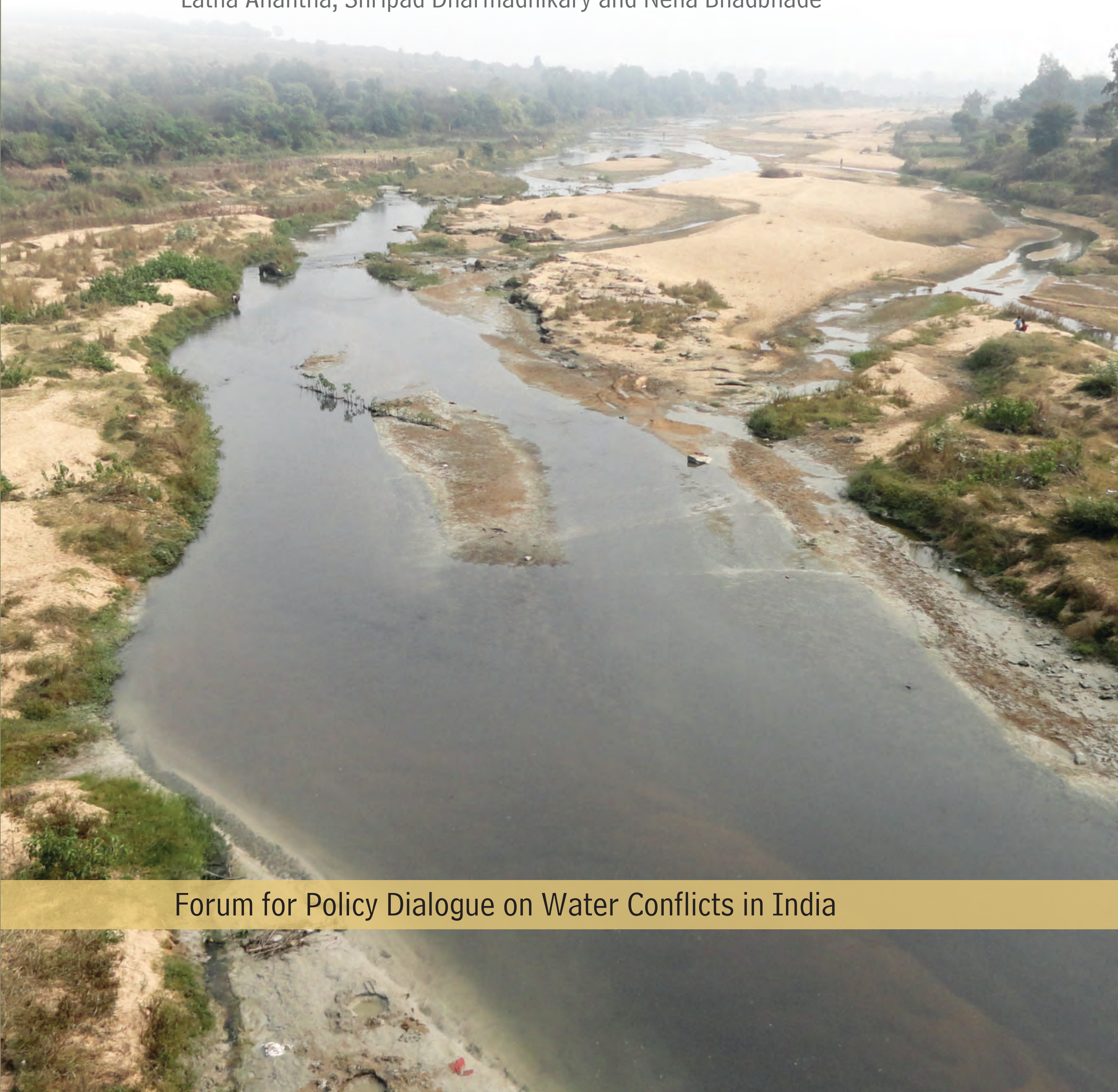
E-flows in Indian Rivers

Methodologies, Issues, Indicators and Conditions
Learnings from Hasdeo Basin

Latha Anantha, Shripad Dharmadhikary and Neha Bhadbhade



Forum for Policy Dialogue on Water Conflicts in India

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FORUM FOR POLICY DIALOGUE ON WATER CONFLICTS IN INDIA

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Foreword and Acknowledgement

The Forum for Policy Dialogue on Water Conflicts in India (Forum in brief) has recently completed its third phase of work. During the third phase of the Forum, one of the thematic activities taken up was "Evolving criteria and institutional framework for environmental flows in India". Water for sustaining and regenerating ecosystems seems to be the last priority in water use. Yet, our future will depend on how well we protect the ability of our ecosystems to provide us with all the water related eco-services that we need, especially, in respect of basic needs which requires water of sufficient quantity as well as quality on a sustainable basis. Thus, through this thematic activity an attempt was made to develop a framework based on important indicators and criteria that are necessary for allocation of water for sustaining the eco-services of river based on multi-stakeholder process.

Through this report we have attempted to present to put together some of the important concepts, methods and concerns related to the implementation of the e-flows approach in India. This report draws from existing literature, experiences of e-flows assessments in India till date, and the Forum's own work in the Mahanadi basin and its Hasdeo sub-basin in particular. In the Hasdeo sub-basin, the Forum's E-Flows Thematic Group has been working to understand how a process of e-flow assessment could be implemented in the basin. At the same time, this report also offers important broader learning for implementation of e-flows elsewhere.

The Hasdeo basin was chosen for the study for many reasons. Firstly, the Hasdeo basin is part of the Mahanadi basin, where the Forum has had a long interaction with the stakeholders through its action research in the previous phases. Secondly, there are a number of interventions on the Hasdeo in form of dams, barrages and anicuts, which have significantly modified the flows of the Hasdeo. Thirdly, the Hasdeo basin is heavily industrialised with major thermal and steel plants utilizing large amount of water in turn polluting the Hasdeo with their effluents. The upper catchment of the basin of has a number of coal mines that are a threat to the health of the basin. Lastly, a number of livelihoods depending on the Hasdeo like the fishing and riverbed farming have been affected due to the regulated flows in the river.

We have primarily used existing literature and secondary data to prepare this report. Important insights on the critical issues in the basin were drawn from field interviews with the stakeholder and riparian communities. The various government offices provided us valuable secondary data regarding the basin. We thank all the concerned officers for the support and co-operation. A number of individuals have helped us in shaping this report. We would firstly like to thank Laxmi Chauhan and Manish Rathod who have helped us tirelessly with the field work in gathering information and conducting field interviews with riparian communities and also conducting water quality tests. We would like to thank Alok Shukla, Dr. Anand Mishra and Shri Nandakumar Kashyap for providing us with useful insights on the Hasdeo basin and the issues related to inter-sectoral allocation of water in the Hasdeo basin. We would like to thank Ramlal

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1 Introduction

One of the defining features of the conventional approach to water management in India is the notion that any water that is not used for human needs is worthless. Its most common articulation has been that "any drop of water that goes to the sea is a waste". This has led to plans and projects geared to extract every last drop of water from our rivers. The consequences have been serious; including dead and desiccated rivers, destruction of the riverine ecology, loss of livelihoods like fish and riverbed agriculture, loss of the ability of rivers to dilute and cleanse pollutants, and impacts on deltas as rivers are no longer able to transport sediments and sea ingress (Joy et al., 2011; Dharmadhikary, 2016b).

This linear approach to river management has been strongly challenged, and over the last several decades, a different vision of managing rivers has emerged. This vision looks at rivers as sustainers of life, as nurturers of ecosystems as well as ecosystems in themselves, as providers of services to human societies and to non-human beings. It recognises that rivers play multiple roles and perform several different functions, including supporting livelihoods, maintaining eco-systems, and sustaining societies and cultures. This multi-dimensional approach to rivers focuses on maintaining and conserving rivers and riverine ecosystems even as the waters of the rivers are used for meeting important human needs. It is based on the principle of limiting human interventions into river systems. It aims at keeping rivers alive and flowing.

The concept of environmental flows or e-flows has emerged in recent years to put into practice this holistic approach to river basin management. As a concept, there is nothing new about e-flows. In essence, it means "keep the rivers flowing". Since decades, riparian communities, people affected by dams and river diversions; activists and environmentalists have been maintaining that rivers must continue to flow, that one cannot divert all the water away from rivers. Rivers need to flow so as to enable them to perform their critical functions and fulfil their roles.

The concept of e-flows is a more structured and formalised articulation of the same principle. Over the last decade and a half, e-flows has globally evolved into a well-developed, scientific, multi-disciplinary field where expert driven specialisations like hydrology, river morphology, biology, ecology, sociology, and economics combine with the knowledge and understanding of riparian and other communities to create a scientific, social as well as political process which determines how much water can be extracted from the river, for what all purposes, how much should continue to flow, who all will determine and decide how much should flow, when and how. E-flows have emerged as the key framework for informed, participatory decision-making in river-basin planning.

A widely accepted definition of e-flows from the 2007 Brisbane declaration is that e-flows describe "the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems" (International Water Centre, 2007). The importance of the e-flows approach derives from the fact that it brings to centre the need to keep rivers flowing. In doing this, it effectively overturns the fundamental premise of the dominant thinking that "every drop that flows to the sea is a waste". In fact, it mandates that significant quantities of water needs to flow all the way to the estuary and the sea (Dharmadhikary, 2016b). Given this, and the fact that e-flows as an approach is gaining recognition in policy and regulatory regimes in India, it is important that this approach be studied and applied properly.

In the third phase of activities of the Forum for Policy Dialogue on Water Conflicts in India (henceforth, Forum), e-flows was taken up as an important theme to broaden its conceptual understanding, explore the possibilities and potential of evolving a suitable methodology, and implement it in the Indian context. In this phase, position papers on several important themes surrounding the water sector were brought out and discussed widely. One of the reports published by the Forum namely, Life, Livelihoods, Ecosystems, Culture: Entitlements and Allocations of Water for Competing Uses (Joy et al., 2011) has a position paper 'Water for Ecosystem Needs', which puts forward the argument that the river basin development framework followed all these years has completely disregarded the ecosystem needs of the river and other water resources like wetlands and lakes.

This report by the Forum is an attempt to put together some of the important concepts, methods and concerns related to the implementation of the e-flows approach in India. This report draws from existing literature, experiences of e-flows assessments in India till date, and the Forum's own work in the Mahanadi basin and its Hasdeo sub-basin in particular. In the Hasdeo sub-basin, the Forum's e-Flows thematic group has been working to understand how a process of e-flow assessment could be implemented in the basin. At the same time, this report also offers important broader learning for implementation of e-flows elsewhere.

The e-flows approach is a rapidly growing field, which already has a rich set of theoretical understandings and practical experiences. Several methodologies have evolved globally for e-flows assessment. Chapter 2 of this report provides an overview of the concept, objectives and methodologies for environmental flows. Chapter 3 looks critically at some of the attempts at e-flows assessments in India. Chapters 4 and 5 details the experiences of the Forum in the Hasdeo basin, drawing out important indicators and conditions for the assessment of e-flows in the basin, and also the further steps needed for better river basin management in the Hasdeo basin, as well as important lessons for e-flow assessment processes in other parts of the country. Chapter 6 explores how the current policy and legal regime includes (or not) the e-flows approach and how it is evolving towards enshrining e-flows as a central component of river basin management. Chapter 7 concludes the discussion with some insights and recommendations.

1.1 Some Important Issues in the Indian Context

While we look at the various methodologies of e-flows assessment in the next section, some important generic issues regarding their implementation in the Indian situation need to be noted. These require the adaptation of the standard methodologies to the Indian situation. We mention a few of the important considerations below, with some ideas on how to address them.

1.1.1 Issues in Setting Objectives

As noted earlier, e-flows assessment is at once a scientific, social and political process. As a political process, the fundamental constituent of e-flows assessment is setting the objectives for e-flows. The importance of this cannot be over-emphasised. Any use of a river, any human intervention, any extraction of water, all would lead to a change in the original (pristine) flow regime. Thus, the use to which we put a river would effectively constrain the levels of flows that can be maintained in the river. Conversely, the levels of flows we want in a river would set limits on the kind and extent of uses to which the river can be put to and the water that can be extracted from it. The process of e-flows determination is essentially a process of choosing the balance between the two. How much flow we want in a river, i.e. e-flows, depends on the roles and functions we want the river (and the waters of the river) to serve including its ecological needs. It is the objectives that will determine which uses, roles and functions of the river are to be prioritised. Hence, the critical importance of the objectives in any e-flows assessment process, as stated by O'Keeffe & Le Quesne (2009),

> "There is no one correct environmental flow regime for rivers — the answer will depend on what people want from a river. Different sorts of rivers are likely to have different requirements and priorities, for example differing approaches for a river in a protected area in contrast to a river in a major irrigation or urban area. Choice and judgement, particularly when deciding on environmental objectives, are an essential part of the environmental flow process".

There are several critical issues with respect to the setting of objectives in the Indian situation. First of all, as the very process suggests, setting the objectives should involve all the key stakeholders, in particular the river basin communities. Yet, there is no existing mechanism —legal, institutional, administrative or social — which will ensure the participation of all and attempt to set the objectives for a river.

Secondly, the key issues of concern for local communities are not necessarily those relating to river flows. For example, one of the major concerns for the local communities living on the banks of the Hasdeo river is the serious pollution of the river, with the pollutants being openly discharged into the streams and the river by the coal mines and power plants in the area. Strictly speaking pollution is not caused by flow related issues, but it is also true that a good flow in the river can dilute the concentration and impacts of pollutants. Hence there is a need to integrate even such issues in the objectives of e-flows, because many of these problems ultimately relate to the health of the river and therefore, to the flows.

Thirdly, communities are not always able to link problems faced by them to the disturbances in quality and quantity of flows. For example, the changes in sediment transport and trapping of sediment behind dams can often reduce sediment transport downstream, impact sediment transport pattern, impact riverbed/ floodplain cultivation through the decrease in the fertility of the soil as nutrients do not get deposited on the riverbed/ floodplain. It is therefore important to involve experts with links to communities in order to integrate such issues into e-flow objective setting.

Lastly, the objective setting for already dammed and overused rivers should be different from those rivers where dams are still in the planning stage. In the former, e-flows allocation is largely a restoration and mitigation strategy to prevent further degradation of the river. In the latter, there is scope for setting norms based on the objectives before the dams are built, including reducing the number of dams that can be built in tune with the e-flows allocation for the river.

1.1.2 Absence of Data

E-flows determination is also a scientific process and one of the prerequisites for this aspect is data regarding several parameters like hydrology, morphology, ecology and so on. Unfortunately in India, the lack of data is more a rule than an exception. Local communities have significant knowledge regarding flows, aquatic and terrestrial flora and fauna, fish behaviour, etc. but it is amorphous, dispersed and not integrated with other structured knowledge streams. Most e-flow assessments in India would have to work with this reality. We too encountered this problem in the Hasdeo basin.

One of the ways to deal with this hurdle is to use indicators which can be proxies for some of the important parameters. For example, Smakhtin et al., (2007) suggests that in India, as there is paucity of data, and in instances where such data exists, as it has not been interpreted in the context of e-flow assessment, one way of conducting e-flow assessments can be to take a set of indicators, like presence of unique biota, percentage of watershed remaining under natural vegetation, etc. and attach scores to each indicator. The sum of such scores would indicate the deviation of the basin from its natural condition, and therefore its environmental management class (EMC).

"Thus, EMC is a management concept that has been developed and used in the world because of a need to make decisions regardless of the limited lucid hydro-ecological knowledge available. In these conditions of uncertainty with regard to which EMC is required for a particular river, the EMCs may be used as default 'scenarios' of environmental protection and associated environmental flows" (Smakhtin et al., 2007).

In other words, the indicators can be used as a proxy to ascertain the state of the river in general, which can in turn be used "to determine the acceptable limits of flow reduction/increase in a river, i.e., actual e-flows."

In the Hasdeo basin as well, we have found that the use of this approach provided important insights. However, there are crucial limitations to this approach, as even the authors acknowledge, namely that the method "does not directly address the issues related to social importance of water use", at least not in its current state. We have found that the social, cultural, and livelihoods related aspects of water use can be integrated by bringing in the key concerns of local communities, like amount of water extraction, loss of livelihoods, deterioration in water quality, etc. which can also form the criteria to be used to determine the acceptable limits of (further) flow reductions, or the need to increase or restore flows.

1.1.3 Inputs from Experts

Apart from data, experts must be involved in the scientific process. E-flows assessments typically would benefit, indeed require the inputs of experts from fields like hydrology, morphology, ecology and so on. In Indian conditions, availability of such expertise is limited, particularly experts with basin-specific knowledge. Moreover, their inputs can often imply significant financial costs. Under such circumstances, a judicious combination of expert input, integration of local knowledge and indicators and criteria as described above can help address this limitation to some extent.

Thus, the situation in India requires the e-flows assessment team to demonstrate an understanding of these limitations and skills in bringing together the different elements that can address the limitations.

2 Overview of Environmental Flows- Concept, Objectives and Methodologies

2.1 From River to Flow Regime —The Concept and Linkages

The concept of e-flows originates from the most primordial need and nature of a river to flow. Hence, an overview of e-flows cannot be complete without delving deeper into the natural and dynamic ecosystem that is a river and its relation to other ecosystems and the people dependent on it. The significance of e-flows as the most important variable deciding the survival of a river would stem from this understanding.

From a scientific perspective, a river is the most important constituent of the hydrological cycle and the most vital link between the land and the oceans (Gopal, 2013). A river is not just a channel carrying water. It is an ecosystem that is controlled by physical processes: the flow of the river, sediment transport and self purification (water quality) (O'Keefe & Le Quesne, 2009). In these physical processes, flow is the main driver that controls the sediment flow and water quality and the biodiversity in the river. Natural flow regimes shape the characteristics of the river that determine the formation of natural habitats, which in turn determine the diversity of riverine species. Flow also maintains connectivity with the floodplains which are a source of livelihood for a number of people.

Thus, according to O'Keefe & Le Quesne (2009), the master variable, the flow of the river defines the types of rivers:

- Depending upon the availability of water, a river can be perennial (flowing all throughout the year), seasonal (flowing only in the wet season) and ephemeral (flowing occasionally).
- From source to the mouth, the river channel has different flow features. The mountain streams are turbulent and have a lot of energy due to higher flow gradients. At the foothills the river channel is characterised by alternating pools and riffles[1], and in the flat plains the river meanders over larger distances and moves slowly.
- Rivers can be flashy, that is prone to flood and drought, or can have constant flow.

The five major attributes, magnitude, frequency, timing, duration and amplitude, give the river flow regime spatial and temporal variability which is dependent on the climatic conditions and the topographical, geological and morphological characteristics of the watershed (Gopal, 2013).

Anthropogenic activities namely, abstraction and diversion of river water, dams, canalisation, sand mining, industrial and domestic wastewater discharge and non-point

1 Riffles are shallow regions in the river channel where the flow is rapid.

source discharge, groundwater exploitation and deforestation, have been responsible for the degradation of rivers in terms of regulation and reduction of flow, deterioration of flow quality and destruction of natural habitats. It is necessary to allow the river to perform its natural functions while providing for human needs. Here is where the concept of e-flow emerges, which will be discussed in detail in this chapter. This chapter also seeks to provide an overview of the methodologies and approaches that have been developed worldwide to determine and implement e-flows. Towards the end, it will present the indicator approach followed in e flows assessment.

2.2 E-Flows — Evolution, Need and Interpretations

Dams capture high and low flows and hence are direct modifiers of flow regimes (Arthington, 2012). Globally, over half of the 292 large river systems in the world are affected by dams (Nilsson, Reidy, Dynesius & Revenga, 2005). The number of large dams blocking the world's rivers has crossed 50,000, with India being the third largest dam builder with more than 5000 dams built and hundreds in the pipeline. Cascades of dams are being planned and built across the tributaries of the Brahmaputra, the Ganga and the Indus, which were free flowing till recent times. Multipurpose and storage dams can significantly affect the flow regime on a daily and seasonal basis. Similarly, the operation of a hydropower dam, peaking or base load, controls the timing, frequency and duration of high and low flows and alters the natural hydrograph of the river. Downstream ecosystems over large distances can be affected by the operations of dams and hydropower projects, depending on the size and design of the structure, thus fragmenting the rivers into static reservoirs and channels. For example, the impact of the operation of the series of hydroelectric projects being planned on the Brahmaputra, especially the Lower Demwe project, are feared to impact the chapories (the river islands) and the Dibru Saikhowa National Park at least 100 km downstream.

The important ecological impacts associated with flow alteration can be summed up as follows (Richter & Thomas, 2007):

- Flow alteration can lead to modified riparian habitats due to changes in the fluvial geomorphology.
- Depending upon the natural flow regimes, aquatic species have developed patterns of reproduction, survival and migration also called as life history strategies. Alteration of flows can disrupt these cycles affecting biodiversity in the river.
- Species that are highly sensitive to connectivity, both lateral and longitudinal, are most vulnerable to changes in river flow and flow alterations can affect their population.
- Exotic and introduced species can invade the river systems.

41% of the global population is living in river basins that are extremely water stressed (Convention on Biological Diversity, 2005). Many international conventions, national policies and legal instruments have included the value of water for nature in their river basin management framework. The Ramsar Convention (1971), The Helsinki Convention on Transboundary Water Courses and International Lakes (1992), The National Water Act (1998) of South Africa, and the Convention on Biodiversity (2001) are few among these.

The earliest efforts to restore and protect rivers were mostly focused on establishing 'minimum flows' and improving water quality so that the rivers and streams do not dry out. From these efforts, the concept of 'e-flows' was born, marking a major shift in the techno-economic view of river basin management. Presently, e-flows are considered as the key driver of river restoration and river basin management all over the world.

There are several interpretations of e-flows. Dyson, Bergkamp & Scanlon (2003) define e-flows as, "the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits, where there are competing water uses and where flows are regulated". As already mentioned in the introductory section, the most accepted definition of e-flows which has been endorsed by more than 800 scientists across 50 countries at the Brisbane Declaration in 2007 perhaps captures the essence of e-flows most succinctly (to which the first author of this report was one of the signatory). The International Water Management Institute (IWMI) (2005) describes e-flow regimes as "discharges of a particular magnitude, frequency and timing, which are necessary to ensure that a river system remains environmentally, economically and socially healthy."

There has been considerable debate on the right perspective with regard to water for environmental needs. According to Iyer (2005), "Is 'apportioning', 'ensuring', or 'allowing' the water for ecosystems the correct perspective? Who are we to decide how much water should be allocated for environmental needs, or the evolutionary and ecological needs of rivers? This may be seen as inappropriate in principle because "water itself is part of nature and one cannot presume to allocate water to nature." In the Indian context, water to be left in the river for cultural and religious needs also assumes significance (Iyer, 2005). All the interpretations agree upon the most critical aspect that a river needs its flow regime to remain environmentally, economically and socially healthy.

Maintenance of spatial and temporal patterns of river flows i.e., the flow variability is the most important criteria for e-flows. From an ecosystem perspective, it is not only the amount of flows that are important, but when and how this water should be flowing in the river to maintain the diversity of habitats. The different types of natural flow regimes found in the river and their importance is as follows (Resh et al., 1988):

- High floods: Flushing of sediments and nutrient transport and inundation of flood plains. Dispersion and diffusion of pollutants
- High flows: Maintenance of riparian vegetation and river channels, bird breeding and wetland flooding
- Moderate flows: Cycling of organic matter and fish migration
- Base flows: Maintenance of in-stream habitats like riffles and pools
- Drought flows: Preventing the growth of invasive species

Therefore, these elements of flow variability have to be maintained in a modified e-flow regime. However it is important to understand that e-flows have limited capability and their objectives can be achieved only if human activities like land use changes, effluent discharges, etc. are effectively controlled, which is ultimately a societal decision (O'Keefe & Le Quesne, 2009).

2.3 Objective Setting in E-Flows

Since a river is a dynamic system, there is no one correct e-flow regime that is best for the river. As mentioned earlier, the e-flow regime depends on what people want from the river (O'Keefe & Le Quesne, 2009). In the entire discourse on e-flows, the most important question is, "What all basic, ecological, social, livelihood and cultural needs can be met through e-flows?'' A sustainable trade-off and negotiation between water use in the river and e-flows can be arrived at only if objectives for e-flows are clearly stated. Objectives will change, based on the river and its various services and values. The second critical question is, "Who sets the objectives for allocating e-flows?'' In India, it is a well-known fact that e-flows are assessed and decided by experts or environmental impact assessment agencies or dam builders with absolutely no involvement or consultation with the communities for whom the e-flows are to be allocated. The perspective and concerns of the river basin communities need to reflect in the management of the flows in the river, and hence the active involvement of the river basin communities is important in setting the objectives for allocating e-flows. The other important aspect while setting objectives is that they should be set within the ecological limits. It is necessary to assess the ecological loss and its impacts in the future with respect to climate change as well, and set realistic objectives so that the river's water resources development would not lead to irreversible damage. More importantly, it is necessary to define these objectives in the planning stage of the water resources development project itself. Especially in the case of rivers where new dams are being built, it is necessary that the cumulative and environmental impact assessment studies do not just determine e-flows but set out clear objectives based on stakeholder consultations and then assess the e-flows.

2.4 Overview of Methodologies

Achieving the required e-flows in the river basin is an adaptive process and therefore there is no method or approach that can be singled out to be the best for e-flow assessment. The e-flow requirement of the river is dependent upon the size, natural state and the future desired state of the river, and the approaches used for deriving the e-flows are broadly classified into two categories: 'Objective based flow setting and scenario based flow setting.' (Acreman & Dunbar, 2004)

Objective based flow setting – As the name suggests, in this approach the e-flows are derived to achieve predetermined ecological, socio-economic and cultural objectives based on the condition of the river. However this approach entails that all the riparian communities, water management experts and the government agree on the desired state of the river. As an example in Acreman & Dunbar (2004) mentions, the Water Framework Directive of the European Union requires member states to achieve "Good Status" (GS) in all surface and groundwater. Good Status is a combination of Good Chemical Status and Good Ecological Status (GES). GES is defined qualitatively and includes populations and communities of fish, macro-invertebrates, macrophytes, phytobenthos and phytoplankton. It also includes supporting elements that will affect the biological elements, such as channel form, water depth and river flow. Setting environmental flows is a key step in achieving "Good Status". In South Africa, a similar classification is used; however, rather than aiming for good status in all cases, the Department of Water Affairs and Forestry sets objectives according to different ecological management targets. Ultimately, setting objectives is a negotiated process with trade-offs involved. Objective based flow settings are basically prescriptive.

Scenario based flow setting – In this approach, several scenarios of flow regimes / flow allocations are examined and the best option is arrived at. For example, for the Lesotho Highland Water Project, various scenarios of e-flows releases from dams were considered. For each scenario, the impacts on the downstream river ecosystems and dependent livelihoods were determined (King, Brown & Sabet, 2003). These scenarios permitted the Lesotho government to assess the trade-offs presented by different e-flows options. Scenario based flow settings are basically interactive approaches, and more complex than those that are objective based.

All objective based and scenario based approaches and methodologies broadly fall under four categories as listed below:

- Hydrological
- Hydraulic rating
- Habitat simulation
- Holistic methods

2.4.1 Hydrological

Hydrological index methods are mainly prescriptive desktop approaches relying primarily on historical flow records or modelled flow data to make flow recommendations for the future. These methods determine a fixed percentage / proportion of flow for the environmental requirements of the river. About 60% of the e-flow methodologies that have been developed fall under this category. Some of the important methodologies include the Tennant Method (Montana Method), Flow Duration Curve Analysis (FDCA), and the Texas Method. They are rapid desktop analysis methods relying on long historical flow data, and hence are most appropriate at the reconnaissance level of water resources development. No ecological data is used or measured in these methods which make them ad hoc, especially in situations where trade-offs over water allocation are involved.

2.4.2 Hydraulic Rating

Hydraulic rating is an improvement over the hydrological method. Here the relationship between the changes in flows and changes in the hydraulic parameters like wetted perimeter, velocity, depth of water in the river, etc. are used to arrive at the acceptable e-flows. A cross section of the river which serves as surrogate for the biological habitat is used for the assessment. E-flows are determined from a plot of the hydraulic variable(s) against discharge, commonly by identifying curve breakpoints where significant percentage reductions in habitat quality occur with decreases in discharge. An assumption is made that at a threshold value of the selected hydraulic parameter, for a particular level of altered flow, the integrity of the aquatic biota can still be maintained (Arthington, Tharme, Brizga, Pusey & Kennard, 2004). Wetted perimeter is the most commonly used hydraulic method. These methodologies rely on the highly simplistic assumption that a single hydraulic variable or group of variables can adequately represent the flow requirements of a target species for a particular activity. (King, Tharme & de Villiers, 2008).

2.4.3 Habitat Simulation

These methodologies, also sometimes referred to as habitat rating methods, are used to derive e-flow requirements based on how changes in micro-habitats occur with changes in river discharge. Discharges are modelled based on hydraulic variables like depth, velocity of flow and composition of substratum (King et al., 2008).These methods are most suitable for conservation of target species and their habitats and require ecological expertise. The limitation of these methodologies is that they are extremely data intensive. Some of the most widely used habitat simulation methods include Instream Flow Incremental Methodology (IFIM), River Hydraulics and Habitat Simulation Program (RHYHABSIM) (King et al., 2008).

2.4.4 Holistic Methodologies

Holistic methodologies are considered as superior approaches in e-flow assessment and the science of river basin management as they try to consider the entire riparian and directly dependent terrestrial ecosystem rather than the needs of only a few keystone species. They are based on the concept of maintaining the natural flow patterns of the river. The common objective of holistic methodologies is to maintain and/or restore fluvial processes thus improving the health of the groundwater systems, floodplains and downstream estuaries and coastal wetlands. Currently only 8% of the total e-flow assessment methodologies are holistic in nature (Arthington et al., 2004). Holistic methodologies broadly fall under two categories, namely 'top-down approach' and 'bottom-up approach.' The fundamental principle of the top-down approach is based on 'what is the maximum permissible limit of flow alteration/modification from natural flow conditions of the river'. In the bottom-up approach, e-flows are derived based on specific requirements starting with zero flows (Arthington, Brizga & Kennard, 1998).The most commonly used holistic methodologies are summarised briefly in Table 2.1.

Table 2.1: Summary of Holistic Methodologies used for E-flow assessment

Methodology	Origin	Description
Top-down approach		
Benchmarking Methodology	Queensland, Australia	Comprehensive, scenario based approach based on field and desktop analysis. Has four main stages: 1) Establishment of expert panel and hydrological modelling of catchments, 2) Ecological assessment, 3) Risk evaluation, 4) Evaluation of future water resources development scenarios. The detailed description of the method can be found in Brizga et al., (2001).
Downstream Response to Imposed Flow Transformation (DRIFT)	South Africa by Southern Waters and Metsi consultants	Based on interactive scenario development. Has four modules 1) Ecological module: describes current ecological state and sensitivity to flow change, 2) Sociological module: Describes the users and their vulnerability to flow alteration, 3) Scenario development module: Extracts risks from flow alterations, 4) Economic module: For cost mitigation and compensation for developed risk scenarios. The detailed description of the methodology can be found in King et al., (2003).

Methodology	Origin	Description
Adapted BBM-DRIFT	Zimbabwe by Mott MacDonald Ltd. and Zimbabwe National Water Authority	Simplified approach for data and resource limited situations for rural people who are directly dependent on riparian ecosystems. This methodology combines the data collection phase of BBM with scenario based workshop process of DRIFT. The detailed description of the methodology can be found in Steward, Madamombe & Topping (2002).
Flow Events Method (FEM)	Australia by Australian Co-operative Research Centre for Catchment Hydrology	This method evaluates the maximum change in the natural flows based on empirical data and/or expert judgement. The method consists of four phases: 1) Determination of ecological parameters affected due to flow modifications, 2) Hydrological analysis for characterisation of flow events, 3) Analysis of sequence of flow events and their occurrence, 4) Setting e-flow targets. The detailed methodology is described in Stewardson & Cottingham (2002)
Bottom-up approach		
Holistic Approach	Developed in Australia	It is a theoretical approach which systematically constructs the e-flow regime on detailed shorter time and spatial scales. It considers e-flow regime for the entire riparian ecosystem which includes the river channel from the headwaters to estuaries, floodplains and groundwater.
Building Block Methodology (BBM)	Developed in South Africa by local researchers and Department of Water Affairs and Forestry (DWAF,1999)	The basic assumption of this methodology is that certain flows in the natural flow regime of the river are more important and it is necessary to maintain their timing, duration, frequency and magnitude for maintenance of riparian ecosystems which is determined based on the desired future state of the river. The methodology is detailed in King & Louw (1998)
Expert/Scientific Panel Assessment Method(EPAM)	Developed in Australia jointly by New South Wales Department of Fisheries and Water Resources	This approach uses the concepts of BBM and Holistic approach but is more suitable for only initial assessment and where releases from dams are easily possible. It focuses on health of river system using fish as indicators. Method is heavily dependent on professional expertise.
Habitat Analysis Method	Developed in Australia by former Queensland Department of Primary Industries and Water Resources	This is a basin-wide quick and low budget method for determining e-flows on presence of less data. In this method generic aquatic habitats are identified and flow requirements for each habitat are evaluated thus developing strategies to meet those requirements and monitor the-flows. The detailed description of the method can be found in Walter, Burgess & Johnston (1994).
Flow Restoration Methodology	Developed in Queensland, Australia	This methodology is useful for highly regulated rivers, and is based on combinations of desktop and field data analysis. Hydrological modelling is used to simulate various changes in the flow regime and determine e-flow requirements which are derived based on critical flow thresholds needed to achieve the set objectives. The detailed description of the methodology can be found in Arthington et al., (1999).

Source: Arthington et al., 2004

2.5 Indicators in E-flow Assessment

In any environmental flows assessment and allocation, it is the flow that we are primarily interested in managing. Therefore, indicators that respond to flow changes play a very critical role in e-flow assessment. As already described in the introductory section, especially in the situation of limited data and resources for carrying our extremely comprehensive river system analysis, certain important indicators can be used for determining the flow requirements. In the context of Indian rivers where the hydrological and ecological information is deficient, it is important to look at indicators that are measurable. As described in Smakhtin et al., (2007), some of the most important indicators that are used for assessing flow changes are described as follows:

- **Percentage of rare and endangered aquatic species and endemic species:** Can be expressed as percentage of number of rare species in country or region depending on the scale. More number of endemic species is an indication of maintenance of more flow variability to suit their habitat types and therefore, greater care needs to be taken in managing the flows in the basin.
- **Unique aquatic biota:** The assumption is that the more the unique aquatic biota present in the basin, the more important it is to ensure that they do not get affected by flow modifications. Therefore, more flow and more flow variability needs to be preserved in the river.
- **Diversity of aquatic habitats:** The assumption is that with more habitat types present (flood plains, pools and riffles, runs, waterfalls, etc.), more incentives should exist to preserve them to ensure the aquatic biodiversity as well.
- **Presence of protected areas of natural heritage value and pristine areas which are crossed by the main watercourse in the basin:** The more the area that is protected, pristine or must be protected, more e-flows are likely to be left in the river or released into the river from dams.
- **Percentage of introduced or exotic species:** Presence of exotic and introduced species indicates a loss of biodiversity and disruption of the natural existing ecosystem which indicates its sustainability.
- **Overall species richness:** The greater the species richness, the better is the functioning of the ecosystem, which indicates that the flows need to be maintained accordingly. The river stretch of basin could also be used as a reference condition.
- **Percentage of natural vegetation in the watershed and in floodplains:** This can be determined from desktop analysis using geographical information system (GIS) and remote sensing images. The higher the natural vegetation, the higher is the sustainability of the watershed.
- **The degree of flow regulation/fragmentation:** This can be calculated as the total dam storage as a percentage of the mean flows, and also the upstream catchment area as a percentage of the total catchment area. The higher the regulation, the poorer is the longitudinal connectivity of the river.
- **Human population density in the entire river basin as a percentage of the population density in the main flood plains:** It is assumed that this measure maybe seen as an aggregate indicator of the human pressure on aquatic ecosystems and as an indicator of the disruption of lateral connectivity in river basins.

According to Smakthin et al., (2007) a predefined scoring system is used for evaluation of each of these indicators, after which all the scores are summed up. This added number is then expressed as a percentage of the maximum possible score that determines the deviation of the river or stream from its ideal conditions, and also helps river basin managers decide a desired state at which the river can be maintained, or to which it can be restored. However, the authors caution that it is important to understand the limitations of the indicators and work within those limits to get the best results possible. In the case of Indian rivers, the ecological database of riparian biota is very limited and hence assessment of biota requires involvement of specialists, which could be a major limitation in case of budget constraints. Also, it may be better to use the indicators at the sub-watershed or watershed level than the entire basin, for better flow management. Therefore, the scale at which they are used is also important. In absence of information about the direct relationship between ecosystems and flow changes, it would be extremely difficult to evaluate the sensitivity of aquatic ecosystems to flow alterations as per the report.

3 Overview of E-flows Assessment in Indian River Basins

The Ministry of Environment Forest and Climate Change (MoEFCC), Government of India, has been giving environment clearances to all the river valley projects since 2007–08 under the condition that certain minimum flows have to be maintained in the river throughout the year. The proposed minimum flow requirement was 10% of the observed minimum flow, which was later revised in 2010 to 20% of the average flow observed in the four lean season months at 90% dependability. In 2011, the Expert Appraisal Committee (EAC) of the MoEFCC for the river valley projects stipulated maintenance of higher flows during the monsoon in addition to the minimum flows. (Thakkar, 2012)

At the beginning of 2011, a number of studies were carried out by several government and non-government agencies to assess e-flows in the Indian river basins, especially the Himalayan and the Eastern Himalayan river basins. The following section attempts to discuss and present a critique on some of the approaches used by government and non-government agencies for assessment of e-flow in the Indian river basins.

3.1 Ganga Basin

Several studies have been conducted in the upper Ganga basin. Some of the e-flow assessment studies discussed in greater detail are those by Alternate Hydro Energy Centre (AHEC) and Wildlife Institute of India (WII) in the Alaknanda and Bhagirathi basin, World Wildlife Fund for Nature, India (WWF) in the Upper Ganga basin, the Inter-Ministerial Group (IMG) in the Ganga basin, and the Ministry of Water Resources (MoWR) in the Upper Ganga basin. Each study has used different approaches and methodologies for assessment of e-flows. The pros and cons of using the specific methodologies or approaches are discussed below.

3.1.1 Assessment of Cumulative Impact of Hydropower Projects in Alaknanda and Bhagirathi Basins

Methodology: Alternative Hydro-Energy Centre (2011) used different hydrological index methods for e-flow assessment at 23 sites, where 8 projects were in operation and 15 projects were in different stages of development. Additionally, 8 sites were selected which were places of religious and cultural importance. A 20 year daily discharge data was used for hydrological analysis. Using different look-up table, Q95, Q90[2] were determined.

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2 Q95, Q90 represent the percentile of flow. Q95 is 5% percentile flow or flow in cubic meters per second which has equaled or exceeded 95% of the flow record available. Similarly, Q90 represents the 10% percentile flow or the flow that has equaled or exceeded 90% of the flow record available for the stream or river.

Indicators: AHEC evaluated the length of the river affected as the major indicator. For Alaknanda basin, the study determined that 48% of the river length would be affected (27%would be diverted and 21% would be submerged), and 70% of the length of the Bhagirathi would be affected (31% would be diverted and 39% would be submerged).

E-flow recommended and comments on their study: The final e-flow requirement was a range of minimum and maximum e-flow discharges. Since the study used hydrological index methods, the overall confidence level of e-flows recommended was low. Looking at the scale and cascade of dams that have been planned in the Alaknanda and Bhagirathi basin, it is necessary to carry out more comprehensive studies to represent the cumulative impact of these dams, which is completely missing in this particular study. The maximum and minimum e-flows recommended at all the 31 sites selected are in the range of 2% – 15% of the Mean Annual Runoff (MAR). The AHEC study cannot be considered as a cumulative impact assessment. The e-flows derived using this approach cannot mimic the natural flow regime of the river as they have filtered out extreme events like floods and drought flows that have their own importance in river ecology. The e-flows are also not recommended for the monsoon, post-monsoon and lean seasons, which takes away the inter annual and seasonal variability in the flows of the river which plays a very important role in the maintenance of the riparian habitats. Secondly, since most of these power projects have peaking operations, the study has not been able to address the impact of these operations on the diurnal flow changes. The cumulative impacts on flows and changes in sedimentation at different sites, as well as the impact on the aquatic and terrestrial flora and fauna across the basin due to multiple projects have not been looked into. To summarise, the hydrological models used for determining e-flows may not be suitable for Indian river basins, and a holistic approach is needed to address not only the ecological needs of the river as well as the social and cultural needs of those dependent on it.

3.1.2 Assessment of Cumulative Impacts of Hydroelectric Projects on Aquatic and Terrestrial Biodiversity in Alaknanda and Bhagirathi Basins, Uttarakhand

Methodology: The major objective of the study by Wildlife Institute of India (2012) was to determine the minimum e-flows requirement only for the dry zones created by the hydro-electric projects (HEPs) in the Alaknanda and Bhagirathi basin which are also a critical habitat of the flagship species, namely the golden mahseer and the snow trout. Therefore, the river basins were categorised as 'mahseer zone', 'snow trout zone' and 'no fish zone'. The study used a combination of Building Block Methodology (BBM) and Habitat Rating Method for assessment of e-flows. Within the BBM, an Environmental Management Class (EMC) for the river stretches was defined to recommend the e-flows requirements.

Indicators: The key indicators used were the golden mahseer and snow trout, and e-flows were derived to maintain their habitats.

E-flow recommended and comments on their study: The study found that 47% of the total river stretches in the Alaknanda and Bhagirathi basins would be affected if all the proposed projects will be implemented, and about 32% of the total river stretch will dry up if the e-flows were not released. The WII team's unscientific observation was that though the river stretches were impacted and fragmented, the ecosystems in the river were intact and therefore, Environment Management Class 'C' was selected for determining the required e-flows. The environmental recommendations made were:

- 21.8% of Mean Seasonal Flow for river stretches that fall in the mahseer and snow trout zone
- 14.5% of the Mean Seasonal Flow in the no fish zone only for the lean season.
- Minimum e-flows requirements in the other dry zones (other than the mahseer and snow trout zone) of the hydropower plants recommended were:
    - 20%of monthly average flow from November to March
    - 25% of monthly average flow in October and April
    - 30% of monthly average flow from May to September

The WII study unlike the AHEC report is definitely a step ahead in making progress in the cumulative impact assessment of hydropower projects. The study has divided the Alaknanda and Bhagirathi basin into 18 sub-basins and evaluated a number of scenarios for cumulative impacts with and without hydropower projects. After mainly assessing the aquatic and terrestrial habitat and ecology, biodiversity scores have been assigned to individual basins. Further, depending upon the type and size of the hydropower projects, impact scores were assigned to develop a matrix of the overall impacts. 24 projects had high impact and were recommended to be scrapped.

However, the e-flows assessment approach used has some limitations. Firstly, an EMC based approach has been used to determine flows needed to meet the ecological needs of the aquatic species mainly the golden mahseer and snow trout. The methodology adopted has been mentioned as BBM with the habitat rating method. Though the habitats have been assessed well, the process of BBM is not documented well. It is not holistic in a way that they have not assigned the EMC considering all the other socio-economic and cultural impacts, and hence the objective setting is not very clear. Other published critiques of the report point out that rivers in the Upper Ganga Basin are some of the most unpolluted, pristine and ecologically important rivers in the country. The social, environmental, cultural, religious, aesthetic, recreational and economic importance of the Bhagirathi, the Alaknanda, their tributaries and the various Prayags needs no elaboration. Considering these facts, rivers in the Upper Ganga Basin deserve the Environment Management class of A or B. However, most of the rivers are relegated to a C or D class. Effect of peaking power operations on the habitats is not assessed. Besides, they have not evaluated the minimum distance between two cascading projects. Even though e-flows have been recommended for the dry zone due to the hydropower projects, the study does not mention if the recommended flows are enough to ensure lateral and longitudinal connectivity between the cascading projects. Another critical drawback of the study is that it has not assessed the aspect of dependence of different consumptive and non-consumptive users on the river.

3.1.3 Assessment of Environmental flows in Upper Ganga Basin

Methodology: The e-flows assessment was carried out by O'Keeffe, Kaushal, Bharati, & Smakhtin (2012) in the Upper Ganga basin with the Building Block Methodology. The major aspects considered in the study were hydrology, hydraulics, fluvial geomorphology, biodiversity, water quality, livelihoods and cultural and spiritual influence. An 800 km stretch was identified as the study area, which was divided into four zones as follows:

- **Zone I:** Gangotri to Rishikesh
- **Zone II:** Rishikesh to Narora
- **Zone III:** Narora to Farukhabad
- **Zone IV:** Kannauj to Kanpur

Within the zones, reference sites were identified where detailed surveys and field interviews were carried out by the specialist teams from different fields namely hydrology, hydraulics, biodiversity, fluvial geomorphology, water quality and livelihoods and culture and religion. Prior to implementing the BBM methodology, the Soil and Water Assessment Tool (SWAT) model was used to derive the natural flows in the river before any water resources infrastructures were built in the river basin.

Indicators used: Since experts from different field were involved in the study, indicators from different fields were used for the study, which are as follows:

Water Quality: Temperature, total suspended solids (TSS), salinity, dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), faecal and total coliforms, heavy metals, pesticides, fertilisers, chlorides, sulphates and nutrients (nitrates and phosphates)

Fluvial geomorphology: Steep cascading reaches, alternating riffle and pool sequences and braided channels

Biodiversity: Endangered species, for example, the Gangetic dolphin, a species that is most sensitive to flow

Livelihood: Changing patterns in livelihoods, introduction of new livelihood

Cultural and Spiritual: Depth and quality of water needed to take a holy dip in the river

E-flow recommended and comments on their study: The e-flows were estimated for the maintenance and drought years. For the Upper Ganga basin, the maintenance flow years and the drought flow years were determined to be 70% and the 30%, respectively. The final e-flows recommendations were made at each of the following places, and the e-flows were calculated as a percentage of the Mean Annual Runoff (MAR) of the natural flows, which are shown below:

- **Kaudilya:** 75% of MAR in normal years and 44% of MAR in drought years
- **Kachala Ghat:** 45% of MAR in normal years and 18% during drought years
- **Bithoor:** 47% of MAR in normal years and 14% of MAR in drought years

  Monthly and seasonal patterns of flows were derived for the above recommended e-flows.

The methodology used was holistic as they considered biological, hydrological and social aspects in their studies compared to Alternate Hydro-Energy Center (2011) and Wildlife Institute of India (2012). All the aspects of the BBM methodology were documented well. This study did not take into account the consumptive users, namely agricultural and industrial users, which abstract water and pollute the river with their return flows. Concerning the livelihood aspects, they did not consider river bed and floodplain cultivators as first hand observation stated that pesticides and fertilisers were used for cultivation. However, the river quality would still get affected and thus would be critical towards dilution of the pollutants. This study too failed to address the issue of peaking power operations in the upstream of the Upper Ganga basin in Uttarakhand state, which will have an effect on the flows. However, the larger question that emerges from this study is that since the approach used could introduce a lot of subjectivity in terms of defining the desired EMC of the river, what norms or processes would need to be defined to minimise the subjectivity?

3.1.4 Report of Inter Ministerial Group (IMG) on Issues Relating to Ganga

Methodology: The MoEFCC constituted the Inter-Ministerial Group (IMG) to address issues related to hydropower and e-flows in the Ganga basin. Chaired by B.K Chaturvedi (member of the Planning Commission), the IMG was constituted to make interim recommendations before the final recommendations were made and norms on e-flows arrived at by the Indian Institute of Technology or IIT consortium (IITC)[3]. The group assessed the different studies carried out by AHEC, WII, WWF, CWC and also the international recommendations for e-flows. Based on their review, the following six options were assessed further for making intermediate e-flows recommendations:

- **Option 1:** Use Environment Management Class- Hydraulic Mean Depth (EMC-HMD) method recommended by IITR
- **Option 2**: Use BBM as used by WWF in the Upper Ganga basin
- **Option 3:** Recommend e-flows based on WII studies in fish and no-fish zones
- **Option 4:** Use CWC recommendation of 20% of daily river flows
- **Option 5:** Fix e-flows as practiced in UK based on Q95 flows
- **Option 6:** Fix river flows at 50–75% of the river flows

Inter-Ministerial Group, 2013)

E-flow recommended and comments on their study: After assessing the six options, the IMG decided that the options recommended internationally were not suitable for

3 Central Government constituted the National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Governments for effective abatement of pollution and conservation of the Ganga river under the EPA Act 1986. The NGRBA entrusted the preparation of a Ganga River Basin Environment Management Plan (GRBEMP). to a Consortium of 7 "Indian Institute of Technology"s (IITs) (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee). on July 6, 2010. The thrust of the GRBEMP .was to frame a roadmap for redeeming Ganga Basin's Environment. The task involved different thematic groups of experts from 7 IITs and other premier organizations identifying different causal factors and assessing their impacts on the basin to synthesize the findings and recommendations in fulfillment of the important missions identified in the Plan.

the Indian scenario. According to them, the BBM used by WWF is a holistic approach which is suitable, however, the studies are too time consuming and expensive. Therefore the final recommendations were as follows:

In Fish Zone (Fixed as percentage of the daily uninterrupted inflows)

- October to November and April to May: 25%
- June to September: 20%
- December to March: 30%

No Fish Zone (Fixed as percentage of daily inflows)

- April to September: 20%
- October to March: 30%

Additionally in the winter months (December to March), if the river water discharges go below 5% of the high season flow discharge, flows released would be increased to 50%.

The report had brought out interim recommendations so that the hydropower projects would not get held up. The studies that have been assessed by the IMG themselves are questionable regarding their approaches. This shows a pro-hydropower bias where the group would like to complete the projects in a hurry without scientifically studying the impacts of the projects. Ideally, the group should also have defined a threshold for the number of projects that should be allowed to be constructed, but this aspect has been completely ignored. The recommendations have again ignored a number of aspects of river flows including the serial discontinuity caused due to cascading projects, the loss of lateral connectivity, and the effects of peaking power operations. The e-flows recommended would be meaningless without a sound, scientific cumulative impact study.

3.1.5 MoWR, RD and GR: Report of the Three Member Committee on Assessment of Environmental Flows

For the first time, the Ministry of Water Resources River Development and Ganga Rejuvenation (MoWR, RD and GR) constituted a three member committee consisting of Dr. Vinod Tare from IIT Kanpur, Dr. Shashi Shekhar from MoEFCC and Dr. Amarjeet Singh from MoWR, RD and GR to bring out a report with far reaching recommendations on a subject as critical as environmental flows. (MoWR, RD & GR, 2015)

Methodology: The methodology used for the study was BBM which they modified and renamed as Bigger Block Methodology. Channel profiling and hydraulic modelling was done for generation of the stage discharge curve for different sections of the river. Assessments were then made to find out the temporal variations in the depth of the flow needed for survival and growth of the keystone species. Additionally, assessments were carried out to determine e-flows needed to maintain lateral connectivity. A hydrograph was then generated based on the 'Minimum Ecological Requirement' for the survival of the keystone species based on 90% dependable flow data and flows needed to maintain lateral connectivity. For the Bhagirathi river basin, flows were considered from 1972 to 1982, and that for the Alaknanda basin were considered from 1977 to 1987. (MoWR, RD & GR, 2015)

Indicators used: Depth of water required for habitat of golden mahseer and snow trout.

E-flow recommended and comments on their study: Three depths D1, D2 and D3 needed for keystone species, were derived, which are defined as follows:

- D1: Minimum depth needed all throughout the year for general movement
- D2: Depth required for spawning and growth
- D3: Depth required from geomorphological point of view to maintain longitudinal and lateral connectivity on the active flood plain of almost 18 days/year

The minimum ecological flows prescribed were calculated as a percentage of the virgin flows and the 90% dependable flows. (MoWR, RD & GR, 2015)

Meanwhile, the most significant statement in the report which states that 'the objective of e-flows is to recognise the physical limit beyond which a water resource suffers irreversible damage to its ecosystem functions, and systematically balance the water needs of a society in a transparent and informed manner', is going to decide the hydrological and ecological limit to the number of hydroelectric and irrigation projects that can be allowed across a river.

Whether the Minimum Ecological Requirements (MER) at D1 and D2 ensure and support lateral connectivity between the riparian vegetation and the flowing river in the non-monsoon season is not clear from the report. (Anantha, 2015a).

In conclusion, though the report mentions that releasing e-flows for the keystone species would to a certain extent help in reviving the habitat of the other species, a comprehensive study would still be required to derive e-flows taking into consideration the livelihood as well as the social and cultural needs. Nonetheless it is a step forward in the assessment of e-flows.

3.2 Brahmaputra Basin

The estimated hydropower potential in the north-eastern Himalayan region is 65,645 MW which accounts for more than 50% of the total hydropower potential of the country. There are mega cascading hydropower projects planned in Dibang, Tawang, Lohit, Siang and Subansiri river basins, which are the major tributaries of the Brahmaputra. A huge hydropower potential has been identified in Arunachal Pradesh where the hydropower project proponents have been trying to harness power greater than 10,000 MW. Some of the major projects are six major cascade dams on main stream of the Lohit river, and 13 (only eleven were allowed) dams on the Tawang River and its tributaries (WAPCOS, 2011; Barik, 2015). Water and Power Consultancy Services (WAPCOS) carried out cumulative impact assessments in the Lohit river basin, while the Northeastern Hill University, Shillong carried out a cumulative impact assessment and basin carrying capacity studies in the Tawang river basin along with IIT, Guwahati, Foundation for Revitalization of Local Health Traditions (FRLHT, Bangalore) and WWF, Tezpur. IRG Systems South Asia Pvt Ltd and EQMS India Pvt Ltd carried out carrying capacity studies in the Subansiri basin.

3.2.1 Lohit Basin Cumulative Impact Assessment (CIA) and Carrying Capacity Study (CCS) Report

Methodology: WAPCOS (2011) used different methodologies in the literature to assess e-flows, which are:

- Tennant Method
- Hughes and Munster Method
- Index method
- BBM

Indicators used: Look up tables were used based on preliminary assessment of landuse and overall water quality.

E-flows recommended and comments on their study: 90% dependable flows (which were in the range of 300–400 MCM) were used for deriving e-flows. The general water quality was good due to low population density, absence of industries and low irrigated lands. In a 144 km stretch, where HEPs are proposed, only 42km (30%) of the river is free flowing. The e-flows recommendations made by WAPCOS (2011) are as follows:

- Using Tennant Method the flow recommended was 10% of average annual flow from October to March and 30% from April to September
- The study reported that BBM was used to construct a synthetic hydrograph based on 90% dependable year. Flows recommended using this procedure for four seasons are:
  - Season I (May to September):30% of average (10 day daily or monthly)
  - Season II (October):25% of average (10 day daily or monthly)
  - Season III (November to March): 20%of average (10 day daily or monthly)
  - Season IV (April): 20%of average (10 day daily or monthly)

WAPCOS has mostly used desktop assessment coupled with habitat mapping to suggest e-flows. The e-flows recommended by WAPCOS are based on 90% dependable flows which are low flows. After mentioning that only 30% of the river will flow freely, the report has not addressed the impact of cascading projects on the longitudinal and lateral connectivity. The desktop methods have recommended flows based on the average annual runoff, which may not suffice for the e-flows requirements due to the significant differences in the annual high and low flows. According to the report, the e-flows recommended mimic the inflow hydrographs. However, the study also acknowledges that the hydropower projects are all peaking stations. These are contradictory to the concept of 'natural inflows' as the peaking operations will cause humongous fluctuations in the downstream flows creating artificial floods and droughts every day. The design discharge of the Demwe dam is 1739 cumecs. According to the study, the variation associated with the projects will not exceed the non-monsoon flood flows. The non-monsoon flood flows are significantly lower compared to this discharge. For example, the non-monsoon flood flow for the month of January as mentioned in the report is 866 cumecs. The design discharge is almost double this value. Moreover, the comparison with the highest non-monsoon flood has little meaning. The high non-monsoon floods occur on a few occasions in the entire season. The variation due to peaking power operation will create a much higher flood (and a much lower discharge) every day, which is not seen in nature. The study has totally failed in interpreting the concept of natural flows. The second method claimed to be used was BBM, however it has not been well documented and does not appear to be holistic as the social and livelihood aspects have not been considered and no 'objective setting' has been done.

3.2.2 Perspective Plan of Development of Tawang River Basin

Methodology: Building block methodology was used for determining the e-flows. Five building blocks were identified,

- Ecosystem structure, function and services
- River biodiversity
- River hydraulics
- Cultural requirements
- Livelihood requirements

Stakeholder meetings were conducted to set objectives for the environmental condition of the river. For the first time, values were assigned to livelihood and cultural requirements for e-flows in an official study. (Barik, 2015)

Indicators used: Different indicators were associated with the five building blocks. For ecosystem structure, function and services, periphyton density, water quality, net primary productivity (NPP), and invasibility by invasive alien species (IAS) were used as indicators. For river hydraulics, bed composition was used as the key indicator. Fish species like *Schizothorax richardsonii, Schizothorax* sp., endemic species (endemic periphyton, endemic zooplankton), and a threatened bird (Black necked crane) were used as indicators for biodiversity. Dead body disposal and the habitat requirement of black necked crane was used as an important indicator for cultural and religious needs for deciding the minimum flow depth. Water use, river resources, and edible algae were used as important indicators for taking into account the livelihood needs for the assessment of e-flows. Additionally, Hydraulic Engineering Centre's River Analysis System (HEC-RAS model)[4] was used for hydraulic analysis to derive parameters like channel width, depth, and flow velocity. 90% dependable flows were used for the analysis of e-flows. (Barik, 2015)

E-flow recommended and comments on their study: E-flows have been recommended as percentage of 90% dependable flows for three different seasons, namely the monsoon, non-monsoon and lean seasons. The other recommendations made along with the e-flows assessment were as follows:

- 40% of the main river should always be free flowing.
- 66% of the total geographical area should be forested.

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4 HEC-RAS is a computer program that models the flow of water in rivers and natural channels. The River Analysis System (RAS) was developed by Hydrologic Energy Center, California (USA) and therefore is called as HEC-RAS

- Population in the basin should not exceed 15% of the present population.
- No projects should be constructed above 3200m above mean sea level.
- Minimum acceptable free flow length of 1 km should be maintained between two dams.
- 1 km wide riparian vegetative buffer corridor should be maintained from the first barrage in the upstream area up to the Bhutan border in the downstream area.
- Tsachu I and Thingbuchu projects had carrying capacity indices exceeding the reference value and hence were recommended to be scrapped. (Barik, 2015)

The BBM approach has been well documented compared to the other studies. The study is comprehensive; however it has a few limitations. The report mentions that the run of the river projects will cause minimal submergence and less ecological devastation; however the equivalent length or more will be diverted through channels perpetually leaving a lot of river stretches parched for water. The minimum distance between two cascading projects has been suggested as 1 km which is very small. Again the study does not address the impacts of peaking power operations on the downstream flows.

However, an important recommendation which is a deviation from the usual, is the allocation of higher e-flows to Nyamjang Chhu (780 MW) as against the extremely low e-flows recommended by the Central Inland Fisheries Research Institute (CIFRI). This has been done particularly for cultural and livelihood values, and to protect the wintering habitat of the black necked crane.

3.2.3 Cumulative Impact and Carrying Capacity Study of Subansiri Sub-Basin Including Downstream Impacts

Nineteen hydropower projects are planned across the Subansiri river and in its sub-basin

Methodology: Habitat rating for migratory and endemic fish species *Schizothorax richardsonii, Schizothorax esonicus, Tor tor, T. putitora, T. progenies and Neolissochilus hexagonalepis.* Hydraulic modelling done using HEC-RAS model. (IRG Systems South Asia Pvt. Ltd, EQMS India Pvt. Ltd, 2014a; IRG Systems South Asia Pvt. Ltd, EQMS India Pvt. Ltd, 2014b)

Indicators used: Migratory and endemic fish species mentioned above

E-flows recommended and comments on their study: 15 projects in the upper, middle and lower Subansiri basin have been assessed, and using the HEC-RAS model different e-flow recommendations have been made. Except three projects, e-flow requirements for monsoon, pre and post monsoon, and lean seasons have been determined to be 20%.

The objective setting of the study is not clearly defined. The study assumes that there are contributions downstream from other tributaries, which is a flawed assumption as flows, sediment carrying capacity and habitats could be very different from the main stream of the river. Also if there are hydropower projects planned on the tributaries, then their contributions cannot be assumed in the e-flow assessment. E-flows requirements are derived in a very poor manner. For example, if the lean season e-flow requirement has been determined to be 20%, the study does not mention whether it is 20% of mean annual or mean seasonal flow. The study suggests release of 240 cumecs from the dam to the power house of the Lower Subansiri project, which would help maintain the natural hydrograph of the Gangetic dolphins. However, they have not assessed the impacts on other aquatic habitats and the natural hydrograph of the river. Though the study is supposed to be a cumulative impact assessment and carrying capacity study (CCS) of the Subansiri basin, the cumulative impacts of so many cascading projects on floods and sedimentation, of the many peaking stations, of deforestation for so many projects, of muck dumping, mining, and blasting, and on aquatic species movement have not been adequately addressed. (IRG Systems South Asia Pvt. Ltd, EQMS India Pvt. Ltd, 2014a; IRG Systems South Asia Pvt. Ltd, EQMS India Pvt. Ltd, 2014b)

3.3 E-flow Assessment under the Current ToR for River Valley Projects

The current Terms of Reference (TOR) for applying for environmental clearance for river valley projects states that the minimum e-flow shall be 20% of the average of four lean season months for 90% dependable year in the lean season, and 30% of the monsoon flow during the monsoon season. During post monsoon months, the flow shall be decided by the Expert Appraisal Committee (EAC) based on the hydrology and the available discharge. Fish diversity studies also need to be carried out for the estimation of e-flows (Ministry of Environment and Forest, 2015). This recommendation in the ToR has raised some serious concerns. First and most important, prescription of e-flows in the ToR is completely wrong as e-flows cannot be prescribed. They have to be derived after proper objective setting, assessment and studies. Secondly, the ToR states that the post monsoon flows will be decided by the EAC which has no basis. How can the EAC decide what flows would be required without any assessments? The ToR also mentions that site specific minimum e-flows need to be derived. The statement is self-contradictory because e-flows, which are those flows that mimic the natural hydrograph of the river, cannot be minimum flows.

3.4 Important Concerns and Discussions from the Review of the Methodologies Used to Assess E-Flows in Indian River Basins

A few points are listed below for further discussion:

1. Based on the review, it is clear that with the exception of some studies like WWF (O'Keefe et al., 2012) and Tawang Basin study (Barik, 2015), the studies have not attempted objective setting.
2. Though there is no one correct approach to estimate e-flows, it is still important to have a holistic approach which considers all aspects like river ecology, morphology, hydrology, livelihoods, and culture. Therefore desktop methods for the sustenance of the aquatic species can determine e-flows in the ball park region, but to satisfy the social and livelihood needs a more comprehensive participatory approach is needed. If the EMC approach is selected, then the EMC needs to be determined in an unbiased manner with minimum possible subjectivity. The EMCs have to be dynamic and change with time and also with the climate change scenario. This means that e-flow assessment and compliance needs to change overtime if necessary.

3. Another important aspect is that the objective setting has to be clearly defined in the ToR of the project. It is incorrect to prescribe the e-flows in the ToR before assessing the impacts, like the MoEFCC (2015) has done in the current ToR for river valley projects.
4. All the e-flows assessments need to address the impacts of lateral and longitudinal connectivity due to the cascading projects. The effects of cascading dams on e-flows also need to be studied because there are no norms on the minimum allowable distance between two projects. None of the above studies have addressed these critical issues. Norms need to be defined to determine e-flows for cascading projects.
5. Another important concern is that most of the e-flows prescribed are a percentage of 90% dependable flows. These flows are generally low flows and equivalent to minimum flows. E-flows are not minimum flows. The 90% dependability figures followed by most agencies are to limit the e-flows to minimum flows. Therefore, instead of making recommendation on the basis of a mean annual runoff, it would be better to base it on a mean seasonal runoff.
6. Projects planned or commissioned in the Himalayan river basins are peaking power projects. Inherently, the concept of e-flows releases contradicts peaking power operation as these operations cause drastic diurnal changes in the downstream flows especially during summer.
7. Flood and sediment releases also need to be mandated. None of the CIA–CCS studies reviewed have given adequate thought to how the floods and sediments can be maintained and released in dam cascade projects and what would be their cumulative impacts on the entire sub basin morphology, ecology and flood dependent livelihoods up to the tributary's confluence with the main river and on the main river. In case of all the tributaries being dammed, the impacts can be humongous especially for rivers like Brahmaputra which carry down huge sediment loads.
8. The implications of e-flows on cascading projects within the same river basin or sub-basin need to the assessed. Especially while considering contributions from downstream tributaries, it is not mandated that their flow regime remains unaltered.
9. E-flows are permitted to be released from dam toe power houses, which negates the very purpose of e-flows. This is because the rate of discharge of water from the dam toe power house would be the flow on the downstream of the dam, which would be more or less similar throughout the year and would not follow the pattern of the natural hydrograph of the river. Moreover, sediments are filtered out before entering the dam toe turbine affecting the downstream sediment transport. The Expert Appraisal Committee is supposed to take notice of all the above concerns before considering any project for environmental clearance. Currently, e-flows are only assessed for obtaining an environmental clearance for new projects.
10. E-flows allocations on existing dammed and 'developed' rivers also need to be assessed. Most of the developed rivers are over allocated and are not reaching the last drainage outlets. Hence, for the survival of these rivers and their river dependent livelihoods and for their restoration strategies allocation of e-flows is a must.

11. A very important part of e-flow assessment is also monitoring and compliance. It would be futile if e-flow requirements are just determined but not provided. Therefore, there needs to be proper monitoring and reporting of daily inflows and outflows from the project which need to mimic the natural hydrograph of the river. This information on the daily inflows and outflows should be made available to the public to ensure transparency and accountability. The participation of downstream communities is imperative in monitoring of e-flows. This brings us to why there is still non-compliance when it comes to e-flows in Indian river basins. E-flows are currently being used under best management practice and to justify as many dams in a river as possible. They need to be mandated by law. E-flows need to be arrived at keeping in mind the ecological limits to extractions, diversions and interventions in rivers.

4 Evolving Indicators for E-flows for the Hasdeo River Basin

E-flows in river basin management are emerging as a critical issue in the Mahanadi basin especially with regard to interstate water sharing. Also in the past couple of decades there have been serious issues of water governance pertaining to inter-sectoral allocations. Chhattisgarh being the upper riparian and a newly formed state has ambitious plans for development. The state has already planned to add 8 new barrages to the existing water infrastructure on the Mahanadi river right from Dhamtari district to Janjgir-Champa district. Out of the 8 proposed barrages, 5 barrages are in the Janjgir-Champa district located at Sheorinarayan, Basantpur, Mironi, Saradih and Kalma. These 5 barrages would be constructed on a 78 km stretch, which will mean that these barrages will be close to each other. Apart from this, the Arpa-Bhaisajhar and the Kelo major irrigation projects are to a large extent completed. There are around 22 anicuts proposed on the Kharun river, and two new proposed projects, namely the Pairy-Mahanadi Intra State link and the Tandula Reservoir Augmentation. There would be significant alterations in the flow and would affect the downstream areas and inflows into Odisha.

The Forum is trying to engage with different government, non-government and civil society organisations (CSOs) to evolve a participatory bottom-up approach to develop criteria for environmental flows and institutional framework for river basin planning. Environmental flow assessment and management needs to begin at the sub-basin level and then expanded to the entire basin. The Hasdeo sub-basin was selected as a suitable basin for the study due to the following reasons:

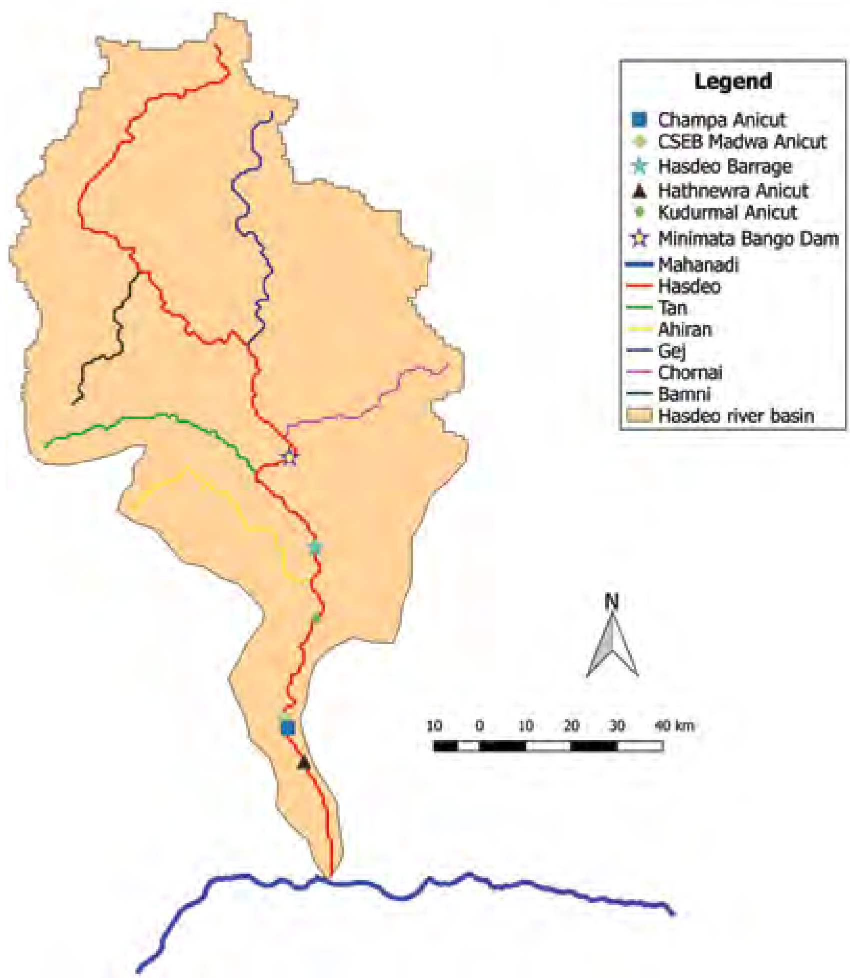
- Water infrastructures (dams, barrages and anicuts) on the river and its tributaries are present.
- It is a heavily industrialised basin with very large coals mines and thermal power plants.
- Livelihoods of those dependent on the river are being affected.
- In spite of large interventions in river and catchments, there is scope for management of the basin on a more sustainable basis.

4.1 Description of the Hasdeo Basin

The Hasdeo river basin lies in the middle portion of the Mahanadi river basin as shown in Figure 4.1. Hasdeo originates in Deogarh (1052m above MSL) in Sonhat Taluka in Koriya district of Chhattisgarh. It then flows through the Korba and Janjgir-Champa districts of Chhattisgarh before joining the Mahanadi at Mauhadih (Singh & Singh, 2010). The Hasdeo river basin covers areas of Koriya, Surguja, Korba and Janjgir-Champa districts. It contributes approximately 4.5 BCM of water to the Mahanadi. The total length of the Hasdeo is 333 km. The total catchment of the river is 10,779 sq. km. The rivers Gej, Bamni and Atem meet Hasdeo in the upstream of the Minimata Bango dam, whereas the Tan and Ahiran join downstream. Other than these major tributaries, there are a number of other large and small streams locally called naalas that join the Hasdeo along its course. Hasdeo flows from north to south and the basin is located between 21°45′ N to 23°37′ N latitude and 82°00′ E to 83°04′ E longitude.

Hasdeo barrage a major irrigation project, 284 m in length was constructed in 1967 in the Korba town. Korba is an industrial hub of Chattisgarh state. Water from Hasdeo Barrage is diverted through canals for irrigation, thermal power plants and industries. It has a gross storage capacity of 80 MCM and a reservoir area of 26 sq.km. The Minimato Bango dam 554.4 m long was built in 1990 about 50 km upstream of Hasdeo barrage for hydropower and irrigation. It has a gross storage capacity of 3417 MCM and reservoir area of 88 sq.km. There are many coal mines in the surrounding catchment area

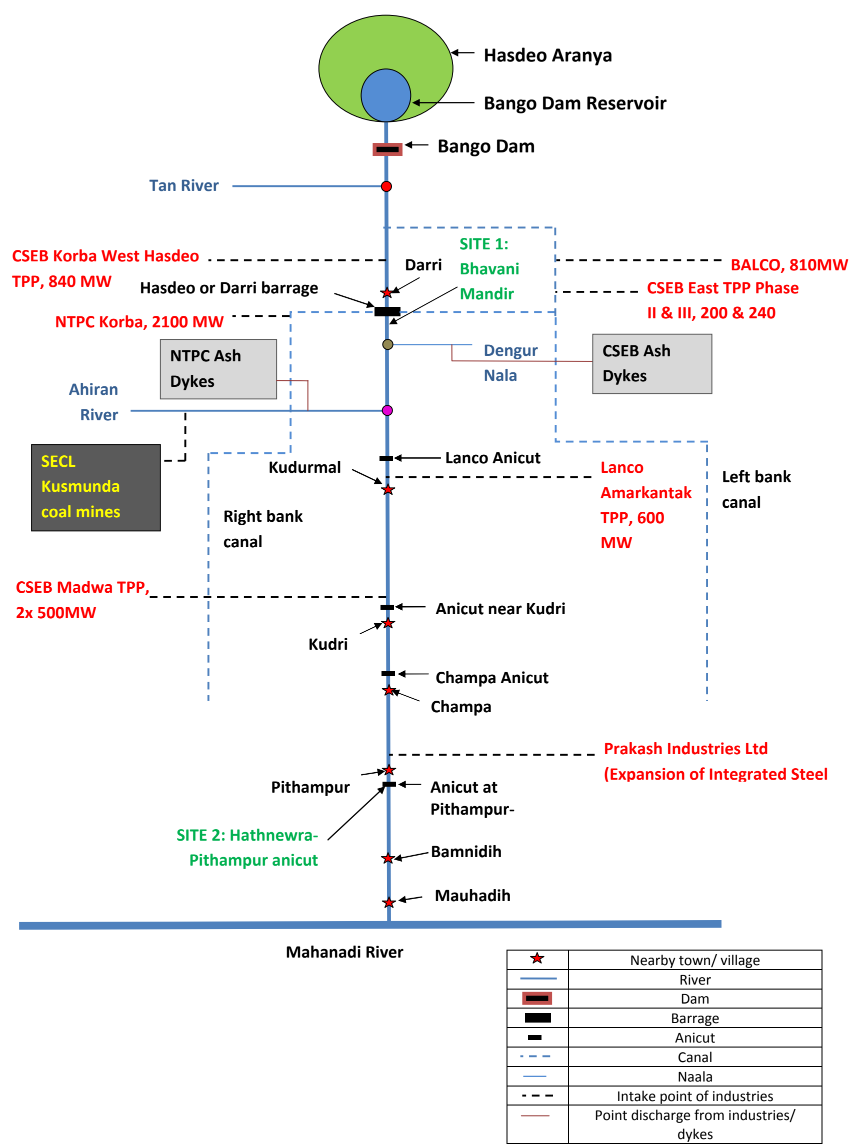
Figure 4.1: Hasdeo basin profile



4.2 Description of the Study Area

Keeping in view the above mentioned reasons for selection of the Hasdeo basin for e-flow assessment studies, two sites were selected within the sub-basin for carrying out detailed field investigations and field interviews with the stakeholders. The first site selected was near Bhavani Mandir in Korba town. The site was selected because it is situated on the immediate downstream side of the Hasdeo barrage and there are very little flows here. There is a small community of fishermen residing near Bhavani Mandir that fish in this stretch of the river for their livelihood, and about half a kilometre downstream there are people practicing floodplain/riverbed cultivation. The second site selected is about 50 km downstream of the Hasdeo barrage near an anicut that connects Hathnewra village on the left bank and Pithampur village on the right bank. The reason for selecting this site is that there is a Prakash Industries Ltd (PIL) Iron and Steel plant about half a kilometre upstream from the anicut. A large number of people depend on the river for fishing, riverbed farming and daily chores. The river is also used for religious and cultural practices at Pithampur where there is a temple dedicated to Lord Shiva. Figure 4.2 shows the line diagram of the interventions in the basin and the approximate location of the sites.

Figure 4.2: Flow diagram of the Hasdeo sub-basin



4.3 Indicators used in the Hasdeo Basin

In the introductory section, we mentioned that e-flows assessment is a very scientific and data driven process. Therefore, information on hydrological, morphological and ecological parameters is necessary for determining e-flows with a high level of confidence. One of the biggest limitations of this study was the very limited availability of hydrological and ecological data. Depending on the information available, the following indicators were used to analyse environmental flows at the two selected sites.

- Percentage of natural vegetation in the watershed and in floodplains
- Percentage of rare and endangered aquatic species and endemic species
- Percentage of introduced or exotic species
- Overall species richness
- Degree of flow regulation/ fragmentation
- Degree of flow modification
- Total population residing in the basin
- Overall water quality
- Social and livelihood indicators
- Conflicts related to water

4.3.1 Percentage of Watershed Area Under Natural Vegetation

Landuse/landcover maps for the year 2013–2014[5] and GIS were used to determine the natural vegetation left in the basin. The overall natural forests left in the Hasdeo basin are about 41%. Greater than 50% natural vegetation indicates that the watershed is still ecologically intact (Smakhtin et al., 2007). However, the hydrological and ecological quality of the forests left needs to be assessed. The upper part of the catchment of the Minimata Bango dam has good forest cover which is called the Hasdeo Aranya. However, the Hasdeo Aranya also has huge coal deposits leading to fragmentation of the forests. As mentioned in Dharmadhikary (2016a), "The Hasdeo Aranya region with its very rich forests and biodiversity, was marked as a 'No-go' area in the proposed 'Go/ No-Go' classification which specified forest areas where no mining would be permitted. In spite of this categorisation, on 23 June 2011, Shri Jairam Ramesh, then Minister of State for Environment and Forests, accorded forest clearance to mine the Tara, Parsa East and Kante Basan coal blocks in a speaking order". Currently there are mining activities going on in these three coal blocks. Our team observed that several hill streams (naalas) which join the Hasdeo have dried up due to the opening up of forests for coal mining. Effluents from the colliery are being discharged into these naalas which have also affected the groundwater in a radius of 1–2 km in the mining region. Groundwater tables have fallen by 20–25 ft within a 1–5 km vicinity of the coal mines affecting drinking water availability as observed in the field. Drying up of the naalas and falling groundwater tables can affect the base-flows of the Hasdeo river and also impact the inflows into the Minimata Bango dam.

5 Landuse/landcover data was obtained from the National Remote Sensing Centre for the period 2010–2014.

4.3.2 Percentage of the Floodplains in the Basin having Natural Vegetation

Floodplains are formed in the middle and lower reaches of the river. In case of the Hasdeo river basin, the middle and the lower order reaches of the basin lie in the districts of Korba and Janjgir-Champa. Korba is a heavily industrialised district with a large number of coal mines and thermal power plants. Agriculture is extensively practiced in the Janjgir-Champa district and is mostly irrigated. Interviews and field observations by our team revealed that ash in the river clogs the riverbed and stops inflow during lean months from groundwater, affecting base flows and lateral connectivity. Floodplain farming is extensively practiced here traditionally by riparian villages. However, over the years, pollution and clogging of ash along with fertilizer and pesticide application is turning the floodplains into waste lands incapable of supporting the river functions. Presently, very little area in the floodplains has natural vegetation. The natural vegetation in the flood plains in the basin is less than 10%.

4.3.3 Percentage of Rare/Endemic Aquatic Species present in the Basin

There is very limited information available on the number of fish species actually found in the Hasdeo river. After an extensive literature review, there were no studies found on fish diversity in the Hasdeo, however there exists fish diversity data on Mahanadi. Therefore, first hand information on species names as listed by fishermen were noted to determine the fish species found in the Hasdeo, which are detailed out in the report 'Hasdeo Basin – A Situation Analysis in the Context of Environmental Flows' by Bhadhade, Anantha & Dharmadhikary (2017). According to the fishermen, 'Sirangi' (*Salmophasia bacaila or Oxygaster bacaila*), a variety of fish has almost disappeared in the Hasdeo basin. However, this species is not in the 'threatened' or 'endangered' category as per the International Union on Conservation for Nature (IUCN) Red list of endangered species (IUCN, 2016). Two varieties of fish that are found in the Hasdeo river and are in the vulnerable and threatened category on the IUCN Red list are 'Padhana' (*Wallago attu*) and Mirgal (*Cirrhinus cirrhosus*). The percentage of rare and endangered aquatic biota in the Hasdeo river is relatively low. It could be interpreted that at one time the river did have all these fish, which are lost due to flow regulations and pollution, and restoring the river could bring these species back.

4.3.4 Percentage of Exotic/Introduced Species

The government of Chhattisgarh has been introducing new schemes to promote aquaculture. The two known introduced species here are the Tilapia and Pangasius pangasius. Pangus, which is commonly known as shark catfish, is being bred in the reservoir of the Minimata Bango dam. Though the types of introduced species in the Hasdeo are less, the population of the fish is large as they are being bred. They could possibly disrupt the natural food chain and cause disappearance of some other local varieties of fish.

4.3.5 Overall Species Richness

The confidence level of determining the overall species richness is very low. From the first-hand information received from the fishermen, only nine varieties of fish could be identified. However, according to some of the scientific studies, there are at least greater than 40 varieties of fish species in the Mahanadi river basin, and therefore the number of species could be higher than that mentioned by the fishermen. Data on wild life, floral and faunal species especially along the riparian lands and flood plains was unavailable inspite of approaching the Forest Department. A multidisciplinary comprehensive study, expertise and community knowledge is needed to determine the overall species richness.

4.3.6 Degree of Flow Regulation

The degree of flow regulation is measured as the total dam storage in a basin as a percentage of the mean flow (Smakhtin et al., 2007). There are two major water resources infrastructures on the Hasdeo river — the Minimata Bango dam and the Hasdeo barrage. Apart from this, there are four anicuts downstream of the barrage at Kudurmal, Madwa, Champa and Hathnewra. 75% mean annual runoff calculated at the dam site according to the revised detailed project report (DPR) (2004) of the project is 2801 MCM. The live storage capacity of the dam at full reservoir level (FRL) is 3046 MCM. Therefore the calculated degree of flow regulation for the Minimata Bango dam is 109%. The number of dams or impoundments on a particular stretch of the river is also an indicator of the quality of the longitudinal and lateral connectivity in the basin. The length of the river from the Bango dam to its confluence with the Mahanadi is about 115 km. There are a total of six impoundments of different sizes on the river in this 115 km stretch. Therefore there is one structure located approximately every 19 km of the river.

4.3.7 Degree of Flow Modification

Analysis of the runoffs for historical flow data from 1971–2010 for Bamnidih gauging station, which is located before the confluence of the Hasdeo with the Mahanadi, on the downstream of the dam and barrage, was carried out. Different statistical calculations were carried out on the discharge data to understand the runoff of the Hasdeo into the Mahanadi.

- Mean annual runoff for each 10-year period was calculated
- Gauge-Discharge curves were plotted for 10-year periods each
- The mean seasonal runoff was calculated
- Monthly flow duration curves were plotted to find out the different flows

Figures 4.3 and 4.4 show the 10-yearly mean annual runoff and mean seasonal runoff at Bamnidih station. As seen from Figure 4.3, the average annual runoff over each decade shows a decreasing trend. This can be attributed to the increased usage (diversion) of water on the upstream, however there is lack of data to establish exact correlations. Also, after 1990 (when the Bango dam was commissioned), the mean seasonal runoff in the monsoon has consistently decreased for 10-year periods as shown in Figure 4.4. There has been a flattening of the seasonal flow distribution, indicating that after the Bango dam was commissioned, it has been storing the monsoon flows and releasing them in the non–monsoon and lean seasons. A preliminary estimate reveals that that over the period 1971–2010, there has been a 38% reduction in the runoff and corresponding discharge rate. This can also be seen from the monthly hydrograph before and after the construction of the dam as shown in Figure 4.5

Figure 4.3: Comparison of the Mean Annual Runoff before and after the construction of the Minimata Bango dam

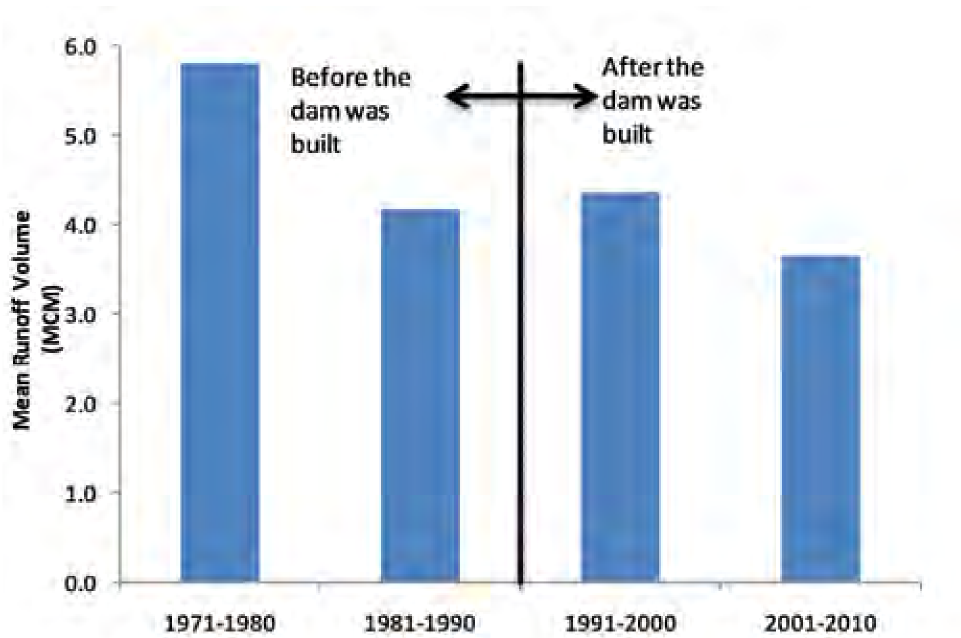


Figure 4.4: Comparison of the Mean Seasonal Runoff before and after the construction of the Minimata Bango dam

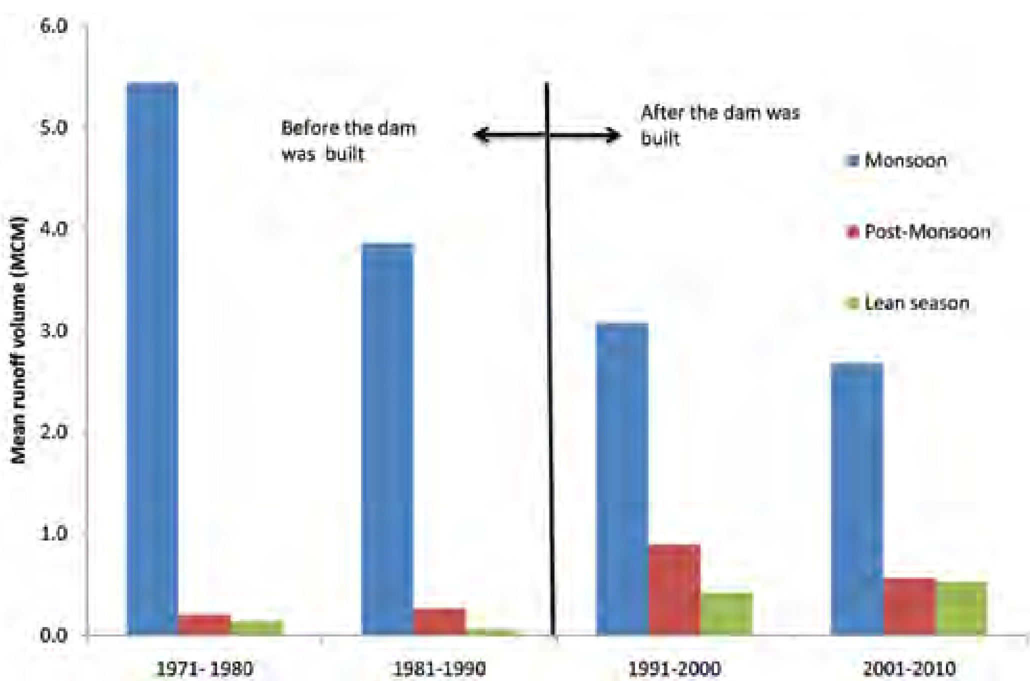
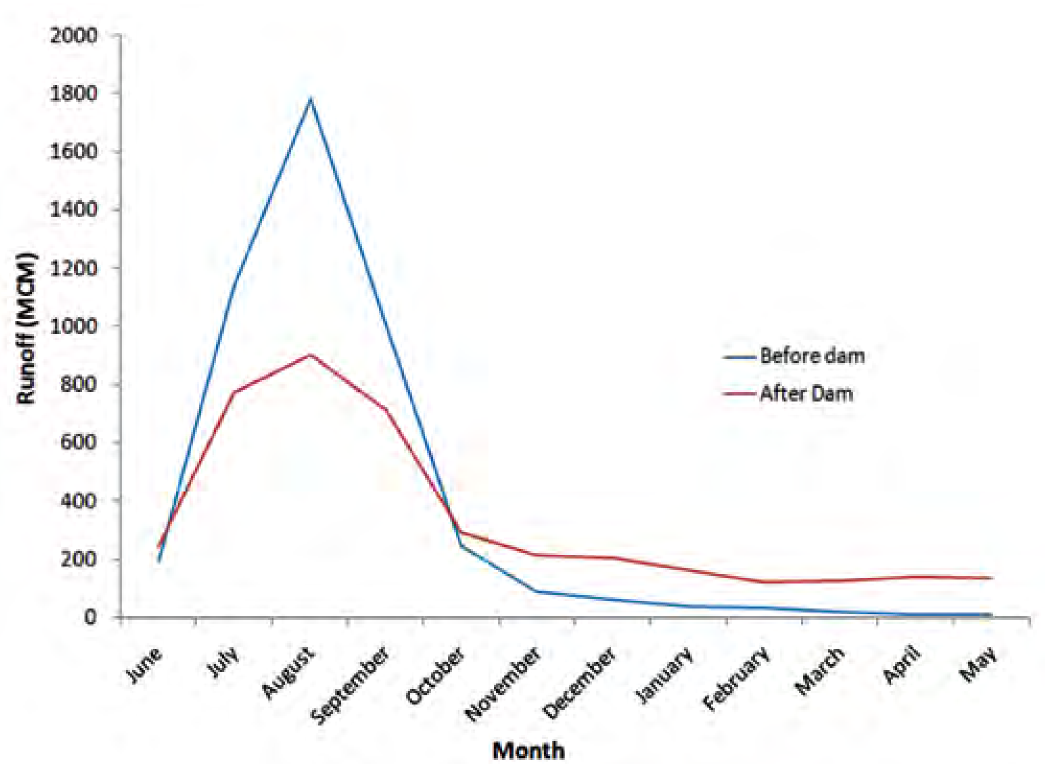


Figure 4.5: Monthly runoff hydrographs at Bamnidih before and after the construction of Minimata Bango dam



4.3.8 Human Population Pressure

Human population especially in the floodplain is considered as a stressor for the overall health of the river. (Smakhtin et al., 2007). Meanwhile the increasing pollution load and interventions like industries, infrastructure, growing cities, thermal power plants etc have also turned into stressors. Human population pressure is expressed as the percentage of the total population residing in the floodplains to the total population in the entire basin. The total population in the Hasdeo basin is 2,375,205 out of which rural population is 1,714,689 and urban is 660,516. If the floodplain areas of Hasdeo river basin need to be identified, they mainly fall in the watershed of Ahiran, Chornai and Lower Hasdeo sub-watersheds of the basin. The total populations residing in the above three watersheds within which the flood plains fall, is 1,360,474. Therefore the total population as a percentage of those residing in the flood plains is about 57%. Higher the percentage, more flows are needed downstream.

4.3.9 Overall Water Quality in the Basin

From the pre and post monsoon water quality tests done in the Hasdeo basin, it is evident that the water quality is a major concern in the Hasdeo river. The water quality immediately on the downstream of the Hasdeo barrage is extremely poor. Dhengur naala and Ahiran river joining the Hasdeo on the downstream of the Hasdeo barrage bring in a lot of flyash. Heavy metals like Lead and Cadmium were detected in the samples collected from the Dhengur naala, and the concentrations of Lead and

Cadmium were significantly higher than the acceptable limits[6] in both pre and post monsoon water quality tests carried out by the team. Field observations revealed that a lot of untreated effluents are being released into streams like the Dhengur naala, degrading the water quality of the river. Hot water from the cooling towers of the thermal power plants is also released into the reservoir of the barrage leading to thermal pollution. Arsenic was detected above permissible limits in the most of the groundwater samples. The hydrogeological strata in the Hasdeo basin is such that Arsenic does not naturally occur the aquifer, therefore its detection above permissible limits may be correlated with leaching from flyash ponds in the vicinity. Overall the water quality in the Hasdeo basin is very poor and is not fit for human consumption or irrigation. To summarise, reduction in the downstream flows have definitely affected the water quality, as the industries which are releasing their effluents are not following rules.

4.3.10 Social and Livelihood Indicators

Fishing and river bed farming are the primary means of livelihoods of the riparian communities in the basin. Insights from field interviews with these communities show that reduction in the flows has definitely affected their livelihoods. Decline in fish populations have forced a number of people to resort to different means of livelihood to support themselves. Also, river bed and floodplain farming, which was practised extensively once, is now limited to a small area and that too only for subsistence. The yields are also not sufficient as the sediment flows have reduced. This could be attributed to the cumulative impact of floodplain loss, floodplain pollution and lower flows, and polluted flows in the river. However, this needs to be properly assessed. Most of the farmers now are using fertilisers to enhance their yield. At Pithampur, which is the second site for the e-flows assessment, the river has a religious and cultural significance. Every year on the day of Holi, thousands of pilgrims come into town for a religious and cultural festival. According to the villagers, the anicut built across the river now ensures that there is water all year round.

4.3.11 Inter State Water Conflict

There is an ongoing issue over sharing of the waters of the Mahanadi between Chhattisgarh and Odisha. This issue reached the Rajya Sabha where the Government of Odisha accused the Government of Chhattisgarh of proposing to build 8 barrages and a number of diversion weirs on the Mahanadi and its tributaries without involving the Government of Odisha in the planning process. The Government of Odisha expressed that the flows coming into the Hirakud dam reservoir would be considerably reduced, and also accused the Government of Chhattisgarh for not maintaining transparency. Chhattisgarh being a relatively new state has claims that inspite of the existing interventions, it gets only about 25% of the water while Odisha gets 75%. In a meeting held by the MoWR on 17 September, 2016 between the two states, the MoWR recommended formation of a Joint Water Control Board. The MoWR said that a special committee would be set up to look into the structures that have been constructed without the approval of the Technical Advisory Committee. Gauge discharge sites would

6 All samples were compared to the BIS drinking water standards (BIS, 2012)

be set up to monitor inflows into Hirakud and a detailed water availability study of the Mahanadi basin would be carried out by the National Institute of Hydrology (NIH), Roorkee. In a stakeholder meeting conducted by the Forum in Raipur in August 2016, where civil society organisations from both the states participated, it became evident that this issue is being politicised and that the real issue is that of the allocation of water to industries. This means that both the states need to come up with a good integrated river basin management plan with implementation of e-flows at its core. In January 2017, a negotiation committee was set up to assess the availability and utilisation of the water of the Mahanadi and its tributaries. The committee would also look into the water sharing agreement between all the water sharing states, namely Chhattisgarh, Odisha, Madhya Pradesh, Maharashtra and Jharkhand. The committee was set up after the complaint from the State of Odisha under the Interstate River Waters Dispute Act (1956), section 3 (MoWR, 2017). The committee was to submit its report in three months; however the status of the report is currently not known. To summarise from the Mahanadi basin study, it is evident that water conflicts do act as qualitative indicators of how the river basin is managed.

4.4 Need for E-flows in the Hasdeo Basin

Looking at the critical issues in the Hasdeo river basin, it is necessary to restore-flows in the river and thus help rejuvenate the health of the Hasdeo. The reduction of flows on the downstream of the barrage appears to be the main reason for the problem of pollution, loss of riparian habitats, aquatic species diversity, and livelihoods. The current reservoir operations of the Minimata Bango dam also show that reservoir levels in the dam are at about 50% at the end of the hydrological year, and therefore provision of some water for the ecological needs of the river is possible.

4.5 Analysis of Live Storage Levels of Dam

Daily data of inflows, outflows and live storage levels in the Bango dam was obtained for the 2005–2015 period and analysed to understand the water availability. The average inflows, releases from the dam and the live storage levels at the start of every month for a hydrological year are summarised in Table 4.1. According to the yield series adopted in the 2004 DPR of the project, the 75% dependable inflow at the dam site is 2801 MCM. From the analysis of the data provided by the dam operators, the average inflows are 2793 MCM. According to the DPR, the Minimata Bango dam was designed to take care of a total water allocation of 3262 MCM, which includes Kharif, Rabi and summer crop irrigation, as well as the industrial and domestic water requirements. However, currently water is not released for Rabi and summer crop irrigation. Analysis of the dam data showed that on an average the total volume of water released from the dam is 2332 MCM. The average annual runoff contributed by the Tan to the Hasdeo is about 200 MCM. The Tan river meets the Hasdeo immediately below the barrage. The flows of Tan are not regulated. Therefore on an average, the volume of water available at the Hasdeo barrage is about 2532 MCM. Out of this volume of water, 1954 MCM is allocated for Kharif irrigation, industries (including downstream industries) and domestic purposes. Under the current reservoir operations, after all the releases and allocations are made at the start of the hydrological year in June, on an average the live storage in the dam is at 50%.

Though assessment of e-flows was not within the scope of this project, considering the downstream impacts and the availability of water in the reservoir, a quick desktop study and scenario analysis was done to understand if there was scope to release e-flows into the Hasdeo while meeting the existing demands. Under this desktop assessment, the following three scenarios were developed: i) average year inflows ii) water scarce year iii) year having higher than average inflows into the dam. It is important to understand that these scenarios are not fixed and that the water allocations will have to be changed on a pro-rata basis depending upon a water surplus, water scare or average year. The detailed description of each scenario is as follows:

Scenario 1: From the analysis of the dam data, the average inflows into the dam were 2793 MCM. The average live storage at the start of the hydrological year is 1368 MCM. These numbers were used as baseline for developing the average year scenario. For this scenario, e-flows were calculated according to the MoEFCC recommendation. Though according to our understanding, the MoEFCC recommendation of e-flows is ad-hoc, it was used as a starting point to assess if such minimum requirements of e-flows can be met with given the constraints of the project. According to the MoEFCC recommendation, 20% of the average lean season flows (February – May) for 90% dependable year would be released during the lean season. 30% of the 90% dependable monsoon flows would be released in the monsoon season (June – October) and 20% of the non-monsoon flows again for the 90% dependable year would be released during the non-monsoon month (November – Jan). According to this scenario, the total e-flow allocation is about 500 MCM. Allocations for irrigation are determined on the basis of 75% dependable flow and therefore, ideally e-flows also should be allocated based on 75% dependable flows. The e-flows derived depending on 75% dependable flow are 785 MCM, but going with the conservative design, e-flows at 90% dependability have been considered for this scenario. Additionally, 1000 MCM of water allocation for Rabi and summer crop irrigation was also considered, which is not given under the current dam operations. Water can be allocated based on this scenario for 60% of the years, looking at the 10-year inflow data (2005–15). The live storage levels in the dam at the end of the hydrological year under this scenario are shown in Table 4.2.

Scenario 2: This scenario is for a water scarcity year. Under this scenario, water has been secured first for drinking and domestic use, food security, livelihood needs and then for industrial use. Therefore, under this scenario 16 MCM of water requirement for drinking and domestic use has been secured. The e-flow requirement was calculated on a pro-rata basis for this year, and was estimated to be 260 MCM. The total water reserved for Kharif and Rabi irrigation is 1200 MCM, and about 332 MCM has been reserved for industries. The live storage levels under this scenario are shown in Table 4.3. After allocating water as mentioned above, the water levels at the end of the hydrological year are estimated to be 660 MCM, which are well above the dead storage level of the dam.

Scenario 3: This scenario has been developed for a surplus year when the inflows are higher than the average inflows. From the 10-year data, it was observed that for about five years out of 10 years, the flows are higher than the average inflows. Therefore, one year 2005–06 was selected where the inflows into the dam were 3100 MCM. For this scenario, e-flows were allocated at 75% dependability and were estimated to 795 MCM as shown in Table 4.4. The live storage at the end of the hydrological year for this scenario was estimated to be 1130 MCM, which can secure flows for the next average flow year or even water scarce year.

Table 4.1: Average live storage, inflows, outflows and Tan river flows

Month	Current Average Live Storage Capacity (MCM)	Average inflows into dam (MCM)	Average releases from dam (MCM)	Average flows in Tan (MCM)
June	1368	126	72	6
July	1405	586	137	10
August	1836	988	471	39
September	2291	578	533	45
October	2306	196	455	41
November	2001	38	57	5
December	1960	40	51	5
January	1958	51	93	8
February	1868	40	93	9
March	1779	46	116	11
April	1661	48	159	14
May	1505	56	96	9
Total	**-**	**2793**	**2333**	**202**

Table 4.2: Scenario 1: Live storage levels after providing Rabi irrigation and e-flows according to MoEFCC recommendation for an average year

Month	Water allocated for Kharif + rabi + sum-mer crop irrigation (MCM)	Water allocated for industries + domestic supply (MCM)	E-flows allocated (MCM)	Total water allocated (MCM) (2+3+4)	Live Storage levels (MCM)
June	50	38	13	101	1368
July	120	38	103	261	1399
August	400	38	209	647	1733
September	450	38	75	563	2113
October	400	38	52	490	2173
November	0	38	10	48	1920
December	0	38	7	45	1915
January	200	38	10	248	1914
February	200	38	8	246	1725
March	200	38	8	246	1528
April	200	38	8	246	1338
May	200	38	8	246	1154
End of May					**972**

Table 4.3: Scenario 2: Live storage levels under water scarcity scenario

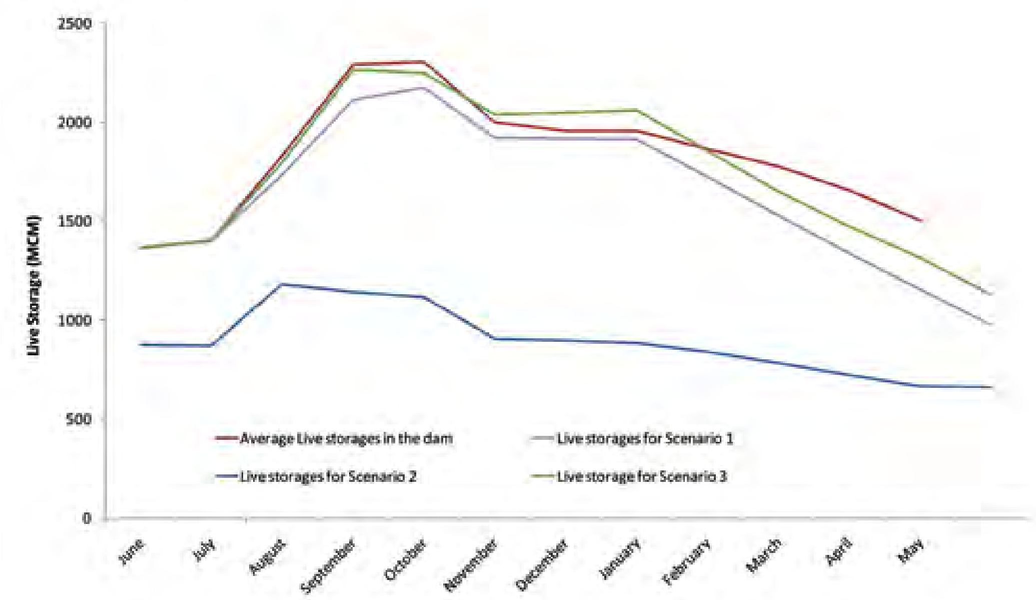
Month	Average inflows in water scarcity year (MCM)*	Average outflows in drought year (MCM)*	Water allocated for Kharif + rabi + summer crop irrigation (MCM)	Water allocated for industries + domestic supply (MCM)	E-flows allocated (MCM)	Total water allocated (MCM) (3+4+5)	Live Storage levels (MCM)
June	56	31	25	29	10	64	874
July	530	48	100	29	90	219	869
August	327	233	300	29	56	385	1184
September	361	42	300	29	61	3390	1146
October	94	421	300	29	16	345	1121
November	20	18	0	29	3	32	906
December	20	9	0	29	3	32	896
January	41	15	50	29	7	86	885
February	22	13	50	29	4	83	841
March	23	15	50	29	4	83	781
April	24	21	50	29	4	83	722
May	23	51	50	29	4	83	666
End of May							**660**

***Actual water scare inflows and outflows and not assumed values**

Table 4.4: Scenario 3: Live storage levels under a scenario of flows higher than average flows

Month	Average inflows in surplus year (MCM)*	Water allocated for Kharif + rabi irrigation (MCM)	Water allocated for industries + domestic supply (MCM)	E-flows allocated (MCM)	Total water allocated (MCM) (2+3+4)	Live Storage levels (MCM)
June	148	50	38	37	125	1368
July	709	120	38	177	335	1405
August	1151	400	38	288	726	1797
September	576	450	38	144	632	2265
October	251	400	38	63	501	2249
November	46	0	38	11	49	2039
December	47	0	38	12	50	2048
January	28	200	38	7	245	2061
February	27	200	38	7	245	1855
March	57	200	38	14	252	1651
April	86	200	38	21	259	1473
May	55	200	38	14	252	1318
End of May						**1130**

Figure 4.6: Graph of live storage levels in Minimata Bango dam for scenarios summarised in Table 1 to 4



The e-flows calculated under the three scenarios are for the complete stretch of the river from below the Hasdeo barrage to the confluence of the Hasdeo with the Mahanadi. The implications of releasing these flows will need further in depth studies which is not within the scope of the current study. Under the average year scenario, at the end of the hydrological year in June, the total live storage in the dam is 972 MCM. This live storage is 2.62 times the dead storage capacity of 370 MCM of the dam. Even in a water scarcity year, the total live storage in the dam at the end of the hydrological year drops to 660 MCM, which is at 21% of live storage capacity at full reservoir level. For 60% of the years, the inflows into the dam were average or higher than average, therefore it is possible to provide e-flows to revive the health of the river. As mentioned earlier, the e-flows calculated are not the recommended e-flows for the Hasdeo river. Proper assessment is needed to derive the e-flow requirement of the Hasdeo, which was not within the scope of this study. This desktop exercise however provided an understanding that there is a possibility of changing the reservoir operations so as to include e-flows in the current allocations.

5 Conditions for E-flows Assessment in the Hasdeo Sub-basin

The ultimate objective is to ensure that the flows in the river are maintained so that the all the basic and livelihood needs of the people living in the Hasdeo basin can be met and the ecological integrity of the river can be sustained. No doubt there will be some trade-offs in trying to achieve the set objectives, however it would create a condition conducive for all, and also increase the sustainability of the basin. Looking at the specific indicators mentioned in the previous section, the conditions that need to be met to arrive at e-flows, and that need to be defined to maintain the overall health of the basin are described below.

5.1 Comprehensive Carrying Capacity Study (CCS) with Post-Facto Assessment of the Dams, Barrages and Anicuts on the Flows

Currently the industrial water use in the lower Hasdeo basin is pegged at 441 MCM. About 390 MCM of water from the reservoir is reserved for upstream industrial schemes. With more interventions in the form of anicuts and barrages coming up on the river, the Government of Chhattisgarh is trying to squeeze in more industries in the Hasdeo basin. The farmers are being encouraged to use more groundwater, while surface water is being reserved for industries. In either case, the total availability of water and its quality are being affected severely in the Hasdeo basin. Before planning any further industrial expansion in the Hasdeo basin, it is necessary to carry out a complete comprehensive cumulative impact assessment study and a carrying capacity study with downstream impacts of the dams and the anicuts including other impacts and the likely impacts of upcoming and proposed projects. The study also needs to look at water for the environment to realistically determine how much industrial growth and urban expansion can be sustained by the basin.

5.2 Maintenance of the Existing Natural Vegetation in the Basin

With only 41% of natural forests remaining in the upper catchment of the Minimata Bango dam, it is necessary to protect these forests as they are responsible for aquifer recharge and of the streams that feed the Hasdeo. As these forests are located over coal blocks, in order to protect them, it is necessary to prevent further expansion of mines in the upper catchment of the forests.

To meet these goals, the mined areas need to be restored on a long-term basis. Also, the natural vegetation in the flood plains needs to be restored by creating riparian buffer zones.

5.3 Maintenance of the Natural Variability of the Flow

The hydrological analysis of the runoff data at the Bamnidih gauging station showed that the natural flow hydrograph of the Hasdeo has completely changed after the construction of the Minimata Bango dam. The monsoon flows in the river have reduced, and the post-monsoon and the lean season flows in the river have increased after the dam was constructed. However, with an average of 50% storage available in the dam at the start of the hydrological year, reservoir operations can be optimised to allocate e-flows such that the monsoon flows in the river can be revived. Releasing more flows in the monsoon season will also ensure that more sediment flows into the river which will benefit the floodplain and river bed farmers. Releases from the Hasdeo barrage should be made so as to mimic the natural hydrograph of the river.

5.4 Conservation of Endemic and Endangered Fish Species

There is very little ecological information available on the Hasdeo basin. A very detailed ecological survey needs to be carried out, in order to determine the presence of fish, other aquatic species, wild life including birds and riparian plant diversity in the basin. From the information received from the fishermen, the population of the 'Sirangi' fish is dwindling and there is a need to conserve its habitat. 'Sirangi' is a migratory fish needing slow moving streams. However, impoundments can affect its movement, and hence in the prevailing conditions it is necessary to understand the migratory path of this fish and assess if its habitat can at least be partially restored by ensuring certain flows. Similarly, there is a need to stop the introduction of exotic species in the river that are creating unnecessary competition and increasing the stress on the endemic species.

5.5 Water Quality

The overall water quality in the basin is of concern. Both surface and groundwater in the basin have shown presence of heavy metals. Fly ash can be visibly seen flowing into the Hasdeo from the Ahiran river and Dhengur naala which are the source of these heavy metals. There is also thermal pollution in the river due to hot water that is released in the Hasdeo barrage reservoir in Korba. To improve the overall water quality, effluent control need to be made more stringent. Strict penalties have to be enforced on the industries that violate the pollution control norms. Implementing e-flows will enhance the quality of the water as there will be more available for self purification.

5.6 Preserving the Existing Livelihoods and Ensuring the Revival of More Livelihoods

Ensuring certain flows in the river can help preserve the livelihoods of the fishermen and riverbed/floodplain farmers living in the basin at present. One drawback of our study has been the inability to analyse the sediment flows due to limited information. As a result, it is difficult to determine the sediment flow downstream and the fertility of the floodplains such that it would ensure that floodplain and riverbed farmers get enough yield during the winter season. Changes in sediment transportation and deposition need to be assessed with the help from relevant experts.

6 Legal, Policy, Institutional and Regulatory Regime for E-flows

Environmental flows as a method and approach finds very limited place in the legal, policy, institutional and regulatory regimes connected with water and rivers in India. One reason could be that the use of e-flows as a formal method and approach is a recent phenomenon. However, such reasoning does not seem convincing, given that the concepts behind e-flows, the notion that a river must flow, are not at all new. The dominant paradigm of water and river management in this country is based on extracting every last drop of water from the water systems, and hence it is natural that such a model will have no place for environmental flows. This is the real reason why we see little importance to the notion and concept of maintaining flows in the current water management practices.

Given this, the recent focus, and increasing acceptance of e-flows offers opportunities to remedy this lacunae. With the practice to extract the last drop of water from rivers dominating, it was not surprising that flows — or their disappearance — did not figure in the planning of river valley projects, nor did they find a mention when the requirements of the environmental impact assessment process were determined. For example, the guidelines for Environmental Impact Assessment of River Valley Projects put out by the then Department of Environment, Ministry of Environment and Forests, as late as in 1985 (Department of Environment, 1985) had no mention of looking at downstream impacts of dams, where flow reduction and flow alteration was to be a major impact, though of course, some of these impacts were implicit in the assessment of impacts on aquatic flora and fauna.

However, the issue of flows was being raised by the movements of river basin communities as well as concerned citizens. Some of the Court orders and judgements around this time started talking about environmental flows, even if they did not use the term itself. For example, the 1999 Order of the Supreme Court of India in the Writ Petition 537 of 1992, which had raised the issue of pollution in the Yamuna and asked the Court to "permit fair levels of water flow in the rivers Ganga and Yamuna", directed the CWC and the MoEFCC to ensure flows of 10 cumecs all-round the year in the Yamuna (Agarwal and Krause, 2013).

The 2002 Water Policy of the Government of India is probably the first document to officially recognise the need for maintaining flows in rivers. The policy states that "minimum flow should be ensured in the perennial streams for maintaining ecology and social considerations" (GoI, 2002). While this did call for maintaining flows and recognised that the flows should serve some specific purposes, namely to maintain the ecology and social considerations, it still talked about 'minimum flows', a concept that is quite different from environmental flows.

One of the first states to introduce e-flows was Himachal Pradesh, which in its Hydropower Policy of 2006 mandated that all run of river hydropower projects should ensure a minimum flow of 15% in the downstream (TERI, 2015). By this time, a fair bit of discussion around the concept, definition, assessment and implementation of environmental flows was developing in the country. In 2011, the Forum came out with a comprehensive document on maintaining flows for ecological, livelihoods and cultural and social purposes (Joy et al., 2011). The report pointed out that,

> "Interpreting environmental flows or ecosystem needs is not easy, especially given the fact that it is not only the amount, but also the timing, quantity, quality, and duration of flows that are important from an ecosystem perspective. Nor is it obvious that 'apportioning' or 'allowing' water to be left in the ecosystem is the correct approach; in addition, there is a view that environmental water requirements should include both terrestrial and aquatic ecosystems. Hence, methodologies appropriate to the Indian context need to be carefully chosen...
>
> "Providing water for ecosystem needs is particularly challenging because of the perception that this would leave less water for present needs, which in turn is likely to trigger conflicts. Further, our understanding of how different ecosystem components in different bio-geographical settings react to changes of flow caused by water use or land use changes is highly inadequate…
>
> "Hence creating a suitable policy and legal framework for ensuring water for the ecosystem is not easy. Among other things, it would involve addressing issues such as the principle of subsidiarity with respect to scale of management, rights framework, the need for compensation, genuine involvement of communities, and practically implementable-flows. The basic unit of planning and decision making could start from the micro watershed level and be scaled upwards and integrated into the entire river basin."

The last few points are important when one looks at what the legal, policy and institutional structures for enshrining the environmental flows approach should be. The report points out similar considerations for flows for livelihood purposes. Last but not the least, the report pointed out certain broader issues that have a direct bearing on water allocations for livelihoods, that is

> "Water for livelihood as a human right; equity and sustainability as basic principles; de-linking of land rights from water rights; import, export and transfer of water; limits to extraction; and balancing of various rights and needs." (Joy et al., 2011)

These points would form important criteria and indicators when assessing environmental flows, as well as for evolving the legal, policy and institutional structures.

In July 2010, the MoEFCC commissioned a consortium of seven IITs to prepare a Ganga River Basin Management Plan (GRBMP). The Memorandum of Agreement clearly indicated recognition of several of the important concepts of environmental flows. The press release by the MoEFCC related to this (MoEFCC, 2010) states:"GRBMP will aim to have adequate provision for water and energy in the Ganga Basin to accommodate the pressures of increased population, urbanisation, industrialisation and agriculture while ensuring the sanctity of the fundamental aspects of the river system are protected. These include:

(i) River must continuously flow (*Aviral Dhaara*),

(ii) River must not be seen as a carrier of waste loads (*Nirmal Dhaara*),

(iii) River must have longitudinal and lateral connectivity,

(iv) River must have adequate space for its various functions,

(v) River must function as an ecological entity."

Several other efforts by official and non-official agencies show the development in the discourse around environmental flows at this time. Some of the important developments were discussed in Chapter 3.

The 2012 National Water Policy reflects a better understanding of what environmental flows mean. It states, in the basic principles section (GoI, 2012,), that

> "(v) Water is essential for sustenance of eco-system, and therefore, minimum ecological needs should be given due consideration."

And further that

> "3.3- Ecological needs of the river should be determined, through scientific study, recognising that the natural river flows are characterised by low or no flows, small floods (freshets), large floods, etc., and should accommodate developmental needs. A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated ground water use."

This reflects the official recognition that environmental flows are more than minimum flows, and mimic the natural flow regime. Unfortunately, even after this clear recognition, such a requirement has not been translated into legal and regulatory instruments.

The only legal instrument at this point to mandate environmental flows seems to be the conditions being imposed by the EAC of the MoEFCC, which appraises projects for environmental clearances. As mentioned earlier in this report, The EAC, when prescribing the ToRs for carrying out environmental impact assessments, prescribes some e-flows, and also requires that "A site specific study on minimum environment flow should be carried out" (MoEFCC, 2015). While it's an important step, there are two issues with this. One, it talks about "minimum" and "environmental" flows in the same breath; and two, it does not suggest any methodology for the e-flows assessment.

The proposed National Water Framework Law, in its Draft Bill (GoI, 2016) also has provisions for mandating environmental flows. Its Clause 6 (6) states that "environmental flows adequate to preserve and protect a river basin as a hydrological and ecological system shall be maintained." If this Bill is enacted into law, it would represent the first legal provision to ensure environmental flows. However, at the point this report is being written, there does not seem to be any roadmap in terms of enacting this law. Since water is a state subject, this poses additional hurdles for the enactment of such central legislation as the proposed Framework Law. As far as the states are concerned too, several states do recognise the need for environmental flows. For example, Odisha puts "ecology" at the second place in the list of priorities of allocation of water, and also requires that "the preparation of the project plan will take into account the requirement of environmental flow in the river as a mandatory consideration" (Government of Odisha, 2007). However, these do not translate into legal provisions for enshrining environmental flows.

Since there are few legal provisions for mandating e-flows, the related institutional and regulatory structures are also missing. However, many states are now moving towards river basin planning, and creating basin level institutions. These institutions can be the first holders of the move to enshrine environmental flows in rivers. They can do this by ensuring e-flows as a mandatory part and parcel of the basin planning and management. However, these institutions should incorporate the principles of subsidiarity, equity, and several others mentioned earlier.

Thus, the status of development of policy, law, institutions and regulations is at a very nascent stage in the country as far as e-flows are concerned. There is some development at the policy level. However, this also needs to be more refined, and made more scientific and participatory. Based on that, a comprehensive regime of law and institutions needs to be built up. In doing so, there is need to integrate several aspects like river basin planning, water as a fundamental human right, equity and so on. Such a process cannot be limited to the central level (where it has taken few initial steps with the draft Framework Law Bill), but has to be happen within the states too, which are responsible for water legislation in today's constitutional scheme.

7 Insights and Recommendations

As we look at how rivers are used and abused in India, we find that though we consider rivers as sacred, Indians generally do not respect their rivers. What is a flowing river, why should a river flow from source to its meeting with the last drainage point, how are the communities going to be ultimately deprived if they do not manage their river judiciously are questions seldom addressed. It is very important that all the diverse communities, departments , industries, agencies who use the river and share a river from source to sea, should respect, understand and recognize the dynamics of a river, its changing seasonal flows. The management and restoration of e-flows depends upon the feeling of stewardship and common responsibility shared among the different users and managers. (Anantha & Dandekar, 2012; Anantha, 2015b). Infact this is at the core of river basin restoration and management.

The experiences from the Hasdeo basin in the Mahanadi river basin have revealed several inherent limitations under Indian conditions in proper assessment and allocation of flows in Indian rivers. Nevertheless, e-flows are the most important element that decides the continued use of the river for humans, the maintenance of the ecological health of the river and the completion of the hydrological cycle. In fact e-flows are the most critical aspect to be considered in any river basin planning. In India, river basin planning is being tried out in many states and is at the nascent stage. In this chapter, learnings and insights from the Hasdeo study will be used to provide a few recommendations on how e-flows should be refined, and the possibilities of their integration in river basin planning.

7.1 E-flows Assessment is not for Environmental Clearance Alone

The Government of India has been trying to standardise e-flows methodology and allocation. Earlier, desktop assessments were mostly followed which do not provide a holistic assessment of e-flows. A few CIAs have attempted BBM methodologies, though inadequate as our analysis reveals. The current ToR for applying for environmental clearance for River Valley projects state that the minimum e-flow shall be 20% of the average four lean months of the 90% dependable flow and 30% of the monsoon flow during the monsoon season. During post monsoon months, the flow shall be decided by the committee based on the hydrology and the available discharge. Fish diversity studies also need to be carried out for the estimation of e-flow (MoEFCC, 2015). Very significantly, the ToR states, 'A site specific study on minimum environment flow should be carried out'.

'Site specific minimum e flows' is an advancement from the earlier just 'minimum flows approach. However, the inherent lacuna of the recommendation of 2015 ToR is that 'site specific minimum environmental flows assessment' should be the norm. Minimum flows would amount to downsizing the flow requirement till the last drainage point of the basin. Rather it should be, 'site specific environmental flows'. Besides, the ToR needs to take into account the heterogeneity in riverine ecology, the issues concerning livelihood dependence on the river, river biodiversity, river hydraulics, river bank ecosystem properties, river morphology and sensitive issues relating to socio–cultural rights and practices vary extensively among ecosystems and human societies. Rivers in the Himalayas are different from the rivers in Central India, which are different from the Western Ghats Rivers. Standardisation is bound to create more problems rather than meet the needs of the people and ecology. Most important, the ToR should have included participatory objective setting for e-flows as a norm.

The MoEFCC needs to broaden the approach to e-flows assessment and acknowledge that a single norm cannot serve the purpose. It is not just a ToR norm to fulfill the environmental clearance process as is the practice presently. This applies to both EIAs and river basin level studies for environmental clearance. Presently river basin studies have been commissioned for many river basins by the MoEFCC. However they lack a river basin approach and are not comprehensive. E -flow assessments in these basin studies are greatly flawed, and done mostly only in context of proposed dams and hydropower projects. A proper River Basin Planning approach, with e-flows at the centre should include many other aspects. E-flows should be seen as an integral part and parcel of a robust river basin planning strategy which includes aspects like environmental clearance of dams, industries, thermal and nuclear power plants, ground water use, and water quality apart from basic and livelihood needs of the people directly dependent on the river and requirements of urbanisation.

According to Joy et.al., (2011), e-flows should address the issues of water for basic needs and livelihoods as a human right; equity and sustainability as basic principles; de-linking of land rights from water rights; import, export and transfer of water; limits to extraction; and balancing of various rights and needs as pointed out in the report of the Forum.

7.2 Participation — the Core of E-flows Assessment, Implementation and Monitoring

Implementing e-flows is also a societal choice. Experts maybe able to do their best for the assessment of flow needs through rigorous procedures. However, they cannot be implemented unless the people, including the politicians and legislators, understand why and for what the flows should be left in the river, and realise their significance for their own benefits along with that of the environment. Their priorities maybe different from the priorities of experts. For instance in the Hasdeo basin, people are more concerned about pollution and water quality than the status of the catchment and loss of floodplains and river bed farming. This implies that they need to be convinced how improved flows can dilute pollution while restoring the riverine ecology. According to O'Keefe and Quesne, (2009), since the 1990s, there has been a complete realisation that environmental flow assessment is a social process with an eco-hydrological core, rather than an eco-hydrological process with a social add-on. We would like to re-iterate this based on our learnings in the Hasdeo basin

Participation of stakeholders is hence a basic principle to be followed in any e-flows assessment and implementation process. In the assessment stage, local communities like fisher people, river bed and flood plain farmers, boatmen and indigenous communities should be given top priority. They know the highs and lows of the river given their living relationship with the river. Assessment followed by consensus building should involve all the stakeholders (departments, communities, industries, farming communities, coal miners, plantation managements for the Western Ghats and North East, tourism lobby, etc. wherever applicable). Even if they do not come to a consensus, such stakeholder consultations enhance the space for negotiation. Implementation maybe the biggest challenge since it involves give and take and capping of water for the intensive users and water wasting parties. Hence, ensuring proper implementation requires the supervision and monitoring by the local communities and departments. Implementation would be a tougher challenge for developed and over allocated basins. The same principles apply to participatory river basin planning. In fact, a participatory e-flows assessment is at the core of river basin planning since it would decide the future allocations possible. Hasdeo is on the verge of being an over allocated basin and hence would require strategic negotiations based implementation.

7.3 Lack of Relevant Data

One of the major hindrances in proper assessment of e-flows is the lack of good, reliable data. As cited in the earlier sections, this problem was faced in the Hasdeo as well. This is true not only for the entire Mahanadi basin but also for most of the rivers in India. In the Hasdeo, there was no data available on the extent of floodplains, floodplain farming, floodplain farming villages, fish species, fisher folk dependent on the river, tribal displacement, riparian lands and riparian biodiversity to name a few. These are all important parameters to be considered while assessing e-flows. Actually in a robust assessment process, the changes in river ecology, riparian ecology and biodiversity due to changes in the flow regime need to be assessed to determine the limits to flow regulation. Hence, non-availability of data becomes an excuse for most of the EIA and CIA agencies to take up desktop methods.

Hence, we suggest that base line studies can be initiated in all river basins, trying to bring together knowledge of local communities and experts. This should include all aquatic species, riparian ecosystems and biodiversity, floral and faunal biodiversity, relation between the ecosystem and flow changes, forest status, climate change effects on biodiversity and ecology etc. Such an attempt is a huge task. India has so many scientific institutions and experts. There is data generation and compilation on different ecological, morphological, social and economic aspects pertaining to rivers in Universities and institutions. It is time such data be pooled for each river basin, compiled systematically, analysed , gaps identified and integrated into the base line studies and then used for holistic e-flows assessment and river basin restoration and management. Such an assessment should be made for each river. This should be used as the basis for any e-flows allocation or river valley project clearance or basin planning. The exercise should be genuine so that it can be used to challenge the shoddy environmental clearances.

7.4 Community led Field Research

Community led field research and surveys should be put in place which can generate data on fishes, fisheries, floodplain and river bed farming, habitats of indigenous communities and other river dependent livelihoods (for example, sedge grass and reeds are raw material for many household uses like mats, containers and artifacts). There is scope for carrying out a community led research in Hasdeo facilitated by activists and grass root CSOs. This data can be used for proper e-flows assessment as well as for better negotiation with the polluters and developers and later integrated into river basin planning. Thaiban research in Thailand carried out by fishing and farming direct river dependent communities for opening the gates of the Pak Mun river is an excellent example of community led research.

7.5 Monitoring and Compliance of E-flows by the Government is on Paper

A brief review of the e-flows assessments for various river basin dam cascades has revealed the shoddy e-flows assessment and allocation process. Many projects have received environmental clearance, of which several are being challenged in the courts. E-flows have been allocated and made a pre-condition in the environmental clearance letters in many of these projects. However, it remains to be seen whether the authorities are complying with the e-flows implementation as per the environmental clearance (EC) norms. Similarly, monitoring of compliance is another grey area which mostly remains on paper. As per the Model ToR for river valley and hydroelectric projects of the MoEFCC, the project proponent is supposed to submit a post-project monitoring plan for implementation based on the environmental management plan (EMP). However, there is no mention of monitoring e-flows in the ToR parameters whose cost has to be borne by the proponent of the project. It is important to carry out monitoring of the allocated e-flows through legally empowered monitoring committees formed out of downstream communities including fisher folk, farmers, riparian communities, experts and local governments. Any violation of the compliance shall be subject to legal action.

7.6 Ensure Proper Objective Setting

Without doubt, the toughest challenge before the governments in the coming years will be to revive the lost flows and functions in our rivers. However, when it comes to actually assessing and implementing e-flows, the foremost question that would arise is why we need certain quantity of flows for a particular river or a stretch of the river? What all social, livelihood and ecological needs are to be met through the flows? Hence, setting objectives is at the core of assessing e-flows. A sustainable trade off and negotiation between water use in the river and e-flows can be arrived at only if objectives for e-flows are clearly stated (Anantha & Dandekar, 2012). In India, no e-flows assessment or allocation has been based on clearly defined objectives. The role of riverine communities in setting objectives is always brushed aside. If communities are not involved in the objective setting exercise, then the resultant e-flows regime and river health cannot be a reflection of 'social choice', and the communities can reject it. Objectives cannot be standardised either. They will change, based on the river and its various services and values and objectives have to be set at the planning stage itself. In the context of river basin planning, objective setting can be done at the planning stage itself which are relevant for e-flows as well. This is applicable to both developed and over allocated rivers, as well as those rivers where new projects are in the pipeline. Meanwhile, objectives can be set only within the ecological and hydrological limits of the river. Hence, objective setting would also mean making the people aware of the limits to development of the river basin beyond which it will dry up and degrade irreparably.

7.7 Post-facto CCA and CIA Recommended for Hasdeo

In the Hasdeo basin, the list of new thermal power plants, coal mines and anicuts in the pipeline calls for more allocation of water. Our research insights confirm that the river is already over allocated. The reserves stored in the Hasdeo Bango reservoir can be reallocated. However, it is a highly politically debated issue and there is suspicion among the activists that the reserve maintained is for allocation to industries and thermal power plants, both existing and new ones. Hence to allay the distrust of the activists and to assess if the river can take in more projects including anicuts, it is essential to carry out a comprehensive cumulative impact assessment study and a carrying capacity study including downstream impacts of the dams and the anicuts till the confluence of Hasdeo with the Mahanadi. The study should also look at the water for the environment (e-flows) to realistically determine how much industrial growth and urban expansion can be sustained by the basin. Governments should realise that there is a limit to the water allocation possible and ultimately all stakeholders are going to lose together. Groundwater has already been impacted and polluted and hence groundwater extraction potential is limited. This is applicable to all river basins which are closing basins/closed basins like the Krishna and Cauvery. Regulations in water withdrawal and further allocation have to be attempted based on the CIA and CCA of Hasdeo basin.

7.8 Enabling Policy and Legal Provisions

As explained in Chapter 6, the concept and implementation of e-flows in India is at a very nascent state with respect to policy, law and enabling institutional and regulatory mechanisms. The proposed National Water Framework Law, in its Draft Bill (GoI, 2016) and the Water Policy 2012 alone have articulated e-flows appropriately. Water being a state subject, such a central legislation can be challenged by the states. The water policy decisions at the state and central levels have not yet been translated into legal instruments either. The MoEFCC norms are not legally binding.

Another option is to have a separate policy for e-flows and integrate it into the river basin plan. Such a policy can include non-prescriptive ‘technical guidelines’ that provide the range and suitability of various e-flows methods and approaches for different river systems in different eco-regions, and ‘operational guidelines’ for undertaking a participatory e-flows assessment integrating it into the river basin planning process. The policy need to be backed by enabling legal norms. Some of the non-negotiable legal norms should be:

- E-flows assessment and allocation will be at the core of a river basin management plan.
- E-flows should mimic the natural flow regime.
- E-flows should be set apart as ‘beneficial use’ on par with other water uses as recommended in Joy et al. (2011).
- E-flows assessment by any agency or government should respect the fundamental principles of equity, sustainability, and gender equality.
- Participatory objective setting shall be mandatory.
- The process of determining the e-flows should be participatory
- Basic and livelihood rights and ecosystem needs shall be given top priority.

- Regulation of water allocation or banning of new development projects requiring constant supply of water from river or ground water should be made mandatory in over allocated river basins.
- The entire process of assessment, implementation and monitoring of e-flows shall be carried out with participation of the direct river dependent local communities (tribals, fisher folk, boatmen and direct river dependent farmers).
- The flow regime and allocation for different sectors shall be made public and placed before the river basin stakeholders for discussion, consensus and negotiation before actual implementation.
- The principle of subsidiarity to the lowest scale of management shall be adhered to.
- Review of the e-flows allocation once in a year shall be mandatory. Since a river is a dynamic entity, e-flows are also a dynamic process and hence needs adaptation.
- Compliance of e-flows flow regime arrived at shall be legally mandatory. Violation of compliance shall be a punishable offence.
- Reallocation strategies between existing massive water uses (users) and domestic/ drinking water/ecosystem needs and uses should be given preference.

7.9 The Indicator Approach Needs to be Refined and Enhanced

Our team that carried out the research study in Hasdeo basin tried to follow the indicators and criteria approach as tried out by Smakthin et al. (2007) in the Krishna, Cauvery, Narmada, Periyar and part of Ganga. Such an approach is valid in a data deficient situation which holds true for the Mahanadi river basin. However, each indicator used needs further refinement. During field work, it was realised that there is a huge data deficit for most of the indicators. Hence, the indicators we have used are mostly based on sparse data and the data from fieldwork that could be generated within limited time and resources. There is further scope for improvement of information on each indicator. Another aspect is the scale of analysis. Indicators have been gauged for e-flows based on site selections, which are just two and far placed, again due to time and resource constraint. For example, particular reaches of the river may reveal more information. The loss of ecosystems and riparian lands is based on estimation and not on actual data. It is evident that the indicators approach though suitable for information deficit rivers, can be refined and enhanced by seeking the expertise of conservation biologists, ecologists and fish experts and communities and thereby including more indicators, and better information about each of these indicators.

7.10 A Comprehensive, Participatory River Basin Planning Recommended for Mahanadi

Against the above narrated insights, an e flows assessment is recommended to be attempted in the Mahanadi basin or at least in the Hasdeo sub basin as a sample case jointly by the Chhattisgarh and Odisha Governments with the participation and coordination of the communities who know the river, activists and NGOs, indigenous communities, all the concerned departments, industries, coal miners, thermal power plant managers, dam or anicut builders and other agencies. The further expansion plans of development in the basin/sub-basin needs to be stopped until such a study is completed. Such a study goes beyond the environmental clearance needs. It would also help to serve as a sample case for trying out a river basin planning in India for the first time with e-flows assessment as its core.

The Hasdeo basin study has brought out a number of gaps and inherent deficits in the e-flows process applicable to India. It has also revealed that water for nature or e-flows is an integral part of any inter-sectoral allocation process. In fact, how much water is left in the entire river basin would decide the future of inter-state water conflicts and the feasibility of gigantic projects like the Inland Waterways Project and the Inter Linking of Rivers. It will in turn decide the future of our riverscapes. It will also depend on how the different stakeholders approach their river basins and whether they are willing to co-operate and implement a robust river basin plan with e-flows at its centre.

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The Forum and Its Work

The Forum (Forum for Policy Dialogue on Water Conflicts in India) is a dynamic initiative of individuals and institutions that has been in existence for the last ten years. Initiated by a handful of organisations that had come together to document conflicts and supported by World Wide Fund for Nature (WWF), it has now more than 250 individuals and organisations attached to it. The Forum has completed two phases of its work, the first centering on documentation, which also saw the publication of 'Water Conflicts in India: A Million Revolts in the Making', and a second phase where conflict documentation, conflict resolution and prevention were the core activities. Presently, the Forum is in its third phase where the emphasis was on backstopping conflict resolution. Apart from the core activities like documentation, capacity building, dissemination and outreach, the Forum would be intensively involved in right to water and sanitation, agriculture and industrial water use, environmental flows in the context of river basin management and groundwater as part of its thematic work. The Right to water and sanitation component is funded by WaterAid India. Arghyam Trust, Bengaluru, which also funded the second phase, continues its funding for the Forums work in its third phase.

The Forum's Vision

The Forum believes that it is important to safeguard ecology and environment in general and water resources in particular while ensuring that the poor and the disadvantaged population in our country is assured of the water it needs for its basic living and livelihood needs. The Forum is committed to the core values of equity, environmental sustainability, efficiency, livelihood assurance for the poor and democratisation.

The Forum's Mission

The Forum's mission is to influence policies and actions at all levels and work towards resolving, and preventing water conflicts in an environmentally and socially just manner, and creating awareness for achieving participatory, equitable, and sustainable water use. The Forum aims to carry out these through stakeholder interactions, knowledge creation, policy advocacy, training, networking and outreach.

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