Ganga River Basin Management Plan - 2015

Mission 5: Geological Safeguarding

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

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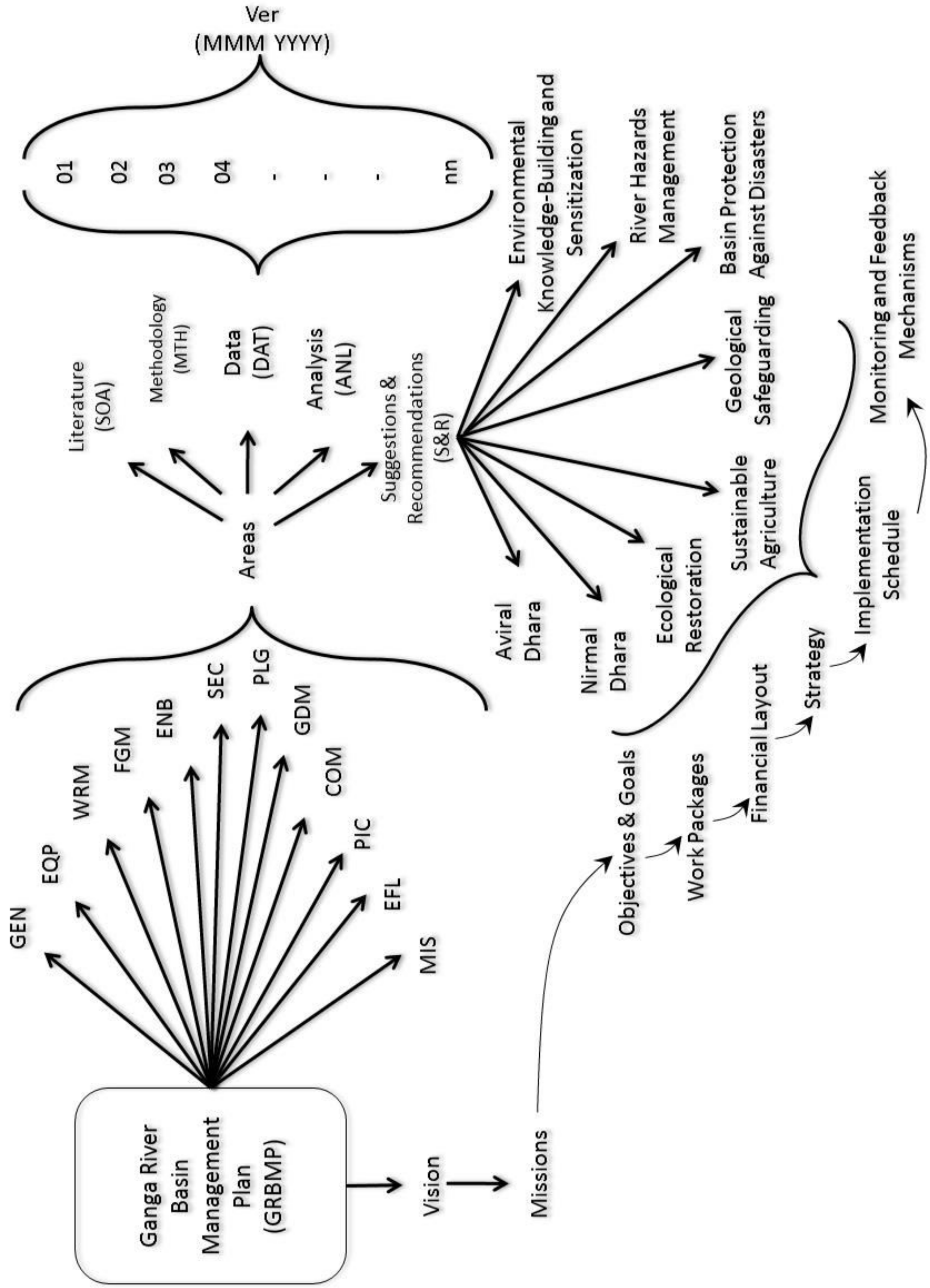
GRBMP Work Structure



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 River Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP). A Consortium of seven "Indian Institute of Technology"s (IITs) was given the responsibility of preparing the GRBMP by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. A Memorandum of Agreement (MoA) was therefore signed between the 7 IITs (IITs Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

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

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

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

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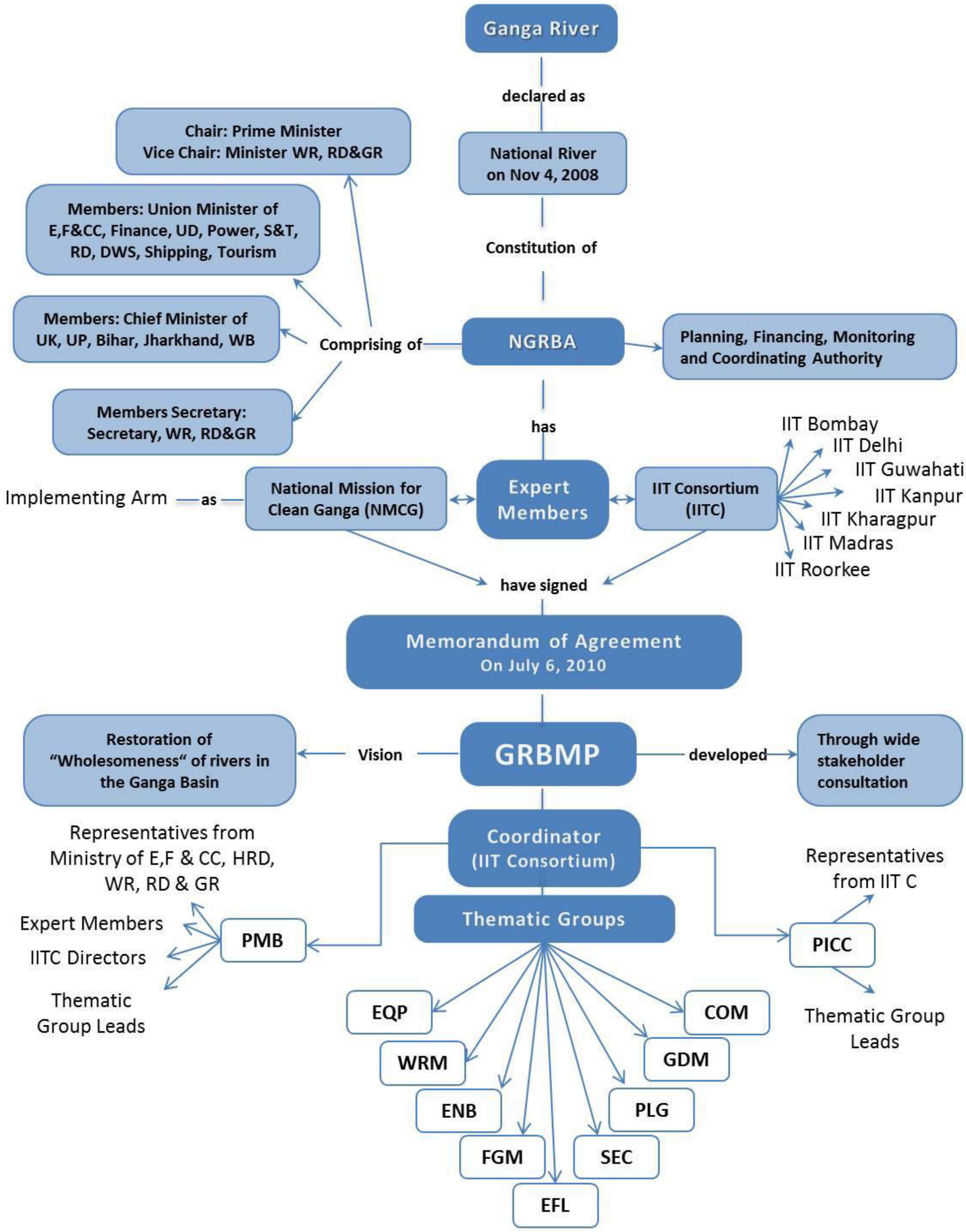
Organizational Structure for Preparing GRBMP



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

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

Project Management Board [PMB]

Expert Members:

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

Project Implementation and Coordination Committee [PICC]

Representatives from IIT Consortium:

- Dr Shyam Asolekar, IIT Bombay
- Dr A K Mittal, IIT Delhi
- Dr Mohammad Jawed, IIT Guwahati
- Dr Vinod Tare, IIT Kanpur
- Dr D J Sen, IIT Kharagpur
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Thematic Group Leads:

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

Composition of Thematic Groups

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3. Fluvial Geomorphology (FGM)

Lead: Rajiv Sinha, IIT Kanpur

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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

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Abbreviations and Acronyms

1.	GRBMP	:	Ganga River Basin Management Plan.
2.	IITC	:	IIT Consortium.
3.	MoEF	:	Ministry of Environment and Forests.
4.	MoEFCC	:	Ministry of Environment, Forests & Climate Change
5.	MoWR	:	Ministry of Water Resources.
6.	MoWRRDGR	:	Ministry of Water Resources, River Development & Ganga Rejuvenation
7.	NGRBA	:	National Ganga River Basin Authority.
8.	NMCG	:	National Mission for Clean Ganga.
9.	NRGB	:	National River Ganga Basin.

Contents

Summary

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 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 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.

1. Introduction

Indian civilization grew up under the care of River Ganga, nourished by her bounties for thousands of years. The Ganga river – along with her many tributaries and distributaries – provided material, spiritual and cultural sustenance to millions of people who lived in her basin or partook of her beneficence from time to time. To the traditional Indian mind, therefore, River Ganga is not only the holiest of rivers and savior of mortal beings, she is also a living Goddess. Very aptly is she personified in Indian consciousness as "MOTHER GANGA". This psychic pre-eminence of River Ganga in the Indian ethos testifies to her centrality in Indian civilization and her supreme importance in Indian life.

The Ganga river basin is the largest river basin of India that covers a diverse landscape, reflecting the cultural and geographical diversity of the India. It is also a fertile and relatively water-rich alluvial basin that hosts about 43% of India's population [*MoWR, 2014*]. It is fitting, therefore, that the Indian government declared River Ganga as India's **National River** in the year 2008. But the declaration was none too early. River Ganga had been degrading rapidly for a long time, and national concern about her state had already become serious in the twentieth century. It was against this backdrop that the Ministry of Environment and Forests (Govt. of India) assigned the task of preparing a Ganga River Basin Management Plan (GRBMP) to restore and preserve National River Ganga to a "Consortium of Seven IITs". The outcome of this effort – the GRBMP – evolved an eight-pronged action plan, with each prong envisaged to be taken up for execution in mission mode.

A river basin is the area of land from which the river provides the only exit route for surface water flows. For understanding its dynamics, a basin may be viewed as a closely-connected hydrological-ecological system. Hydrological connections include groundwater flow, surface runoff, local/ regional evapotranspiration-precipitation cycles and areal flooding, while ecological links are many and varied (such as the food web and transport by biological agents). These linkages provide for extensive material transfer and communication between the river and her basin, which constitute the functional unity of a river basin. Directly and indirectly, therefore, National

River Ganga (along with her tributaries and distributaries), is a definitive indication of the health of the basin as a whole. Hence, GRBMP adopted the Ganga River Network as the primary environmental indicator of the National River Ganga Basin (NRGB).

River basin management needs to ensure that a basin's natural resources (biotic and abiotic) are adequately preserved over time. The main abiotic (or physical) resources of a river basin are *soil* and *water*, along with a multitude of minerals and compounds bound up with them. Now, water is a highly variable resource. Barring variations from year to year, the water in a basin follows an annual cycle of replenishment (primarily through atmospheric precipitation and groundwater inflows) and losses (primarily through river and groundwater outflows, evaporation, transpiration, and biological consumption). In contrast to water, formation of mature soils – from the weathering of parent material (rocks) to chemical decomposition and transformation – is a drawn-out process that may take hundreds or thousands of years [*Jenny, 1994; Wikipedia, 2014*]; but, once formed, soils can be fairly durable. Thus, changes in a basin's water resource status tend to be relatively faster and easily detected, while those of soils are slow and often go unnoticed for long periods. However, soil and water are affected by each other through many biotic and abiotic processes. Being thus interrelated, degradation of both soil and water have a concurrent effect on the other, hence neither can be considered in isolation.

It is not only soil and water that are mutually interactive, living organisms also interact with them and help shape the basin's environment. The biotic resources of a basin consist of plants, animals and micro-organisms. Since biota evolve over time to achieve a stable balance in a given environment, the biotic resources depend on the constituent ecosystems of the basin – rivers, wetlands, forests, grasslands, etc. However, with significant human activity in many ecosystems (as, for example, in agro-ecosystems and urban ecosystems), the complexity of human-technology-environment systems has increased manifold in recent times [*Pahl-Wostl, 2006*]. Nonetheless, GRBMP attempts to incorporate the interactive resource dynamics and human-technology-environment considerations in the Basin Plan. For, with human activities multiplying and diversifying in the basin, the resulting environmental consequences have also been pronounced in recent times. In sum, GRBMP focuses on the basin's overall resource environment and the major factors affecting it (especially diverse anthropogenic activities), and seeks ways and means to protect the basin and its resources against identifiable adverse impacts. For, only thus can we secure the environmental foundation of NRGB for the good of one and all.

2. Objective

The objective of Mission "Geological Safeguarding" is to formulate suitable means to protect the geological foundation of the river basin and safeguard its geomorphological integrity from anthropogenic damages.

3. Why Geological Safeguarding Is Important for Ganga River Basin Management

Geologically, river networks are considered the backbone of most terrestrial landscapes. Dynamic aspects of these networks include channels that shift laterally or expand upstream, ridges that migrate across the earth's surface, and river capture events whereby flow from one branch of the network is rerouted in a new direction. These processes have direct implications for mass transport and the geographic connectivity within and between ecosystems. Ultimately, this dynamic system strives to establish equilibrium between tectonic uplift and river erosion, but transient conditions in river basins are often in response to tectonic perturbation or erosional phenomena [*Willett, 2014*].

In modern times, both tectonic perturbation and erosional phenomena have increasingly come under anthropogenic influence. On the one hand, modern human activities can stimulate tectonic perturbations and threaten the geological formations supporting river basins in new ways. To cite, **"**Human-induced earthquakes have become important … (since) these events may be responsible for widespread damage and an overall increase in seismicity. It has long been known that impoundment of reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations are capable of inducing earthquakes**"** [*Ellsworth, 2013*]. On the other hand, modern human activities are also increasingly influencing natural geomorphological processes in the basin.

Present-day human actions are a known cause for various geomorphological disturbances involving soil erosion, landslides, flood frequencies and intensities, river instabilities, water-logging, and silting of water bodies. Ensuring suitable practices for geomorphological upkeep and geological safety of the basin are therefore of key importance for the safety of NRGB.

4. Problems and Their Remediation

Modern human activities threaten earth's crustal formations in new ways as noted by Ellsworth [*2013*]. The problem becomes significant for river basins when the geological structure supporting them becomes vulnerable to such effects. In particular, underground activities such as excavations, explosions, tunneling, mining and fraccing (or fracking or hydraulic fracturing of rocks) are potential threats to the geological base of river basins. Likewise, over-withdrawal of ground-water from confined and semi-confined aquifers may create unbearable overburden pressures, thereby causing (partial) collapse of the aquifer matrix, land subsidence, and enhanced seismicity in a region (see Box 4.1).

Box 4.1

"Earthquake initiation, propagation and arrest are influenced by fault frictional properties and preseismic stress. … the distribution of shallow slip during the M_w 5.1 **earthquake in Lorca**, southeast Spain, that occurred on 11 May 2011 could be controlled by crustal unloading stresses at the upper frictional transition of the seismogenic layer, induced by **groundwater extraction.**"

– *Gonzales et al. [2012]*

Another potential threat is due to large reservoirs. Operation of such reservoirs – involving their filling up during high flows and emptying during lean periods – produces significant variations in soil water pressures, which build up additional cyclical stress patterns. In fact, the mere creation of large reservoirs is suspected to be a potential cause for geological disturbances in a region (see Box 4.2).

Box 4.2

"… stresses from water piled behind the new **Zipingpu Dam may have triggered** the failure of the nearby fault, a failure that went on to rupture almost 300 kilometers of fault and kill some 80,000 people in last May's devastating **earthquake in China's Sichuan Province** (in 2008)."

–*Kerrand Stone [2009]*

Many of the geomorphological features of river basins are more vulnerable than the underlying geologic strata to both natural and manmade stresses. While naturally occurring phenomena such as storms, cloudbursts, seismicity, landslides and avalanches may not be controllable, various land-use practices that can be geomorphologically disturbing do need to be checked. Such practices include land-uses that significantly affect the physical functioning of catchments such as denudation/ deforestation and construction activities on hill slopes and in floodplains, agricultural tillage causing soil erosion, sand mining from river beds, and river bank modifications for local flood control and other purposes.

Since disruptions in existing geological features of a basin due to natural earth processes may get compounded by anthropogenic threat factors indicated above, the combined damage potential may increase significantly. Thus geological monitoring of critical earth processes in sensitive areas is essential. For example, Himalayan tributaries of the Middle Ganga segment – such as the Kosi and Gandak rivers – are known to be highly dynamic, i.e. with significant tendency to shift their courses. The highly meandering stretches of Ganga river downstream of Varanasi [*IITC, 2011*] may also indicate such tendencies. With regular monitoring of these rivers, timely controls can be imposed on destabilizing anthropogenic activities along with precautions against impending fluvial changes. It is also important to realize that river dynamics is a natural behavior of the river and, hence, it is important to accurately map the extent of migration and reaches prone to migration. This extent must be included in the 'space' defined for the river – comprising the active floodplain and river valley [*IITC, 2010*], and the concept of floodplain zoning must be pursued in order to improve river health.

5. Summary of Recommendations

Assessment and adoption of the following measures are essential for good geologic housekeeping of NRGB**:**

1. Geological safety measures to maintain the integrity of the basin including restrictions on deep groundwater withdrawals, underground excavations, explosions, tunnelling, mining and fracking, and operation of large reservoirs.

2. Region-specific restrictions on geo-morphologically harmful land-use practices including controls on denudation, 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 and land reclamation in low-lying areas should be taken up as also improved drainage and stabilization measures in disturbed areas such as hillslopes subjected to road-cutting, degraded lands, and haphazardly built-up urban areas.
4. Mapping of river migration zones and continuous geological monitoring of the basin to forecast impending geological and geomorphological events.

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