ENVIRONMENTAL FLOWS ASSESSMENT OF THE UPPER STRETCH OF RIVER GANGA – *A WWF-INDIA INITIATIVE*

Nitin Kaushal

ABSTRACT

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.

It was these complexities that 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 the 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 a realisation 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 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 LGP is that the E-Flows are multidimensional and their assessment is both a social and technical process, with a social choice at its core. Social, as it depends on what the society want a river to do for them – to support culture and spirituality or livelihoods or biodiversity or all the above functions and more.

The WWF brought together civil society groups, Indian and international experts (hydrologists, geomorphologists, ecologists, hydraulics engineers, and sociologists) and Government departments to sit together, deliberate and develop a methodology for assessment.

Selection of the methodology for assessment of E-Flows was the most challenging task. This is because, WWF and its partners were clear that any methodology selected should respect the uniqueness of the Ganga and its various dimensions (including socio-cultural importance). The Building Block Methodology (BBM) was selected as it was found to be the most appropriate. BBM is a robust method, which has been used for rivers in many different parts of the world. However, the choice was driven by its flexibility, applicability and reliability under different levels of data and information availability.

In order to characterise the river in its different reaches, zones were defined, based mainly on the changing gradient and consequent geomorphological conditions, overlain by the changing land uses and river developments. Three locations were identified: Kaudiyala (representing Gangotri to Rishikesh), Kachla Ghat (representing Narora to Farrukhabad) and Bithoor (representing Kannauj to Kanpur).

The recommended flows are based on the flow indicators chosen by each working group, i.e. the spiritual/cultural group analysed the results of interviews to ascertain the depths and water quality issues that would affect the religious activities. The Geomorphology group concentrated on flow velocities and depths, sufficient to move, sort and deposit different sizes of sediment, so as to maintain or restore channel size and important channel features. The biodiversity group concentrated on the habitat characteristics for important flow-dependent species such as dolphin, selected fish species, macro-invertebrates and floodplain vegetation, in terms of depths, flow velocities, river widths, and substrate types required for different parts of their lifestyles. The livelihood group analysed their interview data for impressions on the depths, water quality and river width required to maintain services such as ferrying. Each group considered following scenarios:

- *Flows for maintenance years*[1]
- *Flows for drought years*
- *Flows for both maintenance and drought years*

The values arrived at are only indicative as they were based on simulated data (in the absence of access to observed flow data). These could be refined with the availability of more credible and long term real time data.

[1] Maintenance Year – a normal flow year, neither very wet nor dry, when all the river's ecological and social processes and activities are in operation

It is important to recognise that, the assessment and implementation of E-Flows is an adaptive process, in which flows may be successively modified in the light of increased knowledge and changing priorities.

1. GANGA RIVER BASIN

The Himalayas are the origin and source of three major Indian rivers namely the Indus, the Ganga and the Brahmaputra. Ganga drains a basin of extraordinary variation in altitude, climate, land use, flora & fauna, social and cultural life. Ganga has been a cradle of human civilization since time immemorial. Millions depend on this great river for physical and spiritual sustenance. People have immense faith in the powers of healing and regeneration of the Ganga. It is one of the most sacred river in the world and is deeply revered by the people of this country.

As a matter-of-fact Imperial Gazetteer of India[2] allows itself a little poetry while describing the Ganga saying:

> *"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*".

Bhagirathi is the source stream of Ganga. It emanates from Gangotri Glacier at Gaumukh at an elevation of 3,892 m (12,770 feet). Many streams comprise the headwaters of Ganga. The important among these are Alaknanda, Dhauliganga, Pindar, Mandakini and Bhilangana. At Devprayag, where Alaknanda joins Bhagirathi, the river acquires the name Ganga. It traverses a course of 2525 km before flowing into the Bay of Bengal.

The Ganga basin in India covers eleven states viz., Uttarakhand, Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal and Delhi. Rainfall, subsurface flows and snow-melt from glaciers are the main sources of water in river Ganga. Surface water resources of Ganga have been assessed at 525 billion cubic meters (BCM) (AHEC 2009).

1.1 Stressors

Alarming population growth has a critical bearing on the state of this river. Average population density in the Ganga basin is 520 persons per square km as against 312 for the entire country (2001 census). Further, the cities in the basin have large and ever-growing populations. Infact from 1991 to 2001, the urban population has increased by 32%. This alarming trend is likely to continue. This escalates the pressure on already diminishing resources, including rivers. The rising standards of living and exponential growth of industrialization and urbanization have further exposed the water resources, in general, and rivers, in particular, to various forms of degradation.

Another dimension is the upcoming hydropower schemes in the state of Uttarakhand, which compounds the problem by significantly reducing the water in the stretches of the river, as the water is often diverted through Head Race Tunnels (HRT) to the hydropower generation plant. In several cases these HRTs are upto 15 km or even more.

In addition to this, a vast quantum of water from the river is diverted to irrigation canal systems (Table – 1). Though it has brought lot of prosperity in the western-central Uttar Pradesh but has also led to diminishing flows in the river.

Table 1: Details of water withdrawal from canals

S. No	Name of Canal	Water abstraction from the barrage *(in cumecs)*
1	Upper Ganga Canal	594.9
2	Lower Ganga Canal	481.5
3	Madhya Ganga Canal – 1	234.5
4	Madhya Ganga Canal – 2[3]	192.6

[2] Adopted from Starter Document – Assessment of Cultural and Spiritual instream flows by PSI – Dehradun.
[3] Under Construction

5	Eastern Ganga Canal	137.4
6	Parallel Lower Ganga Canal	118.9
	TOTAL	1759.8

SOURCE: Study on 'Problems and Prospects in Saving Water and Energy in Agriculture in Upper Ganga River Basin' by Phanish Kumar Sinha (2009)

2. LIVING GANGA PROGRAMME

The HSBC[4] Climate Partnership's Living Ganga Programme is a five years (2007 – 2011) programme, with key objective to help in the protection and conservation of River Ganga. This partnership supported the WWF – India's work on climate change across the upper Ganga basin, focusing on river restoration, community education and engagement, business and governance involvement and biodiversity conservation.

The Living Ganga Programme aims to bring together knowledge and experience in E-Flows, climate adaptation and water allocation coupled with wastewater management and wise energy management in the water sector in Ganga Basin. For the purpose of this programme, the critical stretch of upper Ganga, from Gangotri to Kanpur was identified, which is about 800 kilometers long. The scope and scale of interventions is crosscutting at various levels of pilots, case studies, institutional mechanisms and state as well as central level policy machinery. The assessment of E-Flows is the crucial component of the Living Ganga Programme.

3. PROCESS – ENVIRONMENTAL FLOWS ASSESSMENT

The vision of WWF under the Living Ganga Programme was 'to develop and apply such an E-Flows assessment and management methodology which conserve biodiversity and support livelihoods in the Upper Ganga Basin'. In order to fulfill this purpose, a detailed E-Flows analysis was carried out for a large river basin for the first time in India.

3.1 Building Block Methodology – a holistic methodology for assessment of E-Flows

There are numerous methodologies being practiced around the globe for the assessment of E-Flows, right from fairly simple and straight forward hydrology based ones to much complex and resource intensive holistic methodologies. However, since Ganga is a complex river basin with competing demands amongst the multiple users, therefore to suit such requirements, a set of holistic methodologies were discussed. The holistic methodologies are more comprehensive, as it not only takes care of the scientific and technical aspects but also the socio-economic and environmental aspects.

Out of the different holistic methodologies, the Building Block Methodology (BBM) was finalized for the assessment of E-Flows under the programme. This methodology has got several merits over others. It allows the user to integrate local requirements, for instance – in case of River Ganga, the spiritual and cultural aspects are of immense importance and thus require due consideration. This methodology was found to be most appropriate for large river basins with multiple users and interests. It is one of the most frequently practiced methodologies under the holistic approaches. This methodology is based on following principles:

- ✓ Water can be used from the rivers without unacceptably degrading them
- ✓ Set pre-defined objectives for the environmental condition of the river
- ✓ Assess a modified flow regime that will meet those objectives
- ✓ Identify the critical components (building blocks) of the flow regime that govern environmental conditions

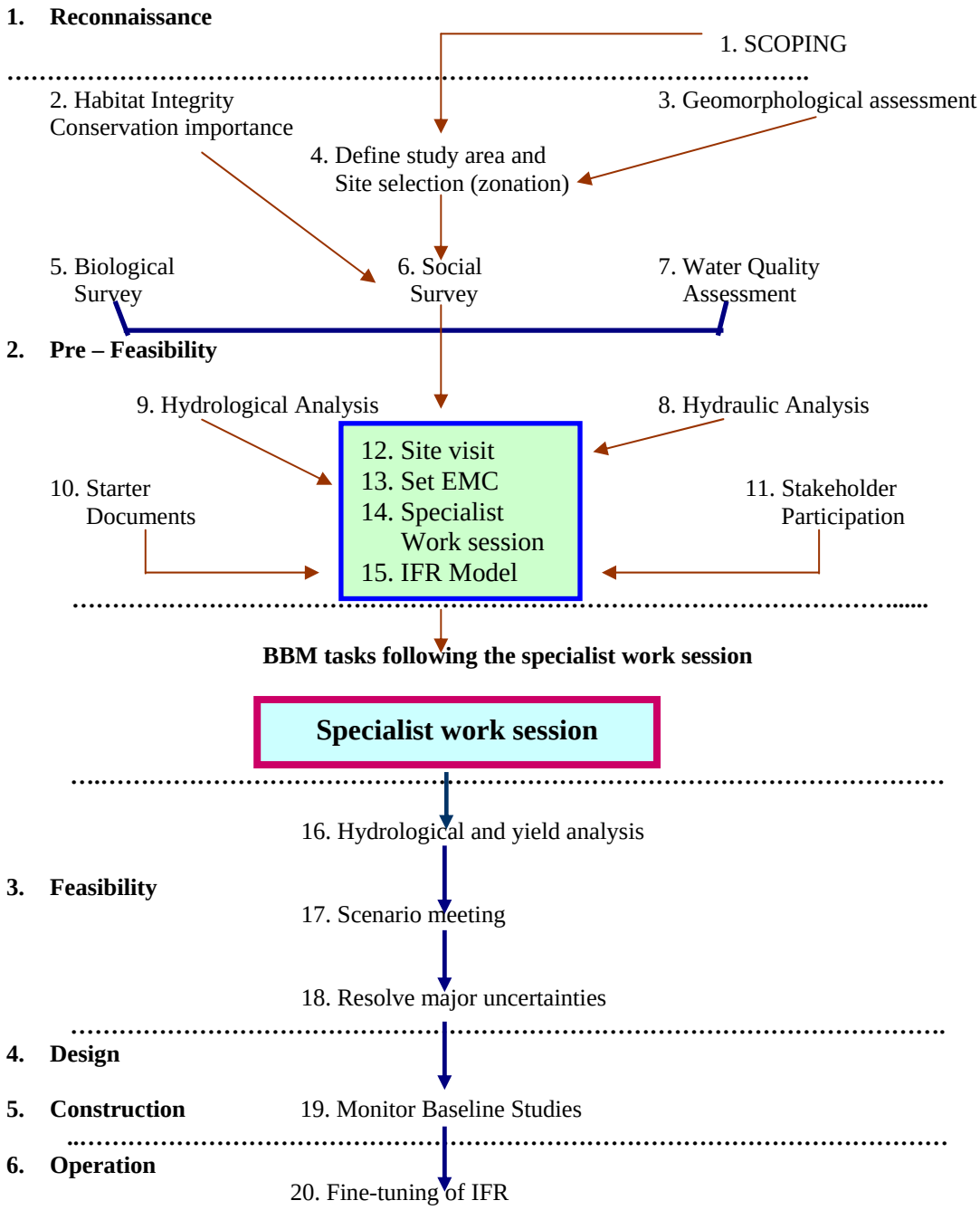
This methodology is currently being practiced in South Africa, USA and Australia. Few of the vital merits of this methodology include:

1. Bottom up approach
2. Much detailed and can be tailored to suit local conditions
3. Rigorous and well documented

[4] HSBC – Hongkong Shanghai Banking Corporation

The process to be adopted for E-Flows assessment under the Building Block Methodology is illustrated in Figure – 1.

Figure – 1: The Building Block Methodology process



3.2 E-Flows Assessment under the Living Ganga Programme

The process of the assessment of E-Flows was a comprehensive one and included various steps. At the time of strategy development, it was felt that there is lack of awareness even within WWF-India with respect to E-Flows and its significance. Therefore, series of meetings/workshops were organized. These events also helped in the strengthening of in-house capacity.

With a view to bring in international expertise in assessment of E-Flows, the WWF had partnered with some international research organization, i.e. International Water Management Institute (IWMI, Sri Lanka) and UNESCO–IHE, Delft-Netherlands. Where the UNESCO–IHE has helped with mentoring and overall facilitation and on the other hand the IWMI extended facilitation for the hydrology component of the study. The IWMI took care of hydrology component f the study.

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 by the INRM Consultants and WWF-India. 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[5])*
3. *Zone – III: Narora to Farrukhabad*
4. *Zone – IV: Kannauj to Kanpur*

Following this, an 'Objectives Setting Workshop' (December 2008) was organized to understand and define different aspects of maintaining E-Flows for River Ganga. During this workshop, the methodology was developed for the assessment of E-Flows. The designation of Ecological Management Classes (EMC) for different stretches of the Ganga was also done through this workshop.

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 Ecological Management Class (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

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

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

Following the completion of the studies, a Methodology Workshop (February 2009) was organized during which Terms of Reference for various components were discussed, drafted, finalized and shared.

After this workshop, partnerships with Working Groups and specialists were formalised (the experts were assigned with the components mentioned above). Table – 2 lists the name of institutions and experts with whom, the WWF-India partnered for this study.

[5] 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.

Table – 2 Partnership for the E-Flows Assessment exercise

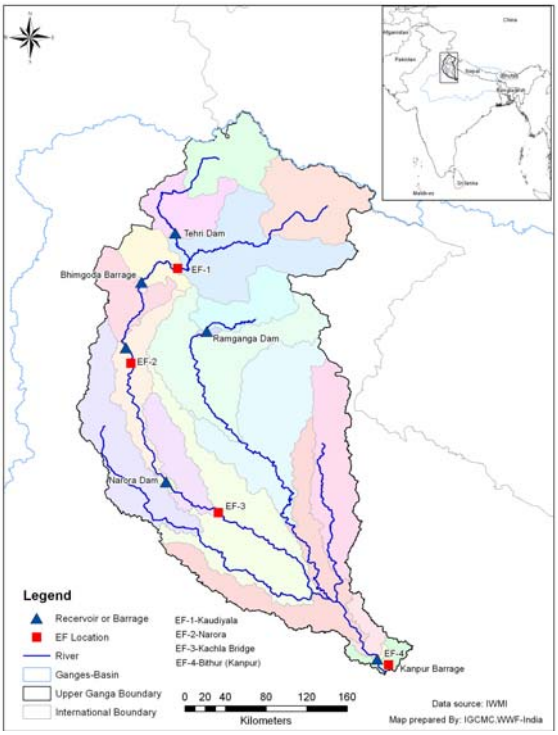
S. No.	Component	Name	Association
1	Overall Facilitation	Prof. Jay O'Keeffe Dr. Vladimir Smakhtin	Formerly with UNESCO-IHE, the Delft and currently with Rhodes University, South Africa IWMI – Sri Lanka
2	Hydrology	Dr. Vladimir Smakhtin Dr. Luna Bharati	IWMI – Sri Lanka IWMI – Nepal
3	Hydraulics	Prof. A. K. Gosain Dr. Sandhya Rao	IIT – Delhi INRM Consultants
4	Fluvial Geomorphology	Prof. Rajiv Sinha Dr. Vikrant Jain	IIT – Kanpur Delhi University
5	Biodiversity	Prof. Prakash Nautiyal Dr. Sandeep Behera	Garhwal University – Srinagar WWF – India
6	Water Quality	Prof. Vinod Tare	IIT – Kanpur
7	Livelihoods	Dr. Murali Prasad	IIT – Kanpur
8	Cultural and Spiritual	Dr. Ravi Chopra Ms. Chicu Lokgariwar	People's Science Institute – Dehradun

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:

1. *Zone – I: Gangotri to Rishikesh (Site: Kaudiyala)*
2. *Zone – II: Garhmukteshwar to Narora (Reference Zone[6]) (Site: Upstream of Narora Barrage)*
3. *Zone – III: Narora to Farrukhabad (Site: Kachla Ghat)*
4. *Zone – IV: Kannauj to Kanpur (Site: Bithoor)*

Figure 2: A map depicting various E-Flows sites is shown below

[6] 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.



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 about a year (May 2009 – April 2010), all the Expert Groups were engaged in field investigations, 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 than 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.

The outcome of field investigation was discussed at a 'Workshop on E-Flows Setting' (May 2010). During this workshop all groups presented their findings in the form of a report called '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 the basis for working groups to develop their recommendations in regard to E-Flows as required by their respective component. This report was crucial for the whole process.

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 Ghat 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 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.

3.3 Flow motivations

While discussing and predicting flows, depth and average velocity for various scenarios and sites, the working groups made vital comments[7] which are summarized below.

3.3.1 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 buildup 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 historical water flows" for cultural activities.

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 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.

3.3.2 Fluvial Geomorphology

It was considered that, longitudinal connectivity[8] and lateral connectivity[9] 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[10] 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, plus the sediment and nutrient movement will also be disrupted. Even in the driest years, some floods are necessary to maintain the longitudinal and lateral connectivity.

It was concluded by the group that, 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.

3.3.3 Biodiversity

---

[7] SOURCE: notes of the workshop and explanations written by experts in the Flow Motivation Forms
[8] Longitudinal Connectivity implies flow depths, velocities and river widths that will ensure the connection of habitats.
[9] Channel-floodplain connectivity is defined as Lateral Connectivity.
[10] Planform – it describe whether a river is braided, meandering or straight in nature.

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.

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

3.3.4 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. The recommended 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 will decline, and this could forces people to abandon a livelihood that is a part of the aesthetic heritage of the river.

3.3.5 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 was therefore not considered as a critical issue at this site.

At Kachla Ghat, 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). It was found that, there has been substantial pollution from sewage and non-point sources. The group 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 maintained that, dilution cannot be the solution to pollution.

The state of the river at Kanpur is the key concern. The river 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’.

3.4 Findings and recommendations

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 river Ganga, 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 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.

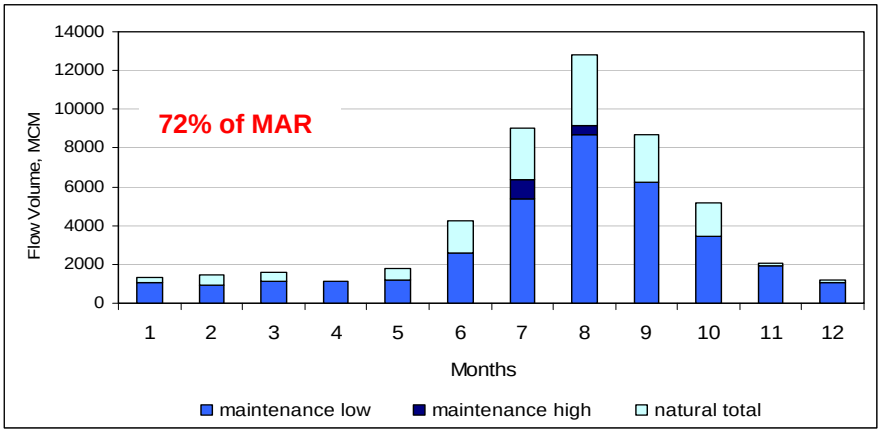
Given below are the recommended flows for each of the zones, compared with the natural and present day flows. (For Zone 1 the present day flows were not calculated, as flow release data from the Tehri Dam was not available).

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 included – the understanding of the preferred habitats of selected species and cultural/spiritual requirements wherever important.

<u>Zone 1 Gangotri – Rishikesh, Site – Kaudiyala</u>

The figure – 3 presents the monthly E-Flows requirement for both the low-flow as well as high flow maintenance for Zone 1. The Naturalised Flows[11] are also plotted in above figure and the E-Flows requirements were calculated as 72% of the natural Mean Annual Runoff[12] (MAR). However, E-Flows is a regime of flows and the same is depicted as monthly pattern in the graph.

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



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 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 would 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, 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.

Zone 3: Narora – Farrukhabad, Site – Kachla Ghat

Figure – 4 presents the monthly E-Flows requirement for both the low-flow as well as high flow maintenance for Zone 3. The figure also presents the Naturalised Flows as well as simulated present day flows. The E-Flow requirements were calculated as 45% of the natural Mean Annual Runoff. 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.

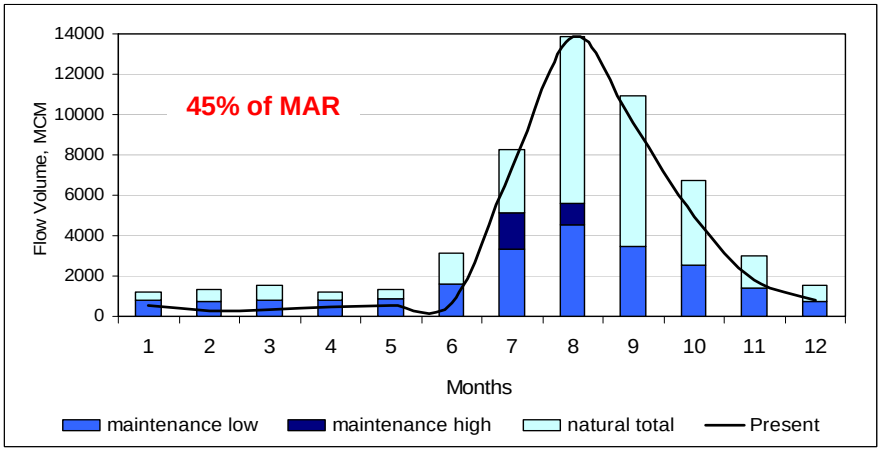
These recommended flows are necessary during the lean season for sustenance of biodiversity including survival of the endangered *gharial*, dolphin and other vertebrates like otters and turtle as well as for sustaining fisheries. The predicted wet season flows are essential for successful spawning of 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.

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

[11] **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

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

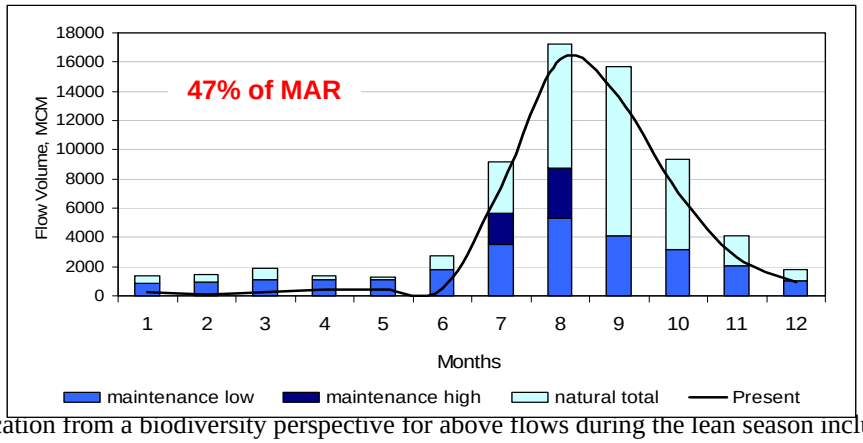


In the case of floods, the torrents in the river as well as prohibitory orders from the state limit the livelihood activities in the stretch. Similarly, the drought (lean flows) conditions not only reduce fish stock but are also not conducive for ferry activities. Thus, the proposed e-flows preserve the resources (aquatic species) as well as promote livelihood activities in the stretch.

Zone 4: Kannauj- Kanpur, Site – Bithoor

Figure – 5 presents the monthly E-Flows requirement for both the low-flow as well as high flow maintenance for Zone 4. The figure also presents the Naturalised Flows as well as simulated present day flows. The E-Flows requirements were calculated as 47% of the natural Mean Annual Runoff. 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.

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



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.

3.5 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).

3.6 Caveats and further information requirements

1. One of the purposes of a preliminary assessment such as this, is to identify areas where further information is required to increase the confidence of the flow recommendations
2. E-Flows assessment is an adaptive process, in which the management of the river can be constantly improved by monitoring and refinement of the initial E-Flows assessment
3. Access to the extensive long-term existing observed hydrological data would considerably increase the confidence in the E-Flows assessment.
4. Further calibration and verification of the existing rated cross-sections and the establishment of additional cross-sections, would also increase confidence in the flow recommendations
5. More precise relationships between water quality parameters and flow would have allowed the prediction of the effects of recommended flows on water quality to be assessed more accurately

4. THE WAY FORWARD

This project has been a learning experience, both for WWF-India, and for the working groups who provided the expertise for the assessment. The results should be seen as preliminary, rather than definitive, and are intended to spark the debate about the state of the Ganga, to summarise existing knowledge, and to suggest further research to improve the confidence in the recommendations. It has contributed to a much greater awareness of E-Flows among freshwater scientists, water resources managers (mainly engineers) and policy makers. Further, the consortia of Indian Institute of Technologies (IITs) engaged in the development of Ganga River Basin Environment Management Plan (GRBEMP) by the MoEF, has been considering the methodology adopted under the Living Ganga Programme for a more in-depth assessment of flow requirements for the entire river. In fact, many of the experts, who were associated with WWF's exercise, are also engaged in this formal initiative to prepare the GRBEMP. Once the plan is finalised, the implementation stage would be initiated. This will have to deal with complex challenges, such as the tradeoffs necessary to free up additional water for E-Flows, how present demand is likely to change under different future trajectories, the possibilities for water-reallocations, and, perhaps most importantly, reaching a consensus among wider stakeholders

Other major spin-offs from the project are that, the capacity has been built and strengthened amongst experts and organizations who would be able to undertake various aspects of EFA for Indian rivers. Further the knowledgebase and the databases on biodiversity, geomorphology, water quality, livelihoods and spiritual/cultural issues have been significantly enhanced for the Upper Ganga.

As an initial stepping stone in EFA for Indian rivers, this work has provided a detailed experiment of the application of field-based assessment of E-Flows, which will hopefully take the debate to the next level. There are, however, several challenges, which need to be addressed before the concept of E-Flows is mainstreamed into river basin policy and planning. These include the assessment itself as well as implementation.

It is hoped that this work would inspire the different Union ministries including MoWR and MoEF, the State Governments, academics, civil society organizations to build on the knowledge base on environmental flows and move towards its implementation. There is a lot of capacity building needed on this count.

India will need to urgently work towards an implementable policy that demands fresh water in its rivers and E-flows would be an important part of the strategy. If this becomes an integral part of India's water policy and management strategy, it can be hoped that our rivers can still be brought back to life.

REFERENCES

1. Keeffe Jay'O, Nitin Kaushal, Vladimir Smakhtin, Luna Bharati (2012) Summary Report – Assessment of Environmental Flows for the Upper Ganga Basin. WWF – India.

BRIEF PROFILE OF THE AUTHORS

Mr. Kaushal post-graduated in Environmental Sciences from Gurukula University, Haridwar in 2001. He has started his professional journey in 2001 with an organization of national repute, set up by the Ministry of Water Resources. During this assignment, he was engaged in research on Participatory Irrigation Management. He was also the lead researcher in the study to ascertain the syllabus contents in regard to 'water resources management' being taught in the tertiary level education system in India.

He has extensive experience of multilateral projects funded by the World Bank. Under various capacities (Social cum Environmental Professional, Environment Expert, Water Resources Management Expert), he has worked

under Uttar Pradesh Water Sector Restructuring Project (UPWSRP) and Madhya Pradesh Water Sector Restructuring Project (MPWSRP) from 2004 to 2009.

In his current engagement with WWF, he is managing and coordinating a multidisciplinary team of national and international experts for the study on assessment of Environmental Flows for the upper Ganga River (since 2009).