Holistic Engineering and Hydro-Diplomacy in the Ganges-Brahmaputra-Meghna Basin

JAYANTA BANDYOPADHYAY, NILANJAN GHOSH

The worldwide paradigm shift in river basin management has not affected policymakers in south Asia. 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 discusses the lacunae of the reductionist engineering paradigm, and stresses the need for a holistic framework in ecological engineering and for hydro-diplomacy in the basin. This framework is based on a new transdisciplinary knowledge base created by the emerging science of eco-hydrology, economics, and new institutional theories.

The Ganges-Brahmaputra-Meghna (GBM) river basin in south Asia (Figure 1, p 51) poses several complex challenges to the existing notions of development and hydro-diplomacy. Spread over the south Asian nations of Bangladesh, Bhutan, India, Nepal, and vast areas in the Tibet region of China, the GBM basin (17,45,400 sq km) is the second largest hydrological system in the world after the Amazon. The rivers in the 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. The two major rivers of the hydrological system are the Ganges and the Brahmaputra. These two rivers and their tributaries flow beyond national boundaries and are prone to disputes that are a common feature of international transboundary water-courses around the world.

The Ganges originates in the *gaumukh* (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 in two distributaries, the Ganges and the Hughli-Bhagirathi. The Ganges in Bangladesh, called Padma, first meets the Brahmaputra and further downstream the Meghna (Figure 1). Several large Himalayan tributaries, notably the Kosi, the Gandak, the Karnali, the Mahakali, and so on, join the Ganges from Nepal. Downstream from the Farakka Barrage, the flow of the Ganges gets divided into Hughli-Bhagirathi – flowing southwards past the mega-city of Kolkata – and Ganges, which flows eastwards into Bangladesh.

The Brahmaputra (the *Tsangpo* in Tibet) originates from the northern aspect of the Himalaya – little east of Lake Mansarovar in Tibet (China). 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 (p 52) shows the hydrographs of the Ganges and the Brahmaputra in Bangladesh.

Due to the interaction of the Bay of Bengal branch of the monsoon with the Himalaya and the hills in north-east India,

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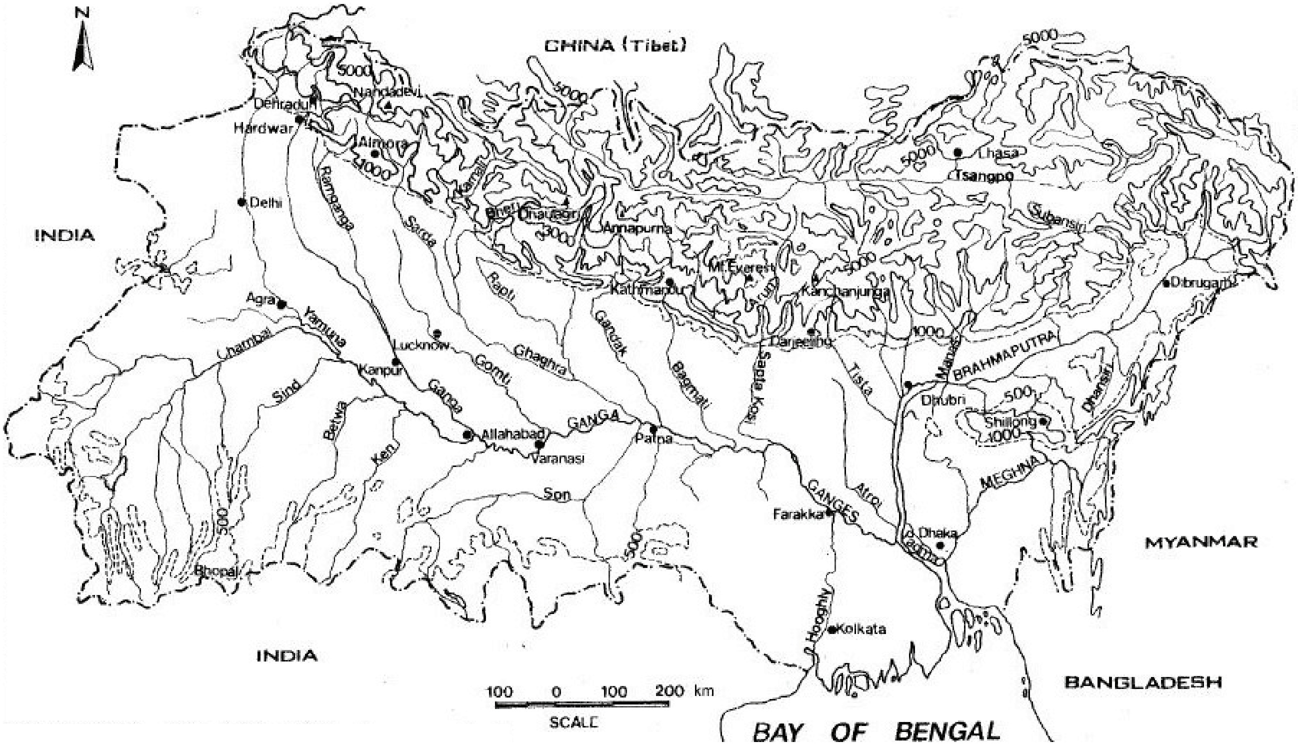
Jayanta Bandyopadhyay (*jayanta@iimcal.ac.in*) is with the Centre for Development and Environment Policy, Indian Institute of Management, Kolkata. Nilanjan Ghosh (*nilanjan.ghosh@taerindia.com*) is with the Takshashila Academia of Economic Research, Mumbai.

Figure 1: Physiographic Features of the GBM Basin



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, p 52). This disparity in precipitation is further aggravated by the wide temporal inequity as around 75% 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. Moderation of the combined effects of all the spatial and temporal disparities and dealing with the challenges of water use for poverty alleviation and promotion of well-being are the basic challenges for a collaborative water management in the basin.

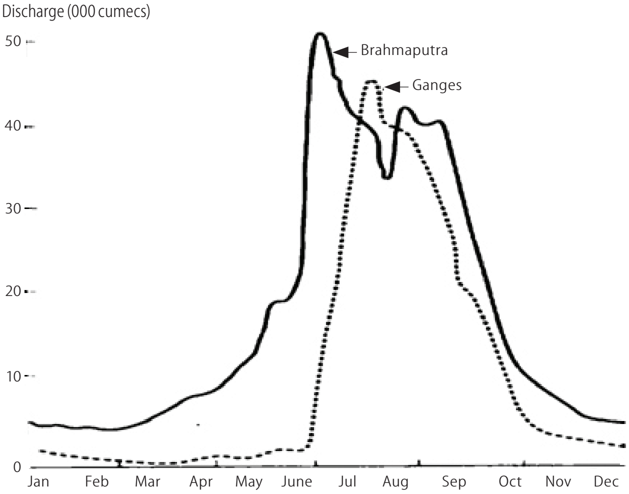
1 Ample Water, Ample Poverty

The high level of precipitation, annual run-off, and a large hydroelectric potential of more than 1,00,000 MW have been seen as enabling factors for economic development and poverty eradication in the basin (Verghese 1990). The basin is inhabited by as many as 535 million people. However, standing 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, Kolkata, and Dhaka. Between 1991 and 2001, the urban population in Bangladesh grew by 37%, while in Dhaka alone the growth was 55%. Interestingly, the percentage of population in absolute poverty (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.

So far, this paradox has not received much attention of development professionals. Damages from the regular annual inundations have often been cited by traditional economists as a major cause for the high level of poverty in the basin. Such explanations have been questioned (Bandyopadhyay 2009: 49-100) 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 effects of global climate change on the basin (World Bank 2009: 64-73) can be a common point for starting a new mode of hydro-diplomacy with holistic objectives.

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



1.1 Human Interventions in the Himalayan Rivers

The story of humanity and water in the GBM basin is the story of numerous anthropogenic interventions. 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 the 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 in that period provided young Indian students with training in the European tradition of water engineering. Early British projects on the Himalayan rivers 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 Haridwar near Roorkee.

In 1947, Partition enhanced the importance of transboundary status of a large number of major Himalayan rivers, like the Ganges, the Brahmaputra, and the Indus. In the 1960s, rapid expansion of water development projects was guided by the priority to food security of newly independent nations. This was closely followed by the development of hydropower projects. The more informal but political role of large projects in the redistribution of river waters should, however, not be underestimated. The Himalayan rivers, especially those providing snow and ice-melt flows, became increasingly important as sources of water for the plains during the lean period. With the enhanced transboundary nature of the rivers in the GBM basin, a new and urgent role was created for hydro-diplomacy in south Asia.

Hydro-diplomacy that followed was guided by the narrow objectives of traditional engineering. 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

Figure 3: Iso-hyets of the GBM Basin

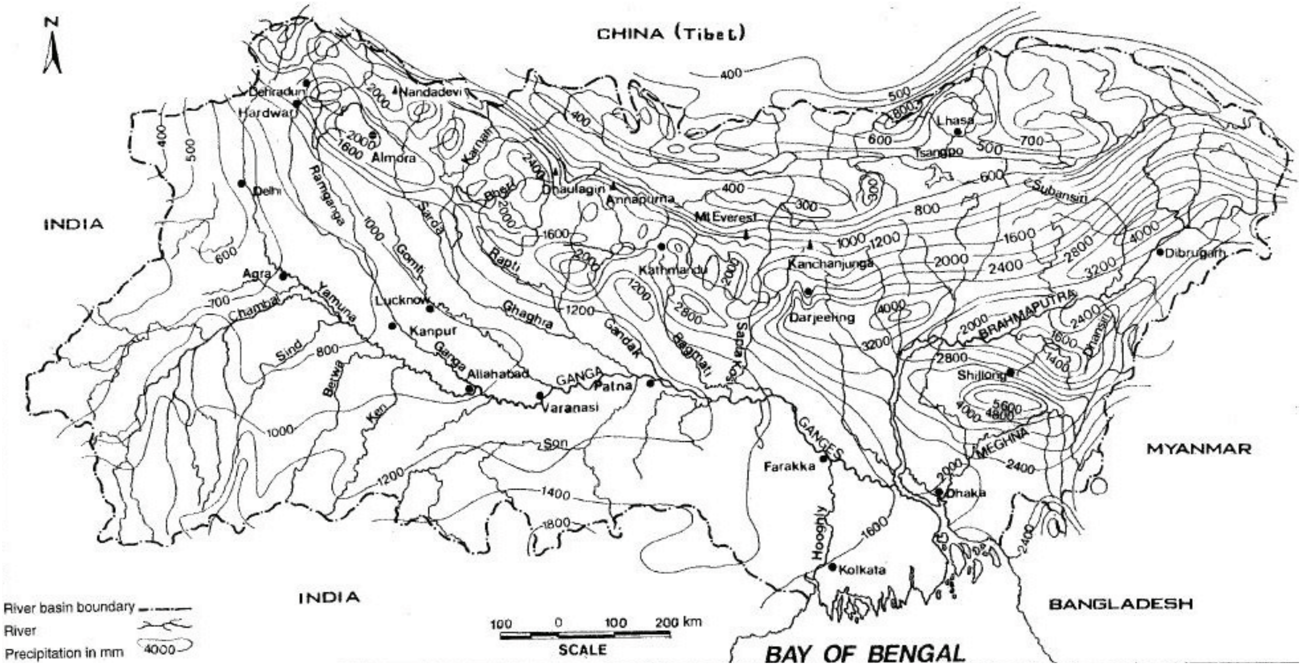
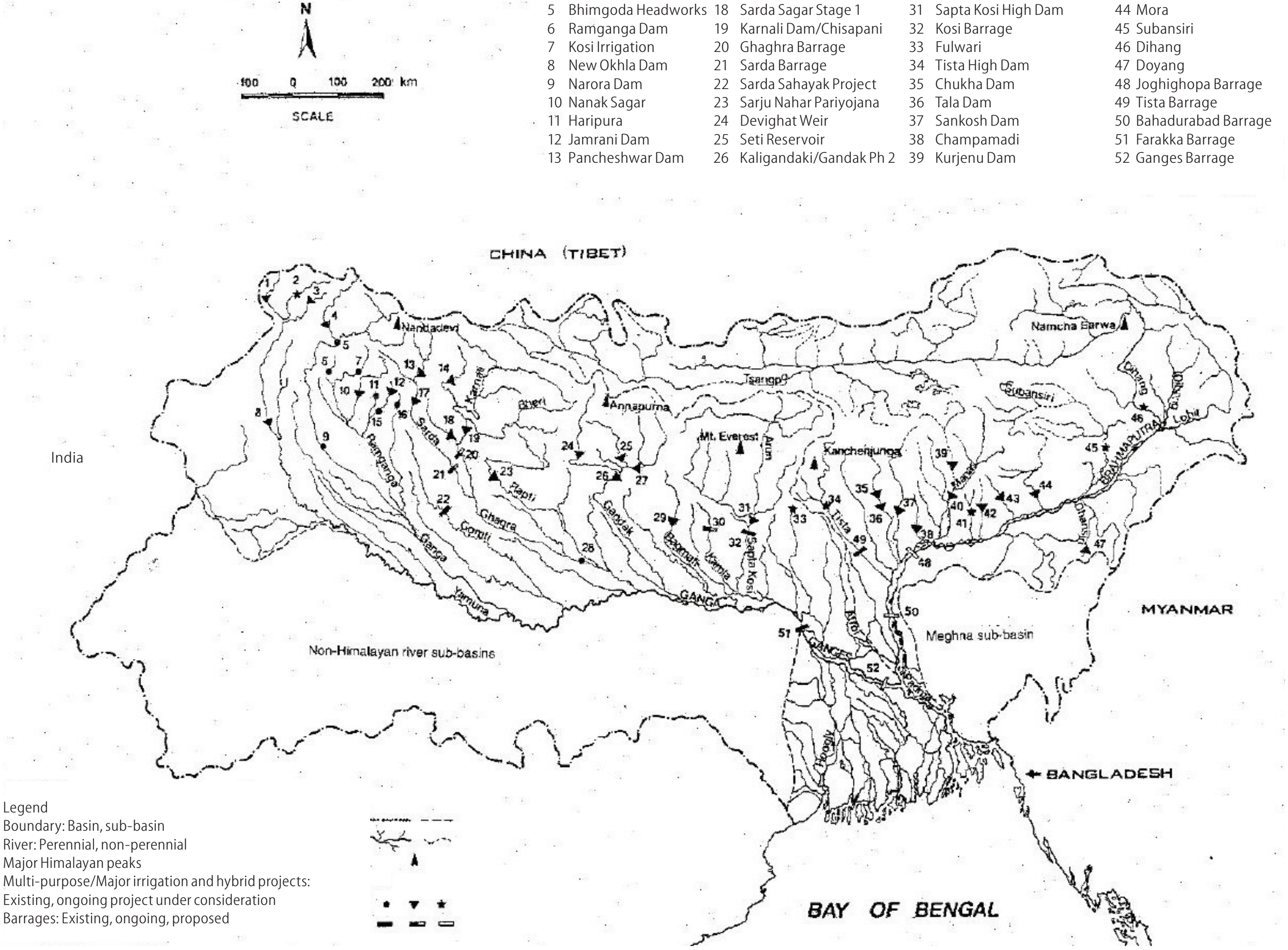


Figure 4: Existing and Planned Water Projects in the GBM Basin



1 Giri Dam
2 Kishau Dam
3 Lakhwarvyasi Dam
4 Tehri Dam
5 Bhimgoda Headworks
6 Ramganga Dam
7 Kosi Irrigation
8 New Okhla Dam
9 Narora Dam
10 Nanak Sagar
11 Haripura
12 Jamrani Dam
13 Pancheshwar Dam
14 West Seli Dam
15 Ebres
16 East Baigul Reservoir
17 Sarda Hydel works
18 Sarda Sagar Stage 1
19 Karnali Dam/Chisapani
20 Ghaghra Barrage
21 Sarda Barrage
22 Sarda Sahayak Project
23 Sarju Nahar Pariyojana
24 Devighat Weir
25 Seti Reservoir
26 Kaligandaki/Gandak Ph 2
27 Trishulganga Reservoir
28 Dohrighat Sahayak Stg 1&2
29 Bagmati
30 Kamla
31 Sapta Kosi High Dam
32 Kosi Barrage
33 Fulwari
34 Tista High Dam
35 Chukha Dam
36 Tala Dam
37 Sankosh Dam
38 Champamadi
39 Kurjenu Dam
40 Manas Dam
41 Pagladiya
42 Puthimarhi
43 Dhansiri
44 Mora
45 Subansiri
46 Dihang
47 Doyang
48 Joghighopa Barrage
49 Tista Barrage
50 Bahadurabad Barrage
51 Farakka Barrage
52 Ganges Barrage

Legend
Boundary: Basin, sub-basin
River: Perennial, non-perennial
Major Himalayan peaks
Multi-purpose/Major irrigation and hybrid projects:
Existing, ongoing project under consideration
Barrages: Existing, ongoing, proposed

gain from such projects as many important negative externalities are conveniently kept out of project assessment.

1.2 Unchanging Approach

Several important issues at various spatial levels operate in the GBM basin on the relation between the use of water and sustainable well-being. Some of those on larger spatial units and transboundary waters have been dealt with mainly at bilateral platforms. Agreement on flood forecasting and warning exists among the countries concerned. Guided by traditional engineering, quite a large number of major structural interventions are being made or planned in the GBM basin. Without addressing the complex and largely unexplored relationship between water and economic development in the GBM basin, these interventions are being heralded as vehicles of poverty removal in the basin (Ahmad et al 2001; Verghese 1990).

Probably, 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 hydroelectricity 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 hydroelectricity 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 hydroelectricity 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 one in 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 crore". However, in the holistic perspective of ecological engineering monsoon flows also provide important ecosystem services that should get recognised. 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.

Progress on large hydroelectric projects in the Nepal Himalaya, such as the Kosi, the Karnali, and the Mahakali, is slow. Subedi (2005) has analysed 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 1982; Mirza 2004). The feelings are based on the perception that 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 contrast with the GBM basin, the diplomatic process in the Indus basin was smoother and faster. A treaty was negotiated between India and Pakistan with the World Bank acting as facilitator. For the Ganges, no such international facilitation has been available. The Bhakra Dam on the Satluj or the Tehri Dam on the Bhagirathi are examples of major water projects on Himalayan rivers built in post-colonial India. The high political priority for such engineering interventions has remained unaltered during the last six decades of India's independence. Along the path of traditional engineering, large projects have received notable support as vehicles for rapid economic development in the basin (Verghese 1990; Ahmad et al 2001). Figure 4 (p 53) gives the location of existing and planned water projects on the Himalayan rivers in the GBM basin. It is clear that the official agenda for structural interventions in the Himalayan rivers of the GBM basin is large and will need enormous investment.

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. This has obstructed the generation of crucial interdisciplinary knowledge on the complex Himalayan river systems. 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. However, one positive externality of the delay in the progress with the projects in the years following India's independence is that ecological knowledge on rivers has advanced considerably. Today it is possible and is an imperative that a re-look of the projects on the Himalayan rivers with a much more comprehensive knowledge base be completed, before huge investments are committed to projects designed on the basis of an outdated knowledge.

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 12,500 kms 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.

1.3 Comprehensive Approach to Water Management and Hydro-Diplomacy

The story narrated so far clearly highlights the important intervention of the discipline of economics, as human intrusion into nature happens purely for satisfying economic needs, and the GBM basin is no exception to this age-old phenomenon. The new paradigm of water resource management, while emphasising managing demand for water, stresses the need for the right type of allocation creating the right type of trade-off between economic and ecosystem services of water.

Scholars stress that appropriate new economic instruments for promoting careful and efficient uses of water resources can address policy issues related to allocation and distribution of water (e g, Bandyopadhyay (2004), Holden and Thobani (1996), Tsur et al (2004) and many others). There has thus been the call for defining the new paradigm in terms of the new economics of water resources. This would provide an objective and impartial tool for integrated management of water resources not only to serve the purpose of proper allocation, but also to provide a complementary instrument to the legal framework at all levels.

The basic rationale of the intervention of economics in water resource management can be discerned from the canonical definition of economics. Water is scarce and needs to be allocated among competing ends, and economics, dealing with the "allocation of scarce resources among competing ends" (Robbins 1936), can provide effective devices to promote the best practices with the scarce water resources. At the same time, literature on the analytical techniques in conflict management buttresses the contention that economics can provide tools for resolving disputes (e g, Chatterji 1992; Isard and Smith 1967). Hence, though economic analyses on transboundary waters have remained a neglected field of research, in the context of globalisation and the consequent domination of the market system, clearer economic analyses can advance the process of identifying the basis of the conflicts and formulation of relevant policies to resolve them.

The element of economics inherent in transboundary water disputes has been unearthed by the various documented cases of water conflicts. One of the best references buttressing the same happens to be the "Transboundary Freshwater Disputes Database" project of the Department of Geosciences, Oregon State University (Wolf 1999; Wolf et al 2003). Ecological economics has emerged as an important discipline in dealing with the problems of water resource management, by helping the process of allocation, and prioritisation of resource use. While economic interests are present either explicitly or implicitly in water disputes, economic analysis is steadily becoming popular in probing into the various issues involved.

The GBM basin entails extensive human intervention into hydrological flows, primarily to satisfy certain myopic economic needs, without really delving into long-term economic, ecological, social and political implications. The inherent economics of water and poverty has been wrongly conceived in the basin, as will be explained in later sections of this paper. On the other hand, the missing fundamental understanding of Himalayan ecology has precluded the importance of applying important instruments provided by the discipline of ecological economics in the planning and policymaking process of the GBM basin. Neither has there been a proper understanding on how to emerge with the right type of institutional mechanism on regional cooperation, nor a detailed comprehensive evaluation of the types of costs and benefits that might evolve with the variety of hydro-political dynamics of the basin. Thus, there is an immense opportunity in the basin, in terms of creating a comprehensive interdisciplinary framework for evaluation and hydro-diplomacy with the discipline of economics being the backbone to the framework.

Economics, therefore, paves the way for the countries sharing the GBM basin to create a more comprehensive agenda for cooperation in water systems management at various spatial levels. Considerations of ecological characteristics in the adoption of a modern engineering approach in the basin and the promotion of a diversity of inputs in the design of hydro-diplomacy can become even more feasible. Based on the requirements of similar situations, quite significant policy changes have been accepted in many countries and are emerging in many others (Aylward et al 2005).

The need for such comprehensive approaches has been articulated by many in south Asia, for example, Datta (1999) and Das Gupta et al (2005) for Bangladesh, Ghosh-Bobba et al (1997) and Niemczyniwicz et al (1998) for India, Gyawali (2001) and Dixit et al (2004) for Nepal. In addition, there are many publications on the urgency for changing the way water governance is dealt with at present (Id21 Insights 2007). Salman and Upreti (2002) analysed the problems of hydro-diplomacy in the GBM basin in the backdrop of recent developments in international water law. Despite such calls all round, a new paradigm in water policy or hydro-diplomacy in the GBM basin is yet to be realised. In the changing perspectives and the changed background, this paper articulates the need and options for widening the present narrow framework of reductionist engineering to a comprehensive model of water systems management, negotiations and cooperation.

2 Changing Paradigm of Water Management

The "changing water paradigm" (Gleick 1998; Bandyopadhyay 2004) represents a fundamental shift in the way humans think about water. The realisation 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 ecological concerns (Gleick 2000). Continued investments in huge engineering interventions is being challenged by those who believe that a higher priority should be assigned to projects that meet basic and unmet human needs for water (Gleick 1996). The US, 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).

The World Commission on Dams (WCD 2000) drew global attention to the problem of limited vision of the reductionist traditional engineering approach to the rivers. A host of literature has drawn up the pathways of the emerging paradigm of water resource management (Bandyopadhyay 2004; Falkenmark 2003; Falkenmark et al 2004) as summarised below.

2.1 Collection of Productive Ecosystems

The reductionist perspective of traditional engineering prescribes supply augmentation as the main use of the rivers. New knowledge has thrown new light on the diverse ecological processes and services associated with the river systems. This has created a fundamental transformation in the way rivers have so far been seen and used by traditional views of engineering. Slowly but steadily the perception of rivers has changed from that of a stock of natural resource (water) that is available for storage, transfer, allocation, and use according to the priorities of the received view of economics and engineering. The rivers are now increasingly being seen as providers of extensive ecosystem services on which a large number of humans depend for survival and livelihood. In the new era of the emerging holistic paradigm, water is viewed as a totality of the global hydrological cycle (Bandyopadhyay 2004). It is now being recognised that the non-realisation of ecological cost due to water diversion elsewhere is an inbuilt subsidy to economic uses of water (Flessa 2004). Related values of water need to be recognised in the conceptual framework for development as well as hydro-diplomacy.

Given below some of the elements of such new perceptions:

(i) Supply of ever increasing volumes of water is not a prerequisite for continued economic growth: Under the traditional paradigm, the availability of increased supplies of water is seen as an essential precondition 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 away the conceptual focus from seeking only supply-side solutions and giving demand-side water management undue importance (Bandyopadhyay 2002, 2004; Gleick 2000; Falkenmark et al 2004).

(ii) Clear and strict prioritisation of various types of needs and demands for water is required, including those of the ecosystems:

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 ecosystems and the needs of human societies. The other is among the various needs of human societies (Bandyopadhyay 2004). Setting the right priorities through an understanding of the trade-offs is an important component of present day water resource management. Ghosh (2008) has stressed that comprehensive valuation of economic and ecosystem services at the scale of river basin can help in such prioritisation. This has been suggested in a scarcity-value framework, which is the value generated if the upper constraint on water availability is relaxed by a unit. This is essentially the shadow value of water emerging from optimisation.

(iii) There is a need for comprehensive assessment of water development projects keeping the integrity of the full hydrological cycle: A crucial element of the new and holistic paradigm is the creation of an interdisciplinary knowledge base that will offer non-partisan and comprehensive assessments of the justifications and impacts of water resource development projects (Bandyopadhyay 2004; Barbier and Thompson 1998). Thus, droughts and floods will be visualised in the wider context of the ecological changes associated with them.

(iv) Emergence of new socio-economic perspectives and water resource economics: The new paradigm emphasises the need for a new economic evaluation of water. The question of pricing of water, the desirability or otherwise of the growing trends of privatisation of water resources as the final solution, and the ecological-economic valuation of 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 US and China, among many others, are well into this paradigm shift (Bandyopadhyay 2004). Such a framework will also deal with the need for restructuring institutional frameworks for water resource development at local, state, river basin, and national levels for making it equitable, sustainable, and participatory.

2.2 Gaps in Knowledge

This global change in knowledge has not affected official practices in south Asia, despite clear suggestions from various professional viewpoints. The traditional viewpoint is exemplified by the publication *Major River Basins of India: An Overview* (MOWR 1989). This document still provides the official engineering agenda for India's rivers. The document describes the planned development of surface water and hydropower projects in the basins in details. However, very little or no information is given on the physiographic and ecological characteristics of the basins. The document does not mention the various ecological processes that keep the natural productivity of the riparian ecosystems and contribute to the livelihood of a large number of people. Given that narrowly perceived economic benefits are of sole concern, it was thought that water diversion was the only key to development.

Several analysts have stressed that it is imperative to understand and internalise the ecological characteristics of the basin given the knowledge gaps and uncertainties that are integral to the Himalaya (Thompson et al 2007; Bandyopadhyay 1992; Ives and Messerli 1989). Crucial elements of this uncertainty are in the consequences of the great differences in the peak and base flows in the Himalayan rivers; the generation, transportation, and deposition of high sediment loads; the rapid changes in the river courses in the foothills and flood plains; the relationship of the flow with large biological productivity of the river; the impact of climate change on the hydrological features, estuaries and the coastal areas; and so on.

The ecological complexity of the GBM basin is further accentuated by the lack of adequate data and knowledge of the ecological processes associated with the Himalayan rivers (Bandyopadhyay 1992, 1995; Bandyopadhyay et al 1997). This new knowledge must become a priority if the GBM basin has to break the logjam in the progress of cooperative river management. The intense monsoonal rainfall on the geologically unconsolidated and tectonically active Himalaya makes the associated ecological processes complex. The Himalaya generates very large sediment loads in the rivers. This is particularly true for the rivers emerging from the eastern Himalaya, where the monsoon precipitation is the most intense. Thus, in the eco-hydrological description, rivers emerging from the eastern Himalaya are to be taken as constituting a combined flow of sediment, water, and energy. For example, the Kosi, a Himalayan tributary to the Ganges, carries 8.220 tonnes of sediment annually per sq km of catchment area, while the Teesta, a Himalayan tributary to the Brahmaputra, has recorded annual sediment load of 12,510 tonnes per sq km. Further to the east, tributaries of the Brahmaputra like the Dibang, the Subansiri, the Manas, and many others also carry large amounts of sediment. Integration of the knowledge of the dynamics of the sediments with the flow of water would make engineering more ecological. The absence of ecological engineering in the design of water projects is exemplified by the Farakka Barrage. Mallik and Bandyopadhyay (2004) have analysed the shortcomings of the barrage in the context of the eastward movement of the river upstream of the barrage.

For bridging the gaps, research publications in the public domain have to receive recognition and serious attention in governmental policies and decisions. The gap will be evident from the citation patterns of official documents on water development projects. The much-needed exchange of views between government engineers and independent water professionals, necessary for the advancement of knowledge, is absent. This has fuelled mutual suspicion not only between officials and independent experts but among co-riparian countries taking part in negotiations.

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, ignoring of long-run economic costs, etc. By not engaging with critical opinions, 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 in south Asia.

Research on these subjects and creation of new knowledge has been going on all over the world. 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. Moreover, 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.

2.2.1 Incomplete Economics, Disrupted Hydro-Diplomacy

For several years, a fundamental rethink on the presently followed narrow economic understanding of water projects has been going on. Feasibility studies on governmental projects related to water in India have been done with very narrow perspective of economics and little recognition of the broader social and ecological dimensions. The problem was never with the discipline of economics, but of the vision with which it was put to use. Feasibility studies were confined to cost-benefit analyses, consisting of some inconsequential parts of the costs and a large part of the benefits. In the case of irrigation projects, the benefit-cost ratio was inflated on paper by considering that command area land would receive irrigation water, while rarely taking into consideration the ecological costs of stream-flow diversion, depletion, and consequent damages to the ecosystem services. Quite disappointingly, holistic economic evaluation consisting of all these parameters has not featured in the governmental feasibility reports.

Yet, worldwide, replicable comprehensive models of economic evaluation of water systems are many. Bouhia (2001) has tried to extend the economic framework for the understanding of the effects and assessment of water projects. Ghosh and Bandyopadhyay (2009a) have interpreted upstream-downstream economic relations in a river basin in the neoclassical scarcity value framework, while Crow and Singh (2008) have analysed the institutional opportunities available for a more dynamic regional cooperation in the basin. Such efforts are of great potential as the contending demands on the available supplies mount.

On the other hand, there is a huge gap in the economic literature in south Asia, and on issues on the economics of hydropolitics. A few attempts on the contentious south Indian river basins have been made (e g, Ghosh and Bandyopadhyay 2009a), but none exists on the GBM basin. In various other contexts, game theoretic frameworks offer an indicative explanation of the nature of conflictual equilibrium that exists in the basin. The most potent explanation of course arises from the prisoner's dilemma type frameworks and asymmetric information models, where mutual distrust plays a crucial role in the creation of hostile hydropolitics. The entire negotiation process, thus, gets pushed to a zero-sum situation, where simple reallocation of property rights can lead to pure conflict. As rightly put forward by Crow and Singh (2000), one of the prime reasons for this non-cooperative behaviour is the existence of inherent bilateralism in negotiations (as opposed to multilateralism), and non-existence of water markets. The emergence of China as a possible big player in the basin who could make possible interventions in the flow of the Tsangpo for hydropower or for transfer outside the basin adds to both the potential and complexity of hydro-diplomacy. Here the economics of property rights and institutions can play an important role.

Such studies can help in filling the huge gap in hydro-diplomacy. Contrary to the progress in cooperative management of many international river basins where stronger potentials for conflicts existed, such as in the Nile, the Rhine, and the Mekong, the progress of hydro-diplomacy for the GBM basin has remained quite slow and narrow. One major reason for this has been the exclusive approach to hydro-diplomacy in the basin. Thus, the possibility of a new paradigm in water policy and hydro-diplomacy on the GBM basin has become very remote (Bandyopadhyay 2002).

3 Broadened Framework for Hydro-Diplomacy

Undoubtedly, the entire hydro-diplomatic process in the GBM basin needs to be viewed in a broadened framework, and not merely through the prism of water and poverty. This will entail the inclusion of several factors, such as ecology, economics, institutions, and the social, in the framework of water resource engineering. This changed perspective will make room for a very different functional format for making development policies in river basins and conducting related hydro-diplomacy.

3.1 Ecology-Livelihood Linkage

The perspective of rivers as a collection of productive ecosystems will greatly enhance and facilitate the process of the evolution of ecological engineering and related hydro-diplomacy in the basin. The growing recognition of the importance of the services ecosystems perform has been highlighted in the report of the Millennium Ecosystem Assessment (2005). For example, while traditional engineering would view flood as a "disaster", the ecosystems service perspective will view it as a valuable free service of nature in cleaning up the river beds of sediments, enriching the floodplains with fertile silt and biodiversity, recharging groundwater in the floodplains, and so on. Similarly, upstream diversions are shown to add value to agriculture in irrigated areas. The decline in the downstream fishing economy all along the river or the enhanced salinity ingress does not get considered in the project appraisal process, 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).

In the past few years, satisfying the Environmental Flows Requirements (EFR) of rivers has become a growing commitment in water management. It has been realised that the needs of the natural ecosystems are not merely quantitative, but there are well-set periodic patterns of the flows that also need to be protected. Such qualitative aspects of the flows are much needed for ecosystems to maintain their productivity. Emerton and Bos (2004) provided an early push for the transformation of the traditional view of rivers, from a stock of resource to a flow that keeps the diverse ecosystems functioning, all the way from the upland catchments to the estuary and the coastal ecosystems. In this perspective, ecosystem processes are seen to act as water infrastructures performing several tasks.

3.2 Perspective of Economic Valuation

In addition to the emerging ecological point of view, a fundamental rethink on the economics of water has also been going on. Economic values are being identified with ecosystem processes (Ghosh and

Bandyopadhyay 2009b); something that was not possible during the early years of major engineering interventions in rivers. Though such valuations are done with big approximations, they are proving to be useful in internalising factors that were totally externalised 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).

Bouhia (2001) has extended the economic valuation framework for the understanding of the impacts and assessment of water projects. The framework has further been extended by the valuation of river systems (Hitzhusen 2007). For India, Desai (undated) has suggested a similar expansion of the valuation framework in the assessment of projects, though, in reality, little has been done to expand the framework. 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.

3.2.1 Inclusive Valuation Framework

It is critically important to choose the right valuation mechanism or pricing for water. Here, an inclusive valuation framework that would encompass the various issues of ecology, economy, and society is needed. In the inclusive valuation framework, 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 is discussed.

In the inclusive valuation framework, the ecosystem and its services are being accounted for and included in the national account statistics of the economy. The important part of this framework is not only to incorporate the monetary values of the natural ecosystems, but also to incorporate values in the input-output (I-O) matrix of the macroeconomy, and delineate its values as intermediate or final goods and services as applicable in the I-O matrix. Several such SES can be defined in the Ganges sub-basin where welfare change through changes in environmental inputs can be traced, and where externalities play an important role. One example can be the loss to fishermen due to reduced catch of fish and crustacean species in the lower Ganges as 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. On the other hand, the services provided by the highland community to the plains, by preserving the water output and quality, also deserve to be compensated, based on the nature of the SES, as also the ecological services. Hence, the inclusive valuation framework moots an integrated approach to include social values, economic contributions as well as ecosystem services provided by the hydrological cycle.

3.3 Institutional Perspective

While institutional economics has an important role to play in water management, the most succinct statement in respect of the GBM basin has emerged from Crow and Singh (2000). They have highlighted two sets of possibilities. The first is extending bilateral barter to multilateral exchange, and the second is expanding negotiations from conventional diplomacy to incorporate private economic actors. However, policymakers have to internalise the diverse aspects of the "transboundary" status of the GBM basin. This needs to be understood from the literature base that has emerged in the new millennium, which has defined water crossing any boundary (geographical boundaries which entail international to the most micro-level; and even sectoral boundaries) as "transboundary" water. The latest sectoral conflict over water that has emerged in the basin is between the economic sectors and the ecological sector. The traditional modes of defining property rights as was existing in western US historically (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. It is therefore better to have peaceful modes of negotiations for defining property rights as defined by the Hobbesian doctrine (Richards and Singh 2001). Just as Crow and Singh (2000) propose multilateral exchange and incorporation of private economic actors in negotiations, this paper proposes a mechanism by combining both proposals. This is in the form of emergence of water markets in the basin.

3.3.1 Development of 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.

Once a baseline valuation of water resources can be obtained, it will facilitate the development of a south Asian water market. While a customised forward contract can exist between nations on water sharing, in a more mature framework, one can think of a futures market where standardised contracts can be traded. This can have considerable significance for dispute resolution and scarcity mitigation. An efficient futures market for water can help in the price discovery of water. Of course, this will require multi-level participations from all the nations in the region. With proper information dissemination, this price will reflect upon the scarcity value of the resource. On the other hand, on the expiry of the contract, rather than physical delivery of the resource (unless a hedge has been rolled over), the settlement can take place at the scarcity value, which will be reflected by the estimated loss due to water scarcity, as shown by Ghosh (2008) and Ghosh and Bandyopadhyay (2009a). The notion of virtual water[1] will be useful in this context (Allan 1998). However, for getting into such mature market frameworks, probably some beginning can be made with forward contracts on dry season flows, and that too, with a proper exchange of information across the various stakeholders.

4 The Way Ahead

The GBM basin is in need of a breakthrough in water management. In order that an effective dynamism can be introduced in the present scenario for the GBM basin represented by a traditional engineering perspective of what needs to be done and a hydro-diplomacy showing slow results following that prescription, the steps identified are being suggested:

(a) Cooperation between and among countries sharing the GBM basin be based on a perspective of the Himalayan rivers as functioning ecosystems, informed by scientific knowledge on the ecosystem services they provide. Negotiations at bilateral or multilateral levels need to be taken up; as the situation merits.

(b) The most critical concern arises with the non-availability of data at public forum on transboundary hydrological flows, and some other associated important variables in the basin. The governments in south Asia have kept such data on the international river basins as "classified", and hence out of public domain. This has totally restricted independent and non-partisan assessments at the scale of the river basin. It is important that there is transparency in information dissemination among the various nations, with data being made available to the scientific community for independent scientific assessments. Without this condition being satisfied, no framework of hydro-diplomacy can lead to a fruitful and a sustainable result.

(c) It is urgent that the effects of climate change on water availability in and ecosystem services of the Himalayan rivers is studied by all countries and given serious consideration in the making of such an ecological perspective.

(d) The annual inundations of flood plains during the monsoon need to be viewed as an anticipated natural process and not routinely described as natural disasters. The ecosystem services provided by monsoon flows in the transportation of the high sediment load in the Himalayan rivers may be studied and accepted as a crucial ecosystem service.

(e) Scope and objectives of structural interventions in these rivers need to be expanded beyond the present preoccupation with water supply and hydropower generation. Structures may play wider roles like ensuring environmental flows and ecosystem productivity.

(f) More comprehensive methods for the assessment and approval of water projects may be employed right from the stage of pre-feasibility studies. There is a need to think of comprehensive evaluation for the "inclusive valuation" framework.

(g) Economics can play an important role through institution building (creation of water markets), as also providing an objective tool for conflict resolution (by the right type of valuation). All the points raised above rest on the fundamental contention of economics providing the backbone to the analysis of hydro-diplomacy.

(h) While the final authority in diplomacy would remain with respective governments, the requirement of inducting diverse knowledge and viewpoints makes it imperative that the foundation for hydro-diplomacy be inclusive and multi-track.

India being the most powerful country in south Asia politically, economically, and technically and having a high level of diplomatic competence, has a special responsibility for taking the lead in bringing about a closer cooperation in the GBM basin. An important diplomatic task lies in changing the negative feelings of the co-riparian countries like Nepal and Bangladesh toward cooperation. Such a situation has largely resulted from a diplomacy that was exclusively guided by objectives identified by traditional river engineering. The engineering community in India has a great standing in traditional engineering and is sure to have the same standing in ecological engineering in a few years. If ecological engineering is used for the management of the Himalayan rivers, the scope and objectives of hydro-diplomacy will get diversified. If, for example, pricing of water for irrigation is practised, there will be a move toward optimal and efficient use of water which is paid for (Ghosh 2008: 29; Ghosh and Bandyopadhyay 2009a). This will correct the impression of countries like Nepal that see inequity in the agreements.

5 Conclusions

The South Asian Association for Regional Cooperation (SAARC) was established for the promotion of regional cooperation. While the rivers connect several countries in the region, and thus, their cooperative management is very important for the economic development of the basin, hydro-diplomacy on the Himalayan rivers has not been on the agenda of SAARC in any serious manner. In fact, the most recent water-related cooperations date back to 1996 when the India-Bangladesh Treaty on the sharing of the lean flow of the Ganges and the treaty between India and Nepal on projects on the Mahakali were entered into. One of the oldest bilateral negotiations between India and Nepal on the river Kosi has been going on for several decades. Such negotiations now need to be rethought from an eco-hydrological perspective in the comprehensive economic framework, as conceived in this paper. In addition, such an agenda should include the opening up of hydro-diplomatic exchanges with China on the projects China plans to take up upstream of the Brahmaputra. In recent years, the SAARC has achieved some quick progress on cooperation on developmental issues like trade and industry.

With advances in economics, serious thought has been given to the economic role of water for its consumptive use as well as for the basis of trade in south Asia (Bhaduri and Barbier 2003). The highly competent diplomatic core of India will surely understand the arguments behind this paper. A review of the writings from Bangladesh and Nepal on various water-related treaties and agreements clearly bring out the feeling of suspicion and anger of the smaller countries. For Bangladesh, whether it is the older writings of Abbas (1982) or the more recent ones of Mirza (2004), they all express a feeling of entering into an unequal treaty. On the other hand, a recent and comprehensive review of water relations between India and Nepal (Dhungel and Pun 2009) reinforces such a feeling among senior Nepalese water professionals. For Indian hydro-diplomacy to be effective and not get bogged down in narrow engineering projects, the approach to diplomacy needs to be inclusive, and be based on the inclusive valuation framework. Inclusiveness has to be from diverse disciplines and diverse stakeholders. Never before has the challenge of poverty alleviation depended on the art of hydro-diplomacy and the science of ecological engineering as it does in the GBM basin today; and never before has the role of economics in providing a comprehensive evaluation framework needed a re-emphasis, as it is needed in the GBM basin today.

NOTE

1 Virtual water is the water entailed in the production of commodities, especially agricultural commodities.

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