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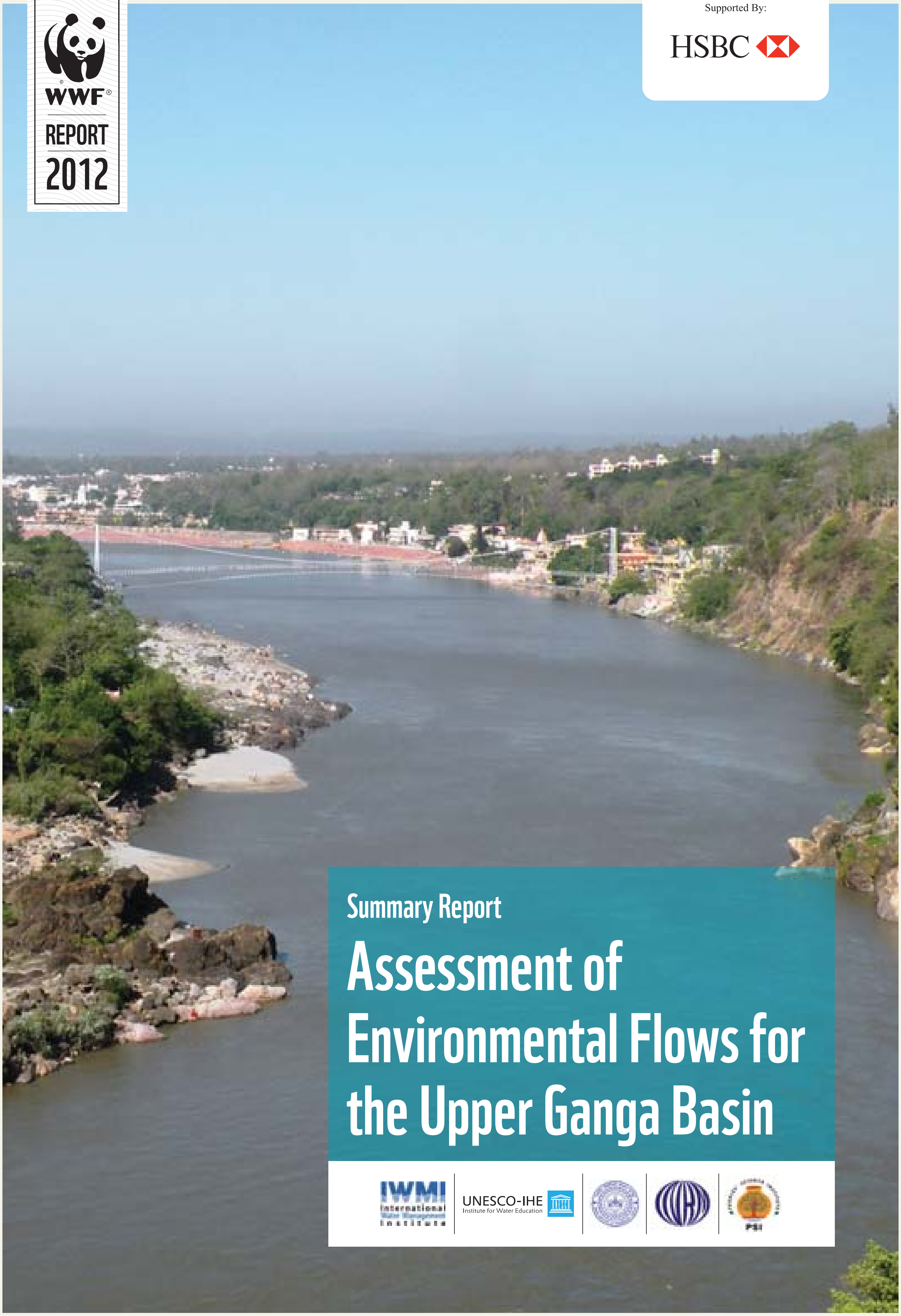

Summary Report

Assessment of Environmental Flows for the Upper Ganga Basin

IWMI International Water Management Institute

UNESCO-IHE Institute for Water Education

PSI

AUTHORS

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ACKNOWLEDGEMENTS

Working on this initiative has been a challenge. We would not have reached this stage without the inputs and support of several individuals and institutions that have helped us in our endeavour.

Dr. Tom Le Quesne at WWF-UK provided us the initial conceptual framework, taught us about E-Flows and got us started on the journey. We also express our gratitude to Mr. Ravindra Kumar from SWaRA, Government of Uttar Pradesh, who has been a constant source of encouragement and for his valuable contribution to this work. We would like to thank Mr. Paritosh Tyagi, Former Chairman of Central Pollution Control Board, who has been associated with the Living Ganga Programme since its inception and shared his rich knowledge on the subject, and Dr. Savita Patwardhan from Indian Institute of Tropical Meteorology, Pune for providing us with much needed climate data.

Key partners who have been part of this study, and without whom it would not have been possible to complete is are Dr Ravi Chopra and Ms. Chicu Lokgariwar, People's Science Institute, Dehradun; Prof Vinod Tare, Prof Rajiv Sinha and Dr Murali Prasad, IIT Kanpur; Dr. Vikrant Jain, Delhi University; Prof Prakash Nautiyal, Garhwal University; Prof AK Gosain, IIT Delhi; and Dr Sandhya Rao, INRM.

At WWF-India, we are highly obliged to Mr. Ravi Singh, Secretary General and CEO, who gave us unparalleled support to us for taking on this tough assignment and Dr. Sejal Worah, Programme Director, who gave critical inputs in shaping this study and developing this publication. Thanks are also due to Dr. Suresh Kumar Rohilla, who coordinated the project in the initial phase. The authors would also like to thank the dedicated support provided by the WWF India Living Ganga team including Mr. Suresh Babu, Dr. Anjana Pant, Dr Sandeep Behera, Dr Asghar Nawab, Ms. Pallavi Bharadwaj, Mr. Anshuman Atroley, Ms. Arundhati Das and Ms. Ridhima Gupta for their support. Thanks to Dr G Areendran and Mr Krishna Raj for GIS and mapping support.

We would like to acknowledge HSBC's financial support through HSBC Climate Partnership.

Published by WWF-India

Designed by: Mallika Das
Printed by: Galaxy Offset (India) Pvt. Ltd., New Delhi

Photo Credit: Cover & facing page Dr. Sejal Worah/WWF-India

Summary Report

Assessment of Environmental Flows for the Upper Ganga Basin

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Photo Credit: WWF-India

Summary Report
ASSESSMENT OF ENVIRONMENTAL FLOWS FOR THE UPPER GANGA BASIN

Ecosystem integrity as well as the goods and services offered by the rivers in India are getting adversely affected by the changes in quantity, quality and flow regimes. Growing water abstractions for agriculture, domestic, industrial and energy use are leaving many rivers running dry, while others are becoming severely polluted.

The mighty river Ganga is no exception. During its over 2,525 km journey from Gangotri to Ganga Sagar, there are complex, nested sets of challenges that threaten the very existence of this river revered by millions of Indians. In the upper Himalayan reaches, the flow of the river is vulnerable to water abstractions by existing and proposed hydropower projects. From the time the river enters the plains, abstractions for agriculture, urban and industrial uses leave the river lean and polluted. As the river's dynamics have been altered by diversions and inefficient use, the freshwater flow has reduced, leading to a reduction in the assimilative capacity. With more pollution added on to the lean rivers, the pollution load in the river has gone up. Climate change is adding another set of complexities to the problems of the Ganga and to the hundreds of millions of people who depend on the basin.

FOR THE LGP, ONE OF THE KEY CHALLENGES WAS TO UNDERSTAND THE ISSUE OF FLOWS - HOW MUCH WATER DOES THE RIVER NEED TO SUSTAIN ITS FUNCTIONS (SOCIAL, CULTURAL AND ECOLOGICAL)

These complexities prompted WWF-India to initiate its Living Ganga Programme (LGP) in 2008 to develop a comprehensive framework for sustainable management of water and energy in the Ganga basin in face of climate change. For the LGP, one of the key challenges was to understand the issue of flows – how much water does the river need to sustain its functions (social, cultural and ecological). World over, there is rising realisation and acknowledgement that managing flows can add a fresh lease of life to dying rivers. Environmental Flows (E-Flows) are increasingly recognised as a key to the maintenance of the ecological integrity of the rivers, their associated ecosystems, and the goods and services provided by them.

The underlying principle that drove the work on E-Flows under the LGP is that, E-Flows are multidimensional and their assessment is both a social and technical process, with social choice at core as it depends on what the society wants a river to do for them – to support culture and spirituality, promote livelihoods or re-generate biodiversity or all the above functions and more.

It is this realisation that prompted WWF to bring together civil society groups, Indian and international experts (hydrologists, hydraulics, fluvial geomorphologists, ecologists, engineers, and sociologists) and Government departments to sit together, deliberate and develop a methodology for assessment of E-Flows. This report presents a summary of the process adopted, methodology adapted for the assessment of E-Flows for upper Ganga basin and the preliminary results from this exercise.

ENVIRONMENTAL FLOWS AND ITS SIGNIFICANCE

Environmental Flows are the flows required for the maintenance of the ecological integrity of rivers, their associated ecosystems and the goods and services provided by them. Environmental Flows are increasingly recognised as a vital contributor to the continuing provision of environmental goods and services upon which peoples' lives and livelihood depend.

The recognition of the need to establish the extent to which the flow regime of a river can be altered from its natural state, for the purpose of water resource development and management, while maintaining the integrity of the river ecosystem and accepted levels of intervention within the ecosystem has provided the impetus for an accelerated development of Environmental Flows Assessments (EFA).

Various challenges that rivers face reinforce the necessity to consider implementing Environmental Flows (E-Flows) for improving overall river health; especially at this juncture, when water withdrawal and usage has reached a stage where many rivers are completely over-allocated. At present, in addition to the pure engineering approach, a more holistic approach for water resources management is required. This approach seeks to restore river flows through a multi-disciplinary and multi-stakeholder process of managing water usage and withdrawal. It advocates the development of effective water allocation mechanisms that manage the use of scarce resources. It also calls for the assessment and maintenance of E-Flows.

In a nutshell, E-Flows are required for –

1. Maintaining river regimes
2. Making it possible for the river to purify itself
3. Maintaining aquatic biodiversity
4. Recharging groundwater
5. Supporting livelihoods
6. Maintaining sediment movement
7. Preventing saline intrusion in estuarine and delta areas
8. Providing recreation
9. Allowing the river to play its role in fulfilling the cultural and spiritual needs of people

E-Flows aim to provide the balance between the use and protection of natural water resources for people. The assessment of E-Flows aims to identify the required quantity, quality and distribution of flow patterns along the whole length of a river, so that the people, animals and plants downstream can continue to survive by utilizing the river's resources. E-Flows ensure that water resources are used equitably and sustainably.


Photo Credit: Anil Cherukupalli

THE GANGA AND ITS CURRENT STATUS

The Himalayas are the origin and source of major Indian rivers, including the Ganga and the Brahmaputra. The Ganga drains a basin of extraordinary variety in altitude, climate, land use, flora & fauna, social and cultural life.

The Ganga has been a cradle of human civilization - millions depend on this great river for physical and spiritual sustenance. People have immense faith in the healing and regeneration powers of the Ganga. It is unarguably the most sacred river in India and is deeply revered by the people of this country. The river plays a vital role in Hindu religious ceremonies and rituals.

The Bhagirathi is the source stream of the Ganga. It emanates from the Gangotri Glacier at Gaumukh at an elevation of 3,892 m. Many small streams comprise the headwaters of the Ganga. Important among these are the Alaknanda, Dhauliganga, Pindar, Mandakini and Bhilangana. At Devprayag, where the Alaknanda joins the Bhagirathi, the river acquires the name Ganga. It traverses a course of 2525 km before flowing into the Bay of Bengal.

The Ganga Basin is a part of the composite Ganga-Brahmaputra-Meghna basin draining 1,086,000 km^2 in China, Nepal, India and Bangladesh, about 79% area of the Ganga basin is in India. It is the largest river basin in the country, constituting 26% of the country's land mass and supporting about 43% of its population (448.3 million as per the 2001 census).

The Ganga basin in India includes eleven states: Uttarakhand, Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal and Delhi. Rainfall and melt water from snow and glaciers are the main sources of water in the river Ganga. Surface water resources of the Ganga (its long term mean annual flow volume as it enters the ocean) have been assessed at 525 billion cubic meters (BCM).

The average population density in the Ganga basin is 520 persons per square km compared to 312 for the entire country (2001 census). Major cities of Delhi, Kolkata, Kanpur, Lucknow, Agra, Meerut, Varanasi and Allahabad are situated in the basin, and these have large and growing populations. Between 1991 and 2001, the urban population of India has increased by 32%, and this trend is likely to continue. This escalates the pressure on already over-allocated natural resources, including rivers. Further, the rising standards of living and exponential growth of industrialization and urbanization have exposed water resources in general and rivers in particular, to various forms of degradation.

On the other hand, the vast irrigation demand, especially in the state of Uttar Pradesh is met by the major canal systems off the river Ganga at various points, namely – Bhimgoda (Upper Ganga Canal), Bijnour (Madhya Ganga Canal) and Narora (Lower Ganga Canal). These canal systems play a significant role in sustaining the agriculture sector in the state of Uttar Pradesh. In fact the sectoral water allocation, like other states in India, is highest for irrigation in the state of Uttar Pradesh, i.e. about 96%. However, the state government appears to be determined to reduce this mammoth allocation to 79% by 2050.

The Imperial Gazetteer of India allows itself a little poetic license while describing the Ganga:

"There is not a river in the world which has influenced humanity or contributed to the growth of material civilization, or of social ethics, to such an extent as the Ganges. The wealth of India has been concentrated on its valley and beneath the shade of trees whose roots have been nourished by its waters the profoundest doctrines of moral philosophy have been conceived, to be promulgated afar for the guidance of the world".

Meyer, William Stevenson, Sir, 1860-1922, et al. Imperial gazetteer of India. Oxford: Clarendon Press, 1908-1931

METHODOLOGY ADOPTED AND ITS APPLICABILITY FOR THE GANGA

Within WWF India's Living Ganga Programme, a key objective was to develop and promote an approach for securing E-Flows under current and Climate Change scenarios.

A global review of current and numerous E-Flows assessment methodologies indicates that they can be differentiated into hydrological, hydraulic rating, habitat simulation and holistic methodologies. An investigation of the different methodologies concluded that the holistic methodologies are most suitable for the Ganga, being the most comprehensive, in that they not only consider scientific and technical aspects but also socio-economic and environmental aspects.

THE BBM IS A FLEXIBLE PARTICIPATORY AND ROBUST MULTIDISCIPLINARY METHODOLOGY THAT CAN BE APPLIED FOR DIFFERING LEVELS OF INFORMATION AND DATA AVAILABILITY

Of the different holistic methodologies, the working group (or the specialist team) decided to use the Building Block Methodology (BBM) for the assessment of E-Flows under this programme. The BBM is a flexible participatory and robust multi-disciplinary methodology that can be applied for differing levels of information and data availability. It allows the user to focus on key issues of local importance, for instance – in the case of River Ganga - the spiritual and cultural aspects which are of immense importance. The BBM was found to be the most appropriate process for large river basins with multiple users and interests. As with other assessment methodologies, it is based on the principle that some water can be used from rivers without unacceptably degrading them. The BBM is based on the following steps:

- Using a stake-holder consultation process to set objectives for the environmental condition of the river
- Assessing a modified flow regime that will meet those objectives
- Using flow-dependent indicators (e.g. river dolphins, *gharial*, turtles, fish, invertebrates, floodplain plants) and non-consumptive human requirements, as well as water quality metrics and sediment transport, to identify water depths, velocities, river widths and substrate types that will provide the required habitats

Photo Credit: Nitin Kaushal/WWF-India

and conditions. Such hydraulic requirements can then be converted to hydrological (flow) requirements

- Identifying the critical components (building blocks) of the flow regime that govern environmental conditions (e.g. dry and wet season base flows, and different-sized high flows and floods)

This methodology has been used extensively in South Africa, and also in Mexico, Brazil, Kenya, Tanzania, and Australia. A flow chart about the methodology is given in Figure – 1. The characteristics of this methodology include:

1. Bottom up approach, with each recommended flow carefully motivated
2. Multi-disciplinary approach means that each recommended flow is carefully analysed by a group of specialists from different fields (ecology, geomorphology, water quality, sociology)
3. Flexible - can be tailored to suit local conditions as required, for instance – in this case the cultural and spiritual aspects were integrated
4. Most frequently used holistic methodology around the world
5. Rigorous and well documented, with an explicit user manual

Figure 1
The Building Block Methodology process

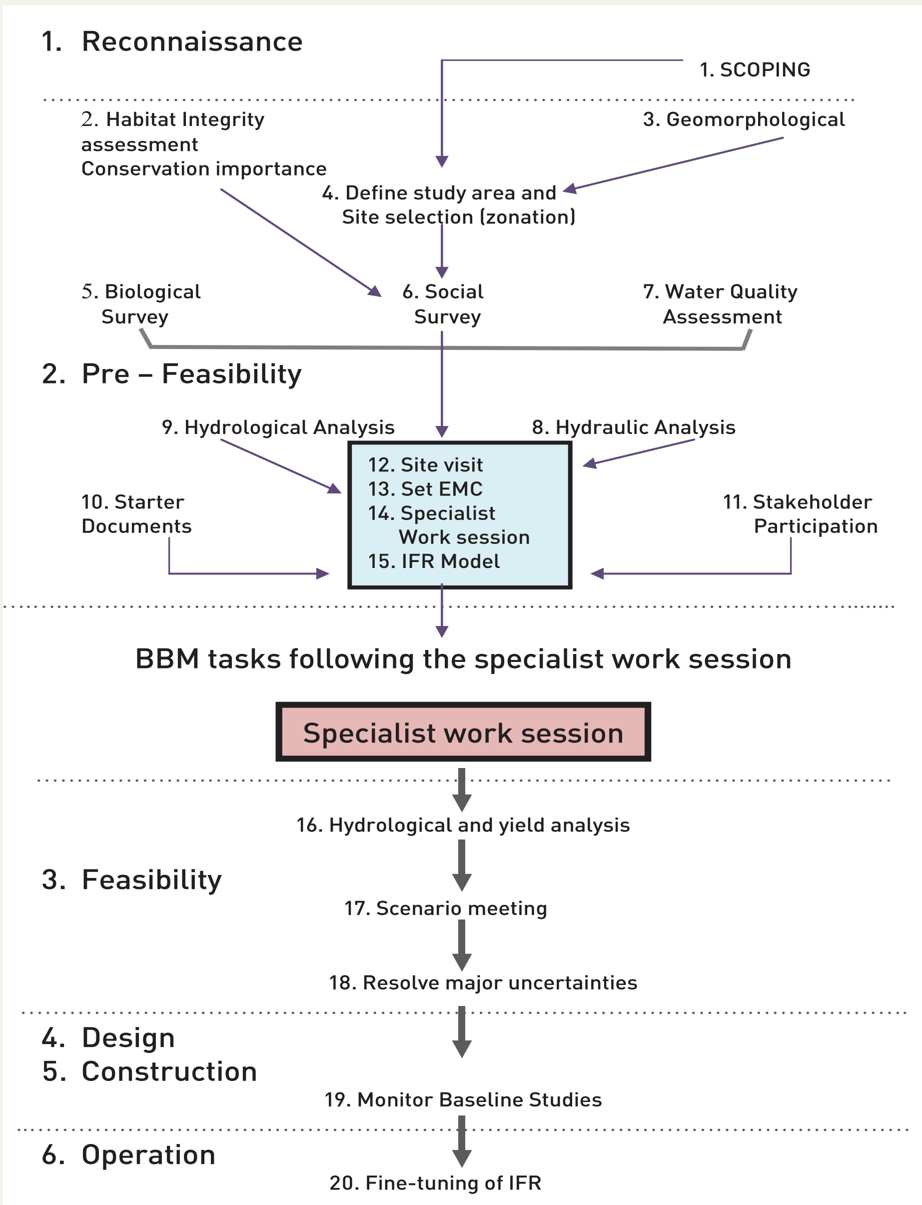


Photo Credit: Amrit Pal Singh

THE PROCESS OF ASSESSMENT OF E-FLOWS FOR THE GANGA

With a view to integrate international expertise in the assessment of E-Flows for river Ganga, WWF–India partnered with the International Water Management Institute (IWMI) and UNESCO–IHE. Initially, WWF-India and IWMI conducted a scoping study on “E-Flows and Climate Change Impacts in the Ganga River Basin”. The purpose of this study was to set the context and objectives, establish the baseline and decide on the scope for a larger programme.

Subsequently, another study on “The Analysis of Stretches of the River Ganga from Gangotri to Kanpur for Homogeneous Zoning” was conducted. The purpose of the study was to analyze this section of the river to establish homogeneous zones. Within each of these zones, a detailed monitoring programme enabled the identification of the most sensitive zones with respect to biodiversity. To capture the activities in the near vicinity of the river, a buffer of 50 km was considered on both sides of the stretch of Ganga River, in addition to the main stem of the river.

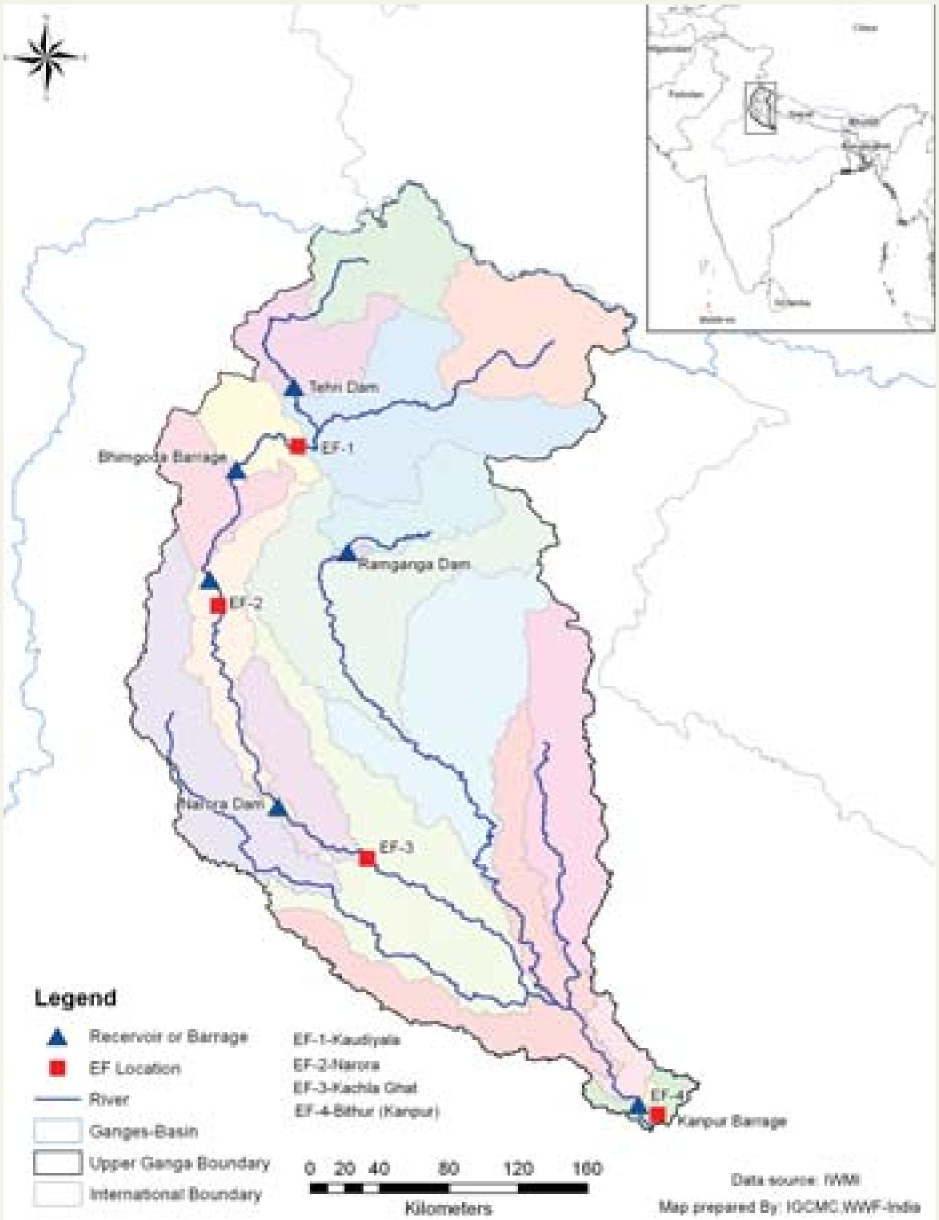
Based on the suggestions of this report and field visits, the upper river was divided into four zones:

1. Zone – I: Gangotri to Rishikesh
2. Zone – II: Garhmukteshwar to Narora (Reference Zone[2])
3. Zone – III: Narora to Farrukhabad
4. Zone – IV: Kannauj to Kanpur

[2] *Reference Zone – the zone which one would ideally refer to, for various aspects/activities/requirements. This zone has water volumes maintained at an optimum level to supply a thermal power plant downstream*

Photo Credit: Anshuman Atroley/WWF-India

Figure 2
A map depicting various E-Flows sites



Zone 1

Zone 2

Zone 3

Zone 4

Photographs illustrating some key physical features of the zones

Following this, an Objectives Setting Workshop was organized to understand and define different aspects of maintaining E-Flows for River Ganga for the conservation of aquatic species and maintaining sustainable flows. The workshop was also used to develop a methodology which would be feasible for the assessment of E-Flows and designation of Ecological Management Classes (EMC) for different stretches of the Ganga.

Six classes of river condition or health, A to F, are recognized, these are designated as the Present Ecological State (PES). From these the overall objective conditions, summarised as the EMC are defined from A to D. (Classes E and F are not considered to be sustainable, and are therefore excluded as potential objectives):

- Class A: close to natural condition
- Class B: largely natural with few modifications
- Class C: moderately modified
- Class D: largely modified
- Class E: seriously modified - no longer providing sustainable services
- Class F: critically modified; no longer providing sustainable services.

Photo Credit: Anshuman Atroley/WWF-India

The outcome of this workshop was about the methodology to be adopted for the assessment of E-Flows. The following sub-tasks were also defined for the detailed study:

1. Hydrology of the upper Ganga
2. Fluvial geomorphology and hydraulic modeling of the upper Ganga
3. Assessment of cultural & spiritual in-stream flow requirements
4. Cultural and livelihood objectives
5. Establishing the habitat preferences of selected aquatic vertebrates in the selected stretch
6. Analysis of water quality and pollution

Following the completion of the studies, a Methodology Workshop was organized during which Terms of Reference for various sub-tasks were discussed, drafted, finalized and shared.

After this workshop, partnerships with Working Groups and specialists were formalised (the experts were assigned with the sub-tasks mentioned above). With a view to identify a site in each zone for detailed investigation, field visits were organized in March 2009. The sites identified for the assessment of E-Flows were:

Kaudiyala
Zone I: Gangotri to Rishikesh
Site: Kaudiyala

Kachla Ghat
Zone III: Narora to Farrukhabad
Site: Kachla Ghat

Bithoor
Zone IV: Kannauj to Kanpur
Site: Bithoor

Zone II, i.e. the stretch between Garhmukteshwar to Narora was identified as the Reference Zone - it was determined that conditions in this zone (flows, habitats, biodiversity, water quality and ecological and social conditions) were adequate to serve as a template for the environmental objectives for the downstream zones. For more than a year, all the Working Groups were engaged in baseline data collection, sampling and surveying at the identified sites. Groups engaged in cultural and spiritual aspects and livelihood aspects also undertook surveying and sampling at places other then the identified sites as per their requirement. For example, to collect the information on cultural and spiritual aspects, interviews and surveys were also conducted during festive occasions in holy towns such as Haridwar and Rishikesh. These towns were adjacent to the sites identified for E-Flows assessment and are crucial to an understanding of cultural and spiritual requirements from the river.

This research and its findings were discussed at a workshop on E-Flows Setting. During this workshop all groups presented their findings in the form of a Starter-Document. It consisted of present and desired conditions of the River Ganga as per the requirements of each component.

Prior to this workshop, the hydrology group prepared a report on ‘Hydrology of the Upper Ganga’. This report explained the in detail the hydrology of the river and formed

Photo Credit: left - Nitin Kaushal/WWF-India; centre & right - Amrit Pal Singh

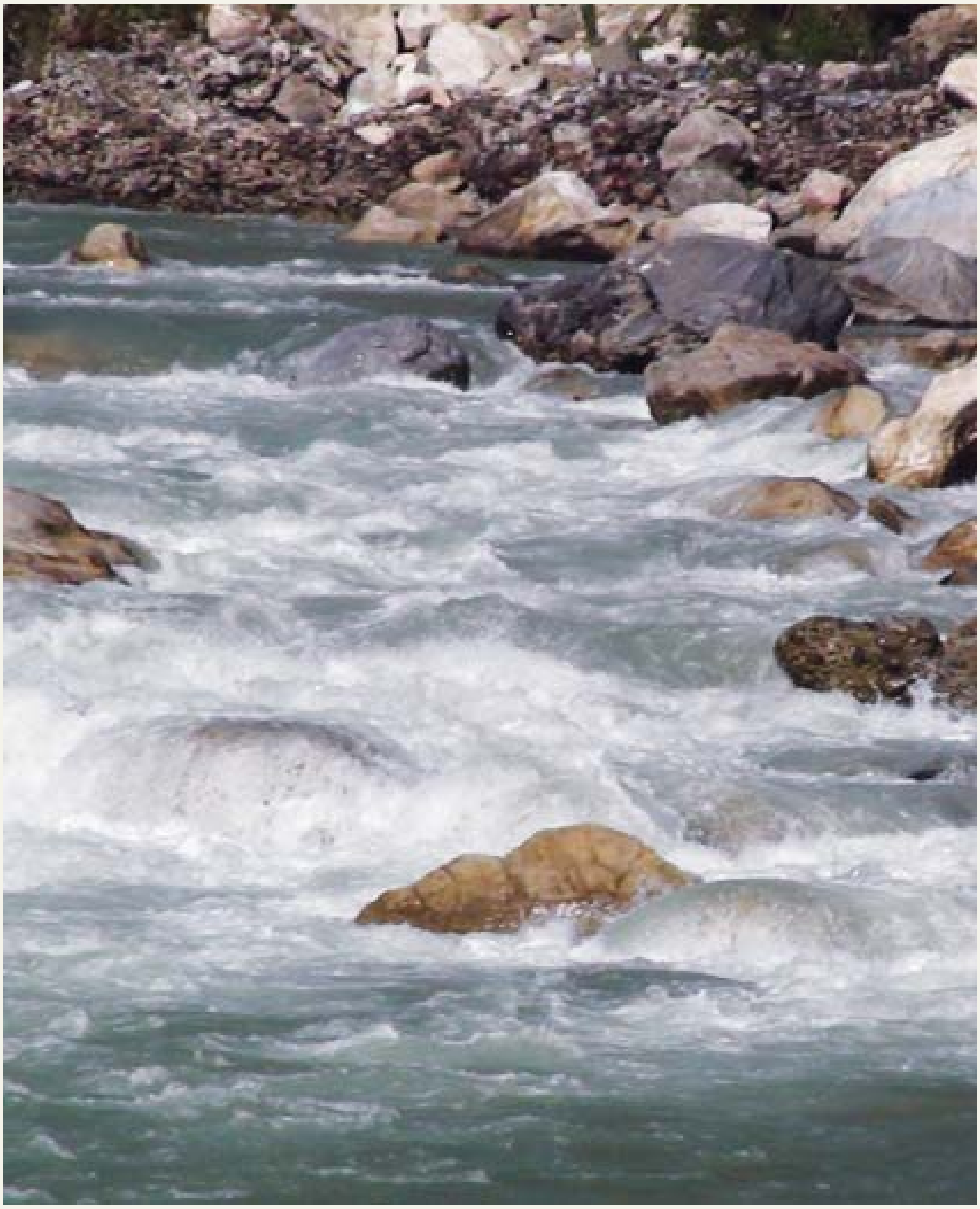


Photo Credit: Nitin Kaushal/WWF-India

the basis for working groups to develop their recommendations in regard to E-Flows as required by their respective component. This report is crucial for the whole process and to illustrate this, an excerpt of this report is given below:

“The focus of the present study has been on the Upper Ganga - the upper main branch of the River. The Upper Ganges Basin (UGB) was delineated by using the 90 m SRTM digital elevation map with Kanpur barrage as the outlet point. The total area of the UGB is 87,787 km^2. The elevation in the UGB ranges from 7500 m at upper mountain region to 100 m in the lower plains. Some mountain peaks in the headwater reaches are permanently covered with snow. Annual average rainfall in the UGB is in the range of 550-2500 mm. A major part of the rains is due to the south-western monsoon from July to October. The main river channel is highly regulated with dams, barrages and corresponding canal systems. The two main dams are Tehri and Ramganga. There are three main canal systems. The Upper Ganga Canal takes off from the right flank of the Bhimgoda barrage with a head discharge of 190 m^3/s, and presently, the gross command area is about 2 million hectare (ha). The Madhya Ganga canal provides annual irrigation to 178,000 ha. Similarly, the Lower Ganga canal comprises a weir across the Ganga at Narora and irrigates 0.5 million ha.

In this study, a catchment scale distributed hydrological model was used (Soil-Water Assessment Tool-SWAT) to simulate water balances and generate flows without any infrastructure projects (Dams, Barrages and Reservoirs) in the Upper Ganges Basin in India. The purpose of this exercise was to:
1. understand the Upper Ganges basin in more “natural” conditions
2. generate “Naturalised” flows for the purpose of calculating E-Flows (EF) requirements in four sites along the main channel.”

The table shows simulation flow results for the 4 EF sites including simulated present flows for EF 2-4. Comparison between natural and present flows showed that on an average, the present annual water volume reduced by 19%, 18% and 25% in EF sites Narora, Kachla Ghat and Bithoor/Kanpur respectively.

Table 1
Annual average simulated flow volume at EF sites

EF Sites	Simulated Flow Volume [MCM]*		% Reduction in Flows
	Natural	Present	
EF1 (Kaudiyala/Rishikesh)	43,112	Not Available	Not Available
EF2 (Narora)	45,974	37,107	19%
EF3 (Kachla Ghat)	46,326	38,043	18%
EF4 (Bithoor/Kanpur)	57,323	42,906	25%

A primary objective of the E-Flows Setting workshop was to use the information collected in the past year by various expert groups, to recommend dry season, wet season and flood flows for maintenance and drought Years, which would meet the pre-defined environmental objectives for ecological, geomorphological, water quality, and socio-cultural aspects of the river.

December to February was designated as the lean flow period and July to September as the high flow period. Out of these spells, January was defined as driest month and August as the wettest month. Flow Motivation Forms were carefully filled by each of the specialists for each site (Kaudiyala, Kachla and Bithoor) and for each season for maintenance and drought years. Rated hydraulic cross-sections at each site provided for the conversion of habitat and process requirements (flow depth, velocity, river width and substrate type) into flows (in cubic meter per second) so that each working group could define the flows required to meet their objectives. Each of the working

** MCM: Million Cubic Metres*

group came up with recommended width, depth and velocity from their perspective, which was then translated into flows by the hydraulics group. These recommended flows were then discussed and a consensus was arrived at. Based on these values, graphs depicting monthly flow requirements were simulated by the hydrology group.

The confidence in the resulting flow recommendations was limited due to unavailability of historical and present discharge data in the public domain.

FLOW MOTIVATIONS

While discussing and predicting flows, depth and average velocity for various scenarios and sites, the working groups made vital comments[4] which are summarized below.

Cultural and Spiritual
Defining the flow requirements for a drought year at Kaudiyala/Rishikesh, it was emphasized that, if the recommended flow is not provided, the build up of debris

and sediment on the lower steps of the ghats will not be washed away. Consequently, the river will no longer be accessible for bathing/worship. However, the people are willing to accept extreme conditions in a drought year to some extent, since they believe that the quantity of water required for purification rituals is minimal. To quote one of the pilgrims, “the water should be enough to cover a cow’s hooves, even this will do. But ideally the water should be up to the waist.”

It was also pointed out that the flows desired by the respondents for cultural and spiritual aspects are not based on a functional demand. It is more of a subjective or emotional need based on a perception of what a mighty goddess-river ought to be like. One comment was that “boulders in the middle of the river should not be visible from the ghats.” If the bed is visible, then it means that the river has shrunk to an unacceptable level which is not the mighty river of their imagination.

It was cautioned that, in general the present dry season level of water at Kachla Ghat is at the threshold of concern, with the following consequences:

1. Cremation rites incomplete - dipping corpse, disposal of remains
2. Bathing not possible as water is above knee depth only in a few isolated pools
3. Washing away of ritual offerings is not possible

The recommended flow for this site is “the

[4] *Source: notes of the workshop and explanations written by experts in the Flow Motivation Forms*

Photo Credit: Nitin Kaushal/WWF-India

historical water flows" for cultural activities. This flow is also necessary for moving sand downstream and for distributing fertile silt. In the absence of the required flows, the productivity of cucurbit farms is in decline, and this forces people to abandon a livelihood that is a part of the aesthetic heritage of the river.

At Bithoor, the local community expects that the temple of Brahma (at Bithoor ghat) be inundated in the monsoon - seeing this inundation as a washing of Brahma's feet. While this might not occur throughout the monsoon, it does need to occur at least once a year, as an expected and welcome event of the year for the local people.

It was concluded by this group that the long term Ecological Management Class (EMC) for all three zones should aim to be 'A'. This is with reference to the unique spiritual importance of the river, it being an essential part of the history and culture of the subcontinent. Near-pristine flows will safeguard the spiritual satisfaction that devotees obtain from gazing at the river. In the short term, some augmentation of the flow is required to ensure satisfactory ritual worship. An EMC of 'B' would be an acceptable goal for the zones in the short term.

Fluvial Geomorphology

It was considered that, longitudinal connectivity[5] and lateral connectivity[6] of the river are key considerations for flows and sediment transport. Stressing the need for floods, it was further pointed out that, lateral connectivity is crucial for the maintenance of ecological systems. Apart from this, the planform[7] and cross-sectional morphology govern the habitat suitability at a reach-scale. In general, the complexity of channel form in terms of bar types, sinuosity, pool-riffle sequence etc. favours ecological diversity. On the contrary, the dynamics of channel configuration as well as position discourage stable ecological conditions.

Floods are often seen as destructive, but are essential for the overall health of the river and its floodplain. If longitudinal connectivity is not maintained, the geomorphic as well as ecological functioning of the river will collapse. Sediment and nutrient movement will be disrupted. Even in the driest years, some floods are necessary to maintain the longitudinal and lateral connectivity.

In the absence of recommended flows the movement of biota will be severely hampered and there will be adverse impacts on nutrient supply and habitat condition, as well as the channel shape and depth in the long term.

Biodiversity

The key criteria was the survival of flagship species, including – Mahsheer, Snow Trout, Otter, Dolphin, *Gharial*, as well as other fish, invertebrates and diatoms which sustain the biodiversity and food-web so that the aquatic and associated floodplain ecosystem remains intact.

[5] Longitudinal Connectivity implies flow depths, velocities and river widths that will ensure the connection of habitats.
[6] Channel-floodplain connectivity is defined as Lateral Connectivity.
[7] Planform – it describe whether a river is braided, meandering or straight in nature.

Photo Credit: Naveen Kumar

Photo Credit: Aditi Pokhriyal

The invasive species of shrubs and trees on the banks of the river at Kaudiyala were observed. This proliferation of invasive species results from changes in the flow regime. This emphasizes the need to restore at least some of the flow variability which maintains the natural biodiversity. It was pointed out that in the absence of the recommended flows at Kaudiyala, the natural riparian flora faces unusual competition for resources and nutrients from alien plant species that are becoming established in this zone. The importance of floods was emphasized, in order to distribute much-needed silt and nutrients onto flood plains for the maintenance and restoration of biodiversity

Livelihoods

The need for adequate base flows at Kaudiyala was emphasized, mainly to maintain tourism activities such as white-water rafting. While floods adversely affect adventure sports, and the Forest Department, Government of Uttarakhand regulates these activities during the flood season, these floods have positive externalities in terms of sand-formation which enhance the beach camping activities in the subsequent seasons.

At Kachla and Bithoor, where the floods in the short term adversely affect fishing, ferry transport and to some extent cultural activities, in the long run they will enhance the livelihoods opportunities such as fishing, by maintaining habitats and productivity.
It has been found that, there has been shift in livelihood activities during droughts, mainly in riverbed farming.

Water Quality

For Kaudiyala, it was reported that water quality at present is in Class – A, as per Best Designated Use (this corresponds to water fit for drinking after disinfection). Water quality is therefore not presently a critical issue at this site.

At Kachla the present status is 'A' with respect to pH and DO; 'B/C' with respect to BOD and 'C/D' with respect to MPN (Most Probable Number of faecal coliforms). There is substantial pollution from sewage and non-point sources. It was concluded that, the recommended E-Flows are expected to improve the Water Quality, but that this should more effectively be achieved by upgrading sewage treatment, and by restricting the discharge of untreated sewage; as the group concluded that, dilution cannot be the solution to pollution.

The state of the river at Kanpur from the water quality perspective is the key concern. The river in this stretch receives considerable pollution from two tributaries, the Kali and Ramganga and also from many point and non-point-sources. The river is classified as 'C/D' due to high BOD, low DO and high TC. The water quality in this zone should be improved to Class 'B'.

Photo Credit: left - Amrit Pal Singh; right - Nitin Kaushal/WWF-India

Photo Credit: Amrit Pal Singh

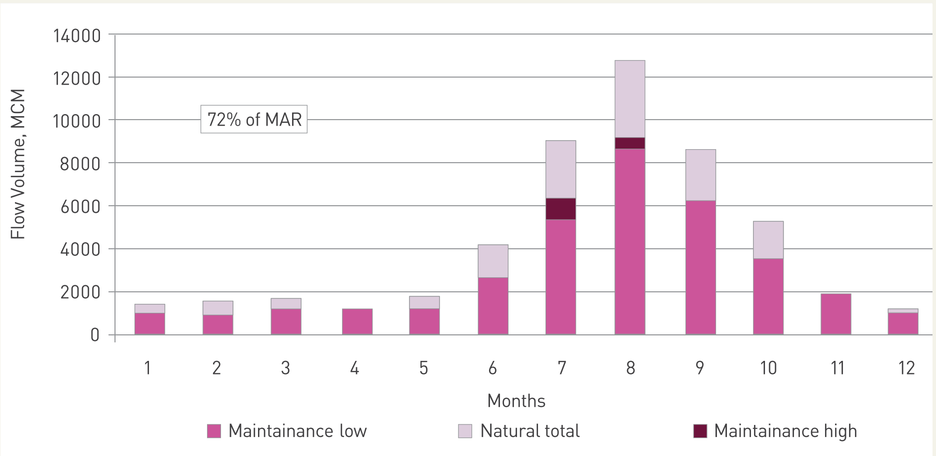
FINDINGS AND RECOMMENDATIONS

As noted earlier, the Maintenance Flows are for "normal" years, not very wet or very dry, when one would expect all the ecological functions and processes (fish breeding, inverts emerging, floodplain wetlands full, sediment transport etc) to be working properly. For this river, it has been estimated that, the Maintenance Flows would be equaled or exceeded during 70 years out of 100; however flows would be lower for 30 years out of 100 or in other words, 70% probability on the flow duration curve. Drought flows are the lowest that would still provide some habitat and survival conditions (i.e. fish would survive but maybe not breed that year). So, for a long-term E-Flows, the water volume required would be at maintenance recommendations or higher for 70% of the time, and between drought and maintenance for 30% of the time.

This section presents a summary of the recommended flows for each of the zones, compared with the natural and present day flows. (For Zone 1 the present day flows were not calculated, as flow release data from the Tehri Dam was not available).

While recommending the final flows, the requirements of respective groups were aligned; For instance the key considerations by the fluvial geomorphology group were (a) to maintain the longitudinal connectivity, and (b) to maintain occasional lateral connectivity through flooding. And for other groups, the key motivations include – the understanding of the preferred habitats of selected species and cultural/spiritual requirements wherever important.

Figure 3
Results: Zone 1 Gangotri – Rishikesh, Site – Kaudiyala; Maintenance Flows



The figure above presents the monthly E-Flows requirement for both the low-flow as well as high flow maintenance for Zone 1. The Naturalised Flows[8] are also plotted in above figure and the E-Flows requirements or Maintenance Flows were calculated as 72% of the natural Mean Annual Runoff[9] (MAR) whereas the Drought Flows were calculated at 44% of natural MAR. However, E-Flows is a regime of flows and the same is depicted as monthly pattern in the graph.

The key motivation for the recommendations is the requirement of such flows by various aspects. For instance – the biodiversity group requires these flows during the lean season, i.e. January to diminish the stress due to drought. Further, the flows are also needed for maximum productivity vis-à-vis instream and riparian biodiversity. The habitat of the flagship *Mahsheer* and the endangered Otters need to be maintained

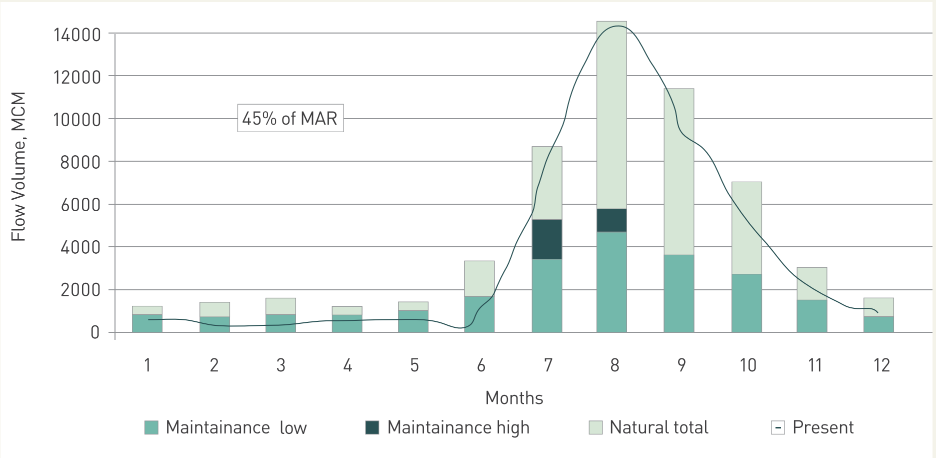
[8] *Naturalised Flows: The flows that would have occurred historically, in the absence of reservoirs, water supply diversions and return flows and other types of water management activities that are reflected in the present day input dataset*

[9] *Mean Annual Runoff: The average volume of water flowing through that site in the river flowing in a year*

through longitudinal connectivity. On the other hand, the same biodiversity group recommended the flow for the wet season month of August, based on the requirements for nutrient replenishment. Further, the high flood level offers the connectivity to spawning grounds for larger number of Mahsheer than in a drought year, leading to high recruitment rates needed to restore dwindling numbers. The same will also be beneficial for other fishes and endangered Otters.

On the other hand, from the livelihoods perspective, the Ganga river resources, in the upper stretch region, provide livelihoods, meet cultural needs (holy dip, immersion of ashes, etc.) and support recreational tourism (beach camping and water rafting). The proposed E-Flows sustain the cultural values and recreational tourism in the stretch. The imbalances in E-Flows i.e. over flows (floods) and lean flows (drought) have implications on livelihoods. In the case of floods, the government itself imposes a ban on the activities of water rafting. Similarly, the inundation of Ghats hampers the activities of cultural tourism. The prevalence of drought (lean E-Flows) conditions too has its impact on livelihoods such as beach camping.

Figure 4
Results - Zone 3: Narora – Farrukhabad, Site – Kachla Ghat; Maintenance Flows



The figure above presents the monthly E-Flows requirement for both the low-flow as well as high flow maintenance for Zone 3 (Narora-Farukhabad Zone; Site: Kachla Ghat). The figure also presents the Naturalised Flows as well as simulated present day flows. The E-Flow requirements for Maintenance Flows were calculated as 45% of the natural Mean Annual Runoff whereas the Drought Flows were calculated as 18% of natural MAR. However, E-Flows is a regime of flows and the same is depicted as monthly pattern in the graph. The present day flows are lower than the environmental requirements in all the dry season months.

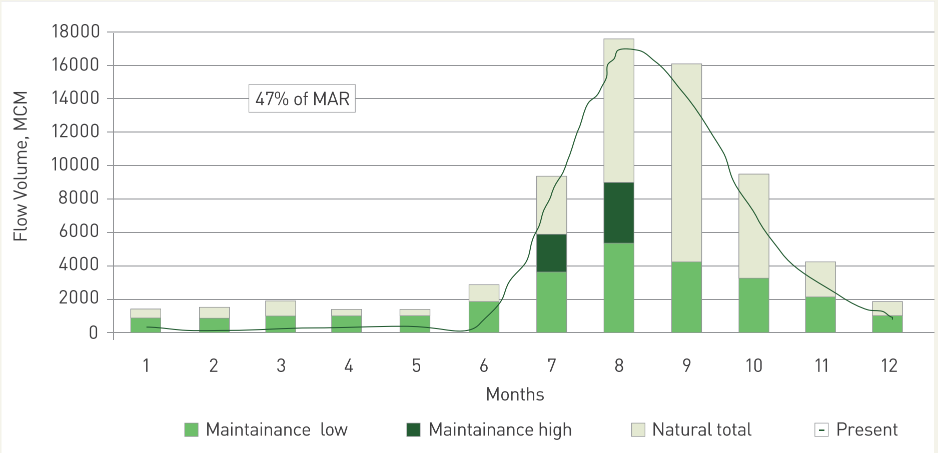
The above mentioned flows are necessary during the lean season for sustenance of biodiversity including survival of the endangered *Gharial*, dolphin and other vertebrates like otters and turtle as well as for sustaining fisheries. The predicted wet season flows are essential for successful spawning of carps and maintaining riparian cover which is important for spawning. The young of dolphins, *Gharials* and turtles get side channels and shallow flood plains to use as shelter. It also helps in consolidation of the sand bars and islands for them.

From the livelihood perspective the above recommended flows are essential because the middle stretch of the river contributes to the ferry transport and fishery activities. However, the field study indicates that these activities are on the verge of extinction.

In the case of floods, the torrents in the river as well as prohibitory orders from the state limit the livelihood activities in the stretch. Similarly, the drought (lean flows)

conditions not only reduce fish stock but are also not conducive for ferry activities. Thus, the proposed E-Flows preserve the resources (aquatic species) as well as promote livelihood activities in the stretch.

Figure 5
Results - Zone 4: Kannauj-Kanpur, Site – Bithoor; Maintenance Flows



The figure above presents the monthly E-Flows requirement for both the low-flow as well as high flow maintenance for Zone 4 (Bithoor – Kannauj Kanpur Zone). The figure also presents the Naturalised Flows as well as simulated present day flows. The E-Flows requirements for Maintenance Flows were calculated as 47% of the natural Mean Annual Runoff whereas the Drought Flows were calculate at 14% of natural MAR. However, E-Flows is a regime of flows and the same is depicted as monthly pattern in the graph. The present day flows are lower than the E-Flows requirements for all the dry season months.

The justification from a biodiversity perspective for above flows during the lean season includes coverage and passage for the critically endangered species and for reviving the food web. On the other hand, the wet season reasoning includes the predicted flow's importance in regard to improving carp and catfish ratio for good fishery. Flooding will also facilitate foraging for Dolphins, *Gharial* and Turtles to become available and to enhance recruitment rates.

Livelihood activities are largely similar to the middle zone, and the motivation for the recommended flows stands similar to that of middle zone.

Accuracy of and confidence in the Environmental Flows recommendations
All the Expert Groups assessed the information available at each of the sites, in order to provide a judgment of their confidence in the assessment methodology and recommendations, and the need for further work to increase these confidence levels. The assessment was based on a scale of 5 (= absolute certainty) to 1 (= very uncertain)

The BBM methodology was assessed as robust and the level of confidence is high, since the justifications are scientific in nature and these are based on firm background knowledge. On average, the expert groups were less confident in the specific flow recommendations, giving 3 marks out of 5 (equivalent to reasonable confidence, but with some uncertainties). The major uncertainties centered on the lack of availability of long-term hydrological records, which meant that environmental flow recommendations could not be checked against present or historical flow trends. The surveyed cross-sections, which provide the data for the hydraulic model which converts flow depths, velocities and widths to discharge, needed improvement. Only one calibration flow measurement at each cross-section resulted in low-confidence in the extrapolations in the model and the flow readings. These uncertainties can be reduced by further calibration of cross sections.

REFLECTIONS & CONCLUSIONS

This was the first attempt to carry out a *comprehensive assessment* of E-Flows for a river in India. Previous EF assessments for India rivers by IWMI, were primarily based on the use of hydrological information and were largely desktop. E-Flow assessment in this study was done by integrating multiple disciplines including ecology, geomorphology, water quality, social/cultural and livelihood aspects. This was aimed at providing a holistic assessment of environmental objectives and the flows needed to achieve them. The multi-disciplinary, multi-stakeholder team and partnership constituted to carry out the EFA was critical. The working groups (specialists) made use of existing and historical information and databases, and supplemented these with carefully designed and directed fieldwork. It brought together different knowledge sets and perspectives which helped shape up the holistic approach to EFA. The BBM proved to be a robust, easy to use and adaptable methodology for the working groups unfamiliar with E-Flows.

Without detracting from the effective and useful outcomes of the EFA, it is important to acknowledge some short-comings which can hopefully be learned from and improved in future Indian initiatives in E-Flows, and in taking forward the sustainable management of the river Ganga:

- The non availability of extensive hydrological database for such (or any other) initiatives reduced the confidence of the flow recommendations.
- There is a need to improve cross-sections, i.e. the surveys of cross-sections could extend onto the floodplains. This would have had significantly enhanced the ability of the biodiversity, livelihood and spiritual/cultural groups to link their habitat requirements to specific features of the river channel at the study sites.
- Detailed assessment of the hydraulic habitat required to ensure the persistence of different biotic communities, could have improved the recommendations of the biodiversity group.
- The impact of recommended flows on diluting the pollution in the river, or whether these would provide sufficient water quality to enable the survival or recolonisation of sensitive species needs to be studied in detail.

Despite these constraints, the project has adapted and pilot tested in the Upper Ganga Basin a holistic EFA methodology for the first time in India and built national capacity to conduct further EFA for Ganga and other rivers in India.

LIVING GANGA PROGRAMME

The HSBC Climate Partnership is a groundbreaking partnership between the HSBC and WWF, The Climate Group, Earthwatch Institute and the Smithsonian Tropical Research Institute, to combat the urgent threat of climate change by inspiring action by individuals, businesses and governments worldwide.

Launched in May 2007, the HCP will: Help to protect four of the world's major rivers – the Amazon, Ganges, Thames, and Yangtze – from the impacts of climate change, benefiting the 450 million people who rely on them.

In India, this partnership supported WWF – India's Living Ganga Programme (LGP), which aimed to develop and implement integrated strategies for sustainable energy and water resources management within the Ganga basin in the face of climate change. The critical stretch of 800 kilometers in the upper Ganga, from Gangotri to Kanpur was identified.

The programme has four arms—research, demonstration (pilot) projects, policy advocacy and communication and awareness creation. In order to have an integrated approach to Ganga basin management, LGP brought together components of climate adaptation, vulnerability assessment, environmental flows and water allocation coupled with pollution abatement and co-management of water and energy. The programme also established partnership with key stakeholders with a focus on river restoration, community education and engagement, business and government involvement, and biodiversity conservation.

Thematic areas

- Sustainable Water Management
- Vulnerability Assessment and Climate Adaptation
- Pollution Abatement
- Water and Energy Co-management
- Sustainable Hydropower
- Biodiversity Conservation
- Communication and Business Engagement

Source : IGCMC

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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