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In-stream Water Flows: A Perspective from Downstream Environmental Requirements in Tungabhadra River Basin

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IN-STREAM WATER FLOWS: A PERSPECTIVE FROM DOWNSTREAM ENVIRONMENTAL REQUIREMENTS IN TUNGABHADRA RIVER BASIN

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Abstract

Environmental water requirements, also referred as 'Environmental Flows', are compromises between the development of water resources and the maintenance of a river in an ecologically acceptable or agreed condition. Managing environmental water flow is a complex task, because there is change in quantity of water as the flow moves downstream. For instance, between a major storage and the places downstream where water is diverted, the quantity of water in a river may change significantly from the natural condition and the seasonal pattern of flow may also be drastically altered. Further downstream, where a large proportion of the river's water is removed for human use, it is likely to be reduced by the overall flow levels. This paper assesses the optimum water requirements for better management of a downstream ecosystem based on field investigations and desk study. Three big dams across a river basin have reduced the natural flow in the main river. It has altered the socio economic condition of the downstream dependent population of the Tungabhadra river basin covering two south Indian states –Karnataka and Andhra Pradesh[†]*.*

Introduction

Hydraulic civilizations highly valued the importance of water in human life and in the entire ecosystem. The fact that this civilization was well acquainted with hygiene and sanitation is evident from the covered drains running beneath the streets of the ruins at Mohenjodaro and Harappa. The degradation of ecosystem services results in social and economic costs. The affected people are largely from the poorer sections of society. Recognising the full value of ecosystem services and investing in them accordingly will safeguard livelihoods and profits in the future, save considerable costs and help achieve sustainable development goals. Failing to do so may seriously jeopardise any such effort (Russell *et al*, 2001; Costanza, 2003; Dyson *et al*, 2003; Emerton & Bos, 2005; Millennium Ecosystem Assessment, 2005; Pearce *et al*, 2006, Emerton & Bos, 2005; Millennium Ecosystem Assessment, 2005; Pearce *et al*, 2006).

Owing to the expanding use of fresh water by humans and resultant growing stress on water resources, an important issue emerges with respect to the sustainability of water provisioning services — that is, being able to continue providing water for human use while also meeting the water requirements of aquatic ecosystems so as to maintain their capacity to provide other services. ''Environmental flows'' refers to the water considered sufficient for protecting the structure and function of an ecosystem and its dependent species. These flow requirements are defined by both the long-term availability of water and its variability and are established through environmental, social and economic assessment (King *et al* 2000; IUCN 2003).

It is not practical to return our rivers to a pristine condition or to return flows to the natural regime. Therefore, some form of compromise is inevitable. The environmental flows set for a given river need to take into account social and economic factors as well as environmental issues. Ideally, environmental flows have to be set to achieve "ecological integrity" — where the flow is sufficient to ensure that all components of the ecosystem are restored/maintained in a sustainable manner. This requires flow in sufficient quantity at appropriate times with the appropriate (natural/semi-natural) variability.

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Environmental Flows

Determination of environmental flow requires decisions on the total volume of flow to be allocated for the environment and the delivery (timing) of that flow. Generally, it is beneficial to maintain the natural variation and timing in flows because many ecological processes are dependent on flow variations and also on implicit links to other triggers such as temperature, rainfall etc. These links are not always understood and are best preserved by maintaining a natural flow pattern.

However, the flows of the world's rivers are increasingly being modified through impoundments such as dams and weirs, abstractions for agriculture and urban water supply, drainage return flows, maintenance of flows for navigation and structures for flood control. These interventions have caused significant alteration of flow regimes mainly by reducing the total flow and affecting the variability and seasonality of flows. Economically and/or politically powerful users have relatively well developed methods for quantifying and justifying their water needs. This is not the case for ecosystems – the silent water user. Therefore, ecosystems are frequently omitted from water allocation decision-making process. It is estimated that more than 60 per cent of the world's rivers are fragmented by hydrological alterations. This has led to widespread degradation of aquatic ecosystems (Millennium Ecosystem Assessment, 2005; Dyson *et al*, 2003; Postel & Richter, 2003; Ravenga *et al*, 2000)

Many factors, such as water quality, sediments, food-supply and biotic interactions, are important determinants of aquatic ecosystems. However, an overarching master variable is the river's flow regime. The Natural Flow Paradigm, where the natural flow regime of a river is recognised as vital to sustaining ecosystems, is now widely accepted. This recognition of flow as a key driver of aquatic ecosystems has led to the development of the Environmental Flows concept (Dyson *et al*, 2003). This concept now serves to enhance informed, equitable and sustainable decision-making in water management. (Postel & Richter, 2003; Tharme 2003). In simplest words, minimum amount of water that is required to maintain the riverine ecosystem integrity can be described by the all-embracing term 'Environmental Flows'.

Definitions of Environmental Flows

An Environmental Flow is the provision of water within rivers to maintain downstream ecosystems where the river system is subject to competing water uses and flow regulations. Regulation of flow can occur through direct infrastructure (like on-stream dams) as well as through diversions of water from the system (for example by pumping water away). An Environmental Flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits (Dyson *et al*, 2003).

Environmental Flows describes the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and human livelihood and well-being that depend on these ecosystems (Brisbane Declaration 2007).

Ecosystem Services

Humankind usually benefits from resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and these services are directly dependent on Environmental Flows (Table 1) which include products like clean drinking water and processes like the decomposition of waste. Ecosystems provide a wide range of services to people (Costanza, 2003; Emerton & Bos, 2005; Millennium Ecosystem Assessment, 2005; Pearce *et al*., 2006). The services provided by Environmental Flows may either be provided directly by flow (e.g. flushing of sediments, salinity control) or indirectly via ecosystem functions. The extent to which ecosystem functions create ecosystem services depends on the cultural, socio-economic and technical setting. Thus, the list of services given in the table below is not entirely determined by the suite of ecosystem functions, but also by human ingenuity in deriving benefits.

Table 1: Ecosystem services from the river

Service category	Service provided	Key flow related function	Key Environmental Flow component or indicator
Production	Water for people - subsistence/rural and piped/urban	Water supply	Floodplain inundation
	Fish/shrimp/crabs (non-recreational)	Habitat availability and connectivity, food supply	In-stream flow regime, floodplain inundation
	Soil fertility	Supply of nutrients and soil moisture	Floodplain inundation
	Wildlife	Habitat availability and food web	Floodplain inundation, flows sustaining riparian productivity
	Fibre/organic raw material for building/firewood/handicraft	Seasonality of moisture in soils	Floodplain inundation, flows sustaining riparian vegetation
	Inorganic raw material for construction and industry (gravel, sand, clay)	Sediment supply, transportation and deposition (fluvial geomorphology)	Instream flow magnitude and variability
Regulation	Chemical water quality control (purification capacity)	De-nitrification, immobilisation, dilution	Instream flow regime,
	Physical water quality control	Flushing of solid waste	Instream flow regime
	Groundwater replenishment (low flow maintenance)	Groundwater (aquifer) replenishment	Floodplain inundation
	Health control	Flushing of disease vectors	Instream flow regime, water quality
	Pest control	Habitat diversity	Instream flow regime
	Erosion control (riverbank/bed and delta dynamics)	Healthy riparian vegetation	Flows sustaining riparian vegetation
	Prevention of saltwater intrusion (salinity control)	Freshwater flow, groundwater replenishment	Instream flow regime
	Microclimate stabilization	Healthy ecosystems	Floodplain inundation, flows sustaining riparian vegetation
Information	Recreation and tourism (incl. fishing and hunting)	Presence of wildlife, aesthetic significance, good water quality	Site specific
	Biodiversity conservation	Sustaining ecosystem integrity (habitat diversity and connectivity)	Natural flow regime
	Cultural/religious/historical/symbolic activities	Site specific	Site specific
Life support	The prior existence of healthy ecosystems	All	Natural flow regime

Source: IUCN

Legislation and Environmental Flows

International Experiences

In 1970, the United Nations General Assembly recommended that the International Law Commission (ILC) conduct a study on the law on non-navigational uses of international watercourses with a view to its codification and progressive development. The ILC then presented Draft Articles on the Law of Non-navigational Uses of International Watercourses. Based on this body of work, a multilateral treaty was finally adopted by the UN General Assembly on May 21, 1997. The United Nations Convention on the Law of Non-navigational Uses of International Watercourses provides a framework of cooperation for the Contracting Parties, which can be adjusted in agreements between States sharing a watercourse. It requires States to protect and preserve the ecosystems of international watercourses, control the sources of pollution and to take preventive action against alien species. States located within an international watercourse have an obligation to co-operate in its regulation. They are thus obliged to work together on any hydraulic works or any other continuing measure to alter, vary or otherwise control the flow of the waters of the international watercourse. Countries must also take, individually or jointly, measures in the international watercourses to preserve the marine environment, including the estuaries.

In addition, there are several agreements covering particular watercourses that contain the general principles of international water law applicable to Environmental Flows, viz:

- The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki Convention)
- The Mekong River Agreement
- The Protocol on Shared Watercourses Systems in the Southern Africa Development Community and
- The Convention on Co-operation for the Protection and Sustainable Use of the Waters of the Portuguese-Spanish River Basins.

Non-River Treaties

Several international 'non-river' treaties address conservation and sustainable use of river basins as part of a wider mandate/approach and can, thus, be seen to relate to the management of Environmental Flows.

1. The Convention of Wetlands of International Importance, (Ramsar Convention) 1995 is the first of these treaties. This Convention seeks to ensure the wise use of all wetlands.
2. World Heritage Convention 1996, provides protection to sites that have been listed as areas of outstanding universal value based upon their natural heritage values where such sites include a lake, a river or the upper catchment of a watercourse.
3. Conservation of Migratory Species of Wild Animals (Bonn Convention), useful for the conservation of environmental flows when rivers and wetlands constitute the habitat of

protected species and the maintenance of water flows is necessary to ensure the survival of a migratory species.

4. The Convention on Biological Diversity 2002 (CBD) applies to the biological diversity of all sources (terrestrial, marine and other aquatic sources) and therefore has a relationship to Environmental Flows. The CBD establishes a comprehensive regime for the conservation of ecosystems and biological resources.

In most cases, existing national legislation is yet to establish a clear and systematic set of rules legitimising the provision of water for Environmental Flows. Only a limited number of countries have so far recognised the importance of non-consumptive uses of water and have developed specific legislation, such as South Africa and Australia.

Environmental flow legislations in other nations

Wild and Scenic Rivers (United States), The National River Inventory lists rivers and river segments that appear to meet minimum eligibility requirements based on their free-flowing status and resource values. If found eligible, a candidate river is analysed on its current level of development (water resources projects, shoreline development and accessibility) and a recommendation is made to place it into one or more of three classes: wild, scenic or recreational (United States' Wild and Scenic Rivers Act 109).

River Habitat Survey (United Kingdom), The River Habitat Survey is a system for assessing the character and quality of rivers based on their physical structure (Raven *et al*, 1998). Originally envisaged as a detailed information tool, the River Habitat System may be used for various management purposes. (Raven *et al*, 1998, p7).

System for Evaluating Rivers for Conservation (United Kingdom), (SERCON) is a broad based technique for assessing conservation value using six conservation criteria and an impact criterion (Boon *et al*, 1997; Boon *et al*., 1998). Rivers are evaluated in discrete lengths, normally between 10 and 30 kilometers, known as evaluated catchment sections.

South Africa's National Water Act: The South African National Water Act, 1998, establishes the 'reserve' consisting of an unallocated portion of water that is not subject to competition with other water uses. It refers to both quality and quantity of water and has two segments: i) the basic human need reserve and the ecological reserve ii) the amount of water required to protect the aquatic ecosystems. The determination of the reserve corresponds to the Minister, who can establish the reserve for all or part of a specific water resource.

The Mekong River Agreement: The Mekong River Agreement was signed in 1995 between Cambodia, Laos PDR, Thailand and Vietnam to create the Mekong River Commission. It set up a framework for cooperation between the riparian States for sustainable development of the river basin. The agreement specifically requires minimum stream flows for the protection of ecosystems, indicating that States will cooperate in maintaining flows "of not less than the acceptable minimum monthly natural flow during each month in the dry season".

The Swiss Water Protection Act 108, establishes specific minimum flow values for different average flow rates, which must be maintained or increased in certain cases, depending on geographic and ecological factors.

Regulated Management of Flows: The regulated management of flows to provide for environmental benefits has been used in the Murray-Darling Basin in Australia, principally through specific decisions reached under the agreement that established the basin wide initiative.

National Experiences

India embarked on infrastructure development with the First Five-Year Plan and irrigation projects have been given high priority since then. However, the objective was to provide food security to the nation and issues like Environmental Flows etc., were not given much consideration. However, to ensure the downstream water demands either from human settlements or industries, provisions/allocations were made for timely release of water through sluices and it differs from river to river.

Objectives of the Study

The condition, in which aquatic ecosystems and their services are maintained, is essentially a socio-political decision. The objectives of this study are:

1. What are the ideal/optimal environmental flows in the Tungabhadra River?
2. What is the present environmental flow status in the river?
3. What are the potential benefits/consequences of maintaining or not maintaining environmental flows.

Methodology and Materials Required

Many early applications of environmental flows assessment (EFA) focused on a single species. As a result, environmental flows were set to maintain critical levels of habitat for these species. However, managing flows without consideration for other components of the ecosystem may fail to capture the system processes and biological community interactions that are essential for creating and sustaining the habitat and ensuring the well-being of the target species. Recent advances in EFAs reflect this knowledge and EFA methodologies are increasingly taking a holistic approach (Brown & King, 2003, Instream Flow Council, 2002). In the most recent review of international environmental flows assessments, Tharme (2003) recorded 207 different methods within 44 countries. Several different categorisations of these methods exist, three of which are shown in Table 2.

Table 2: Overview of Environmental Flow Assessment methods

Organisation	Categorization of methods	Sub-category	Example
IUCN (Dyson *et al,* 2003)	Methods	Look-up tables	Hydrological (e.g. Q95 Index) Ecological (e.g. Tennant Method)
		Desk-top analyses	Hydrological (e.g. Richter Method) Hydraulic (e.g. Wetted Perimeter Method) Ecological
		Functional analyses	BBM, Expert Panel Assessment Method, Benchmarking Methodology
		Habitat modeling	PHABSIM
	Approaches		Expert Team Approach, Stakeholder Approach (expert and non-expert)
	Frameworks		IFIM, DRIFT
World Bank (Brown & King, 2003)	Prescriptive approaches	Hydrological Index Methods	Tennant Method
		Hydraulic Rating Methods	Wetted Perimeter Method
		Expert Panels	
		Holistic Approaches	BBM
	Interactive approaches		IFIM, DRIFT
IWMI (Tarme, 2003)	Hydrological index methods		Tennant Method
	Hydraulic rating methods		Wetted Perimeter Method
	Habitat simulation methodologies		IFIM
	Holistic methodologies		

Source: eflownet.org

This study utilised the 'look up tables' method and desktop analysis. The methodology consists of hydrological analysis, which analyses the inflow and outflow data for the major dams across the main rivers in the basin. We have collected and analysed the inflow/outflow for 35 years. To support the impact of the lack of environmental flows in the river we conducted focus group discussions mainly on the fisheries sector. We had discussions with the downstream dependents of the Bhadra, Tunga and Tungabhadra dams.

From the BRP to Kudli we visited 6 major villages on the right and left banks of the River Bhadra and also interacted with large numbers of fishermen communities from UTP to Kudli and from TB Dam to Siruguppa.

Situational Analysis

The Tungabhadra (TB) River is a composite river of two east flowing rivers namely – The Tunga and The Bhardra. The Tunga rises at Gangamula in the Gangrikal hill ranges north of Kudremukh. The Bhadra rises near Samse in the Aroli Hill range of Kudremukh. The Tunga River initially flows northeast, turns north and subsequently takes an easterly course. The Bhadra River also initially flows easterly, changing course to north and joins the Tunga at KUDLI in Shimoga district. The Tungabhadra River flows up to 298 km and is formed by the confluences of the Tunga and Bhadra Rivers at Kudli of Shimoga district then flows through Karnataka and some parts of Andhra Pradesh and joins the Krishna River. The catchment and command area comprises 27 taluks of 7 districts and covers an area of 48,000 Sq km (Table 3).

Table 3: Details of various administrative units in TB basin

Bhadra Catchment/Command	Tunga Command	Tungabhadra command	Close to TB Dam
Chikamagalore	Koppa	Honnali	Bellary
N. R. Pura	Sringeri	Channgiri	Hospet
Tarikere	Theerthahalli	Hanagal	Sirugoppa
Bhadravathi	Shimoga	Haveri	Dadurga
		Harikerur	Gangavathi
		Ranebennur	Koppal
		Shiggoan	Raichur
		Davangere	Sindhunur
		Harihar	
		H.B. Halli	
		Harappanahalli	

Source: Water Resources Department

General Information‡

Population growth details show that urban population is increasing, adding more pressure on the infrastructure. Particularly between 1991 and 2001, there was 36 per cent increase in urban population while the rural population decreased (Annexure 1).

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 sholas. On the outer edges of the Lakkavalli area, the forests tend to turn into dry deciduous type. On the whole, the Muthodi area is wetter and more and more verdant than Lakkavalli, particularly in the dry seasons. Two important sanctuaries in this reach of the Bhadra River are the Kudremukh National Park and the Bhadra Tiger Reserve (Table 4). The

‡ More details regarding general information on river or basin can be found in complete report available with CEENR, ISEC

Kudremukh National Park has significant biodiversity cover with different kinds of vegetation cover (refer Annexure 2).

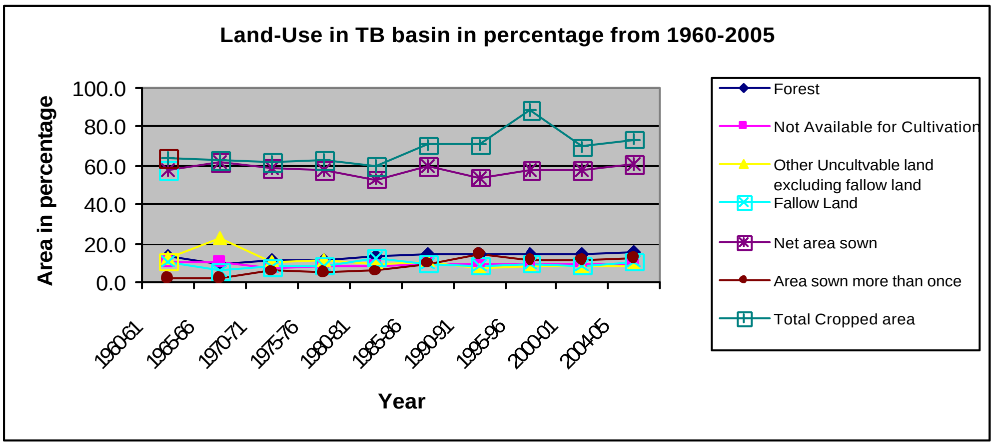
Table 4: List of the Wildlife sanctuaries in the Basin

Circle	Division	Name of the wildlife wing	Geographical Area (Sq.km)
Mangalore Circle	Kudremukh Wildlife Division	Kudremukh National Park	**563.28**
Shimoga circle	Shettihalli wildlife Wing Division	Shettihalli Wildlife Sanctuary	**395.60**
Chikamagalore Circle	Wildlife Division, Chikamagalore	Bhadra Wildlife Sanctuary	**492.46**
Dharwad Circle	Wildlife Sub-Division, Ranebennur	Ranebennur Black buck Sanctuary	119.00

Land Use

It is commonly seen throughout the world that land use pattern changes rapidly. Similar is the case of TB river basin and rate is shown in Figure 1. The wasteland and fallow land is decreasing and net sown area is increasing because of the increasing population over time and also the increase in the extraction of ground water for cultivation. However, it is important to note that the forest cover shows is increasing mainly due to the afforestation programmes of the forest department.

Figure 1: Land-use in TB basin



1.1. Water Resources in the River basin

The needs of the Vijayanagar Empire led to the first major intervention in the natural water flow. In the sixteenth century, especially during the reign of King Krishnadevaraya, many attempts were made to divert the water of Tungabhadra through seven canals in Bellary district, now known as the Vijayanagar Canals. The canals provided water for irrigation as well as satisfied the needs of the large army stationed in the capital city of Hampi. The interests of the Vijayanagar rulers were not limited to canals. Understanding the crucial role of tanks in food production and in providing drinking water, the kingdom undertook a systematic programme of tank construction.

The main sources of water for the Tungabhadra basin are surface water and ground water. Three major reservoirs are built across the river. The designed capacity for storage of water allocated for both Karnataka and Andhra Pradhesh is 320.3 TMC ft and tanks are another source of surface water. Details of the surface water sources and their usage across various sectors are described in Table 5. From the available total water the designed area for surface water irrigation is 6,92,156.36 ha, out of which reservoirs irrigate 6,29,013 ha and tanks 63143.36 ha (Table 6).

Table 5: Designed and Actual Area for surface water irrigation in Ha

Source	Area irrigable in Ha	Actual area irrigated in Ha (2004-05)
Reservoirs	629013	437876
Minor Irrigation Tanks	37006.36	
ZP and TDP Tanks	26137	44015
Total Area Irrigated by Tanks	63143.36	
Total area irrigated Surface Water Sources	692156.36	481891

Source: BRP, UTP, TBP, District at a glance

Table 6: Number of tanks, storage and designed command area

Tanks	Number	Designed Storage Capacity in TMC ft	Total Designed command area in Ha.
Minor irrigation	401	8.4	37006
Total ZP and TDP tanks	4037	5.98	26137
Total Number of Tanks (MI + ZP+TDP)	4438	14.38	63143

Source: MI Census

Fisheries

Until now in Karnataka, 201 freshwater fish species belonging to 9 orders, 27 families and 84 genera have been recorded, of which 40 species are under 'threat' and urgent implementation of conservation measures need to ensure their survival. The systematic record of freshwater fish species from the inland waters of the State is based on the work carried out by Jayaram (1999). There are 81 species from 8 orders with 14 families endemic to the Tungabhara River basin. (Refer Annexure 3). There are 5 fish sanctuaries,all under community responsibility, viz Abhirama, Sreekanteshwara, Hariharapura, Sringeri Matsyadham, in Tunga River.

Annual freshwater fish production in the state is about 1.2 lakh metric tonnes as against an estimated potential of 2.6 lakh metric tonnes. In order to boost inland fish production to meet the ever-growing demand, the State Department of Fisheries has laid more emphasis on the culture of fast-growing Indian major carp like Catla catla, Labeo rohita and Cirrhinus mrigala and also exotic fish like Cyprinus carpio, Hypophthalmichthys molitrix and Ctenopharyngodon idella. These fish species have adopted well in various freshwater bodies. The introduction of exotic species, in a way, has resulted in the decline in native fish population like Labeo, Cirrhinus, Puntius, Catfish, Murrels, etc. The culture of

African catfish - Clarias gariepinus - undertaken by private entrepreneurs is going to damage the indigenous fish species if corrective measures are not implemented at the earliest.

Fish farming offers good scope for rural development apart from providing employment (water spread area in various taluks is given Table 7), income generation, protects livelihoods and also provides inexpensive protein rich food.

Table 7: Talukwise Reservoirs and Water Spread Area

Taluk	Name of the reservoir	Location	WSA >500 ha	WSA <500 ha
H.B.Halli	H.B.Halli	Malvi	1209	-
Hospet	Tungabhadra	Munirabad	37814	-
N.R.Pura	Bhadra	BRP, Tarikere	11250	-
Channagiri	Shantisagar	Channagiri	2977	-
Harihara	Devarabelekere	Devarabelekere	647	-
Manvi	Rajolibunda	Rajolibunda	-	200
Shimoga	Tunga	Gajanur	825	-

Water Utilisation

Agriculture

Agriculture is the main occupation in the TB basin. The water consumption for agriculture has drastically increased in the basin, as is the case with ground water exploitation. Recent trends show that surface water usage is on the decline (refer annexure 4). Cultivation of water demanding crops like sugarcane and paddy and spread of borewells are the main causes.

Drinking water

Both surface and ground water meets the drinking water requirements of the various human settlements across the basin (Table 8 and Annexure 5). The LPCD ranges from 70 to 135 across the towns. The sewage from these ULBs is directly entering the river system or agricultural fields. For instance, the wastewater from Hospet, Sandur, Siraguppa, Gangavathi and Sindhanoor cities reaches the agricultural fields because there is no UGD facility.

Table 8: Surface water Consumption in TMC ft in Tungabhadra Basin

Sectors	Tunga	Bhadra	Tungabhadra	Total
Drinking water Consumption in TMC ft	0.45	1.46	2.58	4.49

Source: Karnataka Planning Commission Report

For villages located in the river basin, the main source of water is ground water, which is supplied through mini water supply schemes.

Industries

In Tungabhadra basin, there are 27 large-scale industries, which are already operating and around 50 industries under various stages of establishment. The major types of industries are iron and steel, paper and pulp, chemical and sugar industries. Across Bhadra River, the major industries are Kudremukh Iron Ore Company Ltd. (presently closed), Mysore Paper Mills and Vishweshvaraiah Iron and Steel Industries. Along Tungabhadra River, Harihara Polyfibres, Raichur Thermal Power Plant and two sugar industries and distilleries are the major industries. In addition, there are 59,500 small-scale industries as on 2006-07 with an investment of Rs 1,17,494 lakh. Water allocated for industrial use is given in Table 9.

Table 9: Industrial water consumption in TB basin

Surface water Sources	Water consumption in TMC ft
Tunga	-
Bhadra	1.54
Tungabhadra	4.56
Total	6.1

Pollution due to industrial activities is mainly observed in Harihara, Raichur, Bellary, Davanagere and Haveri districts. It is estimated that around 100 villages in the basin are affected by industrial pollution. Demand for water from different sectors is given in Table 10.

Table 10: Total Water Consumption across sectors

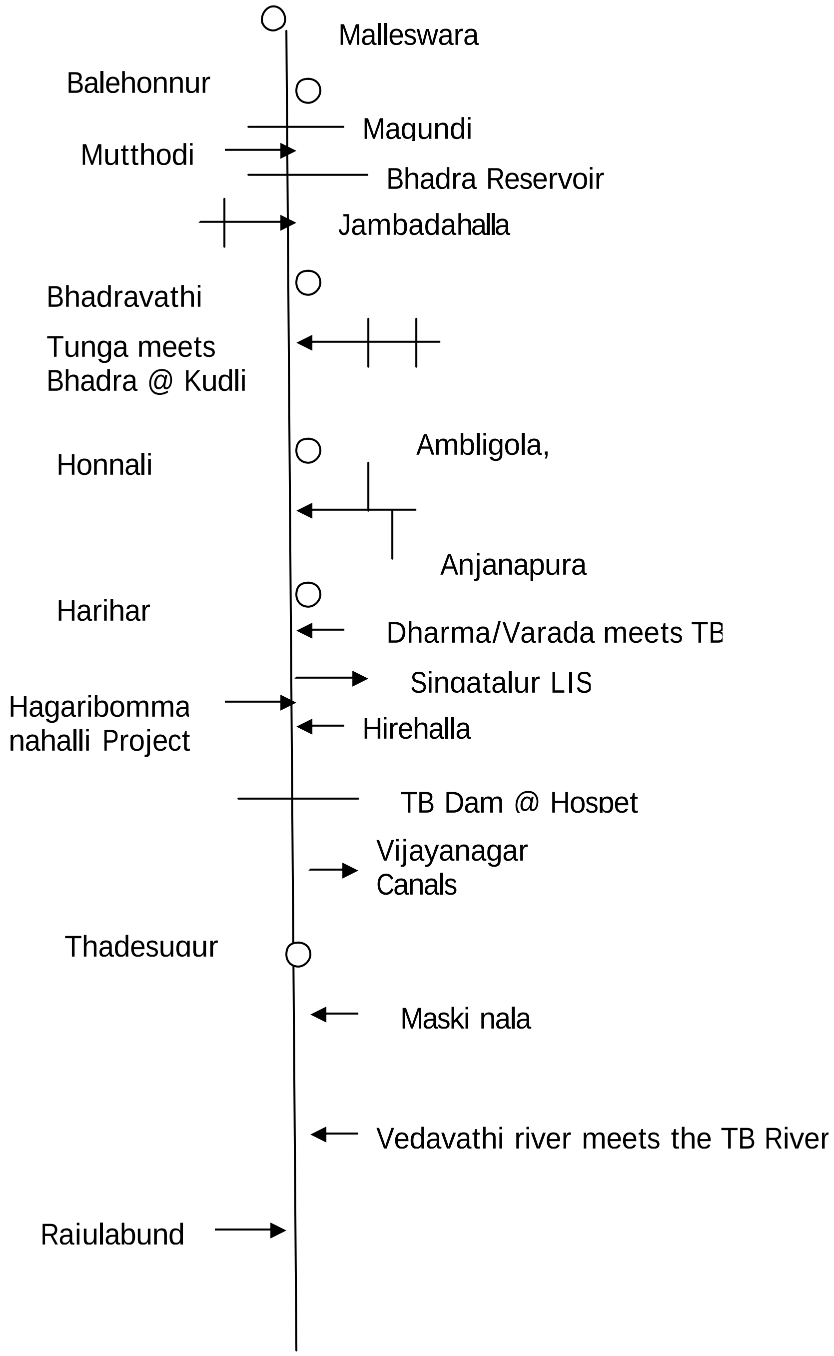
Parameters	Tunga	Bhadra	Tungabhadra	Total Consumption
Agriculture				514.3
Drinking water	0.45	1.46	2.58	4.49
Industries		1.54	4.56	6.1
Total				524.89

Results and Discussions

Schematic Diagram of Tungabhadra Basin

The Tungabhadra River is formed in the north of Shimoga at an elevation of about 610 km by the union of the Rivers Tunga and Bhadra. The Tunga and the Bhadra, start in the Western Ghats at Gangamula at an elevation of about 1197.8 m. Tungabhadra River flows for nearly 531 km in a northeastern direction through Karnataka and Andhra Pradesh and joins the Krishna River beyond Kurnool at an elevation of 264 m. Tungabhadra River has some tributaries which join the river in different points as shown in Figure 2.

Figure 2: Schematic Diagram of TB River in Karnataka



Ecology of the River

Based on the ecology of river, the entire river stretch can be divided into three distinct regions, viz:

a) Region of Surplus

This area comprises the area from the point of origin to the Tunga Anicut and Badhra Reservoir Project. Somavahini River, draining the area inside the crater passes through a narrow gap in the mountain wall and joins Bhadra River at Hebbe. Bhadra River is dammed up at BR project area forming a vast (about 200 sq. kms.) reservoir whose backwaters extend nearly 13 kms backwards. In addition to these major water sources, there are numerous streams and tanks scattered all over the area, some of them being perennial sources.

b) Controlled Flow Region

This is the area from BRP till TBR at Hospet. During the monsoon period, this region has natural flows while in lean periods the flows are governed by agreement with the TB board. Intense cultivation is practiced in this region. Return flows from urban settlements and Industrial units contribute to the riverine flow, but these Return flows are of poor quality, for instance, from from Bhadravathi (first urban settlement after Bhadra reservoir) to Kudli, confluence.

c) Region of Deficit

This region is marked from Tungabhadra reservoir till the confluence with River Krishna. Downstream TB Dam there are 12 anicuts on the left and right banks of the river to facilitate water extraction for irrigation. The changes in water flow regime after the impounding water at TB Reservoir is given in Table 6 below. From the table, it can be observed that the water flow regime downstream has undergone extreme changes and for some years it has had insignificant flow.

Ecosystem Services in the River Basin

'Environmental flows' is the water left in rivers which is managed to ensure downstream environmental, social and economic benefits. Aquatic ecosystems, such as rivers, provide a great variety of benefits to people. These include 'goods' such as clean drinking water, fish and fibre and 'services' such as water purification, flood mitigation and recreational opportunities. Healthy rivers and associated ecosystems also have an intrinsic value to people that may be expressed in terms of cultural significance, particularly for indigenous cultures. This intrinsic value is often overlooked because it is difficult to identify and quantify. A distinction may be made between the amount of water needed to maintain an ecosystem in close-to-pristine condition, and that eventually be allocated to it, following a process of environmental, social and economic assessment. The latter is referred to as the 'environmental flow' and it will be a flow that maintains the ecosystem in a less than pristine condition. Intuitively, it might seem that all of the natural flow, in its natural pattern of high and low flows, would be needed to maintain a near-pristine ecosystem, however, that some small portion of flow could be removed without measurable degradation of the ecosystem. How much could be removed in this way is difficult to assess. The present ecosystem services of the Tungabhadra River are summarised in Table 11.

Table 11: Status of Ecosystem Services of TB River Basin

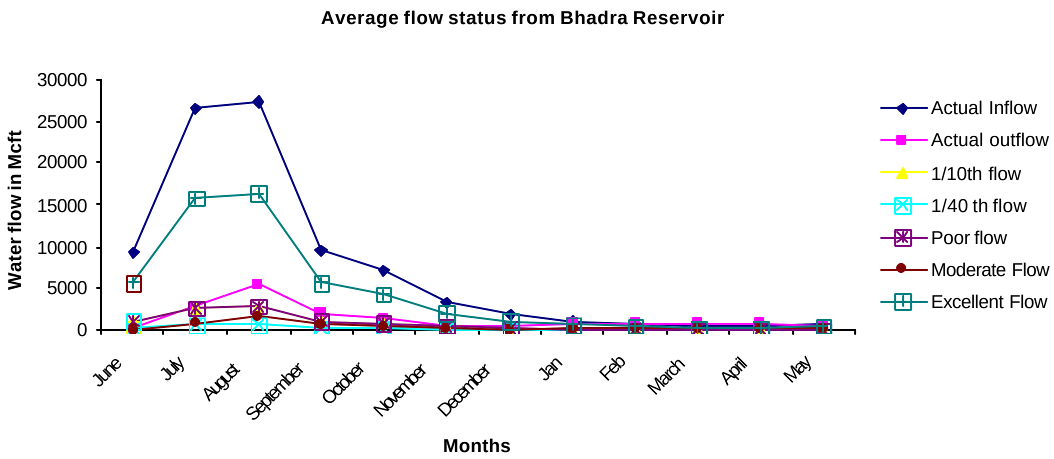
	Services	Region I	Region II	Region III
Provisional services	Food – Fish Catch	S	S	S
	Livestock	S	S	S
	Fuel wood	NS	NS	NS
	Genetic resources	S	NS	NS
Supporting services	Regular flows – recharge of groundwater	S	S	NS
	Flood plains – recharge of soil	NS	NS	NS
	Periodic high flows – seed dispersal	S	Ns	NS
	Well timed flows – water demands	S	S	S
Regulating services	Flood and Irrigation	S	S	S
Spiritual	Religious	S	S	S
Cultural	Kalasa – (Tourism, reduced pressure on natural ecosystem	S	S	S

S: Significant NS: Non-significant

a. Flow status in the River basin

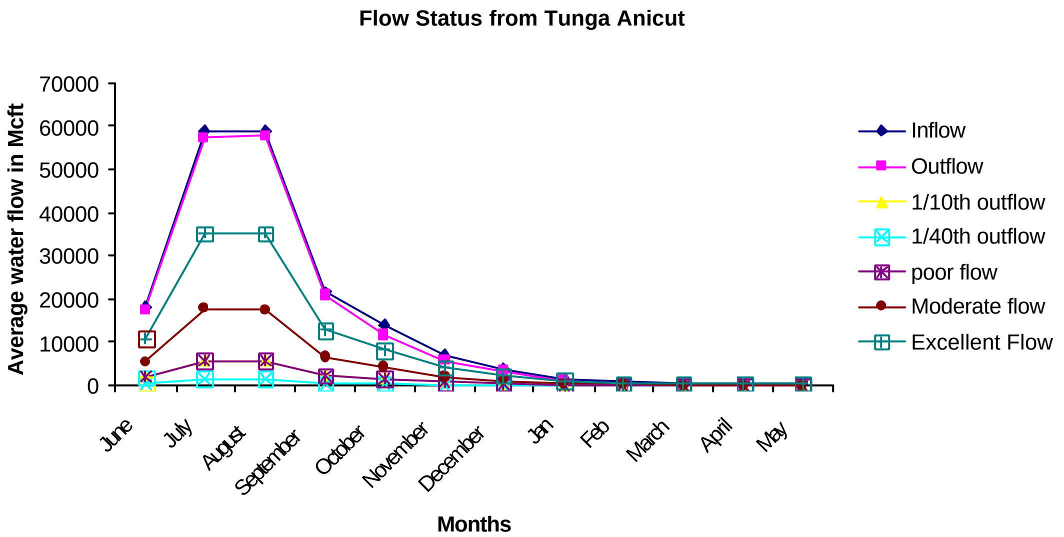
i. Flow status of Bhadra Reservoir

Figure 3: Average Flow from the Bhadra Reservoir



The average flow status of the Bhadra reservoir for 33 years is shown in Figure 3 and refer Annexure 6. During the monsoon season, outflows are moderate. However, percentage of utilisation from this reservoir is high. One interesting aspect is release of significant amount of water during those months when inflows are nil to cater to the downstream users *ii. Flow status of Tunga Anicut*

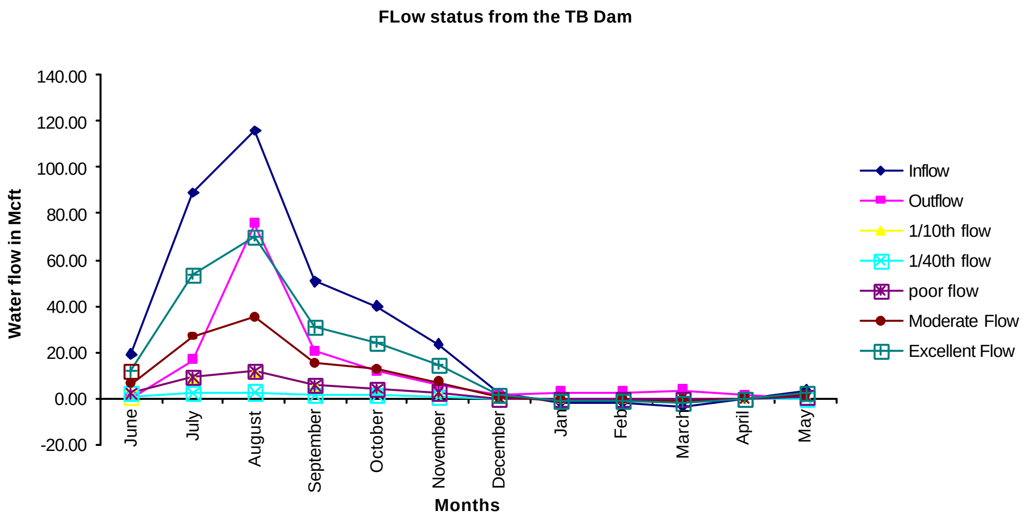
Figure 4: Average Flow Status from Tunga Anicut



Average flow status of Tunga Anicut is shown in Figure 6 and Annexure 7. As it is Anicut only, it cannot impound and divert water completely through canals, during monsoon, Tunga has surplus wat er flow and flow is excellent. From June to January it flows in excellent condition downstream. Only in May the water flow is reduced and it failed to provide minimum flow downstream. In all the other months, the flow is above the poor condition but does not exceed moderate condition.

iii. Flow status of TB Reservoir

Figure 5: Flow status from TB Dam



The water flows from the TB dam downstream is shown in Figure 7 and Annexure 8. Only in a few months of the year, in the non-monsoon months due to less inflow and the commitments with the downstream irrigation and urban water supply there is less flow. May and June showed less flow in the river. Mainly due to the lean months and the pre-monsoon periods, there is less water inflow and there may not be the sufficient water in the reservoir.

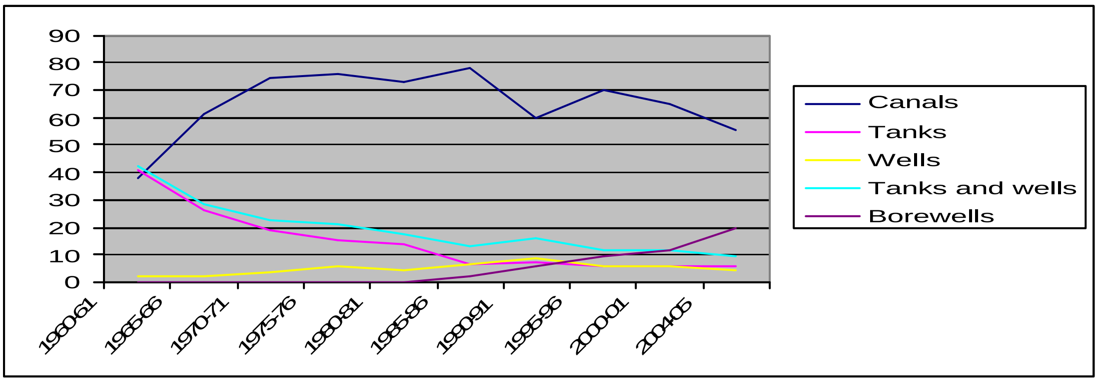
b. Possible impacts due to absence of natural flow: Alteration of Ecosystem

Some of the major alterations of the ecosystem due to the control of minimum flow

i. Massive loss of wetlands

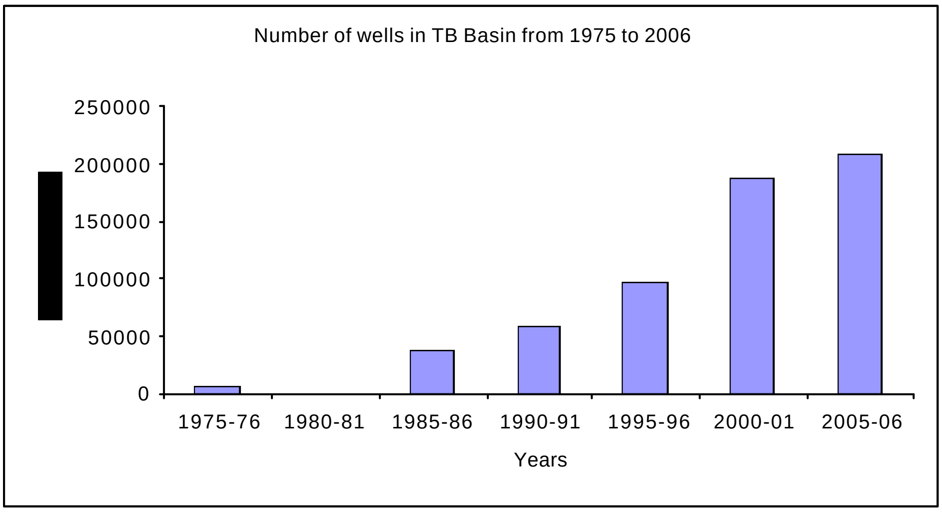
In the river basin it was observed from the field survey that there was decrease in wetlands in the river basin. Traditionally, the TB basin is known for its agricultural prosperity and has supported several civilisations, like Vijayanagar etc. The sources of irrigation were primarily canals, tanks and wells. Bore wells were introduced in recent decades and the historical contribution is given in Figure 6.

Figure 6: Profile of irrigation sources over time (in percentage)



It is clear that with water impoundment, natural flow of water was disturbed in tanks that are basically dependent on such flow of water. The overall area irrigated by wells has shown marginal increase, indicating the recharge of groundwater table in some areas. Over exploitation of ground water in the river basin is another cause for its contamination. In the river basin, 3,878 villages are located and their main source of drinking water is ground water. This has increased the burden on ground water, which is also used in agriculture. There are 5.9 lakh wells in the entire basin and ground water extracted was 2,25,5787 HAM as on March 2004. It was 60,543 HAM in 1994 (Figure 7).

Figure 7: No. of Wells in TB River Basin



Over exploitation of ground water has lead to ground water degradation in water quality in the TB basin. The study carried out by Department of Mines and Geology says that ground water levels have depleted in the taluks in the TB basin as shown in Table 12.

Table 12: Ground Water Levels in mtrs

Districts	Years		
	1978	**1987**	**1997**
Bellary	7.37	7.40	10.91
Chikkamagalur	8.95	9.22	9.95
Raichur	5.96	7.03	6.58
Shimoga	9.23	9.03	9.76

ii. Decline of riparian forests

In the river basin from the origin of the river to the confluence with the Krishna River massive loss of riparian forest cover is observed. In many places on the river bank forest cover has vanished.

iii. Invasion of dry river channels and former wetlands by vegetation

In the river basin, some regions of the river bank have been converted to agricultural land during summer season. In the Honnali it was observed that the local community has been using the river bed as agricultural land during the lean months. The river bed has decreased from its original width and the local community converted it to agricultural land. The community is using pesticides and fertilisers to grow the vegetables and it has resulted in water pollution.

iv. Decline in population and species diversity of invertebrates, fish and water birds

v. *Quality — the chemical quality of groundwater expressed in terms of pH, salinity and/or other potential constituents, including nutrients and contaminants*.

Across Bhadra River, the mining activities of a few industries like, Kudremukh Iron Ore Company Ltd, has affected the river water. There are two more major industries along the bank of Bhadra River at Bhadravathi, the Mysore Paper Mills and Vishweshvaraiah Iron and Steel Industries. Along the Tungabhadra River basin, the major industry is Harihara Polyfibres, two sugar industries, two distilleries and the Raichur Thermal Power Plant. In addition, the mining activities at Hospet, Bellary, Sandur and Hatti have resulted in decreased depth and increased siltation. A study by the (Karnataka State Pollution Control Board (KSPCB), observed that pollution by dumping of agricultural residues/pesticides was immense in 2005 at Balehonnur where ginger, the major crop, was grown using huge quantities of pesticides.

c. Minimum required EF in TB basin

Of all the environmental changes wrought by construction and operation of the dam, the alteration of natural water flow regimes has had the most pervasive and damaging effects on river ecosystems and species (Poff *et al*. 197§, Postel and Richter 2003**). Bunn and Arthington (2002) summarise their review of this study by highlighting four primary ecological impacts associated with flow alteration: (1) because river flow shapes physical habitats such as riffles, pools, and bars in rivers and floodplains, and thereby determines biotic composition, flow alteration can lead to severely modified channel and floodplain habitats; (2) aquatic species have evolved life history strategies, such as the timing of reproduction, in direct response to natural flow regimes, which can be desynchronized by flow alteration; (3) many species are highly dependent upon lateral and longitudinal hydraulic connectivity, which can be broken by flow alteration; and (4) the invasion of exotic and introduced species in river systems can be facilitated by flow alteration.

Endemism is very high in the river basin, both in the terrestrial ecosystem and aquatic ecosystem. Agricultural water demand and industrial water demand has increased the stress on the water resources of the river basin. Several incidents have occurred in the basin due to less flow. Local community has failed to link the effects due to the less flow of runoff.

d. Summary of Findings

- Natural Flow Regime in Tungabhadra basin was completely changed as early the 1960s. As discussed in the results section, from the 1960's onwards more than 70 TMC of the river water was diverted by developmental activities. From the earlier agricultural pattern of semi-arid crops, the entire basin has shifted to water intensive crops whereever possible. Bore wells are another important feature.

- The immediate impact of the flow regime change was observed in the vicinity of river where the farmers' observed that their consumption of inorganic fertilisers has increased because now their fields are getting contaminated by the silt,
- The ground water table has dropped down along the river course and
- Quality of river water has decreased from what it used to be as a result of reduction in the diversity factor

Way Forward

Speaking through the decisions of various tribunals, the higher judiciary has made it clear that environmental flows should be integrated into planning and water use of riverine systems. Concerned agencies should initiate measures to quantify the suitable flows for different stretches of rivers in the country.

Table 13: Summary of Environmental Flows

Water Requirement	Optimum water requirement	Existing Water flows	Potential benefits	Implications
Water requirement	**Desktop analysis**[††] **French fisheries Law** $1/10^{th}$ flow- $1/40^{th}$ flow- **Montana Method** Poor – $1/10^{th}$ flow Moderate Flow- $1/30^{th}$ flow Excellent Flow- $1/60^{th}$ flow	Bhadra Reservoir Project has poor flow Poor flow is high in the BRP	Pollution dilution Ground water table recharge Increase in Fish production	Upper Bhadra project has planned to divert water from Tunga, the region's coffee plantation has increased and the water demand has increased, it cuts the potential benefits and leads to severe environmental damages
		Tunga anicut has excellent flow	Downstream has rich aquatic biodiversity as Tunga River is the water source for Shimoga city and presently Bhadra water pollution is diluted by the Tunga River after confluence near Kudli	Upper Bhadra Project has planned to divert water from Tunga; it affects downstream. Fishermen population is high on the Tunga River
		TB dam has less flow	As this region is water deficit region, it has water scarcity problem, as human settlements and agricultural activities are increased across the river basin,	Tungabhadra River is the major source for many human settlements and industries, and agricultural activities. Most of the downstream agricultural families are traditionally extracting water from the main river.
Water Reduction of natural flow				
Bhadra reservoir Project at Lakkavalli	64.8 TMC			Downstream from Lakkavalli to Holehonnur 38 km (approx) is facing industrial water pollution
Upper Tunga Project at Gajanur	23.74 TMC			It has surplus flow
Tungabhadra Dam at Hospet	132 TMC			Downstream from TB Dam Hospet to Rajola bunda has severe water scarcity due to less flow
Ecosystem	**Region**	**Field Investigation**	**Methodology**	
Upstream Ecosystem	*Origin of river (Gangamula) to Bhadra Reservoir Project (BRP) and Tunga Anicut-Region of Surplus* Has rich biodiversity with, 1 National Park	Interaction with the all the stakeholders in the following locations 1. Malleswara 2. Kalasa 3. Magundi	Desktop analysis	Region has rich biodiversity Human dependency on water is less compared to downstream and mid stream

[††] Due to time limit we used desktop analysis, other methodologies have been discussed in the chapter

	1 Tiger Reserve, 1 Bird Sanctuary			
Mid Stream Ecosystem	*BRP, Tunga Anicut to TB Dam, Hospet- Controlled Flow region* Semi arid region, Agricultural and Industrial activities are high	1. Bhadravathi 2. Kodumagge 3. Holehonnur 4. Honnali 5. Harihar 6. Medleri 7. Singatulur	Desktop analysis	Region is largely dependent on fresh water, fishing activities are high, industrial and human settlements are increasing on the bank of river
Downstream Ecosystem	*Downstream of TB Dam-Region of deficit* There are 12 anicuts on left and right banks of the river to facilitate the water extraction for irrigation	1. Hampi 2. Ramasamudra 3. Kampli 4. Dadesugur 5. Rajolibunda	Desktop analysis	This region has water deficit, drinking water supply and agriculture also facing scarcity
Socio Economic Condition				
Dependent	Total population-78.78 lakh Fishermen Population-92207	Interaction with all the stakeholders,	Agricultural pattern has changed, riverine fishing activities are reduced, Industries are increased	Dependency on water is increasing by all the sectors, agriculture, domestic usage, and industrial sector

Reference

10th International River Symposium and Environmental Flows Conference (2007). A Timely Event in the Right Place – The World's Driest Continent During Severe Drought. *Environmental Flows*, 4 (1).

Arthington, A H, J L Rall, M J Kennard and B J Pusey (2003). Environmental Flow Requirements of Fish in Lesotho Rivers using the DRIFT methodology. *River Research and Applications*, 19: 641-66.

Baartmans, F (1990). *Apah, the Sacred Waters, An Analysis of a Primordial Symbol in Hindu Myths*. Delhi: B R Publishing.

Bernhardt, E S, E Bunn, D D Hart, B Malmqvist, T Muotka, R J Naiman, C Pringle, M Reuss, and B van Wilgen (2006). The Challenge of Ecologically Sustainable Water Management. *Water Policy*, 8: 475-79.

Brian D Richter, Andrew T Warner, Judy lMeyer and Kim Lutz (2006). A Collaborative and Adaptive Process for Developing Environmental Flow Recommendations. *River Research Application*. 22: 297-318.

Christer Nilsson, Catherine A Reidy, Mats Dynesius, Carmen Revenga (2005). Fragmentation and Flow Regulation of the World's Large River Systems. *Science*, 308 (5720): 405-408

Committee on River Science at the U S Geological Survey (2007). National Research Council, River Science at the US Geological Survey.

Damming the Sesan River (2002). Impacts in Combodia and Vietnam. *International Rivers Network Briefing Paper* 4.

Deepa Joshi and Ben Fawcett (2001). Water, Hindu Mythology and an Unequal Social Order in India. Paper presented at the Second Conference of the International Water History Association, Bergen.

Dyson, Megan, Bergkamp, Ger and Scanlon, John (eds) (2007). IUCN, Water and Nature Initiative. Gland: IUCN.

Emerton L (ed) (2005). Values and Rewards: Counting and Capturing Ecosystem Water Services for Sustainable Development. *IUCN Water, Nature and Economics Technical Paper No. 1.*

Flessa, K W (2004). *Ecosystem Services and the Value of Water in the Colorado River Delta and Estuary*. USA and Mexico: Guidelines for mitigation and restoration.

Sudhakar G, V Venkateswarlu (1989). Ecological Imbalances in the Rivers of Andhra Pradesh (India): Effect of Paper Mill Effluents on the Rivers Tungabhadra and Godavari. *International Journal of Environmental Studies,* Volume 34 (1&2): 89-97

Green River, South Eastern United States, Nature Conservancy, Clolarado, pp. 2.

Krishnaswamy Jagdish, Milind Bunyan, Vishal K Mehta, Niren Jain, K Ullas Karanth (2006). Impact of Iron Ore Mining on Suspended Sediment Response in a Tropical Catchment in Kudremukh, Western Ghats, India. *Forest Ecology and Management,* 224: 187-98.

Lankford, B A, Merrey D J, Cour J, Hepworth N (2007). *From Integrated to Expedient: An Adaptive Framework for River Basin Management in Developing Countries*. Colombo, Sri Lanka: International Water Management Institute.

Manikya Reddy, P, V Venkateswarlu (1986). Ecology of Algae in the Paper Mill Effluents and their Impact on the River Tungabhadra. *Journal of Environmental Biology*, 7 (4): 215-24.

Megan Dyson, Ger Bergkamp and John Scanlon (2003). Flow: The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, UK.

Michael Douglas, Eric Valentine, Mark Kennard, Brad Pusey, Sue Jackson, Helen Larson, Steve Tickell, Simon Townsend, Quentin Allsop, Blair Grace, Poncie Kurnoth, Julian Olden (2007). Daly River Fish and Flows Project: An Environmental Flows Study, Land and Water Australia.

Nick Schofield, Alana Burt and Daniel Connell (2003). Environmental Water Allocation: Principles, Policies and Practices, Land and water, Australia.

Pascal Costanza (2003). Dynamically Scoped Functions for Runtime Modification. http://citeseer.ist.psu.edu/rd/3918947%2C719047%2C1%2C0%2CDownload/http%3AqSqqSq.

Poff N L, J D Allan, M B Bain, J R Karr, K L Prestegaard, B D Richter, R E Sparks, and J C Stromberg (1997). The Natural Flow Regime: A Paradigm for River Conservation and Restoration. *BioScience,* 47: 769-84.

Postel, S and B Richter (2003). Rivers for Life: Managing Water for People and Nature. Washington, D.C., USA: Island Press.

Ravenga C, J Brunner, N Henninger, K Kassen, R Payne (2000). Pilot Analysis of Global Ecosystems. Freshwater Systems. Washington, DC: WRI. Source: http://pdf.wri.org/page_freshwater.pdf.

Rashid Hassan, Robert Scholes, Neville Ash (2005). *Ecosystems and Human Well-being: Current State and Trends, Volume 1*. Washington, DC: The Millennium Ecosystem Assessment Series.

Reddy, P M, Venkateswarlu (1987). Assessment of Water Quality and Pollution in the River Tungabhadra near Kurnool, Andhra Pradesh. Journal of Environmental Biology, 8 (2): 109-19.

Reuss, M (2005). Ecology, Planning and River Management in the United States: Some Historical Reflections. *Ecology and Society*, 10 (1): 34.

Richard Davis, Rafik Hirji (2003). *Water Resources and Environment Technical Note C.2, Environmental Flows: Case Studies*. Washington, D.C.: The World Bank.

Richter, B D and G A Thomas (2007). Restoring Environmental Flows by Modifying Dam Operations. *Ecology and Society*, 12 (1): 12.

Roland Jansson, Christer Nilsson and Björn Malmqvist (2007). Restoring Freshwater Ecosystems in Riverine Landscapes: The Roles of Connectivity and Recovery Processes. *Freshwater Biology*, 52 (4): 589-96.

Sandra Postel, Brian D Richter (2003). *Rivers for Life: Managing Water for People and Nature*. Nature Conservancy, Island Press.

Smakhtin, V, M Arunachalam, S Behera, A Chatterjee, S Das, P Gautam, G D Joshi, K G Sivaramakrishnan, K S Unni (2007). *Developing Procedures for Assessment of Ecological Status of Indian River Basins in the Context of Environmental Water Requirements*. Colombo, Sri Lanka: International Water Management Institute. (IWMI Research Report 114)

Study of the Downstream Impacts of the Yali Falls Dam in the Se San River Basin in Ratanakiri Province, Northeast Cambodia, prepared by Fisheries Department, May 29, 2000.

World Commission on Dams (2000). *Dams and Development: A New Framework for Decision-Making*. Earthscan: London.

Annexure 1: Population of the river basin over a period of time

Total Population (Including Institutional and Houseless Population)					Percentage growth
Year		**Population**	**Male**	**Female**	
1961	Total	2953453	1518442	1435011	
	Rural	2453906	1273387	1180520	
	Urban	740216	387900	352316	
1971	Total	4057622	2083106	1974516	27.21
	Rural	3005054	1533123	1471931	18.34
	Urban	1052568	549933	502555	29.68
1981	Total	5456334	2787548	2668786	25.63
	Rural	3905472	1985009	1920463	23.06
	Urban	1550862	802539	748323	32.13
1991	Total	6677109	3408052	3269057	18.28
	Rural	4727507	2402184	2325323	17.39
	Urban	1949602	1005868	943734	20.45
2001	Total	7878749	4002551	3876198	15.25
	Rural	4906678	2486720	2419958	3.65
	Urban	2159817	1103512	1056305	9.73

Source: Census of India, 1961 – 2001

Annexure 2: Types of forests in Kudremukh NP

Forest Type	Total in Sq.km
Evergreen (Poeceiloneuron indicum- Hoppea Canadensis Elaeocarpus tuberculatus series)	48.32
Evergreen Evergreen (Poeceiloneuron indicum-palaquium elliptium- Myristica sp. Series)	58.57
Secondary evergreen	110.27
Semi evergreen	121.10
Moist deciduous	55.92
Shola	36.81
Grasslands	187.78
Sparse grass/rocky	23.01
Scrub	22.19
Forest plantation	5.85
Areca plantation	0.03
Coffee plantation	0.18
Agriculture /fallow	8.37
Mine/mine dump	.28
Water	2.61
Unclassified	.37
Total	681.66

Annexure 3: District-wise Inland Fish Production in Karnataka, (1999-2000 to 2002-2003), (Metric Tonnes)

District	1999-00	2000-01	2001-02	2002-03
Bagalkote	363.09	181.49	426.49	449.49
Belgaum	4134.98	3003.38	2160.38	1637.38
Bellary	11489.07	10394.99	7660.57	6339.79
Bidar	1284.65	1355.75	1130.75	720.75
Bijapur	1902.17	1660.37	1673.37	1762.37
Chickmagalur	4588.19	4302.99	4155.99	2796.99
Davanagere	3300.09	4079.65	3801.49	2906.49
Dharwad	1977.84	2010.84	1358.84	1049.06
Gulbarga	3329.13	3531.63	4289.63	3925.63
Haveri	2203.91	3102.91	2444.91	739.91
Raichur	3463.92	3409.92	3433.92	2597.92
Shimoga	11711.21	12753.71	9297.71	5006.71
Total	126646.33	127468.57	121195.87	86262.61

Annexure 4: Water consumed by the Agriculture Sector

Year	Water usage in TMC ft for Agriculture		
	Surface water	Ground water	Total
1960-61	NA	NA	303.0
1965-66	NA	NA	313.3
1970-71	NA	NA	345.6
1975-76	274.1	70.6	344.7
1980-81	323.9	28.6	352.5
1985-86	279.6	96.6	376.2
1990-91	282.3	136.7	419.0
1995-96	272.7	237.1	509.8
2000-01	279.1	185.6	464.6
2004-05	227.7	286.6	514.3

Source: TB water resource department and DMC
NA: Not Available

Annexure 5: Ground water extraction levels in TB basin (HAM)

District	Total recharge	Net availability	Irrigation	Domestic and industrial	Other uses	Total Usage
Bellary	39364.33	38306.78	10420.27	2705.63	13125.9	103922.9
Chikkamagalur	34463.79	33046.44	10781.39	1728.46	12509.85	92529.93
Davanagere	55370.96	53796.98	36895.82	2939.25	39835.1	188838.1
Haveri	33537.95	32052.33	21214.69	2325.25	1439168	1528299
Koppla	43950.69	42981.72	15024.59	1241.88	16266.48	119465.4
Raichur	58456.3	57232.4	6670.86	2449.38	9120.25	133929.2
Shimoga	35633.6	34459.06	7944.08	1410.94	9355.03	88802.71
Total	300777.62	291875.7	108951.7	14800.79	1539381	2255787

Source: Report on Dynamic Ground Water Resources on Karnataka as on March, 2004, DMG and CGWB, June 2005

Annexure 6: Quantum of EFs in required from Bhadra Reservoir

Month	Average Inflow	Actual outflow	French fisheries Law		Montana Method			Remarks
			1/10th flow	1/40th flow	Poor flow	Moderate Flow	Excellent Flow	
June	9363	261	936.2727	234.0682	936.2727	2808.818	5617.636	Less flow
July	26481	2784	2648.073	662.0182	2648.073	7944.218	15888.44	Poor flow
August	27449	5569	2744.912	686.228	2744.912	8234.736	16469.47	Less than Moderate flow
September	9469	2017	946.8606	236.7152	946.8606	2840.582	5681.164	Less than Moderate flow
October	7107	1319	710.697	177.6742	710.697	2132.091	4264.182	Less than Moderate flow
November	3331	391	333.0606	83.26515	333.0606	999.1818	1998.364	Poor flow
December	1764	311	176.397	44.09924	176.397	529.1909	1058.382	Less than moderate flow
Jan	1011	820	101.1	25.275	101.1	303.3	606.6	Excellent flow
Feb	550	836	55.01212	13.75303	55.01212	165.0364	330.0727	Excellent flow
March	437	884	43.72727	10.93182	43.72727	131.1818	262.3636	Excellent flow
April	489	770	48.85455	12.21364	48.85455	146.5636	293.1273	Excellent flow
May	704	421	70.41563	17.60391	70.41563	211.2469	422.4938	Excellent flow

Annexure 7: Quantum of EFs in required from Tunga Anicut

Month	Inflow	Outflow	French fisheries Law		Montana Method			Remarks
			1/10th outflow	1/40th outflow	poor flow	Moderate flow	Excellent Flow	
June	**18311**	**17494**	**1831.1**	**458**	**1831**	**5493**	**10986.8**	**Excellent flow**
July	**58917.0**	**57352.6**	**5891.7**	**1473**	**5892**	**17675**	**35350.2**	**Excellent flow**
August	**58634.7**	**57675.4**	**5863.5**	**1466**	**5863**	**17590**	**35180.8**	**Excellent flow**
September	**21538.2**	**20839.3**	**2153.8**	**538**	**2154**	**6461**	**12922.9**	**Excellent flow**
October	13745.8	11768.7	1374.6	344	1375	4124	8247.5	Excellent flow
November	7029.3	5709.7	702.9	176	703	2109	4217.6	Excellent flow
December	3725.8	3468.4	372.6	93	373	1118	2235.5	Excellent flow
Jan	1703.4	1133.4	170.3	43	170	511	1022.1	Excellent flow
Feb	658.3	191.6	65.8	16	66	198	395.0	Less than Moderate flow
March	519.8	96.0	52.0	13	52	156	311.9	Less than moderate flow
April	451.0	58.4	45.1	11	45	135	270.6	Less than moderate flow
May	565.0	49.2	56.5	14	57	170	339.0	Less flow

Annexure 8: Quantum of EF required from Tungabhadra Reservoir

Month	Inflow	Outflow	French fisheries Law		Montana Method			Remarks
			1/10th flow	1/40th flow	poor flow	Moderate Flow	Excellent Flow	
June	19.39	0.22	1.938853	0.484713	1.938853	5.81656	11.63312	Less flow
July	89.25	16.46	8.924952	2.231238	8.924952	26.77485	53.54971	Less than moderate flow
August	116.05	75.32	11.60506	2.901265	11.60506	34.81518	69.63037	Excellent flow
September	50.98	20.29	5.097742	1.274435	5.097742	15.29323	30.58645	Moderate flow
October	39.90	11.73	3.989503	0.997376	3.989503	11.96851	23.93702	Moderate flow
November	23.32	5.16	2.33241	0.583102	2.33241	6.997229	13.99446	Less than moderate flow
December	2.04	1.20	0.204158	0.05104	0.204158	0.612474	1.224948	Moderate flow
Jan	-2.16	2.46	-0.2156	-0.0539	-0.2156	-0.64681	-1.29363	Excellent flow
Feb	-2.03	2.53	-0.20299	-0.05075	-0.20299	-0.60898	-1.21796	Excellent flow
March	-3.51	3.07	-0.35141	-0.08785	-0.35141	-1.05423	-2.10846	Excellent flow
April	-0.10	1.17	-0.00973	-0.00243	-0.00973	-0.0292	-0.05839	Excellent flow
May	3.31	0.26	0.33059	0.082648	0.33059	0.99177	1.98354	Less flow

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