

## Case Study 1

# Environmental Flows Assessment in India: The Ganga Experience

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### BACKGROUND

Rivers in India are losing their life. Many of them are running dry due to over abstractions while others are getting reduced to wastewater drains because of pollution.

River Ganga is a lifeline to about 500 million people inhabiting its basin. The river Ganga provides water for drinking, domestic needs, agriculture, livelihoods, industrial use, fishing, boating, recreation, religious, cultural activities and for energy. Besides the humans, the river supports rich fauna and flora, including the endangered Ganges river dolphin (*Platanista gangetica gangetica*), at least nine other species of aquatic mammals, reptiles (including three species of crocodiles along with one species of monitor lizard (*Varanus bengalensis*)) and different freshwater turtles. This mighty river also has the richest freshwater fish fauna anywhere in India.

The ecosystem integrity and the goods and services offered by the river are getting adversely affected by the changes in its water quality and flow regime. Reasons are many: In the Himalayan reaches, until Rishikesh the flow in the river is threatened by water abstractions for existing and proposed hydropower projects. With many dams and barrages the river has become lean over the years, with 60% of its water being diverted before it enters the plains. About 12 billion litres of wastewater are released into the Ganga every day and 80% of this is untreated. As the river's dynamics have been altered by diversions and unproductive uses, the freshwater flow has reduced, resulting in a reduction in the assimilative

capacity of rivers. This has led to a rise in the pollution load. A study by the Central Pollution Control Board in 2007 showed that Ganga contributed to 40% of the polluted river stretches in India. Changing consumption patterns, growing water footprint of cities, industries and agriculture, Ganga and its ecosystem will only aggravate the situation. Business as usual will see more water being consumed, more waste being generated and severe ecological degradation of our rivers.

While the impact on society and livelihoods is becoming more and more evident, it is also important to realise that the river habitats are controlled by physical processes—flow, water quality, sediment transport. Managing (or mis-managing) the flow, can lead to significant changes to the biodiversity of rivers.

### **Environmental Flows: A Driver**

The current paradigm of river conservation programmes in India focuses mostly on sewage and industrial pollution management and no attempt is made to treat the river ecosystem as a whole. Various challenges that rivers face today reinforce the necessity to consider implementing environmental flows (or E-Flows) in water resource management and for improving the river health.

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 assessment of E-Flows aims to identify the quantity, quality and distribution of flow patterns (timing) along the length of a river and provides a balance between the use and protection of natural water resources for people and biodiversity. E-Flows are multidimensional and their assessment is both a social and technical process. Social, as it depends on what the society wants a river to do for them—to support culture and spirituality or livelihoods or biodiversity or all the above functions and more. Multi-disciplinary technical processes are required to carry out detailed studies relating to hydrology, hydraulics, geomorphology, pollution etc. While many countries in the world today have an E-Flows policy, the debate in India has graduated from a rather narrow focus on ‘minimum’ flows to a much comprehensive ‘environmental’ flows. The debate on how much water is needed to sustain riverine ecology is catching up momentum with each hydro-electric project being introduced.

### **WWF’S WORK ON E-FLOWS**

Globally WWF (World Wide Fund for Nature) has been promoting the concept of E-Flows since 2000. However, in India the WWF started studies on E-Flows during 2007-2008. Various stakeholders, including the government, water managers, researchers, scientists, civil society organisations and social experts did not have any case specific and tested methodology to understand a comprehensive process of E-Flows assessment in the country. Therefore, WWF-India initiated the first of its kind attempt to develop a methodology and assess the E-Flows in the Upper Ganga basin, within the framework of its Living Ganga Programme (2008-2012). There were many challenges of which the critical ones were:

1. *Technical:* How to define E-Flows in the context of the Ganga which has a socio-cultural religious dimension (besides its hydrological, hydro-geomorphological

and quality significance)? Globally, none of the methodologies available for the estimation of environmental flows had a cultural dimension. Given the socio-cultural importance of the river, selection of a methodology that could capture the complexity of issues was a daunting task. Further, there was very little hydrological data available for the assessment of flows as most of such data are ‘Classified’.

2. The second major challenge was the lack of capacity within WWF and in the country to develop work on E-Flows assessment.
3. As in any other initiative, creating awareness, building consensus and a buy-in from different stakeholders on the need for environmental flows was always a major area of work. It must be remembered that the debate in the context of flows was limited to ‘minimum’ flows and there was a huge gap in the understanding of E-Flows.

WWF partnered with several national and international institutions/organizations to undertake this study. The international partners were UNESCO – IHE, the Delft Netherlands, and International Water Management Institute – Sri Lanka and at national level, the partners were the IIT – Kanpur, INRM Consultants, IIT – Delhi, Delhi University, People’s Science Institute and Srinagar Garhwal University. Several individual experts also contributed to this work. Over more than three years, WWF-India and its partners debated, discussed, developed and field tested a holistic approach towards environmental flows assessment suited for the Upper Ganga basin. The 800 km stretch from Gangotri to Kanpur was selected for the study because it illustrates almost all the challenges the river Ganga faces across its entire journey. Abstractions or diversions (run-of-the-river dams and irrigation systems), obstructions (reservoir based dams), and critical pollution (both industrial and municipal) are all evident within this stretch. Further, this stretch is also known for rich biodiversity.

### **Objectives of the Assessment**

The objective to undertake E-Flows assessment for Upper Ganga was two pronged;

- a) to improvise one of the existing holistic methodology (in this case the Building Block Methodology (BBM)) to suit an Indian river conditions and pilot test the same for assessment of E-Flows for a river as mighty as Ganga;
- b) to build the capacity of local experts in regard to undertaking assessment of E-Flows through a holistic methodology

The overall goal of E-Flows work under the Living Ganga Programme was not only to mainstream the concept of E-Flows in formal dialogue around river basin management, but also to showcase the suitability and applicability of the developed holistic methodology for Indian rivers. Plus it was also envisaged that, the local partners whose capacity got built and strengthened (in regard to E-Flows assessment) during this process will undertake similar exercises in other river basins of the country.

This paper summarises the process involved, templates for technical assessments and the lessons learned. The underlying principle of the effort was that E-Flows are multidimensional and that its assessment is both a social and technical process, with a social choice at its core. Hence, 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. It started off with an intense capacity building process targeting WWF staff and its partners. International experts with experience on E-Flows facilitated this process. For detailed report, see O’Keeffe et al. (2012).

### **ENVIRONMENTAL FLOWS ASSESSMENT METHODOLOGY**

WWF decided to consider a holistic methodology so that a concerted and comprehensive view of various aspects of the river can be taken care of, especially respecting the uniqueness of the Ganga and its socio-cultural importance. Amongst various holistic methodologies, the Building Block Methodology (BBM) was found to be best suited for Indian conditions due to following reasons:

1. It is a robust and well-defined methodology with detailed manual explaining step-by-step process for assessment of E-Flows.
2. It is a flexible methodology and one can tailor it to suit local conditions, for instance – in the case of river Ganga, the socio-cultural aspects are of immense vitality, so any E-Flows assessment exercise needs to take care of this and BBM provided that room, so that the integration of socio-cultural aspects could be done.
3. This multidisciplinary methodology can work well in data-rich and data-deficient conditions, which made this methodology all the more appropriate for river Ganga, as Ganga is a trans-boundary river and availability of its hydrological data in public domain has always been a challenge.
4. It is a bottom-up approach where each motivation for recommended flows is carefully motivated and well defined.
5. It is one of the most frequently used holistic methodology around the world

A step-by-step process chart of the BBM illustrating various steps is given in Figure 1. The details of methodology are described by King et al. (2000).

### **ENVIRONMENTAL FLOWS ASSESSMENT – THE PROCESS**

The assessment of E-Flows for the upper Ganga stretch included several sub-studies. These studies and the overall process to arrive at the recommendation of E-Flows are discussed below.

#### **Homogenous Zonation Study**

The exercise of E-Flows assessment for river Ganga began with a study to classify the upper Ganga into various zones on the basis on homogeneity, elevation, anthropogenic activities

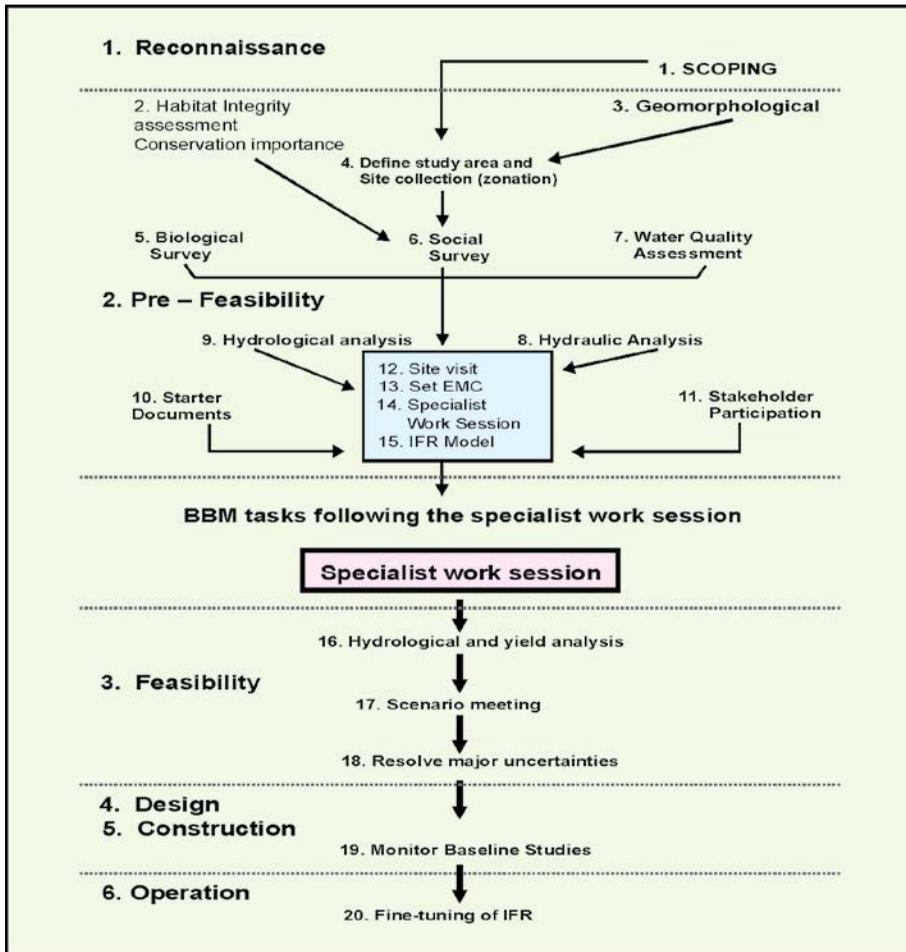


Figure 1. BBM procedures followed in the assessment of E-Flows

and other physiological characteristics of the river. The zonation of the 800 km Upper Ganga was confined primarily to the mainstream, however the floodplains of the river, using a buffer of 50 km on each side of the main river channel, were also considered to provide a general description of the major physiographic and geomorphologic features and the modifications/ alterations along the river. For this study, the WWF partnered with the INRM Consultants (Integrated Natural Resources Management Consultants Pvt. Ltd.<sup>1</sup>).

The methodology to undertake this zonation exercise included a desk-top study to:

- Analyse the changes in river morphology
- Analyse land use changes over the flood plain area

<sup>1</sup>INRM is a R&D based company set up under Technology Business Incubation Plan of the Indian Institute of Technology (IIT) Delhi by the faculty and alumnus of the institute in 2001.

- Identify the confluences of major tributaries, man-made structures such as barrages and other diversions, potential point sources of pollution, meandering and stable sections, etc.
- Collate secondary data on cities, industries, pollution monitoring sites, etc.

This analysis utilised satellite imageries to obtain the land use information. The terrain was analysed from the Shuttle Radar Topography Mission (SRTM) data (90 m resolution).

Through this study, it was concluded that the river Ganga can be classified into seven distinct zones, i.e.

Zone 1: Gangotri to Rishikesh

Zone 2: Rishikesh to Garhmukteshwar

Zone 3: Garhmukteshwar to Narora

Zone 4: Narora to Farrukhabad

Zone 5: Farrukhabad to Kannauj

Zone 6: Kannauj to Kanpur

Zone 7: Downstream of Kanpur (Kanpur to Rai Bareilly)

These zones are shown in Figures 2a and 2b.

### Methodology Workshop

During the ‘Methodology Workshop’ in December 2008, decision was taken to further narrow the approach from seven zones to four zones. These four zones were identified for actual consideration and further studies as the four zones are able to represent the critical challenges of the river Ganga. Table 1 lists the location of the four zones, their critical issues and representative sites. More details are given below.

Table 1. Four zones representing critical issues pertaining to river Ganga and study sites

S. No.	Zone	Critical aspects/Issues	Site ( <i>latitude and longitude</i> )
1	Zone 1: Gangotri to Rishikesh	A mountainous sub-stretch	Kaudiyala [N30°04'29.9", E78°30'09.9"]
2	Zone 2: From upstream of Garhmukteshwar to Narora (Reference Zone)	A sub-stretch which is relatively intact	Upstream of Narora (Reference Site) [N28°10'51.2" E78°23'51.2"]
3	Zone 3: Narora to Farrukhabad	A sub-stretch which is affected by water abstraction through barrage	Kachla Ghat [N27°55'59.8", E78°51'42.5"]
4	Zone 4: Kannauj to Kanpur	A sub-stretch which is affected by pollution	Bithoor [N26°36'51.9" E80°16'28.6"]

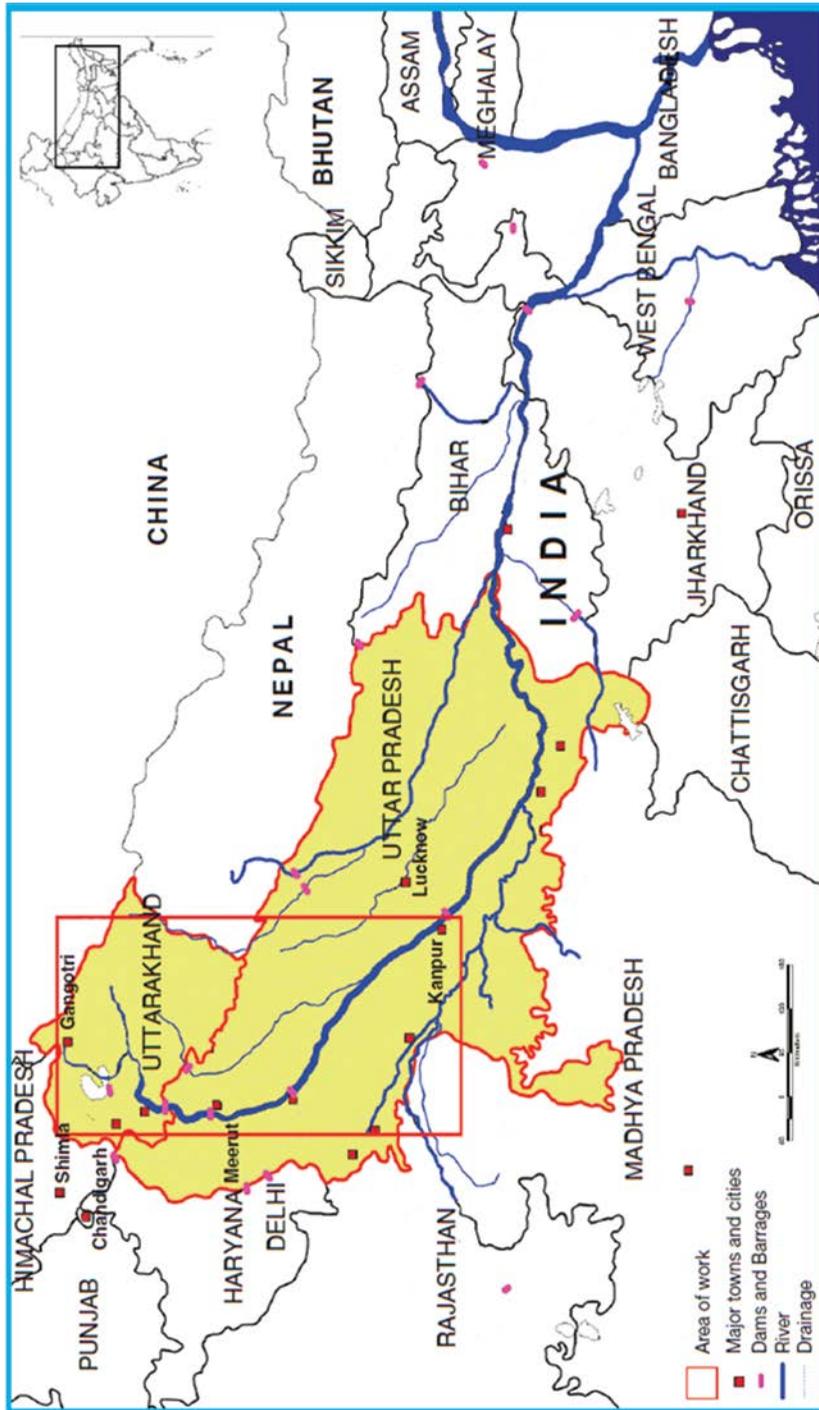


Figure 2a. Project area of Living Ganga Programme showing the Upper Ganga River stretch

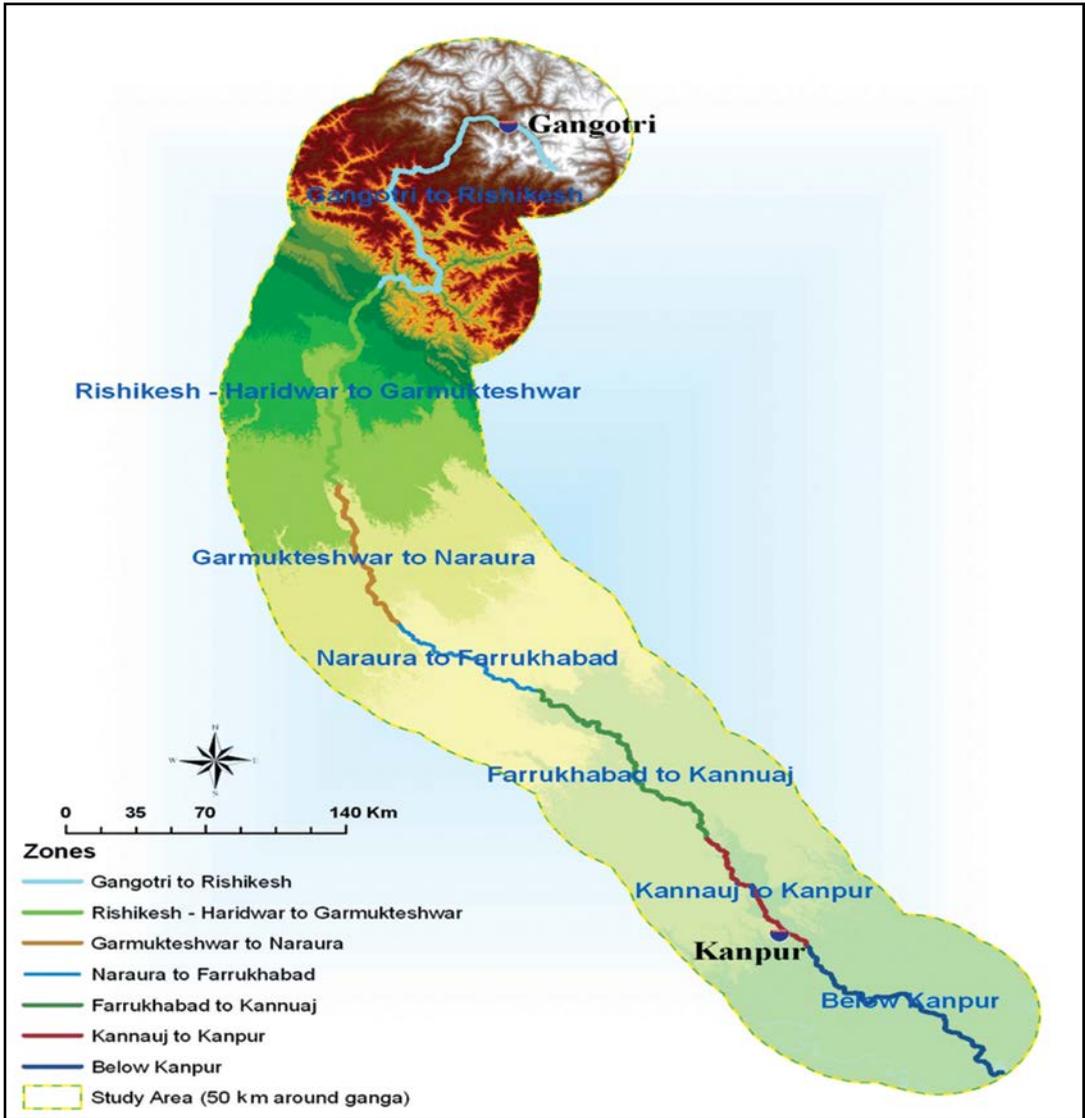


Figure 2b. Upper Ganga River stretch showing various zones

During a meeting in February 2009, one site under each of the zone was selected with a view to undertake detailed field investigations, surveys and associated research. The idea, again, was the representativity of the respective zone by the identified site. Table 1 lists the sites identified for detailed field investigations are listed in Table 1 and described below briefly.

**Site: KAUDIYALA (Zone: Gangorti to Rishikesh)**

Kaudiyala is located about 12 km downstream of Devprayag (where the Alaknanda and Bhagirathi rivers meet to form the Ganga River). The river has a very sharp bend at this location, with gravels and boulders on the concave side, and a road along its right bank. The river is about 100 m wide at this point, while the valley width is in excess of 600 m. The river is flanked on both sides by high mountains. Two reservoirs are planned between this point and Devprayag which are likely to disturb the ecology of the reach significantly, making it an even more important site for an E-Flows assessment.

The channel consists largely of pool/riffle and rapid sequences. The narrow channel widens as the river enters Kaudiyala, forming sandy banks along the left slopes. The dominant sediments carried by the river are gravels, with the river bed at this point consisting of boulders, rocks, cobbles, pebbles and silt.

In the reach between Kaudiyala and Marine Drive (upstream of Lakshman Jhula and Rishikesh), large boulders are common along both banks, suggesting that rock slides are frequent in this area.

In this zone, the biodiversity and cultural and spiritual aspects are highly significant, a brief description of which is given below.

A few kilometers upstream of this site, at Pachelikhal, is the confluence of the Nyar river with the Ganga. It is believed that the Nyar is the only tributary of the Ganga in which mahseer (fish) breed in the monsoon period when the flow in the Nyar is conducive. The construction of dams and hydropower plants in the downstream reaches may change this situation, as the adult mahseer may not be able to migrate upstream to reach the Nyar for breeding.

Downstream of Kaudiyala, a good population of large mahseer was observed at Rishikesh (Ram Jhula) concentrated in the centre of the channel with a gravelly bed and shallow water depth. Along the right bank, the rocky bottom was visible but the deeper water did not encourage the fish population.

The site at Kaudiyala was subsequently found not to be suitable for biodiversity sampling because of a lack of available habitats. Therefore, an alternative site at Shivpuri, 10 km downstream of Kaudiyala, was used for the biodiversity study. The water quality and temperature were similar at the two sites, whilst Shivpuri provided a greater diversity of more accessible habitats. Since both Kaudiyala and Shivpuri are suitable for assessing the riparian vegetation, the biodiversity group decided to carry out their surveys and sampling along the stretch of river from Kaudiyala to Shivpuri.

There are a number of tourist camps in this area, which are very popular with visitors for rafting and camping. Plus, Rishikesh is one of the crucial towns from the perspective of socio-cultural and religious aspects.

### **Site: U/S Narora Barrage (Zone: U/S of Garhmukteshwar to Narora)**

The Baiya and Burh Ganga are the major tributaries joining the main channel. The Lower Ganga Canal take off at Narora barrage which is located in this zone. Channel morphology around this site includes sand bars, islands, flat floodplains and a few ox-bow lakes. The floodplain on the left bank is wider than on the right bank.

This stretch has adequate flows and water depths are sufficiently well maintained to support natural biodiversity and especially the flagship species such as river dolphin and gharial. This stretch is also a declared 'Ramser Site'. Plus this stretch also doesn't face significant pollution load. In view of all this, this zone was decided as a 'reference-zone' to benchmark and assess the downstream zones, which have been very heavily modified, overused and polluted. This means E-Flows assessment for this site representing the respective zone was not undertaken.

### **Site: Kachla Ghat (Zone: Narora to Farrukhabad)**

This site is located approximately 60 km downstream of Narora, at downstream of the confluence of the Mahuwa with the Ganga River. The Central Water Commission (CWC) has a hydrological station (GDSQ) at this site, where water level, discharge, sediment load and water quality are measured. The river macro-channel at this location is very wide (>3 km) but the water is confined to only about 20 m and the water depth is 1 to 2 m (waist deep) at present. Both the banks of the river are quite flat, merging gradually with the floodplain. No sign of any incision was visible on either of the banks. The dominant grain size of channel sediments is fine sand with significant amounts of silt.

Upstream of this site, the Mahuwa River at Jatki village has a much larger valley than the channel occupied by the river at present, suggesting a significant reduction in river discharge in recent times. The river was almost dry at the time of the initial field visit (March), with the river bed being cultivated by local melon farmers, and fishing taking place in the remaining pools. Field investigations revealed that a large amount of effluent from Gajraula is discharged into the Mahuwa, eventually finding its way into the Ganga River downstream of the confluence. Even though the flow from the Mahuwa is diverted, the Ganga River at Kachla Ghat seems to have several other sources of pollution such as city waste. It has a cremation area/*ghat* as well as a bathing *ghat*.

Due to intense human activity at Kachla Ghat, this site was not suitable for the study of aquatic biodiversity, and a better site was selected 1 km downstream where micro-habitats and stable substrate are available. Agriculture is the major form of human impact especially along the right bank.

Kachla Ghat's religious importance is not of extraordinary spiritual significance as in the case of Haridwar and Rishikesh, but is important from the point of view of livelihoods. Several livelihood practices that depend on in-stream flows are evident here, including farming on sand banks, ferrying, retrieving coins, pilgrimage, ritual bathing and cremation.

### **Site: Bithoor (Zone: Kannauj to Kanpur)**

Bithoor (situated at upstream of Kanpur), was selected as the designated site for detailed studies in this zone. The surface elevation at Bithoor is 120-130 m above mean sea level. The active channel presently follows the southern valley margin and has extensive floodplain areas within the valley. Floodplain areas north of the Ganga include abandoned channels, meander scars and ox-bow lakes, together with a few small lakes and waterlogged areas. A very large, conspicuous meander scar which is presently cut off from the present channel is periodically flooded by the Ganga. The southern valley margin is strongly incised and at Bithoor, prominent cliffs up to 15 m high extend in a south-easterly direction for nearly 2 km. The river bed is mainly composed of sand and clay (on the banks of the river). Except during the monsoon months, the river is multi-channeled, with large bars in the channel dividing the flow.

The Kanpur barrage constructed 6 to 7 years ago is located immediately downstream of this site, together with a diversion canal for the barrage. A hydrological station located at Kanpur reports that the long-term average annual discharge at Kanpur is 1679 m<sup>3</sup>/s. Hydrological data published for this station suggest that the discharge variability is significant whereas the flooding intensity is low, with a higher bankfull discharge compared to the mean annual flood.

At the site, the aquatic biota and especially the lower organisms (plankton and benthic invertebrates), which are very sensitive, are highly influenced by intense anthropogenic activities, including bathing, pilgrimage activity and boating. The site has religious and archaeological importance. An old temple dedicated to Lord Brahma is situated at Bithoor. Religious fairs are organised on important occasions, during which religious bathing is common. The site is also known for historical remains of the pre-British period all along the banks. Many local livelihoods depend directly on the cultural importance of this stretch of the Ganga. Whilst this is a good site for generating hydraulic sections, as the right bank is confined by 12 to 14 m high cliffs whereas the left bank is flat, it was not considered suitable for aquatic (biodiversity) sampling. Aquatic sampling was carried out approximately 1 km downstream of the Bithoor temple.

### **Objective Setting Workshop and Preliminary Field Visits**

With a view to do the ground truthing exercise the group undertook extensive field visits (*March 2009*) to all the sites to validate the findings of the initial studies and to reinforce the decisions taken about the site selection etc. All the local potential partners accompanied these visits. After these visits, an 'Objective Setting Workshop' was organized. During this workshop, various critical aspects were discussed and concluded for further work. Thereafter, a multidisciplinary team was set up to undertake detailed field investigations pertaining to the critical aspects. Table 2 lists various critical aspects and partners who undertook respective tasks.

Table 2: Critical aspects (tasks) and entrusted institutions/ organizations who undertook the same

S. No.	Task ( <i>critical aspect</i> )	Partner undertaking the task
1	Overall facilitation	UNESCO – IHE, the Delft WWF – India IWMI – Sri Lanka
2	Hydrology	IWMI – Sri Lanka
3	Fluvial geomorphology	IIT – Kanpur and Delhi University
4	Hydraulic modeling	INRM Consultants and IIT – Delhi
5	Livelihood and economic aspects	IIT – Kanpur
6	Socio-cultural aspects	PSI – Dehradun
7	Establishing habitat preferences of selected aquatic vertebrates (biodiversity aspects)	Srinagar Garhwal University WWF-India
8	Analysis of water quality and pollution	IIT – Kanpur

During this workshop, the Environment Management Class (EMC) of the river was also discussed and based on the international experience and local inputs it was concluded that following EMC would be taken into consideration while defining the EMC for Ganga:

Six classes of river condition or health, A to F, are recognized. These are designated as the Present Ecological State (PES) according to the current state. From these the overall objective conditions, summarized as the EMC are defined from A to D. Class 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

These EMCs are important to understand as most of the thematic groups (including biodiversity, socio-cultural, fluvial geomorphology, livelihoods and economics) who investigated sites/zones of the river Ganga did categorize sites/zones as per these EMCs, except for the water quality group, who considered CPCB (Central Pollution Control Board – India) classification of water quality.

## **Detailed Field Investigation**

With the establishment of various thematic teams, detailed field investigations began by respective teams in and around the sites identified under each of the four zones. This exercise was aimed to capture changes/modifications/transformations within the respective aspect in an annual cycle (pre, during and post monsoon), i.e. the field work continued for a complete one year, i.e. from May 2009 to April 2010. During this period, tri-monthly progress review meetings were conducted to keep track of the work related progress and for course correction, if any. During these meeting the thematic groups used to present past three months progress along with the plan for next 3 months to the rest of the group, so that potential synergies, if any, could also be established.

Some of the thematic groups not only concentrated at the sites, but at the nearby towns and points so as to capture the related aspect in totality. For instance – Kaudiyala site is not of immense socio-cultural importance, so the socio-cultural group, in addition to this site, also undertook field surveys in Rishikesh-Haridwar to capture the socio-cultural aspirations of the visitors, pilgrims, and local people from these towns. Same is the case of biodiversity group, who, while establishing the habitat preferences for selected species, also analysed and investigated the upstream and downstream stretch of the river, so as to understand the migratory/breeding/feeding pattern of the aquatic species.

## **Preparation of ‘Starter Document’ and other Thematic Reports**

Later on, during March 2010 most of the thematic teams (Biodiversity, Fluvial Geomorphology, Socio-Cultural, Livelihoods and Economic and Water Quality) submitted individual ‘Starter - Documents’. The Starter – Documents actually reported following items from a given perspective :

1. Present state of river, i.e. categorization of river state into most suitable EMC (whereas in case of Water Quality group, the CPCB classification of water quality was referred to)
2. Desired state of river, i.e. categorization of river state into most suitable EMC (whereas in case of Water Quality group, the CPCB classification of water quality was referred to)
3. Motivations for recommending respective desired state/class of river.

On the other hand the hydrology group prepared a detailed report on the ‘Hydrology of the river Ganga’. For the purpose of hydrological modeling the thematic group required the hydrological data in time series manner which was not available in the public domain, due to trans-boundary nature of the river. However, in absence of that, the team managed with scattered hydrological data which was made available from other sources (like – local irrigation department and global datasets). Nevertheless, this report formed the basis for other thematic groups to validate and cross check the viability of the recommended E-Flows during the E-Flows setting.

The group undertaking hydraulic modeling and cross sectional work presented a detailed report explaining surveyed cross sections of various sites. They actually took three cross sections at each of the identified site; i.e. one at the upstream of the identified site, second at the site and third at the downstream of the site. The findings of this report were used by rest of thematic groups (excluding hydrology group) to arrive at required E-Flows for specific sites.

### **E-Flows Setting**

A five-day 'E-Flows Setting Workshop' was organized in mid 2010 (May 2010), during this workshop the final E-Flows recommendation were arrived at.

This workshop had an exhaustive agenda to capture all the sites (representing respective zones), taking care of all the concerned aspects for all the seasons, i.e. wet and dry season, also the drought and floods scenario.

The first day of the workshop was devoted to field visit to Kaudiyala site, where both the hydrology and hydraulics group members explained respective aspects at that site. Rest of the thematic groups explained their respective requirements pertaining to the desired state at this site. This visit was aimed at setting the context for all the thematic groups for upcoming in-door exercise of setting E-Flows.

After the presentation of hydrology of river Ganga and hydraulic cross sections of various sites, the larger group discussed wettest and driest months of the year and it was concluded that based on the available data, January can be considered as a driest month and August can be considered as a wettest month of the year.

Based on these decisions, the rest of thematic groups filled individual 'Flow Motivation Forms'. These forms were filled by each of thematic group for each of the season and for each of the site. The groups also filled separate forms for extreme drought and flood conditions. With a view to give an idea, one such form is shown in Figure 3. Through this form, each of the group recommended E-Flows for specific site and for a specific season; the group also gave associated motivations for recommending the flows, depth and average velocity along with the consequences of not providing the same

Prior to filling of Flow Motivation Forms, the concept of 'Maintenance Year' was explained. The Maintenance Year is a normal year, not very wet not 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. Based on the part hydrological datasets, it was concluded 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 a Flow Duration Curve. 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 flood for 30% of the time.

The recommendations from the concerned thematic groups were discussed and debated, and as expected, there were conflicting views in regard to recommended E-Flows for a site and for a season by various thematic groups. At this juncture, the key facilitator

### FLOW MOTIVATION FORM

**River:** Ganga    **Date:** 11-05-10    **Site:** Kaudiyala    **Specialist:** Geomorphology

**Month:** January    **Low flow or flood?** Low Flow (MAINTENANCE Year)

**Discharge:** 400 cumec    **Depth:** 9.5 m    **Average Velocity:** 0.64 m/s

#### **Reasons for recommending this flow:**

At low flow, maintenance of longitudinal connectivity will be critical. Otherwise, the geomorphology is in good condition. According to the cross section (CS-3), plan form parameters along longitudinal direction and field observation, longitudinal connectivity will be lost at a flow lower than 397m (RL) (depth 9.5 m), while water level at 404 m RL will be good to maintain lateral connectivity. Since, discharge of 1400 cumec at 404 MSL is unrealistic, lateral connectivity cannot be maintained at low flows. Hence, the final recommendation at low flow is 9.5 m of flow depth (400 cumec discharge)

#### **Consequences of not providing this flow:**

Flow less than 400 cumec (corresponds to 9.5 m flow depth) will break the longitudinal connectivity and will be critical for movement of biota. Water level less than 404 m will break the interaction between channel and adjoining bars which is an implication for nutrient supply and habitat conditions apart from the general functioning of the river system.

Figure 3. A filled flow motivation form of fluvial geomorphology group for Kaudiyala site for dry season – maintenance year

from UNESCO-IHE, Prof. Jay O Keeffe played critical role and asked the groups that, why do they need such flows and if that is to be curtailed then to what extent, so that it does not lead to detrimental impact onto the required aspect. Finally, the consensus about recommended E-Flows was built for each of the site and for each of the season with clear rationale. The same for different seasons were collated and concluded as recommended E-Flows in terms of ‘Mean Annual Runoff’ (MAR).

This whole exercise of E-Flows Setting was conducted for three sites, excluding the Reference Site, as that was not required since it was a motivation for others to consider, if possible.

## **Motivations Leading to Setting of E-Flows**

The setting of E-Flows for various sites and for various seasons was driven by the motivations from the thematic groups. This sub-section summarizes some of the key motivations who drove the E-Flows recommendations for the given site.

### ***Socio Cultural***

Based on the interviews and discussions with the stakeholders during surveys, the concerned thematic group concluded that, flows desired for socio-cultural aspects are not based on the functional demand; it is more of a subjective or emotional need based on perception of what a mighty river Ganga ought to be like. For instance according to a respondent, “boulders in the middle of the river should not be visible from the ghats”, as that is not true reflection of a mighty river Ganga. However, the respondents were mindful to understand the drought scenarios, and they do not have reservations for this condition in extreme situations.

Another example is the *Bramha*<sup>2</sup> temple at Bithoor near Kanpur, where the respondents stressed that, inundation of Brahma’s feet at the banks of Ganga (atleast once a year) is the welcome event for the following year, so is therefore, a must for the river Ganga. This motivation became the driving force for recommending the E-Flows for wet season at Bithoor.

### ***Biodiversity***

The key driving motivations from the biodiversity perspective is the flagship aquatic species and those species that are critical from the viewpoint of food-chain. The species including – Mahseer (in the upper stretch upto Rishikesh-Haridwar) Ganga Dolphins, gharials, otters, turtles. In addition to this the food and critical prey base of these aquatic animals were also taken into account while recommending flows from this perspective.

### ***Fluvial Geomorphology***

Fluvial geomorphology deals with river channel morphology and also pertains to various complexities in the river morphology, which are essential for a healthy river, therefore the motivations from this thematic group dealt with requirement of all those geomorphic processes/features which are essential for river to be in a desired state.

### ***Livelihoods Aspects***

This thematic group mapped various livelihood activities of the people residing on the banks of the river and tried to understand the trajectory of growth or the declining trend in the past, of such livelihoods. Later, the group analysed those activities and recommended the flow requirements taken into account only those activities which are not detrimental for river.

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<sup>2</sup>According the Hindu mythology, Brahma is the creator of the universe

## RESULTS

At the end, the team came out with graphs depicting the pattern of flows required as E-Flows for respective sites across the entire cycle of the year. It is emphasized that, the MAR values given with each of the graph is an aggregate of required flows for entire year and the idea is not about one time flow to the tune of recommended MAR value, it should actually be spread throughout the year, as illustrated in Figures 4 to 6. Further, Table 3 provides information about the agreed highest requirements from the flows perspective by various thematic groups for different seasons and for draught scenario.

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 requirements to specific features of the river channel at the study sites.

Table 3. Site specific E-Flows motivations for maintenance and drought years

Scenario	Critical Flows (m <sup>3</sup> /s)	Depth (m)	Average Velocity (m/s)	Component
<b>Kaudiyala</b>				
January–Maintenance	400	9.5	0.64	Fluvial Geomorphology
August–Maintenance	3250	21.05	1.15	Biodiversity
January–Drought	290	8.28	0.57	Livelihoods
August–Drought	1469	16.28	0.91	Biodiversity
<b>Kachla Ghat</b>				
January–Maintenance	300	3.49	0.38	Biodiversity
August–Maintenance	1740	5.52	0.3	Cultural and Spritual
January–Drought	161.5	2.99	0.33	Biodiversity
August–Drought	551	6	0.33	Cultural and Spritual
<b>Bithoor</b>				
January–Maintenance	330	3.5	1.03	Biodiversity
August–Maintenance	33.03	8.08	1.2	Cultural and Spritual
January–Drought	193.8	3.08	0.88	Biodiversity
August–Drought	1469	6.08	1.5	Cultural and Spritual

**Site: Kaudiyala (Zone: Gangotri to Rishikesh)**

The E-Flows requirements were calculated as 72% of Mean Annual Runoff (MAR). While estimating the flow requirements for this zone, the present day flows were not calculated, as flow release data from the Tehri Dam was not available. Monthly pattern of recommended E-Flows is shown in Figure 4.

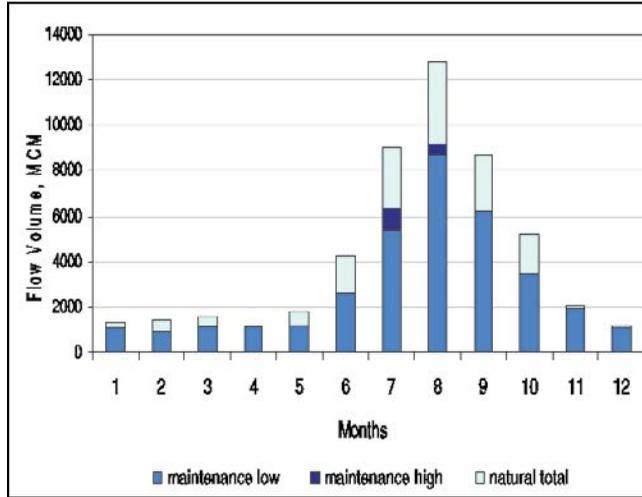


Figure 4. E-Flows recommendations for Kaudiyala site

**Site: Kachla Ghat (Zone: Narora to Farrukhabad)**

The E-Flows requirements were calculated as 45% of MAR. The figure also presents the Naturalized Flows as well as simulated present day flows. The present day flows fulfill E-Flows requirements for August but are lower in all critical months (Jan-May).

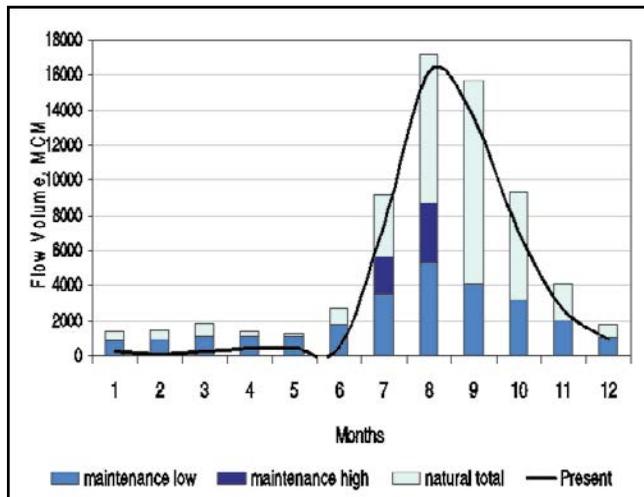


Figure 5. E-Flows recommendations for Kachla Ghat site

**Site: Bithoor (Zone: Kannauj to Kanpur)**

The E-Flows requirements were calculated as 47% of MAR. The figure also presents the Naturalized Flows as well as simulated present day flows. The present day flows are lower than the E-Flows requirements for all twelve months.

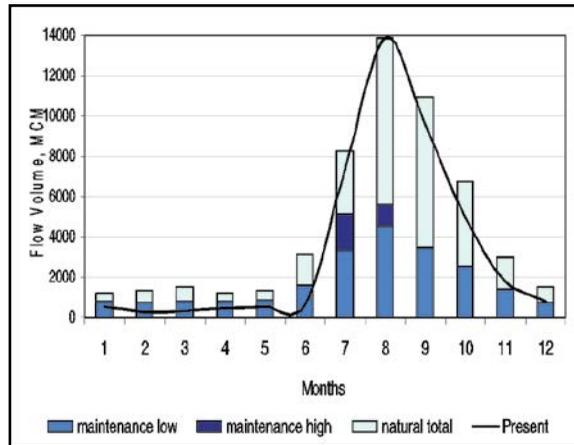


Figure 6. E-Flows recommendations for Bithoor site

- 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.

This study has made the first attempt to define the required flows to be maintained in the river, in order to achieve pre-defined environmental classes and objectives. There is a need for a national debate on a much difficult question of how these E-Flows can be maintained or restored in the river. Absence of an enabling policy environment and the existing water uses, allocations and trade-offs will make implementation of E-flows in India, a complex and a challenging task. Therefore, it becomes imperative to pilot the E-Flows assessment and implementation in a river basin or a sub-basin which is manageable, especially in wake of growing concern for rivers around the country. It is also important to demonstrate and test the various mechanisms for its enforcement and monitoring. This would help in refining the strategy for mainstreaming the implementation of E-flows at a basin level or at the national level.

## REFLECTIONS AND LESSONS LEARNT FROM THE STUDY

This was the first attempt to carry out a *comprehensive assessment* of E-Flows for a river in India. Previous E-Flows assessments for Indian rivers by IWMI, were primarily based on the use of hydrological information and were largely desktop. E-Flows 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.

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