Chapter 8

Epilogue

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Previous chapters presented an overview of rivers as ecosystems and their ecosystem services, human impacts upon them, and the concept of environmental flows and the methodologies for their assessment. The state of the science of environmental flows and its application in South Asian countries has also been summarised. This chapter intends to highlight the issues related to environmental flows that need urgent attention particularly in the South Asian region. The region is distinguished by its geographical location, geological history, the young and lofty Himalayan mountain ranges, variable climates influenced by the highly unpredictable monsoon, high degree of spatial and temporal variability of precipitation, long history of human presence, a large and growing human population, high social, cultural and religious diversity, and increasing pressures of economic development. Major rivers rise in the Himalaya, flow through valleys with steep gradients and traverse vast plains with very little gradient for most of their course. The Himalayan rivers exhibit a flow regime in which the low flows and peak flows vary between extremes, and carry huge sediment loads – highest among the world's rivers. They form vast floodplains and large deltas. The rivers are considered sacred and intricately linked to the social, cultural and religious activities. Like other rivers throughout the world, all rivers in South Asia also are increasingly threatened by various water resource development projects (including hydropower) and embankments, besides pollution.

FOCUS ON HYDROPOWER PROJECTS

As mentioned in an earlier chapter, the concern for river flows rose in North America because of the downstream impacts of hydropower projects on the fisheries in 1950s. During the past six decades, these concerns gradually evolved, hand in hand with the understanding of the river ecosystems, from fish to the river ecosystem and its ecosystem services. However, it is interesting that the hydropower projects and fish continue to take the centre stage of all discussions worldwide. Postel and Carpenter (1997) pointed out many years ago the drivers of impacts on river ecosystems and their ecosystem services (Table 1) but unfortunately, the embankments which reduce or eliminate the floodplains,

Table 1. Summary of drivers of impacts on river ecosystems and their ecosystem services (adapted from Postel and Carpenter 1997)

Human Activity	Impact on Ecosystems	Services at Risk
Dam construction	Alters timing and quantity of river flows, water temperature, nutrient and sediment transport, delta replenishment, blocks fish migration, affects productivity of estuarine fisheries	Provision of habitat for native species, recreational and commercial fisheries, maintenance of deltas, mangroves and their economies
Dike and levee construction	Destroys hydrologic connection between river and habitat,	Habitats, recreational and commercial fisheries, natural floodplain fertility, natural flood control
Flow Diversions (barrages)	Depletes stream flow	Habitats, sport and commercial fisheries, recreation, pollution dilution, transportation
Draining of wetlands	Eliminates key component of aquatic ecosystem	Natural flood control, habitat for fish and waterfowl, recreation, natural water purification
Deforestation/land use change	Alters runoff patterns, inhibits natural recharge, fills water bofies with sediments	Water supply: quality and quantity, fish and wildlife habitat, transportation, flood control
Release of wastewater effluents	Diminishes water quality	Water supply, habitat, commercial fisheries, recreation
Overharvesting	Depletes species populations	Recreational and commercial fisheries, waterfowl, other biotic resources
Introduction of exotic species	Eliminates native species, alters production and nutrient cycling	Recreational and commercial fisheries, waterfowl, water quality, fish and wildlife habitat, transportation
Release of pollutants into the atmosphere	Alters chemistry of water	habitat, fisheries, recreation, water quality
Emission of climate altering air pollutants (green house gases)	Potential for changes in runoff patterns from rise in temperature and changes in precipitation	Water supply, hydropower, transportation, fish and wildlife habitat, pollution dilution, recreation, fisheries, flood control
Population increase and consumption patterns	Increasing pressure on water resources	All ecosystem services

the diversion by barrages or groundwater abstraction, wastewater discharges, and many other large reservoirs do not figure in the environmental flows discussions. Numerous mini- and micro-hydel projects are ignored as of no consequence though vast majority of them are constructed on small tributaries and collectively have the potential of a huge impact on large rivers downstream. Once the floodplains are cut off from the rivers, the environmental flows' requirement for the remaining river channel would decrease substantially, and allow upstream abstraction/ diversion. Environmental impact assessments of development projects started in South Asian region only recently but many activities that directly impinge upon the rivers, floodplains and associated aquatic ecosystems do not attract any environmental consideration.

ENVIRONMENTAL FLOWS AND METHODOLOGY FOR ASSESSMENT

The concept of environmental flows evolved over about half a century from the concept of a fixed value 'minimum flow' which considered the needs of only specific fish species while permitting the hydropower projects in the USA. The recognition of non-human stakeholders (other than fish) in river flows expanded gradually to include river habitats, fluvial geomorphic processes, various biota, ecosystem functions and ecosystem services. The term 'environmental flows' was defined and internationally accepted by the turn of the current century. However, it is surprising that the word 'minimum' is still preferred and widely used by researchers, water resource managers and other concerned groups in many countries including those in South Asia, as they strive for maximum storage and diversion for various purposes of direct economic interest.

This mindset is reflected also in the assessment methodologies which are considered for application in different rivers reaches. Globally, the methodologies have evolved from simple hydrological statistic to holistic approaches which use many hydrological parameters, large amount of ecological data on numerous organisms, detailed fluvial geomorphological analysis, socio-economic data and advanced modeling tools. Dyson et al. (2003) clearly state that different environmental flows assessment methodologies should be and are used for different purposes, which range from general water resources planning to the setting of detailed plans for managed dam releases. In some developed countries, there is a move towards hierarchical two-tier frameworks to guide EFA over a range of spatial scales, driven by the availability or access to resources. These tiers include: (a) comprehensive assessment, using primarily holistic methodologies, and (b) planning-type, desktop assessment, using primarily ecologically relevant hydrological indices. The former adopt a whole-ecosystem view in assessing environmental flow requirements, whereby ecologically and/or socially important flow events are identified and an ecologically acceptable flow regime is defined by a multi-disciplinary panel of experts. These methods include substantial amounts of field work and may take significant amounts of time and resources to complete for a single river basin (e.g. King and Louw 1998). Desktop methods are suitable for only initial, reconnaissance-level assessments of environmental flow requirements in unregulated river basins and/or river basins with little pressure on water resources.

However, it is not even appreciated that all the methods described earlier were developed for the rivers which are not comparable to the South Asian rivers in any manner (physiography, flow regimes, sediment loads, biota) and the socio-cultural requirements are uniquely different. Yet, simple hydrological indices (which were discarded long ago) and other desktop hydrological methods are still being recommended in the region. Given the fact that long-term hydrological data are not available in public domain, the recommendations based on these simpler outdated methods employing modeled discharge data are neither reliable nor can ensure the ecological integrity of affected river reaches. There is no effort devoted to the collection of actual field data for a reasonable period for any ecological, hydrological, geomorphological or socio-cultural aspect related to environmental flows. Intensive research by multidisciplinary teams in required for developing databases on river morphology, flow regimes, and flow-ecology relationships for major taxa of plants and animals and for all rivers in the region. As noted in the previous chapter, most of the recent reports providing recommendations for environmental flows from hydropower projects are not based on adequate and appropriate scientific studies, rather some of them reflect a poor understanding of the subject itself, and are generally arbitrary figures with the sole objective of obtaining a mandatory clearance for the project. In fact, the holistic methodologies depend heavily upon the judgements of experts from a large number of disciplines. Unfortunately, such required expertise is very rare in the region because the studies on rivers have remained focused on monitoring of physical and chemical parameters of water quality or enumeration of planktonic and benthic organisms, and that too without reference to flow variability.

In this context, a recent review of the environmental flows assessment, for the California Federal Energy Regulatory Commission, by Williams (2011) is highly appropriate and noteworthy. He states that "environmental flows assessment remains an extraordinarily difficult problem, for which no existing methods provide a defensible technical solution; this makes an adaptive approach with careful attention to uncertainty appropriate. The difficulties with environmental flow assessments spring from the complexity and variability of stream ecosystems, so improved understanding of stream ecosystems and aquatic organisms will be a critical component of a long-term resolution of the problem". Williams (2011) points out, among other things, that "It is virtually impossible to predict the future states of such a system when it is disturbed" (quoted from Healey 1998) because ecosystems are not stable equilibrium systems. social objectives evolve, fish evolve, streams adjust, climate changes, fish populations vary, habitat selection is conditional, spatial and temporal scales matter, and the methods may be objective or subjective. Thus, environmental flows assessment is a major challenge. Nevertheless, the situation can be improved "in the short-term by (1) technological improvements in collecting, displaying and analyzing physical data on stream ecosystems; (2) proper attention to sampling and; and (3) Bayesian hierarchical modeling for more complex problems than was possible with other statistical methods" (Moyle et al. 2011).

PLANNING FOR ENVIRONMENTAL FLOWS

While the concept of environmental flows is rapidly gaining recognition at various levels in the South Asian countries, there is no well defined policy on subject and there is no mechanism to give effect to such a policy. It is necessary to promote the concept of environmental flows by communicating its scientific basis and the value of ecosystem services of rivers to correct the people's perceptions about the importance of water flowing in the rivers and to the sea,and to create awareness among the concerned policy- and decision makers in all departments concerned with water resources.

At another level, it is necessary that environmental flows requirements are considered and assessed at the very planning phase of any water resources development project as an essential part of its environmental impact assessment (EIA). This will involve, besides an environmental flows assessment, also a thorough appraisal of the effects of a provision for environmental flows on all other components of the project (design, operation, economic viability, etc.) and evaluation of various scenarios and options. Hydropower projects and their relationships with environmental flows have been discussed in several recent publications (Vovk-Korze et al. 2008, Robson et al. 2011, SHARE 2012, ICPDR 2013, Person 2013).

IMPLEMENTATION OF ENVIRONMENTAL FLOWS

Generally, the reservoirs of hydropower projects are operated with the goal of maximizing energy revenue but do not consider flow regimes that sustain the healthy aquatic ecosystems. Jager and Smith (2008) discussed three approaches to reservoir operations: (a) flow regimes are considered for maximum hydropower generation, while satisfying legal requirements, including environmental flows; (b) flow is released from a dam to meet water quality constraints; and (c) flows are released and timed to improve the health of fish populations. They suggested steps for reservoir operations with multiple objectives closer to the goal of ecological sustainability. For the new projects which are still in planning or early stages of construction, it is easy to review them for incorporating a provision for environmental flows. However, operational changes to meet the environmental flows requirements by releasing water from the reservoirs is often difficult. The situation is even more complicated by the cascades of reservoirs in projects developed close to each other. Richter and Thomas (2007) and Krchnak et al. (2009) have discussed the issues concerning reservoir operations and the potential for modifications for providing environmental flows. The issue of dams and their management in relation of fish migration and rehabilitation of rivers for fisheries has been discussed by Marmulla (2001) and Roni et al. (2005).

MONITORING FOR ENVIRONMENTAL FLOWS

After the project is implemented, a programme for monitoring of environmental flows will be required. This will include the monitoring of the releases of flows from the project site (or reservoir) according the desired variability of flow regime downstream. Equally important is the monitoring of the downstream affected stretch of the river for the sediments, water quality, channel morphology, fish and other instream biota and also the riparian and floodplain habitats. The flows release may require adaptive management in case any component of the river ecosystem is affected adversely beyond the expected levels, or large variation is experienced in the upstream flows.

In conclusion, the science and application of environmental flows are in their nascent stages in the South Asian region as also in most of the developing countries. Their growth and development require intensive effort and adequate resources for capacity building and research, policy making, implementation and management. The rivers are to be not only saved from dying but have also to be revived and restored, and this calls for an urgent action.

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