Environmental flows in river basins: a case study of River Bhadra

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Environmental water requirement, also referred to as 'environmental flow', is a compromise between water resources development and maintenance of a river in ecologically acceptable or agreed conditions. For instance, between a major storage and downstream, the quantity and also seasonaility of water flow in a river may be greatly changed from the natural condition, thus paving the way for drastic changes in the riverine ecosystem. This article presents the gist of the present scenario in Bhadra river, which has one big dam that is altering the natural flow. This study is based on both the field investigations and desk study.

Keywords: Dams, environmental flow, riverine ecosystem, river basin.

HYDRAULIC civilizations had highly valued the importance of water in human life and in the entire ecosystem. This is evident from the covered drains running beneath the streets of the ruins at both Mohenjodaro and Harappa. Degradation of ecosystem services has resulted in both social and economic burden. Recognizing the full value of ecosystem services, and investing in them accordingly, can safeguard livelihoods and profits in the future, save considerable costs and help achieve sustainable development goals. Failing to do so may seriously jeopardize any such efforts[1]. Environmental flow is one factor which ensures such ecosystem services. 'Environmental flow' refers to the water considered sufficient for protecting the structure and function of an ecosystem and its dependent species. This means enough water is left in our rivers, which is managed to ensure downstream environmental, social and economic benefits. Realizing its importance, several countries have made ensuring environmental flows mandatory. For example, The Mekong River Agreement, 1995; South Africa's National Water Act, 1998 and the Swiss Water Protection Act, 108. These legislations attempt to ensure required minimum flow in the river system to sustain ecosystem services.

The present study was made to estimate: (a) the present environmental flow rates in a river; (b) the ideal/optimal environmental flows to be maintained in the Tungabhadra, and (c) the potential benefits.

Methodology adopted

The last couple of decades have seen evolution of various methods, approaches and frameworks for estimating environmental flows. 'Methods' typically deal with specific assessments of the ecological requirement. 'Approaches' are ways of working to derive the assessments, e.g. through expert teams. 'Frameworks' for flow management provide a broader strategy for environmental flow assessment (Table 1). Each one of these has its own disadvantages and advantages (Table 2). For this study, Tenant Method was adopted[2,3].

Situational analysis

The Tungabhadra (TB) is a composite of two east-flowing rivers, namely Tunga and Bhadra, rising in the Western Ghats with confluence at Kudli, Shimoga District, Karnataka to form the TB river. It flows 298 km through Karnataka and some parts of Andhra Pradesh before joining River Krishna. The catchment and command area comprises seven districts and 27 taluks and covers an area of 48,000 km^2. Population statistics of the basin shows an increase in urban population (36%), while the rural population is on a decline. Land use has recorded rapid changes with more area brought under cultivation.

Vegetation

The forests in the upper reaches of the river are of wet deciduous type. The inner slopes are covered by grassy downs with wet deciduous semi-evergreen shoals giving way to dry deciduous type. Two important sanctuaries in this reach of the Bhadra river are Kudremukh National Park and Bhadra Tiger Reserve.

Fisheries

There are 81 fish species from eight orders with 14 families endemic to the TB river basin. In order to

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Table 1. Various approaches for estimating environmental flows

Approach	Nature	Description
Methods	Look-up tables	Using the rules of thumb based on simple indices given in the look-up tables. Can be adopted when few or no local ecological data are available. Commonly used index is the Q95 Index: the flow that is equalled or exceeded 95% of the time and is chosen purely on hydrological grounds.
	Tenant method	Another index method developed using calibration data from hundreds of rivers in USA. Percentages of the mean annual flow are specified that provide different quality habitats for fish, e.g. 10% for poor quality (survival), 30% for moderate habitat (satisfactory) and 60% for excellent habitat.
Desk-top analysis	Ritcher method: identifies the components of a natural flow regime, indexed by magnitude (of both high and low flows), timing (indexed by monthly statistics), frequency (number of events) and duration (indexed by moving average minima and maxima).	Defines benchmark flows for rivers where the primary objective is the protection of the natural ecosystem.
	Hydraulic rating methods use changes in hydraulic variables, such as those in the 'wetted perimeter', and the area of riverbed submerged, to define environmental flows. These provide simple indices of available habitat in a river at a given discharge	Provide simple indices of available habitat in a river at a given discharge perimeter declines rapidly. More appropriate to support scenario-based decision-making and water allocation negotiations
Functional analysis	Building block methodology: The basic premise is that riverine species are reliant on basic elements (building blocks) of the flow regime, including low flows and floods that maintain the sediment dynamics and geo-morphological structure of the river. An acceptable flow regime for ecosystem maintenance can thus be constructed by combining these building blocks.	Led to development of computer model called PHABSIM (Physical Habitat Simulation) by the US Fish and Wildlife Service. Over the years, this has led to other models that follow basically the same method.

Table 2. Comparative advantages and disadvantages

Method type	Sub-type	Advantages	Disadvantages
Look-up table	Hydrological ecological	Inexpensive, rapid to use once calculated	Not site-specific. Hydrological indices are not valid ecologically. Ecological indices need region-specific data to be calculated
Desk-top	Hydrological, hydraulic, ecological	Site-specific, limited new data collection	Long time series required. No explicit use of ecological data
Functional analysis		Flexible, robust, more focused on whole ecosystem	Expensive to collect all relevant data and need for a wide range of experts
Habitat modelling		Replicable, predictive	Expensive to collect hydraulic and ecological data

Table 3. Total water consumption across sectors (TMC)

Parameter	Tunga	Bhadra	Tungabhadra	Total consumption
Agriculture				514.3
Drinking water	0.45	1.46	2.58	4.49
Industries		1.54	4.56	6.1
Total				524.89

boost the inland fish production to meet the ever-growing demand, the State has promoted fast-growing Indian major carps like *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*, as also exotic fish like *Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*, resulting in the decline of native fish population comprising Labeo, Cirrhinus, Puntius, Catfish, Murrels, etc.

Table 4. Status of ecosystem services of TB river basin

	Services	Region I	Region II	Region III
Provisional services	Food – fish catch	S	S	S
	Livestock	S	S	S
	Fuel wood	NS	NS	NS
	Genetic resources	S	NS	NS
Supporting services	Regular flows – recharge of groundwater	S	S	NS
	Flood plains – recharge of soil	NS	NS	NS
	Periodic high flows – seed dispersal	S	Ns	NS
	Well-timed flows – water demands	S	S	S
Regulating services	Flood and irrigation	S	S	S
Cultural/spiritual	Religious	S	S	S

S, Significant; NS, Non-significant.

Table 5. Recommended environmental flow as per Tenant law (TMC)

Month	Average of 30 years	Poor flow @ 10%	Moderate flow @ 30%	Excellent flow @ 60%
June	8,510	851	2,553	5,106
July	27,352	2,735	8,206	16,411
August	27,702	2,770	8,311	16,621
September	9,490	949	2,847	5,694
October	7,201	720	2,160	4,321
November	3,234	323	970	1,940
December	1,834	183	550	1,101
January	1,024	102	307	614
February	537	54	161	322
March	424	42	127	254
April	513	51	154	308
May	744	74	223	446
Total	88,548	8,855	26,565	53,129

Table 6. Status of environmental flow rates in TMC

Year	Actual release of water downstream of Bhadra reservoir	Poor flow @ 10% (8,855)	Moderate flow @ 30% (26,565)	Excellent flow @ 60% (53,129)
1967–68	7,748	–1,107	–18,817	–45,381
1969–70	4,506	5,613	23,323	49,887
1975–76	19,626	14,013	–3,697	–30,261
1978–79	60,305	46,292	64,002	90,566
1980–81	49,053	2,761	–14,949	–41,513
1981–82	21,027	18,266	35,976	62,540
1982–83	1,536	–16,730	–34,440	–61,004
1990–91	5,093	21,823	39,533	66,097
1991–92	27,527	5,704	–12,006	–38,570
1992–93	54,546	48,842	66,552	93,116
1993–94	18,951	–29,891	–47,601	–74,165
1994–95	63,452	93,343	111,053	137,617
1995–96	4,157	–89,186	–106,896	–133,460
1997–98	13,232	102,418	120,128	146,692
1998–99	13,143	–89,275	–106,985	–133,549
1999–00	20,180	109,455	127,165	153,729
2000–01	8,452	–101,003	–118,713	–145,277
2005–06	17,230	118,233	135,943	162,507
Total years meeting requirement		12	10	10

–ve mark indicates less flow in downstream of reservoir.

Table 7. Impacts of flow alteration

Component	Sub-component	Direct impact	Indirect impacts	Potential benefits if environmental flow is maintained	Implications if inadequate environmental flow is continued
Hydrology	Drinking water	Quality of river water is no more in 'A' class and has to be treated	Dependence on groundwater along the entire streach of the river	Health of population along would improve. Electrical energy will be saved. Groundwater table will not fall further	Cost of providing good drinking water will rise. Increasing gap between energy demand and supply. Higher energy bills for villages along the river
	Groundwater table	Depleting levels of groundwater table along the river stretch. All the villages along the river course are dependent on groundwater for drinking purposes	Excessive extraction of groundwater for conjunctive use for rice, sugar, etc. in the basin	Recharge of groundwater table along the river course	Will put villages along the river course in a fragile condition
	Fisheries	Native species are on the verge of extinction	Dependent fishing community is fast becoming an 'ecosystem refugees'	Higher production of fisheries and conservation of native species	Alarming levels of declining production
	Water pollution	Water quality has dropped from 'A' to 'C' and in some stretches even to 'D'	Contamination of groundwater table, rendering it unfit for consumption	Higher dilution factor would be available thus restoring water quality	Water quality would further degrade
Land	Soil fertility	Fields all along the 500 km stretch of the river are deprived of their periodical silt amendments during floods	Higher consumption of fertilizers along the river course. Salination in other parts of basin	Improved soil fertility	Higher consumption of fertilizers in the basin
	Erosion	Siltation of reservoirs	As more land is brought under cultivation, it has led to soil erosion, thus reducing soil fertility	Soil erosion would be controlled	Precious top soil will be lost
Livelihood support base	Marginal livelihoods like fishermen etc.	Decreased support base	Declining quality of life for these marginal groups	Enhanced livelihood support base of river	
Social system	Harmony	Conflicts among farming community in different stretches	Social unrest		

Water utilization

Agriculture is the main occupation in the TB basin and demand for water from this sector has drastically increased, as is the case with groundwater. Shift in cropping pattern from dry crops to water-intense crops like sugarcane and paddy and spread of borewell technology are causative factors.

Both surface and sub-surface water meet the drinking water requirements for various human settlements across the basin. The LPCD ranges from 70 to 135 across towns, but none of them has sewage treatment facility. For villages located in the river basin, the main source of water is groundwater, through mini water-supply schemes.

There are 27 large-scale industries (iron and steel, paper and pulp, chemical and sugar), and 59,500 small-scale

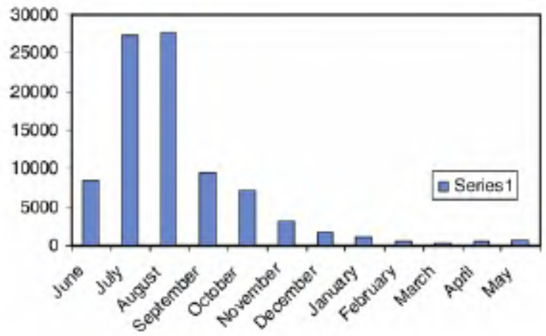

Figure 1. Average monthly inflows into the Bhadra reservoir (M.Cft).

industries. Summarized details of present water use/allocation are given in Table 3.

Ecology of the river

Based the ecology of the river, the entire river stretch can be divided into three distinct regions: (a) Region of surplus (comprises upper stretches of Tunga and Bhadra up to Tunga Anicut and Badhra Reservoir Project (BRP), having more or less pristine flow regime); (b) Controlled flow region (from BRP till Tungabhadra Reservoir (TBR) at Hospet. During the monsoon period, this region has natural flows but in the lean periods, flow rates are governed by agreement with Tungabhadra Board. This region shows intense cultivation and return flows are polluted in nature from urban settlements and industrial units as well) and (c) Region of deficit (marked from TBR till its confluence with River Krishna, and also water shortage).

Ecosystem services in the river basin

Aquatic ecosystems provide a great variety 'goods' such as drinking water, fish and fibre, and 'services' such as water purification, flood mitigation and recreational opportunities; all these are dependent on environmental flows. The present ecosystem services by TB are summarized in Table 4.

It appears that natural flow conditions are needed to restore all these services back, but it would be an uphill task. However, with minor flow-pattern changes, some of these services can be restored.

Current flow regime

The 30-yr average monthly inflows into the Bhadra Reservoir are shown in Figure 1. Similarly, the required environmental flow rates according to Tenant Law at various conditions are given in Table 5 and actual flow rates in Table 6.

As can be observed from the 32-yr average flow data in Table 6, only for 10 years the environmental flow rate is required in the Bhadra Reservoir and its impact is both direct and indirect (Table 7).

Summary of findings

- There are gains in terms of more cultivated areas and associated economic and social benefits, but farming costs are increasing yearly.
- River water quality is deteriorating.
- Livelihood support base of river ecosystem is shrinking.

Way forward

Implementing environmental flows requires either an active management of infrastructure such as dams, or a restrictive management, for example, through reducing the abstractions for irrigation. When active flow management is applied, an entire flow regime can be generated, including low flows and floods. Restrictive flow management involves allocation policies which ensure that enough water is left in the river, particularly during dry periods, by controlling abstractions and diversions. Both types of intervention depend on a change in the behaviour of people and should be based on an informed decision that has broad societal support.

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