Challenges to Environmental security in the Context of India-Bangladesh Transboundary Water Relations: An Agenda for Research

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Abstract

This paper presents the critical challenges to the concerns of environmental security in the context of the trans-boundary water relations between India and Bangladesh. It provides a definition of the notion of environmental security as the state of "absence of conflicts, explicit or latent" in the socio-ecological-economic space of human existence, and defines the spatial scope of trans-boundary waters in the present study as the physical extent of the Ganges-Brahmaputra-Meghna basin, with focus on the movement of water and sediments generated and transported by its flows. The paper then moves on to identify and discuss the ecosystem processes and services provided by the flows, highlights the critical linkages among ecosystem services and livelihoods, and emphasizes that the dominating perceptions of reductionist engineering have generated a hydro-political situation of disputes, over the sharing of the lean flow in one of the numerous trans-boundary rivers. The need is to enhance the priority of ensuring overall environmental security related to the trans-boundary flows. By addressing the limitations of such a reductionist vision of trans-boundary waters, this paper highlights the need for relating ecosystems and life, more precisely ecosystem services and well-being in the holistic context of all trans-boundary flows.

Accordingly, this paper proposes a change from the traditional supply-oriented paradigm of water resource development to a more holistic paradigm of integrated river basin management with an ecosystemic perspective. As stated in the paper, the proposed research issues need to be addressed from three perspectives in a holistic and inclusive framework combining various disciplines, rather than in a reductionist framework of poverty and water availability. These perspectives entail a> *The ecological perspective: Ecosystem service–Livelihood linkage*, b> *The Perspective of Economic Valuation from the concern of the above linkage*, and c> *The Institutional Perspective.* The perspectives, however, should not be treated as independent modes of looking at the challenges of environmental security in the context of the India-Bangladesh trans-boundary water relations. There is a need to combine the three perspectives in order to conduct research in a holistic framework. In the process, this paper offers an agenda for research the outcome of which would facilitate such a paradigm shift and promote well-being. As stated in the paper, the research issues can be categorized as: i> *Status of the biodiversity and ecosystems services in*

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trans-boundary waters; ii> *Ecosystem services and Human wellbeing in the delta regions of the Sundarbans, a critical Socio-Ecological System;* iii> *Environmental Flows, Ecosystem Services of Floods and a Sediment Budget for the Basin*; iv> *Economics of Water Conflicts;* v> *Scarcity Value of Water in an Inclusive Valuation Framework;* v> *Climate Change*; and vi> *Development of Regional Water Markets*.

To move towards environmental security in the context of the trans-boundary water relations between the two nations, there needs to be a movement from a state of distrust and suspicion to a state of cooperation. However, such regional cooperation needs to take off at the scale of the GBM river basin, rather than being confined to bilateral negotiations between two nations. However, research and knowledge creation has to precede policy dialogue to bridge some critical knowledge gaps in policy making.

Keywords: Environmental Security, India-Bangladesh Relations, Transboundary Waters, Ganges-Brahmaputra-Meghna Basin, Ecosystems-livelihoods linkages, Scarcity Values, Inclusive Valuation, Sundarbans, Inclusive Valuation, Institutional Perspective, Water Markets.

1. Introduction

This paper essentially designs a research agenda on the environmental security issues concerned with India with respect to its critical trans-disciplinary water relations with Bangladesh at the critical interface of the ecosystem services – wellbeing linkages. While relating to the title of the paper, there are thus two critical notions that deserve to be defined in order to put in place the research issues. The first is related to defining “transboundary water regime”, while the second is related to defining “environmental security”. The entire scope of this study rests on the delineation of these two notions. In this paper, there has been an attempt to provide a generic definition of “environmental security” first, and then internalising and customising the definition in the context of the “transboundary water regime” as will be defined here.

Growing scarcity of freshwater has created a global trend among the stakeholders at all levels for obtaining and maintaining hegemony over the limited water resources. This generates more intense disputes over ownership or usage of the resource among the stakeholders. Water, as a flowing resource, essentially crosses boundaries of various forms. Recent literature defines “transboundary” waters as waters flowing across any boundary including the sectoral. Transboundary issues over water take place not only between nations, but also between federal states of a nation, and occur even between districts within federal state, villages within a district and also between sectors. Therefore, transboundary disputes over water happen not only between nations, but also between federal states of a nation, and occur even between districts within a federal state and at times go even further down to happen between the ultimate micro-level units of a society or an economy, like village level organizations.

On the other hand, sectoral water conflicts have become more frequent. Intersectoral water disputes are not necessarily transboundary in the physical sense of the term. Though, they do not literally involve crossing of political boundaries, they can be thought to be emerging from transfer of water from one sector of use to another. At a certain point in time, a finite resource used in agriculture, cannot be used for other sectors. In a majority of the cases, agriculture accounts for the largest proportion of the water consumed. Often, under conditions of scarcity, the reprehensible squandering of water in agriculture causes problems for the urban sector, by reducing the amount of available water.

The competing uses of water in industry, irrigation and urban sectors comprise the use of water in an economy, and the sectors together are known as the economic sectors. The existing database of literature, at times explicitly, and at times tacitly, has acknowledged these competing uses (e.g. Bandyopadhyay 1995; Bouhia 2001; Bandyopadhyay and Mallik 2003; Kumar et al 2003; Holden and Thobani 1996; and many others). However, the realisation that urban water crises often arise due to the extensive wastage in the agricultural sector has not really come to the fore except for the account provided by Ghosh (2009).

In the past two or three decades, intersectoral conflicts have been moving to take a new shape. This is because, the intersectoral water conflicts have taken a new shape with the steady paradigmatic emergence of Integrated Water Resource Management (IWRM), where the allocation of water for the ecosystems has increasingly been accepted (Aylward et al. 2005). . At a broader scale, therefore, the two major competitors for water use are the economic sectors and the ecological sector.

With the extensive water use in the economic sector, the environment has been made to suffer, as with every drop of water lost, there is a consequent loss in the ecosystem services. As noted by Flessa (2004), in the Colorado Delta and Imperial Valley in the Western United States, and in the northern Gulf of California, the environmental effects of water diversion and the conversion to agriculture have been severe. Nearly 500 dams in the USA and elsewhere have already been removed and the movement towards river restoration is accelerating (Gleick 2000). The Murray-Darling Basin Commission in Australia is also seriously thinking in terms of provision of financial incentives to farmers for saving on their allocation of irrigation water and allows the savings to remain instream (Bandyopadhyay and Perveen 2008).

While many developed nations are recognizing the vital importance of the ecosystem services related to water, and hence raising their rationale for keeping the natural flow unperturbed, the same realization seems to be missing in the context of the developing nations. Some such ecological concerns have been raised by some concerned water professionals (e.g. Bandyopadhyay and Perveen 2008) in the context of the proposed interlinking of the rivers in India, as will be briefly discussed in this paper. Therefore, on the basis of the available literature, and looking at the nature of the study, the scope of "transboundariness" in this paper has been delineated in the context of the international political boundary of India and Bangladesh, by further including needs and demands on water across sectors, including requirements of the ecosystems.

On the other hand, there also remains the critical task of defining "environmental security". The notion of environmental security came under policy and strategic considerations since the 1980s mainly for two groups: (1) the environmental policy community, addressing the security implications of environmental change, and (2) the security community, looking at new definitions of national security, particularly in the post-Cold War era. From these perspectives, the *Environmental Change and Security Programme* of the Woodrow Wilson School of Public and International Affairs quite succinctly appeals, "... Environmental challenges—such as land degradation, deforestation, climate change, and water scarcity and pollution—can threaten our security. But managing these environmental challenges can also build confidence and contribute to peace".[1] Despite such concerns, there hardly exists a proper delineation of "environmental security", though such a notion can be found in the academic literature amply. Most of the few existing definitions are context-specific, with a generic one being conspicuous by its absence.

[1] http://wilsoncenter.org/index.cfm?topic_id=1413&fuseaction=topics.categoryview&categoryid=A82CCAEE-5BF-E7DC-46B3B37D0A3A575F

The initiation to the problems of environmental security is offered by the spatial inequity in distribution of environmental resources across the globe. In fact, the initial endowment and distribution of environmental resources as a potential contributor to conflict has been the subject of considerable research. The literature amply shows evidence of the Malthusian creed of hypothesising “scarcity induces disputes” as an explanation of environmental conflicts in general (Westing 1986; Homer-Dixon 1991 and 1994; Gleick, 1993; Richards and Singh, 1997; Hall and Hall 1998; Rowley 1998). Chalecki (2002) attempted to offer a definition of “environmental security” in a broader context by defining the notion in terms of the ability of a nation or a society to withstand environmental asset scarcity, environmental risks or adverse changes, or environment-related tensions or conflicts. The idea comes close to Homer-Dixon’s *Ingenuity* thesis, where Homer-Dixon stated that the ability of a nation to combat resource scarcity is through generation of new ideas, which he called “ingenuity” (Homer-Dixon 2000). Steiner (2006) expresses that environmental security is an overarching term that entails energy security, climate security, water security, food security, and health security. He defines environmental security as a state when cleaner technologies and renewable energy sources can co-exist with economic development with environmental and social objectives. Myers (1989, 2004 and 2008), one of the long-standing scholars working in the arena of environmental security, feels that the nature of the concerns of environmental security have been changing because of the changing nature of the relation between human society and its ambient environment. Environmental security, therefore, needs to be construed in terms of humankind and its institutions and organizations anywhere and at anytime (Myers 2004).

This interpretation of Myers (2004) is a very important entry point to the entire discourse on environmental security as, essentially, the interaction of human society with nature and their resulting dynamic relationship have been at the core of post-Cold War interest (Stucker 2006). Human activities have transformed the natural environment to such an extent that in many instances the security of humans themselves has often been threatened as a result. This state of symbiotic relation between the changing natural environment and security of human societies is one of the ways of looking at Environmental Security (Myers 2008, Homer-Dixon 1999).

One important concern here is the state of the social stress created by resource scarcity or extreme natural events thereby often leading to conflicts. The other important concern is environmental change that often acts as a stressor at the socio-ecological stratum of human existence (Homer-Dixon 1990 and 1994). Therefore, a conflictual state may exist within the human societies with nature acting as the stressor, while there might also be a state of conflict between the human society and nature that poses a threat on environmental security. The context of conflict within human societies for natural resources is well-evidenced and well-understood. They can be evidenced from the various cases of water conflicts, conflicts over agricultural land-use, forest rights, and conflicts over oil resources. The less understood part is related to human interventions in the natural resource flows, and eventually disrupting ecosystem service flows for short term economic gains in the name of "development". As an example, anthropogenic interventions in the natural hydrological flows have often proved counter-productive in the long-run, despite yielding short-run economic benefits, as has already been stated earlier. Such interventions have negatively affected human livelihoods further downstream by affecting ecosystem services (Bandyopadhyay and Ghosh 2009). These are all concerns for environmental security.

Environmental Security can thus be defined as *a state of absence of conflicts* in the complex and interconnected relations in and between the biological, social, economic and cultural processes of human societies and the natural environment. In the process, one may state that environmental security depends on the dynamics in the natural environment, population change, degree of access to the environmental resources, etc. Interaction between and among the determinants of environmental security sets the stage for addressing the environmental security challenges.

2. The Trans-boundary Water regimes of India with respect to Bangladesh

The boundary between India and Bangladesh runs mainly over the delta area of rivers Ganges and Brahmaputra. Flow of water and sediment across the boundary is almost a continuum big and small rivers being considered as transboundary. Most of them outflow into the Bay of Bengal. Essentially all these rivers are parts of a broader ecosystem that has more aptly been delineated as the Ganges-Brahmaputra-Meghna basin or GBM region (Bandyopadhyay and Ghosh 2009, Bandyopadhyay 2007). This transboundary river system has been subject to disputes over water use at various levels beginning from the level of the international hydropolitics to the most micro-level of water use, and extending to sectoral levels of conflict with the concerns of environmental flows and ecosystem services bringing a new dimension to the conflictual use of water resources. Hence, the concerns of environmental security in the context of the transboundary waters entail a study of the dynamics of changes in the natural environment and water usage in the basin, the associated drivers of growth in water demand, the understanding and assessment of ecosystem services, and the linkages between ecosystems and livelihoods (including food production and biodiversity).

Spread over the South Asian nations of Bangladesh, Bhutan, India, Nepal, and vast areas in the Tibet region of China, the GBM basin (1,745,400 sq km) is the second largest hydrological system in the world after the Amazon. The two major rivers of this hydrological system are the Ganges and the Brahmaputra. With these two rivers and their tributaries flowing beyond the national boundaries, they are prone to disputes that are a common feature of international transboundary water-courses around the world. The rivers in the entire basin collect water emerging from both the northern and southern aspects of the Himalaya. The total run-off of the basin gets discharged through numerous channels that drain into the Bay of Bengal and spread roughly between the two mega-cities of Dhaka in Bangladesh and Kolkata in eastern India. The annual run-off of the basin is about 1,150 billion cubic meters (BCM) and the peak outflow is 1,41,000 cumecs at the estuary (Bandyopadhyay 1995).

The Ganges originates in the *Gaumukh* (meaning the mouth of a cow) glacier in the southern aspect of the Himalaya in the Indian state of Uttarakhand and flows south-eastwards towards Bangladesh. Before crossing over from India to Bangladesh, the Ganges divides itself into two distributaries, the Ganges (which is the main stream) and the Bhagirathi-Hugli, downstream from the Farakka Barrage. The Bhagirathi-Hughli flows southwards past the megacity of Kolkata—and the main stream of Ganges flows eastwards into Bangladesh. As the Ganges enters Bangladesh, the main branch of the Ganges is known as the Padma River until it is joined by the Jamuna River, the name that the Brahmaputra assumes in Bangladesh. The Ganges (or the Padma, as it known in Bangladesh) meets the Meghna River further downstream, and the total flow enters the Estuary known by the name of Meghna. Here, in the process of forming the largest delta in the world known as the Ganges-Brahmaputra-Meghna delta, it finally empties into the Bay of Bengal (Figure 1). Several large Himalayan tributaries, notably the Kosi, the Gandak, the Karnali, the Mahakali, and so on, join the Ganges from Nepal.

(Figure 1: About here)

The other major river in the GBM basin, the Brahmaputra (the *Tsangpo* in Tibet) originates from the northern aspect of the Himalaya—little east of Lake Manasarovar in Tibet (China)—and is said to be flowing out of the mouth of a horse (*Tamchok Khambab*). It flows eastwards along the northern foothills of the Himalaya for about 1,600 km and takes a turn towards the south around the Himalayan peak of Namche Barwa (7,755 metres). It then passes through India, flowing south-westwards in the Assam valley, and crosses over to Bangladesh after taking a southward turn. It meets the Ganges near Dhaka. The combined flow then travels further southwards where it is joined by the Meghna a little downstream of Dhaka. The combined flow meets the Bay of Bengal further southwards. Figure 2 shows the hydrographs of the Ganges and the Brahmaputra in Bangladesh.

(Figure 2: About here)

Due to the interaction of the Bay of Bengal branch of the monsoon with the Himalaya and the hills in Northeast India, the eastern parts of the basin receive substantially high rainfall with Mawsynram in the Meghalaya hills recording 11,873 mms of average annual precipitation. In the western parts of the basin, semi-arid areas in Rajasthan in India and in the northern parts in the Tibet region of China, the annual precipitation can be less than 200 mms. This makes the GBM a basin of large spatial disparity in precipitation (Figure 3). This disparity in precipitation is further aggravated by the wide temporal inequity as around 75 per cent of the total annual precipitation occurs during the two and a half months of monsoon starting mid-June.

An interesting feature of the basin is that the two main rivers, the Brahmaputra and the Ganges, carry water from the drier parts of the basin to the regions that are abundant in rainfall. The monsoon precipitations, which occur from mid-June to mid-September, cause various types of floods in diverse regions of the basin (Bandyopadhyay 2009:49-100). While the higher regions of the basin face the fury of floods from cloud bursts, glacial outbursts, and so on, the lower regions get regularly inundated to accommodate the high flows in the rivers that drain the intense monsoon precipitations.

2.1. A Paradox in Developmental Theory

The high level of precipitation, annual run-off, and a large hydro-electric potential of more than 100,000 MW have often been cited as enabling factors for economic development and poverty eradication in the GBM basin (Verghese, 1990). However, it is quite a paradox that the basin, inhabited by as many as 535 million people, stands out as an exception to the traditional theory that relates poverty with water scarcity: the basin has remained the home for the largest number of people living in poverty (UNEP 2008:11). And here the GBM basin stands as a paradox of traditional development theory! The run-off in the GBM basin is higher than in most South Asian rivers. Yet, it is the most poverty-stricken in entire South Asia. The basin also supports some of the very large urban centres of South Asia like Delhi, Kanpur, Kolkata, and Dhaka. Between 1991 and 2001, the urban population in Bangladesh grew by 37%, while in Dhaka alone the growth was 55% (Bandyopadhyay and Ghosh 2009). The matter is of no less concern at this stage in terms of poverty and food security. The percentage of population in absolute poverty has (defined by daily calorie intake) increased to 52.5% in 2001, as compared with 49.7% in 1991. In parts of India, the states of Uttar Pradesh, Bihar, and West Bengal in the Ganges sub-basin have been inflicted by higher urban and rural poverty as compared with those lying at the more arid regions of the basin like in Haryana and Rajasthan. Moreover, poverty in rural areas where agriculture is the main livelihood is substantially higher. With GBM basin countries projected to record some of the highest growth of population in South Asia during the first half of the 21st century, it is apprehended that such high growth rates will be a matter of deeper policy concern in terms of water and food security, poverty alleviation, natural resource conservation and eventually the ecosystem services flows (Sharma et al 2008).

So far, the "ample water, ample poverty" paradox has not received much attention of development professionals. The traditional economic explanation of the causes of the high poverty level has been sought from the damages from the regular annual inundations in the basin. Bandyopadhyay (2009: 49-100) has raised questions against these explanations on the grounds of the complexity and unexplored links between ecology and development in the context of the basin. Hence, a more realistic and ecologically informed understanding of the relationship, if any, between water management and the high level of poverty in the basin needs to be developed. The commitments by the concerned countries to achieving the Millennium

Development Goals and the compulsions posed by the diverse impacts of global climate change on the basin (World Bank 2009:64-73) can be a common point for starting a new mode of thinking on environmental security.

(Figure 3 about here)

3. Environmental Security Concerns and Anthropogenic Interventions over Transboundary Waters

3.1. Water Resource Development in the GBM Basin: The Traditional Engineering Paradigm

The history of the development of human civilisation in the GBM basin is marked by numerous anthropogenic interventions over the hydrological flows. In the process, human societies in the basin have substantially transformed the natural flows and environment of the basin, from the Himalayan uplands to the estuaries, where the highly productive mangrove forest, the *Sundarbans,* is located. This is the largest mangrove forest in the world. The changes in land cover have expressed themselves in the changed hydrological features of the Himalayan Rivers (Ives and Messerli 1989).

Many water development projects guided by traditional engineering have been executed in the basin—in the forms of barrages and dams—ever since the arrival of the British engineers in the 1850s. Huge constructions intruded the hydrological flows for the promotion of irrigation and transportation. The establishment of the Thompson Engineering College at Roorkee during that period provided young Indian students with training in the European tradition of water engineering. Early British projects in the basin had been exemplified by the Sarada Barrage, while flood control of the Kosi had been studied in detail by British engineers. Some of the other large interventions by British engineers involved the Upper Ganges Canal that diverted water from the Ganges at Hardwar near Roorkee. .

In 1947, as India was partitioned into India and Pakistan, the "international transboundary" characteristic of Ganges and Brahmaputra was realised. The 1960s witnessed rapid expansion of water development projects primarily motivated by food security concerns of the newly independent nations. This was closely followed by the development of hydro-power projects. The more informal but political role of large projects in the redistribution of river waters should, however, not be underestimated. The rivers emerging from the Himalayas, i.e. those providing snow and ice-melt flows, became increasingly important as sources of water for the plains during the lean period.

As a result, “structuralist”[2] interventions, from the traditional engineering perspectives followed over the GBM waters, primarily being guided by the narrow economic objectives. Such structural interventions were frequently based on site selections made several decades back (MoWR 1989). Many of these were prone to creating hydro-political tensions in the basin. The reductionist traditional approach to river engineering, as initiated by the British, continued to guide the interventions in post-colonial India. Though, in course of time, the name of the government department in post-colonial India has changed from “irrigation” to “water resources”, the culture of reductionist traditional engineering, devoted to mainly provisioning of water for irrigation, has remained the main objective of governmental water engineering even today. This resistance to change has been explained by Urs and Whittell (2009), but the resistance may also be linked with the advantage that the politically powerful gain from such projects as many important negative externalities are conveniently kept out of project assessment.

(Figure 4 about here)

3.2. Reductionist Engineering, Hydro-political tensions and Environmental Security

The large structural interventions over the hydrological flows in the GBM basin have hardly taken into consideration the extremely complex and largely unexplored relationship between water and economic development in the GBM basin. At the same time, it ignored the extremely critical issue of the ecosystem services-livelihoods linkages that is been prevalent throughout the basin, and gets even more magnified further downstream in the delta regions. Interestingly, while all these structural interventions are being heralded as vehicles of poverty removal in the basin (Ahmad et al. 2001; Verghese 1990), the inherent reductionism in vision and the ensuing lack of integrated approach without consideration of ecosystems-livelihoods

[2] Construction of large “structures” like dams and barrages to harness water was thought of as the means to promote regional development. Such engineering interventions over the hydrological flows have been delineated here as “structuralist” interventions.

linkages resulted in further aggravation of human living conditions (Mallik and Bandyopadhyay 2004). The other critical issue is related to aggravation of social conflicts caused by the anthropogenic interventions over the water flows (Rudra 2004).

One of the critical aspects at the forefront of the transboundary water relations have been the continued discussions on the water related projects. The most widely discussed transboundary projects are the proposed dams on rivers in Nepal—like the Kosi, the Karnali, the Mahakali, and so on. Generation of hydro-electricity is added on as an objective for such projects. Water from such projects could be transferred to the western and southern parts of India, where it will be used for supporting the high rate of urban-industrial growth. Bangladesh, on the other hand, has been expressing interest in the dams in Nepal for the augmentation of flows in the Ganges–Padma entering that country. The role and construction of such dams in Nepal is itself a matter of diplomatic negotiation between India and Nepal. The future use of the water that could be stored in such reservoirs in Nepal would be demanded both from the West, and from the East, creating a need for tripartite diplomacy.

Generation of hydro-electricity by the proposed dams in Nepal, Bhutan, and the Indian Himalaya has been an integral objective with the power to be generated having a ready market in the plains of India. Between Bhutan and India, the agreements on hydro-electricity projects have been heralded as the foundation for economic development to deal with poverty in the mountain country. However, such a model of bilateral cooperation has not worked for Nepal and India.

The question of how to deal with monsoon floods in the basin has remained as an unsolved question to traditional engineering. The traditional perspective of engineering views floods as sources of unmixed damage and loss. In describing floods, the National Disaster Management Authority (NDMA 2008) of India pointed out that "on an average every year, 75 lakh hectares of land is affected, 1,600 lives lost, and damage caused to public utilities is of the order of Rs 820 crores." However, in the holistic perspective of ecological engineering monsoon flows also provide important ecosystem services that should get recognized. Flood control measures in rivers flowing from Nepal into India, such as the Kosi, have been discussed by engineers for a long time, though the efficacy of such structural control is yet to be clearly established. It is now clear that professional approach requires that diplomatic negotiations and agreements now need to be based on the emerging holistic knowledge on river systems and ecological engineering.

However, so far, very little progress has been made on the large hydro-electric projects in the Nepal Himalaya, such as the Kosi, the Karnali, and the Mahakali. Subedi (2005) has analyzed the various issues related to and reasons behind the slow progress in hydro-diplomacy in the GBM basin. Crucially, the various agreements between India and Nepal have been dogged with a feeling of unequal returns to Nepal (Dhungel and Pun 2009). A similar feeling of unequal treatment had arisen in Bangladesh after the Farakka Barrage was built by India on the Ganges (Abbas 1984; Mirza 2004). In both cases of Bangladesh and Nepal, there is a common perception that the smaller countries have received an iniquitous and poor share of the benefits of the projects. Moreover, during the last decade or so, political uncertainties in both Nepal and Bangladesh have created additional hurdles in the negotiations on such future projects.

In this context, it is important to mention that one of the most crucial factors affecting the Indo-Bangladesh hydro-political relation and the transboundary environmental security issues is the construction of the Farakka barrage. It is a large barrage at the small town of Farakka, at the upstream from the Indian border with Bangladesh. The barrage was initially planned to resuscitate the dying Calcutta port, which is connected by the Hooghly to the sea. The government of Pakistan and, after 1971, the government of Bangladesh opposed the construction and operation of the barrage as they apprehended that the barrage will result in reduction in the dry season flow of the Ganges and would have serious implications for their economy.

Despite the Indo-Bangladesh treaty of 1996 on dry season flows from Farakka, the crucial issue on ecosystem flows is yet to be resolved. Moreover, the un-substantive myths hang over the hydro-political relations, thereby causing further threat over environmental security in the GBM region. As recognized by Richards and Singh (2000: 1915), "… In Bangladesh, the Farakka Barrage has been widely portrayed in political and media discussions as a symbol of India's evil intent toward Bangladesh. Technical controversy about the 'flushing' process through which the barrage was expected to save the port of Calcutta and its industrial hinterland, as well as India's failure to recognize the downstream consequences of the project, left space for the assertion that the barrage was built *because of* its deleterious effects on Bangladesh (then East Pakistan). A second myth of Indian malice has also been widely repeated. This is the assertion that India can cause flooding in Bangladesh through the release of water stored behind the Farakka Barrage. Brief description of the barrage indicates that it is unable to store more than trivial quantities of water, far too little to have a significant effect on floods in Bangladesh".

Failure to resolve these issues has caused harm to both sides of the border for decades now. Notwithstanding several important publications stressing the need for adopting a holistic approach, the perspective of the governments involved has remained unchanged over decades. The progress in the evolution of new ideas has also been hindered by the lack of open availability of detailed hydrological data for research (Bandyopadhyay and Ghosh 2009). This has obstructed the generation of crucial interdisciplinary knowledge on the complex river systems of the GBM basin. Further, professional criticisms from within water technocracy were ignored, as has been the fate of Bhattacharya (1954) whose views on river engineering for the Farakka Barrage were not fully in tune with the official policy.

A series of events on the hydro-political front has actually led to a lack of trust between the co-riparians. While on the one hand, Bangladesh feels that the lack of flow in the summer months causes sedimentation and makes Bangladesh more prone to flood damages, a proposal for linking the Brahmaputra to the Ganges to improve the water flow in the Ganges as part of the larger River Link Project has come to the fore. The proposed River Link Project (RLP) is the latest project promoted from the traditional engineering perspective. It is a very large project for storage and long-distance transfer of water, mainly from the GBM basin to river basins in drier areas in western and southern India. The project includes the construction of nine large and 24 small dams and digging of 12500 km. of canals. The project depends on dams being constructed in Nepal. This project has drawn serious criticism from the perspective of sustainability and equity (Bandyopadhyay 2009:147-83) and from that of economics (Alagh et al 2006). Unfortunately, these views, critical of the scientific credibility of such a large project, have not had any impact on the official policy. Hence, the question remains whether the official approach will continue to take investment decisions following a traditional engineering perspective or be willing to accept the emerging holistic perspective of ecological engineering.

3.3. Environmental Security as a two-level game

The other important aspect of hydro-diplomacy and environmental security in the context of the GBM basin is that it needs to be understood not merely at an international level, but also at sub-national and sectoral levels. This has already been stated earlier, when this report defined the scope of the word “transboundary” in terms of international, sub-national and sectoral boundaries. Water management over the GBM basin requires fundamental changes at the national and the international levels: domestic policies will have to be reformed to rationalize expectation of water availability and use, and transnational (or trans-state) agreements on water sharing must be forged. The importance of the domestic economic policies with their consequence on water use can be assessed from their subsequent impacts on international hydro-politics, as has already been discussed in details in the previous sections.

As rightly observed by Richards and Singh (1997), usually national governments get engaged in a "two-level game" (e.g., Putnam 1988). They have to deal with their domestic water regimes, and almost simultaneously get into international transboundary water negotiations, keeping in view their domestic objectives. On the other hand, international agreements also affect domestic hydro-political conditions. Therefore, a move in one game will typically have implications for the outcome of the other. The case of the Indian and Bangladesh governments over the transboundary waters complies well with this contention. There is no doubt that the domestic economic interests have been the prime drivers of international negotiations as far as the India-Bangladesh transboundary water relations are concerned.

On the one hand, domestic policies based on the structural engineering paradigm have led to domestic problems over the basin. As Rudra (2004) notes, the changing course of the Ganges in the upstream and the downstream of the Farakka barrage, has been responsible for land reallocation causing border dispute between the federal states of Jharkhand and West Bengal and created a class of neo-refugees. Bandyopadhyay and Perveen (2008) have expressed their apprehensions on the interlinking of rivers project and feel that the project may further aggravate interstate water disputes, apart from aggravating the international hydro-political situation in South Asia. They identify avenues through which new inter-state conflicts may emerge with the project. It is a fact that the federal states in India have always enjoyed right over water for apportionment and allocation. However, under the centralized scheme of allocation under ILR, the existing modes of riparian rights of the states get disturbed, and that would fundamentally lead to conflicts. Already a few states have revealed their dissent against the project.

One critical factor here is the description of the total requirement of the states in the ‘surplus’ basins, for example, Assam or West Bengal. It is a fact that based on per capita measures dictated by the “arithmetical hydrology” paradigm, it will be possible to estimate the “supply oriented requirements” over time and space, the problem will arise on the requirements that arithmetical hydrology can not recognize. “… Take for example, how would one scientifically arrive at the need for minimum flow in Padma (the other name of the Ganges in Bangladesh) or Meghna or the Hooghly-Bhagirathi for the sustainability of the livelihoods of the millions involved in fishing in southern Bangladesh and the state of West Bengal? What will be the impact of the diversion of the 10 per cent of the lean season flow from ‘surplus’ river basins (read Ganges) on the groundwater resources and saline incursion in the downstream areas? These estimates are not easy to make.” (Bandyopadhyay and Perveen 2008: 71).

On the other hand, a recent IDSA (or Institute of Defense Studies and Analyses, New Delhi) Task Force Report, expresses the strong role of the civil society in Bangladesh in the context of the international dialogues over water sharing with India (IDSA 2010).

The above examples not only hint at a possibility of interstate conflict, but also at an intersectoral conflict (irrigation needs versus livelihoods issues, as also ecosystem services like fisheries nursery function) whose implications will widely be felt in international hydro-politics. This magnifies the two-level dimension of the environmental security concerns over the transboundary waters that are to be handled by the national governments.

4. Paradigm Shift in Water Management and the Knowledge Gaps over the Transboundary Water Regime: A concern for Environmental Security

4.1. The Paradigm Debate of Water Management

Existing strands of literature reveal that the 'business as usual' way of managing water is unsustainable, and would lead to severe stress, and even conflicts. Such concerns have been expressed from the highest international professional platforms (Cosgrove and Rijsberman 2000: xxi), and in diverse contexts at various points of time by many leading water professionals over the past several years (see for example Biswas 1976, Falkenmark et al. 2000, Gleick 1998). With such concerns, the last few years have witnessed the ubiquitous call for a change in the existing visions of water resources development. The new vision, emerging with the continuous accrual of knowledge with upward shifts of the frontiers of the discipline, involves the replacement of the present reductionist and engineering centered paradigm by a new holistic and interdisciplinary notion (Bandyopadhyay 2004).

There still exist the protagonists of the old paradigm who think that the old paradigm can address the new challenges with some adjustments and modifications. It is a fact that the human ability to build bigger and bigger engineering structures to modify the flows of streams and rivers helped the civilization to move ahead. Human control over the aquifers was established through stronger and stronger pumping technologies to take water out from deeper and deeper levels of aquifers. Dams were effectively used for controlling floods and generating hydro-electricity at a very large scale. This offered a reasonable protection against seasonal water shortages and even spatial inequities in water availability. The irrigation canals made it possible for humans to grow food in newer and newer areas as much it enhanced the growing seasons for crops.

On the other hand, as demand for water for meeting the basic human needs started being satisfied, forces of development started showing its signs. Perhaps, the gravest effect of the escalating urbanization was felt in the agricultural water use, which encountered manifold increase, over the last two centuries, in order to meet needs of the burgeoning urban population. Traditionally, water has been looked at as a resource occurring in "abundance" in nature, and hence, increasing demand was never seen as posing any potent threat. Hence, the impression that became predominant, emanated from the idea that water scarcity is spatial, and more water can be diverted to the water-scarce zones from the water-rich zones, through appropriate supply augmentation plans. In order for "water to be distributed equitably", the traditional thought process provoked the idea of supply expansion plans through interventions in the natural hydrological flows (e.g., Rao 1975). As a result, water resource planning was generally reliant on linear projections of future populations, per capita demand, agricultural production and levels of economic productivity (Gleick 2000).

Towards the middle of the last century, serious concerns started being expressed on the long-term wisdom of following such a strategy that is focused exclusively on the increasing intervention into the hydrological cycle. Despite its impressive short term successes in providing larger supplies, it is increasingly being realized that addressing the new and emerging challenges is no more possible over the long term, unless some fundamental changes take place in the way humans have looked at water resources so far. The "business as usual" process has started to be feared as counter-productive. There emerged the need for a fundamental change in terms of a new interdisciplinary paradigm that has been constantly gaining ground over the years. The new ways of managing water on the basis of a holistic knowledge base has increasingly been identified as Integrated Water Resource Management (IWRM).

4.2. *The emerging paradigm of Integrated Water Resources Management*

The professional views of water resource management are changing rapidly, based on the scientific analyses of past mistakes and availability of new information. This 'changing water paradigm' (Gleick 1998, Bandyopadhyay 2004) represents a real shift in the way humans think about water. The realization of the need for holistic modes of water management has been reflected in some of the policy actions of the developed world, primarily with the dawning of the ecological concerns (Gleick 2000). Continued investments in huge engineering interventions is being challenged by those who believe a higher priority should be assigned to projects that meet basic and unmet human needs for water (Gleick 1996). USA, the country which started the global trend of building large dams, is following "… a new trend to take out or decommission dams that either no longer serve a useful purpose or have caused such egregious ecological impacts so as to warrant removal. Nearly 500 dams in the USA and elsewhere have already been removed and the movement towards river restoration is accelerating" (Gleick 2000).

Following these paradigmatic shifts in notions worldwide, various other means to conserve water instream is becoming evident in various parts of the world (Gazmuri 1992). The Murray-Darling Basin Commission in Australia is seriously contemplating on extending financial encouragement to farmers for saving on their allocation of irrigation water and to allow the savings to remain instream (Bandyopadhyay and Perveen 2004). In another instance, Chile's National Water Code of 1981 established a system of water rights that are transferable and independent of land use and ownership. The most frequent transaction in Chile's water markets is the 'renting' of water between neighbouring farmers with different water requirements (Gazmuri 1992). Helming and Kuylenstierna (2001), while cautioning against the damages that can be caused by supply augmentation plans, emphasizes that "*...Demand side management is therefore slowly becoming a new paradigm for water governance".*

The new emerging thought processes in our vision of water recognizes that the old modes of supply development, through large constructions for harnessing the crucial natural resource, are unsustainable. The thought dominating the old paradigm was primarily "water for food security" associated with some use of water in industry, hydropower, and urban sectors, and supply augmentation plans were thought of as offering the solutions. The new emerging paradigm of Integrated Water Resources Management (IWRM) adds a newer dimension to the thought process, by proclaiming the notion of "water for ecosystems" (Postel 1996, Postel *et al* 1996, Falkenmark *et al* 2004, Gleick 2000). The new paradigm recognises the human society as a subsystem in the biosphere in which water is a key element (Falkenmark 1997, Falkenmark 2003).

The emergence of and transition to the new paradigm for water resources is not free from extensive conflict of ideas and serious struggle for existence of the old and the pressure generated for a change by the emerging situations. However, efforts by professionals have exemplified the fundamental changes in the ways the subject of water resource development and management is being conceptualized (e.g., Falkenmark 2003, Gleick 2000, Falkenmark *et al* 2000, Cosgrove and Rijsberman 2000, Biswas 1976). Based on the various contending thoughts and ideas, the notion of IWRM has been conceptualized, and has been presented by Bandyopadhyay (2004) in the form of the following points:

a) *Water is viewed as an integral part of the global hydrological cycle, and not as a stock of material resource to be used for the satisfaction of human requirements:* The old paradigm of water resources development has been dominated by the reductionist engineering perspective that water is a stock of natural resource waiting to be extracted and used. Reductionism is based on the perceived economic benefits from water resources, without showing any consideration to the ecohydrological processes (Bandyopadhyay and Perveen 2008). With the idea that economic benefits are all-important, water diversion was thought of as the key to development. Water was being developed for supply to the fields to the fullest extent. It has never been thought that every drop of water has an ecological function, which sustains the ecosystem health, and eventually human health, via the ecosystem processes. This viewpoint of reductionist engineering is the reason behind the emergence of many of the critical problems faced by water management today.

In the new era of the emerging paradigm that is holistic and interdisciplinary in nature, water is viewed in the context of the totality of the global hydrological cycle. It is now being recognized that the non-realization of ecological cost due to water diversion elsewhere is an inbuilt subsidy to use water for economic purposes at will (Flessa 2004).

b) *Supply of ever increasing volumes of water is not a pre-requisite for continued economic growth. Hence, solutions to the problems of water resource development need not be searched in supply side management alone.*

Under the traditional paradigm regime, the availability of increased supplies of water is seen as an essential pre-condition for continuing economic growth. Thus, suggestions for reduced consumption of water are instantly seen as a prescription for declining economic growth (Bandyopadhyay 2004).

The new paradigm, however, suggests opposing thoughts. Economic growth has been delinked from water supply augmentation plans. This delinking of economic growth with the availability of larger water supplies helps in shifting the conceptual focus away from seeking only supply side solutions and to give demand side management of water its overdue importance (Gleick 2000, Falkenmark *et al* 2004).

c) *Clear and strict prioritization of various types of needs and demands for water is needed, including those of the ecosystems: an examination of the various descriptions of environmental flows in the Bangladesh-India context.*

The new and interdisciplinary paradigm assigns clear priorities to the various competing requirements of water. The competing needs primarily involve two levels. One is between the needs of the ecosystems and the needs of the human societies. The other is among the various needs of the human societies itself (Bandyopadhyay 2004). Setting the right priorities through the understanding of the trade-offs is an important component of water resource management of the present day.

d) *There is a need for comprehensive assessment of the water development projects keeping the integrity of the full hydrological cycle.*

A crucial element of a new and holistic paradigm is the creation of an interdisciplinary knowledge base that would be able to offer non-partisan and comprehensive assessments of the justifications and impacts of water resource development projects (Bandyopadhyay 2004, Barbier and Thompson 1998).

e) *A transparent and interdisciplinary knowledge base for the understanding of the social, ecological and economic roles played by water resources is required*.

In the old paradigm of water resource development, disciplines were not intersecting with each other in a way truly to understand the potential contributions of other areas of competence, not even from closely neighbouring disciplines (Falkenmark *et al* 2004). The complexities of the water management problems that include a real understanding of the nature of water resources and their complex links and interrelations with other systems can no longer confine the discipline in the domain of compartmentalized sector and single-disciplinary approaches. Hence, there is the need to devise new and innovative strategies for coping with water problems, involving multidisciplinary approaches (Falkenmark *et al* 2004, Bandyopadhyay 2004).

f) Droughts and floods are to be visualized in the wider context of the ecological processes associated with them.

g) Appropriate new social and economic instruments for promoting careful and efficient uses of water resources or for the reduction of damage to their quality from pollution should be developed.

The new paradigm emphasizes the need for a new economic perspective evaluation of water. The question of pricing of water, the desirability or otherwise of the growing trends of privatization of water resources as the final solution, the ecological economic valuation of the ecosystem services provided by water systems are all part of a rapidly emerging knowledge base of water economics. Integrated water management is rapidly following this new economics of water resources and perceptions are changing rapidly. Countries like the USA and China, among many others are well into this process.

h) *There is a need of acceptance of the need for restructuring the institutional frameworks for water resource development at local, state, river basin and national levels for making it equitable, sustainable and participatory*.

These elements should be seen as indicative and not exhaustive. They are subject to further refinement as the process of the shaping of a new paradigm progresses. Such a list, for the time being, can offer the fundamental guidelines for putting the new paradigm into force.

Given the above, the new emerging paradigm recognises that irrigation development has often come with a high environmental price tag (Molden and Fraiture 2004). The costs range from aquatic ecosystem degradation, fragmentation and desiccation of rivers, and drying up of wetlands. Barbier and Thompson (1998) and Acreman (2000) show that in many cases the values generated by irrigation proved to be less than the values generated by the ecosystems they replaced. Lemly *et al* (2000), in a global study of wetlands, sums it up by stating, "The conflict between irrigated agriculture and wildlife conservation has reached a critical point at a global scale". Hence, as realised by Rijsberman and Molden (2001), the main competition for water is between agriculture and the environment. Falkenmark (2003) stresses that by benefitting from the shared dependence of humans and ecosystems on water, IWRM can integrate land, water and ecosystems and promote the three E's – two human dependent ones (social equity and economic efficiency) and one related to ecosystem (environmental sustainability). As an unbiased catalyst for reconciling between these concerns, and prioritising between the competing ends, valuation of the economic vis-à-vis environmental uses of water becomes critical.

4.3. *Disconnect of South Asian Hydro-policy with global paradigm change*

There is a clear "disconnect" between this global change in knowledge resulting in the paradigmatic shift in water management globally and the official policy practices in South Asia. The adherence to the traditional engineering paradigm is exemplified by the publication *Major River Basins of India: an Overview* (MoWR 1989). This document, describing the planned development of surface water and hydro-power projects in the basins in details, provides another detailed statement of the official engineering agenda for India's rivers. Quite recognisable in this document is the non-recognition (or ignorance) of the various ecological processes that keep the natural productivity of the riparian ecosystems and contribute to the livelihood of a large number of people (Bandyopadhyay and Ghosh 2009). On a more recent account, the draft *Comprehensive Mission Document of National Water Mission* (MoWR 2008), as part of the India's National Action Plan on Climate Change, is still made from the traditional engineering perspective of looking at rivers for availability and allocation. There is no doubt that what has dominated the thought processes of policy makers are narrowly perceived short-term economic benefits, for which water infrastructure development was thought to be the key.

The ineffectiveness of traditional water engineering to bring in development and hence, the continuing poverty in the GBM basin can be linked to the absence of an ecological perspective, use of an incomplete framework for economics, non-recognition of the long-run economic costs, and ignorance of the ecosystems-livelihoods linkages etc. By not engaging with critical opinions worldwide, the existing view of governmental water engineering has exposed its inability to evolve with time. The result has been an exclusive mode of hydro-diplomacy that has essentially resulted in bilateral negotiations between India and Bangladesh for the downstream flows in the basin, and bilateral talks of India with Nepal and Bhutan (Richards and Singh 2000). Whereas worldwide there has been a call for taking an "ecosystemic" approach for integrated river basin management, the bilateral approach to water resource development moves away from considering the entire river basin as the unit for water resource management. Rather, such "fragmented" approach not only obliterates the vision of considering the river basin as an integrated ecosystem, but can also create disputes over water allocation at various levels.

The "disconnect" between the changing paradigm and the South Asian water policy is going to be critical for water management and environmental security in the context of the transboundary water relations. With global climate change seriously affecting the hydrology of the Himalayan Rivers, water endowment of the rivers and future flows would become more uncertain (World Bank 2009). Further, the effects of sea-level rise on the coastal ecosystems and estuaries of these rivers will become significant.

4.4. *Gaps in Knowledge*

There are crucial gaps in knowledge that need to be bridged for a more holistic approach to hydro-diplomacy, which is extremely important from the perspective of environmental security in the basin. The gaps in knowledge have revealed themselves in various forms as suggested below.

a) *Gaps in eco-hydrological knowledge on surface water systems, in particular on the ecosystem services and assessment of environmental flows:* While the knowledge about the economic contribution of water has been used extensively in the decision-making process, there is a critical gap in the eco-hydrological knowledge on surface water flows. There are extensive and diverse ecosystem services offered by the waters in the basin right from the upland watersheds till the delta and estuaries. Critical livelihoods are dependent on such services. On the other hand, the knowledge gap also exists in terms of the environmental flow requirements.

Policy makers rarely took these into considerations in the initial phases of dam construction after the Indian independence. As the long-term environmental impact of altered flow regimes are expressing themselves, serious degradations of the downstream ecosystem services are becoming apparent. In the country of origin of large dams, the US, approach to large dams has now changed fundamentally based on optimization at the river basin level. However, the new concepts are not being easily internalized in the formal water governance in south Asia (Bandyopadhyay 2007). On the other hand, the general perception of embankments as flood protection has further aggravated the scenario in various parts of the basin. There is a crucial knowledge gap in relation to the fluvial processes, and generally floods have been treated as "villain of piece" without much understanding of the holistic ecohydrological process with which they are associated.

b) *Gaps in eco-hydrological knowledge on groundwater systems and institutional mechanisms for its sustainable use and protection from pollution:* The Indo-Gangetic basin is rich in groundwater, both static and dynamic. The other critical problem is groundwater pollution, and primarily those resulting from arsenic. Arsenic toxicity in groundwater has affected major parts of the Basin, and is highly prominent in Bangladesh and southern West Bengal. The presence of arsenic in groundwater exceeding the permissible potable limit of 50 μg/l was recorded in West Bengal in 1978, and initial cases of arsenic poisoning was diagnosed in 1983 (Chakraborti and Saha 1987; Acharya and Shah 2010). There has been quite a bit of research and documentation going on with respect to the various problems caused by arsenic pollution in the domains of human health, food security, and the social concerns (Das et al 2008; Samanta et al 2007; Pal et al 2007; Acharya et al 1999 and 2000). However, there is no such documentation of the effects of arsenic pollution on the ecosystem health, and its consequent impact on human livelihoods. This is an important knowledge gap. On the other hand, since the property rights status of groundwater is very different from that of surface water, conflicts over it are more localized. Therefore, the other potential policy research areas on groundwater include work on an ecologically informed property rights regime with an inter-disciplinary approach with policy, law and management of water systems. The related areas of research would be spread over engineering geology to soils sciences to sociology of local water institutions to environmental law (Bandyopadhyay 2007).

c) *Gaps in knowledge of flood management:* The regular monsoon inundations are summarily seen as "flood disasters" with a relief dominated approach to their management. In the water relations between Bangladesh and India, a holistic understanding of the monsoon flows and the ecosystem services they offer, is lacking. Till now, the relief-dominated approach has not really resulted in any long-term solution to flood management, but has rather resulted in ad-hoc temporary solutions, that often exacerbate conflictual situations. The principle of IWRM that calls for floods and droughts to be treated as integral components of the larger ecohydrological cycle has not been recognized by the vision that has led to the fragmented approach of flood management in the basin. This, indeed, is a crucial concern of environmental security.

d) *Gaps in knowledge of social dimensions of water systems use, local governance and water conflicts:* While the social and cultural aspects of water use in the basin has traditionally been prominent and have moved in folklores, the documentation is not yet proper. Engineering interventions have rarely taken these aspects into account. Moreover, there is little recognition and documentation of the local governance issues in the policy documents. As Bandyopadhyay (2007) notes in the context of South Asian Rivers in general, "… For nearly a millennium, water in south Asia was managed by community-based organizations which were as diverse, as are the water endowments and physiographic characteristics of the specific areas. In the past few decades nongovernmental initiatives have established effective and revitalized institutional structures for such local water management. Various activities related to water are also divided between the two genders". Moench et al (1999) have presented a compendium of experiences on local level management from various parts of the region evidencing the effectiveness of the community-based organizations.

On the other hand, constructions of large dams and barrages have not been free from the social costs of rehabilitation and conflicts. Such social costs have often been ignored at the phase of conception of the projects. The lack of knowledge about conducting integrated impact assessments of the large projects still presents itself as a major challenge for river basin management and environmental security in the context of not only the transboundary waters between India and Bangladesh, but for South Asia as a whole.

e) *Environmental security needs sound knowledge of the diverse demands and requirements of water, which is a critical knowledge gap in the region*: In order to promote an integrated and ecosystemic approach to river basin management, there is a need for prioritization of water demands as well. This becomes even more pronounced when the national governments in basin are committed towards the fulfillment of the Millennium Development Goals. Sound knowledge of the diverse demands including that of the ecosystems is of utmost importance for more informed decision-making.

f) *Gaps in knowledge in emerging technological and practice-oriented options in water systems management*: Newer and newer technological options to provide water for drinking and sanitation are being thought of worldwide. Technological and practice-oriented innovations have also been taking place for promoting water-use-efficiency in irrigation. The core of the problem with the transboundary waters of India and Bangladesh is related to waters for agriculture. It is also interesting to note that both these nations score very low in terms of water-use efficiency in irrigation, thereby resulting in some of the lowest crop productivities per unit of water in the world.

On the drinking water front, the technology for desalination has presented itself as a very promising option that may bring about dramatic changes in the domestic water supply scenario all along the south Asian coasts. Uche et al (2006) have given a detailed account of the potential of the desalination technologies. The other area in which research needs to be focused is the re-use of water and innovation of related technologies. As a practice-oriented innovation, System of Rice Intensification (SRI) has been talked of as an intervention reducing water use for rice production. However, the efficacy of such innovations is yet to be inferred with conviction (Ghosh 2008). This calls for more field level experiments.

g) *Identification of the knowledge gaps on the Himalayan components*: In detailed analyses of the ecological and political challenges associated with Himalayan waters, Gaur (1993), Bandyopadhyay and Gyawali (1994) and Bandyopadhyay (2002) have identified several knowledge gaps resulting in the problems in the traditional approach to developing the Himalayan rivers based on dams and embankments. These knowledge gaps in knowledge can be best summarized as gaps under the following heads: i> the mechanism of the generation and draining out of flood waters in the Himalayan foothills and floodplains; ii> the dynamics of the generation, transportation and deposition of sediments all along the course of the Himalayan rivers; iii> the nature of seismic risks associated with high dams in the Himalaya; iv) the impacts of structural interventions in the Himalayan rivers, like embankments; and v> the impact of the four points above on the economic feasibility of water development projects.

Even the data gaps on the Himalayan components have been noted officially by the NCIWRDP (1999a, b). This has indeed led to a clear void in terms of objective and professional assessments of large projects, thereby casting uncertainty about their viability.

h) *Gaps in knowledge in the relation between water and food security:* The more interesting knowledge gap is the changing relation between water and food. Food security in a region has so far been thought of as a linear function of water availability. Recent literature, however, refutes such a relation (e.g. Förare 2008; Molden 2007; Ghosh and Bandyopadhyay 2009 a). While most of these experiments that have refuted the direct proportionality between water and food availability have emerged from US and EU, Ghosh and Bandyopadhyay (2009) have emphasized that there is a need for creating knowledge base on such a relation in South Asia. Whereas there has been a worldwide call for an ecosystemic approach to food security, there has not been any knowledge created in South Asia in this domain.

i) *Lack of detailed hydrological data in public domain:* Sensitive flow data have not been made available in the public domain by the national governments. Non-availability of data at public forum on transboundary hydrological flows, and some other associated important variables in the basin has totally restricted independent and non-partisan assessments of hydrological projects and livelihoods issues on the basin. It is important to have transparency in information dissemination among the various nations, with data being made available to the scientific community for independent scientific assessments. Such lack of data has created a void in knowledge on some of the important transboundary issues like floods, ecosystem services, as also for implications for conflicts, -- all of which are crucial issues for environmental security.

5. Way Forward to Research

The modes of water management followed in the Ganges-Brahmaputra-Meghna region as also the serious knowledge gaps as discussed earlier have led to situations that have aggravated the threats to environmental security in the context of transboundary water relations between India and Bangladesh. As it is, the "state of conflict" over water use exists at various levels in the basin, and has moved to the detriment of the hydro-political situation in the South Asian region as a whole. The most important remedy to address such knowledge gaps and eventually impact policy level thinking is to undertake research in some of the areas that are of utmost relevance in terms of affecting environmental security in the region, and disseminate the findings at relevant corners.

5.1. *A Combination of Three perspectives*

The proposed research issues need to be addressed from three perspectives in a holistic and inclusive framework combining various disciplines, rather than in a reductionist framework of poverty and water availability. These perspectives, entailing the following, have otherwise been suggested by Bandyopadhyay and Ghosh (2009).

a. *The ecological perspective: Ecosystem service–Livelihood linkage:* The river basin needs to be looked at as a collection of productive ecosystems that greatly affects livelihoods further downstream. The growing recognition of the importance of the ecosystems services has been highlighted in the report of the Millennium Ecosystem Assessment (2005). While upstream diversions help agriculture, there is a consequent decline in the downstream fishing economy all along the river as also enhanced salinity ingress affecting downstream economies, leading to partisan and suboptimal decisions. Based on recent research on the economic role of ecosystem services, the satisfaction of the needs of natural ecosystems has become a genuine contender for allocation of water in many countries (Aylward et al 2005; Dyson et al 2003).

b. *The Perspective of Economic Valuation:* To complement the ecological perspective, a fundamental re-think has been going on with the internalization of important perspectives of ecological economics, which, more importantly entails identification of economic values with ecosystem processes (Ghosh and Bandyopadhyay 2009 b). Such valuation exercises are often conducted with offering a range of values (which, by themselves, are approximations). The important aspect of such valuation exercises is their usefulness in providing means to internalize factors that remained to be considered in the traditional assessment of river projects. Even theoretical papers, at times, become useful in providing a baseline for broader assessment at the local level (e g, Ghosh and Shylajan 2005). Some interesting applications on extensions of the valuation frameworks for the understanding of the impacts and assessment of water projects, as also river systems have been conducted by Bouhia (2001) and Hitzhusen (2007). However, a very comprehensive process of valuation has evolved from the Water Allocation Systems (WAS) developed by a project at Massachusetts Institute of Technology (MIT) on water management and conflict resolution in west Asia. One of the outcomes of this project is a volume by Fisher et al (2005). The volume not only incorporates social and private economic issues, but also environmental concerns. It is models like these that need to be developed for comprehensive evaluation at the river basin scale, in the context of GBM. For India, Desai (undated), Bandyopadhyay and Ghosh (2009) and Ghosh (2008) have suggested expansions of the valuation framework in the assessment of projects, though, in reality, little has been done to expand the framework.

c. *The Institutional Perspective:* There has not been much work on the institutional aspects of water management at the basin scale over the Ganges-Brahmaputra-Meghna basin barring those by Crow and Singh (2000). Crow and Singh (2000) have highlighted the need for extending bilateral exchange to multilateral exchange, and the second is expanding negotiations from conventional diplomacy to incorporate private economic actors. On other hand, as already emphasized in this paper, there is a critical need for the policymakers to consider the term "transboundary" in the context of the renewed definition as has been presented by Beach et al (2000), and also considered in this paper. This implies the consideration of intersectoral modes of water distribution, and considering the ecosystem as an important sector that plays an important role in human civilization. On the other hand, there needs to be a redefinition in the ways the property rights over water are being looked at. In western US, property rights over water had been defined in terms of three doctrines: History, Harmon and Hobbes. While the doctrines of History (right belongs to the one who has appropriated the resource first), and Harmon (right belongs to the one who has the water falling on his roof), were leading to conflicts, as different actors in the basin at various levels and sectors defined property rights as per their own convenience, it is therefore better to have peaceful modes of negotiations for defining property rights as defined by the Hobbesian doctrine (Richards and Singh 2001). This might even lead to the development of water markets for defining property rights.

The perspectives, however, should not be treated as independent modes of looking at the challenges of environmental security in the context of the India-Bangladesh transboundary water relations. There is a need to combine the three perspectives in order to conduct research in a holistic framework.

5.2. *A Few Research Concerns*

While some critical concerns at a broader scale have already been talked of, the other research problems over the transboundary water regime unfold themselves in the forms as discussed below.

Status of the biodiversity and ecosystems services in transboundary waters: The yawning gap in knowledge exists in the context of the biodiversity and the ecosystems services over the transboundary waters. There is some research on the species diversity over the Ganges and the Brahmaputra (Sood et al 2010, Payne et al 2004, Biswas and Boruah 2000, and Sinha et al 2010). However, there is rarely much research on a temporal scale on the issues related to loss in species, and associated its diversity, due to the anthropogenic interventions in the hydrological flows. The other important aspect is the knowledge gap between biodiversity and the ecosystems services. This research needs to be taken up on an immediate basis in the basin region, as also at the basin scale.

Ecosystem services and Human wellbeing in the delta regions of the Sundarbans, a critical Socio-Ecological System: From an ecosystemic perspective, it is important to look at the GBM as an ecosystem production unit that interplays a critical role in the socio-economic existence of humans. In this process, one critical unit is the Sundarbans. The Sundarbans is the classic example of an endangered ecosystem that is highly populated and both fragile and economically valuable (Danda 2007). Some of the most celebrated components of the Sundarbans biodiversity are the mangrove vegetation, periodic tidal flooding, and the unique wildlife of which the Royal Bengal Tiger has been prime subject for tourist attraction. However, a more interesting aspect of Sundarbans is the inherent deep-rooted entrenchment of human life with ecosystemic processes.

Therefore, an immediate concern that arises is with understanding to what extent Sundarbans ecosystem and its associated services have been affected due to upstream infrastructure development. One needs to look at the impacts on the mangroves, the subsequent impacts on the fishery production function, and eventually on livelihoods at meso and micro levels, through the mangrove-fishery linkages. This needs to be detected through an inclusive valuation framework that combines all the three perspectives.

This inclusive valuation framework entails the valuation of not only the socio-ecological systems (SES) as defined by Ostrom (2005), but also a broader ecological system that is contingent upon the intricate dynamics of the SES (Bandyopadhyay and Ghosh 2009). In the inclusive valuation framework, the scarcity values of ecosystem and its services are being accounted for and included in the national account statistics of the economy. Sundarbans is one of the several such SES in the Ganges sub-basin where welfare change through changes in environmental inputs can be traced, and where externalities play an important role. As an example, the loss to fishermen due to reduced catch of fish and crustacean species in the lower Ganges can be a result of upstream diversion, pollution and eventual damage to the mangrove forests. Compensation to the fishermen for the loss of economic opportunity is not enough. The value of the ecological damage also needs to be taken into account. This is where the inclusive valuation framework moots on an integrated approach to include social values, economic contributions as well as ecosystem services provided by the hydrological cycle.

Environmental Flows, Ecosystem Services of Floods and a Sediment Budget for the Basin: One of the least understood and least researched components of environmental security is the ecosystem services of floods that carry and deposit the sediments in the downstream plains to create some of the most fertile agricultural fields of the world. For that matter, there have not been much rigorous estimates of the environmental flows at the basin scale over the GBM, except a few attempts though at a sub-basin level (e.g. Smakhtin and Anputhas 2006). One critical research gap is with the sediment budget in the basin, as also (from economists' perspective) the agricultural and other economic contributions of such sediment deposits. Wasson (2003) uses Nd/ Sr tracer results to suggest that the High Himalaya is the main source of sediment, providing for the first time a focus for more detailed research on the role of land use and other factors in the generation of sediment. Hardly any significant publication has taken up this theme after this documentation by Wasson, thereby creating a huge void in the existing literature base. Understanding the sediment budget is important from the perspective of food production and other economic and ecosystem services, thereby having broader implications on environmental security in the basin.

Water Conflicts: From the viewpoint of water conflicts, it has often been hypothesized that water scarcity induces conflicts, acts as a social stressor, and poses a threat on environmental security. However, such contentions have been negated under the new emerging paradigm of IWRM. Nations in the Jordan basin, namely, Israel and Jordan, are water-scarce ones. According to the Falkenmark Water Barrier Scale (defined in terms of per capita availability), Israel transcended beyond water barrier in 1982 (Jobson 1999: 11), while Jordan did so in 1960 (Jobson 1999: 14). These two nations were engaged in water conflicts with each other. However, effective management of the available water resources, lately, has resulted in the two nations moving toward peaceful hydropolitics, despite problems in other political matters persisting in the region. These examples are some of the best in the world to reveal the validity of the modified relations between water availability and environmental security. Therefore, the hydro-political relations between India and Bangladesh need to be construed in terms of this changed relation between water, food security, economic development, thereby redefining the water-environmental security dynamics.

Scarcity Value of Water in an Inclusive Valuation Framework: In cue with the issues of water conflicts, Ghosh and Bandyopadhyay (2009) and Ghosh (2009) have argued that explanations to water conflicts need to be sought in the temporal coincidence of demand based on scarcity value, rather than in mere physical availability of water. While there have been few attempts to look at scarcity value of water in India and other parts of the world, the attempts on the Ganges basin is almost negligible except the one by Chowdhury (2005). At this stage, therefore there needs to be serious research on both sides that looks at scarcity values of water in the transboundary context, as has been done by Ghosh and Bandyopadhyay (2009) in the context of the Cauvery River in South India. An increasing scarcity value of water is indicative of an alarming condition for environmental security. Research therefore needs to suggest the demand management options to reduce the scarcity value of water.

However, such a scarcity value cannot be confined to merely the economic service of water. But it should entail a broader framework that would encompass the various issues of ecology, economy, and society, thereby providing the policy makers with values for ecosystem services not only in the biological but also in the social and cultural domain of human existence. This is where one may delineate a broader framework for inclusive valuation. Even in the context of the SES of Sundarbans, the scarcity value of water needs to be estimated in this redefined broad framework.

Climate Change: As stated earlier, there is a knowledge gap in terms of the impacts of climate change on the GBM ecosystem. Here, one needs to keep in mind that the most crucial threat to environmental security in the ecosystem can be posed by climate change. This is because Ganges and Brahmaputra are essentially mountain rivers, and though largely snow-fed, the summer monsoons (June to September) provide a significant portion of the region's annual precipitation within a period of only four months. Any deviation of the seasonality of the monsoon can create severe problems of water availability in the region.

That climate change is a reality in South Asia has been accepted in the international literature (Mirza and Ahmad 2005). The Intergovernmental Panel on Climate Change (IPCC) third assessment report (IPCC-TAR) has also indicated the possibility of greater frequency and intensity of the extreme events related to water. The impact of global climate change on precipitation, stream flow and water availability have been major areas of global research in the past decade (see for example, Erda et al 1996; Milli et al 2005).

The possibility of increasing intensity of such events has also been documented, and the additional impact of nature's variability is expected in lower Ganges sub-basin comprising the Indian Sundarbans Delta (Hazra 2002). On the other hand, preliminary observations indicate that in addition to the reduction in the snow and ice cover in the Himalaya, water scarcity and extreme events in the region may be accentuated, thereby posing a threat on the environmental security further downstream in the context of the transboundary water relations between India and Bangladesh (Hosterman et al 2009; Bandyopadhyay 2007). Initial forecasts also suggest that changes in climate will further exacerbate the existing variability (Cruz et al. 2007). In the Ganges basin, climate change is expected to increase temperatures, resulting in the retreat of glaciers, increase variability in precipitation, resulting in increased magnitude and frequency of droughts and floods; and lead to sea-level rise (Hosterman et al 2009). Gossain et al (2006) and Gossain and Rao (2004) have further indicated seasonal and frequent water stress over the Ganges.

With this accepted premise of climate change in the GBM basin, the uncertainty still remains with the precision of various climate change predictions. On the other hand, there still remains a blurred idea of the possible impacts of climate change on food production and other ecosystem services. Critically, the most ignored area of research is the impact of climate change on delta regions of the basin, and more specifically the innumerable islands of Indian and Bangladeshi Sundarbans. Hazra (2002) has been extremely categorical on the issues of the alarming level of sea level rise in the Indian Sundarbans delta. Danda et al (2011) conceive of a vision of 2050 for the Indian Sundarbans Delta, and talks of a process of phased relocation from climatically vulnerable zones. The document states that the process of relocation should also entail creation of adequate employment opportunities, training, counseling, and at the same time it should voluntarily be left to the population. However, no research so far has been able to draw up the critical impacts that climate change might have on the critical ecosystems-livelihood linkages. There is a chance that with the alterations in ecosystems services cause by changes in climate, livelihood processes might get negatively affected, and as a result newer modes of adaptation have to follow. On the other hand, the emerging thesis of climate change and environmental conflicts, as has been propounded by Homer-Dixon (1994) also needs to be reviewed. However, all these are parts of the research agenda and need to be taken up on a priority basis before taking up policy measures.

Regional Water Markets: Richards and Singh (2001) have discussed the problems of developing regional water markets in the west Asia due to high transaction costs (which arise from information accession and high entry and exit barriers in the markets), and existence of wealth effects (e g, religious or other emotional sentiments attached to water can make the resource not amenable to a market framework transaction). While transaction costs are an integral part of markets, wealth effects never allow markets to develop. Such behaviour might also be rampant in the GBM basin. It is in such contexts that Crow and Singh's proposal of incorporating private economic actors in negotiations can be of help.

In this context, researchers also need to think of whether a regional water futures exchange can be set up in the region, and to what extent such an exchange can help in mitigation of scarcity. The important research concerns here are: Can South Asian regional water derivatives market act as an institutional intervention bringing down the scarcity value of water, as suggested by Ghosh (2010)? Can trading in water index futures in such an exchange help in the process of conflict resolution? Ghosh (2010) has further suggested that the regional water futures exchange can also be a mode of thinking to combat the variability of water availability that will accentuate under climate change. However, all such preliminary thoughts need to be studied in further details combining the perspectives of institutions and inclusive valuation.

6. Concluding Remarks

The above discussion presents the agenda for research in relation to environmental security in the region. The list, of course, is far from exhaustive. Yet, these issues are to be prioritized in the research agenda. The central issue of this note is that the concerns of environmental security in the context of transboundary water relations between India and

Bangladesh should be viewed through the lens of the ecosystems services and livelihoods linkages, rather than from the perspective of traditional engineering paradigm followed for myopic national interests. Such perspectives and interests have so far led to conflicts at international, national and sectoral levels between stakeholders, and have posed threats to environmental security.

To ensure environmental security in terms of the transboundary water relations between the two nations, there needs to be a movement from a state of distrust and suspicion to a state of cooperation. However, such regional cooperation needs to take off at the scale of the GBM river basin, rather than being confined to bilateral negotiations between the two nations. This implies that on the one hand, all the stakeholder nations in the Ganges-Brahmaputra-Meghna basin have to be involved in a dialogue. On the other hand, since the environmental security concerns boil down to the most micro-level stratum of the society, there is a need to involve the sub-national actors in the deliberation processes, as also involve them in the decision-making and policy-making. This can lead to an inclusive developmental framework, as also providing leeway away from the conflictual situation prevailing in the basin at various scales and at various levels.

However, research and knowledge creation has to precede policy dialogue to bridge some critical knowledge gaps. While on the one hand, the worldwide paradigm shift in river basin management has not affected policymakers in South Asia, on the other hand, there is clearly a dearth of research on the critical issues of environmental security in the Ganges-Brahmaputra-Meghna basin. Therefore, hydro-diplomacy in the Ganges-Brahmaputra-Meghna basin is still based on reductionist engineering, and looks at marginal economic benefits, without showing any concern for the long-run implications for livelihoods and ecosystem. The governments in the river basin are already facing the challenge of extreme poverty, despite the countries experiencing high levels of precipitation. This paper has already highlighted the limitations of the reductionist engineering paradigm in combating the newer and newer challenges that are being posed on environmental security in the basin.

In the process, a holistic framework for ecological engineering and water management has been proposed in the basin. While this paper has talked of inclusiveness of diverse stakeholders, it further stresses inclusiveness of diverse disciplines for conducting research. The new research framework needs to be based on a new transdisciplinary knowledge base created by the emerging science of eco-hydrology, economics, and new institutional theories. There is a need to specially consider the important developmental issues of the delta region that is allegedly "dying". The Indian Sundarbans delta specifically presents a critical challenge of vulnerability of nature, species and human life in the wake of the concerns of climate change. On the other hand, there is a need to reconsider the ways floods are being looked at further upstream, and consider their ecosystem functions and services.

On the whole, there needs to be an economic assessment of the demand for water based on scarcity value framework on an immediate basis, with the results being disseminated at a broader policy scale, with clear recognitions of the ecosystemic delineations of concerns of development, food security, poverty, and hydropolitics. This is because, never before has the challenge of MDGs depended on the science of a better informed ecological engineering as it does in the GBM basin today; and never before, has the role of a transdisciplinary framework combining economics with other disciplines of social sciences and engineering, in providing a comprehensive evaluation framework needed a re-emphasis, as it is needed in the GBM basin today.

References

Acharya, S.K. and B.A. Shah (2010): "Groundwater arsenic pollution affecting deltaic West Bengal, India", *Current Science*, 99 (12), 1787-94.

Acharya, S.K., P. Chakraborty, S. Lahiri, B.C. Raymahashay, S. Guha, and A. Bhowmik (1999): "Arsenic poisoning in the Ganges Delta", *Nature*, 401 (545).

Acharya, S.K., S. Lahiri, B.C. Raymahashay, and A. Bhowmik (2000): "Arsenic toxicity of groundwater in parts of the Bengal basin in India and Bangladesh: the role of quarternary stratigraphy and Holocene sea-level fluctuation", *Environmental Geology*, 39:1127-1137.

Acreman, M. (2000): *Background study for the World Commission of Dams, reported in World Commission on Dams (2000)* (as cited in Molden and Fraiture (2004)).

Ahmad, Q. K., A. K. Biswas, R. Rangachari and M. M. Sanju, ed. (2001): *Ganges-Brahmaputra-Meghna Region: A Framework for Sustainable Development* (Dhaka: University Press).

Alagh, Y. K., G. Pangare and B. Gujja (Eds.) (2006): *Interlinking of Rivers in India: Overview and Ken-Betwa Link* (New Delhi, Academic Foundation).

Bandyopadhyay, J. (1995): “Water Management in the Ganges± Brahmaputra Basin: Emerging Challenges for the 21st Century”, *Water Resources Development,* 11 (4), 411-42.

Bandyopadhyay, J. (2004): “Adoption of a New and Holistic Paradigm is a Pre-condition for Integrated Water Management in India” in G. Saha (Ed) *Water Security and Management of Water Resources* (Kolkata: National Atlas and Thematic Mapping Organization).

Bandyopadhyay, J. (2007): “Water Systems Management in South Asia: Need for a Research Framework”, *Economic and Political Weekly*, 42 (10), 863-73.

Bandyopadhyay, J. (2009): *Water, Ecosystems and Society: A Confluence of Disciplines* (New Delhi: Sage).

Bandyopadhyay, J. and B. Mallik (2003): “Ecology and Economics in Sustainable Water Resource Development in India”, in Chopra, K., C.H.H. Rao, and R.P. Sengupta (eds.) *Water: Resources, Sustainable Livelihoods and Ecosystem Services.* (New Delhi: Concept Publishing).

Bandyopadhyay, J. and N. Ghosh (2009): “Holistic Engineering and Hydro-diplomacy in the Ganges-Brahmaputra-Meghna Basin”, *Economic and Political Weekly*, 44 (45), 50-60 (with Jayanta Bandyopadhyay).

Bandyopadhyay, J. and S. Perveen (2008): ‘The Interlinking of Indian Rivers: Questions on the Scientific, Economic and Environmental Dimension of the Project’ in M. Q. Mirza, A. U. Ahmed and Q. K. Ahmad (Eds.) *Interlinking Rivers in India: Issues and Concerns* (Abingdon: Taylor and Francis), P. 53–76.

Barbier, E.B. and J.R. Thompson (1998): “The value of water: Floodplain versus large-scale irrigation benefits in northern Nigeria”, *Ambio,* 27(6), 434-40.

Bhattacharya, K. (1954): *Bangladesher Nod-Nadi O Parikalpana*. (Kolkata: Vidyodaya Library) in Bengali.

Biswas, A.K. (ed.) (1976): *Systems Approach to Water Management*. (Tokyo: McGraw Hill).

Biswas, S.P. and S. Boruah (2000): “Fisheries ecology of the northeastern Himalayas with special reference to the Brahmaputra River”, *Ecological Engineering,* 16 (1), 39-50.

Bouhia, H. (2001): *Water in the Macro Economy* (Aldershot: Ashgate).

Chakraborti, A. K. and K. C. Saha (1987): “Arsenical Dermatosis from Tube-well Water in West Bengal”, *Indian Journal of Medical Research,* 85, 326–334.

Chalecki, E. (2002): "Environmental Security: A Case Study of Climate Change", Paper Presented at the *2002 Biennial Conference on Enhancing Regional Security*. Asia-Pacific Centre of Security Studies, Honolulu HI.

Chowdhury, N.T. (2005): "The Economic Value of Water in the Ganges-Brahmaputra-Meghna River Basin", *Beijer Discussion Paper 202*. Available at www.beijer.kva.se/publications/pdf-archive/Disc202.pdf.

Cosgrove, W. J. and F. R. Rijsberman (2000): *World Water Vision: Making Water Everybody's Business* (London: Earthscan).

Cruz, R.V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li and N. Huu Ninh (2007): Asia. In *Climate Change 2007: Impacts, Adaptation, and Vulnerability; Contribution to Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, 469–506. (Cambridge, UK: Cambridge University Press).

Danda, A. (2007): *Surviving in the Sundarbans: Threats and Responses*. Doctoral Dissertation submitted at the University of Twente, Netherlands. ISBN: 90-365-2566-4.

Danda, A., G. Sriskanthan, A. Ghosh, J. Bandyopadhyay, and S. Hazra (2011): *Indian Sundarbans Delta: A Vision*. (New Delhi: WWF).

Das, B., M.K. Sengupta, M.A. Hossain, S. Ahamed, B. Nayak, A. Pal, S. Maity, M. M. Rahman, K.C. Saha and D. Chakraborti (2008): "Groundwater arsenic contamination and its health effects in the Ganga – Meghna – Brahmaputra plain" in Bhattacharya, P., A.L. Ramanathan, J. Bundschuh, A. K. Keshari and C. Chandrasekharan (eds.) *Groundwater for Sustainable Development- Problems, Perspectives and Challenges* (The Netherlands: Taylor and Francis).

Dhungel, D.N. and S.B. Pun (eds.) (2009): *The Nepal-India Water Resources Relationship: Challenges*. (Springer).

Erda, L., W. C. Bolhofer, S. Haq, S. Lenhert, S. K. Mukherjee, J. B. Smith and J. Wisniewski (eds.) (1996): *Climate Change Vulnerability and Adaptation in Asia and the Pacific*, (Dordrecht: Kluwer).

Falkenmark, M. (1997): "Society's interaction with the water cycle: A conceptual framework for a more holistic approach", *Hydrological Sciences*, 42, 451-466.

Falkenmark, M. (2003): “Water Management and Ecosystems: Living with Change”, *TEC Background Paper 9*. (Stockholm: Global Water Partnership).

Falkenmark, M., C. Folke and L. Gordon (2000): “Water in the landscape: Functions and Values” in Lundquist J. et al. (eds.) *New Dimensions in Water Security* (Rome: FAO).

Falkenmark, M., L. Gottschalk, J. Lindquist, and P. Wouters (2004): “Towards Integrated Catchment Management: Increasing the Dialogue between Scientists, Policy-makers and Stakeholders”, *Water Resources Development*, 20(3), 297-309.

Flessa, K.W. (2004): “Ecosystem services and the value of water in the Colorado River delta and Estuary, USA and Mexico: Guidelines for mitigation and restoration”. *International Seminar on Restoration of Damaged Lagoon Environments*, 79-86. Matsue, Japan.

Förare, J. (ed.) *Water and Food* (Stockholm: The Swedish Research Council Formas).

Gaur, V.K. (ed.) (1993): *Earthquake Hazard and Large Dams in the Himalaya.* (New Delhi: Indian National Trust for Art and Cultural Heritage).

Gazmuri, R. (1992): “Chilean Water Policy Experience” paper presented at the *Ninth Annual Irrigation and Drainage Seminar,* Agriculture and Water Resources Department (Washington DC: The World Bank).

Ghosh, N. (2008): “System of Rice Intensification: More Rice with Less Water” in Förare, J. (ed.) *Water and Food* (Stockholm: The Swedish Research Council Formas).

Ghosh, N. (2009): *Economics of Hostile Hydropolitics over Transboundary Waters: Scarcity Values and Interstate Water Conflicts in India and US* (Saarbrucken, Germany: VDM Verlag).

Ghosh, N. (2010): “Conceptual Framework of a South Asian Water Futures Exchange”, *Commodity Vision*, 4 (1), 8-18.

Ghosh, N. and J. Bandyopadhyay (2009a): “A *Scarcity Value* Based Explanation of Transboundary Water Disputes: The Case of the Cauvery River Basin in India”, *Water Policy*, 11(2): 141-67.

Ghosh, N. and J. Bandyopadhyay (2009b): “Methods of Valuation of Water Resources: A Review”, *South Asian Water Studies*, 1(1), 19-50. Visit: www.sawasjournal.org

Gleick, P.H. (1993): “Water and Conflict: Fresh Water Resources and International Security”, *International Security*, 18 (1), 79-112.

Gleick, P.H. (1996): “Basic Water Requirement for Human Activities: Meeting Basic Needs”, *Water International*, 21 (2), 83-92.

Gleick, P.H. (1998): *The World’s Water: 1998-1999* (Washington DC: Island Press).

Gleick, P.H. (2000): *The World’s Water: 2000-2001: The Biennial Report of Freshwater Resources* (Washington DC: Island Press).

Hazra, S., T. Ghosh, R. Dasgupta, and G. Sen (2002): “Sea Level and Associated Changes in Sundarbans”, *Science and Culture,* 68 (9-12), 309-21.

Helming, S. and J. Kuylenstierna (2001): “Water – A Key to Sustainable Development” Issue paper for the *International Conference on Freshwater*, Bonn, 03-07 December.

Hitzhusen, F. J. (2007): *Economic Valuation of River Systems* (Cheltenham: Edward Elgar).

Holden, P. and M. Thobani (1996): “Tradable Water Rights: A property rights approach to resolving water shortages and promoting investment” *World Bank Policy Research Working Paper no. 1627,* (Washington DC: World Bank).

Homer-Dixon, T. (1999): *Environment, Scarcity, and Violence*. (Princeton, NJ: Princeton University Press.

Homer-Dixon, T. (2000): *The Ingenuity Gap.* (New York: Knopf).

Homer-Dixon, T. F. (1991). On the threshold: environmental changes as causes of acute conflict. International Security, 16 (2), 76–116.

Homer-Dixon, T. F. (1994). Environmental scarcities and violent conflict: evidence from cases. International Security, 19(1), 5–40.

Hosterman, H. R., P. G. McCornick, E. J. Kistin, A. Pant, B. Sharma, and L. Bharati (2009): “Water, Climate Change, and Adaptation: Focus on the Ganges River Basin”, *Nicholas Institute for Environmental Policy Solutions Working Paper* No. 3. NI WP 09-03.

Hosterman, H. R., P. G. McCornick, E. J. Kistin, A. Pant, B. Sharma, and L. Bharati (2009): “Water, Climate Change, and Adaptation: Focus on the Ganges River Basin”, *Nicholas Institute for Environmental Policy Solutions Working Paper* No. 3. NI WP 09-03.

IDSA (2010): *Water Security For India: The External Dynamics* (New Delhi: Institute for Defence Studies and Analyses).

Ives, J. D. and B. Messerli (1989): *The Himalayan Dilemma* (New York, Routledge).

Jobson, S. (1999): “Water Stressed Regions: The Middle East & Southern Africa – Global Solutions”, *Occasional Paper No. 16*, Water Issues Study Group, School of Oriental and African Studies (SOAS).

Kumar, P., A. Love, R. S. Sharma, and C.R. Babu (2003): “Valuing the Hydrological Impact of Changing Land-Use: A Case of Yamuna Floodplain Wetland Ecosystems, Delhi”, in Chopra, K., C.H.H. Rao, and R.P. Sengupta (Eds.) *Water Resources, Sustainable Livelihoods and Eco-system Services*, (New Delhi: Concept Publishing).

Lemly, A.D., R.T. Kingsford, and J.R. Thompson (2000): “Irrigated agriculture and wildlife conservation: Conflict on a global scale”, *Environment Management*, 25(5), 485-512.

Mallik, B. and J. Bandyopadhyay (2004): “Conflicts from Reductionist Engineering: the Case of Ganga in West Bengal” in Subba, V. and K. Pradhan (Eds.) *Disputes Over the Ganga* (Kathmandu: Panos South Asia).

Milli, P C D, K. A. Dunne and A V Vecchia (2005): “Global Pattern of Trends in Stream-flow and Water Availability in a Changing Climate”, *Nature*, 438(17), pp 347-50.

Mirza, M. M. Q. (2004): *The Ganges Water Diversion: Environmental Effects and Implications. (*Dordrecht: Kluwer).

Moench, M., E. Caspari and A. Dixit (eds.) (1999): *Rethinking the Mosaic: Investigations into Local Water Management*, (Kathmandu: NWCF).

Molden, D. (ed.) (2007): *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture* (London: Earthscan).

Molden, D. and D. Fraiture (2004): “Investing in Water for Food, Ecosystems and Livelihoods”, Discussion draft, *Comprehensive Assessment of Water Management in Agriculture*, Stockholm.

MoWR (1989): *Major River Basins of India: An Overview* (New Delhi: Ministry of Water Resources).

MoWR (2008): *Comprehensive Mission Document of National Water Mission* (draft) (New Delhi: Ministry of Water Resources).

Myers, N. (1989): “Environment and Security”. *Foreign Policy*, 74 (1), 23-41.

Myers, N. (2004): “Environmental Security: What's New and Different?” Paper presented *at The Hague Conference on Environment, Security and Sustainable Development*, The Peace Palace, The Hague, The Netherlands, 9 - 12 May 2004.

Myers, N. (2008): “Environmental Security Concerns: Sources”, in Stec, S. and B. Baraj, eds., *Energy and Environmental Challenges to Security* (Springer-Verlag).

National Commission on Integrated Water Resource Development Plan (NCIWRDP) (1999a): *Integrated Water Resource Development: A Plan for Action*. (New Delhi: NCIWRDP, MoWR).

National Commission on Integrated Water Resource Development Plan (NCIWRDP) (1999b): *Report of the Working Group on Inter-basin Transfer of Water*. New Delhi, NCIWRDP, MoWR, 1999b.

NDMA (2008): “National Flood Risk Management Project”, Invitation for Expression of Interest No 3-3/2008-PMU (New Delhi: National Disaster Management Authority).

Ostrom, E (2005): *Understanding Institutional Diversity* (Princeton: Princeton University Press).

Pal, A., B. Nayak, B. Das, M.A. Hossain, S. Ahamed, and D. Chakraborti (2007): “Additional danger of arsenic exposure through inhalation from burning from cow dung cakes laced with arsenic as a fuel in arsenic affected villages in Ganga–Meghna–Brahmaputra plain”. *Journal of Environmental Monitoring*, 9(10), 1067 – 1070.

Payne, A.I., R. Sinha, H.R. Singh, and S. Huq (2004): “A Review of the Ganges Basin; its Fish and Fisheries”, In: Welcomme, R. and T. Petr, (Eds.) *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries*, *Volume I*, (FAO Regional Office for Asia and the Pacific. Bangkok, Thailand. RAP Publication 2004/17)

Postel, S.L. (1996): *Dividing the Waters: Food Security, Ecosystem Health, and the New Politics of Scarcity*. (Washington DC: Worldwatch Institute).

Postel, S.L., G.C. Daily, and P.R. Ehrlich (1996): “Human appropriation of renewable fresh water”. *Science*, 271, 785-788.

Putnam, R. D. (1988): "Diplomacy and Domestic Politics: The Logic of Two-Level Games", *International Organization*, 42, 427-460.

Rao, K.L. (1975): *India’s Water Wealth* (New Delhi: Orient Longman).

Richards, A. and N. Singh (1997): “Two Level Negotiations in Bargaining over Water”, in T. Parthasarathy, B. Dutta, J.A.M Potters, T.E.S. Raghavan, D. Ray, and A. Sen (eds.) *Game Theoretical Applications to Economics and Operations Research*, (Boston: Kluwer Academic Publishers).

Richards, A. and N. Singh (2000): “Impediments and Innovation in International Rivers: The Waters of South Asia”, *World Development*, 28 (11), 1907-1925.

Rijsberman, F.R. and D. Molden (2001): “Balancing Water Uses: Water for Food and Water for Nature”, Thematic Background Paper, *International Conference on Freshwater*, Bonn, 3-7 December, 43-56.

Rowley, G. (1998): “The Tragedy of the Common Waters: Towards the deepening crisis within the Jordan Basin”, Paper presented at *Congres International de Kaslik*, Liban, 18-20 June.

Rudra, K. (2004): *The Encroaching Ganga and Social Conflicts: The Case of West Bengal*, (Independent Broadcasting Associates, Littleton, MA).

Samanta, G., D. Das, B.K. Mondal, T. Roychowdhury, D. Chakraborti, A. Pal, S. Ahamed (2007): “Arsenic in the breast milk of lactating women in arsenic affected areas of West Bengal, India and its effect on infants*”, Journal of Environmental Science & Health*, Part A. 42 (12), 1815 – 1825.

Sharma, B., U. Amarasinghe, and A. Sikka (2008): “Indo-Gangetic River Basins: Summary Situation Analysis”, *Mimeo.*

Sinha, R. K., S. K. Behera, and B.C. Choudhary (2010): *The Conservation Action Plan for the Ganges River Dolphin 2010-2020*. Ministry of Environment and Forests, Government of India.

Smakhtin, V. and M. Anputhas (2006): *An assessment of environmental flow requirements of Indian river basins*. Colombo, Sri Lanka: International Water Management Institute. 42p. (IWMI Research Report 107)

Sood, A., P. Pandey, S. Bisht, S. Sharma, M. P. Gusain, O. P. Gusain (2010): “Assessment of bacterial diversity in the Gangetic river system of Uttarakhand, India”, *Current Science*, 99 (12), 1660-63.

Steiner, A. (2006): “Environmental Security”, Paper prepared for G8 Summit.

Stucker, D. (2006): *Linking Natural Capital, Rural Livelihoods, and Conflict: Toward Governance for Environmental Security and Peace in Tajikistan*, Masters’ Dissertation in submitted at the University for Peace, headquartered in Ciudad Colón, Costa Rica.

Subedi, S. P. (ed.) (2005): *International Watercourse Law for the 21st Century: The Case of the River Ganges Basin* (Aldershot: Ashgate).

Uche, J, A Valero and L Serra (2006): 'The Potential for Desalination Technologies in Meeting the Water Crisis' in P.P. Rogers, M R Llamas and L Martinez-Cortina (eds), *Water Crisis: Myth or Reality*, 323-32. (London: Taylor and Francis).

UNEP (2008): *Freshwater Under Threat: South Asia* (Nairobi: UNEP).

Urs, K. and R. Whittell (2009): *Resisting Change: Water Profits and Democracy* (New Delhi: Sage).

Verghese, B. G. (1990): *Waters of Hope* (Dhaka: University Press).

Wasson, R.J. (2003): "A sediment budget for the Ganga–Brahmaputra catchment", *Current Science*, 84 (8), 1041-47.

Westing, A.H. (ed.) (1986): *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action*. (Oxford: Oxford University Press).

World Bank (2009): *South Asia Climate Change Strategy*. Technical Report. http://siteresources.worldbank.org/SOUTHASIAEXT/Resources/Publications/448813-1231439344179/5726136-1232505590830/1SARCCSJanuary192009.pdf viewed on 19 February 2009.

Figures

Figure 1: Physiographic Features of the GBM Basin

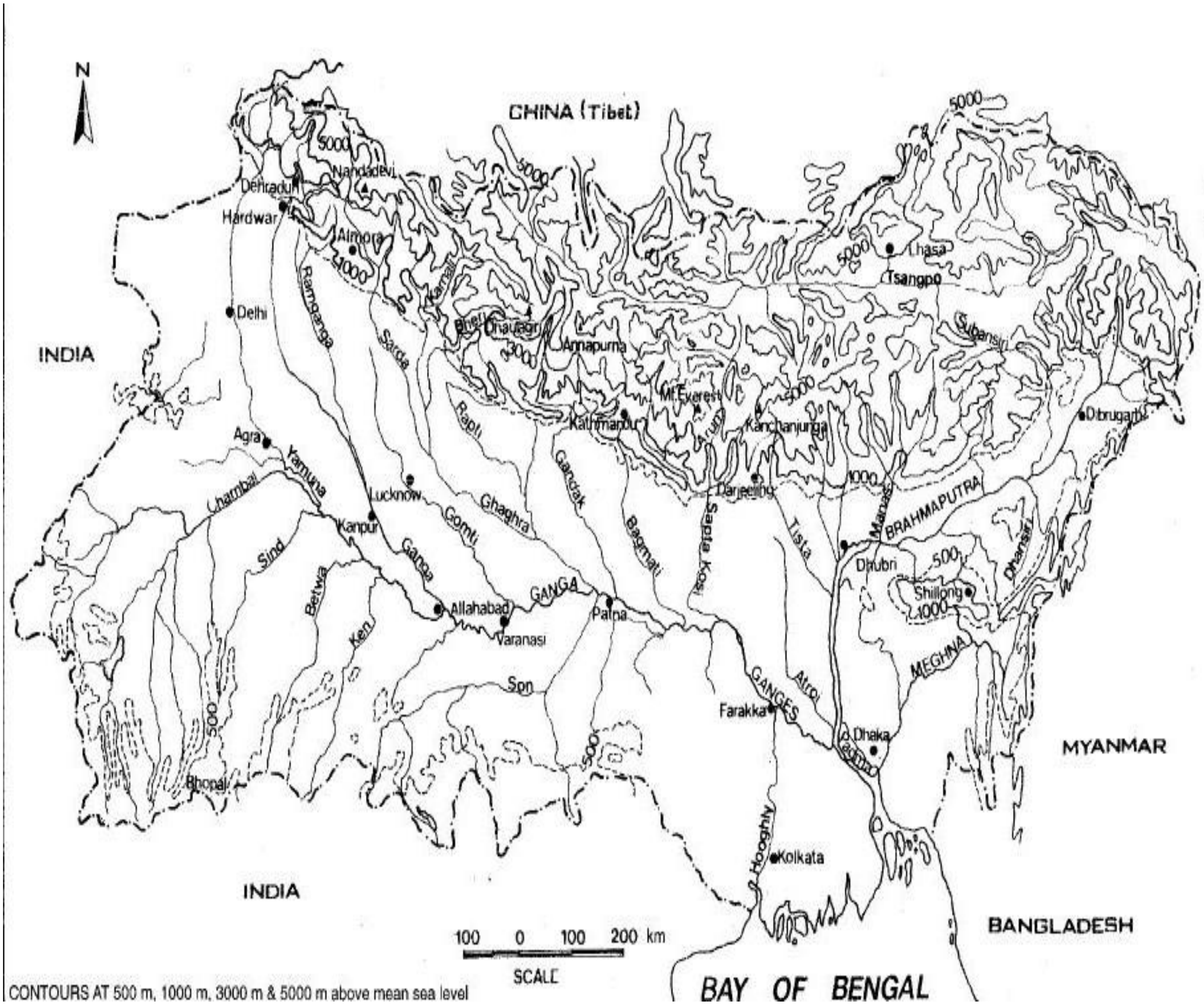

Fig. 2: Annual Discharge Hydrographs of the Brahmaputra and the Ganges Rivers at Hardinge Bridge and Bahadurabad (1981)

Discharge (000 cumecs)

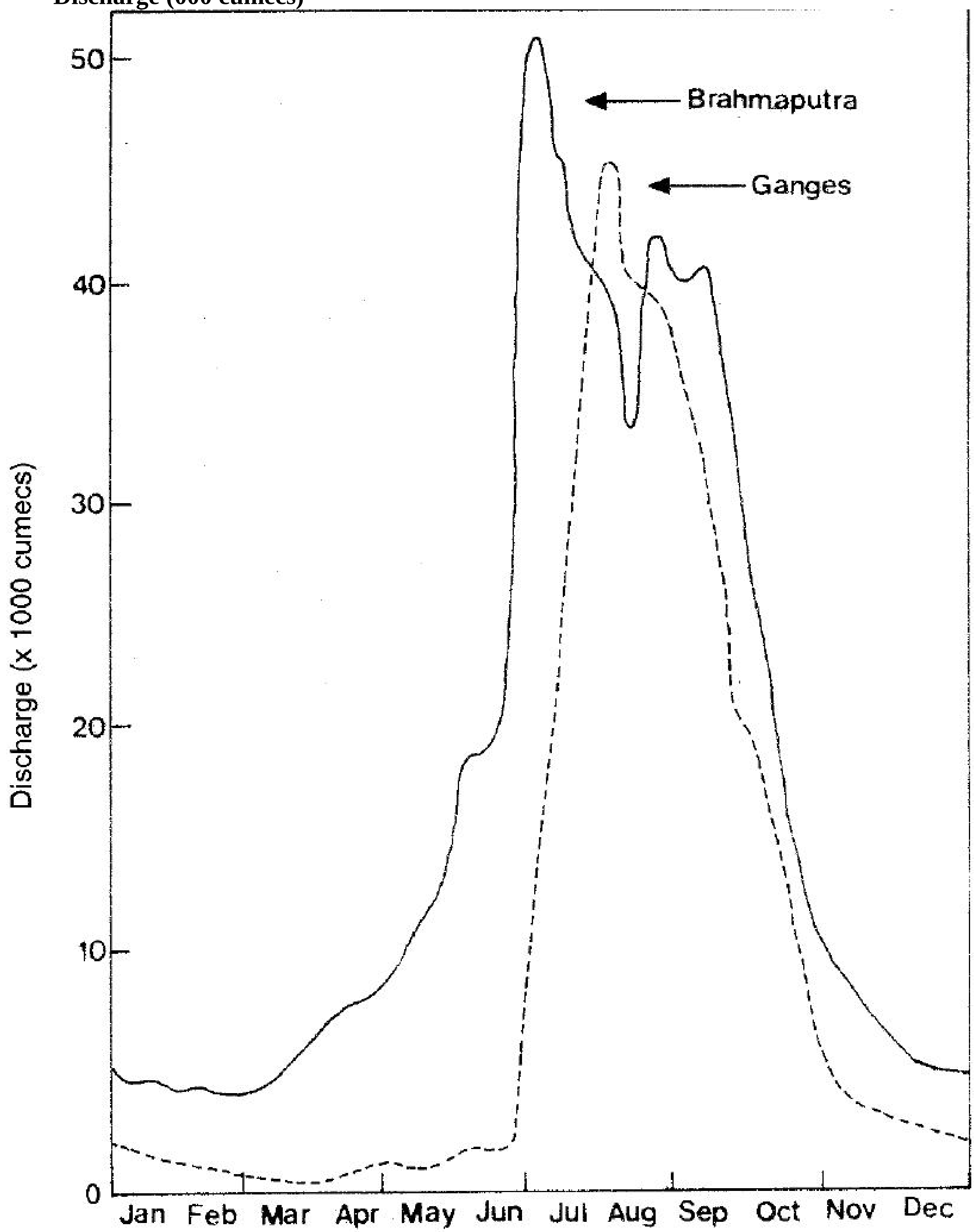

Figure 3: Iso-hyets of the GBM Basin

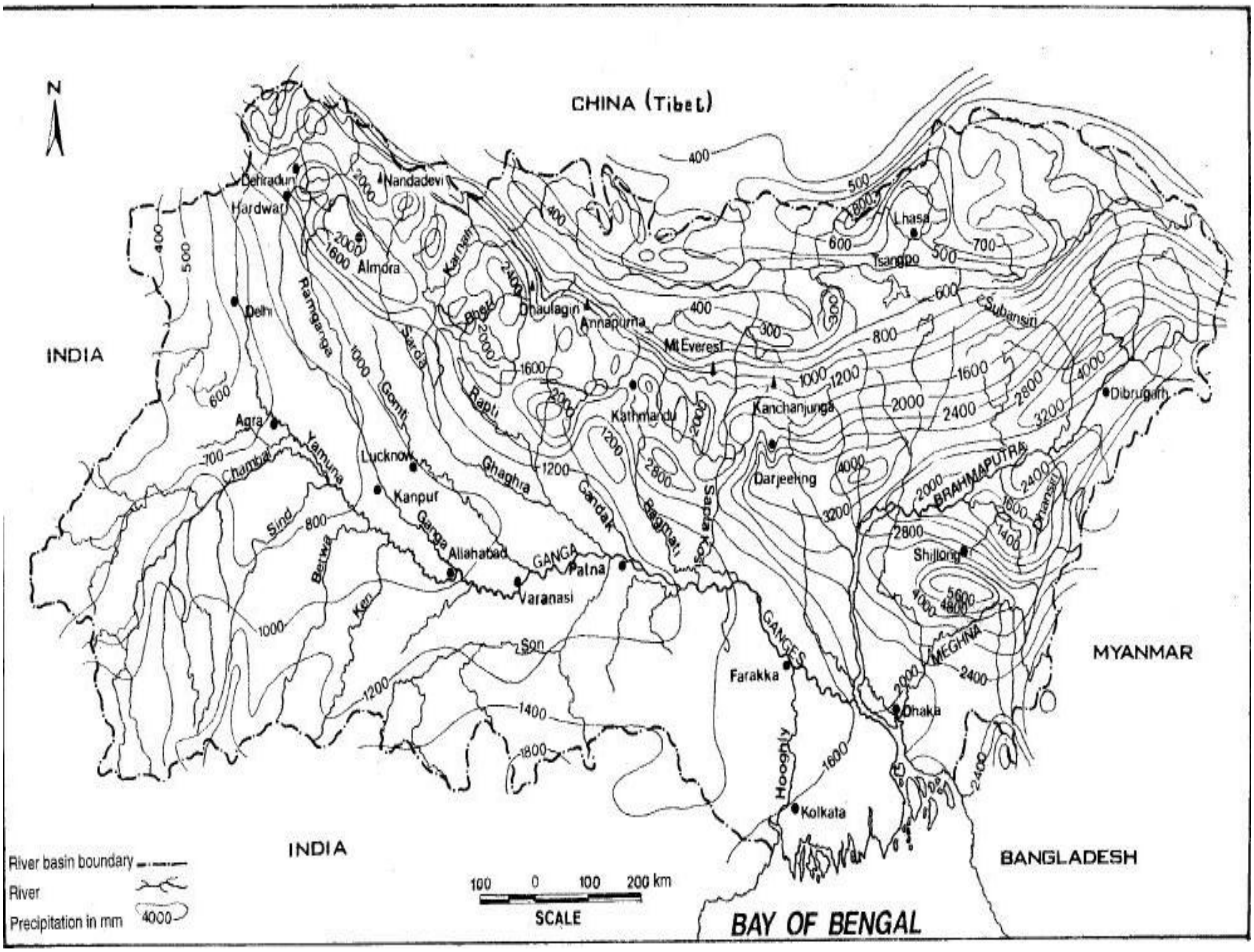

Figure 4: Existing and Planned Water Projects in the GBM Basin