Chapter 8
Towards Better Human–Environment Interactions

Abstract The Damodar riverbed has provided a home for marginalized communities, but the riverine environment itself has deteriorated; presenting us with a challenge to develop a more holistic and sustainable water management system. There should be a mix of structural and non-structural measures that acknowledge and incorporate local cultural attitudes, experience and knowledge. For effective water resource management, river communities must be part of the effort so their interests are aligned with the aims of the project and they feel committed to the success of the endeavor. River regimes should be treated as economic assets since ongoing economic and human development depend on an ecologically sound riverine environment.

Keywords Cultural attitude · Ecologically sound · Holistic · Integrated water resource management · River community · River regime

8.1 Discussions and Suggestions

Human beings through millennia have impacted the fluvial environment, directly through engineering projects (Leopold et al. 1964; Agarwal and Narain 1997; Bhattacharyya 1998, 1999; Gregory 2006) and indirectly through changing land use and landscape (Nüsser 2001; Goudie 2006a, b; Wohl 2006; Wohl et al. 2009; Kondolf et al. 2007; Kummu and Sarkkula 2008; Richter et al. 2010). The natural resources of the planet are now controlled mostly by anthropogenic forces rather than natural forces (Turner et al. 1990; Misserli et al. 2000), a dynamic that has led to the suggestion that the current geological epoch be renamed "Anthropocene" in place of "Holocene" (Crutzen and Stoermer 2000; Ehler 2008; Zalasiewicz et al. 2008).

The Damodar River has been controlled by government and riparian communities through the centuries using macro- and micro-level planning and river training programs. Embankments, canals, sluices, weirs, dykes, barrages, dams, and reservoirs are now integral components of a historically conditioned geomorphic

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landscape (Bhattacharyya 1998, 1999–2000a, 2008b). The Damodar River landscape therefore, like other major rivers of the world today, is ordinarily shaped by anthropogenic processes. Though geomorphologists are a bit skeptical that these alterations have "permanently altered the river dimensions. As we know from fluvial geomorphology, nothing is permanent – certainly not in the scale of millennia" (Personal communication with R Sengupta, October 12, 2010).

River basin planning has long been viewed from a management perspective as an ecologically-sound and economically cost-effective means of reconciling the conflicting objectives of development and conservation (Wengert 1985). Rivers are integrators of the landscape that they drain. So hydrological, geomorphological and biological assessment can provide indicators of ecological health across broad spatial scales (Allan and Johnson 1997; Riseng et al. 2010). In 1890s John Powell, an American land use planner, proposed organization of water management by basin-scale as essential concomitants of a wise development plan (Grantham et al. 2008), which was never implemented. In the Tennessee Valley, basin-scale management agencies are not existent or have little power. There is very little geographical integration as well as interdisciplinary integration in the management of water resources (Grantham et al. 2008).

River valley projects were seen as symbols of social development and technological achievement in the mid-century. From 1960 onwards several investigations were initiated globally for a number of projects such as the Kariba, Volta, Aswan, and Lower Meckenzi. By 1970, however, criticism of large river-valley projects from different angles became increasingly common. Dams provide many benefits by reducing flood flows, providing irrigation water, and securing the life of people in downstream sectors by generating electricity. But with these benefits come environmental consequences i.e. changing flow regime, eroding river banks and river sandbars, and concerns for safe recreational use. Despite their benefits, it is undeniable that control structures strongly impact the natural environment and lives of people, often in very negative ways (McCully 2001; Dharmadhikary 2005, 2008; D'Souza 2006, 2008; Molle et al. 2009; Baghel and Nüsser 2010).

There has been intense social and environmental debate worldwide about the need for water control structures and ways of mitigating their negative impact. Recently the Narmada Valley project in India and the Three Gorges dam of China have provoked bitter controversy. In some cases, existing dams have even been decommissioned in parts of the developed world. Criticism of large dams, endorsed to some extent by the 2000 World Commission on Dams (WCD) report, overlooks pressing problems in developing countries that are addressed by large dams. It is recognized that a number of environmentalists and non-governmental organizations (NGOs) have played a vital role in increasing the awareness of dam engineers and supporting them in planning environmentally sustainable dam projects. On the other hand, there have also been demands for total cessation of all dam construction (Gupta 1998). According to Gupta (1998),

> If these directives on dams would have strictly been followed during the 20th century, there would not have been most of the existing, even well planned, designed and constructed

major dams and hydropower projects, providing the needed additional water sources, flood control, protection against drought, and power generation around the world.

This would have severely hampered the development of many countries. A recent careful evaluation of the Aswan Dam's impact on Egypt concludes that it has been overwhelmingly beneficial to the country (Biswas 2003). The Sunday Express (2003, June 8th Edition) stated that the positive impact of the Narmada dam project has finally been recognized. The current debate on CO_2 reduction through hydropower revitalizes the global discussion of large dams by placing them as so called “green” alternatives (Baghel and Nüsser 2010).

I believe that the Damodar river control project, like many others, has been extremely beneficial (Tables 3.5 and 3.6). The DVC has developed a large number of thermal power plants which are a major supplier of electricity in the region encouraging huge industrial growth. Irrigation potential has been drastically increased (Bhattacharyya 2002). In the Damodar River, human intervention through control structures has augmented the resource potential of the river and the dependence on the Damodar has increased over the years with increasing encroachment on the riverbed. The geo-fluvial resources, a series of sandbars on the river, were once perceived as unproductive by the local agrarian community. People previously used those resources only in the form of silt but now the semi-fluid or flexible resource have been exploited into a permanent resource in the form of productive sandbars (Bhattacharyya 2008a, b). Professor M. Gordon (Reds) Wolman while talking about riverbed settlers of the Damodar River, wrote (personal communication, January 11, 2007) “The land use, cropping and settlement patterns, at a micro level, represent a sophisticated understanding of the flood regime and opportunities to maximize the productive capacity of an unpromising environment”. While people benefit, however, the river ecosystem deteriorates and we need strategies to safeguard this valuable ecological resource as well. The lower parts of the Lower Damodar i.e., Amta channel, has deteriorated so much that it cannot cope with excess water released from an upstream reservoirs. It is too early to state conclusively that excessive aggradation is due to control structures since, in the studied section, sediment is also supplied from an extensive unconfined section, particularly in the Ranigunj coalfield area. What must be noted is that the entire physical system should be taken into account before the impact of river control measures or human impact on the downstream environment is assessed. Insights gathered from geomorphologists may be useful but flood and water resource management requires a comprehensive approach to floodplain problems and a synchronized effort by geomorphologists, geologists, ecologists, water resource engineers, land use planners, economists, foresters, recreation and environmental specialists, and riparian communities.

Reviewing the history of floods and flood control in the Lower Damodar, it is clear that doing away completely with floods is neither possible nor desirable. Despite great success in the reduction of floods, they remain problematic and potentially devastating as in 1978. Furthermore, even if a river could be brought under complete control, a total lack of floods would only lead to ecological deterioration of the river system as is evident in the Lower Damodar River. It is important to remember that, with a dam in place, we forego an entirely natural environment below a dam (Collier et al. 1996). The responsibility of ensuring the ecological health of the river, therefore, falls on us. Doyle et al. (2005) has also outlined this reduced range of floods on ecosystem processes. Clearly, an alternate perspective is needed; one that views the river more as an ally than an adversary, one that apprehends not only the hazards of floods but also the benefits. The goal should be not to eliminate floods but to incorporate them within our water management strategy, as with "flushing floods" discussed below. Only such an intelligent strategy, based more on understanding of the river system than solely on the attempt to control, can ensure a balanced and sustainable outcome in meeting the diverse needs of the people who live with the river.

Many impacts of dams are technologically impossible to mitigate if dams are to offer their planned benefits (Bergkamp et al. 2000). The WCD recommended thorough periodic reevaluation of the facilities, operation and performance of dams every 5–10 years (River Revival Bulletin No 22, Nov 29, 2000). While addressing large dams, the WCD has also identified programs to restore, improve, and optimize benefits from existing dams (WCD Report, Nov 2000). The WCD model was regarded widely as a unique experiment in global public policy making (Srinivas 2001; Bandyopadhyay 2002; Bandyopadhyay et al. 2002; Brinkerhoff 2002; Dubash 2009). The country review studies prepared by the WCD on Dams, however, were deemed unsatisfactory by many countries and water professionals as stated before.

Within the last decade, river resource management policy has undergone a major paradigm shifts (Pahl-Wostl et al. 2007) from an initial focus on water chemistry to increased acknowledgment of the importance of aquatic ecology and the role of geomorphology in balancing riverine ecosystem function (Grantham et al. 2008). The concept of a river basin as a management or planning unit reemerged in the 1990s as a foundation stone of integrated Water Resources Management (IWRM), enriched and intermingled with watershed and ecosystem management approaches (Molle 2006). The European Union's Water Framework Directive (WFD) defines a new strategy for meeting human demands while protecting environmental demands and values and may be helpful in informing water management practices and policies in different regions of the world. The WFD sets focus on basin-scale, public participatory and environmental economics approaches as well as establishes a holistic environmental assessment method according to which water status is defined by its ecological, chemical and in the case of ground water, quantitative status (WFD 2000; Grantham et al. 2008). Maybe we can think of better human environment interactions through holistic watershed management i.e., "treating the catchment areas, harnessing waters before they reached the major rivers and establishing vegetative cover were felt to be better suited for flood management" (Lacy 2006), and "Integrated water resources management (IWRM)" which is "now recognized across the world as the process to promote the coordinated development and management of water, land and related resources in river basins, to maximize the economic benefits and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Pangare et al. 2009). Keeping this in view, some recommendations for the Damodar River are provided below.

1. One vital area of emerging scientific knowledge is the assessment of "flushing floods" (DVC 1957a), "beach building flows" (Schmidt 1992), "habitat-maintenance flow" (US Department of Interior 1995), or Environmental Flow Requirements (EFRs), which deal with the amount, timing, and conditions under which water should be discharged from the dams to retain the natural integrity of the downstream river ecosystem (Bergkamp et al. 2000). For the maintenance of the downstream ecosystem, there is a need for flushing floods. In fact, this was suggested earlier by the DVC itself (DVC 1957a). Flushing of the early storms through the reservoirs will help scour the main channel and, at the same time, will route the sediment-laden flow through the impoundment. At the end of the flushing period, the bottom sluices are closed and reservoirs are operated normally until the end of the next dry season when the same process can be repeated. In India, where many dams lack the high-capacity bottom sluices required for flushing, reconstruction would be required to provide sediment-proof low level outlets. Though it is expensive, reconstruction is less costly than dredging or abandonment of reservoirs (Morris 1995). Sediment routing during the first half of the monsoon months has not been successfully employed in India and in the DVC. In order to preserve the long-term storage capacity of reservoirs, it is necessary to pull the reservoir down to a low level at the beginning of the monsoon. On the other hand, in order to maximize the power generation, it is desirable to maintain the water level over the turbines at the highest possible level. Moreover, irrigation and power have opposing claims and their demand does not coincide. As an instance, the Damodar Valley Corporation (DVC) wants to operate the dam for optimization of power benefits, whereas the West Bengal Government wants more water for irrigation downstream (Bhattacharyya 2003).
2. Previously the Lower Damodar used to adjust with excess discharge through a well defined distributary system on the left and spill channels on the right. The connection between the Damodar and the distributary channels must be revived. Connection between the Damodar and the Banka must be restored. The artificial separation of the Banka from the mother stream has increased flood hazards in the Banka basin. So re-opening of the Jujuti sluice may solve this problem. According to Opperman et al. (2009), reconnection to rivers is helpful for sustainable floodplain management.
3. Embankments should be properly maintained during life span of the barrage and reservoirs. To cope with shifting banklines, embankments are usually retired. On the Amta Channel, multiple retirements have been observed on the left bank. But more important is the proper maintenance of the embankments. It is suggested, therefore, that earthen embankments be strengthened using soft engineering approaches. Embankments should be clothed with vegetation.
4. Had all the eight DVC dams been constructed or taken up per design assumptions, the design flood would have been moderated to 7,080 m^3/s. While the four dams have served their purpose, the lower part of the Amta channel is not capable of carrying a discharge of 849.6 m^3/s. Despite control structures, drainage congestion is still a problem below Paikpara, thus underlining the need

for an immediate solution of the problem of drainage congestion of the lower reaches in order to derive the maximum benefits of flood moderation. A separate drainage scheme is required for the Amta channel.

5. A permanent thalweg is needed to maintain a perennial thalweg flushing flood. Perenniality of the thalweg can be achieved if a more uniform streamflow pattern is maintained and extreme seasonal peak streamflow is evened out by creating some check dams. Controlled releases should be maintained without excessive flooding of the populated char lands while at the same time sustaining sufficient channel capacity to carry many common floods of frequent recurrence (personal communication with M.G. Wolman, April 10 1996).
6. Careful analysis of storage requirements, adequate management, and proper distribution of floodwater should be emphasized. There is a need for integrated flood management, with coordinated development and management of water, land, and related resources in the basin/sub-basin as a means of restoring at least active channel areas and geomorphic complexity of the shrunken systems downstream (Graf 2006).
7. The most crucial problem in the Lower Damodar, however, is that of anthropogenic stabilization of the active riverbed by the riverbed occupiers. The problem has taken a different dimension as most of the riverbed occupiers are Bangladeshi refugees. Refugee issues are very sensitive ones, and always politicized. Since many other riverbeds in West Bengal have become second homes of the refugees, colonization in the riverbed and stabilization of bars due to year-long cultivation are no longer local issues but also have regional dimensions. Lowering river water-level for quick-growing vegetables is a common seasonal practice throughout India. A few huts of rudimentary structure are always to be seen when riverbeds are put to agricultural uses. It is possible that some of the riverbeds of seasonal rivers of India will be occupied permanently in the near future due to population pressures and food crises. Increasing demand for space creates a pressure to utilize hazard zones, including flood-prone areas (Bird 1980). So it is not unlikely that riverbeds in other countries, particularly in tropical countries, will be occupied for permanent settlements and transient sand bars will become immobile causing channel deterioration. Stabilization of bars may have fortified the resource base of riverbed occupiers, but the Lower Damodar ecosystem has deteriorated. Other riverbeds of the Ajay, Bhagirathi-Hooghly, and Mahanadi with settlements may meet the same fate today or tomorrow. That is why it is crucial to settle the question of allowing permanent use of the active riverbed.

Relocation and resettlement of displaced populations for dam closure have always been a problem all over the world. Resettlement problems of active riverbed populations are of equal significance, if not more, particularly when the riverbed users are refugees. When the DVC was conceived these problems were not anticipated. In the case of the Lower Damodar the government's decision on land ownership issue in the active riverbed is not above criticism as permanent use of active riverbed has become detrimental for the river itself. Following are measures that can be taken to solve these problems:

a. Further encroachment on the active riverbed should be discouraged and a rational refugee rehabilitation policy is required.
b. Active riverbeds, floodplain and wetlands with the greatest ecological value should be delineated properly. Proper measures should be taken to avoid impacting active riverbeds and wetlands during development of char lands and floodplains. Increase of storage in the river system through floodplain and wetlands helps trapping more water in the catchment, thus lowering flood peaks (Kundzewicz and Kaczmarek 2000).
c. DVC should be very much aware of the problem of misuse and mismanagement of catchments and should take initiative to identify the priority area for catchment treatment as well as implementation of programs to lessen soil erosion and sediment generation (Chaudhuri 2006). Natural resources evaluation as well as public awareness must play a part in their reduction (Douglas 1981).
d. The knowledge of people in evaluating and managing their environment should be an important element of a comprehensive and participatory approach to flood management (Correia et al. 1998). The lack of efficient community participation is a significant barrier in developing regional governance strategies (O'Toole et al. 2009) and the involvement of the community in environmental monitoring should be an essential part of sustainable catchment management so that their interests are aligned with the aims of the project and they feel committed to the success of the endeavor.

8. Apart from the anthropogenic changes mentioned so far, the climate itself is being changed in ways we are just beginning to recognize. It is reported (Pottinger 2010) that catastrophic flooding in Pakistan, dam breaks around the world, and drought-caused blackouts in Africa provide profound threats to our hydrological cycle and changes in river systems (Goudie 2006b). It poses danger to biodiversity and ecosystem services (Turner et al. 2010) and tens of millions of people are going to be displaced within this century (Dasgupta et al. 2009). "It's something that's been neglected, hasn't been talked about and it's something the world will have to do," said Rajendra Pachauri, chairman of the Intergovernmental Panel on Climate Change. "Adaptation is going to be absolutely crucial for some societies." (Borenstein 2009). In other words, growing water consumption, hydrological, land use, and climatic change acting together ensure that our rivers as well as our watersheds will face a future of rapid ecological change. This is also true for our Damodar River basin. Roy and Majumdar (2005) studied the impact of climate change on water resources of the Damodar River basin and observed that seasonal shifts in streamflow and precipitation pattern, changes in temperature will have a significant negative impact on river ecosystem.
9. After the 2000 flood in West Bengal, UNICEF initiated a program of "Community Based Disaster Preparedness (CBDP)." This type of CBDP and adaptation programs must be encouraged with easy access to information. An

adaptation strategies database should be developed based on long-standing adaptation strategies and community-developed knowledge from the riparian communities who have adapted to fluctuating flood regime in the Damodar riverbed.

10. An emphasis on non-structural measures including land use planning, flood plain zoning, flood proofing and developing a culture of community-based disaster preparedness should be the backbone of the program for the integrated river basin management (Bhattacharyya 2011 and personal communication with Ray C. February 15, 2008).
11. The Russian River case study in California demonstrates that WFD is not a 'silver bullet' that provides "simple solutions to challenging problems" but the "WFD can provide a useful framework for building the capacity of communities to conduct long-term planning at the basin-scale and manage water resources in a more deliberate and efficient manner" (p, 85; Grantham et al. 2008).
12. It is suggested, therefore, regional preparation for large-scale, systematic hydrological/ecosystem responses and mitigation when possible must join site-specific conservation and restoration as key foci in the management of the Damodar watershed. To first understand and then encourage effective preparation for systematic hydro-ecological and climate changes in the Damodar watershed we need an integrated, scale-flexible, analysis and information sharing system to bring the best available-science to bear on the combined impacts of consumptive water use, land use and climate change (Wiley et al. 2010).

8.2 The Need for Integrating Watershed Science and Management

Policy makers in the domain of flood and water resource management are faced with the enormously challenging task of parsing vast amounts of data to arrive at rational decisions that affect the lives and livelihoods of millions. The scope and scale of these problems make accessible decision support systems linking scientific databases, modeling analyses and Geographic Information Systems (GIS) processing, a necessity. GIS is widely used in the field of flood and river resource management (Correia et al. 1998) and more recently in studies of the impact of sea level rise due to climate change on coastal communities (Dasgupta et al. 2009). Collaborative exploration of alternate management scenarios using GIS-based frameworks can be an essential component of linking government policy and action with academic expertise and local stakeholder interests (Burrough and McDonnell 1998; Stevenson et al. 2008; Wiley et al. 2008). Some of the important matters to be addressed on the Domodar include: how much water do we now have in the river, how much we are using, and how much we will need later (Maidment 2002), as was also asked by Prof. M. Gordon (Reds) Wolman (Kobell 2007). Therefore, there is an urgent need to compile and update flood- and water-related data and to make them systematically available through computerization. GIS can play a key role in making the data and their analysis explicable to both managers and public where these can be integrated into a public and participatory conversation about the future.

Risk analyses need to be effectively communicated with and effectively explored by stakeholders as well as by decision makers at multiple levels of Governments and across the Damodar Valley Corporation. Our goal should be the establishment of a coherent basin-wide, integrated analytical framework for both hydro/ecological and social impact forecasting (e.g. Wiley et al. 2010). Such a framework could make use of extensive use of GIS technologies both to perform analyses and effectively communicate.

The risks and uncertainties inherent for communities living in close symbiosis with a river system are large. Natural flood hazards and variability in geomorphic process are compounded by larger scale forces of climate change, regional land cover transformation, and changing political will for expanding and/or maintaining existing engineering infrastructure (Personal communication with M. J. Wiley, July 15, 2009, October 6, 2010 and S Vaddey, July 28, 2009).

Changes in land use and climate along with hydro regime management scenarios can be quantitatively evaluated and graphically depicted providing a unified "model" for local and regional discussions of preparation and mitigation. The development of such a capacity would place the Damodar Valley Corporation (DVC) and its hydraulic society at the forefront of national water resource and climate change planning and policy development (personal communication with M. J. Wiley, July 15, 2009, October 6, 2010).

The Lower Damodar, a small part of the greater Damodar river system, is located in West Bengal, India but the findings on the controlled Lower Damodar are relevant to river communities across India and elsewhere (Bhattacharyya 1998). In this age of heightened environmental awareness, we all know that the survival of our civilization depends on rational and constructive maintenance and use of our water resources. The major challenge in the coming decades is to develop a holistic and sustainable water management system that will be environmentally accountable, socially acceptable and economically feasible. River resources should be treated as economic assets since ongoing economic development depends on a riverine regime that is ecologically sound and socially just (Saha and Barrow 1981). The primary issue to be addressed, therefore, is not whether dams are needed but how a river system is cared for in the presence of dams, floods and riparian communities. These worthwhile goals, however, will remain out of reach unless we have effective government policy and the legal structure to support it.

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