or so abused his position as to render his continuance in office prejudicial to public interest; or
   e. Has become physically or mentally incapable as such.
3) Notwithstanding anything contained herein before, no member shall be removed from his office unless the Supreme Court, on a reference being made to it in this behalf by the Central Government, has on an enquiry, held by it in accordance with such procedure as may be

prescribed in this behalf by the Supreme Court, reported that the Chairperson or the members, ought on such ground or grounds to be removed.

16. Restrictions on Employment of Members in certain cases

The Chairperson and every other member shall not, for a period of two years from the date which he ceases to hold Office, accept any employment in, or be connected with the Management or Administration of, any enterprise which has been a party to a proceeding under the Act or associate in any capacity or establish any NGO in related field;

Provided that nothing in the section shall apply to any employment under the Central Government or a State Government or Local Commission or in any statutory Commission or any corporation established by or under any Central, State or Provincial Act or a Government company as define in Section 617 of the Companies Act 1956(1 of 1956).

17. Salary and Allowances and other terms and conditions of service of Chairperson and other members

1) The salary and other terms and conditions of service, of the Chairperson and other members including travelling expenses, house rent allowance and conveyance facilities, sumptuary allowance and medical facilities shall be such as may be prescribed.
2) The salary allowances and other terms and condition of service of the Chairperson or any member shall not vary to his disadvantage after appointment.

18. Procedure for Transaction of Business

1) The Commission shall meet regularly at its Office at such time as the Chairperson thinks fit, but four months shall not intervene between its last and next meeting.
2) All decisions shall be taken by majority;
   Provided that in the case of equality of votes, the Chairperson or in his absence the person presiding, shall have to exercise casting vote;
3) The Commission shall observe such rules of procedure in the transaction of its business at a meeting, including the quorum at such

meeting, as may be prescribed by the Central Government under the Act;

4) All decisions of the Commission shall be authenticated by the Chairperson or any other officer duly authorised in this behalf.

19. Duties, Powers and Functions of the Commission

1) The powers and function of the Commission shall relate to the following:
   a. To formulate strategies, plans, programmes, policies and guidelines for the due discharge of functions in furtherance of the object of the Act;
   b. To review the working of the Commission and prepare Annual Report;
   c. To review and monitor the working of the Wings under the Act;
   d. To coordinate and strengthen the efforts of the Central and State Governments for conservation and development of the National River Ganga Basin, and prohibition, restriction and promotion of activities in National River Ganga Basin in consonance with the object of the Act;
   e. Issue Directions to the Central and State government;
   f. To inquire and investigate into alleged contraventions of provisions of the Act;
   g. To direct such investigations and inquiries as may be necessary from time to time;
   h. To pass such orders or issue such directions as it may deem fit.

2) It shall be the duty of the Commission to take necessary steps for the elimination of all practices prejudicial to the interests of the National River Ganga Basin and promote the conservation and development of the Basin in consonance with the object of the Act.

20. Power of Superintendence

The Chairperson of Commission shall have the powers of general superintendence direction and control in respect of all matters of the Commission.

Provided that the Chairperson may, for the internal conduct of business of the Commission, delegate such powers relating to administrative matters to any memberof the Commission, including the power to monitor the working of the Wings, established under the Act, and such member shall coordinate with the Director, appointed hereinafter, with regard to implementation of the policies of the Commission.

Provided that the Investigation Wing shall, at all times be monitored by the Retired or Sitting Judge of the High Court as specified under Section 12 of the Act.

21. General Administration and Finance Division

1) There shall be a General Administration and Finance Division under the control of the Chairperson of the Commission.
2) Such division shall
   a) Undertake all activities pertaining to the internal management of the Commission;
   b) Create and maintain the National River Ganga Basin Management Fund to be generated from the deposit of damages awarded by the Commissionand Tribunalfrom time to time;
   c) Maintain proper accounts and relevant records;
   d) Prepare annual reports and statement of accounts;
   e) Audit Accounts as may be required by the Central Government.

22. Constitution of Wings

1) The Commission shall constitute the following Wings for the efficient discharge of its duties and functions under the Act:
   a. Information and Communication wing;
   b. Environmental Monitoring and Impact Assessment Wing;
   c. Investigation Wing;
   d. Research and Development Wing;
   e. Policy, Planning and Advocacy Wing.
2) The Commission may constitute such other regional or specialised units under each of the wings, and at such places, as may be necessary from time to time.

23. Composition of Wings

1) Each wing shall consist of the following:
   a. The Director;
   b. Such other Officers and Employees as may be necessary for the efficient performance of the functions under the Act;
2) The Wing shall be headed by the Director who shall be assisted by Additional, Joint, Deputy and Assistant Directors and such other officers or employees as may be decided by the Commission;
3) The Director shall be of the level of Joint Secretary or equivalent of the Central Government;
4) Regional units/branches shall be headed by the Joint Director and he shall report to the Director on all matters relating to the unit/branch.
5) The Director and other officials shall be whole time members.

24. Powers and Functions of Wings

The wings shall discharge the necessary powers, functions and responsibilities in furtherance of its specific subject matter.

1) The Investigation Wing shall investigate matters relating to:
   a) Non-implementation of appropriate measures relating to prohibition, restriction, conservation and promotion activities;
   b) Non-compliance of policy decisions and guidelines in furtherance of integrated River Basin Management;
   c) Continuance of existing practices in contravention of the provisions of the Act; and
   d) Such other matters as the Commission may direct from time to time.

2) The Research and Development Wing shall
   a) Identify research needs of National River Ganga Basin;
   b) Undertake and/or outsource need based specific research;
   c) Conduct economic, social and cultural analysis on National River Ganga Basin;

d) Prescribe scientific details on measures relating to prohibition, restriction, conservation and promotion activities on National River Ganga Basin, as may be necessary from time to time;
e) Provide technical know-how related to building of infrastructure on National River Ganga Basin;
f) Such other matters as the Commission may direct from time to time.

3) The Environmental Monitoring and Impact Assessment Wing shall
   a) Conduct regular and random field measurement of environment related data on river basin;
   b) Monitor developmental and infrastructure projects on the river basin approved by the Government;
   c) Coordinate developmental projects and anthropogenic activities on National River Ganga Basin;
   d) Conduct impact assessment of existing practices, activities and infrastructure on National River Ganga Basin;
   e) Such other matters as the Commission may direct from time to time.

4) The Information and Communication wing
   a) Procure all types of data relating to scientific, technological, economic, social, cultural and such other forms as the commission may determine time to time on river basin;
   b) Preprocess all data collected referred to in clause (a);
   c) Compile data and reports referred to in clause (a);
   d) Store the data and reports in easily retrievable system;
   e) Provide public access to all such data;
   f) Such other matters as the Commission may deem fit.

5) The Policy, Planning and Advocacy Wing shall
   a) Periodically review and frame the environmental strategies, plans, programmes, policies and guidelines on National River Ganga Basin;
   b) Formulate good governance guidelines;

c) Promote awareness of issues pertaining to National River Ganga Basin;
d) Conduct advanced interactive Programmes, including Seminars, Workshops and Training of stakeholders;
e) Conduct special campaigns to sensitize and motivate people;
f) Prepare educational material; and
g) Such other matters as the Commission may deem fit.

25. Appointment and service conditions of Director, officers, inter alia of the Commission

1) The Commission shall appoint the Director, Additional Director, Joint Director, Deputy Director and Assistant Director, officers and other employees required to assist the Commission in the discharge of its functions.
2) The terms and conditions of the service of the Director, Additional Director, Joint Director, Deputy Director and Assistant Director, officers and other employees of the Commission shall be made by the Chairperson in such manner as may be prescribed.
3) The officers and other employees of the Commission shall discharge their functions under the general superintendence of the Chairperson.
4) The salaries and allowances and conditions of service of the officers and other employees of the Commission shall be such as may be prescribed.

26. Power and Functions of Director

The Director shall discharge the following:

a) Be responsible for the overall working of the Wing.
b) Control and Superintend the administrationof the Wing
c) Implement the policies, programs, etc. of the Commission, as may be decided, from time to time.
d) Report to the Commission, on regular basis, about the activities of the Wing.
e) Coordinate with the individual member of the Commission, where so appointed under Section 20, the working of the Wing.

f) Prepare Internal Report annually
g) Such other matters as may be decided by the Commission from time to time.

POWERS OF INQUIRY AND INVESTIGATION

27. Procedure for Inquiry and Investigation

1) On receipt of a complaint by any person or a reference from an Authority or on its own knowledge or otherwise, if the Commission is of the opinion that there exists a prima facie case, it shall direct the Director, Investigation to cause an investigation to be made into the matter.
2) Where however the Commission is of the opinion that there exists no prima facie case, it shall close the matter forthwith and pass such orders as its deems fit and send a copy of its order to the Authority or the person concerned, as the case may be.
3) The Director shall, on receipt of direction, submit a report on his findings within such period as may be specified by the Commission.
4) The Commission may forward a copy of the report to the parties concerned;

   Provided that in case the investigation is caused to be made based on a reference from any authority, the Commission shall forward a copy of the report to the authority as the case may be.
5) If the report of the Director recommends that there is no contravention of the provisions of this Act, the Commission shall invite objections and suggestions from the Authority or the person concerned or any other person, as the case may be.
6) If, after consideration of the objections or suggestions, the Commission agrees with the recommendation of the Director, it shall close the matter forthwith and pass such orders as it deems fit and communicate its order to the Authority or the persons concerned, as the case may be.
7) If, after consideration of the objections or suggestions referred to above the Commission is of the opinion that further investigation is called for, it may direct such further investigation in the matter by

the Director or itself proceed with further inquiry in the matter in accordance with the provisions of the Act.

8) On receipt of report of the Director or a further inquiry referred to above, the Commission may close the matter forthwith and pass such orders as he deems fit and communicate its order to the Authority or the persons concerned as the case may be.

28. Power of Commission to Regulate its own Procedure

1) The Commission shall not be bound by the procedure laid down by the Code of Civil Procedure, 1908 (5 of 1908), but shall be guided by the principles of Natural Justice and, subject to the provisions of these Act and of any rules made there under, the Commission shall have powers to regulate its own procedure including the places at which they shall have their sittings, duration of oral hearings when granted, and times of its inquiry.
2) The Commission shall have, for the purposes of discharging its functions under these Act, the same powers as are vested in a Civil Court under the Code of Civil Procedure, 1908 (5 of 1908), while trying a suit.
3) Every proceeding before the Commission shall be deemed to be a judicial proceeding within the meaning of sections 193 and 228 and for the purposes of section 196 of the Indian Penal Code (45 of 1860) and the Commission shall be deemed to be a civil court for the purposes of disposal of the matters pending before it and shall be deemed to be civil court for the purposes of section 195 and Chapter XXVI of the code of Criminal procedure 1973 (2 of 1974).
4) The Commission may call upon such experts, from the field of Science and Technology, Legal Affairs, Economics, Finance, Socio-Cultural, Faith Leaders as it deems necessary, to assist the Commission in the conduct of any inquiry or proceeding before it.

29. Power of Director, Investigation Wing

1) The Director, Investigation shall, when so directed by the Commission, assist the Commission in investigating into any

contravention of the provisions of these Act or any rules or regulations made there under.

2) The Director shall have all the powers as are conferred upon the Commission herein before stated.
3) The Director shall have power to direct every person/company/authority against whom the enquiry/investigation is ordered to afford reasonable facilities for the same.

30. Orders by Commission after Inquiry/ Investigation

Where after inquiry or investigation, the Commission finds that any act in contravention of the provisions of the Act has been established on the part of any person or authority, it may pass all or any of the following orders, namely:

a. Direct the immediate discontinuance of the act;
b. Order payment of damages;
c. Order restitution, restoration and such other remedial measures for the conservation and protection of the National River Ganga Basin as may be necessary in the circumstances;
d. Pass such other order as it may deem fit.

31. Power to grant interim relief

1) Where during an inquiry or investigation before the Commission or under the directions of the Commission, it is proved to the satisfaction of the Commission, by affidavit or otherwise, that an act in contravention of the provisions of the Act has been committed or continue to be committed or that such act is about to be committed, the Commission may, by order, grant a temporary injunction restraining any party from carrying on such act till the conclusion of the inquiry/investigation or until further orders.
2) The provisions of rules 2A to 5 (both inclusive) of Order XXXIX of the first Schedule to the Code of Civil Procedure, 1908, shall, as far as may be, apply to a temporary injunction issued by the Commission under the Act, as they apply to a temporary injunction issued by a civil court, and any reference in any such rule to a suit shall be

construed as a reference to any inquiry/investigation before the Commission.

32. Appeal

Any person or authority aggrieved by any decision or order of the Commission may file an appeal to the National River Ganga Basin Tribunal within sixty days from the date of communication of the decision or order of the Commission;
Provided that the Tribunal may, if it is satisfied that the appellant was prevented by sufficient cause from filling the appeal within the said period, allow it to be filed within a further period not exceeding thirty days.

33. Execution of Orders of Commission

1) Any order passed by the Commission under this Act shall be enforced and executable by the Commission in the same manner as if it were a decree or order made by Civil Court in a suit pending therein and for that purpose the Commission shall have all the executing powers of a civil court.
2) For the sake of expeditious disposal or otherwise the Commission if deems fit, may transmit any order or award or decision made by it to a civil court having local jurisdiction and such civil court shall execute it as a decree by that Court.

34. Penalty for failure to comply with orders of the Commission

Whoever fails to comply with any order made by the Commission, he shall be punishable with imprisonment for a term which may extend to 3 years, or with fine which may extend to ten crore rupees, or with both.

35. Members, Officers, etc. of Commission deemed to be Public Servants

All members, officers and other employees of the Commission shall be deemed, when acting or purporting to act in pursuance of any of the provisions of this
Act, to be public servants within the meaning of Section 21 of the Indian Penal Code (45 of 1860).

36. Protection of Action taken in good faith

No suit, prosecution or other legal proceedings shall lie against any member, officer or employee of the Commission for anything done or intended to be done in good faith under this Act or rules or regulations made thereunder.

37. Contravention of Order by Companies and Authorities

1) Where any contravention under this Act has been committed by a company, every person, who, at the time, the contravention was committed was in charge of, and was responsible to, the company for the conduct of the business of the company, as well as the company itself, shall be deemed to be liable to be proceeded against in accordance with the provisions of the Act.

   Provided that nothing contained in this section shall render any such person liable, if he proves that the contravention was committed without his knowledge or that he had exercised all due diligence to prevent the commission of the contravention and the contravention was an Act of God.

2) Notwithstanding anything contained above, where any contravention under this Act has been committed with the consent or connivance of or is attributable to, any neglect on the part of any director, manager, secretary or other officer of the company, such person aforesaid shall be deemed to be liable for such contravention and proceeded against.

   Explanation: For the above purposes,

   (a) "company" means any body corporate and includes a firm or other association of individuals; and

   (b) "Director" in relation to a firm, means a partner in the firm and proprietor in a proprietorship firm and in case of trust, cooperative and society the person responsible for management of the same.

3) Where any contravention under this Act has been committed by an authority, every person, who, at the time, the contravention was committed was in charge of, and was responsible to, for the conduct of the business of the authority, as well as the authority itself, shall

be deemed to be liable to be proceeded against in accordance with the provisions of the Act.

Provided that nothing contained in this section shall render any such person liable, if he proves that the contravention was committed without his knowledge or that he had exercised all due diligence to prevent the commission of the contravention and the contravention was an Act of God.

4) Notwithstanding anything contained above, where any contravention under this Act has been committed with the consent or connivance of or is attributable to, any neglect on the part of any superintendent, manager, secretary or other officer of the authority, such person aforesaid shall be deemed to be liable for such contravention and proceeded against.

CHAPTER VIII
NATIONAL RIVER GANGA BASIN TRIBUNAL

38. Establishment of Tribunal

1) The Central Government shall, by notification, establish an Tribunal to be known as National River Ganga Basin Tribunal:
   a. to hear and dispose of appeals against any direction issued or decision made or order passed by the Commission under the Act;
   b. to adjudicate on claim for damages that may arise from the findings of the Commission, or orders for the recovery of damages under this Act.
2) The Headquarter of the Tribunal shall be at such place as the Headquarter of the Commission.

39. Jurisdiction of the Tribunal

Any person or authority, aggrieved by any direction, order or decision passed by the Commission may prefer an appeal to the Tribunal.

40. Limitation

1) Every appeal under sub-section (2) shall be filed within a period of sixty days from the date on which a copy of the direction or decision

or order made by the Commission is received by the authority or person referred to and it shall be in such form and be accompanied by such fee as may be prescribed within the rules so framed by the Commission;

2) The Tribunal may entertain an appeal after the expiry of the said period of sixty days if it is satisfied that there was sufficient cause for not filing it within that period.

41. Procedure of the Tribunal

1) On receipt of an appeal, the Tribunal may, after giving the parties to the appeal, an opportunity of being heard, pass such orders thereon as it thinks fit, confirming, modifying or setting aside the direction, decision or order appealed against.
2) The Tribunal shall send a copy of every order made by it to the Commission and the parties to the appeal.
3) The appeal filed before the Tribunal shall be dealt with by it as expeditiously as possible and endeavor shall be made by it to dispose of the appeal within six months from the date of receipt of the appeal and beyond that period on recording the reasons.
4) No appeal under clause (1) shall lie unless the memorandum of appeal is certified with the copy of the order, direction or decision passed by the Commission and with the grounds to the effect that the appellant has plausible defense to be protected against such order. However, while admitting the appeal, the Tribunal may direct to deposit a part or whole of the amount so payable under the direction, order or decision appealed against.
5) The appellant shall get the deposited amount back, with rate of interest fixed by nationalized bank during that time, in case he/it succeeds in the appeal.

42. Composition of Tribunal

The Tribunal shall consist of a Chairperson and at least one Judicial Member and other members to be appointed by the Central Government from the panels of name so recommended by the Selection Committee constituted for that purpose.

43. Qualifications for appointment of Chairperson and Members of Tribunal

1) The Chairperson of the Tribunal shall be a person, who is, or has been a Judge of the Supreme Court of India.
2) The other members of the Tribunal shall be persons of ability, integrity and standing having special knowledge of, and professional experience of not less than twenty years in science and technology, environmental matters, law and policy, public affairs or in any other matter which in the opinion of the Central Government, may be useful to the Tribunal.

44. Selection Committee

1) The Chairperson and Members of the Tribunal shall be appointed by the Central Government from a panel of names recommended by a Selection Committee comprising of:
   a. the Chief Justice of India, Chairperson;
   b. the Cabinet Secretary, Central Government, Member Secretary
   c. the Chairperson, Law Commission of India, Member
   d. the Director of any National Institute of importance so nominated, Member
2) The terms of the Selection Committee and the manner of selection of panel of names shall be such as may be prescribed.

45. Term of office of Chairperson and Members of Tribunal

The Chairperson or a member of the Tribunal shall hold office as such for a term of five years from the date on which he enters upon his office, and shall be eligible for re-appointment only for a period of two years and not afterwards;

Provided that no Chairperson or other member of the Tribunal shall hold office as such after he has attained,

1) in the case of the Chairperson, the age of seventy years;
2) in the case of any other member of the Tribunal, the age of sixty-seven years.

46. Terms and conditions of service of Chairperson and Members of Tribunal

1) The salaries and allowances and other terms and conditions of service including the conditions of removal of the Chairperson and other members of the Tribunal shall be such as may be prescribed by the rules so notified by the Central Government.
2) The salaries, allowances and other terms and conditions of service of the Chairperson and other members of the Tribunal shall not be varied to their disadvantage after their appointment.

47. Vacancies

1) If, for any reason other than temporary absence, any vacancy occurs in the office of the Chairperson of the Tribunal, the senior most Member shall act as Chairperson until another person is so appointed by the Central Government in the above stated manner to fill the vacancy and the proceedings may be continued before the Tribunal from the stage at which the vacancy is filled by the Tribunal with that new combination and there shall be no irregularity of law in disposal of such matter pending before the Tribunal.
2) When the Chairperson of the Tribunal is unable to discharge his functions owing to absence, illness or any other cause, the senior-most member or, as the case may be, such one of the Members of the Tribunal, as the Central Government may, by notification, authorize in this behalf, shall discharge the functions of the Chairperson until the date on which the Chairperson resumes his duties.

48. Resignation of Chairperson and Members of Tribunal

The Chairperson or a member of the Tribunal may, by notice in writing under his hand addressed to the Central Government, seek resignationfrom his office;

Provided that the Chairperson or a member of the Tribunal shall, unless he is permitted by the Central Government to relinquish his office sooner, continue to hold office until the expiry of three months from the date of receipt of such

notice and until a person duly appointed as his successor enters upon his office or until the expiry of his term of office, whichever is earlier.

49. Removal and suspension of Chairperson and Members of Tribunal

1) The Central Government may, in consultation with the Chief Justice of India, remove from office the Chairperson or any other member of the Tribunal, who;
   a. has been adjudged an insolvent; or
   b. has engaged at any time, during his term of office, in any paid employment; or
   c. has been convicted of an offence which, in the opinion of the Central Government, involves moral turpitude; or
   d. has become physically or mentally incapable of acting as such Chairperson or other Member of the Tribunal; or
   e. has acquired such financial or other interest as is likely to affect prejudicially his functions as such Chairperson or Member of the Tribunal; or
   f. has so abused his position as to render his continuance in office prejudicial to the public interest.
2) Notwithstanding anything contained above, no Chairperson or a Member of the Tribunal shall not be removed from his office on the ground specified in clause (e) or clause (f) of sub-section (1) except by an order made by the Central Government after an inquiry made in this behalf by a Judge of the Supreme Court in which such Chairperson or member had been informed of the charges against him and given a reasonable opportunity of being heard in respect of those charges.

50. Restriction on employment of Chairperson and other Members of the Tribunal

The Chairperson and other members of the Tribunal shall not, for a period of two years from the date on which they cease to hold office, accept any employment in, or connected with the management or administration of, any enterprise which has been a party to a proceeding before the Tribunal under

this Act, nor shall they associate or personally establish any NGO in related field.

Provided that nothing contained in this section shall apply to any employment under the Central Government or a State Government or Local authority or in any statutory authority or any corporation established by or under any Central, State or Provincial Act or a Government Company as defined in section 617 of the Companies Act, 1956 (1 of 1956).

51. Staff of Tribunal

1) The Central Government shall frame the rules by way of Notification, in consultation with the Chairperson of the Tribunal, for providing the procedure of appointment of such officers and other employees as it may think fit.
2) The salaries, allowances and conditions of service, including tenure and terms of removal, of the officers and other employees of the Tribunal shall be such as may be prescribed.
3) The officers and other employees of the Tribunal shall discharge their functions under the general superintendence and control of the Chairperson of the Tribunal.

52. Procedures and Powers of Tribunal

1) The Tribunal shall not be bound by the procedure laid down in the Code of Civil Procedure, 1908 (5 of 1908), but shall be guided by the principles of natural justice and, subject to the other provisions of the Act and of any rules made by the Central Government, the Tribunal shall have power to regulate its own procedure including the places at which they shall have their sittings.
2) The Tribunal shall have, for the purposes of discharging its functions under this Act, the same powers as are vested in a Civil Court under the Code of Civil Procedure, 1908 (5 of 1908) while trying a suit in respect of the following matters, namely:
    a. summoning and enforcing the attendance of any person and examining him on oath;
    b. requiring the discovery and production of documents;
    c. receiving evidence on affidavit;

d. subject to the provisions of Sections 123 and 124 of the Indian Evidence Act, 1872 (1 of 1872), requisitioning any public record or document or copy of such record or document from any office;
e. issuing summons for the examination of witnesses or documents;
f. reviewing its decisions;
g. dismissing a representation for default or deciding it *ex parte*;
h. setting aside any order of dismissal of any representation for default or any order passed by it *ex parte*;
i. any other matter which may be prescribed.

3) Every proceeding before the Tribunal shall be deemed to be judicial proceeding within the meaning of Sections 193 and 228, and for the purposes of Section 196, of the Indian Penal Code (45 of 1860) and the Tribunal shall be deemed to be a Civil Court for the purposes of Section 195 (2 of 1974) and Chapter XXVI of the Code or Criminal Procedure, 1973.

53. Execution of Orders of Tribunal

1) Every order made by the Tribunal shall be enforced by it in the same manner as if it were a Court of appeal, and it shall be lawful for the Tribunal to send, in case of its inability to execute such order, to the court within the local limits of whose jurisdiction:

a. in the case of an order against a company, the registered office of the company is situated; or
b. in the case of an order against any other person, place where the person concerned voluntarily resides or carries on business or personally works for gain, is situated.

2) Notwithstanding anything contained in sub-section (1), the Tribunal may transmit any order made by it to a Court (civil or criminal, as the case may be) having local jurisdiction and such Court shall execute the order as if it were the orders passed by that court.

54. Saving of inherent Powers of the Tribunal

Notwithstanding anything contained in this Act or any other provisions of any enactment in force, nothing shall be deemed to limit or affect the inherent powers of the Tribunal as of the powers of any High Court of India, to make

such orders as may be necessary to give effect to any order passed under this Act or to prevent abuse of the process of the Tribunal or otherwise, to secure the ends of justice, needed to impart justice inconsonance of object and reasons and effect to the enactment of the Act.

55. Suo-moto Powers of the Tribunal

Notwithstanding anything contained in this Act or any other provisions of any enactment in force, nothing shall be deemed to limit or affect the Suo-moto powers of the Tribunal as of the powers of any High Court of India or Supreme Court, to make such orders on its own motion if the Tribunal feels in rarest of rare circumstances and on taking cognizance of the facts to be taken by the Tribunal in the interest or relating to the National River Ganga, as may be necessary to give effect to any order passed under this Act or to prevent abuse of the process of the Tribunal or otherwise, to secure the ends of justice, needed to impart by the Tribunal.

56. Power to Punish for Contempt

The Tribunal shall have, and exercise, the same jurisdiction, powers and authority in respect of contempt of itself as a High Court has and may exercise and, for this purpose, the provisions of the Contempt of Courts Act, 1971 (70 of 1971) shall have effect subject to modifications that:

1) the reference therein to a High Court shall be construed as including a reference to the Tribunal;
2) the references to the Advocate-General in Section 15 of the said Act shall be construed as a reference to such Law Officer as the Central Government may, by notification, specify in this behalf.

57. Contravention of Order of the Tribunal

Without prejudice to the Act, if any person or authority contravenes, any Order of the Tribunal, he/it shall be liable for a damages not less than fifty crore or forfeiture of property or imprisonment for a term upto ten years or with both.

58. Vacancy in Tribunal not to invalidate acts or proceedings

No act or proceeding of the Tribunal shall be questioned or shall be invalid merely on the ground of existence of any vacancy or defect in the constitution of the Tribunal.

59. Right to Legal Representation

1) A person or authority preferring an appeal to the Tribunal may either appear in person or authorize one or more legal practitioners or any of its officers to present his or its case before the Tribunal.
2) The Commission may authorize one or more legal practitioners or any of its officers to act as presenting officers and every person so authorized may present the case with respect to any appeal before the Tribunal.

60. Appeal to Supreme Court

Any person aggrieved by any decision, direction or order of the Tribunal, may, file an appeal to the Supreme Court, within ninety days from the date of communication of the decision, direction or order of the Tribunal, to him, on any one or more of the grounds specified in Section 100 of the Code of Civil Procedure, 1908.

CHAPTER IX
MISCELLANEOUS PROVISIONS

61. Power of the Central Government to Make Rules

The Central Government may, by the notification in the Official Gazette, make rules for carrying out the purposes of this Act, however such rules shall be framed only in consultation with the Full House comprising of the Chairman and the Members of the commission and only after confirmation.

62. Bar of Jurisdiction

No Civil Court shall have jurisdiction to entertain any suit or proceedings in respect of any matter which theTribunal constituted under this Act is empowered by or under this Act to determine, and no injunction shall be granted by any court or other authority in respect of any action taken or to be taken in pursuance of any power conferred by or under this Act.

63. Overriding effect

The provisions of this Act shall have effect notwithstanding anything inconsistent therewith contained in any enactment other than this Act.

64. National River Ganga Basin Management Fund

1) Where any amount by way of damages is ordered to be paid under any order made by the Commission or Tribunal, that amount shall be remitted to the National River Ganga Basin Management Fund established under the Act;
2) The National River Ganga Basin Management Fund under sub-section (1) shall be utilized by Central Government on the advice and with concurrence of the Commission.
3) The National River Ganga Basin Management Fund shall be used for,
   a. Environmental development and improvement of National River Ganga Basin
   b. Conduct of research on National River Ganga Basin
   c. Institution of Award
   d. Any other purpose as may be identified and advised by the Commission.
4) Restitution, Restoration and Rehabilitation of the Basin caused due to Natural calamity or disaster shall be done by Government independent of funds being available from the National River Ganga Basin Management Fund established under the Act.

65. Institution of Award

The Central Government shall institute Monetary Rewards for exceptional contributors including Researchers, Academicians, Institutes, Universities, Centres of Excellence and civil society for conservation, development and improvement of the National River Ganga Basin, in conformity with the Commission's goals and guidelines.

---------- END ----------