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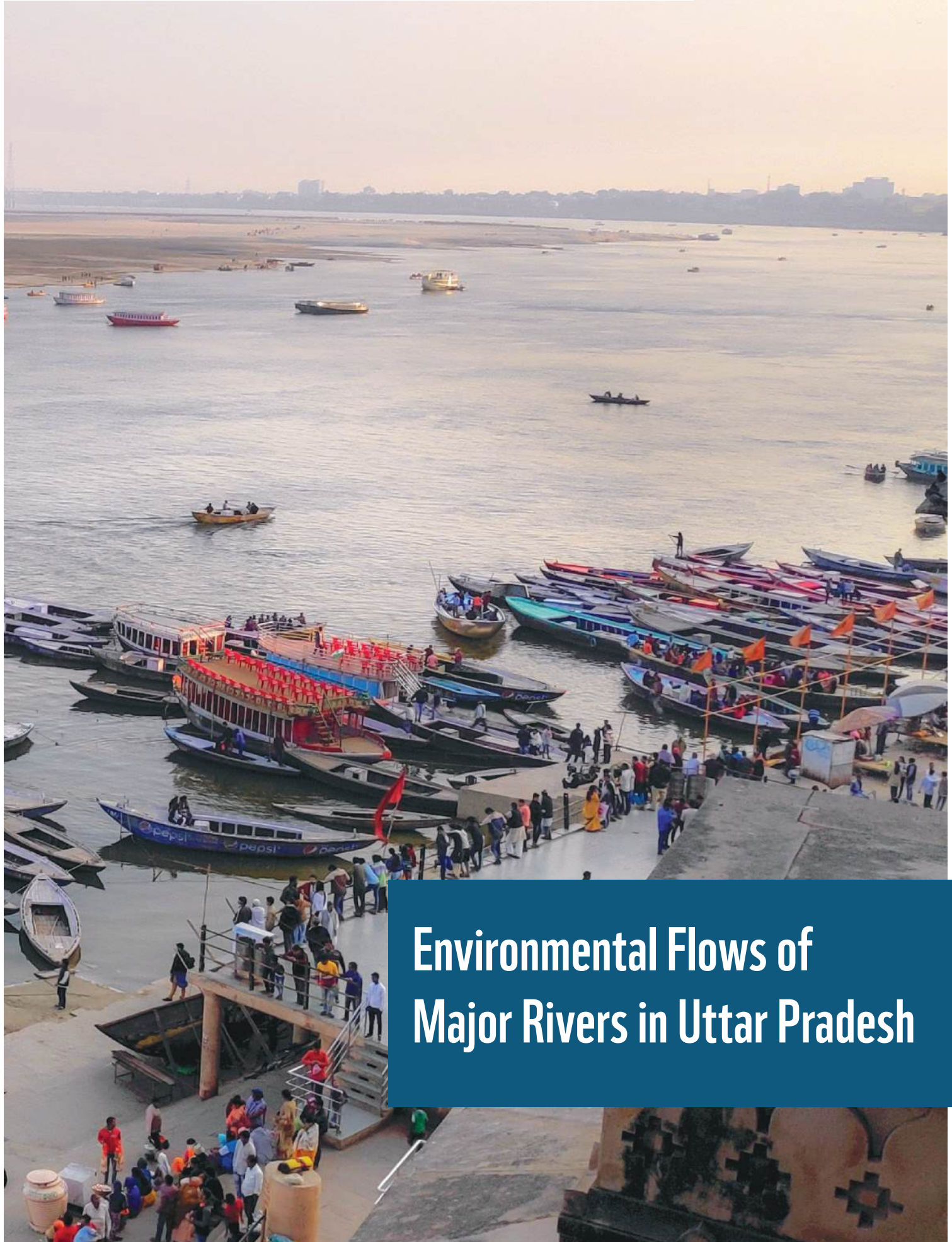
HSBC



सिंहकेल लक्ष्मि भारती



सिंहकेल लक्ष्मि भारती



# Environmental Flows of Major Rivers in Uttar Pradesh



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Mr Himanshu Kumar, Basin Planning Expert and Mr Karunesh Kumar, Executive Engineer, UP SWaRA, were actively involved in the E-Flows assessment exercise and for that, we are thankful. Their involvement in the process enriched the exercise manifold.

We are thankful to National Mission for Clean Ganga - which is also a knowledge partner of WWF-India for their constant engagement and guidance for WWF-India's work on Ganga rejuvenation.

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**JOINT INITIATIVE:** Uttar Pradesh Water Management and Regulatory Commission (UP WaMReC)  
World Wide Fund for Nature-India (WWF-India)

February 2024











**Yogi Adityanath**



**CHIEF MINISTER  
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### **Message**

Rivers are an integral part of the Indian society, its culture and its history. They are revered since the time immemorial and various life-forms are dependent on these rivers.

Whilst all river systems are critical to the nature and to the human beings, the Ganga River system holds special status. Respected as 'mother', Ganga River is the lifeline of millions of people who are dependent on it. Close to half of River Ganga's stretch passes through the state of Uttar Pradesh and various tributaries, e.g. Yamuna, Ghaghra (Saryu), Gomti, Rapti, Sharda, Ramganga, Gandak and Sone join River Ganga during this stretch. These tributaries, are large river systems themselves and in many ways contribute to the mightiness of the River Ganga.

Government of India, through Namami Gange programme is working towards rejuvenation of River Ganga. The Government of Uttar Pradesh is actively contributing to this exercise. We realise that, maintaining the sanctity of the tributaries of River Ganga is critical for a healthy Ganga. Therefore, it is essential to ensure that the tributaries of river Ganga also remain healthy. The State Government has taken effective steps in this direction.

I am happy to note that, U.P. Water Management & Regulatory Commission and World Wildlife Fund for Nature-India have conducted a joint exercise to assess the Environmental Flows (E-Flows) for all these major rivers of Uttar Pradesh. Maintenance of E-Flows in our river systems is essential for the well-being and healthy state of our rivers. Participation of credible institutions like ICAR-National Bureau for Fish Genetic Resources, Lucknow, Centre of Ganga River Basin Management Studies (IIT Kanpur), People's Science Institute Dehradun, U.P. State Water Resources Agency and local experts has enriched this exercise.

I hope that the E-Flows report for these rivers would be a valuable input for the basin management planning exercise and the recommendations made in the report will go a long way in realising our collective dream of Aviral and Nirmal dhara in our rivers. As I understand, Uttar Pradesh is the only state to have done an environmental flows assessment for all its rivers, which I hope will inspire other States to follow suit.

My best wishes for the entire endeavour.

  
( Yogi Adityanath )



स्वतंत्र देव सिंह

मंत्री

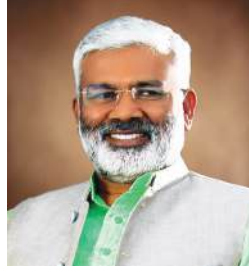
जलशक्ति

(सिंचाई एवं जल संसाधन, बाढ़ नियंत्रण,  
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The state of Uttar Pradesh is blessed with freshwater resources, mainly rivers and numerous wetlands. There are various major rivers in the state. These rivers, either passes through the state or originate in the state or complete its journey in the state or confluence in another river in the state. These rivers include – Ganga, Yamuna, Gomti, Rapti, Sharda, Ghaghra (Saryu), Ramganga, Gandak and Sone. These rivers not only play vital role in the lives and well-being of the scores of the people that resides in the basin area of these rivers; but also supports impressive aquatic biodiversity, while providing required habitat conditions for these very species. Some of the key species include – the Ganga River Dolphin, the Gharial, the Otter and the Turtle and the Mahseer. These rivers are also an abode for various types of fish species of Indian Major Carps. Another most critical role of these rivers is to fulfil the socio-cultural aspirations of the scores of the people; as many cultural festivities and auspicious mass-bathing occasions are organized on the banks of some of these rivers. In this context, rivers like – Ganga, Yamuna, Ghaghra (Saryu), Ramganga, Rapti and Gomti are crucial.

We, the residents of the Uttar Pradesh, are fortunate to live along these rivers or in the basin area of these rivers. The Government of Uttar Pradesh takes pride in having these rivers in the state and attaches immense value to these rivers. Besides this, the Government of Uttar Pradesh is actively engaged with the Government of India for the Ganga Rejuvenation (*Namami Gange*). We feel that, it is our duty to preserve and conserve the River Ganga and its key tributaries, which are also coincidentally the major rivers of our state. We also believe that, the might of these major rivers comes from their numerous tributaries and it is because of this reason, the Government of Uttar Pradesh has decided to rejuvenate one river in each of its district.

I am happy to note that, WWF-India (World Wide Fund for Nature – India), as part of an initiative from Uttar Pradesh Water Management & Regulatory Commission (UP WaMReC), has assessed the Environmental Flows (E-Flows) requirements for all the major rivers of Uttar Pradesh. I also appreciate that, this work is supported (in terms of contextual guidance and required information) by our state's water resources institutions and department, namely – Uttar Pradesh State Water Resources Agency (UP SWaRA) and Uttar Pradesh Irrigation & Water Resources Department (UP I&WRD).

I congratulate the team of WWF-India and its partners to accomplish this ambitious task of assessing the E-Flows requirements for these major rivers of Uttar Pradesh, whose combined length is over 5,000 kilometers. I am hopeful that, the concerned department will make use of the recommendations from this report for the benefit of the rivers in the state of Uttar Pradesh.

  
(Swatantra Dev Singh)





**जी अशोक कुमार, भा.प्र.से.**

**विशेष सचिव एवं महानिदेशक  
राष्ट्रीय स्वच्छ गंगा मिशन**

**G Asok Kumar, IAS**

**SPECIAL SECRETARY & DIRECTOR GENERAL  
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सत्यमेव जयते



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अमृत महोत्सव

**भारत सरकार  
जल शक्ति मंत्रालय**

**जल संसाधन,**

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**GOVERNMENT OF INDIA**

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**DEPARTMENT OF WATER RESOURCES,**

**RIVER DEVELOPMENT & GANGA REJUVENATION**



## FOREWORD

Rivers, our invaluable freshwater assets, serve as the lifeline for all organisms that rely on them. They contribute significantly to India's economic prosperity and shape our cultural and spiritual identities. The health of our rivers mirrors and influences the activities within their basins, and we derive numerous benefits from them.

The Government of India accords the utmost priority to the conservation of the National River Ganga. We are witnessing a paradigm shift in the Ganga rejuvenation program, characterized by a holistic approach to address the river's primary challenges. This rejuvenation is anchored in two fundamental principles: nirmal dhara (ensuring a pollution-free Ganga) and aviral dhara (ensuring its continuous flows). The necessity to maintain aviral dhara, in the Ganga and its tributaries is a cornerstone of the National Mission for Clean Ganga (NMCG).

In recognition of the escalating hydrological alterations impacting our rivers and the resulting environmental degradation, the science of Environmental Flows (E-flows) has been established. This discipline determines the necessary quantity, quality and timing of freshwater flows in a river to conserve the riverine ecosystem and the services that the river extends to the nature and the people.

The rejuvenation of the River Ganga is a commitment of national significance. The Government of India, in collaboration with all riparian states, is diligently working through the Namami-Gange Programme to fulfil this commitment. Various Government Departments, Institutions, Research Organizations, and NGOs in India have conducted important work on E-Flows. From the government side, some of the most significant step is the Ganga Notification 2016 and Ganga E-Flows Notification 2018 issued by the National Mission for Clean Ganga (NMCG), Ministry of Jalshakti, Government of India.

It gives me immense pleasure to acknowledge that, the Uttar Pradesh Major Rivers Environmental Flows Assessment has been successfully completed and the report has been drafted. This marks the first-ever comprehensive endeavour on E-Flows assessment for all the major rivers of a state (Uttar Pradesh) in India.

This initiative, while led by WWF-India, is conducted under the aegis of Uttar Pradesh Water Management & Regulatory Commission (UP WaMReC) of Government of Uttar Pradesh. In this ambitious journey, I understand that the Uttar Pradesh State Water Resources Agency (UP SWaRA) and Uttar Pradesh Irrigation & Water Resources Department (UP I&WRD) played a key role. I commend the team's efforts in advancing the cause of improving the health of the Ganga River and its tributaries. Their work in securing E-Flows in the tributaries of Ganga River and in other river systems, across the country is of paramount importance. I look forward to seeing their continued valuable contributions towards Sustainable Water Management across other river systems in the country.

(G. Asok Kumar)



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## **Foreword**



Rivers- a major fresh water resource, are a lifeline for all the living beings dependent on it. Besides this, rivers play a key role in the economic prosperity and cultural and spiritual life of the people. In fact we draw a multitude of benefits from the rivers and in many ways the health of a river is an indicator of the nature of activities that are prevalent in its basin.

A critical aspect of Water Management across centuries has been allocation of this resource. Water was thought to be a stock of resource to be used for satisfying human needs. Over time ecosystem services supported by flow regimes started emerging as an integral part of the Water Management Framework. This Framework is not merely concerned with extraction and allocation of water for economic use but focuses on the challenge of – how much water to leave flowing in a river and how much to allocate for extractive uses, hydropower generation or storage in reservoirs. This is a very critical decision and depends on the timing, space, quantity and quality of the flow, without compromising with the integrity of the ecosystem structure.

Recognition of the escalating hydrological alterations of rivers on a global scale and resultant environmental degradation has led to the establishment of the science of Environmental Flows (E-flows), whereby the quantity, quality and timing of water required for ecosystem conservation and resources protection are determined.

Some work on E-flows has been done in India by various Government Departments, Institutions, Research Organizations and NGOs. One of the most notable amongst these is the E-flows assessment and consequent Ganga E-flows Notification (2018) issued by the National Mission for Clean Ganga (NMCG), Jalshakti Mantralay, Government of India.

Rejuvenation of River Ganga is a national commitment. Government of India in association with all the riparian states is working to fulfill this commitment through Namami-Gange Program. Almost half of the total length of River Ganga is in Uttar Pradesh during which it is joined by some major tributaries e.g. Ramganga, Sharda-Ghaghra, Gomti, Rapti, Yamuna, Gandak and Sone. The mightiness of River Ganga is largely because of these tributaries, and *Aviral & Nirmal Dhara* in River Ganga is possible only if these major tributaries remain *Aviral* and *Nirmal*.

In the above context, conservation of these rivers and maintenance of conducive Environmental Flows (E-flows) in them- arrived at through a robust socio-technical and



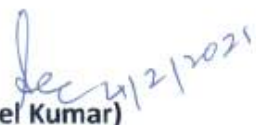
scientific process, is essential. With this objective in mind UPWaMReC partnered with WWF India in the Year 2019 and embarked on an ambitious journey to assess E-flows for all these major rivers of Uttar Pradesh.

Given its scale and complexity, this exercise was divided into two phases- Phase 1 comprising Sharda, Ghaghra, Gomti, Rapti and Ganga; and Phase 2 comprising Yamuna, Gandak and Sone. The Environmental flows assessment for rivers taken up in Phase 1 is now complete. UPWaMReC and WWF-India have decided to adopt Building Block Technology Method (BBM), regarded as a holistic, multidisciplinary approach, for E-flow assessment. A team comprising the National Bureau for Fish Genetic Resources (Lucknow), Center for Ganga River Basin Management Studies (cGanga IIT Kanpur), Terraqua UAV Pvt. Ltd. (an incubated firm of IIT Kanpur), People's Science Institute (Deharadun based NGO), State Water Resources Agency (SWaRA) Lucknow and individual experts were engaged in this exercise.

During April 2019 – November 2020, the team conducted various field activities (cross section, aquatic biodiversity, socio-cultural, geomorphology and river health surveys) at seventeen different locations spread over 4,000 kilometers of rivers considered under phase 1. Findings of these surveys were deliberated upon with an objective to develop the E-flows motivations, leading to site specific recommendations.

I am happy to note that the E-flows assessment for all eight rivers stands completed and the Report have been drafted. It is the first ever comprehensive work on E-flows for the major rivers of Uttar Pradesh. River Basin Management Plans with a roadmap for restoration of Environmental Flows will not only contribute to the enhancement of ecosystem services, but also place Uttar Pradesh on the global map for driving a holistic and integrated management of water resources.

I wish all the best to the team in furthering the concept of E-flows in the other river systems in the country. I also encourage the team to continue to contribute towards Sustainable Water Management in the state of Uttar Pradesh.

  
(Susheel Kumar)  
Chariman, UPWaMReC



**अनिल कुमार**

प्रमुख अभियन्ता एवं विभागाध्यक्ष



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Rivers, one of the critical freshwater resources, are lifeline for the human beings. It is these very rivers, which play crucial role in people's well-being, while providing various services, including – water use for domestic, irrigation, industrial and institutional purposes. At the same time, these rivers are abode of various species of aquatic biodiversity. The rivers play vital ecosystem functions, which are critical for both biotic and abiotic components of the ecosystem.

The state of Uttar Pradesh is blessed with various rivers, which serve various functions for the people and the nature. The dependency of the people onto the rivers is not only consumptive in nature, the rivers also plays vital role in the lives of people from the perspective of socio-cultural aspects and aesthetic value. For instance – the value of residing on the banks of a healthy river is difficult to quantify and therefore, the unaccounted and hidden values of the rivers are equally critical. On the other hand, it will be difficult to put value on the satisfactory bathing by the people in the river during auspicious occasions at sacred places on the banks of some of these rivers (Ganga, Yamuna, Ghaghra (Saryu), Gomti, Rapti, Ramganga).

We, at the Uttar Pradesh Irrigation and Water Resources Department, as the apex water resources management institution of the state, manages these rivers and their water resources. The state of Uttar Pradesh has various major rivers, namely – Ganga, Yamuna, Ghaghra (Saryu), Gomti, Sharda, Rapti, Ramganga, Gandak and Sone. Whilst the water resources of some of these rivers are diverted for consumptive uses, mainly – irrigation; the health of the rivers cannot be overlooked and therefore, the rivers conservation is high on the agenda of the Government of Uttar Pradesh. The state of Uttar Pradesh is one of the pioneer in implementing Environmental Flows (E-Flows) in its rivers. Whilst the E-Flows implementation in the Ganga River in the state, is in pursuance to the Ganga E-Flows Order 2018 of the Government of India; however, the initiative to implement E-Flows in the Ramganga River, is a purely state-level one, which is implemented during the lean seasons since 2021, through an Office-Order of the Chief Engineer.

I am happy to note that, WWF-India (World Wide Fund for Nature – India), as part of an initiative of the Uttar Pradesh Water Management & Regulatory Commission (UP WaMReC) conducted the E-Flows assessment for all major rivers of the Uttar Pradesh. In this ambitious task, the Uttar Pradesh State Water Resources Agency (UP SWaRA) and Uttar Pradesh Irrigation & Water Resources Department (UP I&WRD) also contributed in terms of providing valuable contextual guidance and information, which was critical for this assignment.

I hope that, this knowledge input, pertaining to E-Flows requirements of state's major rivers, who's combined length is over 5000 km, will go a long way in managing and conserving the rivers of the state. I am sure; with E-Flows input for our major rivers, we, the water managers of the state, will be better informed in terms of understanding the conservation needs of these very rivers. Eventually, this work will help in effectively managing and conserving these rivers in the state of Uttar Pradesh.



सिंचनेन समृद्धिः भवति

  
(अनिल कुमार)  
प्रमुख अभियन्ता एवं विभागाध्यक्ष  
सिंचाई एवं जल संसाधन विभाग





## Ravi Singh

### Secretary General & CEO, WWF India

The *Namami Gange* programme of the Government of India envisions an *aviral* (uninterrupted flow) and *nirmal* (clean) Ganga. Concerted efforts are being made by the Government of India, State Governments, technical institutions, academia, individuals and civil society organisations in realizing this long-term vision for one of the most revered rivers in the world.

Over a decade and half, WWF-India and its partners embarked on a journey to understand the issues around Environmental Flows (E-Flows) and water allocations in the Ganga River. Existing global E-Flows methodologies were adapted to develop an appropriate approach for the Ganga system. This approach, based on the building block methodology, integrated various aspects of the river — social and livelihood needs, cultural and spiritual requirements, hydrology and hydraulics, geomorphology, water quality and biodiversity values. This journey has been possible with the help of several partners who have worked with WWF-India since 2007. Later, the consortium of seven Indian Institute of Technologies responsible for the Ganga River Basin Management Plan further improvised on this approach while framing the E-Flows recommendations for the Ganga.

It is very satisfying to note that the Uttar Pradesh Water Management and Regulatory Commission (UP WaMReC) along with WWF-India and other partners is working on developing E-Flows recommendations for all the major rivers of Uttar Pradesh. These rivers include – Ganga, Sharda, Ghaghra, Rapti, Gomti, Ramganga, Yamuna, Gandak and Sone. It is hoped that, the E-Flows recommendations coming out of this exercise will go a long way in supporting sustainable river basin management in the state of Uttar Pradesh. We hope this initiative will also better inform and help the water allocation, use and management within the state of Uttar Pradesh. I am also aware the Uttar Pradesh State Water Resources Agency (UP SWaRA) is leading an ambitious exercise to develop River Basin Management Plans for all these major rivers of Uttar Pradesh and therefore the E-Flows recommendations coming of this initiative will inform the Basin Management Planning exercise as well, so that our river basins are managed sustainably while ensuring the well-being of the society and the conservation of our freshwater ecosystems, including all these rivers.

It is a matter of immense satisfaction for WWF-India that, the E-Flows assessment for River Sharda, River Ghaghra, River Gomti, River Rapti, River Yamuna, River Gandak, River Sone and few sites of River Ganga stands completed and the same is documented in this report.

We believe assessing, releasing and maintaining environmental flows will go a long way in realising the goal of making our rivers '*aviral*', one of the key components of the *Namami Gange* and other river conservation programmes.







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# List of Abbreviations

|                     |                                                                                             |
|---------------------|---------------------------------------------------------------------------------------------|
| °C                  | Degree Celcius                                                                              |
| AD                  | Anno Domini                                                                                 |
| ASL                 | Above Sea Level                                                                             |
| avg                 | Average                                                                                     |
| BA/CA               | Bar Area-channel Area Ratio                                                                 |
| BBM                 | Building Block Methodology                                                                  |
| BOD                 | Biological Oxygen Demand                                                                    |
| cGanga IIT Kanpur   | Centre for Ganga River Basin Management Studies, IIT Kanpur                                 |
| CGIAR               | Consultative Group on International Agricultural Research                                   |
| COD                 | Chemical Oxygen Demand                                                                      |
| COVID 19            | Corona Virus Pandemic, 2019                                                                 |
| CS                  | Cross Section                                                                               |
| cumec               | Cubic Meter Per Second                                                                      |
| cusec               | Cubic Feet Per Second                                                                       |
| CWC                 | Central Water Commission                                                                    |
| D/S                 | Downstream                                                                                  |
| DO                  | Dissolved Oxygen                                                                            |
| EFA                 | Environmental Flows Assessment                                                              |
| E-Flows             | Environmental Flows                                                                         |
| GEFC                | Global Environmental Flows Calculator                                                       |
| GIS                 | Geographic Information System                                                               |
| GRBMP               | Ganga River Basin Management Plan                                                           |
| HFL                 | Highest Flood Level                                                                         |
| HSBC                | Hongkong and Shanghai Banking Corporation Limited                                           |
| ICAR-NBFGR, Lucknow | Indian Council of Agricultural Research- National Bureau of Fish Genetic Resources, Lucknow |
| IMC 2013            | Inter-Ministerial Group 2013                                                                |
| IMCs                | Indian Major Carps                                                                          |
| India-WRIS          | India Water Resources Information System                                                    |
| IUCN                | International Union for Conservation of Nature                                              |
| IWMI- Sri Lanka     | International Water Management Institute - Sri Lanka                                        |
| kg                  | Kilogram                                                                                    |
| km                  | Kilometre                                                                                   |
| LULC                | Land Use Land Cover                                                                         |
| m                   | Meter                                                                                       |
| m/sec               | Meter Per Second                                                                            |
| m <sup>3</sup> /sec | Cubic Meter Per Second                                                                      |
| Max                 | Maximum                                                                                     |
| mg/l                | Milligram Per Liter                                                                         |
| Min                 | Minimum                                                                                     |
| MoEF& CC            | Ministry of Environment, Forests and Climate change                                         |
| MSL                 | Mean Sea Level                                                                              |
| NCIWRDP             | National Commission on Integrated Water Resources Development Plan                          |



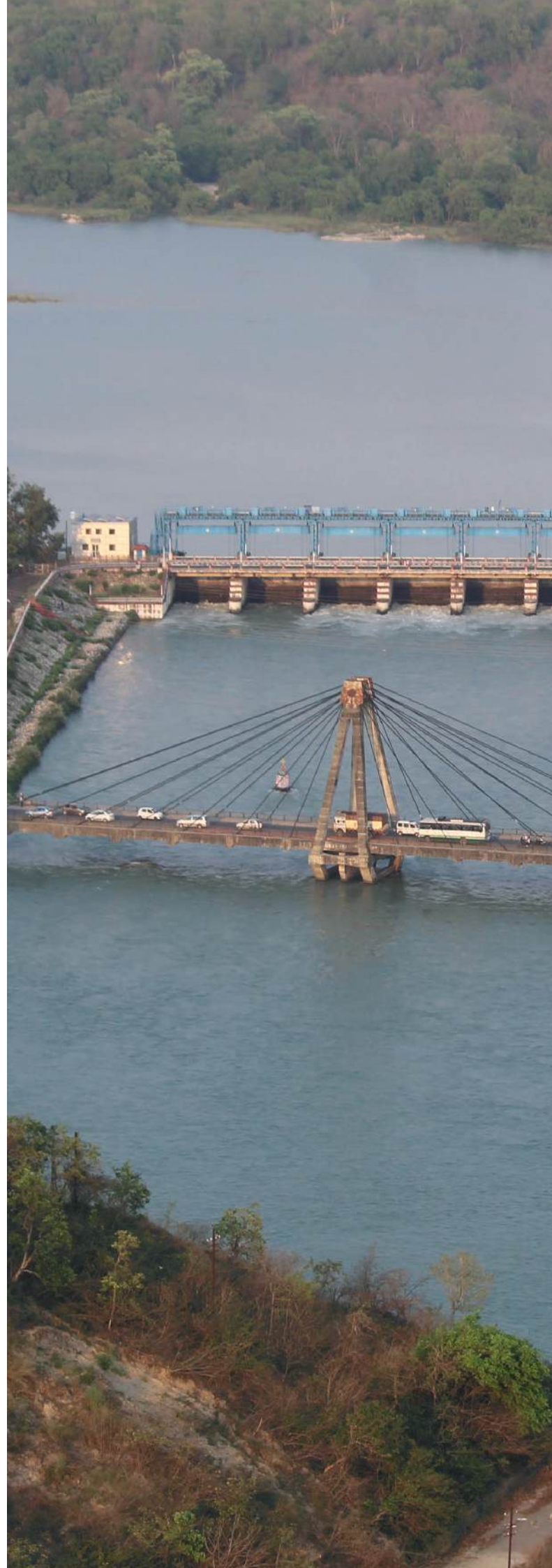
|              |                                                          |
|--------------|----------------------------------------------------------|
| NCR          | National Capital Region                                  |
| NIH Roorkee  | National Institute of Hydrology, Roorkee                 |
| NMCG         | National Mission for Clean Ganga                         |
| NTPC         | National Thermal Power Corporation                       |
| NTU          | Nephelometric Turbidity Unit                             |
| pH           | Potential of Hydrogen                                    |
| PSI Dehradun | People's Science Institute, Dehradun                     |
| RHC          | River Health Class                                       |
| RRBMP        | Ramganga River Basin Management Plan                     |
| SDGs         | Sustainable Development Goals                            |
| sq. km       | Square Kilometer                                         |
| TDS          | Total Dissolved Solids                                   |
| U/S          | Upstream                                                 |
| UP           | Uttar Pradesh                                            |
| UP PIM Act   | Uttar Pradesh Participatory Irrigation Management Act    |
| UP SWaRA     | Uttar Pradesh State Water Resources Agency               |
| UP WaMReC    | Uttar Pradesh Water Management and Regulatory Commission |
| UPI&WRD      | Uttar Pradesh Irrigation & Water Resources Department    |
| UPJVNL       | Uttar Pradesh Jal Vidyut Nigam Limited                   |
| w/dmax       | Width-Maximum Depth Ratio                                |
| WUA          | Water Users Association                                  |
| WWF-India    | World Wide Fund for Nature-India                         |



# ANNEXURES

- 1A Homogenous Zonation Report – Sharda River
- 1B Homogenous Zonation Report – Ghaghra River
- 1C Homogenous Zonation Report – Gomti River
- 1D Homogenous Zonation Report – Rapti River
- 1E Homogenous Zonation Report – Yamuna River
- 2 Cross Sections and Hydraulics Modelling Reports
- 3 Starter Documents – Fluvial Geomorphology
- 4 Starter Documents – Aquatic Biodiversity  
(mainly fishes and Ganga river dolphin)
- 5 Starter Documents – Socio-cultural Aspects

All the annexures can be accessed at  
<https://bit.ly/49mzlii>











# Executive Summary

## Context

***Ganga River Basin Management Plan defines E-Flows "as a regime of flows in a river or stream that describes the temporal and spatial variation in quantity and quality of water required for freshwater as well as estuarine systems to perform their natural ecological functions (including sediment transport) and support the spiritual, cultural and livelihood activities that depend on these ecosystems".***

Rivers are the lifeline of the landscapes that they pass through. Nature, human beings and other biotic and abiotic components draw valuable ecosystem services from rivers. A healthy river is critical to sustain water security, reduce flood-risk and provide ecosystem services for people and nature, benefiting the economy of the land it flows through.

It is well known that the growing demand for water is leading to increased water abstraction from various resources like rivers, aquifers, wetlands, etc. leaving them stressed and polluted. Water from rivers is diverted for various purposes like irrigation, domestic supply, industrial and commercial use. While this is much needed for the well-being of people and economic development, there is a need to address the deteriorating state of rivers as a result of this over-abstraction.

In order to contain the adverse impact of water diversion and use on a river, it is important to ensure a conducive flows regime to maintain the health of the river, especially from the perspective of water quantity. Therefore, the assessment of Environmental Flows (E-Flows) and its maintenance is essential, so that a river can remain and continue to exist as a healthy freshwater entity. On the other hand, pollution in water bodies is a critical issue that needs to be dealt with at source.

The necessity of E-Flows has been advocated in the National Water Policy 2012, and later on through the National Mission for Clean Ganga Authority Notification 2016 (07 October 2016), and Gazette Order on Ganga E-Flows 2018 (09 October 2018). The Ministry of Jal Shakti – Government of India, as part of the Ganga E- Flows Order, stipulated E-Flows that need to be maintained downstream of various dams and barrages on the Ganga River.



The critical stretch of Ganga River passes through the state of Uttar Pradesh, from Bijnor in Western Uttar Pradesh to Balia in Eastern Uttar Pradesh. In fact, various major diversion structures are managed by the Uttar Pradesh Irrigation & Water Resources Department (UPI&WRD), including Bhimgoda Barrage in Haridwar, Madhya Ganga Barrage in Bijnor, Narora Barrage in Bulandshahr, Lav-Kush Barrage in Kanpur. These structures are largely meant for irrigation (except Lav-Kush Barrage in Kanpur), with some allocation for industrial and domestic purposes. It is in this context, that the E-Flows maintenance in the Ganga River is critical. It would not only ensure the wholesomeness of the river, but also allow the river to extend ecosystem services to nature (such as providing conducive habitat conditions for aquatic life and support for other terrestrial life forms) and to human beings (such as fulfilling socio-cultural aspirations and subsistence of livelihood).

The Ganga River is joined by numerous tributaries or sub-tributaries, and their convergence significantly contributes to the Ganga's strength. Many of these tributaries are major rivers in their own right, including Sharda, Ghaghra, Saryu, Gomti, Rapti, Yamuna, Ramganga, Gandak, and Sone. Consequently, maintaining the health of these rivers becomes pivotal for the overall rejuvenation of the Ganga.

Moreover, these tributaries hold socio-cultural importance, exemplified by the Yamuna River's significance for Mathura-Vrindavan, the Ghaghra-Saryu River's relevance for Ayodhya and Dohrighat, the Rapti River's importance for Gorakhpur, the Gomti River's cultural value for Lucknow, and the Ramganga River's significance for Chaubari-Bareilly and Katghar-Moradabad.

However, urbanization has led to increased pressure on rivers like Gomti and Ramganga due to the presence of cities and towns along their banks. Additionally, various challenges, including diversions and obstructions, negatively impact the health of rivers such as Sharda, Ramganga, Yamuna, Sone, Gandak, Gomti, Rapti, and Ghaghra. Hence, addressing these issues is crucial for the sustainable well-being of these water bodies and, consequently, the Ganga River.

Besides this, the Ganga River and its aforementioned tributaries, which are also regarded as major rivers of Uttar Pradesh, support millions of people that live on its banks. Several major districts and cities (Meerut, National Capital Region of Delhi, Mathura, Agra, Kanpur, Prayagraj, Varanasi, Lucknow, Moradabad and others) are largely dependent on the water resources of these rivers. Millions of villagers are also dependent on the Ganga River system for their day-to-day activities and socio-cultural activities.

Ecologically, the Ganga River and many of these tributaries are an abode to many iconic aquatic life forms, including India's National Aquatic Animal the Ganga river dolphin (*Platanista gangetica*), gharial, otter and some species of Indian major carps. In addition to that, the Ganga River and many of these rivers pass through various Protected Areas (National Parks and Wildlife Sanctuaries) and are therefore the lifeline of the terrestrial wildlife (tiger, elephant, deer and so on). Some of the notable Protected Areas include Upper Ganga Ramsar stretch, Hastinapur Wildlife Sanctuary, Corbett National Park, Pilibhit Tiger Reserve, Dudhwa Tiger Reserve, and Katarniaghat Wildlife Sanctuary. It is in this context that the conservation of these rivers is critical. Therefore, the maintenance of a conducive flows regime (E-Flows), arrived at through a robust socio-technical and scientific process, is critical.



## About This Study

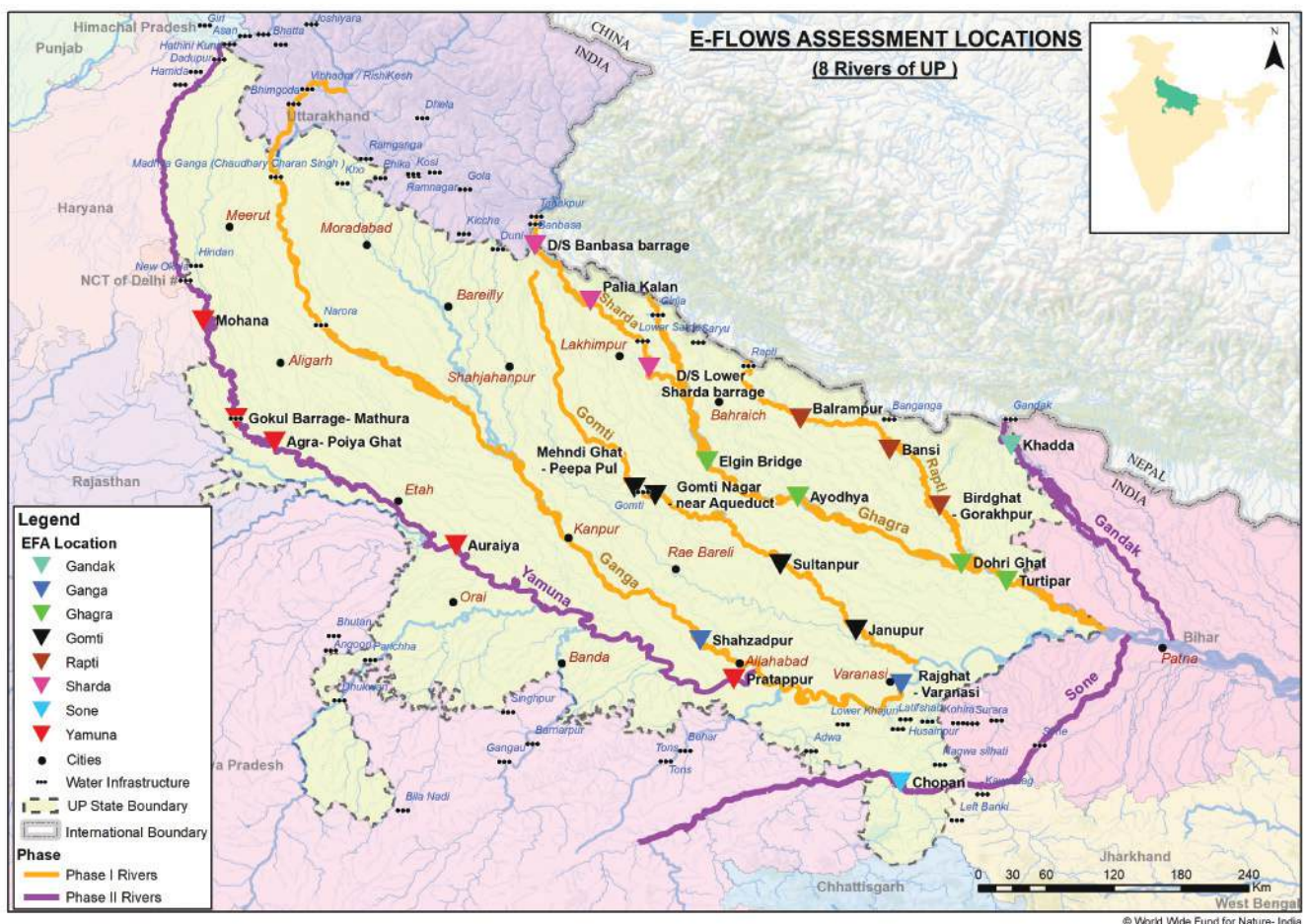
Uttar Pradesh State Water Resources Agency (UP SWaRA), which is a technical secretariat of Uttar Pradesh Water Management and Regulatory Commission (UP WaMReC) has developed River Basin Management Plans for all major rivers in the state of Uttar Pradesh. These basin management plans focus on water resources, its allocation, management and sectoral utilization. With an objective to enrich this exercise and develop an understanding about Environmental Flows (E-Flows) requirements for these major rivers across critical locations, the Uttar Pradesh Water Management and Regulatory Commission (UP WaMReC) has partnered with World Wide Fund for Nature-India (WWF-India) to conduct E-Flows assessments for all major rivers (Sharda, Ghaghra, Gomti, Rapti, Ganga, Ramganga, Yamuna, Gandak and Sone) of Uttar Pradesh. WWF-India has been working towards furthering the concept of E-Flows in river systems for the last 14 years. This E-Flows assessment for all major rivers of Uttar Pradesh is a unique opportunity to embed this concept into river management.

Since several institutions have already conducted E-Flows assessments in the Ganga River, it was agreed that under the current exercise, E-Flows assessment for the Ganga River would only be conducted at the key location of Shahzadpur and Rajghat in Varanasi. The E-Flows assessment for the Ramganga River had already been undertaken by WWF-India along with partners between 2013-15. The findings have already been shared as part of the Ramganga River Basin Management Plan (RRBMP) and a separate report on Ramganga E-Flows, which was released by the then Hon'ble Irrigation Minister of Uttar Pradesh in September 2018.



Therefore, E-Flows assessment for over 460 km of Ramganga's total length in Uttar Pradesh already stands covered. So, out of nine major rivers of Uttar Pradesh, E-Flows assessment is required for eight rivers (including few locations on the Ganga River). Since the E-Flows assessment of so many major rivers is a complex task, it has been divided into two phases. In Phase-1, Rivers Sharda, Ghaghra, Gomti, Rapti and additional locations of Ganga have been taken up. In Phase-2, Rivers Yamuna, Gandak and Sone were taken up (Figure 1). The total length of these eight rivers is about 4630 kms within Uttar Pradesh. Out of that, E-Flows assessment for 17 locations, spread across over 3,620 km, has been carried out as part of Phase-1 rivers and the remaining length of over 1010 km of Phase-2 rivers was conducted for seven E-Flows locations.

In the Executive Summary, figures are provided to give an indication of the recommended Environmental Flows for the Maintenance Year (a normal hydrological year with flow patterns falling between extreme dry and wet condition).



**Figure 1: UP's major Rivers map with E-Flows locations marked on 8 rivers**

# Partnerships

This exercise has been undertaken in partnership with the following institutions, and aided by their input as described below:

- a. **Uttar Pradesh State Water Resources Agency (SWaRA) Lucknow:** Overall contextual guidance in regard to river systems and various E-Flows locations
- b. **Centre for Ganga River Basin Management Studies (cGanga), IIT Kanpur:** Cross Sections and Hydraulic Modelling inputs, led by Prof. Vinod Tare
- c. **Terraqua UAV, IIT Kanpur:** This firm is incubated within IIT Kanpur and has provided support for the initiative with Fluvial Geomorphology inputs, led by Prof. Rajiv Sinha
- d. **ICAR-National Bureau of Fish Genetic Resources (ICAR-NBFGR), Lucknow:** Support for aquatic biodiversity inputs (mainly fishes) with contributions from Dr Kuldeep K. Lal, Dr K.D. Joshi, Dr Rajesh Dayal and Mr Priyam Nath with Dr Mohammad Alam (WWF-India)
- e. **People's Science Institute (PSI), Dehradun:** Inputs pertaining to socio-cultural and livelihood aspects, led by Dr Anil Gautam and Ms Chicu Loggariwar, under the guidance of Dr Ravi Chopra
- f. **WWF-India:** Responsible for conceptualizing and conducting the exercise, including E-Flows assessment inputs, overall coordination and management of the study, along with technical inputs from in-house experts







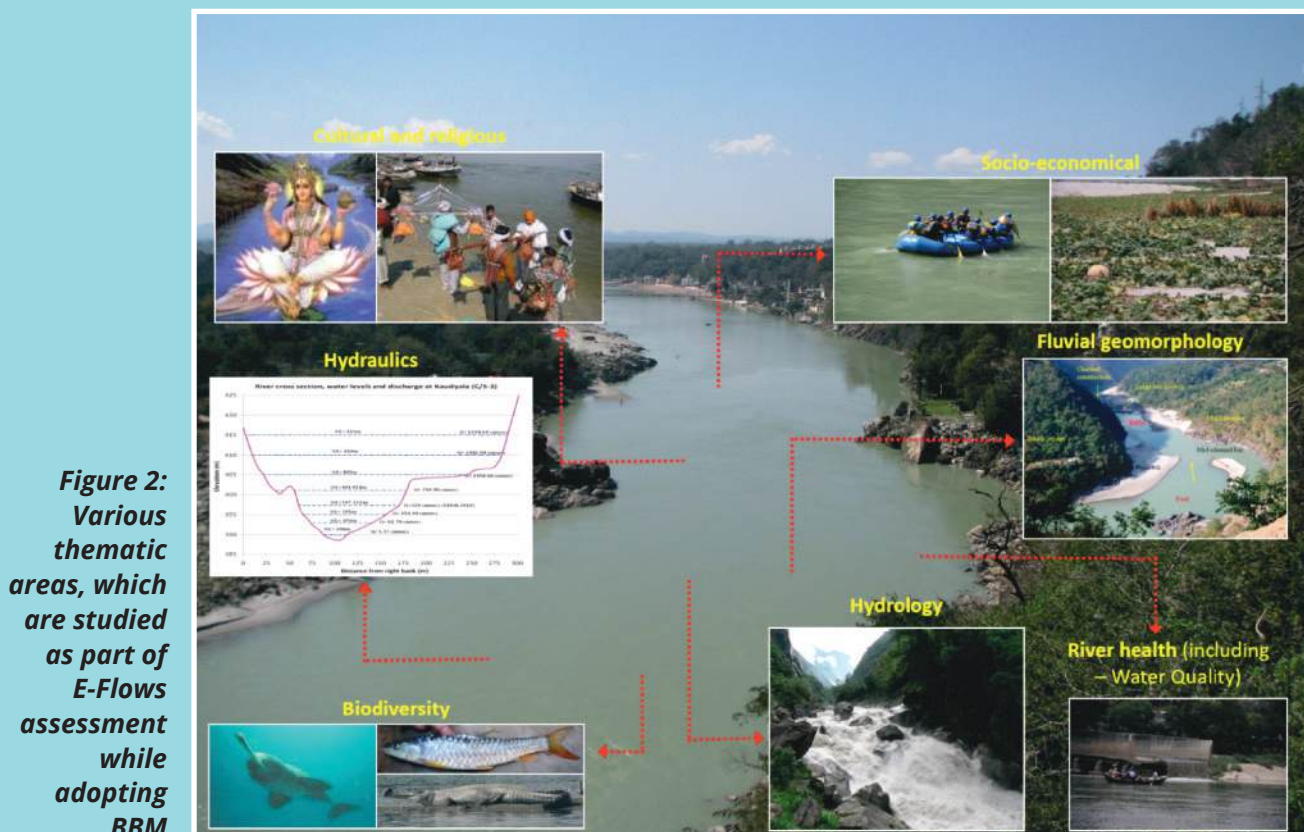


# Environmental Flows (E-Flows) Assessment Process

WWF-India and its partners adopted the globally-known and well-accepted Building Block Methodology (BBM), which is one of the holistic methodologies for E-Flows assessment. This methodology allows the user to combine assessment of all critical functions, processes, aspirations (associated with the river) into the E-Flows assessment, besides integration of local requirements (socio-cultural and socio-economical, including subsistence livelihood). This multidisciplinary exercise calls for a thorough understanding of various critical thematic areas, including-hydrology, hydraulics, fluvial geomorphology, aquatic biodiversity, socio-cultural and livelihood aspects and river health. This is illustrated in Figure 2.

Before the start of these field-based thematic assessments, a desktop study of dividing the river into homogenous zones was undertaken. The zonation for a river is done based on the following parameters, i.e.:

- Elevation
- Tributary confluence
- Major towns or cities
- Industrial activities
- Gauge and discharge monitoring stations
- Agro-climatic zones
- Temperature zones
- Land Use Land Cover (LULC)
- Precipitation





This homogenous zonation is essentially a scoping study, assessing the number of homogenous zones in the rivers which helps to identify potential E-Flows locations to carry out detailed thematic studies.

With this clarity on zones and E-Flows locations, the thematic surveys were conducted. With a thorough understanding of all the thematic aspects, the flows motivations for specific E-Flows locations were discussed and deliberated upon within the team. This deliberation led to a consensus, i.e., specific water levels desired to sustain all the required functions, processes and aspirations were decided for both wet and dry seasons at a particular E-Flows location. Later on, these seasonal water levels (depth) values were converted into flows mimicking the national flow patterns to arrive at the E-Flows recommendations in terms of flow rate (cubic meter per second).



# E-Flows motivations – Reasoning for E-Flows Requirements

Knowledge of hydrology and hydraulics forms the backbone of any E-Flows assessment exercise. Thematic areas like fluvial geomorphology, aquatic biodiversity, socio-cultural and livelihood aspects motivate or suggest the desired flows at various locations of a river.

Fluvial geomorphology considers longitudinal, lateral and vertical connectivity along with planform<sup>1</sup> dynamics and sediment movements as their critical parameters while motivating E-Flows. However, for aquatic biodiversity, the flagship species, Vulnerable, Threatened, Near Threatened status of species, native species, flows and water-level sensitive species are the prime motivations for E-Flows. The socio-cultural and livelihood thematic area considers societal interactions with the river, in terms of cultural rituals (bathing, worshipping, other auspicious activities). This thematic also considers aesthetic value of the river along with non-consumptive subsistence livelihood aspects such as boating, fishing, selling of offering material for socio-cultural activities, etc.

The E-Flows recommendations are given for two scenarios, i.e. Maintenance Year (a normal hydro-meteorological year) and Drought Year.

- a. Maintenance Year: This is considered a normal hydro-meteorological year-with average precipitation and flows during the last 30 years. During such years, various river processes and functions need to be comfortably met. The river-related socio-cultural aspirations of the people are also met during such years.
- b. Drought Year: This is an extreme condition for the river, but still certain fundamental river-centric functions, processes and societal aspirations are required to be met, to save the collapse of the riverine ecosystem.

In a Maintenance Year or in a Drought Year, there are two key months, i.e. Driest Month and Wettest Month. These are used for motivations and development of E-Flows regimes. However, these specific months vary from river to river, depending upon the water source i.e. snow/glacier-fed, rain-fed, spring/aquifer-fed, base-flows conditions and flow regulations.

Globally and nationally, E-Flows is an evolving area of science, and efforts are made to constantly learn and improve the processes and various steps in assessment. During E-Flows assessment process every effort was made by SWaRA and WWF-India to make use of all the available hydrological information for this exercise. However, for certain locations, there was a lack of reliable hydrological and hydraulic information especially the hydraulic gauge-discharge

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<sup>1</sup> The planform of a river reflects the quasi-equilibrium form of a channel in response to concentration/dissipation of energy and associated transfer and storage of sediment



data, which at certain water-level ranges provided a very wide band of erroneous discharge values. This resulted in difficulties in calibrating the hydraulic models which were used for arriving at E-Flows recommendations. Generally, provided as monthly temporal variations over a year (discharges per unit time, i.e. in terms of m<sup>3</sup>/sec or cumec), sometimes due to various local issues or data limitations, the water levels/hydraulic depths across the river cross section are recommended. Efforts should be made to constantly improve river flows monitoring mechanisms, not only for better-informed future studies, but also for revisiting and updating the past recommendations around E- Flows values. As a result of these factors and other local complexities, out of 23 E-Flows locations across eight rivers, the water levels/depth were recommended for seven locations.

These seven locations are:

- a. Sharda River - Downstream of Banbasa Barrage
- b. Sharda River - Downstream of Sharda Barrage
- c. Ghaghra River - Dohri Ghat
- d. Gomti River - Mehndi Ghat (Upstream of Gomti Barrage in Lucknow)
- e. Ganga River - Rajghat Varanasi
- f. Khadda – Gandak River
- g. Chopan – Sone River

For all other sites, the E-Flows requirements as discharges (cubic meter per second, m<sup>3</sup>/sec are recommended.

Another challenge arose due to the absence of extended temporal data on river flows, hindering the derivation of flow data for drought years in these river systems. This limitation posed difficulties for the team for formulating E-Flows recommendations for drought years due to unavailability of sufficient data. Consequently, to represent drought year E-Flows regime, long-term average observed flows from maintenance year was utilized as an upper limit.



## Sharda River

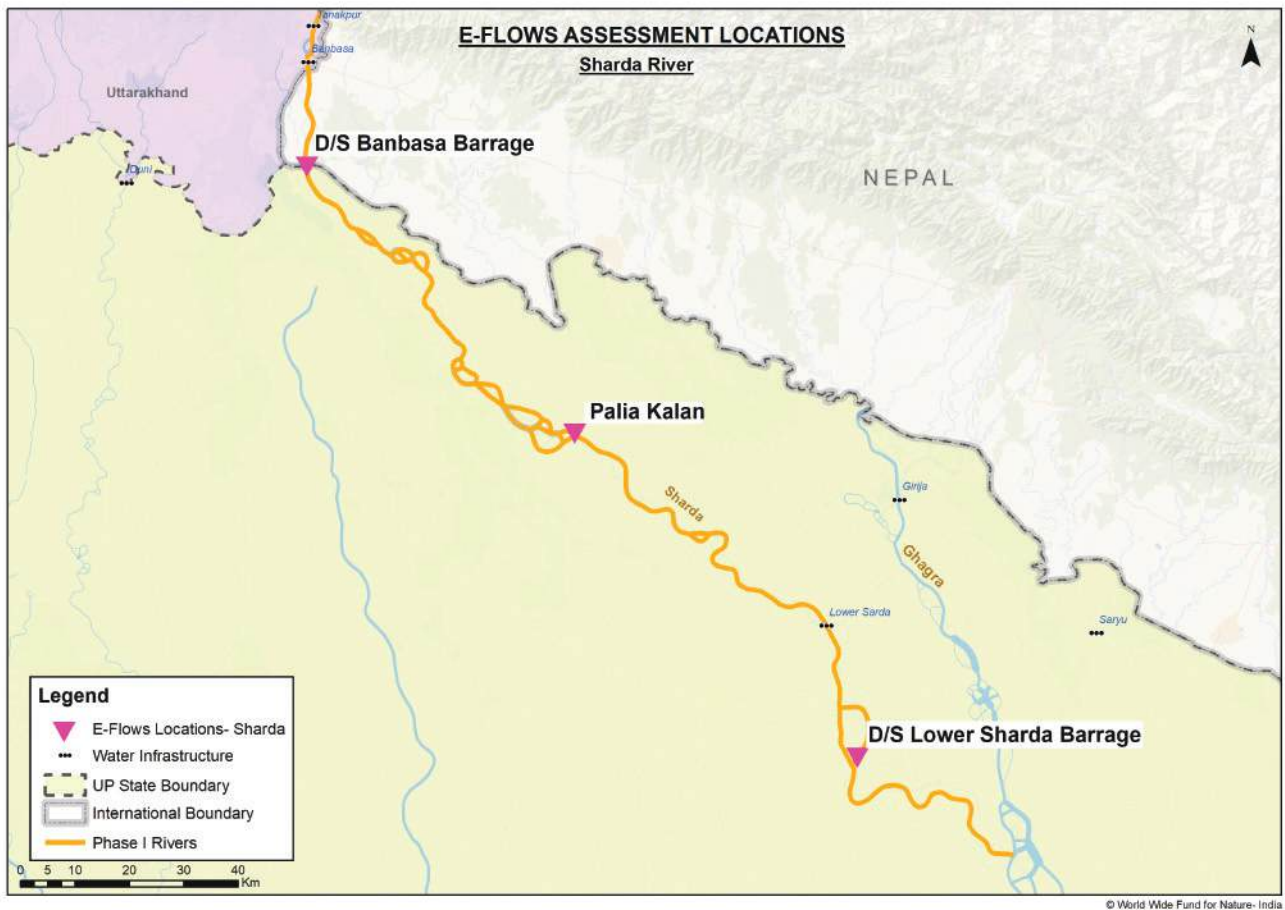
The Sharda River flows for over 260 km in the state of Uttar Pradesh. The magnitude of diversions, obstructions and present state of river health on the Sharda River make a clear case for maintaining E-Flows across the river. The E-Flows assessment was conducted at three locations on the Sharda River as given in Figure 3, where a total of 43 fish species were recorded. The upper Sharda River stretch is known as an abode for the golden mahseer (*Tor putitora*). This fish species was the prime motivation for flows recommendations for the location downstream of the Banbasa Barrage. But due to habitat changes and loss of connectivity, *T. putitora* is rarely sighted in this stretch. In addition, geomorphic and socio-cultural requirements also drove flows motivations for this location. The other two locations, Palia Kalan and downstream of the Lower Sharda Barrage, showed the presence of the Ganga river dolphins, making it the flow motivating species in these locations. Certain species of Indian major carps (IMCs), including – *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* were also reported/found at these two locations. It was stated that their hydraulic habitat requirements would be met, if the Ganga river dolphin's hydraulic habitat requirements were maintained.

As mentioned earlier, water levels (depth) have been recommended for two locations along the Sharda River and E-Flows recommended for one location– Palia Kalan.

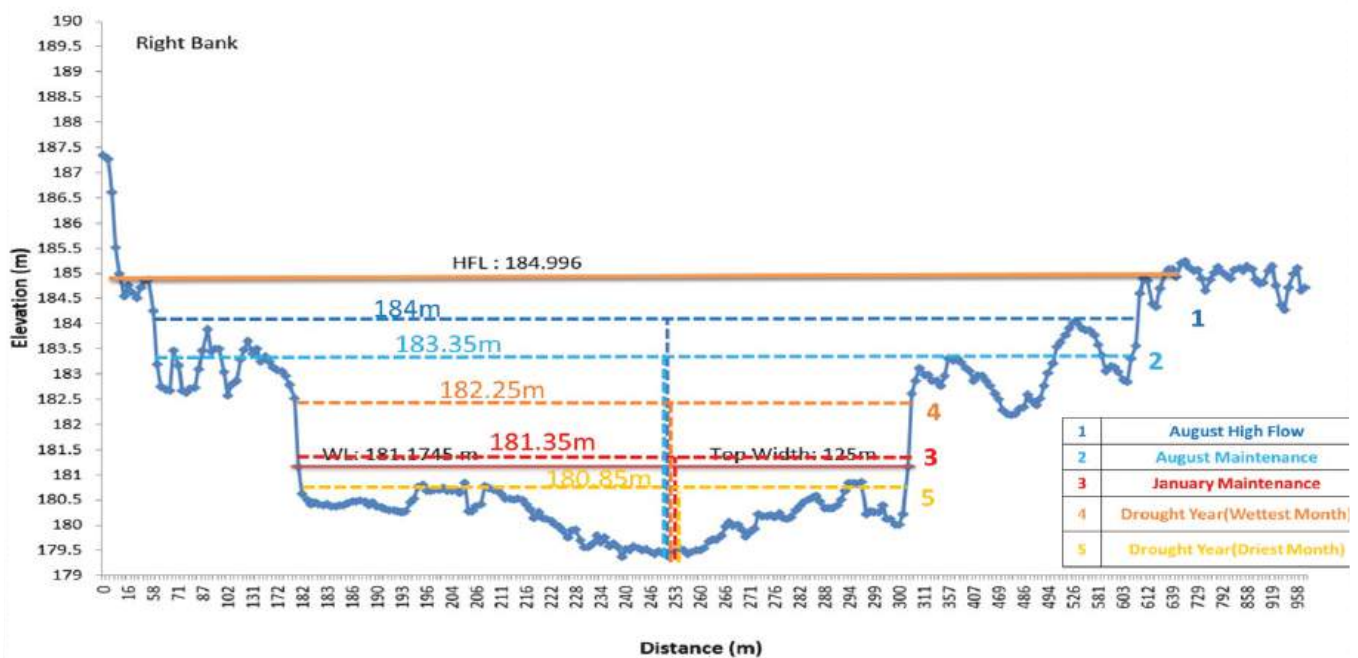
The Environmental Flows requirement, in terms of water levels (depth) for Downstream Banbasa Barrage is depicted in Figure 4. The recommended E-Flows for Palia Kalan is shown in Figure 5, and E-Flows requirements, in terms of water levels (depth) for Downstream of the Lower Sharda Barrage is shown in Figure 6.

It is worth mentioning here that all the depth recommendations (seasonal and thematic) is considered from the lowest elevation on the river channel bed.

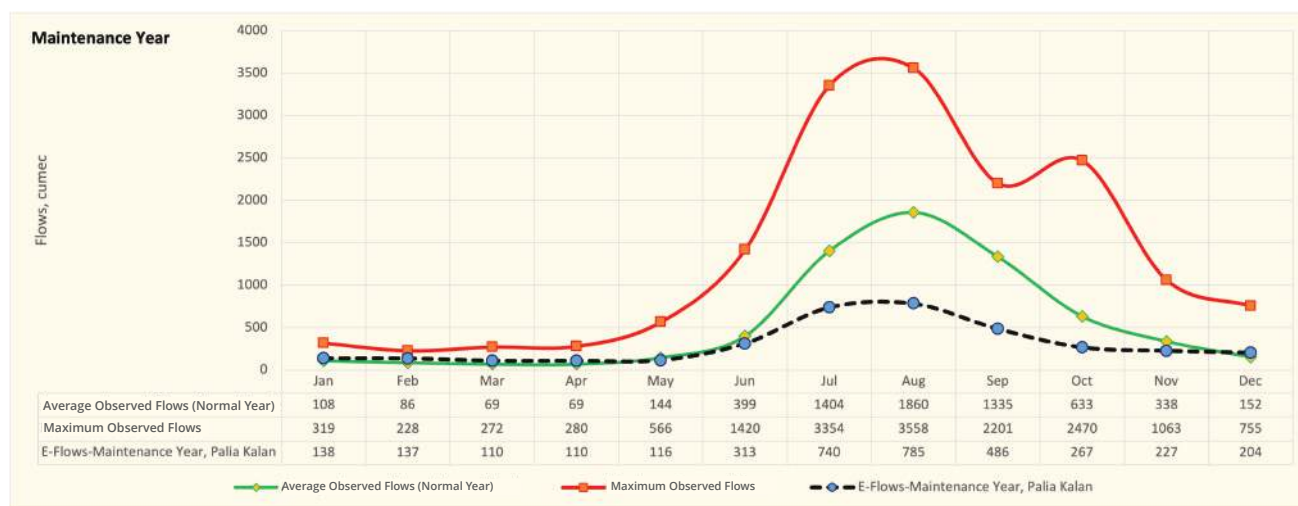




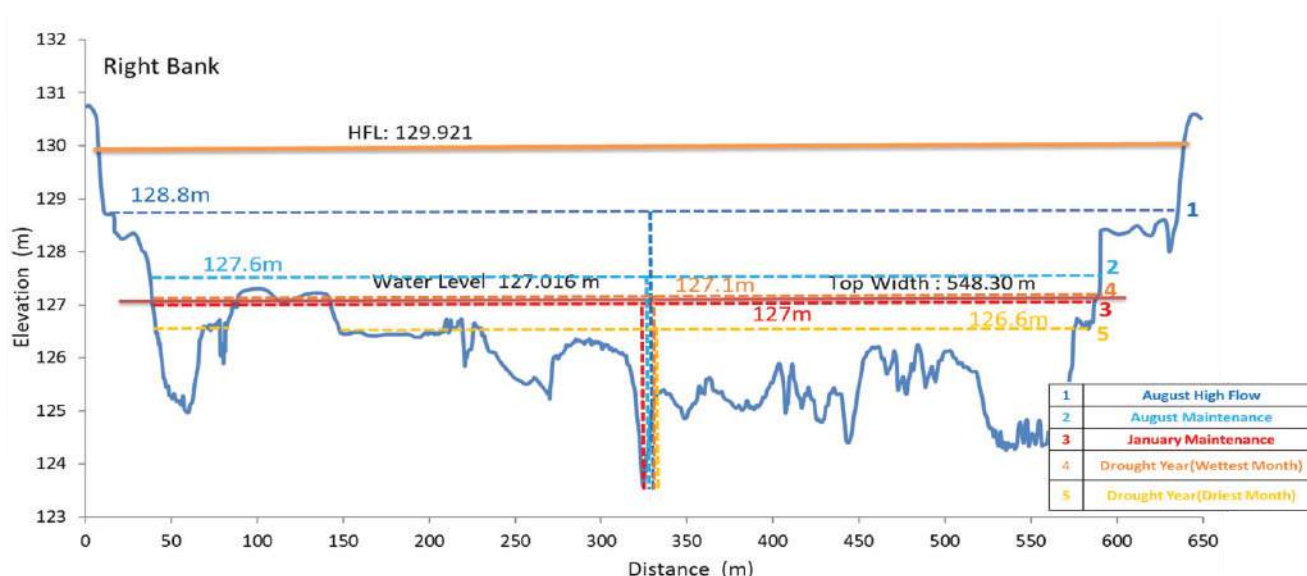
**Figure 3: Sharda River stretch and location of the E-Flows sites**



**Figure 4: Cross-section profile with water-levels/depth recommendations for both Maintenance Year and Drought Year for Downstream Banbasa Barrage E-Flows location on the Sharda River**



**Figure 5: E-Flows recommendations in a monthly flows pattern–Palia Kalan location (Maintenance Year)**



**Figure 6: Cross-section profile with water-levels/depth recommendations for Downstream Lower Sharda Barrage E-Flows location on the Sharda River**

Looking at the E-Flows graph of the Palia Kalan location, it can be inferred that the present-day average flows are unable to meet E-Flows requirements for the lean months from December to April.

The recommended depth and corresponding active channel width for all the sites are summarised below.

| River  | Name of Sites            | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|--------|--------------------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|        |                          | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|        |                          | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Sharda | D/S Banbasa barrage      | 2                | 125                  | 4          | 554                  | 1.5          | 118                  | 2.5        | 131                  |
|        | Palia Kalan              | 3.4              | 350                  | 4.8        | 510                  | 3            | 294                  | 3.8        | 480                  |
|        | D/S Lower Sharda barrage | 3.4              | 530                  | 4          | 535                  | 3            | 528                  | 3.5        | 3.5                  |

\*All values are in meters





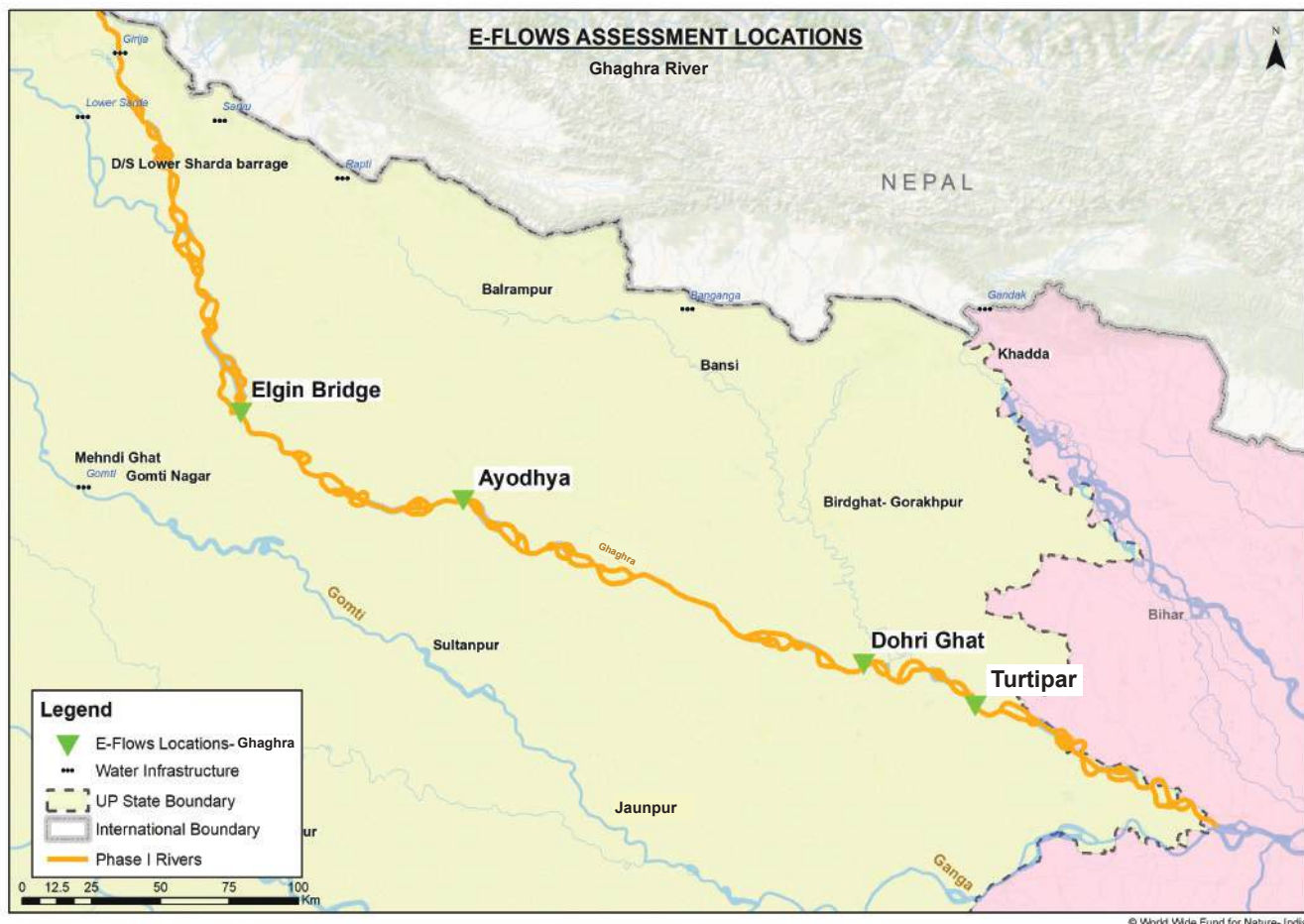
## Ghaghra River

The Ghaghra River flows for over 600 km in the state of Uttar Pradesh. It faces diversions and obstructions and therefore, E-Flows assessment is critical for this river. The E-Flows assessment was conducted for four locations along the Ghaghra River where presence of the Ganga river dolphin was reported. Therefore, for the aquatic biodiversity thematic, the prime motivation for these locations is the presence of the Ganga river dolphin. The desired flows or water levels at these locations would also maintain a healthy hydraulic habitat for IMCs (including – *Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*). Overall, about 40 fish species were recorded from these locations. The thematic groups like fluvial geomorphology concentrated on river channel morphology<sup>2</sup>, the socio-cultural group carefully looked at the requirements for cultural rituals at some of the most critical locations like Ayodhya and Dohri Ghat and flows from that perspective.

Out of the four locations on the Ghaghra River, E-Flows recommendations are given for three locations (as given in Figure 7), and water levels or depth is recommended for one location, i.e. Dohri Ghat.

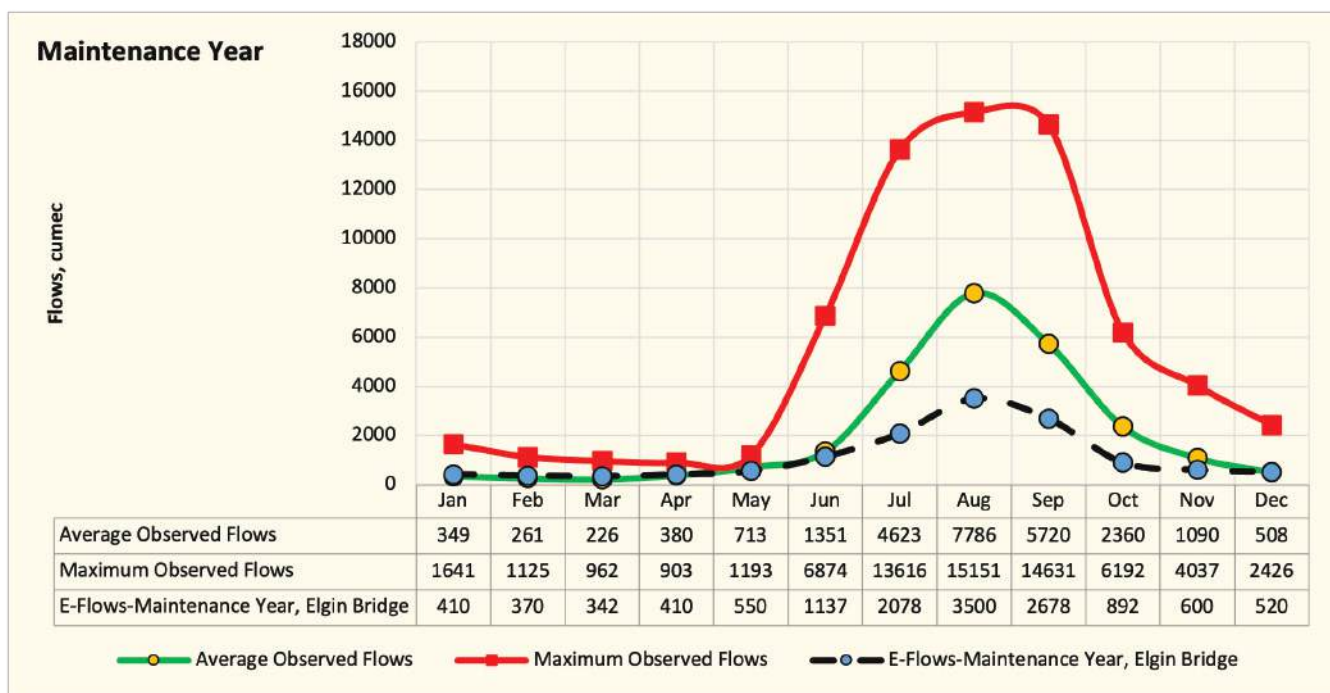
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<sup>2</sup>The morphology of a river channel is a function of a number of processes and geomorphic setting, including the composition and erodibility of the bed and banks (e.g., sand, clay, bedrock); erosion is facilitated by flow regime and stream power, and can change the river path through time, which is referred to as river dynamics



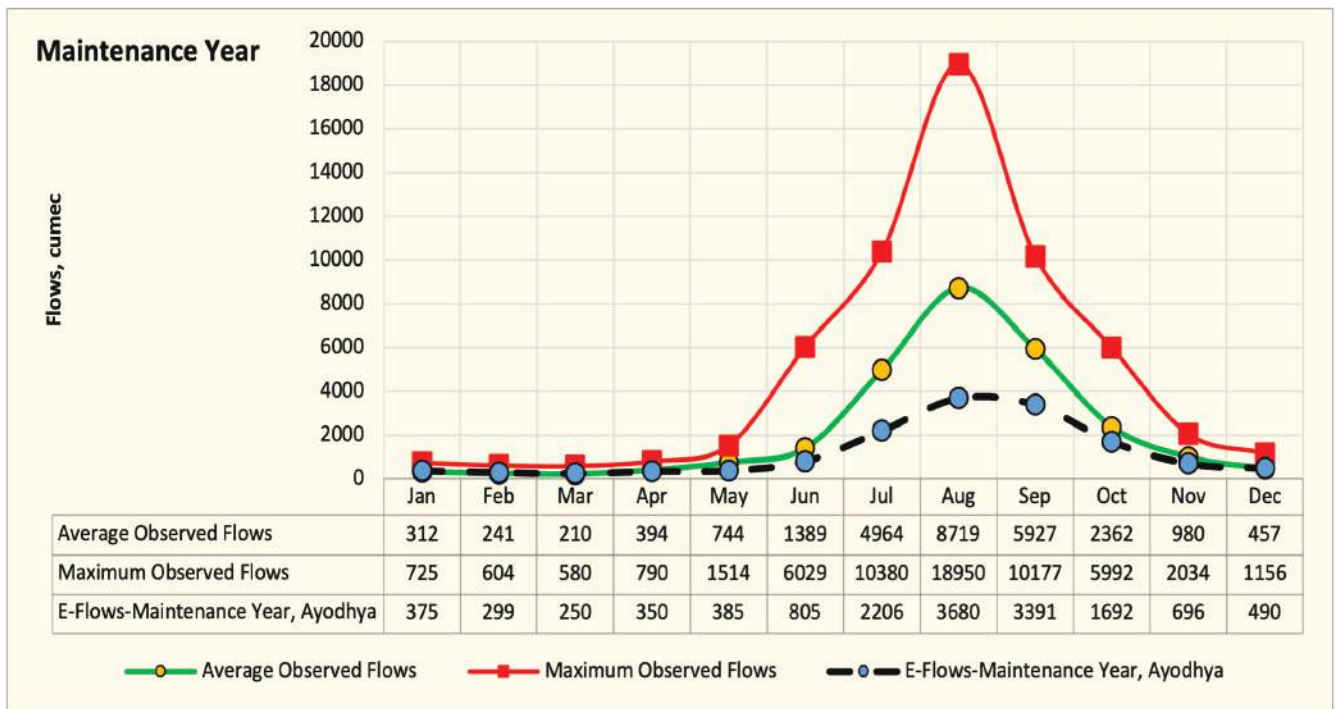
**Figure 7: Ghaghra River stretch and location of E-Flows sites**

The E-Flows recommendations for Elgin Bridge, Ayodhya, Dohri Ghat (water depth recommendations) and Turtipar are shown in Figure 8, Figure 9, Figure 10 and Figure 11, respectively.

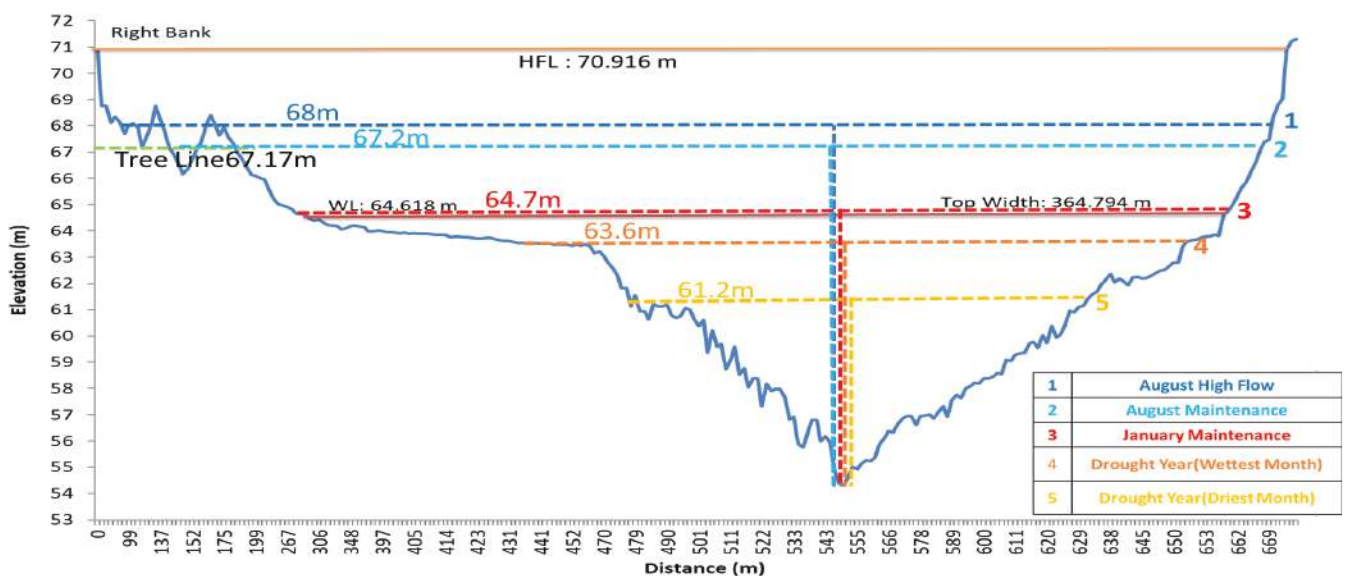


**Figure 8: E-Flows recommendations in a monthly flows pattern – Elgin Bridge location (Maintenance Year)**

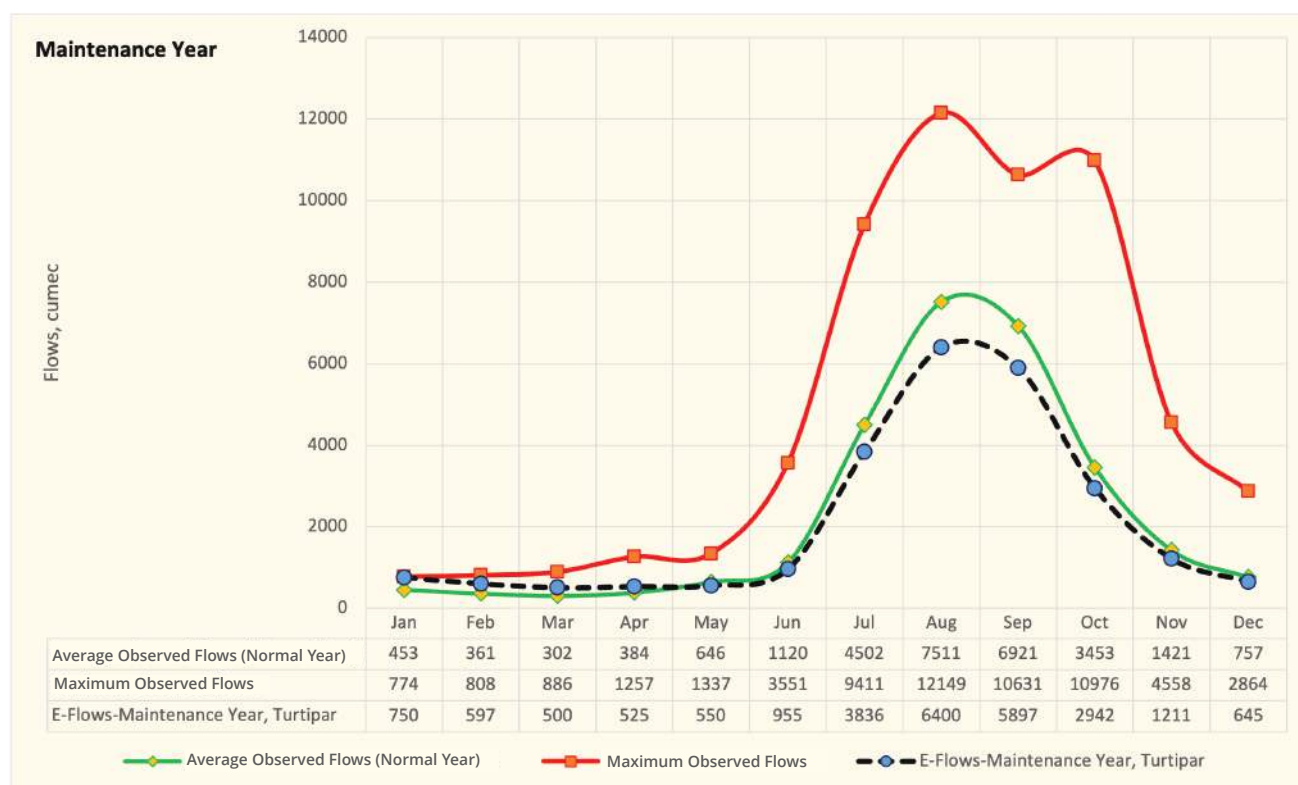




**Figure 9: E-Flows recommendations in a monthly flows pattern – Ayodhya location (Maintenance Year)**



**Figure 10: Cross-section profile with depth recommendations for the Dohri Ghat E-Flows location on the Ghaghra River**



**Figure 11: E-Flows recommendations in a monthly flows pattern – Turtipar location (Maintenance Year)**

Lean season flows was found to be an issue in the Ghaghra River, wherein the present day observed flows are lower than the recommended E-Flows. The wet season E-Flows were nearly achieved by the present-day observed wet-season flows.

The recommended depth and corresponding active channel width for all the sites are summarised below.

| River  | Name of Sites | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|--------|---------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|        |               | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|        |               | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Ghagra | Elgin Bridge  | 4.9              | 315                  | 9.5        | 910                  | 3.5          | 280                  | 6.2        | 505                  |
|        | Ayodhya       | 4.3              | 396                  | 8.6        | 508                  | 3.5          | 303                  | 7          | 479                  |
|        | Dohri Ghat    | 10.5             | 357                  | 13         | 528                  | 7            | 150                  | 9.4        | 211                  |
|        | Turtipar      | 4                | 390                  | 7.95       | 1044                 | 3            | 355                  | 6          | 651                  |

*\*All values are in meters*



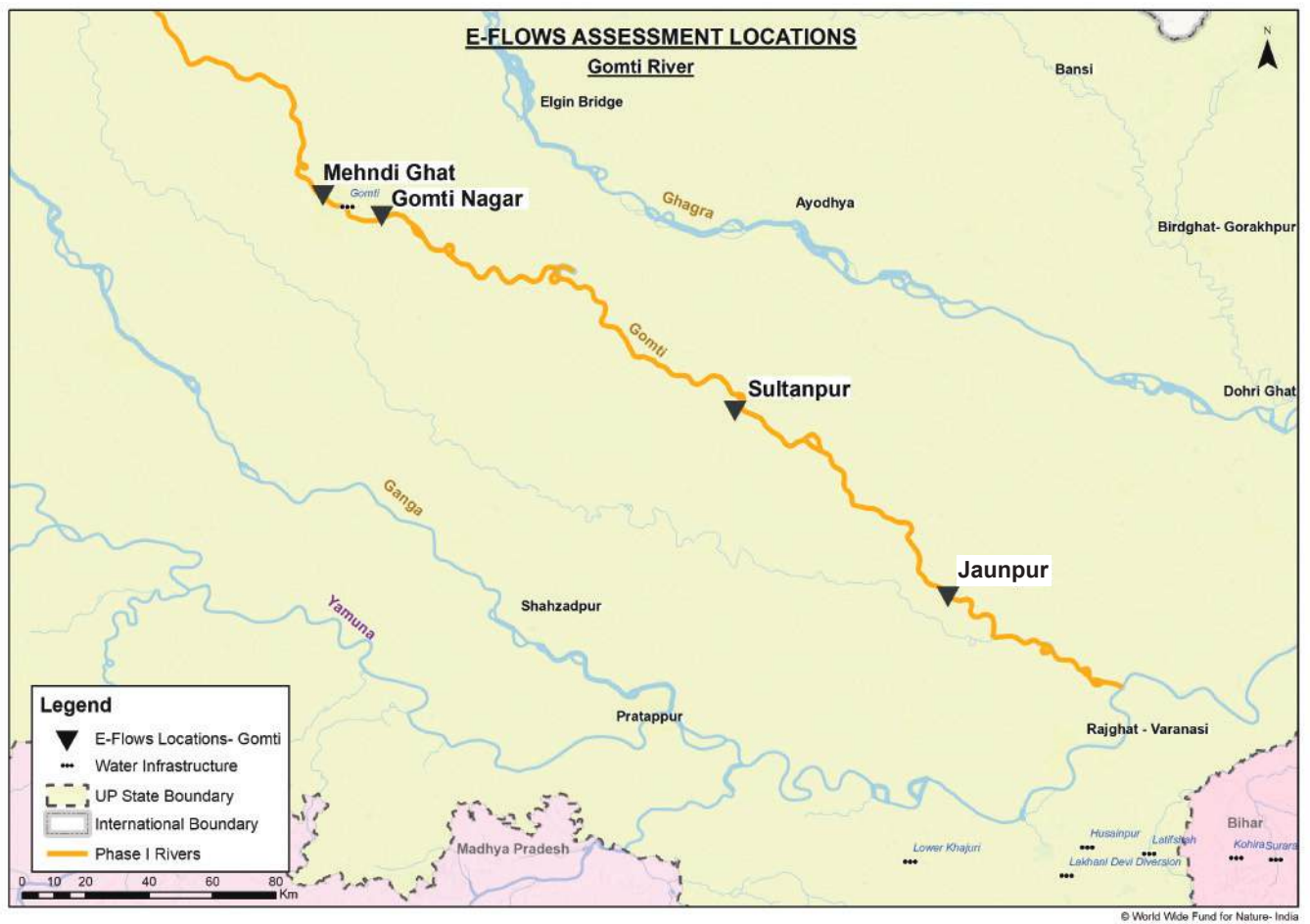


## Gomti River

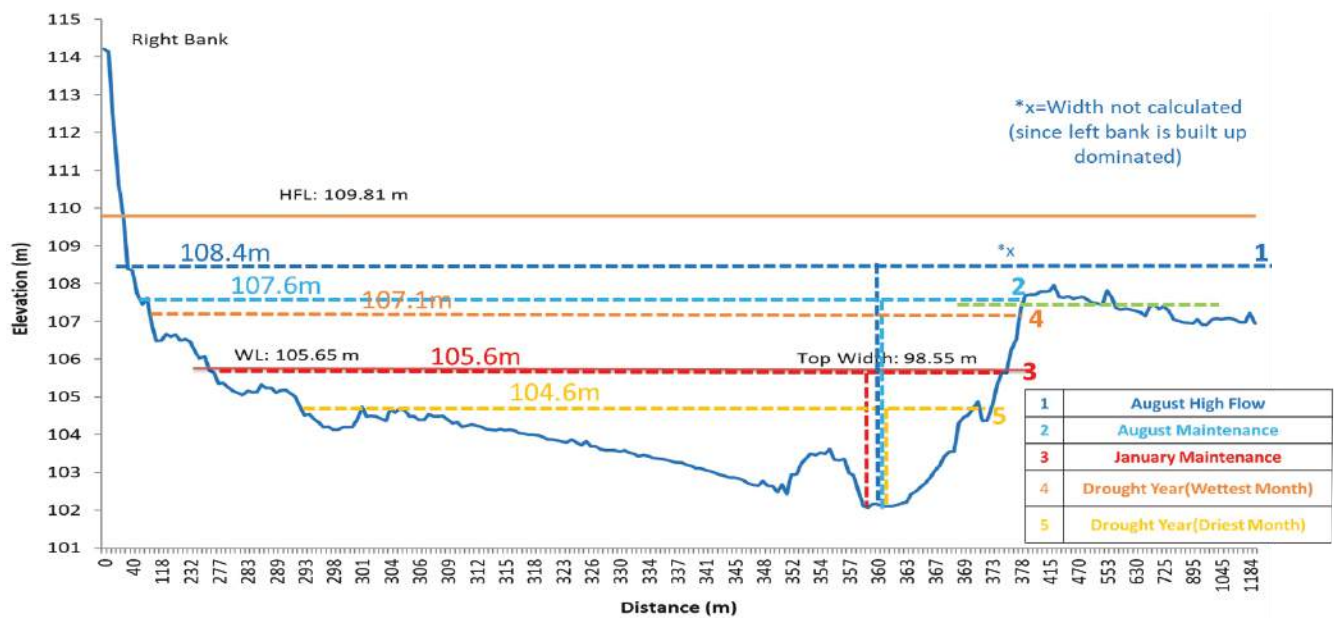
The entire stretch of the Gomti River flows through the state of Uttar Pradesh, covering over 940 km. The Gomti River is in a critical state and faces a host of challenges across all the stretches. The upper stretch faces floodplain encroachment, while the middle and lower stretches face pressure from pollution and excessive groundwater exploitation. The upper stretch of the river till Lucknow is relatively in better health, (in terms of water quality, flows, aquatic biodiversity) as compared to downstream of the city which is impacted by both pollution and lean flows due to over-abstractions.

Overall, 81 fish species were recorded from various E-Flows locations on the Gomti River, of which seven are exotic species. From the aquatic biodiversity perspective, the key concern was proliferation of invasive and hardy species in the river (owing to severely altered water-quality parameters and flows), and the main consideration was to provide conducive hydraulic habitat for Indian major carp (IMCs). The E-Flows recommendations from the aquatic biodiversity perspective are driven by the aspiration for the revival of IMC fish species and reduction of invasive hardy fish species.

The fluvial geomorphology group looked at the longitudinal and lateral connectivity, and sediment transport as their prime motivation for E-Flows. The socio-cultural group realised that the local communities have a primary problem with the water quality, while water quantity is a secondary concern. However the team fully recognizes that water quality is an important issue, it needs to be addressed separately. The realisation of proposed E-Flows recommendations (leading to improved water levels/depth) would help rejuvenate the river. Four E-Flows locations were selected for the Gomti River as given in Figure 12. For the first location Mehndi Ghat, water levels or depth as E-Flows have been recommended, as depicted in Figure 13. E-Flows recommendations have been made for the rest of the locations: Gomti Nagar near Indira Aqueduct (Figure 14), Sultanpur (Figure 15) and Jaunpur (Figure 16).



**Figure 12: Gomti River and location of the E-Flows sites**

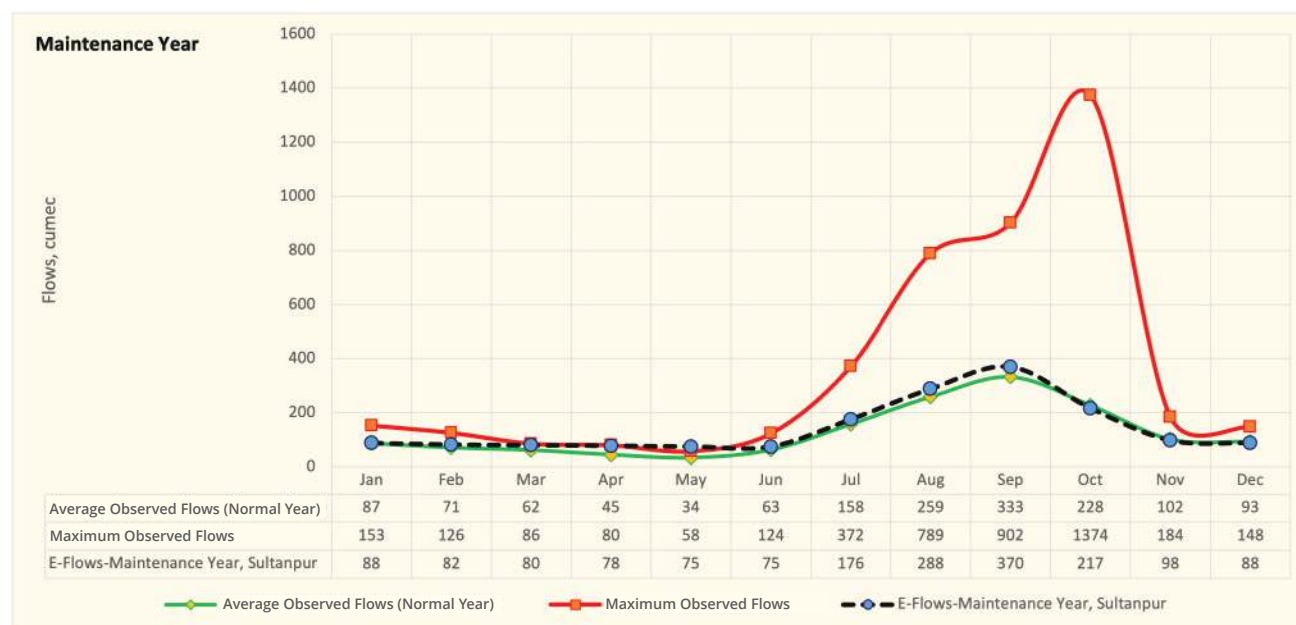


**Figure 13: Cross-section profile with water-levels/depth recommendations for the Mehndi Ghat E-Flows location on the Gomti River**

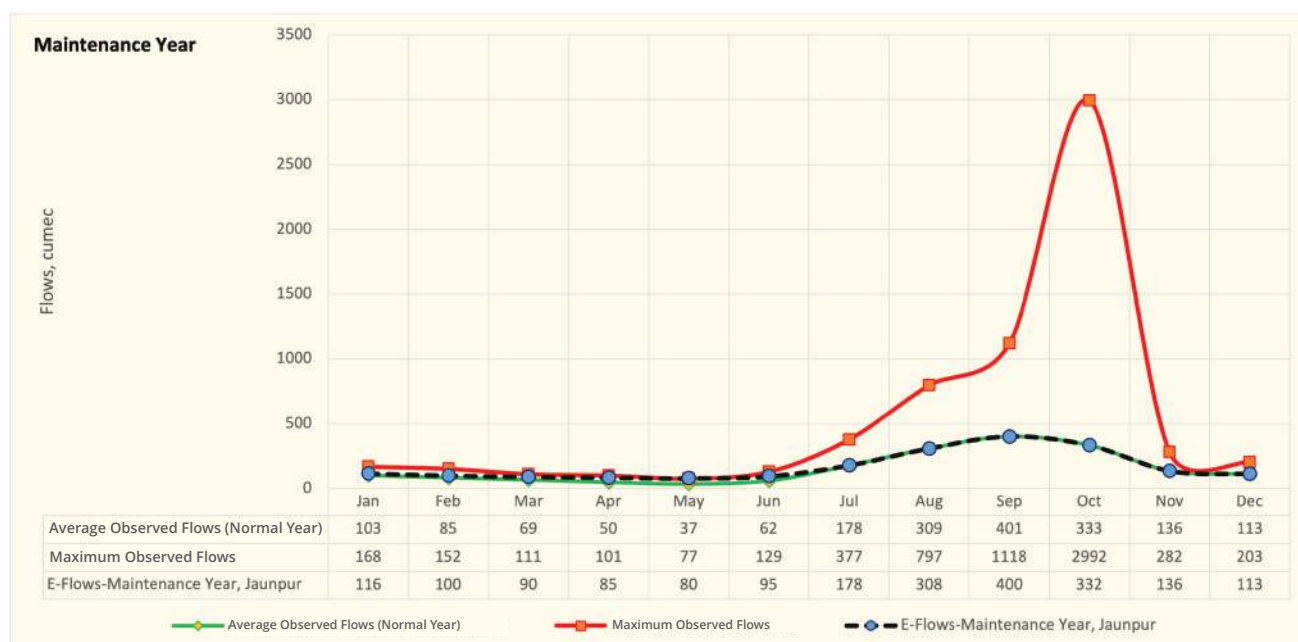




**Figure 14: E-Flows recommendations in a monthly flows pattern – Indira Aqueduct location (Maintenance Year)**



**Figure 15: E-Flows recommendations in a monthly flows pattern – Sultanpur location (Maintenance Year)**



**Figure 16: E-Flows recommendations in a monthly flows pattern – Jaunpur location (Maintenance Year)**

All thematic groups agreed that the Gomti River is in a deteriorated condition, and therefore, a suite of interventions would be required to improve the state of the river, with restoration of flows being one possible strategy. Water quality is another critical issue that needs to be dealt with separately. Nevertheless, maintaining E-Flows in the Gomti River would require complex and difficult decisions.

The E-Flows recommendations for the Gomti River, especially the first two locations, appear close to the present-day flows (especially in lean season). However, there is a huge difference as the present day flows are not satisfactory in terms of water quality and the E-Flows recommendations are made while considering that there is freshwater flow in the river. Therefore, its E-Flows recommendations should be seen in light of this critical factor.

The recommended depth and corresponding active channel width for all the sites are summarised below.

| River | Name of Sites             | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|-------|---------------------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|       |                           | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|       |                           | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Gomti | Mehndi Ghat*              | 3.5              | 125                  | 5.5        | 326                  | 2.5          | 80                   | 5          | 63                   |
|       | Gomti Nagar near Aqueduct | 2.5              | 60                   | 5.25       | 118                  | 2            | 47                   | 3.5        | 65                   |
|       | Sultanpur                 | 2                | 122                  | 4.2        | 141                  | 1.62         | 110                  | 3          | 127                  |
|       | Jaunpur                   | 2.75             | 101                  | 5          | 20                   | 2.3          | 92                   | 3.6        | 106                  |

\*All values are in meters

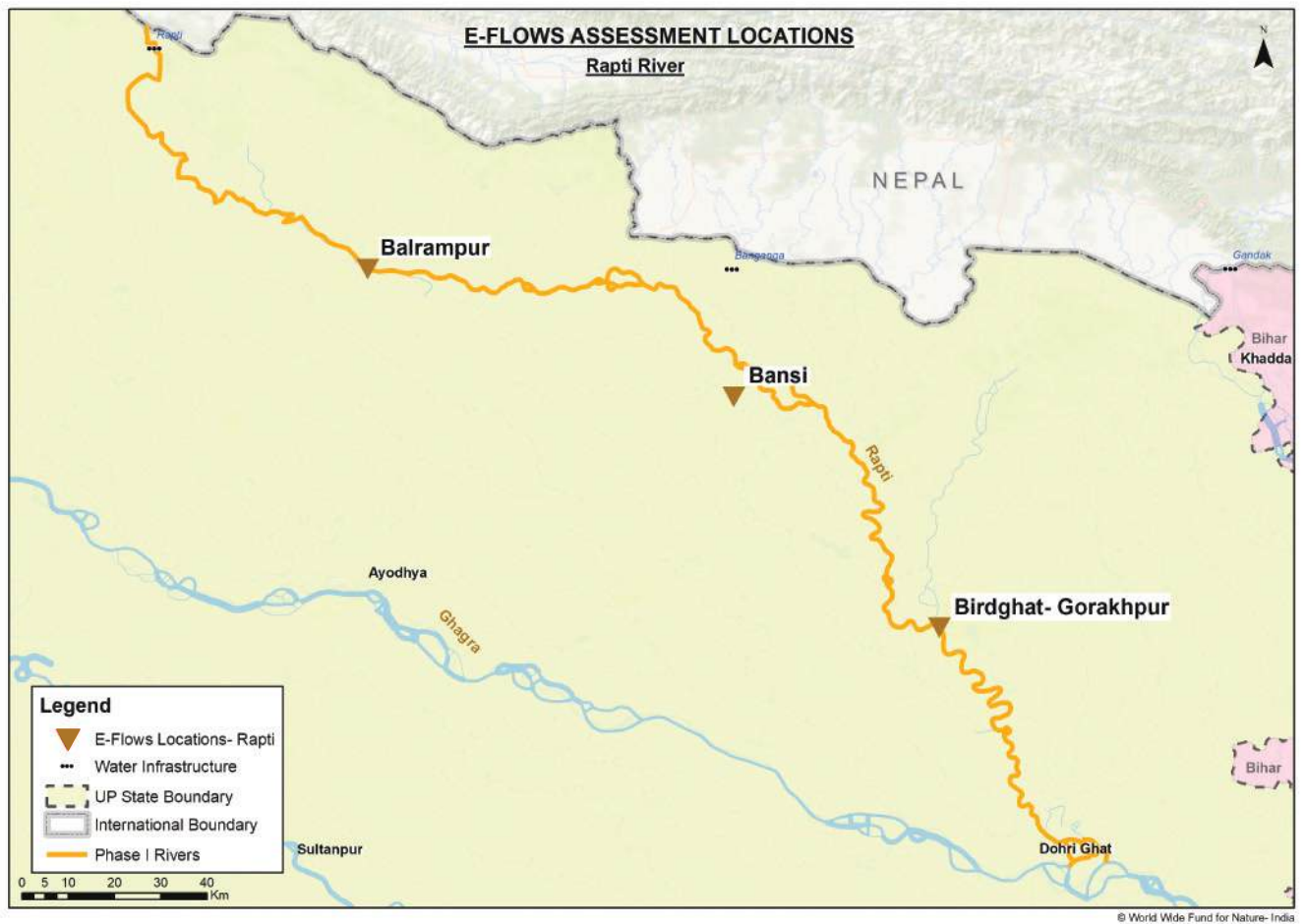




## Rapti River

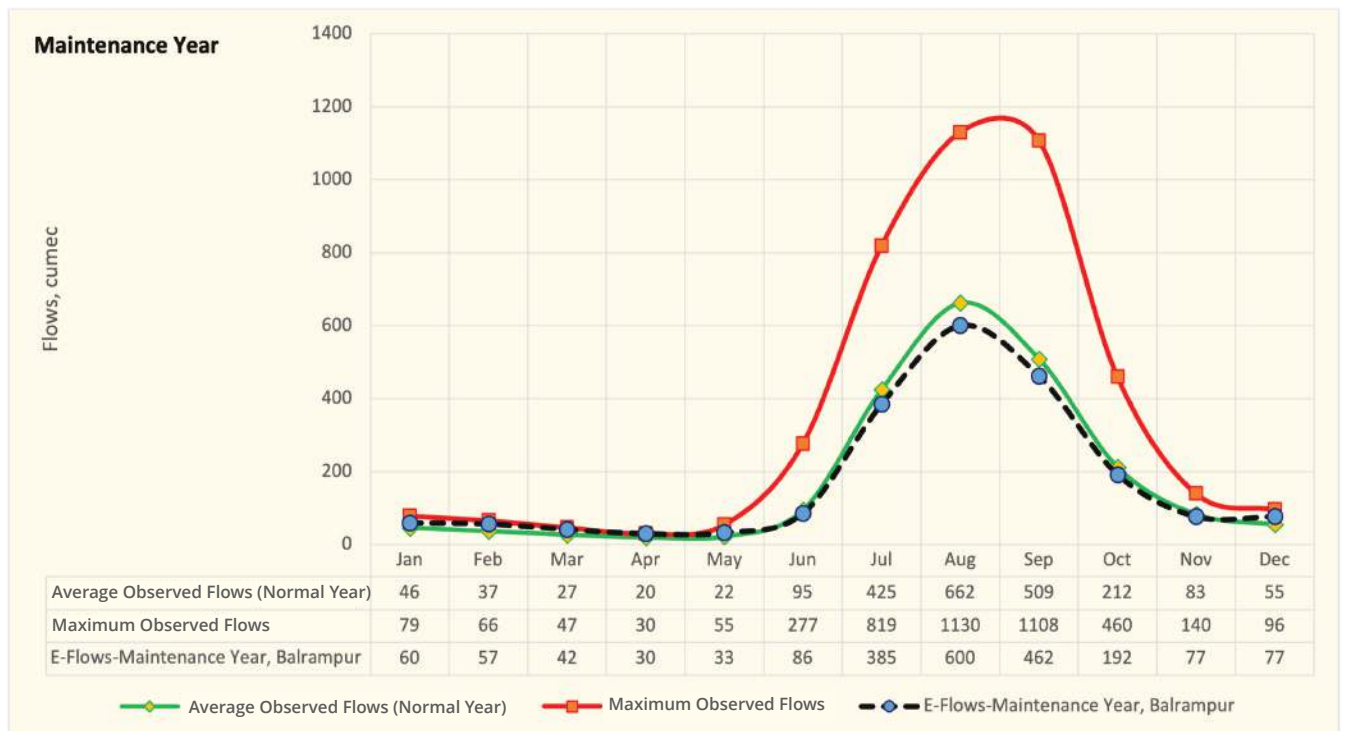
The Rapti River, a tributary of Ghaghra River flows for over 550 km in the state of Uttar Pradesh, is a typical meandering stream. The most prominent features of the lower Rapti floodplain are ox-bow lakes, alternative channel bars, flood chutes, point bars, swirl pit, swamps or marshes, natural levee, dry channel and branching streams. This makes it a geomorphologically healthy river. Three E-Flows locations were selected for the Rapti River as given in Figure 17. Over 49 fish species were recorded across all the three E-Flows locations. Socio-culturally, this river is crucial and Gorakhpur is one of the most important places from that perspective.

Most of the critical water-quality parameters falls within the permissible ranges across all the locations, indicating it to be a reasonably healthy river.



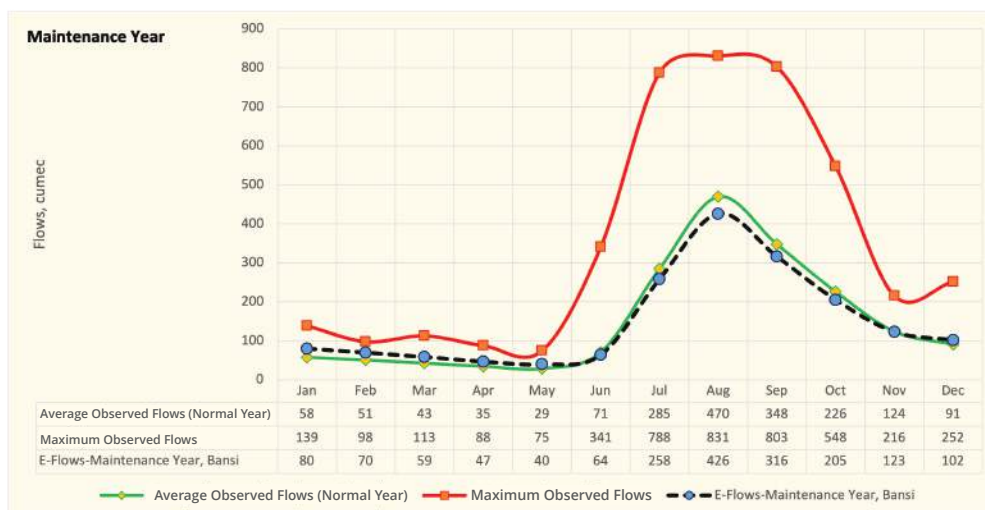
**Figure 17: Rapti River stretch with location of the E-Flows sites**

The E-Flows recommendations have been made for all three locations - Balrampur (Figure 18), Bansi (Figure 19) and Birdghat Gorakhpur (Figure 20).

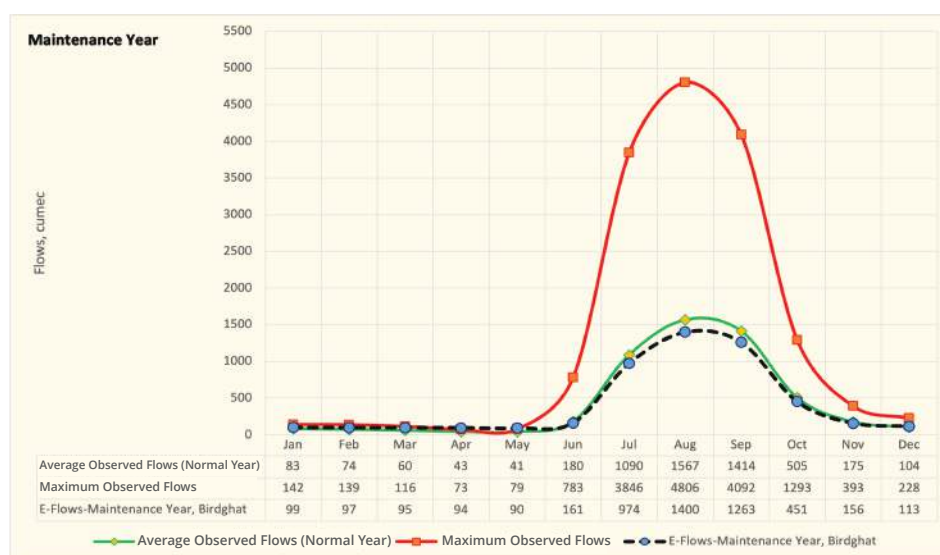


**Figure 18: E-Flows recommendations in a monthly flows pattern – Balrampur location (Maintenance Year)**





**Figure 19: E-Flows recommendations in a monthly flows pattern – Bansī location (Maintenance Year)**



**Figure 20: E-Flows recommendations in a monthly flows pattern – Birdghat Gorakhpur location (Maintenance Year)**

The Indian major carps are the prime motivation from the aquatic biodiversity perspective in the first two E-Flows locations (Balrampur and Bansī) on the Rapti River. For the third location, Birdghat Gorakhpur, presence of the Ganga river dolphin was observed during wet season, making that the key motivation for wet season E-Flows requirements for this location.

The recommended depth and corresponding active channel width for all the sites are summarised below.

| River | Name of Sites      | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|-------|--------------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|       |                    | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|       |                    | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Rapti | Balrampur          | 5                | 315                  | 9.5        | 910                  | 3.5          | 280                  | 6.2        | 505                  |
|       | Bansī              | 5                | 396                  | 8.6        | 508                  | 3.5          | 303                  | 7          | 479                  |
|       | Birdghat-Gorakhpur | 10.5             | 357                  | 13         | 528                  | 7            | 150                  | 9.4        | 211                  |

*\*All values are in meters*

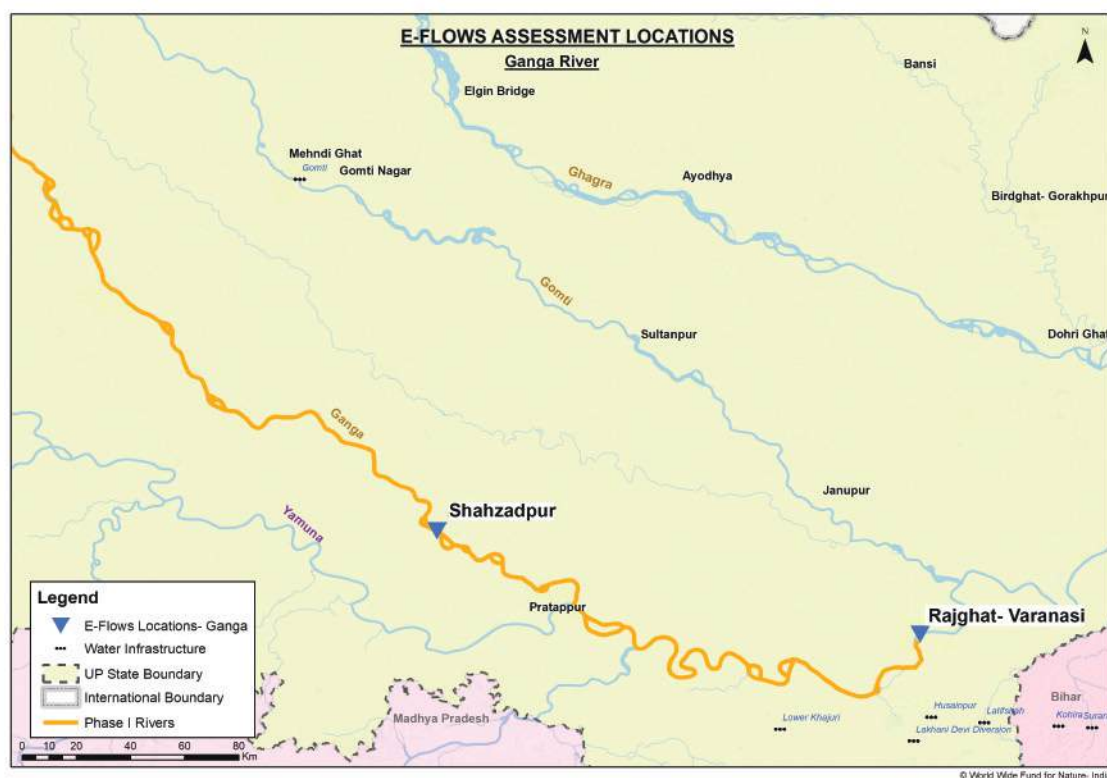


## Ganga River

The Ganga River flows for over 1270 km in the state of Uttar Pradesh, which is over half of its total length. The E-Flows assessment for the Ganga River have been conducted by several institutions. Therefore, this study is focused on two critical locations on the river flowing through Uttar Pradesh, in areas where assessments have so far not been conducted, i.e. Shahzadpur and Varanasi, (Figure 21) for which the E-Flows recommendations are now provided.

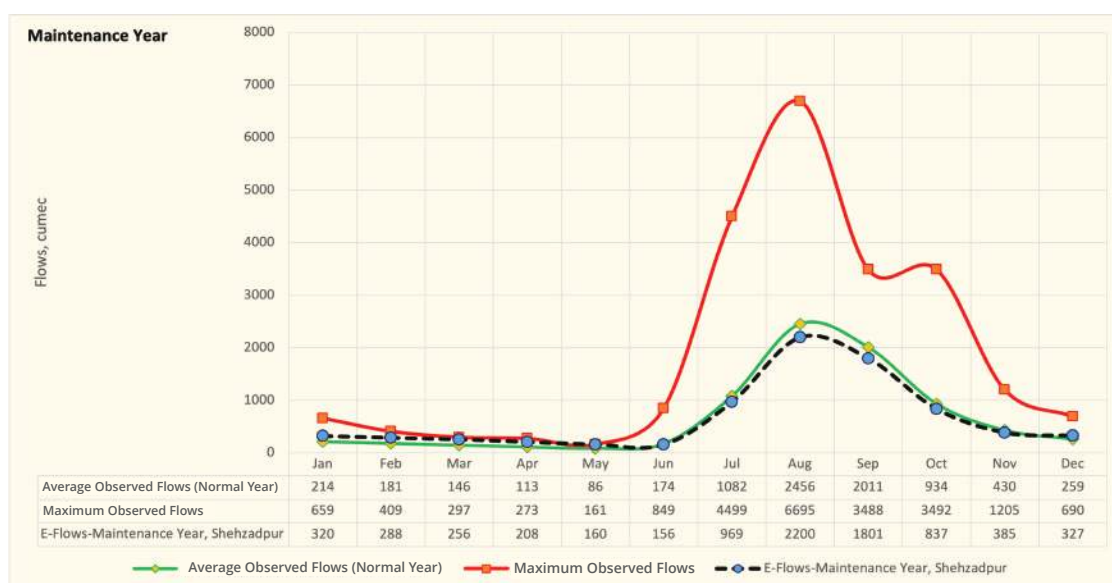


**Figure 21:**  
**Ganga River**  
**stretch and**  
**location of**  
**E-Flows sites**



The Shahzadpur location is over 150 km downstream of Kanpur and upstream of Prayagraj. This location is marked with lesser urban disturbances. However, the impact of deteriorated water quality in the upstream locations, including Kanpur and Jajmau, are apparent. A number of invasive and hardy fish species were recorded around this location. Overall, more than 80 fish species were reportedly available in this stretch, out of which 11 fish species were recorded during this study. There was a general observation that less fish diversity is recorded from this location. However, it is a reasonable habitat of the Ganga river dolphin and therefore, this species is the prime motivation from the aquatic biodiversity perspective, besides geomorphological and other considerations.

The E-Flows recommendations for the Shahzadpur location is shown in Figure 22.

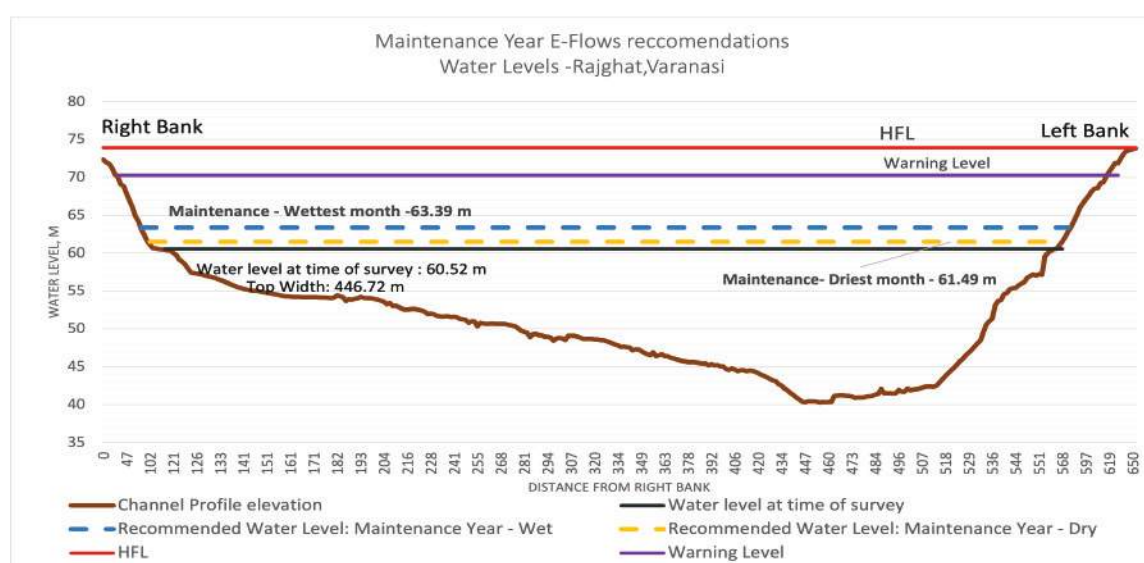


**Figure 22: E-Flows recommendations in a monthly flows pattern –**  
**Shahzadpur location (Maintenance Year)**

Varanasi, perhaps one of the most critical cities along the banks of the Ganga River, gets its name from Varuna and Assi-the two tributaries to the Ganga River that once demarcated the boundaries of the city. One of the oldest cities in the world, Varanasi is mentioned in mythology as well as in several travel memoirs. It holds significance in both the Mahabharata and the Ramayana. The age of the city also finds mention in Buddhist mythology, as it is considered the second city to arise in the last recreation of the world. Varanasi, or Benares as it was then known, was one of the holiest places for Hindus and attracted millions of pilgrims. It retains this reputation today, with religious tourism and the temples forming an important part of the city's economy. This activity is mainly concentrated along the right bank of the Ganga River. For centuries, the right bank has been lined with ghats, often donated by royalty and temples.

The Rajghat-Varanasi location is in the city of Varanasi. This location is marked by the CWC gauge-discharge monitoring station close to a road bridge across the Ganga River. The substrate around the Rajghat-Varanasi location mainly comprised sand and silt. Deep pools were found, which provide good shelter for the Ganga river dolphin and other species. The Ganga river dolphins were spotted during both lean and wet seasons. A total of 12 fish species were recorded from Varanasi during the survey. However, the number of species reported in secondary literature around this location is higher.

The E-Flows recommendations for this location is given in Figure 23, in terms of depths.



**Figure 23: E-Flows recommendations in terms of water levels for the Rajghat Varanasi location (Maintenance Year)**

The recommended depth and corresponding active channel width for all the sites are summarised below.

| River | Name of Sites    | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|-------|------------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|       |                  | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|       |                  | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Ganga | Shahzadpur       | 3                | 673                  | 7.8        | 1179                 | 2.5          | 434                  | 5          | 940                  |
|       | Rajghat-Varanasi | 21.5             | 458                  | 23.4       | 488                  | 14.4         | 380                  | 21.4       | 444                  |

\*All values are in meters





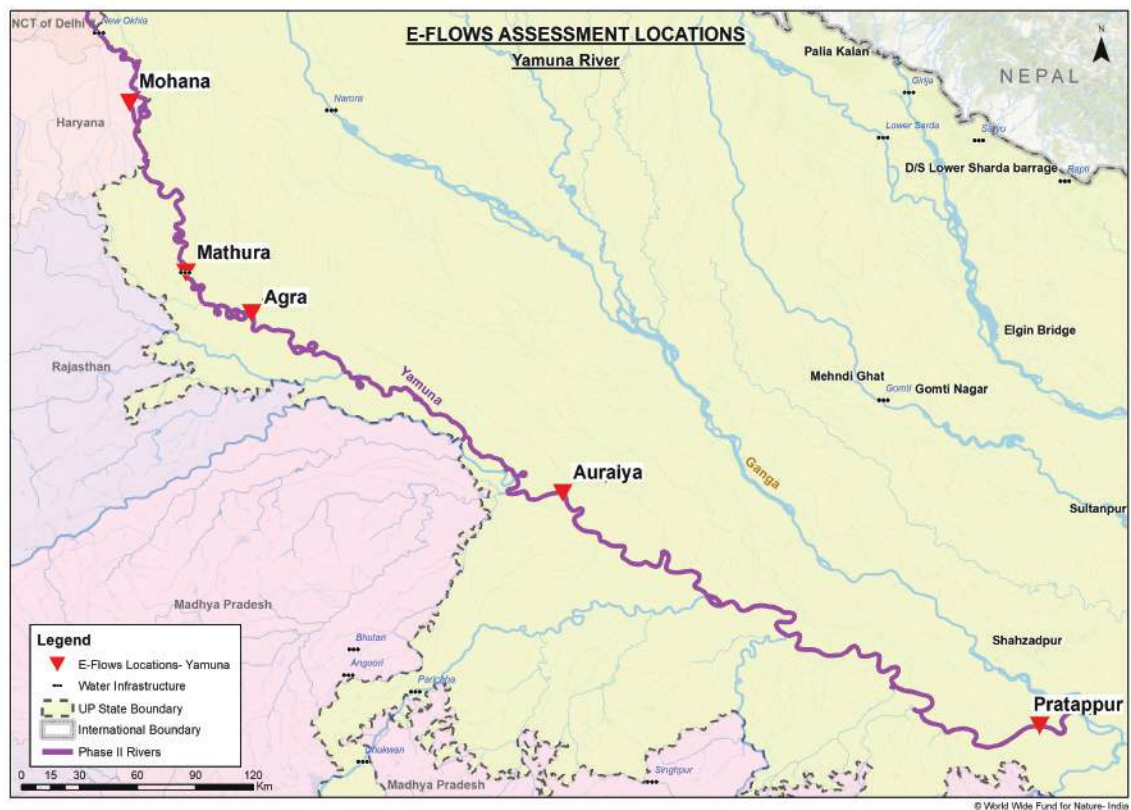
## Yamuna River

The Yamuna River holds a prominent place in India, carrying rich cultural and historical significance. As a major tributary of the Ganga River, it boasts the longest drainage area among its counterparts. Its course spans various states, including Uttarakhand, Haryana, Himachal Pradesh, Delhi and Uttar Pradesh, covering a total distance of around 1,260 kilometres until it merges with the Ganga in Prayagraj.

In Uttar Pradesh alone, the Yamuna River has an extensive course, flowing for a distance of over 890 kilometres. The team considered the identification of an Environmental Flows (E-Flows) site in Haryana, specifically just before the Yamuna River enters Uttar Pradesh. The objective was to assess the river's flow in quantitative terms before it crossed into Uttar Pradesh. In this context, the Mohana site on the Yamuna River was chosen as the initial E-Flows site, followed by subsequent sites in Uttar Pradesh, namely Mathura, Agra, Auraiya, and Pratappur (Figure 24). This stretch of the Yamuna is characterized by sinuosity, channel multiplicity, and distinct features like alluvial islands, large point bars, mid-channel bars and lateral bars. The river maintains an active floodplain, albeit with some fluctuations over the years, and has been home to an impressive diversity of aquatic life, hosting more than 105 fish species.

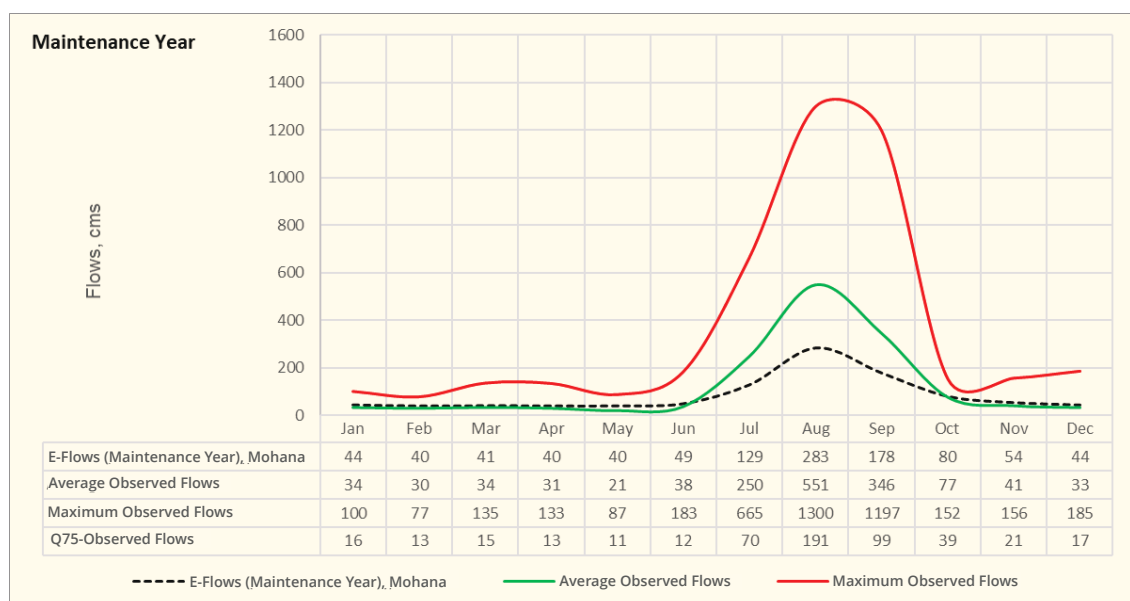
The socio-cultural importance of the Yamuna cannot be overstated, considering its sacred status in Hinduism. Mythological stories highlighting the river's purity and holiness contribute to its revered place in the religious landscape. Mathura, situated along the Yamuna's banks, is particularly significant as the birthplace of Lord Krishna, further enhancing the river's religious importance. However, the Yamuna faces significant pollution challenges, especially in the upstream E-Flows sites. Human activities, industrial discharges, untreated sewage and agricultural runoff contribute to elevated levels of pollutants, impacting critical water-quality parameters. The management of water at diversion structures has led to low and fluctuating flows in the river, exacerbating the concentration of pollutants.

From a biodiversity perspective, IMCs is critical, particularly at the initial three locations–Mohana, Mathura and Agra. In the latter two locations, Auraiya and Pratappur, the presence of the Ganga river dolphin serves as a key motivation.



**Figure 24: E-Flows sites in the Yamuna River**

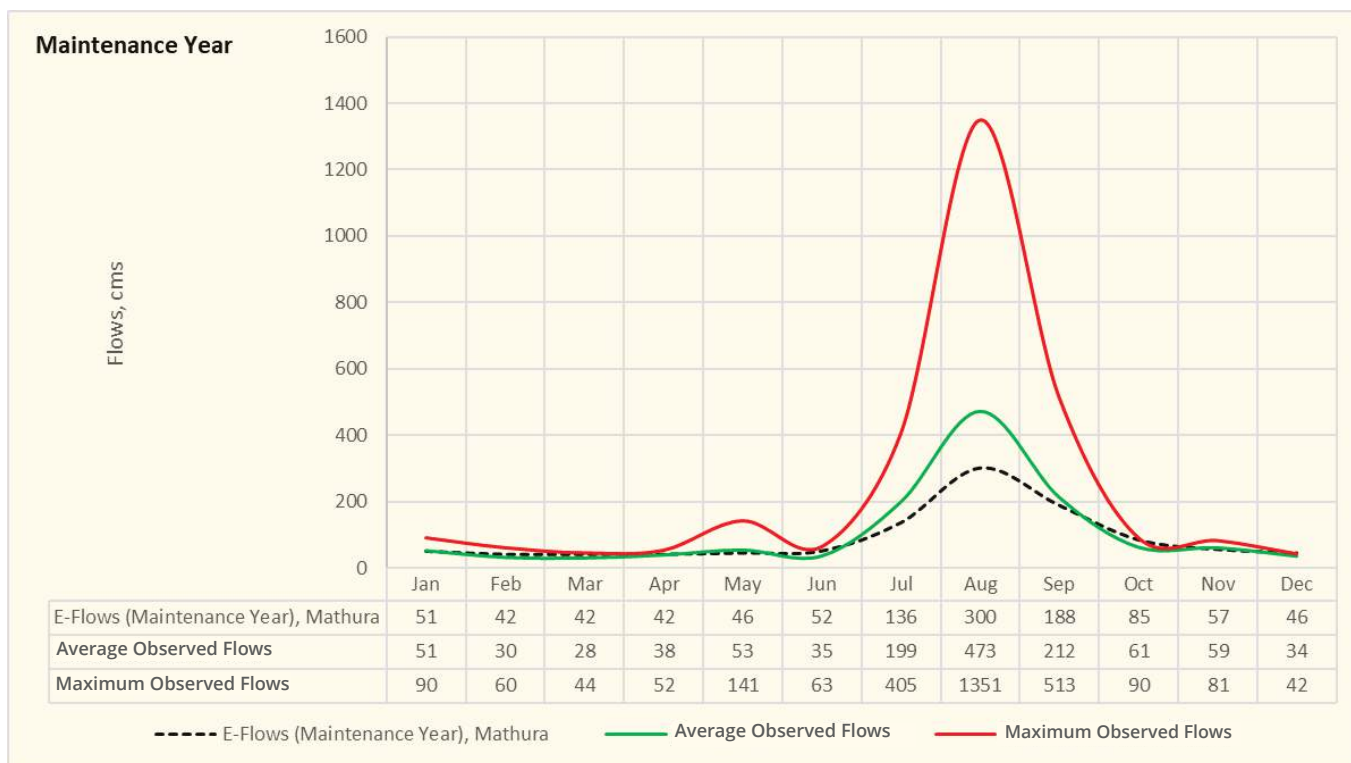
The E-Flows recommendations have been made for all five locations in the Yamuna River- Mohana (Figure 25), Mathura (Figure 26), Agra (Figure 27), Auraiya (Figure 28) and Pratappur (Figure 29).



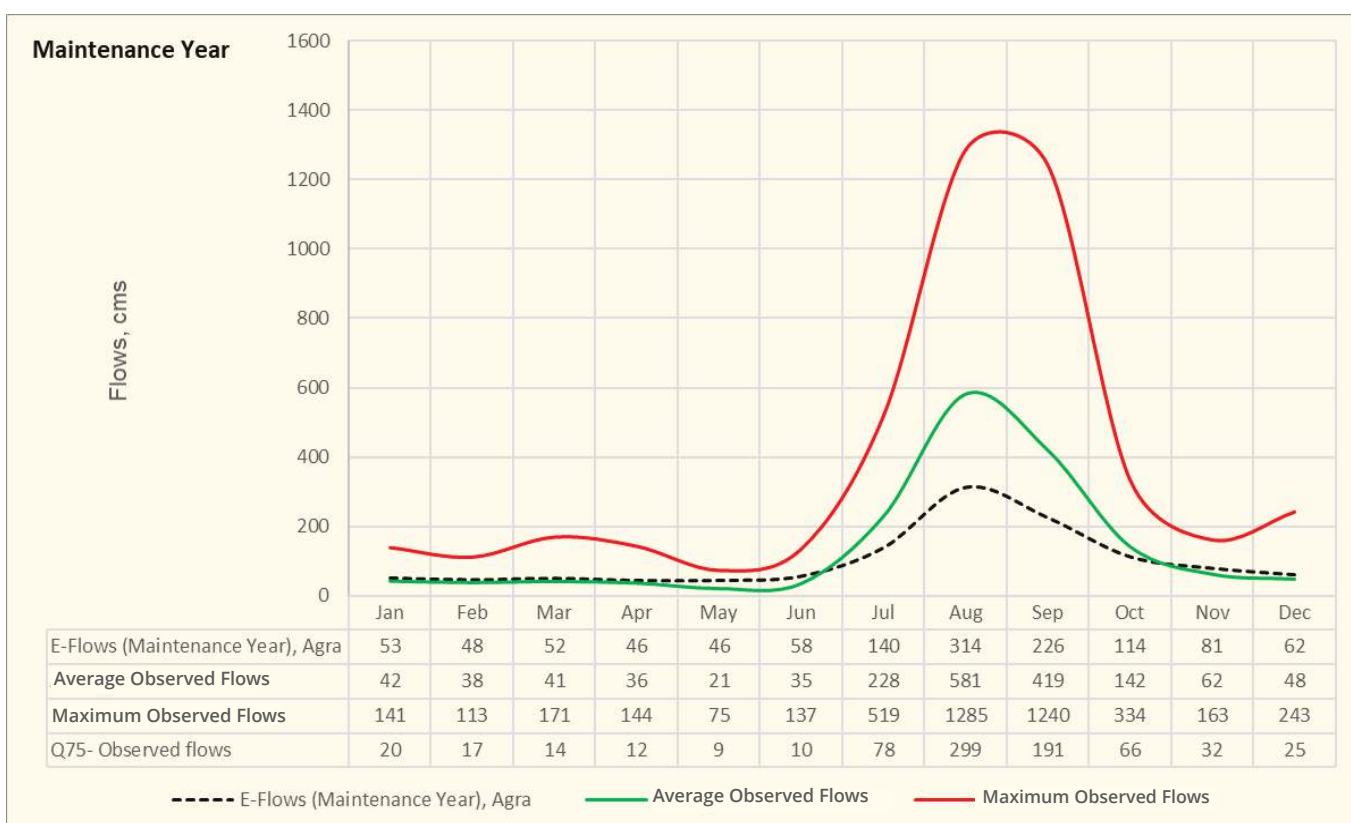
**Figure 25: E-Flows recommendations in a monthly flows pattern - Mohana (Maintenance Year).**

(In this graph, Q 75 (flows at 75% dependability) flows values are only shown in figures.)



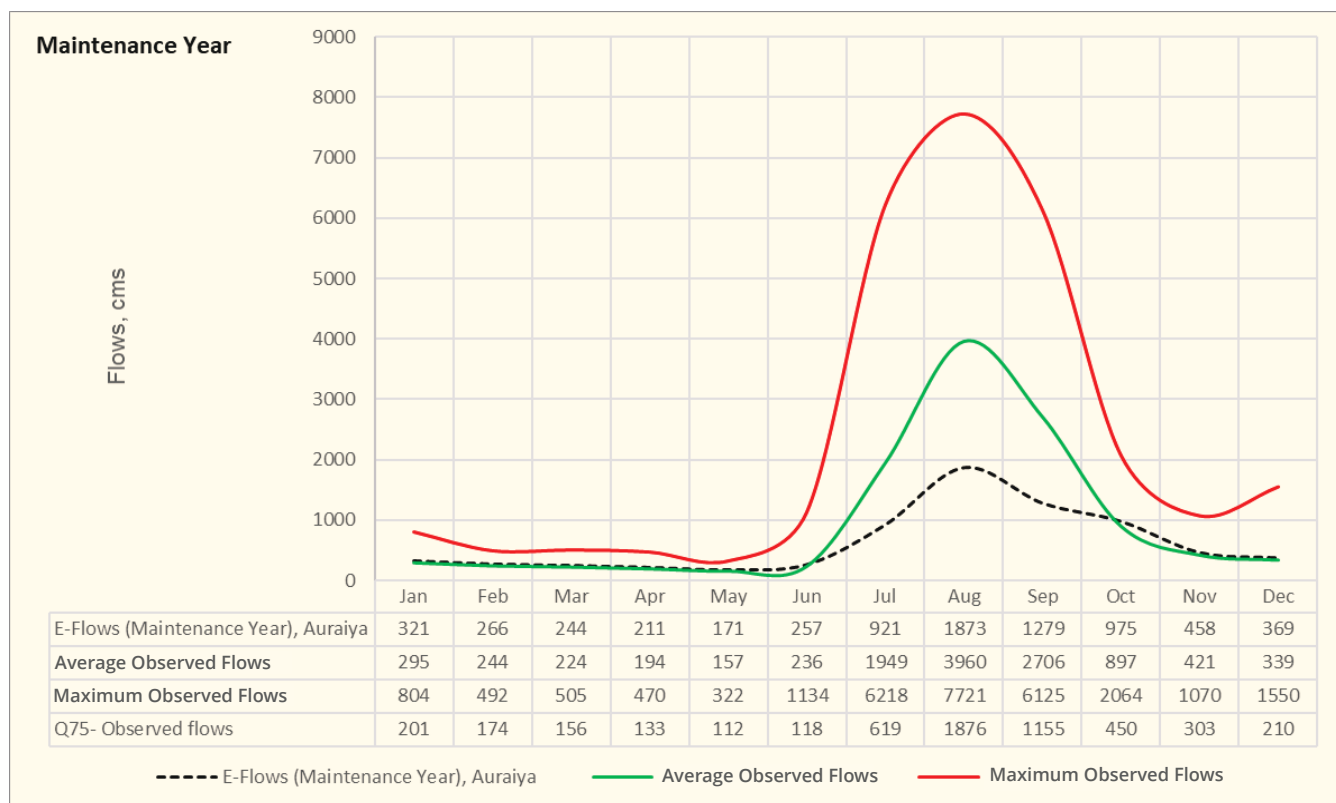


**Figure 26: E-Flows recommendations in a monthly flows pattern – Mathura (Maintenance Year)**



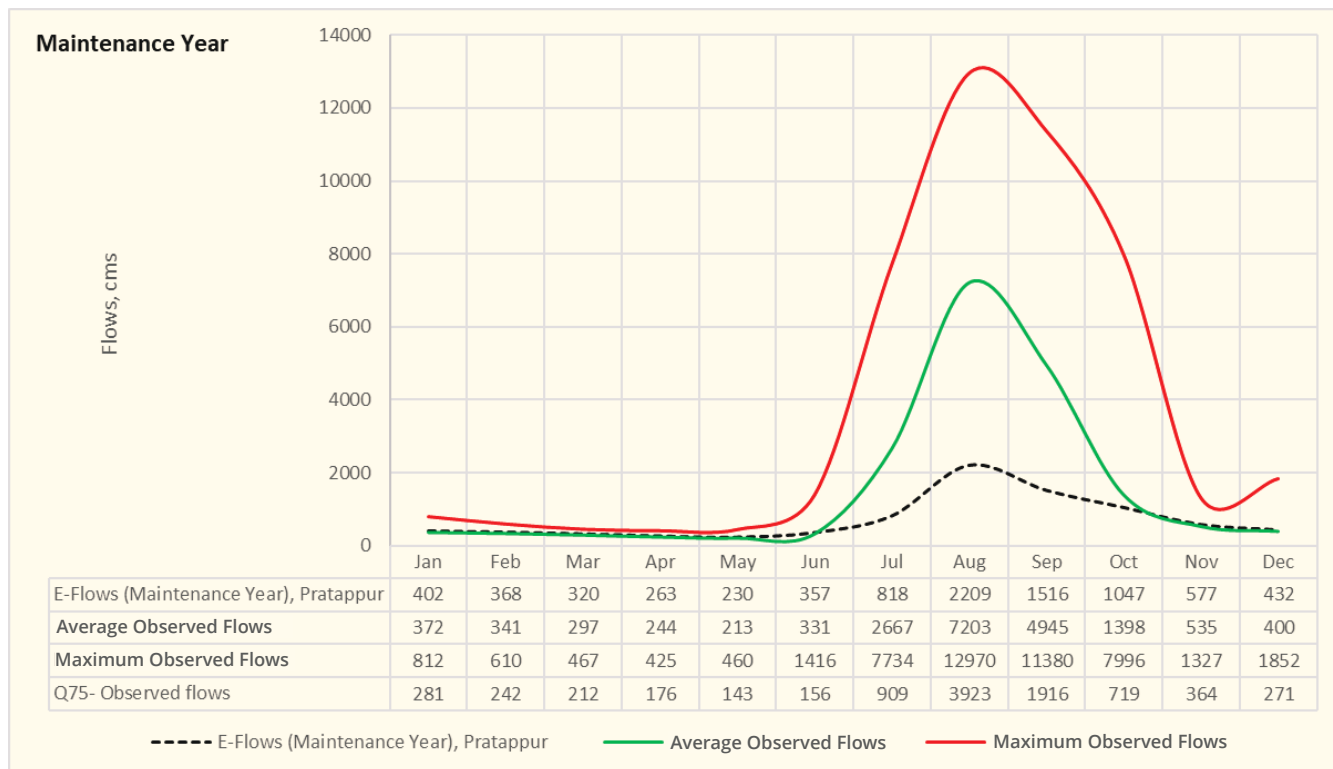
**Figure 27: E-Flows recommendations in a monthly flows pattern – Agra (Maintenance Year)**

(In this graph, Q 75 flows values are only shown in figures.)



**Figure 28: E-Flows recommendations in a monthly flows pattern – Auraiya (Maintenance Year)**

(In this graph, Q 75 flows values are only shown in figures.)



**Figure 29: E-Flows recommendations in a monthly flows pattern – Pratappur (Maintenance Year)**

(In this graph, Q 75 flows values are only shown in figures.)



The recommended depth and corresponding active channel width for all the sites are summarised below.

| River  | Name of Sites         | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|--------|-----------------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|        |                       | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|        |                       | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Yamuna | Mohana                | 2.8              | 165                  | 4.5        | 270                  | 2            | 105                  | 3.1        | 175                  |
|        | Gokul Barrage-Mathura | 1.8              | 135                  | 3.5        | 290                  | 1            | 100                  | 2.1        | 145                  |
|        | Agra-Poiya Ghat       | 2.7              | 55                   | 4          | 365                  | 2            | 110                  | 3.1        | 345                  |
|        | Auraiya               | 5                | 310                  | 8.5        | 735                  | 3.35         | 165                  | 6.5        | 425                  |
|        | Pratappur             | 4.3              | 585                  | 10         | 840                  | 3.25         | 515                  | 7.5        | 795                  |

*\*All values are in meters*



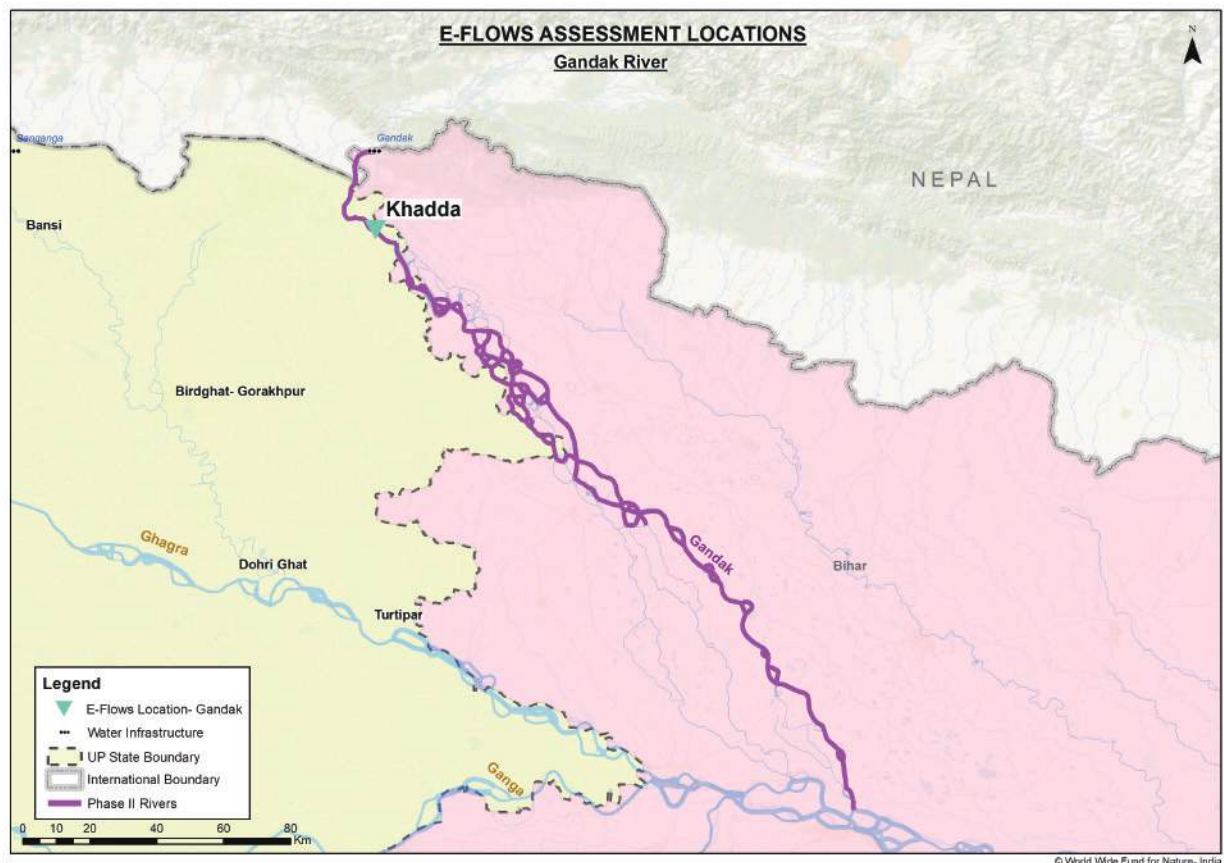


## Gandak River

The Gandak River is a transboundary river, which originates from the Himalayas, the river stretches over a length of 630 kilometres, with 250 kilometres running through India and 380 kilometres in Tibet and Nepal. After entering India, the river flows southerly direction and forms a boundary between Uttar Pradesh and Bihar for about 40 km. The Gandak River exhibits pronounced geomorphological dynamics, particularly during the monsoon season, marked by a substantial sediment load that often results in alterations to its course at multiple locations. A significant water-resource infrastructure along the river is the Valmikinagar Barrage, situated at the India-Nepal boundary. This structure serves the purpose of diverting water for irrigation, primarily benefiting the state of Uttar Pradesh. However, it has also introduced partial modifications to the river's natural stream power.

The Gandak River in its stretch has been documented to host a diverse aquatic ecosystem, showcasing a remarkable total of 61 fish species. This biodiversity highlights the ecological richness of the river and underscores its significance as a habitat for various fish species. The river serves as a vital resource, offering diverse livelihood opportunities to the riparian communities residing along its banks. These opportunities include floodplain agriculture, fishing activities, engagement during socio-cultural events, and the potential for tourism. The river is considered sacred by the local populations and it is associated with various religious and cultural practices. The E-Flows site is at the Gandak bridge at Khadda, located downstream of the Gandak Barrage and at the border of Uttar Pradesh and Bihar (Figure 30). The absence of industries in this location ensures the absence of effluents. The presence of dolphins and gharials further indicates the healthy state of the site.

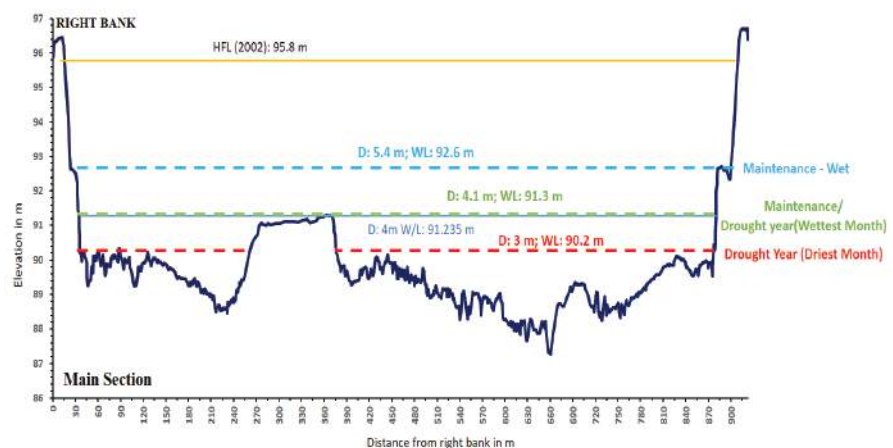




**Figure 30: E-flows site location on the Gandak River**

For the location, water levels or depth as E-Flows have been recommended, as depicted in Figure 31.

**Figure 31:  
Cross-section  
profile with E-Flows  
recommendations,  
in terms of  
water-levels/depth  
for Khadda E-Flows  
location on the  
Gandak River**



The recommended depth and corresponding active channel width for site are summarised below.

| River  | Name of Sites | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|--------|---------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|        |               | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|        |               | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Gandak | Khadda        | 4.1              | 845                  | 5.4        | 865                  | 3            | 835                  | 4.1        | 835                  |

\*All values are in meters



## Sone River

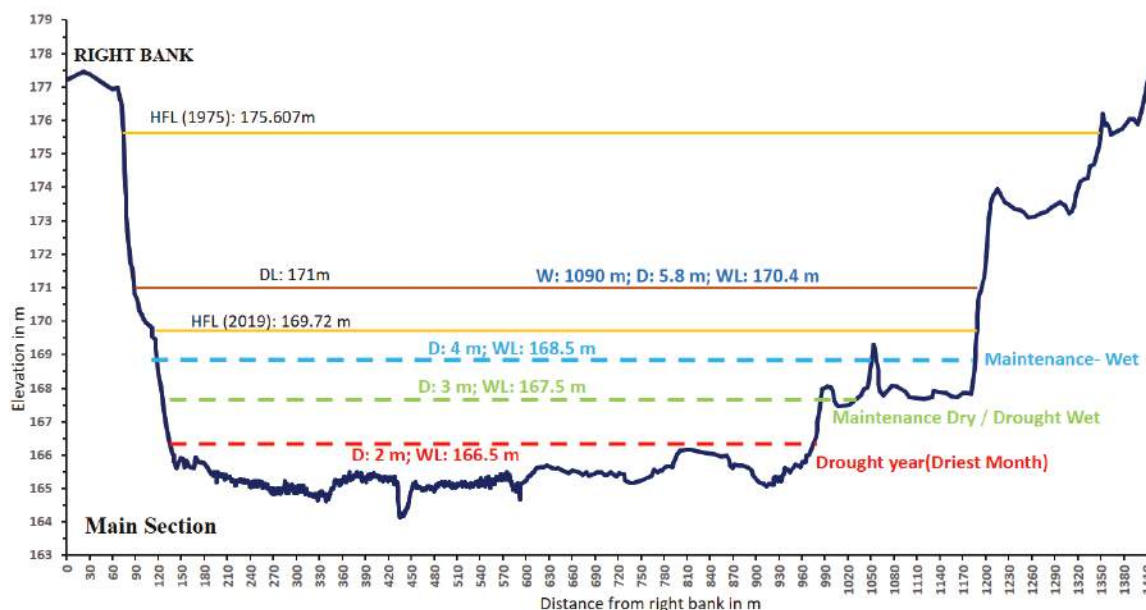
The Sone River is one of the major rivers and a critical tributary of Ganga in India, flowing through the states of Madhya Pradesh, Chhattisgarh, Bihar and Jharkhand. It joins the Ganga above Dinapore, after a course of just over 880 kilometres. The length of the river in the state of Uttar Pradesh is around 80 km. One E-Flows site is identified on the Sone river- Chopan. The Sone River at this site is characterized by a braided pattern, with high multiplicity mostly in the upstream reaches and is partly confined by the valley setting. The channel form is mostly asymmetric and has variable widths while the floodplain width has remained consistent over the last three decades. The E-Flow site at Chopan is located after the major reservoirs and close to the confluence of three rivers (Figure 32) – the Tijul and Ren (both tributaries of Sone), and Sone. Typically, the water-quality parameters at this site adhere to standard limits. However, upstream of the site, the water remains unpolluted. In contrast, downstream, pollution becomes evident, primarily due to the discharge of industry effluents. A total of eight species have been documented at this site, with IMCs being identified as the motivational or key species for this E-Flows site.





**Figure 32: E-Flows site in the Sone River**

For the location, water levels or depth as E-Flows have been recommended, as depicted in Figure 33.



**Figure 33: Cross-section profile with recommendations in terms of water-levels/depth, for the Chohan E-Flows location on the Sone River**

The recommended depth and corresponding active channel width for site are summarised below.

| River | Name of Sites | Maintenance Year |                      |            |                      | Drought Year |                      |            |                      |
|-------|---------------|------------------|----------------------|------------|----------------------|--------------|----------------------|------------|----------------------|
|       |               | Dry Season       |                      | Wet Season |                      | Dry Season   |                      | Wet Season |                      |
|       |               | Depth            | Active Channel Width | Depth      | Active Channel Width | Depth        | Active Channel Width | Depth      | Active Channel Width |
| Sone  | Chohan        | 3                | 905                  | 4          | 1065                 | 2            | 835                  | 3          | 905                  |

\*All values are in meters

# State of Flows in Rivers: Recommended E-Flows vis-a-vis Present Day Flows

For a quick snapshot, a summary is presented below about the shortfall in E-Flows vis-à-vis present-day average flows during both dry and wet seasons for both Maintenance and Drought Year scenarios (Table 1A).

| S. No. | River  | Site                     | Shortfall in Maintenance Year                                                    |                   | Shortfall in Drought Year                         |                   |
|--------|--------|--------------------------|----------------------------------------------------------------------------------|-------------------|---------------------------------------------------|-------------------|
|        |        |                          | Dry Season Months                                                                | Wet Season Months | Dry Season Months                                 | Wet Season Months |
| 1.     | Sharda | D/S Banbasa Barrage      | Only water levels suggested                                                      |                   | Only water levels suggested                       |                   |
| 2.     |        | Palia Kalan              | December to April (Average shortfall of 42 cumec ranging between 30-52 cumec)    | No shortfall      | February to April (marginal shortfall of 1 cumec) | No shortfall      |
| 3.     |        | D/S Lower Sharda Barrage | Only water levels suggested                                                      |                   | Only water levels suggested                       |                   |
| 4.     | Ghagra | Elgin Bridge             | January to April (Average shortfall of 140 cumec ranging between 80-175 cumec)   | No shortfall      | No shortfall                                      |                   |
| 5.     |        | Ayodhya                  | December to April (Average shortfall of 265 cumec ranging between 190-380 cumec) | No shortfall      | No shortfall                                      |                   |
| 6.     |        | Dohri Ghat               | Only water levels suggested                                                      |                   | Only water levels suggested                       |                   |
| 7.     |        | Turtipar                 | January to April (Average shortfall of 220 cumec ranging between 140-300 cumec)  | No shortfall      | No shortfall                                      |                   |
| 8.     | Gomti  | Mehndi Ghat              | Only water levels suggested                                                      |                   | Only water levels suggested                       |                   |
| 9.     |        | Indira Aqueduct          | January to June (Average shortfall of 3 cumec ranging between 3-4 cumec)         | No shortfall      | No shortfall                                      |                   |



| S. No. | River | Site                 | Shortfall in Maintenance Year                                                |                                                                               | Shortfall in Drought Year                           |                   |
|--------|-------|----------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------|-------------------|
|        |       |                      | Dry Season Months                                                            | Wet Season Months                                                             | Dry Season Months                                   | Wet Season Months |
| 10.    | Gomti | Sultanpur            | January to May (Average shortfall of 20 cumec ranging between 11-40 cumec)   | June to September (Average shortfall of 24 cumec ranging between 12-38 cumec) | 10 in April and 16 cumec in May                     | No shortfall      |
| 11.    |       | Jaunpur              | January to June (Average shortfall of 3 cumec ranging between 3-4 cumec)     | No shortfall                                                                  | 4 cumec in April and 13 cumec in May                | 10 cumec in June  |
| 12.    | Rapti | Balrampur            | December to May (Average shortfall of 15 cumec ranging between 10-22 cumec)  | No shortfall                                                                  | Marginal shortfall in February and March of 1 cumec | No shortfall      |
| 13.    |       | Bansi                | December to May (Average shortfall of 15 cumec ranging between 11-22 cumec)  | No shortfall                                                                  | No shortfall                                        |                   |
| 14.    |       | Birdghat – Gorakhpur | December to May (Average shortfall of 30 cumec ranging between 10-50 cumec)  | No shortfall                                                                  | 9 cumec in April and 9 cumec in May                 | No shortfall      |
| 15.    | Ganga | Shahzadpur           | December to May (Average shortfall of 92 cumec ranging between 68-110 cumec) | No shortfall                                                                  | No shortfall                                        |                   |
| 16.    |       | Rajghat-Varanasi     | Only water levels suggested                                                  |                                                                               | Only water levels suggested                         |                   |
| 17.    |       | Mohana               | January to June (Average shortfall of 11 cumec ranging between 7-19 cumec)   | No shortfall                                                                  | No shortfall                                        |                   |
| 18.    |       | Mathura              | January to June (Average shortfall of 56 cumec ranging between 29-92 cumec)  | No shortfall                                                                  | No shortfall                                        |                   |

| S. No. | River  | Site      | Shortfall in Maintenance Year                                                   |                   | Shortfall in Drought Year   |                   |
|--------|--------|-----------|---------------------------------------------------------------------------------|-------------------|-----------------------------|-------------------|
|        |        |           | Dry Season Months                                                               | Wet Season Months | Dry Season Months           | Wet Season Months |
| 19.    | Yamuna | Agra      | January to June (Average shortfall of 15 cumec ranging between 10-25 cumec)     | No shortfall      | In June, 12 cumec shortfall | No shortfall      |
| 20.    |        | Auraiya   | January to June (Average shortfall of 20 cumec ranging between 14-26 cumec)     | No shortfall      | No shortfall                |                   |
| 21.    |        | Pratappur | January to June (Average shortfall of 24 cumec, ranging between 17 to 30 cumec) | No shortfall      | No shortfall                |                   |
| 22.    | Gandak | Khadda    | Only water levels suggested                                                     |                   | Only water levels suggested |                   |
| 23.    | Sone   | Chopan    | Only water levels suggested                                                     |                   | Only water levels suggested |                   |

**Table 1A : Shortfall in E-Flows vis-a-vis present day flows at different locations on 8 rivers**



# Implementation Framework for long-term E-Flows in Major Rivers in Uttar Pradesh

The Implementation Framework for long-term Environmental Flows (E-Flows) maintenance includes a structured plan and a set of procedures to ensure the sustainable and effective management of river systems including basins and processes through multi-stakeholder engagement and collective action. The long-term E-Flows implementation across these rivers would call for application of multiple measures, including technical, social and institutional. With an objective to arrive at plausible management scenarios, the team has looked at some key issues and challenges and then come up with suggestions in regard to long term E-Flows implementation.

The team emphasizes that achieving long-term implementation and realization of Environmental Flows (E-Flows) goes beyond simply releasing water from dams or barrages at all river sites. Instead, it requires collaborative efforts from diverse stakeholders and thematic areas to actively participate in the sustainable management and conservation of freshwater resources. This involves adopting holistic river basin management approaches that consider the interconnectedness of various elements (wetland restoration, groundwater management, conjunctive use of water, overall water demand side management across sectors and so on) within the river ecosystem. The collective actions of stakeholders are integral to ensuring the effectiveness and sustainability of E-Flows initiatives.

Some of the key aspects and activities, that will aid E-Flows implementation, are discussed here:

## Technical

- Demand and supply side management
- Sustainable water management practices in agriculture
- Systematic promotion of conjunctive use
- Groundwater management for enhanced baseflows
- Pricing of water
- Water balance and tradeoff analysis at control structures
- Small tributary rejuvenation initiatives
- Wetland restoration and conservation

## Monitoring

- Monitoring of flows and river health
- Monitoring of groundwater

## Social

- Community awareness
- River health assessment
- Water footprint campaigns

## Institutional

An assessment of some of the relevant stake-holding institutions, departments, ministries and organizations has been undertaken to ascertain the linkages and potential roles of such entities with respect to furthering the cause of E-Flows in these rivers. The key points of this assessment are given in Table 1 b.

| Stakeholder                                                                  | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                                                | Support Desired for the E-Flows Implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Potential Achievements and Impact                                                                                                                                                                              |
|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UTTAR PRADESH</b>                                                         |                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                |
| <b>UP Irrigation and Water Resources Department (UPI&amp;WRD)</b>            | It is the custodian of major water-resources infrastructure on the river Ganga and its tributaries. It is in-charge of providing irrigation in Uttar Pradesh and also, water resources management at the state level.                                                                                                                                  | <p>The UPI&amp;WRD should conduct a thorough analysis of trade-offs, taking into account sectoral demands, long-term river flow availability, and E-Flows requirements.</p> <p>Revise the barrage/reservoir operations to account for E-Flows releases downstream of these structures.</p> <p>Encourage and incentivize farmers to adopt efficient irrigation practices.</p> <p>Establish WUAs and strengthen them through technical and administrative support. Implement revised water allocations.</p> | It will become one of the pioneering irrigation departments in the country to secure E-Flows in the river, while sustaining all other committed uses.                                                          |
| <b>Farmers, Water Users Associations (WUAs), Krishi Vigyan Kendras(KVKs)</b> | <p>Major water users; State-wide Water User Associations (WUAs) establishment is under process. Overall, there is a substantial scope of improvement in agricultural water use efficiency, due to conventional agricultural practices, which mainly include flood irrigation.</p> <p>The mandate of KVK is technology assessment and demonstration</p> | Adoption of efficient irrigation practices. Contribute towards the formation of WUAs and actively participate in its activities. Contribute towards the river's rejuvenation initiatives of the government by using less water for irrigation. Suggest and promote efficient and sustainable agriculture technologies and practices in various crops. Support in                                                                                                                                          | <p>It will help the government to achieve its targets of 20 per cent water-use efficiency in irrigation.</p> <p>Effective agriculture water management technologies and capacity building can help farmers</p> |



| Stakeholder                                                                                               | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                               | Support Desired for the E-Flows Implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Potential Achievements and Impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                           | for its application and capacity development.                                                                                                                                                                                                                                                                         | training and capacity building of farmers through imparting training and exposure visits.                                                                                                                                                                                                                                                                                                                                                                                                                                      | improve their water use efficiencies, reduce input costs, and increase yields. This will eventually reduce pressure on freshwater resources like rivers and groundwater.                                                                                                                                                                                                                                                                                                                                                                            |
| <b>District Administration</b>                                                                            | Apart from law, order, disaster management, one of the key role of District Administration, which is executive hand of State Government, is to implement, monitor various schemes, policies and initiatives of Central and State government.                                                                          | Develop District Ganga Plans for all riparian districts in the Ganga basin including tributaries and implement, monitor and provide financial resources for conservation actions through District Ganga Committees platform.                                                                                                                                                                                                                                                                                                   | It will become the country's leading water resources institution to account for E-Flows in water-allocation processes at the state level.                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Related Line Departments to support restoration and rejuvenation (Revenue department, MNREGA cell)</b> | <p>The Revenue Department's mandate is to document, map, register land records including ownerships, transfer for various activities.</p> <p>MNREGA cell's mandate is to provide livelihood opportunities/employment to rural communities through carrying out various developmental and conservation activities.</p> | <p>Revenue Departments can contribute in river rejuvenation and E-Flows realization and monitoring activities through landuse planning and regulations, surveys and mapping of floodplains, channel encroachments, river and wetlands space prevention from encroachments etc.</p> <p>Various developmental and river/wetlands conservation actions like wetland restoration/creation of new ponds, inlet channel creation, desilting works have been actively carried out by various district through their MNREGA cells.</p> | <p>Revenue Department can help supporting conservation and restoration of rivers, channels, wetlands through mapping, surveys, establishing ownerships, demarcation of boundaries, mapping inlets and identify lost river stretches, which had been encroached.</p> <p>Through various restoration activities, the District MNREGA cell can support in various conservation and restoration activities like channel rehabilitation , desilting, dewatering, construction of new ponds etc. by engaging local communities (MNREGA card holders).</p> |

| Stakeholder                                       | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                              | Support Desired for the E-Flows Implementation                                                                                                                                                                                                                                                                                                          | Potential Achievements and Impact                                                                                                                                                                                                                                                    |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UP-WaMReC and UP-SWaRA</b>                     | <p>It is responsible for planning of surface water resources in the state of Uttar Pradesh.</p> <p>Develop the policy and legal framework for water resources management in an integrated way at a river-basin scale and at state-level.</p>                                                                                         | Drafting rationalised water-allocation principles. Draft revised water allocations and publicise it to seek comments from the stakeholders. Bring in measures to curb the practice of water wastage and over-use across all sectors. Appraise the Government of UP and Irrigation Department to seek their support towards the above-mentioned reforms. | It will become the country's leading water resources institution to account for E-Flows in water-allocation processes at the state level.                                                                                                                                            |
| <b>Decision Makers</b>                            | Generally, they set the agenda for various activities and play a vital role in representing the masses. Their decisions are orders for the executives.                                                                                                                                                                               | They will understand the steps of UP-WaMReC, SWaRA, UP Irrigation Department and other organizations towards river rejuvenation and take informed decisions in favour of society, nature and natural resources, including rivers. Support and incentivise water-use efficiency across all sectors.                                                      | Political support is a must for river rejuvenation. Implementation of these steps has the potential to get the project recognised at the national and international levels as a leader in E-Flows initiatives; as part of the mission for rejuvenation of Ganga and its tributaries. |
| <b>Groundwater Department</b>                     | Monitoring of groundwater levels, managing groundwater resources, improving groundwater recharge, and planning.                                                                                                                                                                                                                      | Increase monitoring network with more frequency of samples, carry out detail gaining-losing stretch mapping and develop understanding on river-groundwater flow linkages, identify potential catchment areas to carry out demand and supply side management, carry out recharge activities in stressed areas with support from other stakeholders.      | Through various monitoring, planning, and aquifer recharge initiatives, not only can river base-flows be enhanced, but this will also help improve local water security.                                                                                                             |
| <b>Uttar Pradesh Pollution Control Department</b> | <p>Identification, assessment and control of industrial and municipal pollution sources.</p> <p>Assessment of quality of inland surface waters.</p> <p>Mass awareness programmes.</p> <p>Notification of effluent and emission standards.</p> <p>Development of Pollution Control technologies.</p> <p>Instituting legal action.</p> | <p>Expand monitoring network to smaller tributaries.</p> <p>Demonstrate effective technologies in pollution abatement with focus on various nature-based solutions.</p> <p>Curb pollution through legal actions.</p>                                                                                                                                    | Various actions will help in pollution abatement and improve river health and habitats for aquatic biodiversity.                                                                                                                                                                     |

| Stakeholder                                                                                   | Mandate/<br>Goal/ Interest                                                                                                                                                                                                                                                                                        | Support Desired for<br>the E-Flows<br>Implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Potential<br>Achievements<br>and Impact                                                                                                   |
|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Forest<br/>Department</b>                                                                  | The department looks after various forest reserves, national parks and sanctuaries within the state limits. It has interest in maintaining E-Flows in the rivers, improving health of wetlands and conservation actions etc.                                                                                      | It can play a crucial role in monitoring of river flows and its benefits vis-à-vis aquatic species like: Dolphins, major carps, gharial, otters and key aquatic species.                                                                                                                                                                                                                                                                                                                                                                                                 | It will become one of the correlations between river flows and habitat viability.                                                         |
| <b>GOVERNMENT OF INDIA</b>                                                                    |                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                           |
| <b>Ministry of Jal<br/>Shakti</b>                                                             | <p>Responsible for laying down policy guidelines and programmes for the development and regulation of country's water resources.</p> <p>Responsible for Ganga Rejuvenation. The NMCG works under this ministry, hence both these entities are critical for E-Flows work across the entire Ganga River system.</p> | The Ministry can incentivise efforts and the application of water-efficient means in irrigation, through additional financial support and packages. As part of implementation of Ganga Notification 2016 and Ganga E- Flows Order 2018, the Ministry can incentivise the state's initiatives for rejuvenation of tributaries of the Ganga. The revised water allocation (taking into account the E-Flows requirements) should be provided with additional support (from the Ministry) in terms of share and quota of financial resources for water resources management. | The Ministry becomes one of the rare governmental entities, on a global scale, that supports the cause of E-Flows and river rejuvenation. |
| <b>Ministry of<br/>Environment,<br/>Forests and<br/>Climate<br/>Change<br/>(MoEF&amp; CC)</b> | It is the nodal agency in the administrative structure of the Central Government for the planning, promotion, co-ordination and for overseeing the implementation of India's environment and forest policies and programmes.                                                                                      | The implementation of E-Flows will improve the health of the river and help in ensuring conducive habitats for aquatic species. Thus, the Ministry should support E-Flows implementation through additional incentives to the state entities or departments who are making efforts towards E-Flows implementation with an aim for river's rejuvenation.                                                                                                                                                                                                                  | It will become one of the leading government entities to support E-Flows in the river system.                                             |



| Stakeholder                           | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                                                                                                        | Support Desired for the E-Flows Implementation                                                                                                                                                                                                                                                                            | Potential Achievements and Impact                                                                                                                                                |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Central Water Commission (CWC)</b> | <p>Monitoring of hydrological data, including – river flows, water levels and maintain a data repository.</p> <p>Initiates, coordinates and leads project sanctions and consultations between concerned State Governments for control, conservation and utilisation of water resources; mainly for the purpose of flood control, irrigation, navigation, drinking water supply and hydropower development.</p> | <p>CWC's support to access hydro-meteorological data is critical for the E-Flows work. Going forward, CWC can play a key role in monitoring of flows regime and sharing the results with the concerned stakeholders.</p> <p>It can develop policies and guidelines for E-Flows implementation in other river systems.</p> | <p>It becomes the leading state-of-the-art agency to deal with water resources management in a holistic manner, taking into account the environmental and social dimensions.</p> |

**Table 1 B : Goals and potential contributions from various stakeholders for E-Flows implementations**

It is hoped that the E-Flows recommendations proposed in this report will serve two purposes, one is to get integrated in the River Basin Planning and Management processes for each of the rivers, thereby mainstreaming the concept of E-Flows and E-Flows allocations into water resources planning, management and use at the state level. The other purpose is to bridge the existing 'knowledge-gap' around E-Flows requirements across major rivers of the state of Uttar Pradesh and therefore support the decision-makers and water-managers to take up next steps towards implementation of E-Flows regimes in these rivers.



# The structure of the report

**Chapter 1** introduces the UP major rivers E-Flows initiative.

**Chapter 2** focuses on the general E-Flows assessment approaches in India and the relevance of holistic E-Flows assessment approaches for the Indian river systems.

**Chapter 3** delves into the systematic process of UP major river E-Flows assessment. With the help of illustrations, efforts have been made to simplify the process for the reader.

**Chapter 4** looks at the 'Present' and 'Desired' states of each river at each of the E-Flows locations from the perspective of various thematic areas, i.e. fluvial geomorphology, aquatic biodiversity (mainly fishes and the Ganga river dolphin) and socio-cultural and livelihood aspects.

**Chapter 5** discusses the process of setting the E-Flows values for each of the locations for both seasons (dry and wet) at each river for different type of years in terms of cubic meters per second or water levels (in metres)–as the case may be. This chapter details the specific rationale for each of the locations and for different seasons from various thematic perspectives.

**Chapter 6** discusses the broad contours of E-Flows implementation in each of the rivers. However, the suggestions have limitations like the lack of thorough and in-depth studies to confirm the preliminary ideas. Nevertheless, this chapter offers useful guidance towards E-Flows implementation in these river systems.





# 1. Background

World Wide Fund for Nature – India (WWF-India) has been working towards the conservation of nature and natural resources, including rivers and wetlands, in the country for the last 50 years. Headquartered at New Delhi, through its various nationwide programmes and projects, WWF-India is actively engaged with the Ministry of Jal Shakti (National Mission for Clean Ganga, National Water Mission and other institutions), the Ministry of Environment Forests & Climate Change, Niti Aayog and other departments and organizations of the Government of India. WWF-India works extensively with State Forest Departments, Irrigation & Water Resources Departments, District Administrations, Panchayati Raj Institutions and the State Environment Departments to execute projects in various landscapes and river basins.

Rivers and Wetlands team of WWF-India is working towards the conservation of the Ganga River system and sustainable management of the Ganga River basin for over 14 years.

Recently, the Uttar Pradesh Water Management & Regulatory Commission (UP WaMReC) with WWF-India launched a joint initiative on Environmental Flows Assessment for major rivers in Uttar Pradesh, including Ganga, Yamuna, Sharda, Ghaghra, Gomti, Rapti, Gandak and Sone. The Uttar Pradesh State Water Resources Agency (UP SWaRA) is supporting the initiative by extending contextual guidance on river systems and E-Flows locations on these rivers. This initiative has been carried out in two phases. Phase-1 is focused on Sharda, Ghaghra, Gomti, Rapti, and specific locations on the Ganga River. Phase- 2 focused on Yamuna, Gandak and Sone rivers. This exercise began in April 2019 and the E-Flows Assessment (EFA) for Phase - 1 rivers was completed by December 2020. The E-Flows Assessment (EFA) for Phase-2 rivers was completed in December 2023.

The Government of Uttar Pradesh, through the Uttar Pradesh Water Management & Regulatory Commission (UP WaMReC) and State Water Resources Agency (UP SWaRA) is developing River Basin Management Plans for all the major river basins in the state. While these basin plans focus on the water resources, allocation, use and management, the recommendations outlined in this report are likely to be included so that the Environmental Flows requirement (to sustain the riverine ecology and for the fulfilment of people's aspirations) can be secured for these rivers. For this complex exercise, WWF-India has partnered with several institutions. This report presents the E-Flows assessment process, the findings and E-Flows recommendations for eight rivers – Sharda, Ghaghra, Gomti, Rapti, Ganga (Shahzadpur and Rajghat Varanasi), Yamuna, Gandak, and Sone at 23 E-Flows assessment locations on these rivers.



## 2. E-Flows Assessment Approaches in India- An Overview

E-Flows assessment needs to be conducted through a holistic approach and methodology, as it takes into account all the associated aspects and functions related to the riverine ecosystem. Therefore, this study has adopted and improvised the Building Block Methodology (BBM) developed by the scientists from South Africa. This approach has the flexibility to improvise the methodology and integrate local and contextual sensitivities or requirements. The complete BBM Manual<sup>3</sup> is available in the public domain. In fact, based on the BBM, WWF-India, along with its partners, conducted E-Flows assessments for the Upper Ganga River (2008-2010) and the Ramganga River (2013-2015).<sup>4</sup>

The International Water Management Institute (IWMI-Sri Lanka) published a macro-level E-Flows assessment approach for Indian rivers<sup>5</sup> in 2006, and also developed the Global Environmental Flows Calculator (GEFC). Based on their paper, they also developed a Ganga specific Environmental Flows Calculator as part of a WWF-India funded project (Upper Ganga E-Flows Assessment 2008-2010)<sup>6</sup>. This software is freely shared by IWMI Sri Lanka<sup>7</sup>. This macro-level and basic desktop model relies on global data-sets of river flows. This approach is based on considering Environment Management Class and adopting Flows Duration Curves.

WWF India has been undertaking E-Flows assessments for the last 16 years. The first exercise was conducted for the upper Ganga stretch from origin to Kanpur (2008-2012). Subsequently, E-Flows assessment was conducted at Triveni Sangam, Prayagraj during the Kumbh mela in 2013. Such assessments have also been conducted for the Ramganga River in 2013-15 and the Upper Bhavani River in 2017-18<sup>8</sup>, Moyar and Beas Rivers (2020-21). With vast experience in such assessments, WWF-India and partner institutions have adopted the same approach and methodology (BBM) in this current joint initiative on E-Flows assessment for the major rivers of Uttar Pradesh.

The Inter-Ministerial Group (IMG 2013) set-up by the Government of India for issues relating to the Ganga River, suggested that “The environmental, societal, religious needs of the community as well as the status of the Ganga River as

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<sup>3</sup> <http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20354-CONSERVATION.pdf>

<sup>4</sup> [https://wwfin.awsassets.panda.org/downloads/ramganga\\_e\\_flows\\_report\\_2018.pdf](https://wwfin.awsassets.panda.org/downloads/ramganga_e_flows_report_2018.pdf)

<sup>5</sup> [http://www.iwmi.cgiar.org/Publications/IWMI\\_Research\\_Reports/PDF/PUB107/RR107.pdf](http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB107/RR107.pdf)

<sup>6</sup> [https://wwfin.awsassets.panda.org/downloads/wwf\\_e\\_flows\\_report.pdf](https://wwfin.awsassets.panda.org/downloads/wwf_e_flows_report.pdf)

<sup>7</sup> <https://www.iwmi.cgiar.org/resources/data-and-tools/models-and-software/environmental-flow-calculators/#Ganges>

<sup>8</sup> [https://wwfin.awsassets.panda.org/downloads/environmental\\_flows\\_for\\_kumbh\\_2013\\_at\\_triveni\\_sangam\\_\\_allahabad.pdf](https://wwfin.awsassets.panda.org/downloads/environmental_flows_for_kumbh_2013_at_triveni_sangam__allahabad.pdf)



India's 'National River' should be taken into account, and thus Building Block Methodology (BBM) is appropriate for assessing the Ganga E-Flows requirements."

The Ganga River Basin Management Plan<sup>9</sup> (GRBMP 2015) commissioned by the National Mission for Clean Ganga (Government of India) noted that 'for assessment of E-Flows for the Ganga River system, the Building Block Methodology (BBM) is the most appropriate methodology. The BBM is among the most holistic set of methodologies and is known for being flexible in accommodating critical local aspects. This methodology works well in data-rich and data-deficient conditions.'

While talking about E-Flows, the Ganga Vision (2018) document (National Mission for Clean Ganga) points out that 'Building Block Methodology is most comprehensive<sup>10</sup> for E-Flows assessment.

The Central Water Commission with the support from GIZ (German development agency since 2018) is working on E-Flows approaches for three typologies of Indian River, i.e.:

- a. Himalayan rivers – Ramganga River
- b. Peninsular rivers –Mahanadi River
- c. Southern rivers –Bharathapuzha River

In all these approaches, the aquatic biodiversity, hydraulic modelling and hydrology forms the basis of E-Flows assessment. WWF-India is contributing to this exercise, mainly for the Ramganga River, under which the hydraulic information (Cross Sections) and aquatic biodiversity information is shared with the CWC.

The National Institute of Hydrology (NIH), Roorkee has conducted Environmental Flows Assessment (2019-20) for a stretch of the Yamuna River from Hathnikund Barrage to Okhla Barrage<sup>11</sup>. This initiative is entrusted to them by the Ministry of Jal Shakti, Government of India, in pursuance to the order from the National Green Tribunal. As part of this initiative, the team from NIH has identified various fish species for motivating the E-Flows requirements. The NIH team undertook cross sections at multiple locations in this stretch and also conducted primary fish surveys around these locations.

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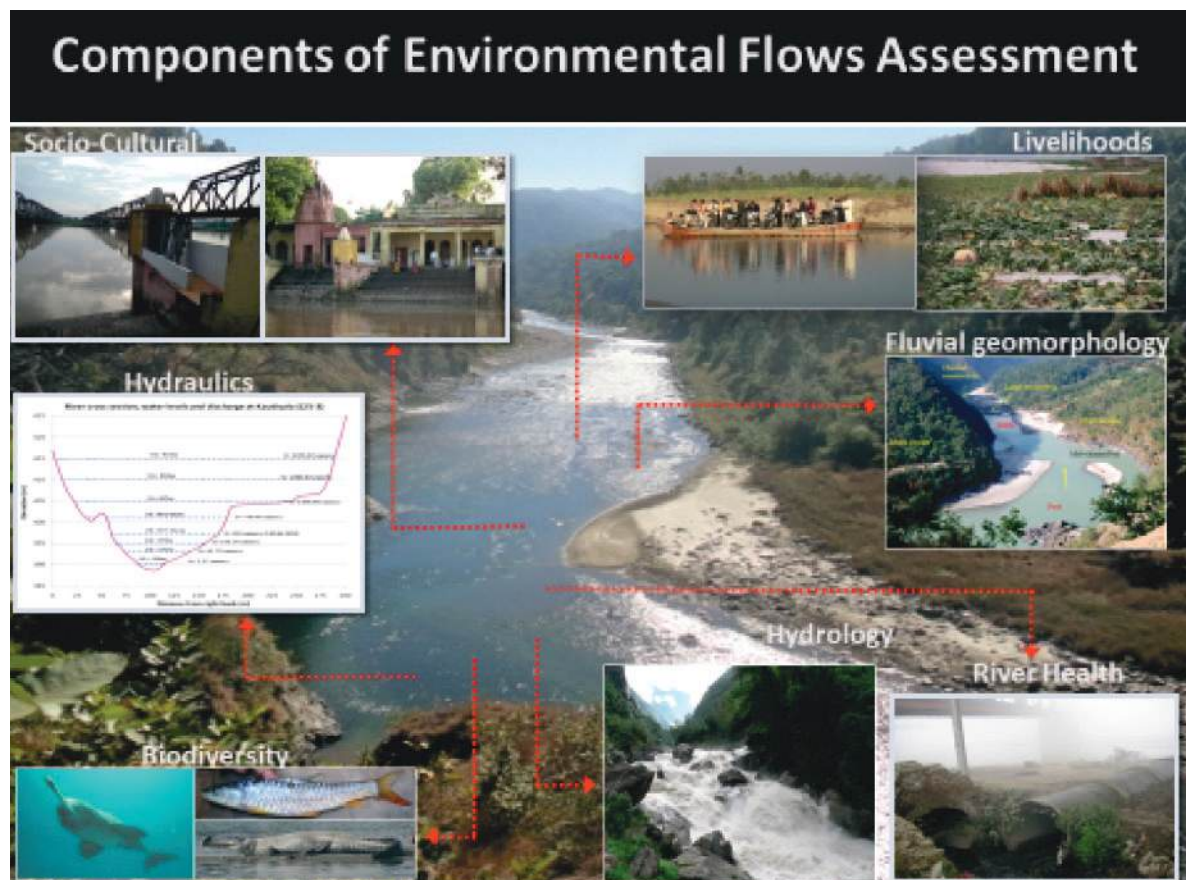
<sup>9</sup> [https://nmcg.nic.in/writereaddata/fileupload/25\\_GRBMPInterim\\_Rep.pdf](https://nmcg.nic.in/writereaddata/fileupload/25_GRBMPInterim_Rep.pdf)

<sup>10</sup> [https://nmcg.nic.in/pdf/Vision%20Ganga%20Eng\\_Compressed.pdf](https://nmcg.nic.in/pdf/Vision%20Ganga%20Eng_Compressed.pdf)

<sup>11</sup> <https://www.outlookindia.com/newscroll/comprehensive-eflow-study-of-yamuna-to-be-undertaken-by-govt-officials/1466372>

# 3. Approach & Methodology for UP Major Rivers E-Flows Assessment

The approach and methodology for UP Major Rivers E-Flows Assessment (EFA) builds upon the on going and past EFA exercises in India. The foundation of this work is the Building Block Methodology (BBM), which has been acknowledged as one of the most holistic approaches for E-Flows assessment for Indian rivers (as noted in the last section). The BBM allows for the integration of local, but critical aspects into the overall methodology framework and works well in both 'data-rich' and 'data-deficient' conditions. The E-Flows assessment through BBM is multidisciplinary in nature. Various environmental aspects, ecological functions, and societal aspirations are taken into account (i.e. all of them are studied) while assessing E-Flows when applying the BBM approach. This is illustrated in Figure 34.



**Figure 34: Various aspects that are studied as part of E-Flows Assessment**

Whilst all these aspects are important for an E-Flows Assessment, at times, if some aspects are less relevant, these are discounted.

## 3.1 Thematic areas for E-Flows Assessment

This section highlights the roles and activities undertaken by different teams from partner organizations. Table 2 lists the names of institutions and experts along with their thematic area of contributions.

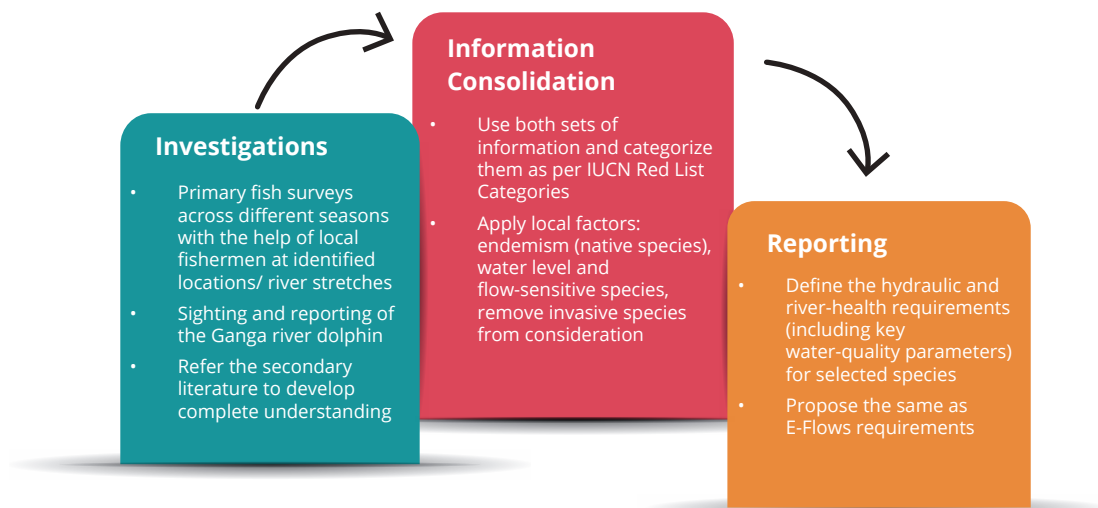
| S. No. | Thematic area                                                                                                       | Name of Institution and Expert                                                                                                                                                                                     |
|--------|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1      | Hydrology (understanding the pattern of seasonal and annual flows and contextual guidance about river systems)      | UP SWaRA, Lucknow<br>Mr Himanshu Kumar, Basin Planning Expert and Chief Engineer and<br>Mr Karunesh Kumar, Executive Engineer                                                                                      |
| 2      | Cross Sections and Hydraulic Modelling                                                                              | cGanga IIT Kanpur<br>Prof. Vinod Tare–Founding Head cGanga and faculty–Department of Civil Engineering IIT Kanpur,<br>Dr Suresh Kumar Gurjar–Executive Officer (Technical), Mr Abhishek Gaur and Team              |
| 3      | Fluvial Geomorphology                                                                                               | Terraqua UAV Private Limited–IIT Kanpur<br>Prof. Rajiv Sinha–Mentor Terraqua and Professor Department of Earth Sciences IIT Kanpur,<br>Mr Smruti Ranjan Patra and Dr Kanchan Mishra                                |
| 4      | Aquatic Biodiversity (mainly fishes and the Ganga River Dolphin)                                                    | ICAR–National Bureau of Fish Genetic Resources, Lucknow<br>Dr Kuldeep K. Lal, Director; Dr K.D. Joshi, Principal Scientist; Dr Rajesh Dayal, Chief Technical Officer; Mr Priyam Nath; Dr Mohammad Alam, WWF-India  |
| 5      | Local and contextual knowledge-sharing and guidance                                                                 | Mr Ravindra Kumar, formerly with SWaRA and Advisor WWF-India                                                                                                                                                       |
| 6      | Overall Conceptualization, Coordination and Management (including report preparation) on developing E-Flows regimes | Mr Nitin Kaushal, Director- Rivers & Wetlands, Mr Arjit Mishra, Associate Director- River Basins, Mr Devanand MR, Hydrologist with support and guidance from Mr Suresh Babu, Senior Director-Ecological Footprints |

**Table 2: UP's Major Rivers E-Flows Assessment – Various thematic areas of work along with institutions/experts**



Various activities conducted under each of the thematic areas are highlighted below:

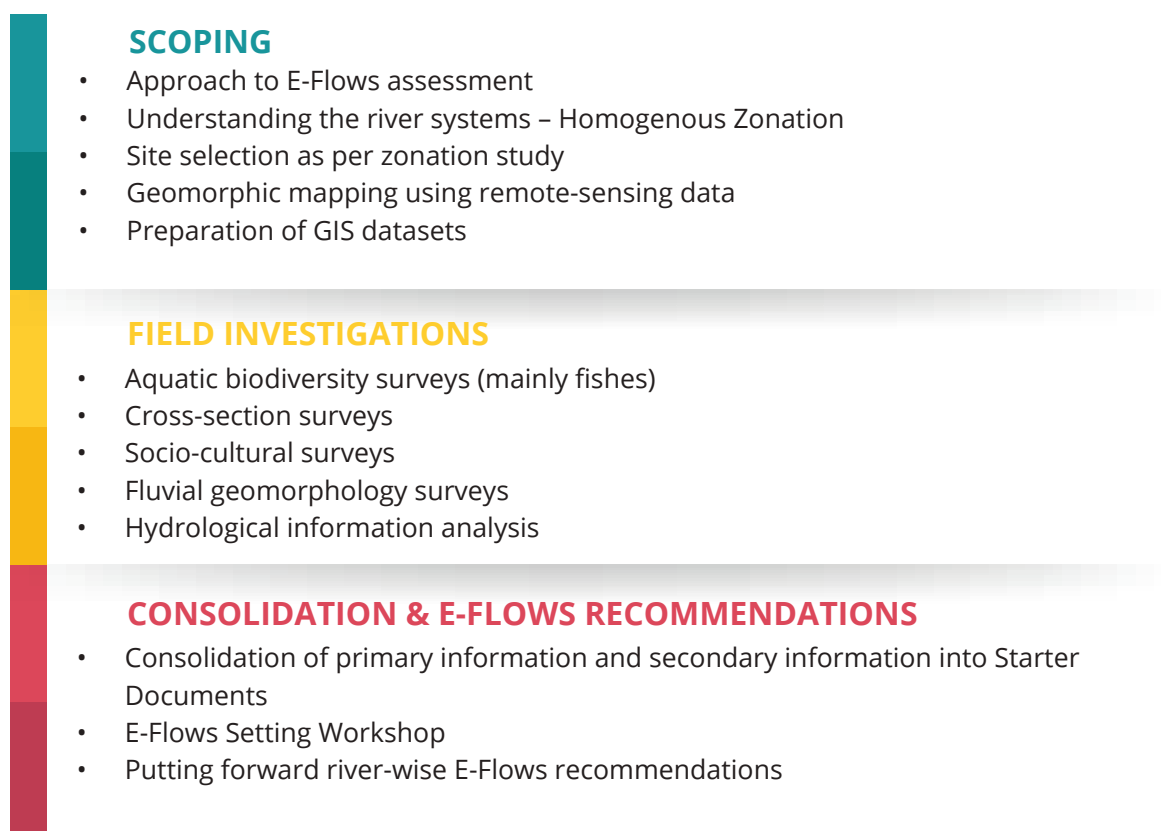
- 1. Hydrology (Understanding the pattern of seasonal and annual flows):** The general, the river flows pattern over various seasons, months and years (over 30 years) were studied in the current water-use scenario to develop a clear understanding about the nature of each river. The purpose here was to get a clear understanding of the regime of flows in a river, in present and past scenarios. Some basic information in this regard was made available to the team for the purpose of this assignment and the team made use of that information to develop its understanding of flows elements of various rivers for which the E-Flows exercise was conducted.
- 2. Cross Sections and Hydraulic Modelling:** This exercise involved Cross Section and Longitudinal Section Profile at the identified E-Flows locations on the eight rivers. For each location, multiple Cross Sections were taken (five to seven CS in a reach of 2-4 km around the location on a river). This information helps in setting up Hydraulic Models, which is calibrated and validated. The E-Flows recommendations were made for these specific locations on the rivers.
- 3. Fluvial Geomorphology:** This exercise involved the use of temporal high-resolution satellite imageries and GIS information sets to understand the geomorphologic characteristics, complexity and dynamics of the river channel at a given location. Under this thematic, sediment influx was also studied to understand the aggradation and degradation at each location. The key motivations for having E-Flows for Fluvial Geomorphology include:
  - a. Maintaining required river channel complexity to ensure healthy habitats of aquatic species (fishes, Ganga river dolphin, etc.)
  - b. Maintaining the longitudinal and lateral connectivity of the river
  - c. Assessment of the sediments dynamic to maintain the desired morphology
  - d. Appropriate rate of sediments transport across various locations
- 4. Aquatic Biodiversity:** This is one of the most critical thematic areas of E-Flows Assessment. The process for this exercise is illustrated in Figure 35.
- 5. Socio-Cultural Aspects:** Under this exercise, primary surveys were conducted with the help of a pre-decided questionnaire to assess the social and cultural dependencies of the local communities on the river at the identified locations. It is to be noted that such dependencies should be 'non-consumptive' in nature, for example – ritual bathing. The information obtained from the local communities is then used to define various river depths and width parameters, which would be conducive for people to carry out their socio-cultural rituals and perform various related activities. The thematic groups including fluvial geomorphology, aquatic biodiversity, socio-cultural and livelihood aspects have defined the 'Present' and 'Desired' state of the river for each of the E-Flows locations in every river.



**Figure 35: Process (including various steps) for Aquatic Biodiversity work under E-Flows Assessment**

## 3.2 Step-by-step process for UP Major Rivers E-Flows Assessment

This section delves deeper into each of the work packages and discusses details of key steps and activities that are undertaken as part of this initiative. The step-by-step process chart is given in Figure 36.



**Figure 36: Step-by-step process chart of UP Major Rivers E-Flows Assessment**

## 3.2.1 Scoping phase

After receiving formal communication from the office of the Chairman, UP WaMReC, the exercise began in March-April 2019. The scoping phase mainly comprised initial deliberations between the team members of UP WaMReC, UP SWaRA and WWF-India around the methodology to be adopted for this exercise. The Building Block Methodology (BBM) was selected for the reasons discussed earlier.

With BBM as the methodology for UP major rivers EFA, the first and foremost task was to conduct desktop-based study on 'Homogenous Zonation' for each of the rivers. Under this, the river was divided into various homogenous zones on the basis of:

- a. Elevation: A relatively common elevation stretch is kept in one zone, elevation breakpoints are generally the boundaries for various zones.
- b. Biogeographic zones<sup>12</sup>: They are also called 'eco-zones'. These are the areas of animal and plant distribution having similar or shared characteristics throughout a zone.
- c. Tributary confluences: Confluences of the tributaries change the nature and flows in the river stretch, and hence also play a role in zonation.
- d. Water resources infrastructure: Various kinds of water-resource infrastructure impact the nature of the river stretch and therefore become a factor that influence the zonation activity for the river.
- e. Cities and towns: The location of such places also influences zonation, as urban activities may change the nature of a river stretch.
- f. Land-use land-cover: General land-use patterns in terms of agriculture, forest, water, etc. are important elements for zonation.

With application of these 'lenses' (parameters), the homogenous zonation exercise is completed. The detailed Homogenous Zonation reports for the rivers Sharda, Ghaghra, Gomti, Rapti and Yamuna are available as Annexure 1A to Annexure 1E. The Homogenous Zonation for the Ganga River was not required, as a relatively shorter stretch from Shahzadpur to Varanasi was studied and the slope in this stretch is not significant. Homogenous zonation exercise was also not conducted for the Gandak and Sone rivers, primarily because very small stretch of these rivers falls in Uttar Pradesh. The team identified one location in each of the key zones, assuming that the identified location is representative of that zone. In general, 'observed hydrology' is critical in E-Flows Assessment, therefore, the locations are selected based on existing gauge and discharge locations, as well as accessibility. Confined cross-sections and logistics were among the other considerations.

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<sup>12</sup> <http://www.cpreec.org/pubbook-ecozone.htm>



Based on Homogenous Zonation for these rivers, a total of 23 locations were shortlisted which are presented in Figure 37:

# EFA Locations

|         |                                                         |           |           |
|---------|---------------------------------------------------------|-----------|-----------|
| SHARDA  |                                                         | Latitude  | Longitude |
|         | a. Downstream of Banbasa Barrage                        | 28.823062 | 80.107825 |
|         | b. Palia Kalan                                          | 28.381305 | 80.550812 |
|         | c. Downstream of Lower Sharda Barrage                   | 27.845637 | 81.018129 |
| GHAGHRA |                                                         | Latitude  | Longitude |
|         | a. Elgin Bridge                                         | 27.097074 | 81.481711 |
|         | b. Ayodhya                                              | 26.811366 | 82.206087 |
|         | c. Dohri Ghat                                           | 26.276795 | 83.511942 |
| GOMTI   |                                                         | Latitude  | Longitude |
|         | a. Mehndi Ghat near Peepa Pul upstream of Gomti Barrage | 26.886972 | 80.899669 |
|         | b. Downstream of Gomti Nagar near Aqueduct              | 26.828009 | 81.066497 |
|         | c. Sultanpur                                            | 26.275593 | 82.067611 |
| RAPTI   |                                                         | Latitude  | Longitude |
|         | a. Balrampur                                            | 27.436801 | 82.228577 |
|         | b. Bansi                                                | 27.188833 | 2.940713  |
|         | c. Birdghat – Gorakhpur                                 | 26.742515 | 83.340735 |
| GANGA   |                                                         | Latitude  | Longitude |
|         | a. Shahzadpur                                           | 25.667544 | 81.425876 |
| YAMUNA  |                                                         | Latitude  | Longitude |
|         | a. Mohana (in Haryana)                                  | 28.22424  | 77.45728  |
|         | b. Mathura- Gokul Barrage                               | 27.44119  | 77.71967  |
|         | c. Agra- Poiya Ghat                                     | 27.254    | 78.0258   |
|         | d. Auraiya                                              | 26.42615  | 79.47443  |
|         | e. Pratappur                                            | 25.35512  | 81.69688  |
| Gandak  |                                                         | Latitude  | Longitude |
|         | a. Khadda/ Gandak Barrage                               | 27.2255   | 83.9095   |
| Sone    |                                                         | Latitude  | Longitude |
|         | a. Chopan                                               | 24.52997  | 83.02487  |

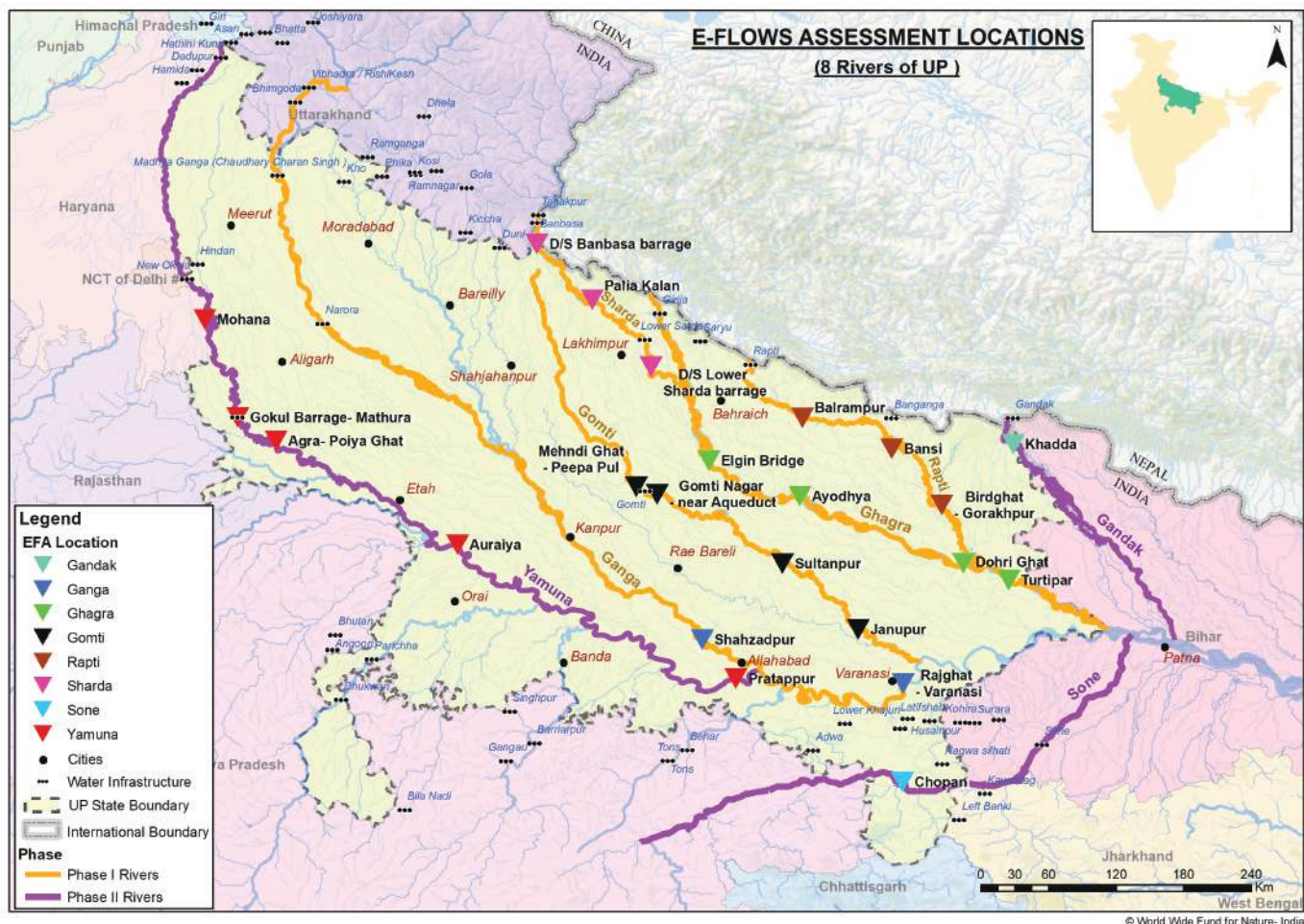


Figure 37: Map of UP's Major Rivers with E-Flows locations marked on the rivers

### 3.2.2 Field Investigations Phase

This is the phase where all thematic investigations were conducted. These include:

- Hydraulic Modelling:** The team conducted Cross Section and Longitudinal Profile surveys at all the identified locations. The cross section surveys were carried out between December 2019 - March 2020 (phase 1 rivers) and April 2021 to August 2021 (phase 2 rivers). This field activity is one of the most critical field surveys, providing valuable information on depth and discharges, organized as a joint exercise with participation from all thematic partners. This helps different thematic teams (including aquatic biodiversity, fluvial geomorphology and socio-cultural) to relate their thematic processes, aspirations and requirements in a concise and focused manner. In general, at each location, it took about 2-3 days to conduct this exercise as five to seven Cross Sections are to be surveyed from the Highest Flood Level (HFL) on one bank to the other bank. Substrate type, velocity and other prominent features such as treeline, vegetation, temples, ghats, structure, etc. are also recorded. The equipment used in such activities include Differential Global Positioning System, Total Station, Velocity Meter and Gauge Staffs. The complete Cross Sections and Hydraulic Modelling Report is available as Annexure 3.

- b. Aquatic Biodiversity:** The team conducted seasonal primary fish surveys at all locations and conducted experimental fishing with the help of local fishermen, while following a standard protocol developed for this objective. Pre and post-monsoon fish surveys were conducted between 2019 -2021 (phase 1 rivers) and 2021 - 2022 (phase 2 rivers). In addition to this, there is a wealth of secondary literature available in the public domain which the team took advantage of, mainly to better inform themselves in regard to the full suite of identified and established fish species in and around all the locations in these river systems. Besides fishes (including Indian major carps), the Ganga river dolphin was another iconic aquatic species which was motivating the flows requirements at different locations on the rivers, where they are found. Ganga river system is known as the original abode of Indian major carps (Rohu, Catla and Mrigal), therefore in the absence of the dolphin in the suggested river stretches, the flow motivations are targeted for these fish species. While conducting the aquatic biodiversity surveys, general hydrology (water depth, flows velocity, channel width) and water-quality parameters (Dissolved Oxygen, Total Dissolved Solids, pH, Temperature) were also assessed.
- c. Fluvial Geomorphology:** The team made use of three sets of information:
1. Primary surveys at the time of cross-section surveys
  2. The secondary literature available in the public domain
  3. High-resolution temporal satellite imageries and advanced GIS tools to understand the river channel behaviour, morphology-related changes over a period of time, aggradation and degradation, sediment transfers and dynamics. The field surveys for developing geomorphology scenario was carried out between December 2019 and June 2020 (phase 1 rivers) and May 2021 and July 2021 (phase 2 rivers).
- d. Socio-cultural:** The team conducted primary surveys (based on an agreed questionnaire) with local community members at each of the locations of all the rivers to understand the socio-cultural aspects and subsistence livelihoods, which are dependent on the river and flows. This helped them aspire for a desired state of the river, which is envisioned by the local communities who have witnessed these rivers flow down the ages. In addition, the team also used secondary information available in the public domain.

### 3.2.3 Consolidation and E-Flows Recommendations

This phase focusses on consolidating the information that is generated and collated from various sources and transforming it to a readily usable form for arriving at E-Flows recommendations. Once the information was documented in thematic 'Starter Documents', the E-Flows Setting Workshop was conducted and E-Flows recommendations for each of the locations for all rivers were arrived at. The E-Flows Setting Workshops are brainstorming sessions, which are iterative and deliberative, where each of the thematic groups presents, discusses and finalizes the desired flows in the river from their thematic perspective.











## 4. The ‘Present’ and ‘Desired’ State of the Rivers

This section addresses the 'Present' and 'Desired' conditions of all the identified E-Flows locations across the 8 rivers. Each thematic team presented an analysis of the river's current state and articulated their vision for its desired state from their unique perspectives. While this content has been documented separately in thematic reports, this chapter summarizes the findings. Further details are available in the thematic reports or thematic Starter Documents (Annexure 4 to Annexure 6). The description of the 'Present' and 'Desired' state of each of the E-Flows location on every river leads to categorization of a given E-Flows location into a River Health Class (RHC). These RHCs were proposed, deliberated and finalized by the team (as part of the Ramganga E-Flows Assessment exercise in 2014-15). These RHCs are considered by the thematic teams while categorising river health. These RHCs are discussed here.

### (i) Near-Pristine

#### *Minimal human interference*

- The most sensitive species are present in abundance
- All biophysical processes are operational
- Minimal erosion and sedimentation, river well connected longitudinally
- Largely unmodified channel morphology with natural riparian vegetation cover
- Floodplains, if present, are natural, with no intensive agriculture, largely unmodified wetlands and flooding regime
- Natural water quality with no or insignificant anthropogenic contamination
- Almost all river-based sustainable livelihood needs and recreational activities are met
- People's expectations of what a holy river looks like are met
- All religious rituals and cultural activities can be carried out without reservation



## **(ii) Slightly Modified**

*Some evidence of human interference, but still functionally intact*

- Sensitive species may not be in abundance, but they are not at a risk of disappearance, even during extreme events.
- Slight or negligible effects on biophysical processes
- Some erosion and sedimentation may be evident, but with slight or negligible effects on biodiversity
- Slight or insignificant modifications to channel morphology, good longitudinal connectivity
- There may be some introduced or exotic riparian plant species, but natural species are still dominant
- Floodplains, if present, are connected to the main channel at regular intervals with no intensive agriculture, but most wetlands are largely unmodified under a natural flooding regime
- Water quality is natural or only slightly modified, with zero industrial waste, possibly insignificant agricultural runoff and domestic waste
- Most sustainable river-based livelihood needs are met
- People's expectations of what a holy river looks like are met
- Cultural activities are carried out

## **(iii) Moderately Modified**

*Clear evidence of human interference, but still largely, functionally intact*

- Reduction in the abundance of sensitive species, and possible risk of disappearance of the most sensitive, during extreme periods (e.g. drought, flood, pollution, etc.)
- Observable effects on biodiversity and biophysical processes
- Significant erosion and sedimentation may be evident
- Significant modifications to channel morphology, possibly with introduced or exotic riparian plant species, which may be common
- Longitudinal connectivity disturbed particularly during lean flow
- Floodplains often used for agriculture, but contain some wetlands, which may be modified; flooding regime is mostly natural but doesn't inundate the entire floodplain, thereby reducing lateral connectivity

- Water quality may be moderately modified, with the possibility of industrial waste, agricultural runoff, and/or domestic waste. A shift from sustainable river-based livelihood to other livelihoods is clearly observed
- 
- People's expectations of what a holy river looks like is met during certain seasons
- 
- All cultural activities and rituals are carried out, but with hesitation

Only the above three categories may be applied as environmental objectives. For sites/stretches presently in a Degraded or Critically Degraded category (see below), the minimum objective will be to improve them to at least a 'Moderately Modified' category over the long term.

#### (iv) Degraded

*Evidence of considerable human interference and functionally disturbed state:*

- Sensitive species absent (except during rare improved flow and/or water quality conditions)
- 
- Increased abundance of hardy species
- 
- Serious erosion and sedimentation may be evident, with significant effects on biodiversity and biophysical processes, which will only be partially intact
- 
- Serious modifications to channel morphology may be present, with significant reduction in longitudinal connectivity
- 
- Dominance of introduced or exotic riparian plant species, which may be invasive
- 
- Floodplains usually completely modified for agriculture, containing occasional surviving modified wetlands, flooding regime may have been significantly reduced and lateral connectivity is lost
- 
- Water quality may be seriously affected, with one or more of industrial waste, agricultural runoff, and/or domestic waste.
- 
- A shift from sustainable river-based livelihood to other livelihoods which may harm the river, was observed; migration and people's shift to other livelihoods that may harm the river was also observed
- 
- People's expectations of what a holy river looks like is met during certain seasons
- 
- Religious rituals, other than cremation, are not carried out
-

## (v) Critically Degraded

### *Dominated by human interference*

- Sensitive species will be permanently absent, and species communities will be dominated by hardy species, some of which may be pests or disease vectors
- Very little natural biodiversity will be apparent (except for hardy species)
- Serious erosion and sedimentation may be evident, to the extent that channel morphology will be permanently altered (possibly channelized), longitudinal connectivity is completely lost, and the river is reduced to isolated pools
- Riparian vegetation, if present, will be dominated by introduced or exotic invasive species
- Floodplains may have been drained and disconnected from the river but will anyway be completely modified for agriculture or industrial uses, no surviving wetlands, flooding regime may have been significantly reduced, diverted or intercepted
- Water quality will probably be completely modified, with flow usually dominated by industrial, agricultural and/or domestic effluents
- Sustainable river-based livelihoods are non-existent
- No river-based recreation activities are carried out
- No religious or cultural activities are carried out
- Cremation is not practised if alternative sites are available



## 4.1 Sharda River

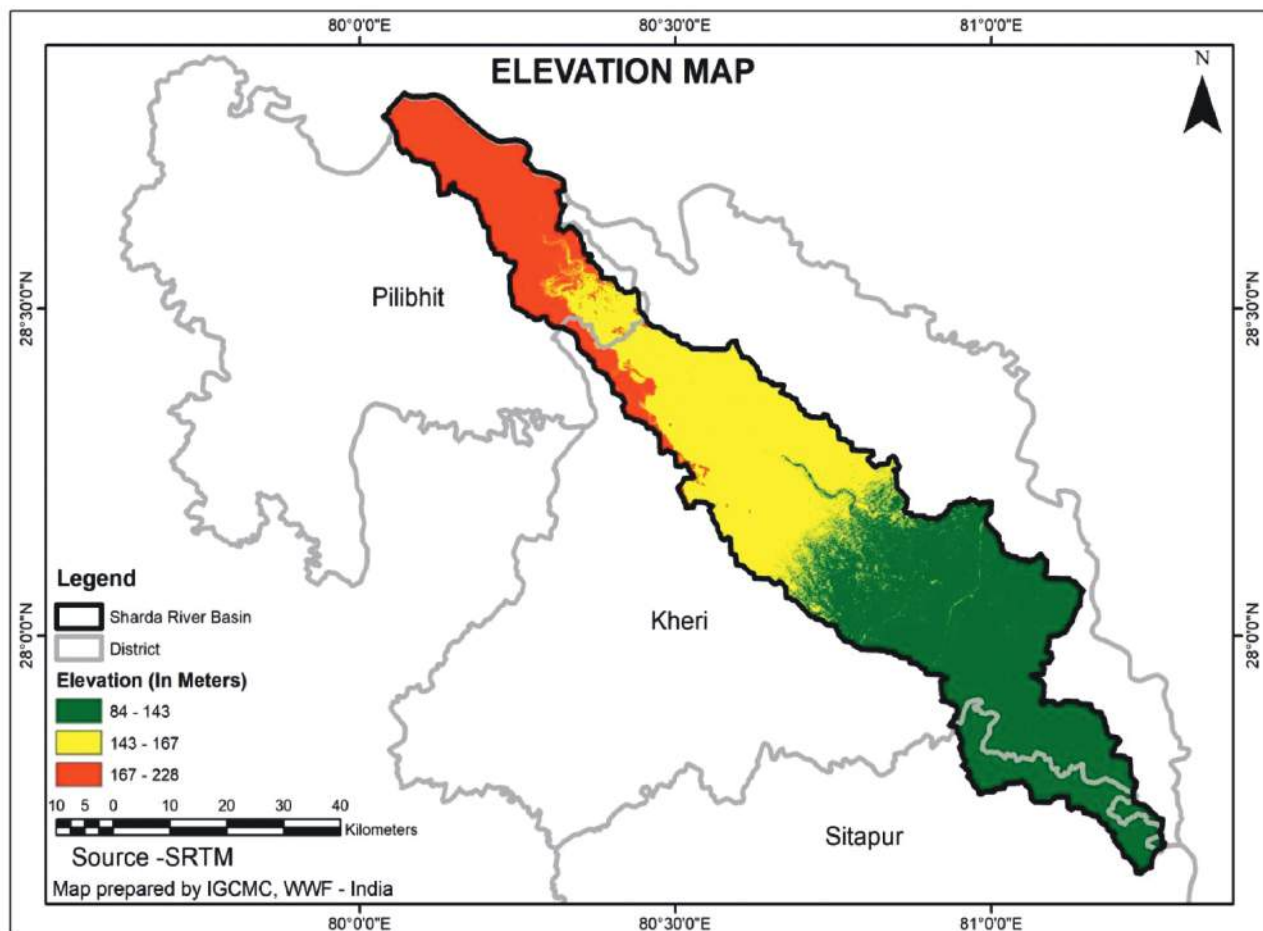
The river originates from Kuthi Yankti and Kalapani rivers, rising in the Pancha-Chuli mountains at an elevation of 3,600 m (11,800 feet) in the Pithoragarh district in Uttarakhand, India. They unite after a few kilometres to form the Kali River or Kaliganga which divides Nepal from the Kumaun region of Uttarakhand. The Kali River joins the Ramganga (east) or Sarju at Pancheshwar. From this junction, the name 'Kali' is gradually lost and the river is known as Sarju or Sarda or Sharda from Baramdeo-Tanakpur town of Champawat district. The Sharda River (Mahakali in Nepal) is a transboundary river which marks the international boundary between India (Uttarakhand) and Nepal. The Banbasa Barrage is constructed across the Sharda River near Tanakpur at the India-Nepal border (on the Indian side) which diverts water for irrigation primarily for the state of Uttar Pradesh.

The total length of the river within Uttar Pradesh is about 260 km. The Homogenous Zonation (Annexure 1A) exercise for this river was conducted and three distinct Homogenous Zones were identified (Figure 38).

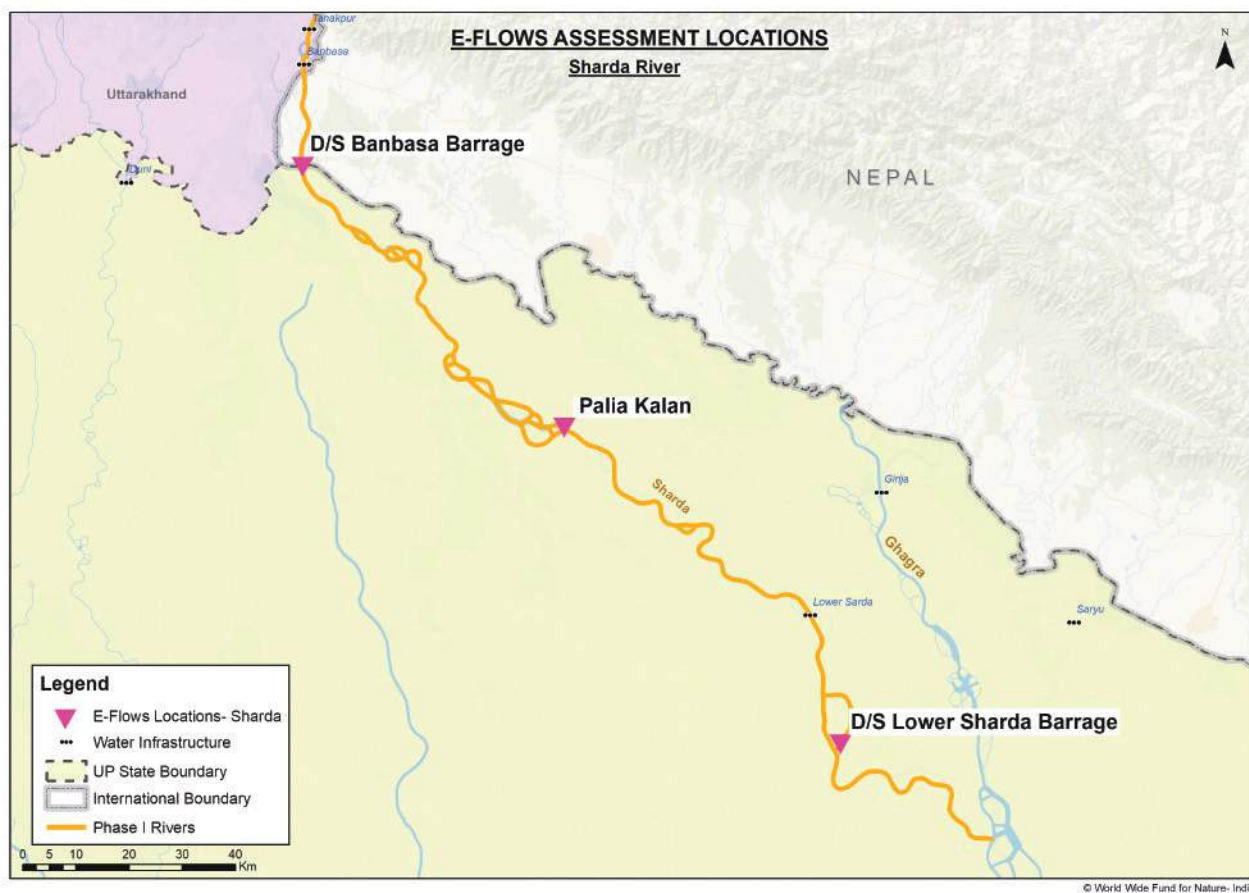
These three zones have distinct features such as:

- a. **Zone 1:** The length of the river course in zone 1 is about 46.8 km (in the UP portion, this length would be a little more, as the team identified Downstream of the Banbasa barrage as an E-Flows location, which is situated in Uttarakhand). The elevation range in the main river stretch within this zone is from 228 to 167 metres. The Downstream of the Banbasa Barrage E-Flows location falls in this zone.
- b. **Zone 2:** The length of the river course in zone 2 is about 85.2 km. The elevation range in the main river stretch within this zone is from 167 to 143 metres. The second E-Flows location, Palia Kalan, falls in this zone.
- c. **Zone 3:** The length of the river course in zone 3 is about 120 km. The elevation range, in the main river stretch within this zone, is from 143 to 84 metres. The third E-Flows location, Downstream of the Lower Sharda Barrage, falls in this zone.

There is only one river gauge/discharge monitoring location (Palia Kalan) on the main stem of the river (CWC). Based on the Homogenous- Zonation work, three locations were identified, as marked on Figure-39.



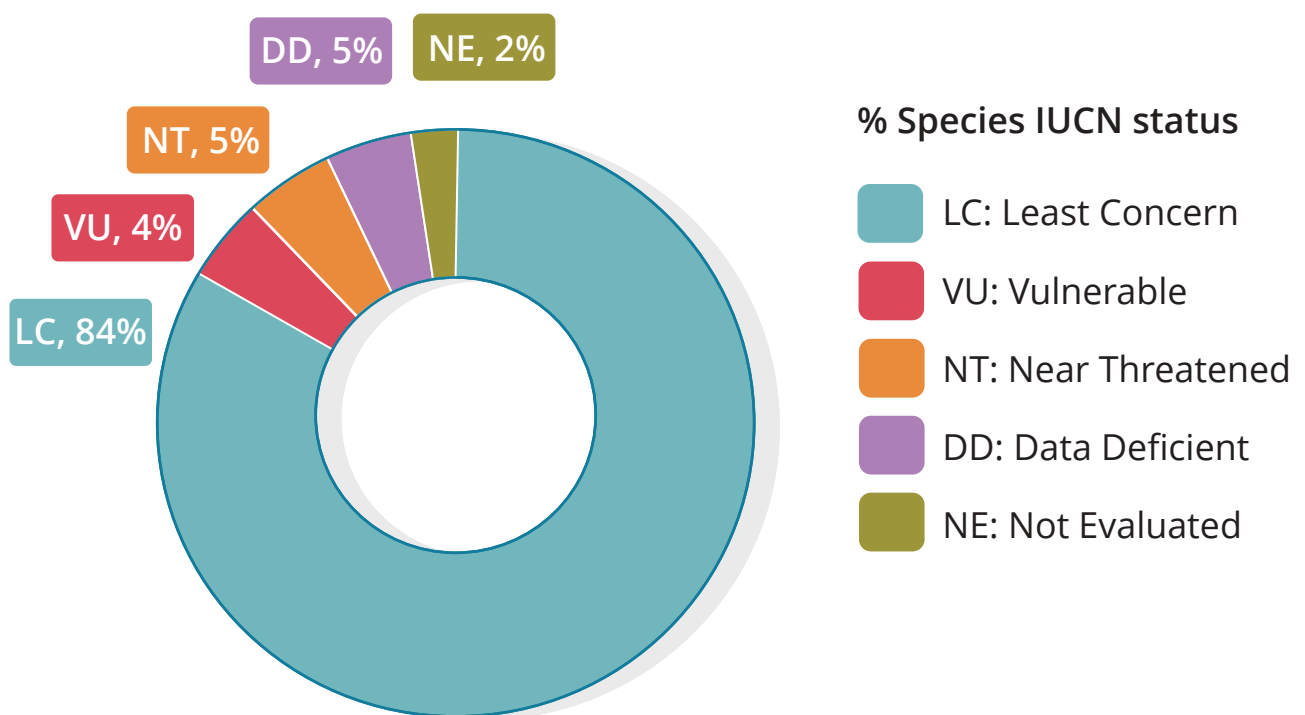
**Figure 38: Homogenous zones in the Sharda River stretch (that falls in Uttar Pradesh)**



**Figure 39: Sharda River map (UP stretch) with E-Flows location marked**

Ritual bathing is carried out in this river, especially during the festival days of *Kartik*, *Ganga Dussehra* and *Makar Sankranti*. One respondent however, narrated a story concerning the etymology of the river being known as the Mahakali. According to him, *'The river is very rough. If a man stands in it, he will get washed away. She has the power to kill, and so is called Mahakali.'*

A total of 43 fish species belonging to 30 genera, ten families and four orders are recorded in the Sharda River. These figures include information from both primary surveys and secondary literature. These fish species are categorised as per the IUCN<sup>13</sup> Red List. The composition of fish species in percentages as per the IUCN Red List category is presented in Figure 40.



**Figure 40: Percentage of fish species of the Sharda River as per IUCN Red List Categories (LC: Least Concern, VU: Vulnerable, NT: Near Threatened, DD: Data Deficient, NE: Not Evaluated)**

<sup>13</sup> IUCN: International Union for Conservation of Nature.



The general hydrological and basic water-quality information about the Sharda River during the survey period, as recorded at all three locations, is given in Table 3.

| Hydrological and Water-quality parameters | Downstream Banbasa Barrage |          | Palia Kalan |           | Downstream Lower Sharda Barrage |           |
|-------------------------------------------|----------------------------|----------|-------------|-----------|---------------------------------|-----------|
|                                           | Summer                     | Monsoon  | Summer      | Monsoon   | Summer                          | Monsoon   |
| River depth in m Average, (min-max)       | 0.91-2.44                  | 0.76-1.4 | 0.24-1.77   | 0.76-4.94 | Surveys not conducted           | 1.07-2.41 |
| River Width (m)                           | 900                        | 500      | 500         | 750       |                                 | 450       |
| Average Current velocity (m/sec)          | 5.25                       | 0.080    | 0.500       | 1.180     |                                 | 0.470     |
| pH                                        | 8.2                        | 8.9      | 7.9         | 8.4       |                                 | 8.8       |
| Temperature (°C)                          | 28.2                       | 22.2     | 29.3        | 25.7      |                                 | 26.6      |
| Dissolved Oxygen (DO) mg/l                | 8                          | 8.6      | 8.6         | 8.4       |                                 | 8.6       |
| Total Dissolved Solids (TDS) mg/l         | 122                        | 175      | 115         | 151       |                                 | 160       |
| Physical appearance                       | Turbid                     | Turbid   | Clear       | Turbid    |                                 | Turbid    |

**Table 3: General hydrological and water-quality information of the Sharda River at identified E-Flows locations**

The water quality for the proliferation of fishes is found to be good, with D.O. over 8 mg/l at all locations.



### 4.1.1 Downstream of the Banbasa Barrage

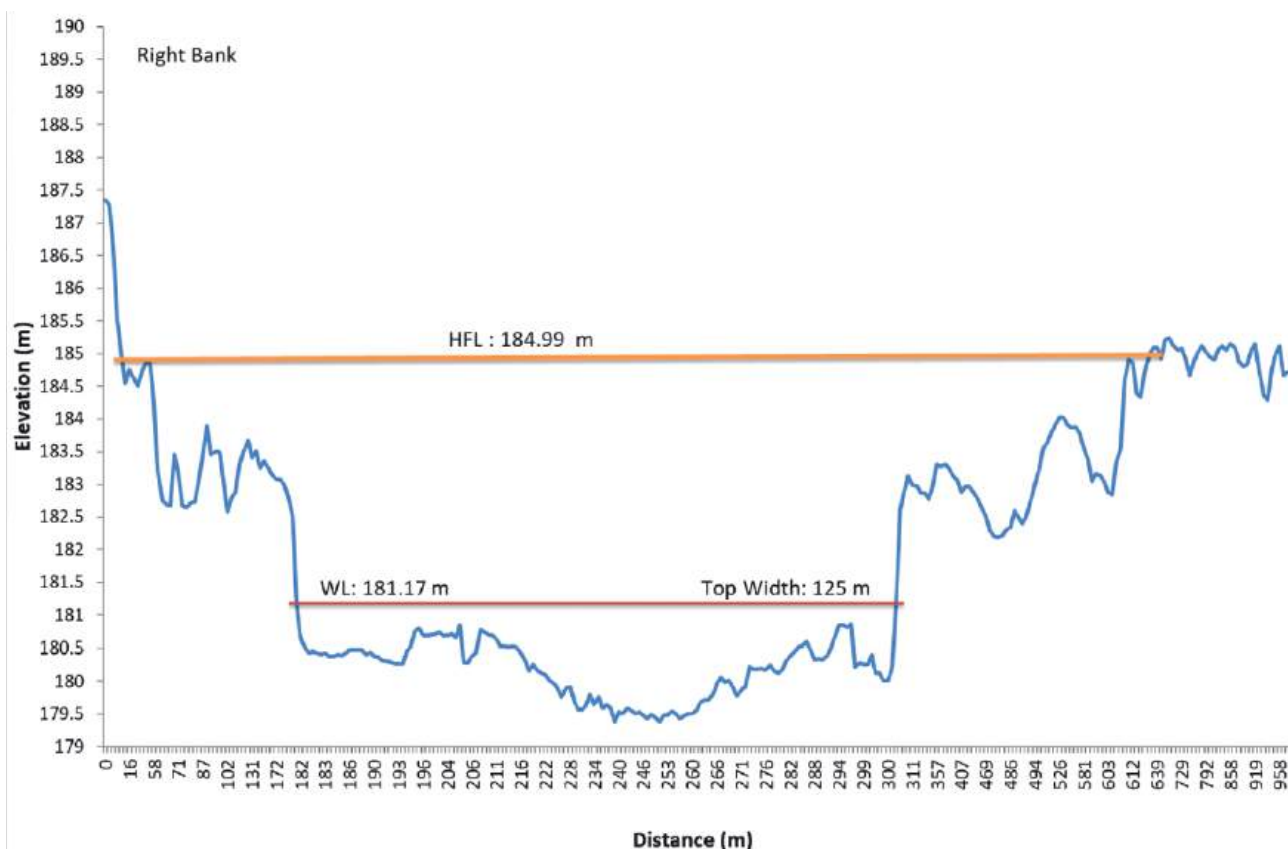
The Sharda River flows through the Banbasa town in Champawat district in Uttarakhand, near the Nepal border, 10 km from Tanakpur. There is a barrage on the Sharda River at Banbasa and an irrigation canal takes off from its right bank. The flows of the river are regulated by the barrage.

Though the Banbasa Barrage location falls in Uttarakhand, but was selected for E-Flows Assessment. The aim was to quantify the river's flow before it crossed into Uttar Pradesh following a significant diversion.

The hydraulic cross section of the E-Flows location, downstream of the Banbasa is given in Figure 42. The water level at the time of the survey is also shown in the figure.



**Figure 41: Sharda River, Downstream of the Banbasa Barrage**



**Figure 42: Cross Section of the E-Flows location Downstream of the Banbasa Barrage on the Sharda River**

The cross-section parameters are shown in Table 4.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 620       | 5.27           | 1.93                        | 107.83                   |

**Table 4: Cross-sectional parameters for the Sharda River Downstream of the Banbasa Barrage (From HFL)**

The 'Present' and 'Desired' state of the Sharda River downstream of the Banbasa Barrage, as per thematic areas, is presented in the following section.

#### 4.1.1.1 Downstream of the Banbasa Barrage – Present State

##### A. Fluvial geomorphology

The upstream portion at this location has a wide active floodplain region which lies in Nepal. Being characteristically braided in the upstream portion, the banks are unstable. The confluence zone of the Jagbura River and the main channel, i.e. Sharda River, may mark a gravel-sand transition zone as visible in Figure 43. The presence of meander scars along the left bank in the downstream reaches suggests that the channel may have been susceptible to channel avulsions towards the right during high flow events.



The river channel bed around this location is composed of large cobbles and pebbles mixed with finer sediments. A few marshy areas/wetlands have been mapped through the satellite images, adjacent to the meander scars in the left bank side of the downstream region. The floodplains are agriculture dominated on the right bank side in the vicinity of the Kilpura, Khatima and Surai ranges of the Pilibhit Tiger Reserve, while the left bank side has forest cover comprising tall grasslands, scrub savannah and Sal trees of the Tiger Reserve of Nepal.

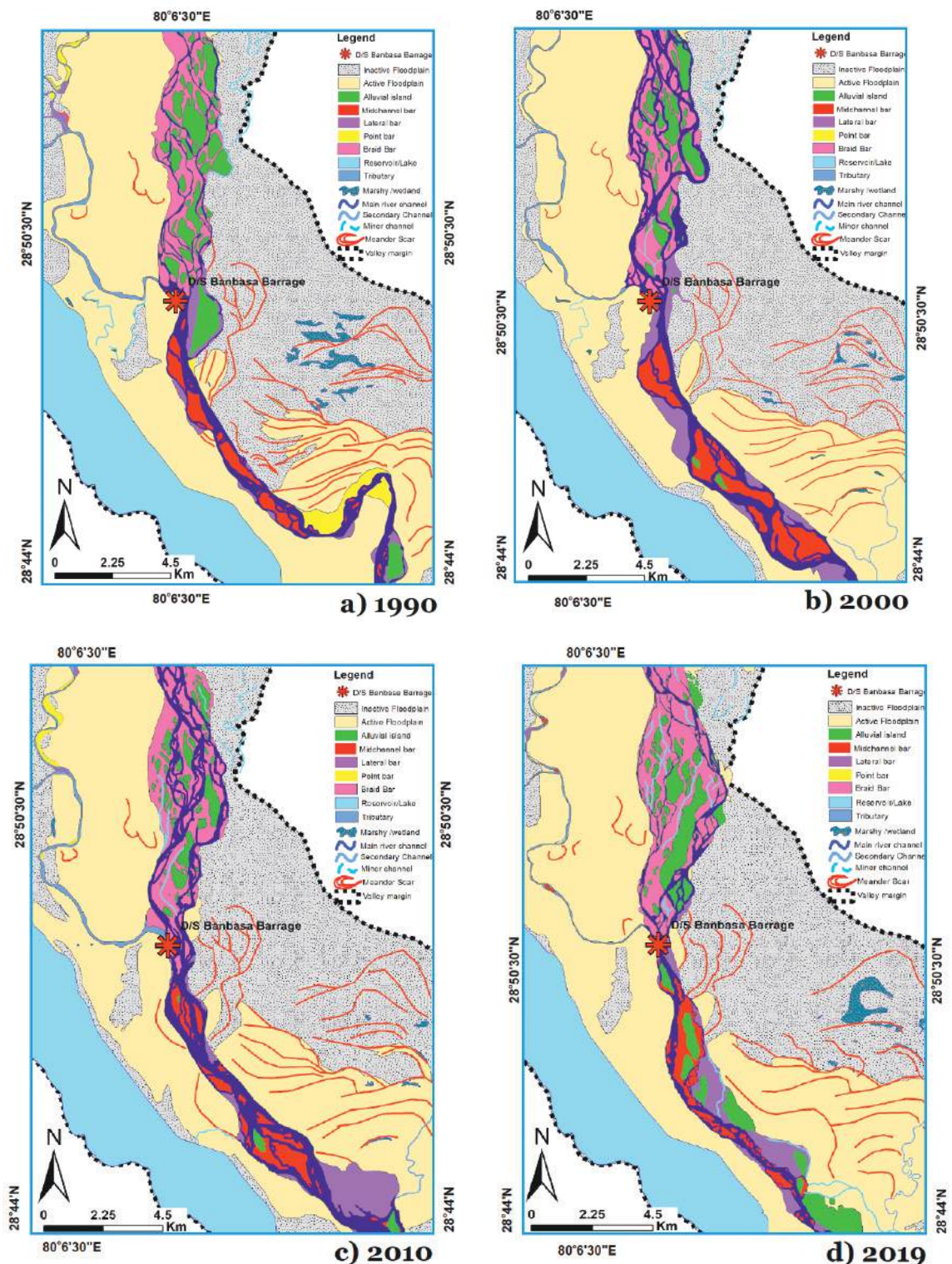


**Figure 43 Geomorphic characteristics at the location Downstream of the Banbasa Barrage**

In terms of planform dynamics, the main river channel around this location shows more braiding in the upstream part of the Banbasa Barrage from the year 1990 to 2019, as shown in Figure 44.

In summary, the Sharda River at this location is characterised by a gravel-sand transition zone and a braided-sinuuous pattern. Multiple alluvial islands (mostly in the upstream portion), braided bars, mid-channel bars and lateral bars have been noted. The river at this location is characterised by predominant in-channel migration, though a significant lateral shift of the river is noted in the downstream reaches from left to right. The channel is asymmetric with a wide main channel (avg. 228m in low-flow condition) and the village settlements on the right bank side are susceptible to flooding. The right bank is erosion-prone since the thalweg<sup>14</sup> runs closer to the right bank side. A mixed substrate has been noted.

<sup>14</sup>Thalweg: a line connecting the lowest points of successive cross-sections along the course of a river



**Figure 44: Changes in Planform Dynamics – Sharda River stretch (Downstream of the Banbasa Barrage)**

The maximum channel depth observed is 5.75m and the maximum width observed is 620m. The HFL is recorded at 184.996m MSL, i.e. approximately 4.5m above the bed level. The longitudinal connectivity is good (in the immediate vicinity of the E-Flows location and not long-range connectivity) and lateral connectivity is moderate to good (on the upstream side). The floodplain in the upstream side is well inundated during the monsoon.

Planform dynamics: It reflects the changes in the quasi-equilibrium form of a channel in response to concentration/ dissipation of energy and associated transfer and storage of sediment.



## B. Aquatic biodiversity

Due to regulation from the Banbasa Barrage, large fluctuations in water levels were observed around this location. This has led to altered substratum, volume, velocity and flow pattern of the downstream river stretch. This river stretch is the abode of fishes of the transitional zone, such as *Chagunius chagunio*, *Bangana dero*, *L. dyocheilus*, *L. boga*, *Tor putitora*, *T. tor*, *Schizothorax richardsonii*, *Garra* sp., etc. However, these species are rarely seen in the stretch.

At this location, seven fish species were recorded during the river surveys. As per IUCN Red List categorisation, among these species, one is Near Threatened (i.e. *Bagarius bagarius*). As per records *B. bagarius* is a migratory fish which moves upstream during monsoon seasons. This species is also reported in secondary literature by Upadhyay and Pandey (2013)<sup>15</sup> around 20km upstream from the Banbasa Barrage. It is also a commercially important fish and commonly known as “Goonch”.

The river at this location is not well connected longitudinally (long-range, i.e. including river reaches upstream of the barrage) due to human interferences. However, the water quality is good with no industrial and domestic effluent.



**Figure 45: *Tor putitora***



**Figure 46: *Tor tor***

---

<sup>15</sup> Upadhyay Hem Chandra, Pandey Anupama (2013). The Freshwater Fish Diversity in the Sharda River at Tanakpur, Champawat District of Uttarakhand (India). International Journal of Science and Research (IJSR). ISSN: 2319-7064





**Figure 47: *Bangana dero***

### C. Socio-cultural

In the last 20 years, the local communities have lived through two cataclysmic events. One was a major flood less than two decades ago when the river suddenly shifted towards the village from the forest. About 1/3<sup>rd</sup> of the village land was lost at that time. Several houses were also washed away. After that, during the intense rainfall of 2013, debris from the floods upstream washed down the river. These two situations have made this the most difficult location to survey till date.

The community's memories of the river only extend back to about fifty years. Since the Banbasa Barrage was constructed shortly after that period, very few people have information about an unregulated river. Further, the two devastating floods have overwhelmed the community's memories as well. As a result of this, most of the farmers in the village fear the river. One woman respondent also said that she now has stopped going to the river.

While the respondents complained about the damage due to erosion, the majority of them acknowledged the benefits they receive from the river. Additionally, farmers are aware of the impact the river has on groundwater levels, i.e., a healthy Sharda River improves the groundwater levels.

The quantum of water during the survey was considered to be 'normal' for winter flows at present. In the summer, the level of water goes down by 1.5 to 2 feet. Given the channel profile, this means that the river becomes very shallow for a long stretch. More than the quantum of flows, people are distressed by the changes in the profile of the river channel. At present, the channel is shallow and very wide.



### 4.1.1.2 Downstream of the Banbasa Barrage–Desired State

The ‘Desired’ state of the river downstream of the Banbasa Barrage is given in Table 5.

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                   | Desired State     |
|--------|-----------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Slightly Modified   | The longitudinal connectivity is good and lateral connectivity is moderate to good. The floodplain in the upstream side is well inundated during monsoon                                             | Near Pristine     |
| 2      | Aquatic Biodiversity  | Moderately Modified | Long-range connectivity for species migration is hampered by barrages upstream. Some human interference is also evident. However, the water quality is good with no industrial and domestic effluent | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | Whilst the winter season flows are considered to be adequate, summer flows are on the lower side and that causes inconvenience for the communities                                                   | Slightly Modified |

**Table 5: Present and Desired state of the river Downstream of the Banbasa Barrage E-Flows location**



## 4.1.2 Palia Kalan

Palia Kalan is a town in the district of Lakhimpur, close to the Dudhwa National Park and about 35km from the Nepal border. The E-Flows location is about 6km from the Palia Kalan town, near the Sharda River bridge. There is a road and a railway bridge, the location is in between both the bridges (towards road-bridge side).

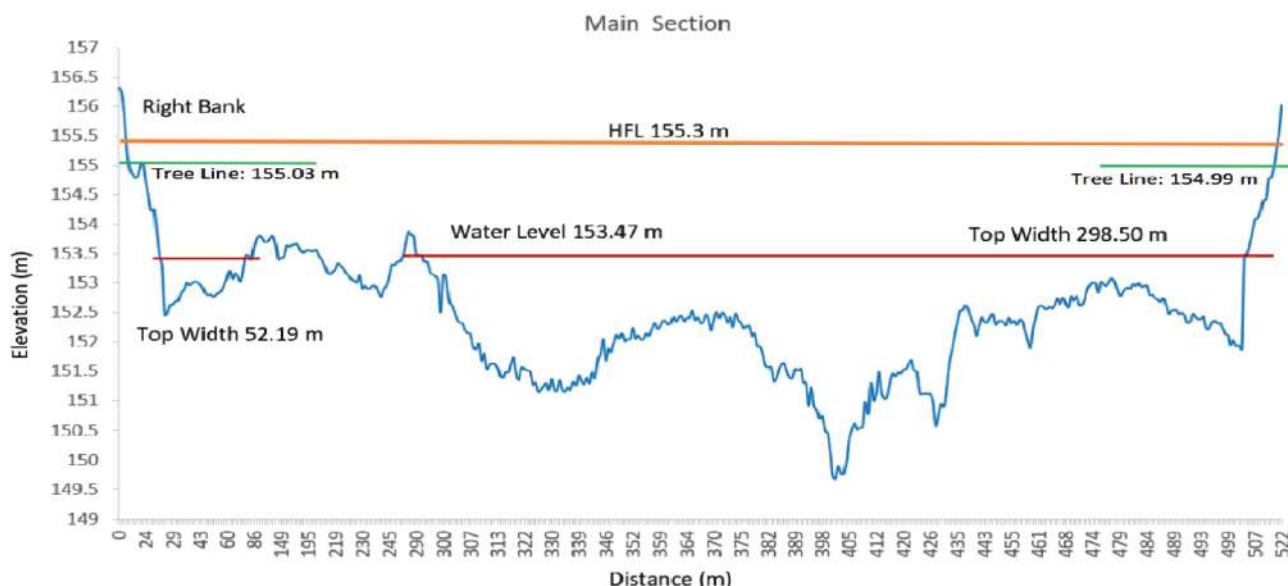
Riverbanks are largely sandy and exposed. The dominant substrate is composed of sand and silt. The river stretch around this location is given on lease every year to the fishermen for fishing during the post-monsoon period. Fishing and agriculture are the main activities observed around this location with sugarcane as a primary crop.

The cross section of the Sharda River at the Palia Kalan E-Flows location is given in Figure 49 (water level at the time of survey is also shown).



**Figure 48: Palia Kalan location on the Sharda River. This is also a CWC site.**





**Figure 49: Cross Section of the Palia Kalan E-Flows location on the Sharda River**

The cross-sectional parameters are shown in Table 6.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 520       | 6.25           | 3.72                        | 83.20                    |

**Table 6: Cross sectional parameters for the Sharda River at Palia Kalan (From HFL)**

The Present and Desired state of the Sharda River at the Palia Kalan location is discussed thematically in the following section.

### 4.1.2.1 Palia Kalan – Present State

#### A. Fluvial geomorphology

The active floodplain width is variable with the *downstream* portion being wider and consisting of multiple minor channels. This location is characterised by an unconfined floodplain with valley margin farther from the left bank. The channel thalweg mostly lies along the left bank near the Palia Kalan Bridge. Multiple minor channels in both the upstream and downstream reaches have been mapped. The meander scars are mapped upstream of the road bridge indicating regions of channel shift.

Large lateral bars and mid-channel have also been noted (Figure 50). The alluvial islands are indicative of emergence at bank full stage and are mapped using satellite images. Marshy areas/wetlands are found in the proximity of the bridge reinforcement structures, which were portions of the old active floodplain of the river. These are poorly drained (unchanneled), low energy, vertically accreting environments having a characteristic wetland vegetation association.

While floodplains are usually aggradational, scour occurs around obstructions. The sinuous pattern in the vicinity of the road and railway bridge is indicative of

scouring, leading to the removal of considerable volumes of soil to drive accelerated sedimentation and formation of large lateral bars downstream. The planform dynamics and associated changes around the main river channel (Palia Kalan location) from the year 1990 to 2019 are shown in Figure 51.



**Figure 50: Pictures exhibiting various geomorphic features around the Palia Kalan location on Sharda River**

The main channel of the Sharda River at the Palia Kalan bridge is braiding in nature. The river channels of the years 1990 and 2000 show almost similar flow lines. In the year 2010, the river migrated towards the north east in the reaches upstream of Palia Kalan. In the downstream reaches, it has a similar flow line to that of the year 2000. However, the river migrated again in 2019 in the south-west direction.

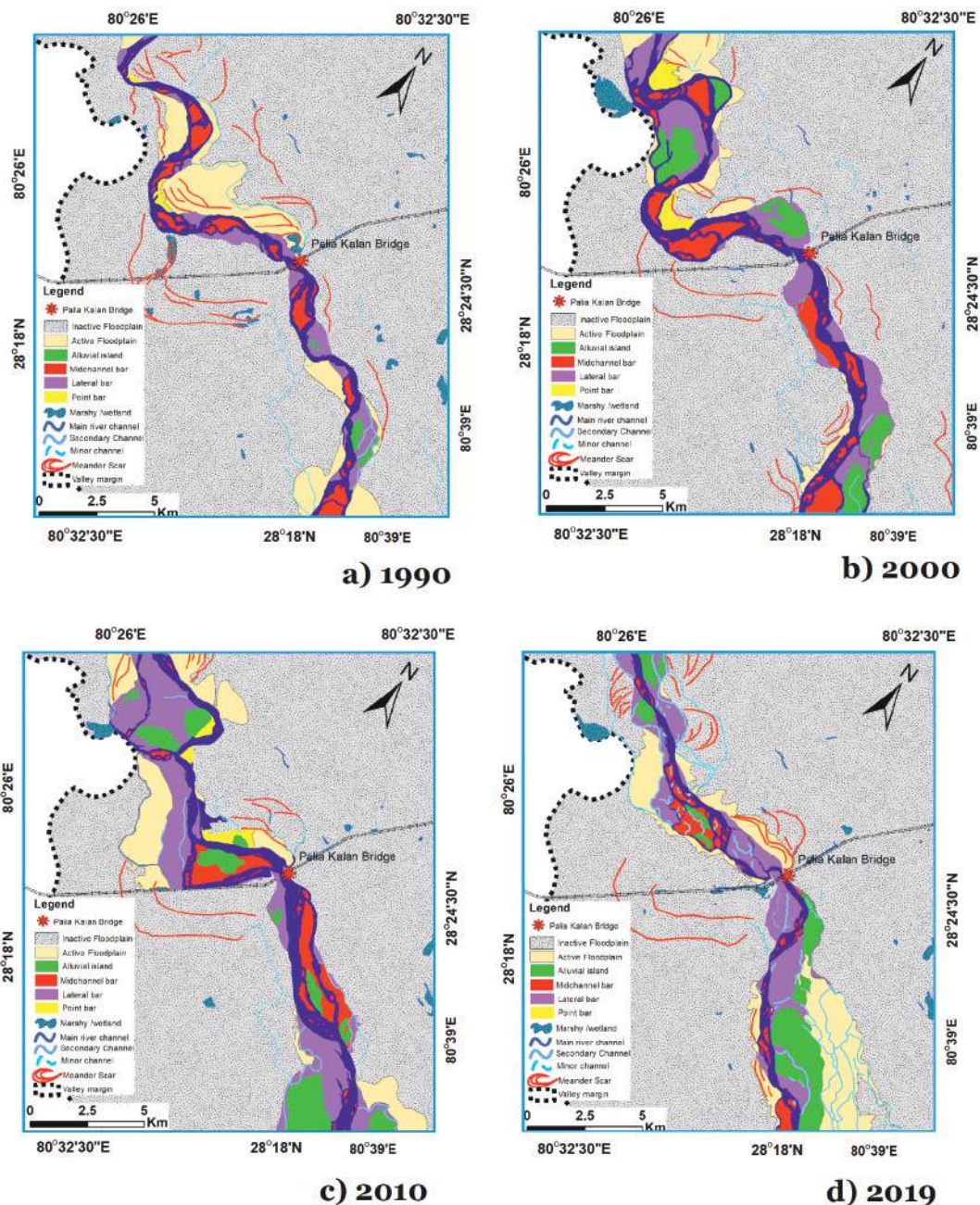
The cross-sectional morphology of the Sharda River at Palia Kalan is quite similar to that of the previous location Downstream of the Banbasa Barrage.

In summary, the Sharda River at this location is characterised by a sinuous channel pattern and hosts large lateral bars, mid-channel bars and alluvial islands. The channel is mostly asymmetric with a main channel (avg. 330m in low flow condition) and is susceptible to bank erosion and floods along the left bank (downstream of the road bridge) of the channel belt. A sandy substrate and banks are noted. The capacity for channel migration is high in the reaches of both the upstream and downstream of the road bridge. In general, the longitudinal connectivity is good throughout and the lateral connectivity is good mostly in the downstream side. Additionally, the floodplains are well inundated during monsoon.

## **B. Aquatic biodiversity**

The Sharda River supports a wide range of fish species in general. During this study, the maximum number of fish species, i.e. 16 species, were recorded from





**Figure 51: Planform dynamics of the Sharda River around Palia Kalan for 1990, 2000, 2010, 2019**

the Palia Kalan location, which is in the middle stretch of the river. Among these recorded species, *Schizothorax richardsonii* (rarely available) is Vulnerable (VU) and *Ailia coila* is Near Threatened (NT) as per the IUCN Red List data. *Schizothorax richardsonii* is also reported by Naganyal and Saxena (2019)<sup>16</sup> in this river, about 100km from this location. *Ailia coila* commonly called "Patasi" or 'India Ailia' and *Schizothorax richardsonii* commonly termed as "Asaila" or "Snow trout" is also a commercially important fish species. *Mystus bleekeri*, *Mystus cavasius*, *Sperata seenghala*, *Rita rita* and *Clupisoma garua* are some of the economically important fish species found at Palia Kalan.

<sup>16</sup>Naganyal Archana, Saxena Amita (2019). Food and feeding habit of fishes in Kosi and Sharda Rivers of Uttarakhand. International Journal of Zoology Studies. Volume 4; Issue 3; 36-39. ISSN: 2455-7269



The river stretch was originally known for the admixture of fishes of the Himalayan region and that of the plains. The fish characteristic of the zone are Indian major carps (*Labeo rohita*, *Catla catla*, *Cirrhinus mrigala*) other carps (*Bangana dero*, *Labeo dyocheilus*, *L. gonius*) and other species such as *Chagunius chagunio*.

The Ganga river dolphin was spotted multiple times during the survey in monsoon season. An adult dolphin was spotted around the bridge pillars. According to the fishermen, the Ganga river dolphin is present in the river and is visible in both the seasons. However, the frequency of spotting is much more during the monsoon season, when the water level increases.

### C. Socio-cultural

Deliberations were held with shopkeepers, priests, farmers, *pallage* farmers (riverbed farming, sometimes immediate floodplains are also used by farmers), boat owners, fisher-folk, government employees, livestock herders and visitors to gain an understanding of the socio-cultural needs met by the river. The respondents were residents of the nearby villages including Shrinagar, Daulatpur and Palia Kalan as well as the now-lost village of Barua.

The local villagers consider Sharda River as a 'pure' river. There is also a great awareness of the blessings conferred upon them by the river.

Apart from fishing, riverbed farming (*pallage*) is another source of livelihood for the local communities. Therefore, they welcome sandbars and island formation during the lean season and extensively use that space for growing *cucurbitaceae* family of fruits and vegetables.

The fishermen community is dissatisfied with the low flow conditions at this location, as it reduces water levels and consequently results in an unsatisfactory catch compared to the past. Mahseer was one of the fish species that is now no longer available. A fisherman who was interviewed had once caught a goonch that weighed about 50kg. Now, he is able to catch 1-2kg with great difficulty. He attributes the lack of fish to the shallowness of the river, primarily caused by reduced flows and excessive siltation in the riverbed.

Respondents mentioned that flows in winter are adequate. However, the flows during the summers are unsatisfactory, being less than half of what they were at the time of the interview, which was conducted during the winter season. The river is confined to a very narrow channel, either on the left or the right bank (this varies with the years). Ritual bathing, boating, fishing- all become difficult in this situation. According to a priest, cremation rites are also affected by low flows. Due to the insufficient velocity, funeral offerings and leftover pyres continue to accumulate on the riverbank.

The team was informed about another occasional but critical problem faced by the local community, i.e. pollution due to occasional releases of effluent (two to three times a year) from the sugar factories, leading to fish mortality.

### 4.1.2.2 Palia Kalan–Desired State

The ‘Desired’ state of the Sharda River for the Palia Kalan location is shown in

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                        | Desired State     |
|--------|-----------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Slightly Modified   | Good longitudinal and lateral connectivity, with well-inundated flood-plains during monsoon                                                               | Near Pristine     |
| 2      | Aquatic Biodiversity  | Slightly Modified   | Rich fish diversity, including native fish species, along with presence of the Ganga river dolphin                                                        | Near Pristine     |
| 3      | Socio-cultural        | Moderately Modified | Shallower river stream, reduced water levels lead to difficulty in carrying out rituals during summer season, plus declining fish catch is another reason | Slightly Modified |

**Table 7: Present and Desired state of the Sharda River at the Palia Kalan location**



### 4.1.3 Downstream of the Lower Sharda Barrage

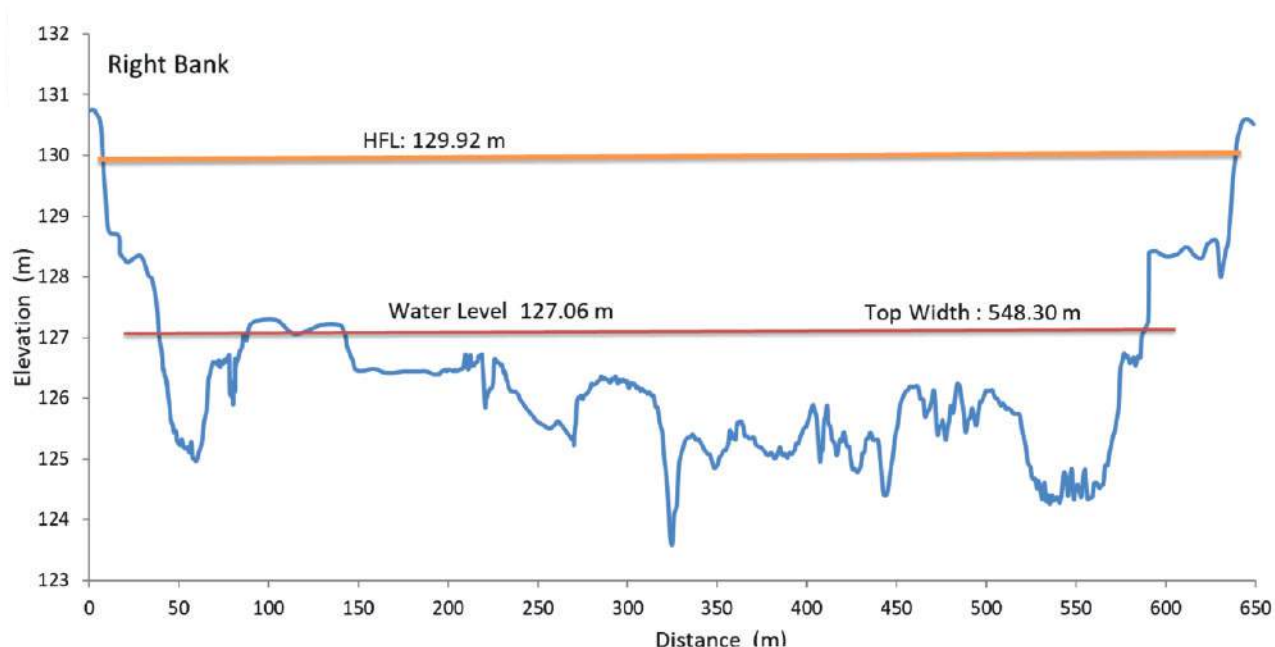
Downstream of the Lower Sharda Barrage E-Flows location is about 65 km from the Palia Kalan. Forty kilometres from Lower Sharda Barrage location, the river merges with the Ghaghra River. The river is fast flowing at this location and the active channel width is vast, as compared to the same in Palia Kalan. Agricultural land on both the banks is visible (Figure 52). The substrate is mainly composed of sand and clay. Banks are unstable and erosion is apparent.

The cross section of the river channel Downstream of the Lower Sharda Barrage is given in Figure 53 (water level at the time of survey is also shown in the figure).



**Figure 52: Sharda River Downstream of the Lower Sharda Barrage**





**Figure 53: Cross Section of the river channel Downstream of the Lower Sharda Barrage E-Flows location**

The cross-sectional parameters are shown in Table 8.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 640       | 7              | 3.3                         | 91.43                    |

**Table 8: Cross-sectional parameters for Downstream of the Lower Sharda Barrage E-Flows location (from HFL)**

The Present and Desired state of the Sharda River downstream of the Lower Sharda Barrage E-Flows location are discussed in a thematic manner.

### 4.1.3.1 Downstream of the Lower Sharda Barrage – Present State

#### A. Fluvial geomorphology

The channel has an asymmetric form, moderate sinuosity and high multiplicity. It flows mostly towards the left bank in the vicinity of the road bridge. A large anabranch has been noted upstream of the road bridge with a lower width/depth ratio compared to the main channel.

This anabranch turns southward to the right bank, before turning northward to re-join the main channel. Numerous marshes/wetlands have been mapped, which are representative of low energy and vertically accreting environments, which get sufficiently inundated during the monsoon.



**Figure 54: Geomorphic complexities in the Sharda River Downstream of the Lower Sharda Barrage E-Flows location**

Multiple large mid-channel bars are found at this location, elongated in the direction of the flow. Bank-attached lateral bars have been observed. A few alluvial islands could also be identified using the satellite image. The floodplains are agriculture-dominated on both sides, with major crops being wheat and sugarcane. The left bank, downstream of the road bridge, is more susceptible to erosion.

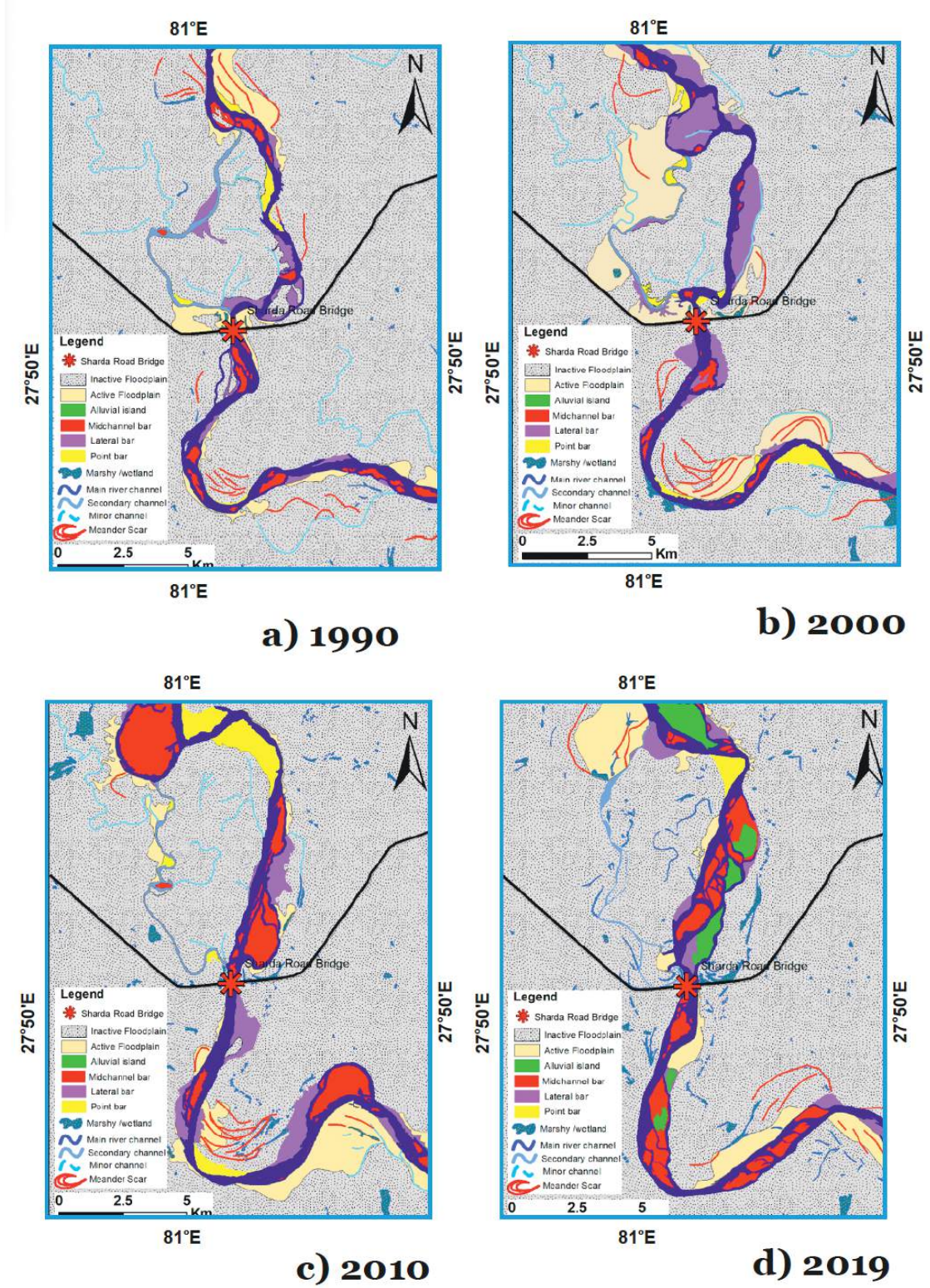
Rotational failure of bank material is observed on the left bank of the channel belt, downstream of the road bridge. This leads to sliding or toppling of bank material to the channel, which gets further carried downstream. This type of channel instability characteristically involves the redistribution of large amounts of sediment impacting the local balance between erosion, transport and storage, as well as adjustments to the channel slope. This may progress upstream through the system and make changes to the supply of sediment in downstream reaches.

Figure 55 shows the temporal planform maps around the Sharda River (close to road bridge near Lakhimpur) region for the years 1990, 2000, 2010, 2019, respectively. There is an increase in the active floodplain extent from 1990 to 2019. It also shows that mid-channel bars were prominent features which increased from the year 1990 to 2010. Lateral bars have decreased over this time period.

Planform dynamics suggest that the upstream reaches of the river are highly migratory, with an anabranch toward the right bank side, and downstream of the road bridge, the river exhibits consistent straight to sinuous patterns. The cross section of E-Flows location is highly irregular suggesting uneven bed due to submerged bars.



In summary, the Sharda River at this location is characteristic of a wandering-sinuuous pattern and hosts numerous mid-channel bars, few lateral bars and a few alluvial islands. The channel is mostly asymmetric with a wide main channel (avg. 610m in low flow condition) and is susceptible to bank erosion along the left bank of the channel belt. The bank material and the channel substrates are sandy.



**Figure 55: Planform dynamics of Downstream of the Lower Sharda Barrage 1990, 2000, 2010, 2019**



## B. Aquatic biodiversity

A total of ten fish species were recorded during the river surveys, of which *Wallago attu*, commonly called “*Lanchi*” or “*Paran*”, is found to be Vulnerable (VU) as per the IUCN Red List data. This fish species also has good commercial value. Some of the other fish species found at this location are *Cirrhinus mrigala*, *Cirrhinus reba*, *Mystus cavasius*, *Channa punctata*. *Tor putitora* was not found during primary surveys, but is reported from this river by Naganyal and Saxena (2019)<sup>17</sup> and Upadhyay and Pandey (2013)<sup>18</sup> about 160 km to 180 km upstream from the current E-Flows location.

A few deep pools were observed in the river, where the Ganga river dolphin was spotted multiple times during the survey in monsoon season. Two adult dolphins were observed in the river. According to the fishermen and the farmers, they see the Ganga river dolphin during both the seasons (summer and monsoon). However, the frequency is much more during the monsoon season, when the water level increases.

## C. Socio-cultural aspects

The respondents access the river for cutting and gathering wood. Other activities include fishing, bathing livestock and cultural and religious rituals. The *Chhat Puja* is celebrated extensively along Sharada Nagar, which is a social highlight. Respondents were proud to show the banks where the puja is conducted and relate the arrangements (lighting etc.), organized by the *Gram Panchayat*.

Increased scouring downstream of the river is a major concern of nearly all those interviewed. Nearly all the interviewees have either lost their own land, or know someone who has lost land due to erosion of the banks. Despite this, they continue to see value in the river. One of the respondents told the team, “if there was no water in the river, we would all be finished.”

In the summer, the water level is low, making it inadequate for bathing or fishing. As a result, the river does not support livelihoods or socio-cultural sustenance. In the winter, the flows improve marginally. In the monsoon, the flows are considered to be adequate for all the user groups. Floods too are welcomed into the fields for their fertile silt.

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<sup>17</sup> Naganyal Archana, Saxena Amita (2019). Food and feeding habit of fishes in Kosi and Sharda Rivers of Uttarakhand. International Journal of Zoology Studies. Volume 4; Issue 3; 36-39. ISSN: 2455-7269

<sup>18</sup> Upadhyay Hem Chandra, Pandey Anupama (2013). The Freshwater Fish Diversity in the Sharda River at Tanakpur, Champawat District of Uttarakhand (India). International Journal of Science and Research (IJSR). ISSN: 2319-7064

### 4.1.3.2 Downstream of the Lower Sharda Barrage – Desired State

The 'Desired' state of the Sharda River for the Downstream of the Lower Sharda Barrage location is shown in Table 9.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                | Desired State     |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | The longitudinal and lateral connectivity is good. Multiple well-scattered marshy areas in both the left and right portions of the channel belt are indicative of a good floodplain inundation during the monsoon | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | A reasonable fish diversity is observed, however long-range migration of fishes is hindered due to upstream barrage                                                                                               | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | People are distressed by low flows during summers and to some extent in winters as well. This does not match their recollections of the river                                                                     | Slightly Modified |

**Table 9: The Present and Desired state of the Sharda River at the Downstream of the Lower Sharda Barrage E-Flows location**



## 4.2 Ghagra River

The Ghaghra River is said to rise not far from the origin of the Rivers Brahmaputra, Indus and Sutlej, within 'the remarkable hydrographical focus contiguous to the Manasarovar lakes'.<sup>19</sup> From here, it crosses the Himalayas near the Almora group of passes. The name is derived from 'gharghara' (rattling or laughter) - a reference to the noise made by the turbulent river in its higher reaches. The river rises in Tibet, flows through Nepal and crosses the Himalayas at Chisha Pani before finally meeting with the Ganga River. Along its entire length, the Ghagra River bears several names including Ghagra, Sarayu, and Dehwa.

In January 2020, the Government of Uttar Pradesh decided to change the name of the Ghaghra River (between the river stretch from Gonda in UP to Rewalgaanj in Bihar) to Saryu.<sup>20</sup>

Until the opening of the railways, navigation on the Ghaghra River and its tributaries was a major commercial activity. Steamers plied as far upstream as Bahramghat (near the Elgin Bridge) in Barabanki. Timber, grain and spices were the primary cargo. Passenger steamers also regularly plied between Patna and Ayodhya.

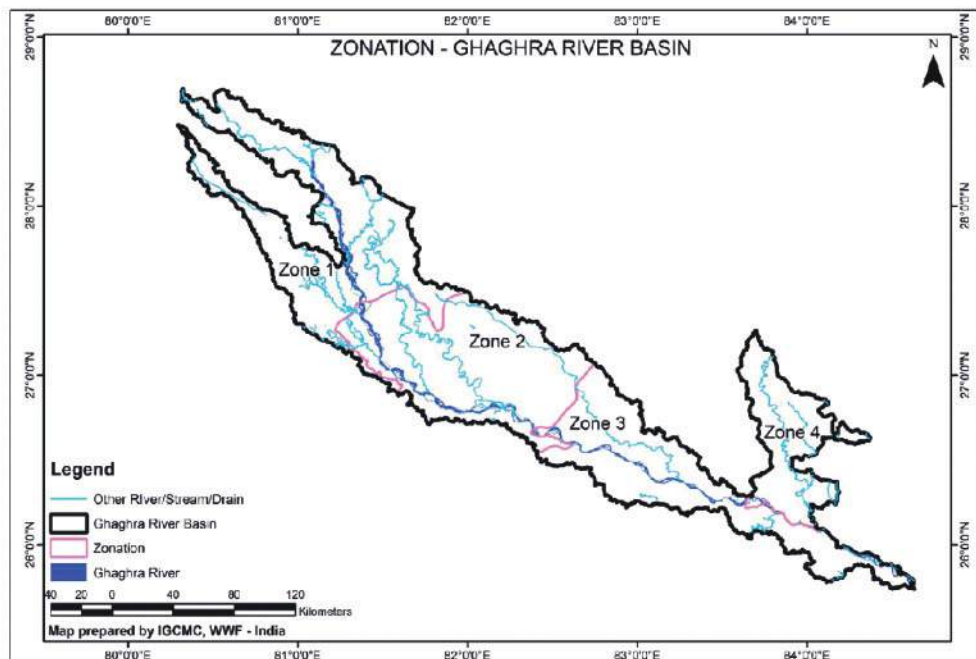
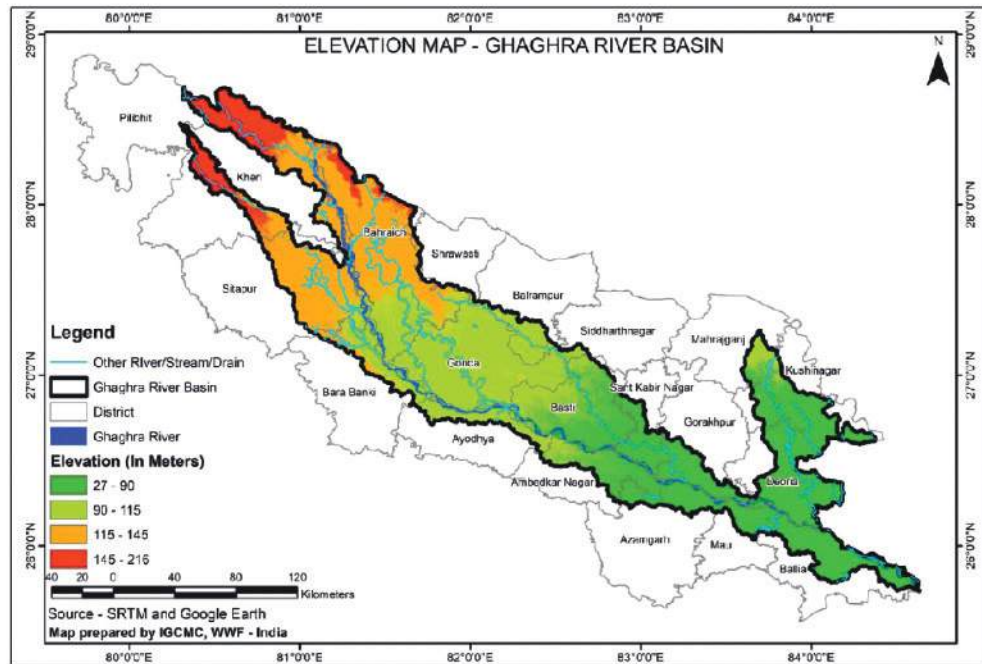
The total length of the Ghaghra River is about 1,080 km, out of which a significant portion flows through Uttar Pradesh. As per the Homogenous Zonation study (Annexure 1B), Ghaghra River in Uttar Pradesh exhibits four homogenous zones, as shown in Figure 56 A & B. Girija Barrage, a water-resource infrastructure located near the Indo-Nepal border, diverts water primarily for irrigation leading to regulated flows downstream of barrage in the river.



<sup>19</sup> Imperial Gazetteer of India, v. 1, p. 18

<sup>20</sup> <http://www.uniindia.com/up-cabinet-decides-to-change-name-of-ghagra-river-as-saryu/north/news/1852561.html>.





**Figure 56 A & B: Homogenous Zones of the Ghaghra River**

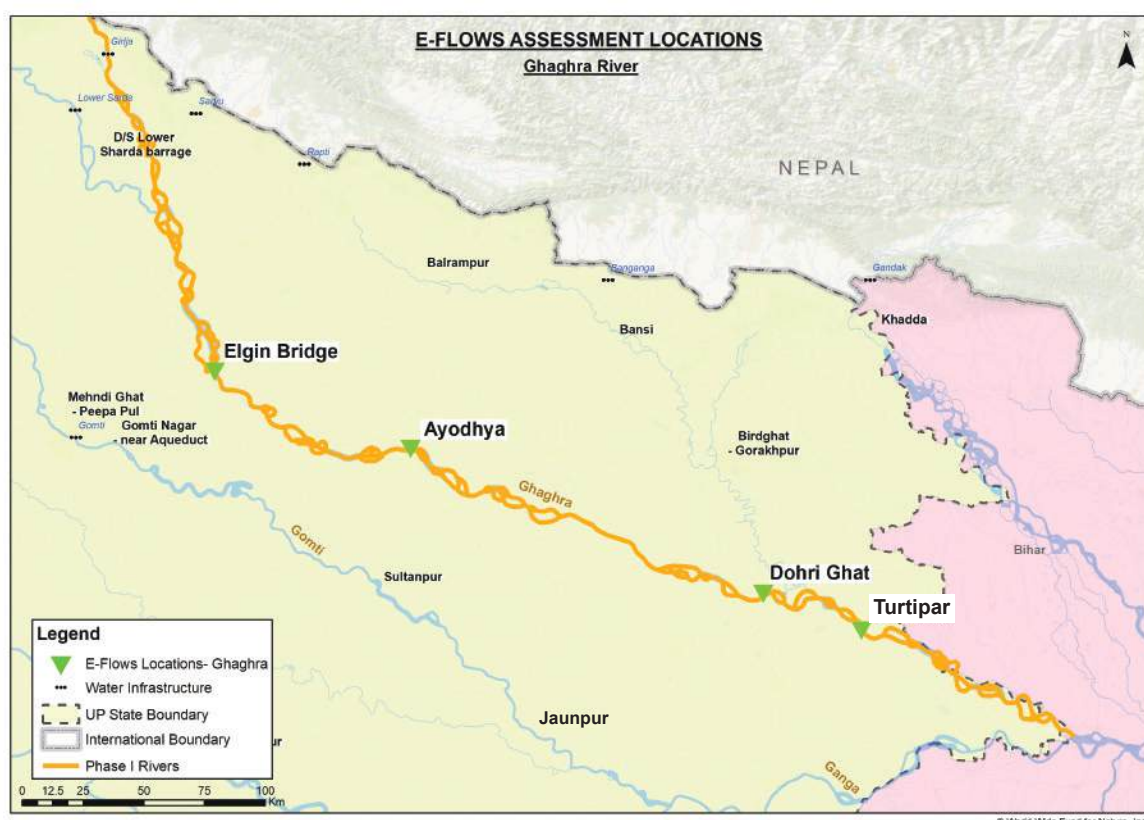
A brief of Homogenous Zones of Ghaghra River is as follows:

- a. **Zone-1:** This zone falls within Pilibhit, Kheri, Sitapur, Bahraich, Barabanki and Shravasti districts of Uttar Pradesh. The length of the river course in this zone is about 121km. The elevation range in the main river stretch is from 216 to 145 metres. Major places are Bannirpur, Tikunia, Dhakia, Abhepur, Garwa, Lakhimpur, Oyal, Buandi, Bahraich, Biswan and more. Major dam is Kaliashuri and major barrage is Girija.
- b. **Zone-2:** This zone falls within Barabanki, Sitapur, Bahraich, Balrampur, Siddharthnagar, Basti and Ayodhya districts of Uttar Pradesh. The length of

the river course is about 176km. The elevation range in the main river stretch is from 145 to 115 meters. Some of the known places include Paraspur, Gonad, Itithok, Bangain, Nawabganj, Haraiya, Elgin Bridge, and Ayodhya. Looking at the criticality of this stretch from the socio-cultural perspective, two E-Flows locations are selected from this stretch, i.e. Elgin Bridge and Ayodhya.

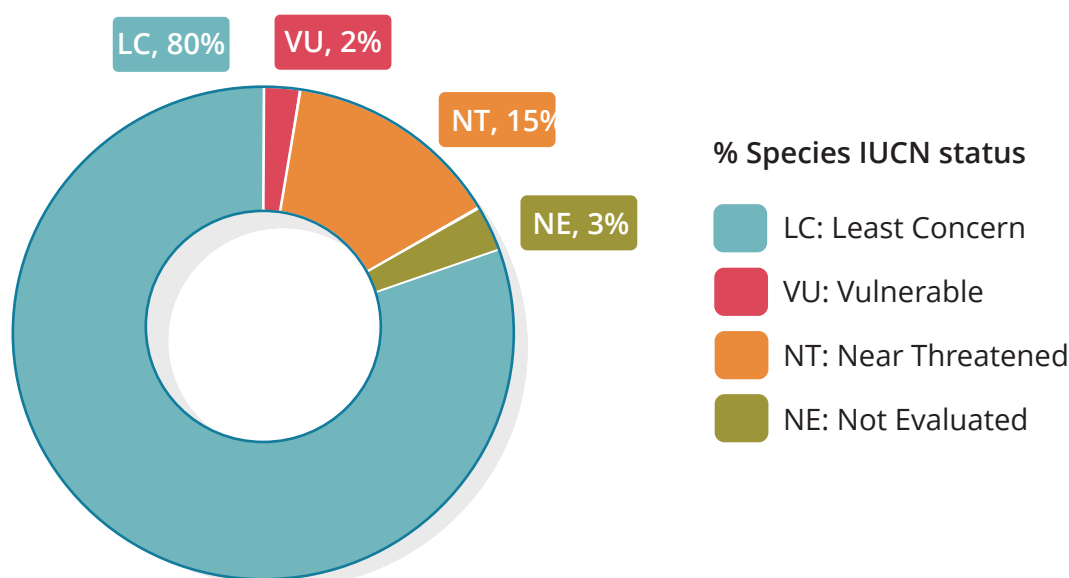
- c. **Zone-3:** This zone falls within Basti, Sant Kabir Nagar, Gorakhpur, Ambedkar Nagar, Mau and Ballia districts of Uttar Pradesh. The length of the river course is about 307km. The elevation range in the main river stretch within this zone is from 115 to 90 metres. Major places are Dhelmau, Tanda, Khetpur, Hanswar Samda, Basti, Alapur, Balrampur, Gola Bazaar, Dohri Ghat, Barhalganj. One E-Flows location at Dohri Ghat was selected from this zone.
- d. **Zone-4:** This zone falls within Mahraganj, Kushinagar and Deoria districts of Uttar Pradesh. The length of the river course is about 23km. The elevation range in the main river stretch is from 90 to 27 metres. Major places are Siswa Bazar, Captain-ganj, Ramkola, Hata Deoria, Baikauli, and Turtipar. One E-Flows location at Turtipar was selected from this zone.

As noted, there are four E-Flows locations on the Ghaghra river as shown in Figure 57.



**Figure 57 : Ghaghra River stretch in Uttar Pradesh with the E-Flows locations**

Among the four E-Flows locations, Ayodhya is the most important from a socio-cultural perspective. The Ghaghra river is also known as Saryu in Ayodhya town. Therefore, this location bears special significance. About 40 fish species belonging to 29 genera, 13 families and six orders were recorded in the Ghaghra River (from both primary surveys and secondary literature). These species are categorised as per the IUCN Red List data. Figure 58 exhibits the number of species that fall under different IUCN Red List categories.



**Figure 58: Fish diversity in the Ghaghra River as per IUCN Red List category**

During the field surveys, basic hydrological and water-quality parameters were also assessed, which are shown in Table 10.

| Hydrological and Water-quality Parameters | Elgin Bridge near Barabanki |                   | Ayodhya Downstream Rajghat Bridge                         |                  | Dohri Ghat                                                |                  | Turtipar         |                   |
|-------------------------------------------|-----------------------------|-------------------|-----------------------------------------------------------|------------------|-----------------------------------------------------------|------------------|------------------|-------------------|
|                                           | Summer                      | Monsoon           | Summer                                                    | Monsoon          | Summer                                                    | Monsoon          | Summer           | Monsoon           |
| River depth (m) Average, (min-max)        | 2.38 (1.22-6.07)            | 6.94 (0.91-13.41) | Surveys not conducted, as the location was selected later | 2.40 (0.76-4.39) | Surveys not conducted, as the location was selected later | 5.49 (1.07-13.7) | 2.35 (0.79-5.12) | 5.53 (0.76-11.19) |
| River Width (m)                           | 600                         | 700               |                                                           | 800              |                                                           | 400              | 750              | 950               |
| Average Current velocity (m/sec)          | 0.325                       | 0.12              |                                                           | 0.25             |                                                           | 0.340            | 0.345            | 0.390             |
| pH                                        | 7.8                         | 9.2               |                                                           | 9.4              |                                                           | 8.7              | 7.6              | 8.6               |
| Temperature (°C)                          | 27.3                        | 22.8              |                                                           | 21.5             |                                                           | 25.8             | 29               | 26.5              |
| Dissolved Oxygen (DO) mg/l                | 8.8                         | 9                 |                                                           | 8.2              |                                                           | 7.6              | 8.5              | 8.8               |
| Total Dissolved Solids (TDS) mg/l         | 90.7                        | 160               |                                                           | 145              |                                                           | 186              | 116              | 178               |
| Physical appearance                       | Clear                       | Turbid            |                                                           | Clear            |                                                           | Turbid           | Clear            | Turbid            |

**Table 10: Hydrological and basic water-quality information at various E-Flows locations in the Ghaghra River**

The present and desired state for the E-Flows locations on the Ghaghra River are discussed in the following section.







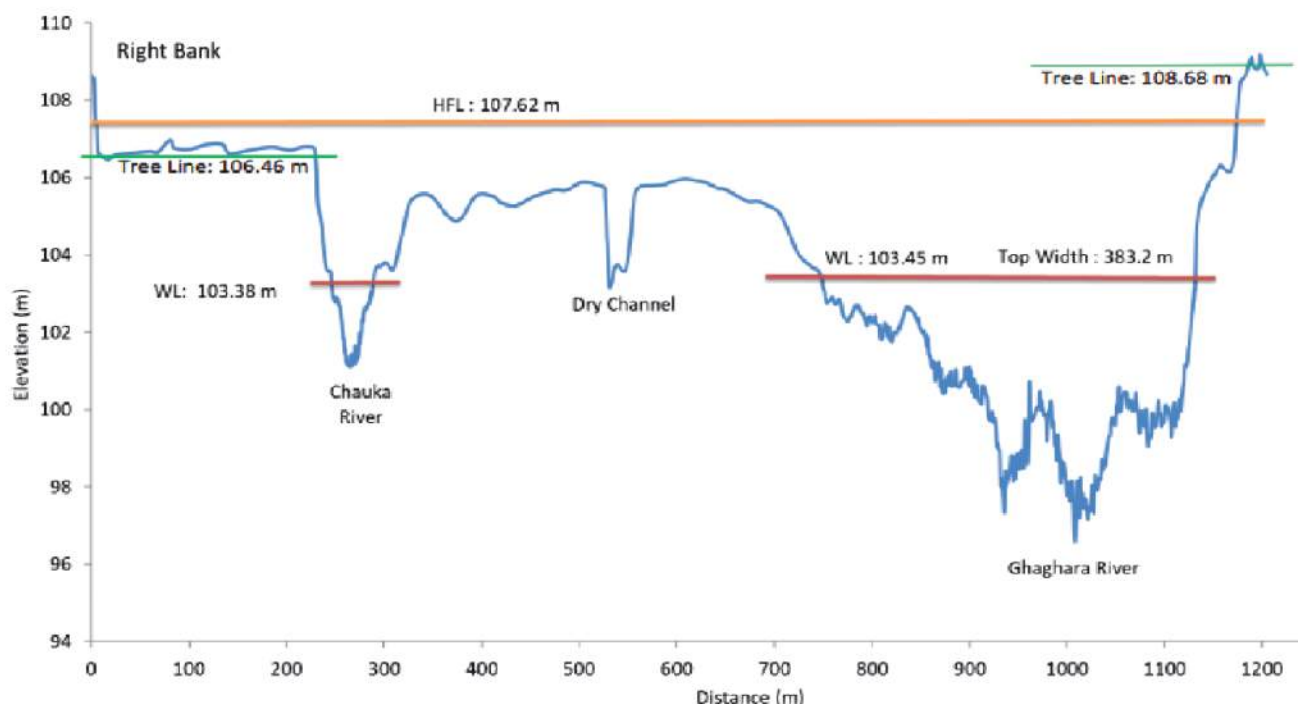
## 4.2.1 Elgin Bridge

The Elgin Bridge location (near Barabanki) falls between a railway and road bridge. The railway bridge is 3,695 feet long. Due to the variability of the river's course, Elgin Bridge was built on dry land, and the river was diverted through it. Thus, the selected river stretch around the E-Flows location only came into existence at the time of the construction of the railway bridge in the early nineteenth century.

The flows velocity was moderate to fast during summer and monsoon. The substrate is largely composed of sand and silt. Riverbanks are largely sandy and both the banks are exposed. Main habitat types include deep pools and run in the river. The cross section of this location is given as Figure 60 (water level at time of survey, i.e. early January 2020, also marked).



***Figure 59: Fishing near the Elgin Bridge E-Flows location on the Ghaghra River***



**Figure 60: Cross Section of the Elgin Bridge E-Flows location on the Ghaghra River**

The cross-sectional parameters are shown in Table 11.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 1175      | 12             | 6.8                         | 97.92                    |

**Table 11: Cross-sectional parameters for the Ghaghra River at Elgin Bridge (from HFL)**

### 4.2.1.1 Elgin Bridge – Present State

#### A. Fluvial geomorphology

The channel around Elgin Bridge is characterised by asymmetric form, low sinuosity and high multiplicity except those close to the bridge. For most parts, the primary channel is flowing along the right bank. A number of secondary channels are mapped as co-existent anabranches (repeated bifurcation and rejoining) with a lower width/depth ratio compared to the primary channel. These are generally open channels which remain connected to the trunk stream of the main channel. These are reactivated at high flow conditions and are also potential locations for avulsions. These channels are dominated by low-energy suspended sediment deposits.

A number of alluvial islands and compound vegetated mid-channel bars were mapped. These are emergent even at 'bank full' stage, both at upstream and downstream of the Elgin Bridge location. The islands are commonly elongated in form, aligned with the direction of the flow. These are relatively stable features and they act as secondary storage of instream sediments.





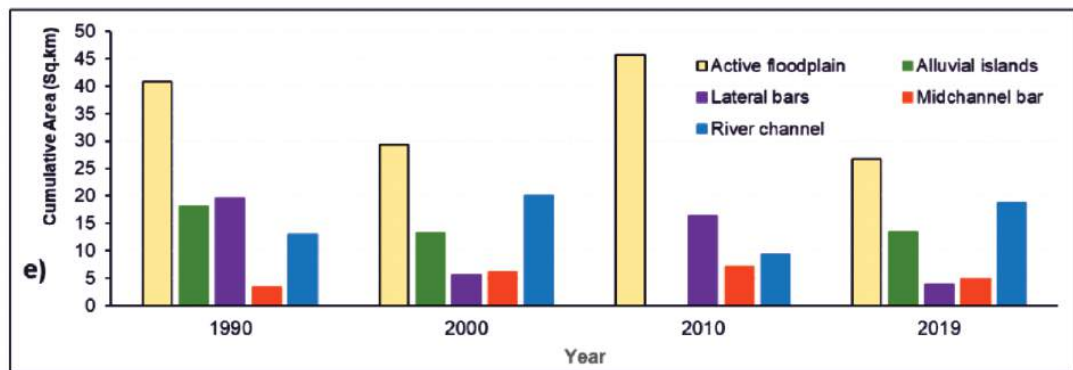
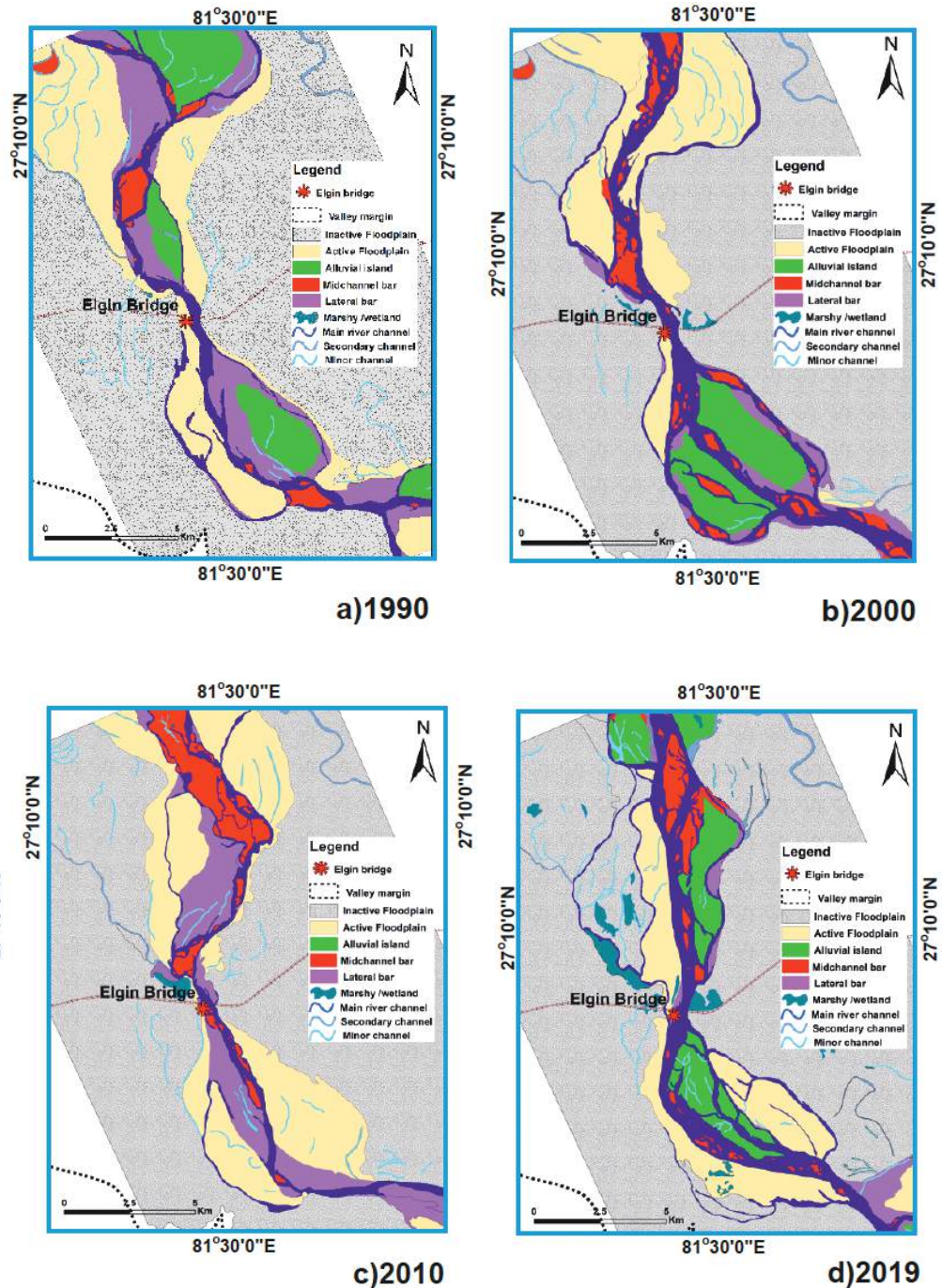
**Figure 61: Geomorphic features of the Ghaghra River channel around the Elgin Bridge E-Flows location**

The floodplains are agriculture dominated and there are scattered village settlements. The major crops types are wheat and sugarcane. The right bank downstream of the Elgin Bridge is more susceptible to flooding and erosion. There seems to be increased flood risk towards the right bank, downstream of the Elgin Bridge section.

Figure 62 shows a large number of alluvial islands and lateral bars in the year 1990 both upstream and downstream of the Elgin bridge, in terms of planform dynamics of the Ghaghra River around this location. The main channel traversing through the floodplain shows a braided pattern in the locations upstream and downstream of the Elgin Bridge. At the Elgin Bridge, the river becomes confined and displays a single channel system. In the year 2000, the main channel showed numerous small mid-channel bars with a few lateral bars in the location upstream of the Elgin Bridge. In the downstream reaches, the main channel gets separated by large alluvial islands. The planform morphology for the year 2010 is marked by numerous mid-channel bars and lateral bars with narrow and thin channels in the upstream reaches with a narrow and single-thread channel in the downstream reaches of Elgin Bridge. Finally, the channel once again shows the development of large alluvial islands in 2019 and is highly braided with mid-channel bars and few lateral bars in the upstream.

The main channel of the Ghaghra River has frequently shifted between the left and right banks during the period of investigation (1990 – 2019). Floodplains are formed by the deposition of sediments derived from the river during high flow events on both sides of the river channel.

In summary, the Ghaghra River at this location is characterised by a braided morphology and is anabranching with large alluvial islands, small mid-channel bars and lateral bars. The channel is mostly asymmetric with a wide main channel (avg. 300m in low flow condition) and is susceptible to floods along the right bank of the channel belt. A sandy channel substrate and banks are noted. Many reaches upstream as well as downstream are identified as highly aggrading.



**Figure 62: Planform dynamics map of the Ghaghra river around Elgin Bridge for 1990, 2000, 2010, 2019. The graph shows temporal changes in the area covered by different geomorphic units**

## B. Aquatic biodiversity

As per secondary literature, this river stretch harbours more than 35 fish species. However, a total of four species were recorded during summer and monsoon season and none fall in the IUCN Red List. Studies have reported four species which are Near Threatened (NT), i.e. *Chitala chitala*, *Ompok bimaculatus*, *Ompok pabda* and *Ompok pabo*. *Chitala chitala* is a commercially important fish species and commonly known as “Chital”.

The team spotted the Ganga river dolphin during monsoon season. The local farmers report their presence round the year. Calves and adults of the species are spotted occasionally.

## C. Socio-cultural aspects

People see the river as unpredictable. The survey team had interviewed one of the last steamboat operators. He spoke of running the ferry across the Ghaghra River when it was much wider than it is today. Apparently, the ferry could carry two trucks at one time. The depth of the water was enough to accommodate these huge boats.

This river is worshipped as a divine river, its Himalayan origin adding to its sanctity. Several people come to the ghats to bathe during festival days.

According to local people, the river is clean and has a relatively good biodiversity, with the Ganga river dolphin seen every day. The flows at present are considered low, with the river having shrunk to less than half its original width. At the same time, the floods are seen as extremely destructive. The water level during the time of the survey was considered barely adequate.



### 4.2.1.2 Elgin Bridge – Desired State

The 'Desired' state of the Ghaghra River at the Elgin Bridge location is given in Table 12.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                                                                                                      | Desired State     |
|--------|-----------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | Longitudinal and lateral connectivity is good. Floodplain is well inundated during the monsoon. Planform dynamics indicate that the river is highly migratory in this reach. Several reaches are prone to bank erosion as is also evidenced by bank protection measures in this stretch | Slightly Modified |
| 2      | Aquatic Biodiversity  | Slightly Modified   | Good connectivity and a reasonably intact section, apart from some fishing-related human interferences                                                                                                                                                                                  | Near Pristine     |
| 3      | Socio-cultural        | Moderately Modified | The summer flows are perceived to be lower than what is desired – the people's aspiration of a roaring river is not met                                                                                                                                                                 | Slightly Modified |

**Table 12: Present and Desired state of the Ghaghra River at the Elgin Bridge E-Flows location**



## 4.2.2 Ayodhya

The Ghaghra River is also known as Saryu as it flows through the Ayodhya town. This ancient city was the capital of Kosala, the Kingdom of Dashrath and Lord Ram. It is also Lord Ram's birthplace. As a result, all the legends and stories around the river focus on the Ramayana. This location, therefore, has attained much significance, as scores of people visit this place.

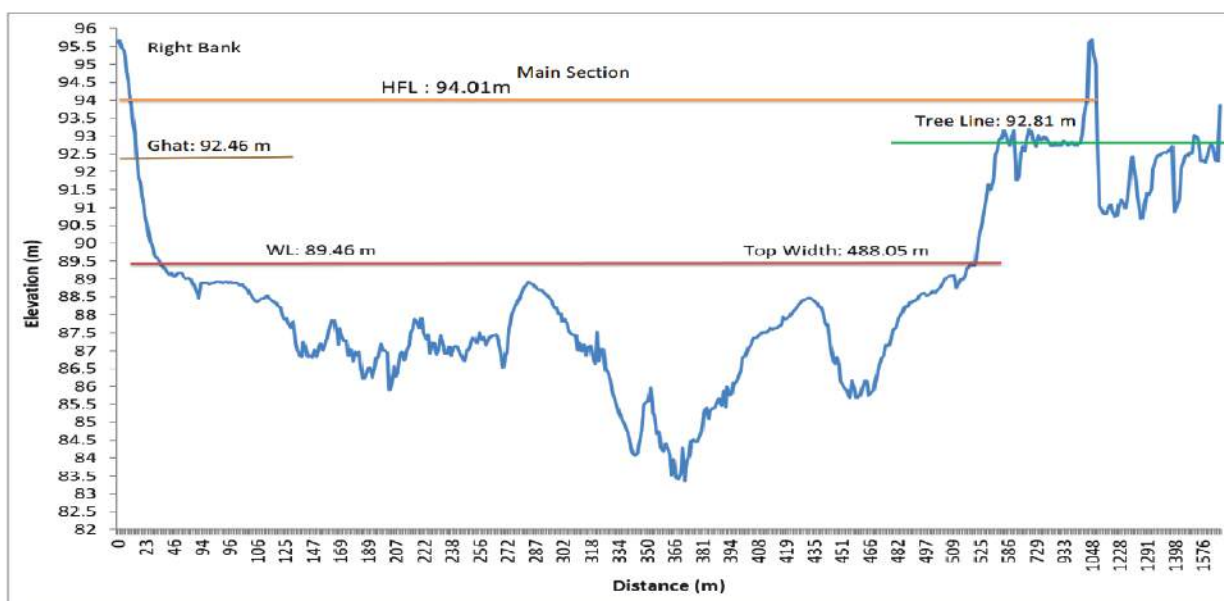
This E-Flows location falls between the two road bridges – the old bridge was constructed in 1966 and the new bridge came up as a part of the National Highway project. It is characterised by a partly confined floodplain, with a valley margin close to the right bank adjacent to the Old Saryu Road Bridge.

Agriculture was observed on the right bank. As informed by the fishermen, fishing is not allowed by the local priests and religious leaders in some particular stretches, especially where temples are located. The substrate is mainly composed of sand and silt. There were few small channels coming from the settlement on the left bank carrying wastewater into the river. However, they were not clearly visible from far away in a boat. Main habitat types include pools and run.



**Figure 63: The Ghaghra (Saryu) River around Ayodhya**

The E-Flows location is at Naya Ghat and the Cross Section is given as Figure 64.



**Figure 64: Cross section of the Ghaghra (Saryu) River at the Naya Ghat E-Flows location in Ayodhya**

The cross-sectional parameters are shown in Table 13.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 1045      | 12             | 5.7                         | 87.08                    |

**Table 13: Cross-sectional parameters for the Ghaghra River at Ayodhya (HFL)**

The Present and Desired state of the Ghaghra (Saryu) River around the Naya Ghat location in Ayodhya is discussed in the sections ahead.

### 4.2.2.1 Ayodhya – Present State

#### A. Fluvial geomorphology

The channel belt as well as the active floodplain have quite variable widths with a wider floodplain along the left bank of the river. The active floodplain is much wider along the left bank near the bridge location. The channel, both upstream and downstream around Old Saryu Road Bridge, is characterised by an asymmetric form, high sinuosity and high multiplicity. The primary channel flows towards the left bank downstream and towards the right bank upstream of the Saryu Bridge, respectively. Like Elgin Bridge, the channel is anabranch and the secondary channels remain connected to the main channel through reactivation at high flow conditions.

The left bank hosts a few village settlements such as Jaitpur, Etmadpur, Deipur, Ismailpur, Lolpur, Ranipur. Among these, Deipur remains most affected by



recurrent floods. The major crop types here are wheat and sugarcane, with some sparse seasonal agriculture in the alluvial islands and mid channel bars. The left bank adjacent to the road bridge is more susceptible to bank erosion and recurrent flooding. The concrete Naya Ghat on the right bank side stabilises and protects the banks.

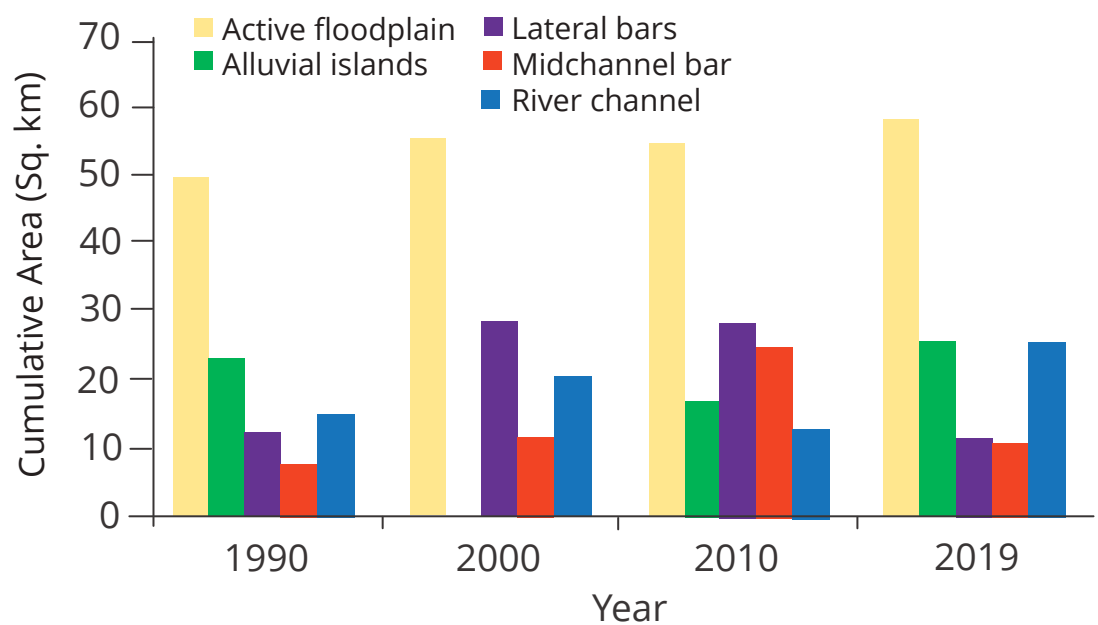
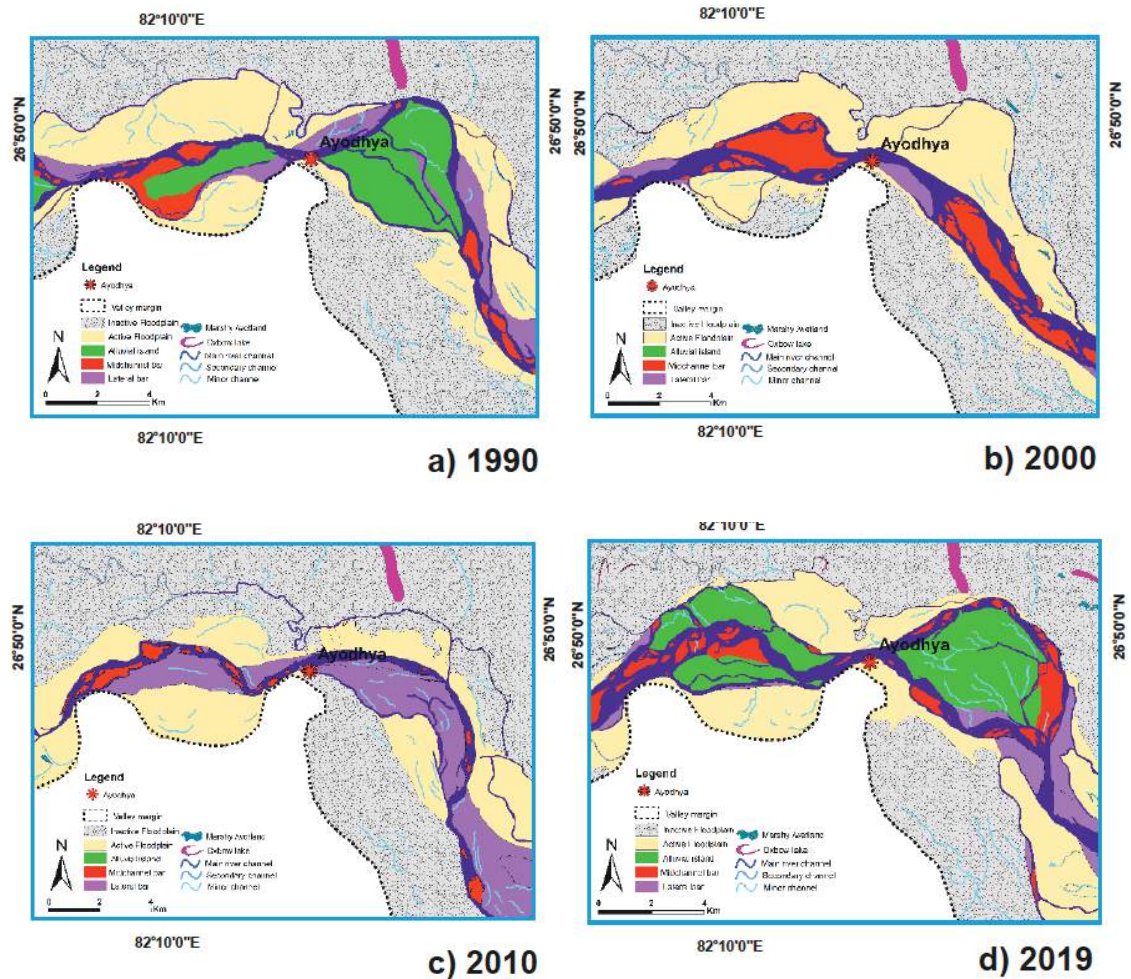


**Figure 65: Geomorphic features around the Naya Ghat E-Flows location in the Ayodhya town**

Dredging and river training activities were observed in the downstream portion of the new road bridge on the alluvial island.

In terms of Planform Dynamics, (Figure 66) the Ghaghra River at this location has a morphology very similar to that at the Elgin bridge location and the temporal changes are also quite similar. Alluvial islands and lateral bars dominate the planform morphology in 1990 both upstream and downstream of Ayodhya. The presence of the bridge and embankments has resulted in a very narrow single channel at Ayodhya, with minimal changes over the years. A remarkable rise in the alluvial islands in 2019 is particularly noted at this location. Another important change is a sharp increase in the active floodplain area from 1990 to 2019. Similar increase is also visible in different bars suggesting a general aggradation in different reaches.

The Ghaghra River at Ayodhya is characterised by a braided morphology and is anabranching with large alluvial islands both upstream and downstream, along with large mid channel and lateral bars. The channel is mostly asymmetric with a wide main channel (avg. 600m in low flow condition) and is susceptible to floods along the left bank of the channel belt near the cross-section locations. Both sandy channel bed material and banks are noted. Several reaches of the river in this stretch are identified as hotspots of aggradation.



**Figure 66: Planform dynamics of the Ghaghra River near Ayodhya for 1990, 2000, 2010, 2019. Temporal changes in area covered by different geomorphic units.**

## B. Aquatic biodiversity

During field surveys, seven fish species were recorded out of the 20 fish species reported in the secondary literature. None of these seven species are in the IUCN Red List. However, three species recorded in the secondary literature have been reported from Faizabad, which is close to Ayodhya, and these species are under Near Threatened (NT) category of IUCN Red List, i.e. *Chitala chitala*, *Ompok bimaculatus* and *Ompok pabda*. *Chitala chitala* is commonly called “Chital” and is an economically important species.

At this location, the Ganga river dolphin were spotted during the survey and their occurrence was reported by the fishermen as well. During fishing, they had observed the species many times a little upstream of this location.

## C. Socio-cultural aspects

The river here is intricately connected with stories from the Ramayana, including Lord Rama’s birth and life. Hindu devotees also come here for a ceremonial dip after bathing in the Ganga River.

This location is one of the key socio-cultural destinations because of its mythological association with Ayodhya city. Various socio-cultural activities such as ritual bathing, *aachman*, daily *aarti*, etc. are common here.

The banks of the Ghaghra River at Ayodhya are also considered a holy place for cremations. According to respondents, hundreds of cremations take place at the crematorium downstream of Naya Ghat every day. Beyond Naya Ghat, there are several *pallage* farmers. The farmers live in the city and walk every day to attend to their farms.

Pilgrims are dissatisfied with the water levels in the river during summers, as they find it difficult to bathe and the river does not match their memories of the flowing and resounding Ghaghra. People desire higher flows in the summer. At present, pilgrims consider the winter flows unsatisfactory. The Government releases additional flows during festivals, and the pilgrims are aware of this.





***Figure 67: Livelihood and recreational activities on the banks of the Ghaghra (Saryu) River in Ayodhya***

### 4.2.2.2 Ayodhya – Desired State

The 'Desired' state of the Ghaghra River at Ayodhya is shown in Table 14.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                                                                     | Desired State     |
|--------|-----------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | Longitudinal connectivity is good, and lateral connectivity is fair. The valley setting has a partly confined floodplain and the active flood plain is well inundated during monsoon. Planform dynamics indicate that the river is susceptible to in-channel migration | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | From the species perspective, there is human disturbance around the location, although local priests do not permit fishing. The boats have long rotors, which impacts local biodiversity                                                                               | Near Pristine     |
| 3      | Socio-cultural        | Degraded            | Low flows are a concern with the people. Pilgrims are dissatisfied with the river, as it does not match their memories of the flowing, resounding Ghaghara and they also find it difficult to bathe.                                                                   | Slightly Modified |

**Table 14: Present and Desired state of the Ghaghra River at Ayodhya**

### 4.2.3 Dohri Ghat

The Dohri Ghat town is located on the south bank of the Ghaghra River, near the bridge connecting Ghazipur to Gorakhpur. This town is located in Mau district. The name (Do Hari) comes from the fact that two Vishnu (Hari) avatars met here – 6<sup>th</sup> avatar Parshuram and 7<sup>th</sup> avatar Shri Ram. The town is said to have been founded by a Raja of Azamgarh towards the end of the eighteenth century. Till the middle of the nineteenth century<sup>21</sup>, Dohri Ghat was the chief port in the district of Azamgarh and handled cargo of grain, salt, tobacco, jute, sugar, etc.

Apart from its cultural significance, this location is also known for the second largest pump canal in Asia built in 1952, which pumps water from the Ghaghra River and then transfers it to an irrigation canal. The Ghaghra River runs in an east-west course in this region and is characterised by a ~300m-wide channel. The E-Flows location is close to a road bridge which is a part of the National Highway 29 constructed in 2019.

The cross section of the Dohri Ghat location is given in Figure 69 with water level at the time of survey.

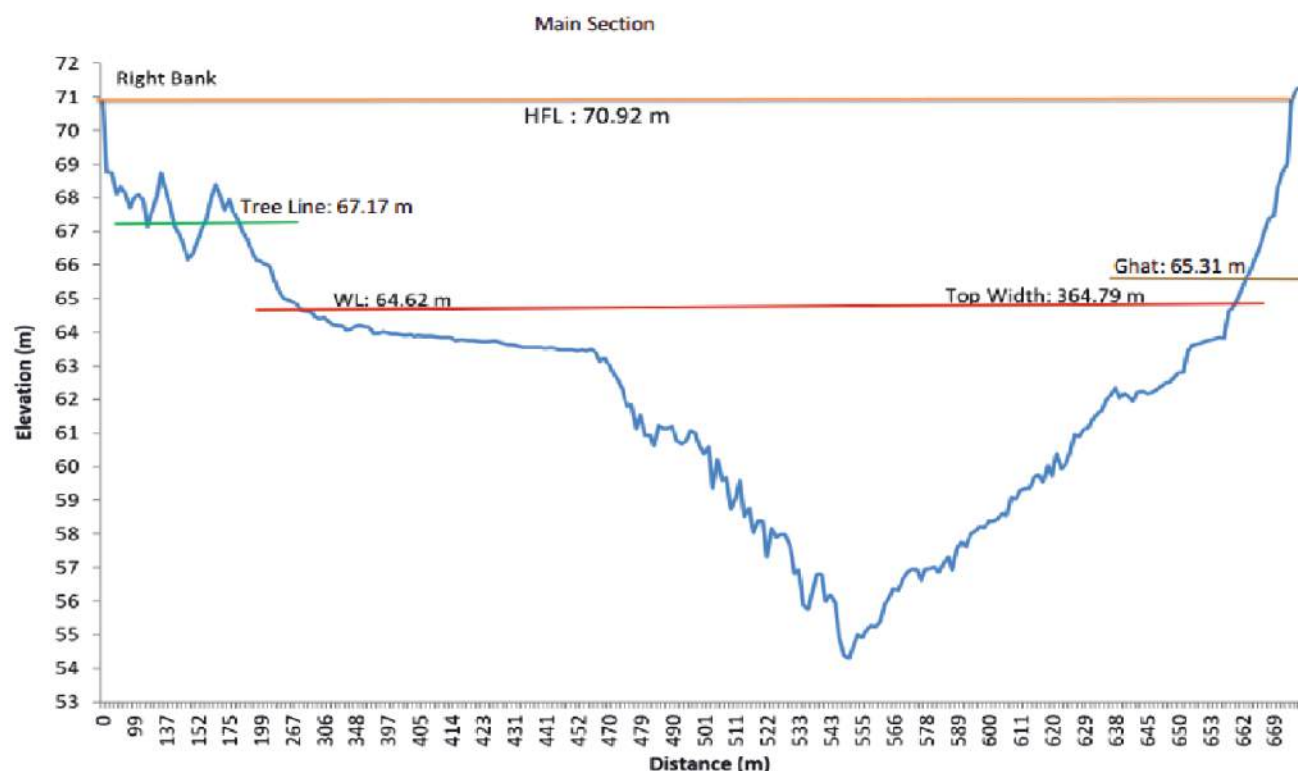


**Figure 68: Dohri Ghat E-Flows location on the Ghaghra River**

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<sup>21</sup> Imperial Gazetteer of India, v. 11, p. 367.





**Figure 69: The Cross Section of the Dohri Ghat E-Flows location on the Ghaghra River**

The cross-sectional parameters are shown in Table 15.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 680       | 17             | 10.7                        | 40.00                    |

**Table 15: Cross sectional parameters for the Ghaghra River at Dohri Ghat (from HFL)**

The Present and Desired state of the Ghaghra River at the Dohri Ghat location is discussed in upcoming sections.

### 4.2.3.1 Dohri Ghat – Present State

#### A. Fluvial geomorphology

The Ghaghra River channel around the road bridge near this location is characterised by an asymmetric form, high sinuosity and high multiplicity, except those in the vicinity of the road bridge. This is owing to a ~2km long valley confinement in this region. The primary channel mainly flows along the left bank adjacent to the ghats of the Barhalganj town. A few alluvial islands, elongated in the direction of the flow, are mapped both at upstream and downstream of the Dohri Ghat location. Sand-dredging operations are also being conducted to the left of the channel belt, causing the primary channel to shift towards the right bank, specifically towards the Mukti Dwar region on the left (figure 70).



**Figure 70: Geomorphic settings of the Ghaghra River around the Dohri Ghat E-Flows location**

The planform dynamics of a 20 km-long stretch of the Ghaghra River around the Dohri Ghat location is shown in Figure 72. The year 1990 is marked by the presence of large alluvial islands both upstream and downstream of Dohri Ghat in a span of 32.63 sq. km. The upstream alluvial was reduced to small lateral bars and then merged with the active floodplains. In the downstream reaches also, the large alluvial island was dissected by the main channel which led to the reduction in its area from 32.63 sq. km in 1990 to 16.73 sq. km in the year 2019.

Both upstream and downstream of the Dohri Ghat, a major part of the main channel shows braided nature. However, the intensity has decreased in the consecutive years. The channels are confined near the Dohri Ghat.

In summary, the Ghaghra River at the Dohri Ghat location is characterised by a sinuous pattern near the bridge location with much less braiding and lesser mid-channel bars, lateral bars and alluvial islands compared to other locations along the river. The channel form is variable from being symmetric in the main section to asymmetric in the upstream section (~500m wide in low flow condition).

A sandy channel substrate and a sandy to loamy bank material is observed. Overall, longitudinal connectivity is good, while lateral connectivity is poor near the bridge location. However, it is satisfactory both upstream and downstream of the bridge. The active floodplain appears to be inundated in the monsoon and the upstream left bank has higher susceptibility to flooding.

## B. Aquatic biodiversity

Although this river stretch bears a wide range of fish species, a total of 17 fish species were recorded from Dohri Ghat during the river surveys under this exercise. Among these, one is found to be Near Threatened (NT) under IUCN Red List data, i.e. *Ompok bimaculatus*.

The Ganga river dolphin was not spotted at this location during the survey, but the fishermen claimed to spot them at this location. They also stated that sometimes during high flows in the monsoon, the species is seen in upstream areas.

## C. Socio-cultural aspects

The river is considered to be holy and 'pure', where Lord Ram and Lord Parshuram met. There are several ghats here, such as Leta Ghat, Janaki Ghat, etc, each of which has a legend of its own. Its popularity is attested by a respondent who said that the river never runs short of crowds even at night. The cremation ghats, boating, various cultural festivities, for which people keep coming here, keep the place populated all the time.

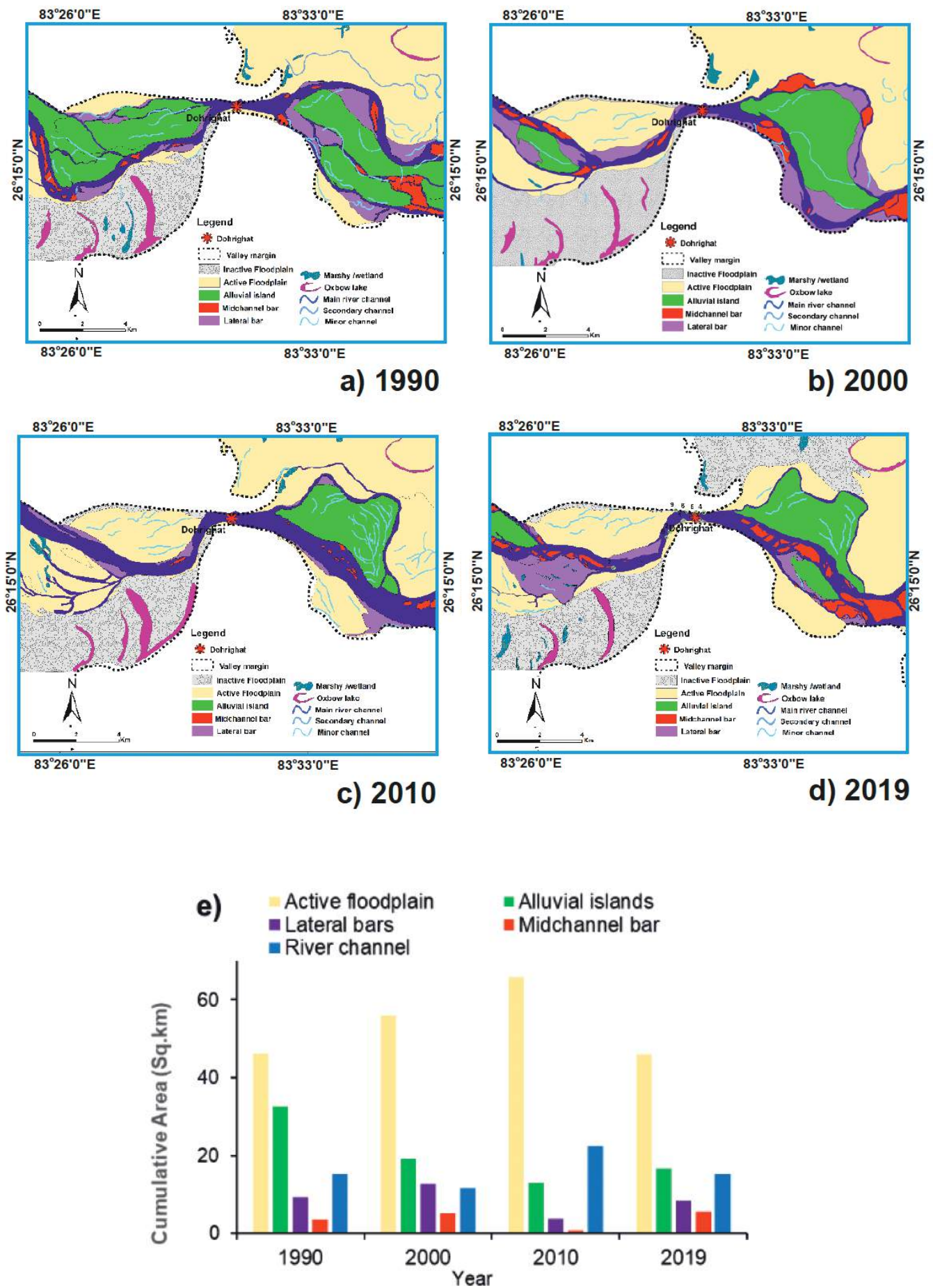
Local people follow several occupations depending on the season. Several respondents work as boatmen or do labour work during the monsoons, and farming or fishing during the winters. The festivities during *chhat*, *kartik*, etc. are greatly appreciated by local people as a source of income.

Low flows in the summers, and to some extent in winters, is a cause of concern for local people as they face inconveniences while performing cultural rituals. The respondents also identified pollution as an issue at this location.



**Figure 71: Socio-cultural activities on the banks of the Ghaghra (Saryu) River in Dohri Ghat**





**Figure 72: Planform dynamics of the Ghaghra River near Dohri Ghat for 1990, 2000, 2010, 2019. Temporal changes in area covered by different geomorphic units.**

### 4.2.3.2 Dohri Ghat – Desired State

The 'Desired' state of the Ghaghra river for Dohri Ghat is shown in Table 16.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                               | Desired State     |
|--------|-----------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | The modification in the channel form around road bridge, significant river dynamics and bank erosion, and excessive sedimentation warranting dredging operations | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | Inadequate native abundance and diversity of fishes; some level of human interference also observed                                                              | Slightly Modified |
| 3      | Socio-cultural        | Degraded            | The present flows are inadequate for satisfactory bathing. Low velocity lean flows also cause stagnation and pollution                                           | Slightly Modified |

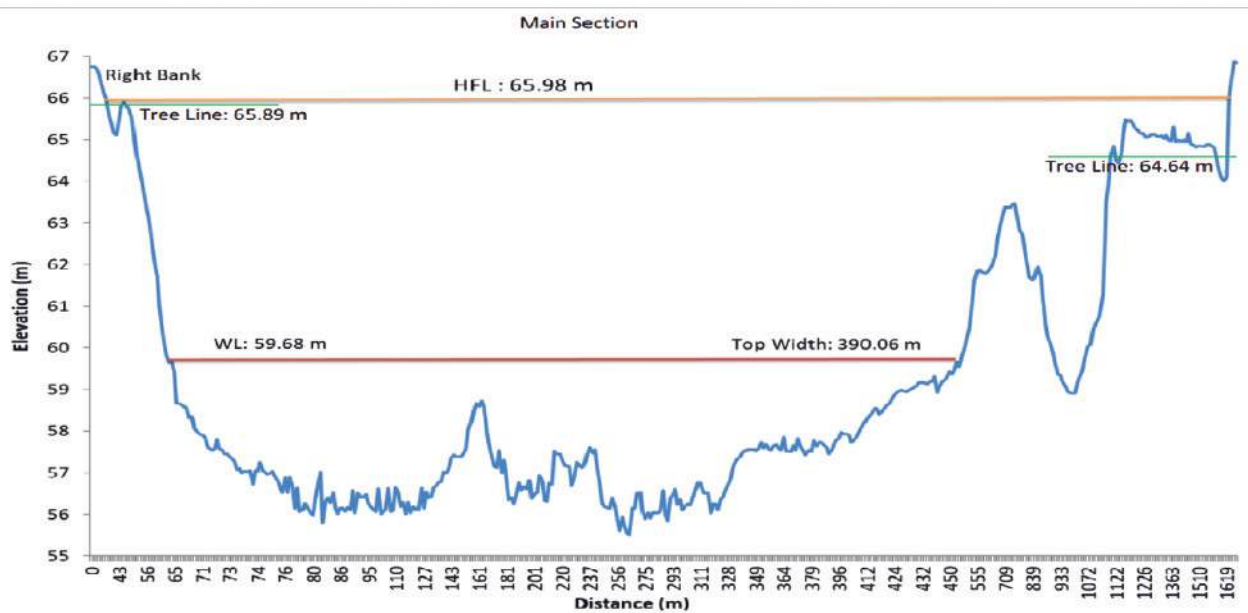
**Table 16: Present and Desired state of the river around the Dohri Ghat E-Flows location**

### 4.2.4 Turtipar

The Turtipar location on the Ghaghra River falls in the Balia district of Uttar Pradesh and is the most downstream location on the Ghaghra River before it joins the Ganga River around 105km downstream. The Ghaghra River flows in northwest-southeast direction in this stretch. Except for a 100-year-old state highway and a railway bridge across the river, there is no major intervention around this location.

The location is in a rural setup. Deep pools and run were observed in the river, which make a good habitat for the Ganga river dolphin. The substrate type was mainly composed of sand and clay. Fishing is the only activity observed at this location.

The cross section of Turtipar location is shown in Figure 73 (with water level at time of survey).



**Figure 73: Cross Section of the Turtipar E-Flows location on the Ghaghra River**

The cross-sectional parameters are shown in Table 17.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 1124      | 11.5           | 5.2                         | 97.74                    |

**Table 17: Cross-sectional parameters for the Ghaghra River at Turtipar (from HFL)**

The Present and Desired state of the Ghaghra River at the Turtipar location is discussed in the section ahead.



**Figure 74: The Ghaghra River at Turtipar E-Flows location. Assessment of hydraulic parameter underway.**



## 4.2.4.1 Turtipar – Present State

### A. Fluvial geomorphology

This location is characterised by a channel belt mostly confined by the valley margin for almost ~6 km, and a portion of partly confined floodplains in the upstream and downstream areas. Therefore, there is very little development of any active floodplain adjacent to the road and railway bridge. The main channel around the road bridge is characterised by an asymmetric form, low sinuosity and very low multiplicity. For most parts, the primary channel is flowing along the right bank. The floodplains are mostly agriculture dominated and there are scattered village settlements. The major crops in this region are wheat and sugarcane. An important irrigation facility at this location is the pump house on the right bank that diverts the water for irrigation in the command area.

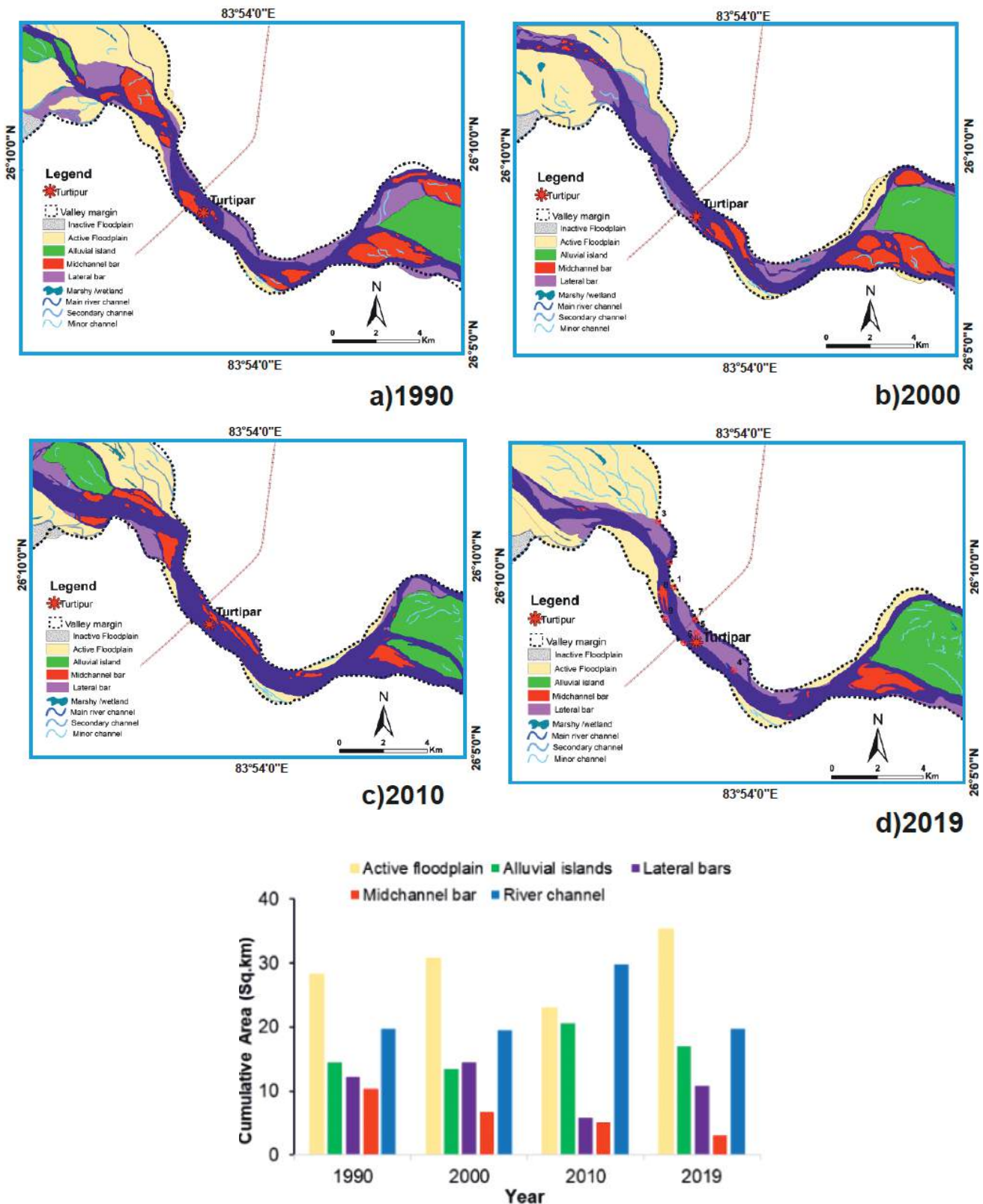


**Figure 75: Geomorphic settings of the Ghaghra River around the Turtipar E-Flows location**

The maps in Figure 76 show planform dynamics over last 30 years. The temporal maps do not show any major change in the planform features. In the downstream reaches, all maps show a prominent alluvial island. The main channel is mostly confined in nature throughout the stretch.

The Ghaghra River at this location is characterised by a sinuous pattern and hosts large lateral bars, mid-channel bars and few alluvial islands. The channel is mostly asymmetric with a wide main channel (avg. 450m in low flow condition)

and is susceptible to floods along the right bank of the channel belt. A sandy channel substrate and banks are observed, with calcretic bed material exposed in some areas during low flow conditions, along with portions of pedogenic calcrete bank material.



**Figure 76: Planform dynamics around Turtipar location in the Ghaghra River over different time periods**

## B. Aquatic biodiversity

The maximum number (25) of fish species in the Ghaghra River was observed from the Turtipar E-Flows location. Out of these, one is Vulnerable (VU) *Wallago attu* and another is Near Threatened (NT), i.e. *Bagarius bagarius* as categorised under IUCN Red List data. Both the species are economically important. The Ganga river dolphin was spotted many times during the survey, including adults and calves. As per the fishermen, the species is seen round the year at this location, but the frequency of observation increases during monsoon.

## C. Socio-cultural aspects

Turtipar has been settled since ancient times, as is evidenced by the presence of Khaira Dih. Khaira Dih is the location of an ancient city on the border of the village of Khaira, which lies on the right bank of the Ghaghra River, very close to Turtipar. Khaira Dih is said to have been the residence of Jamadagni Rishi and the birthplace of his son Parasuram<sup>22</sup>. The bridge here at Turtipur, built in 1903, has a length of 3,912 feet which indicates the width of the river bed. Before the construction of the bridge, the passage over the river was by a ferry. Even today, a large number of boats continue to navigate the river at this point- smaller ones for fishing and larger vessels for transporting grass and other cargo. This location experienced great disturbance during the earthquake of 1934, and an eyewitness account by the railways staff maintaining the bridge at Turtipar narrates that the whole river washed from side to side to a great height<sup>23</sup>.

Turtipar exhibits a variety of river-dependent livelihoods and cultural practices. Fishing remains popular here, both as a primary livelihood activity and for subsistence. Several boats continue to ferry goods and people across the river. The location opposite Bilthara bazaar is an important cremation ghat, and it also offers livelihood to several shopkeepers, priests, and eatery owners. Similarly, activities on the banks of the river include grazing of livestock, collecting and selling grass, and *pallage* farming, which depends on the subsoil moisture maintained by the river.

Most of the interviewees were fishermen, both anglers and boatmen. The team were able to speak to some shopkeepers and devotees as well. It is at this location, on the left bank, that the custom of inviting the river to one's wedding was observed, which illustrates the warm relationship between the river and the communities that live along the river. The people of Turtipar and Bilthara bazaar continue to have a deep dependence on the river and an affection for it. Besides the above-mentioned custom where the first wedding card is addressed and given to the river, all respondents mentioned their gratitude towards the river. One respondent said, 'For us fishermen, our farms are in the water. All that we

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<sup>22</sup> Carlleyle AC. 1885. Report of tours in Gorakhpur, Saran and Ghazipur in 1877-78-79 and 80. Volume XXII. Archaeological Survey of India. Calcutta

<sup>23</sup> Roy SC. 1939. Memoirs of the Geological Survey of India. Volume 73. The Bihar Nepal Earthquake of 1934, Government of India. Calcutta.



need, whether it is food, money or grass for our roofs, comes from the river.’ About 50 families are entirely dependent on fishing for their livelihood. It is they who lament lowered summer flows as this leads to a decrease in the catch. Besides this, extensive *pallage* farming is undertaken along this stretch. One farmer spoke of the importance of good post-monsoon flows. He explained that planting when the water level recedes ensures a good crop yield.

Healthy flows in the summer benefit the *pallage* farmers, only if they are steady. The Ganga river dolphin is present around this location and was also sighted during the survey. The fishermen here have several interesting stories about the species. Since the Ganga river dolphin here has recessed eyes, there is a belief that if humans touch it, they become blind. They also believe that the Ganga river dolphin is a young girl who has been transformed into an aquatic animal. A popular piece of folklore says that, a group of girls asked their school-teacher if they may go down to the river to answer the call of nature. Several hours passed and the girls did not return to the classroom. The worried teacher went down to the river to check on them and saw the girls frolicking in the water. He commanded them to always stay in the water. They turned into dolphins and stay there to this day. The stories are testament to the fishermen’s awareness that the Ganga river dolphin is a mammal and not fish. They also serve to protect the Ganga river dolphin from being hunted, though some were reported to be caught in nets.

As per the historical information, the flows during the monsoon were considered to be an ‘impenetrable barrier<sup>24</sup>’. The length of the bridge (1.19km) attests to the span of the river. In the lifetime of the respondents, out of the 18 bays of the bridge, the water in summer covered 10-12 bays.

The present-day summer flows are considerably lower than what the respondents remember from their childhood. At present, the water only extends from four to seven bays of the bridge in summer, which is troublesome for the fishermen, boatmen and farmers. Equally troublesome is the sudden increase in water in the summer, which washes away *pallage* crops. The monsoon flows are considered adequate as they fill the entire channel, up to the top of the ghats across the river from Belthara bazaar. The floods rise 6 feet above the level of the channel bank once a year.

**Desired flows:** Monsoon flows and floods are considered adequate. People desire greater flows in the summer, at least as much as two decades ago, if not corresponding to historical flows. This means that the water surface should stretch across at least 10-12 bays of the bridge in normal years, and ten bays in drought years.

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<sup>24</sup>Johnston J. 1933. Inland navigation on the Gangetic Rivers. Thacker Spink and Company. Calcutta.

#### 4.2.4.2 Turtipar – Desired State

The 'Desired' state of the Ghaghra River at the Turtipar location is shown in Table 18.

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                                                                                             | Desired State     |
|--------|-----------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | The longitudinal connectivity is good. In-channel sedimentation is noted in downstream reaches and dredgers are used to remove excess sediments                                                                                                                                | Slightly Modified |
| 2      | Aquatic Biodiversity  | Slightly Modified   | Rich fish species diversity, with active presence of the Ganga river dolphin and relatively negligible human interference is noted.                                                                                                                                            | Near Pristine     |
| 3      | Socio-cultural        | Moderately Modified | The present-day summer flows are considerably lower. At present, the water only extends from four to seven bays of the bridge in summer. This causes trouble to the fishermen, boatmen and farmers. The monsoon flows are considered adequate as they fill the entire channel. | Slightly Modified |

**Table 18: Present and Desired state of the Ghaghra River at the Turtipar location**

## 4.3 Gomti River

The Gomti River rises from a spring at 'Gomat Taal – Madho Tanda' in the east of Pilibhit in Uttar Pradesh. After this, it flows along a sandy bed, often disappearing along its course. It is said that the Gomti River, daughter of the Earth, is cursed to flow underground for 20 Kos (61.5km) from its origin. For the next 100km, till it reaches Sitapur, it meanders across the flat alluvial plains, forming braided patterns and widening out into wetlands. It meets several small streams that swell its course, which are all fed by groundwater. The Gomti River is fed by innumerable springs.

According to another local story, several thousand years ago, the world was plunged into mayhem. To bring peace, 88,000 *sadhus* decided to come together to offer joint prayers. The location was decided by Brahma, who let loose a chakra and bade the sages to pray at the spot where it landed. As it turns out, when the chakra did strike the Earth, it created a spring that was named Chakratirth.

According to the Imperial Gazetteer<sup>25</sup>, the width of the river increases from 120-200 feet in Lucknow and Barabanki to 200-400 feet in Sultanpur and 400-600 feet in Jaunpur.

However, at present, the river is much shrunken. It completes its journey at its confluence with the Ganga River in Ghazipur district. The Gomti River, with its very gentle slope and large catchment area, has always been susceptible to floods. Both written records and verbal history speaks of high flow levels in all the cities that the Gomti River flows through. Perhaps the most notable event was in 1774, when the Gomti River rose so high at Jaunpur that boats sailed over the Shahi Pul.

***The spring feeding the Gomti River is perennial, and local people tell a story related to it. The most famous of these is of the vast area known as Naimis Aranya. Today, only the name indicates that it was once an impenetrable forest. The area is dotted with tiny temples, each of which is a replica of a famous temples from across the country.***

The total length of the Gomti River is about 940 km, all within the state of Uttar Pradesh. Lucknow is the first major city that it passes through. The homogenous zonation exercise (Annexure 1C) was conducted as per the approach and methodology discussed in earlier section. Figure 77 exhibits four distinct homogenous zones in the Gomti River.

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<sup>25</sup> Imperial Gazetteer of India, v. 12, p. 385.

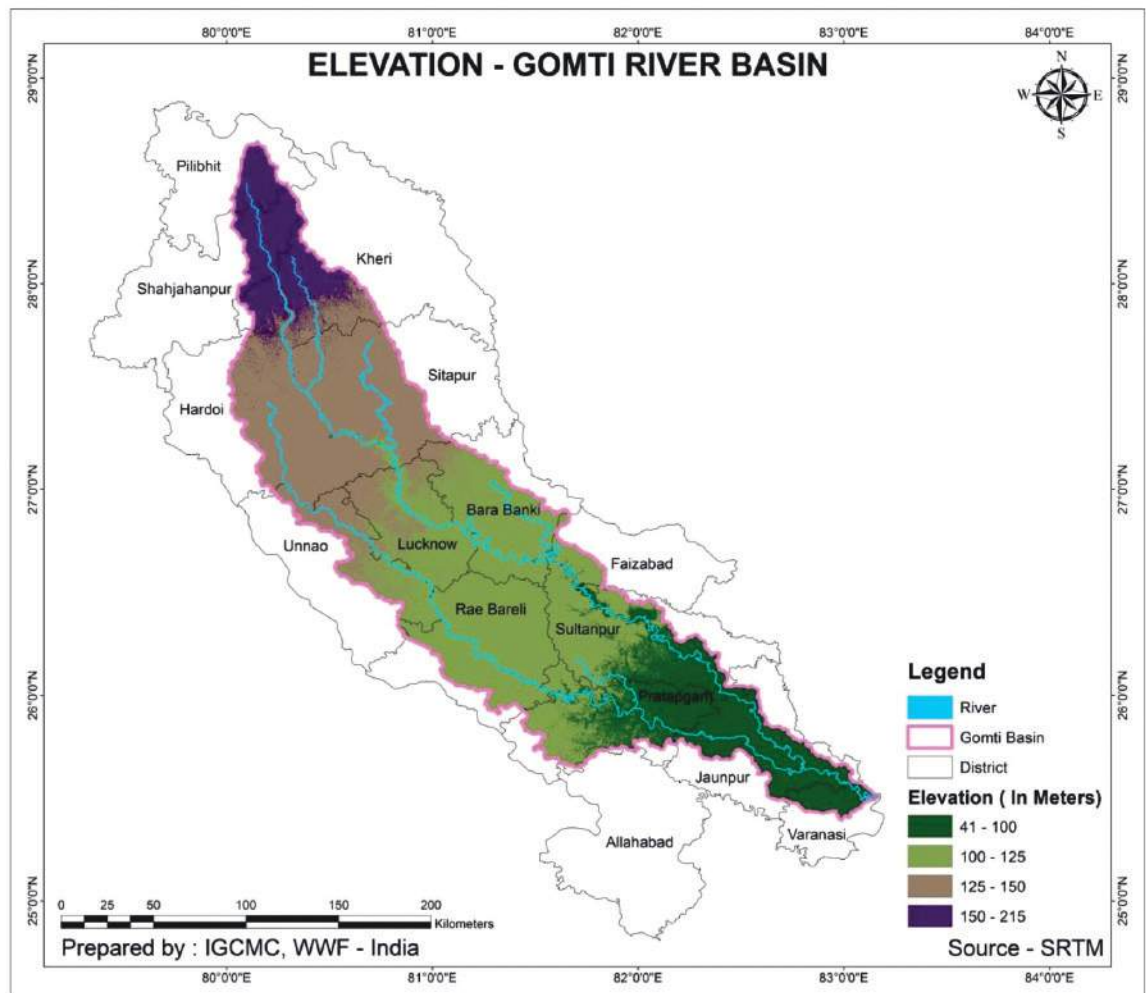


Various homogenous zones of the Gomti River are:

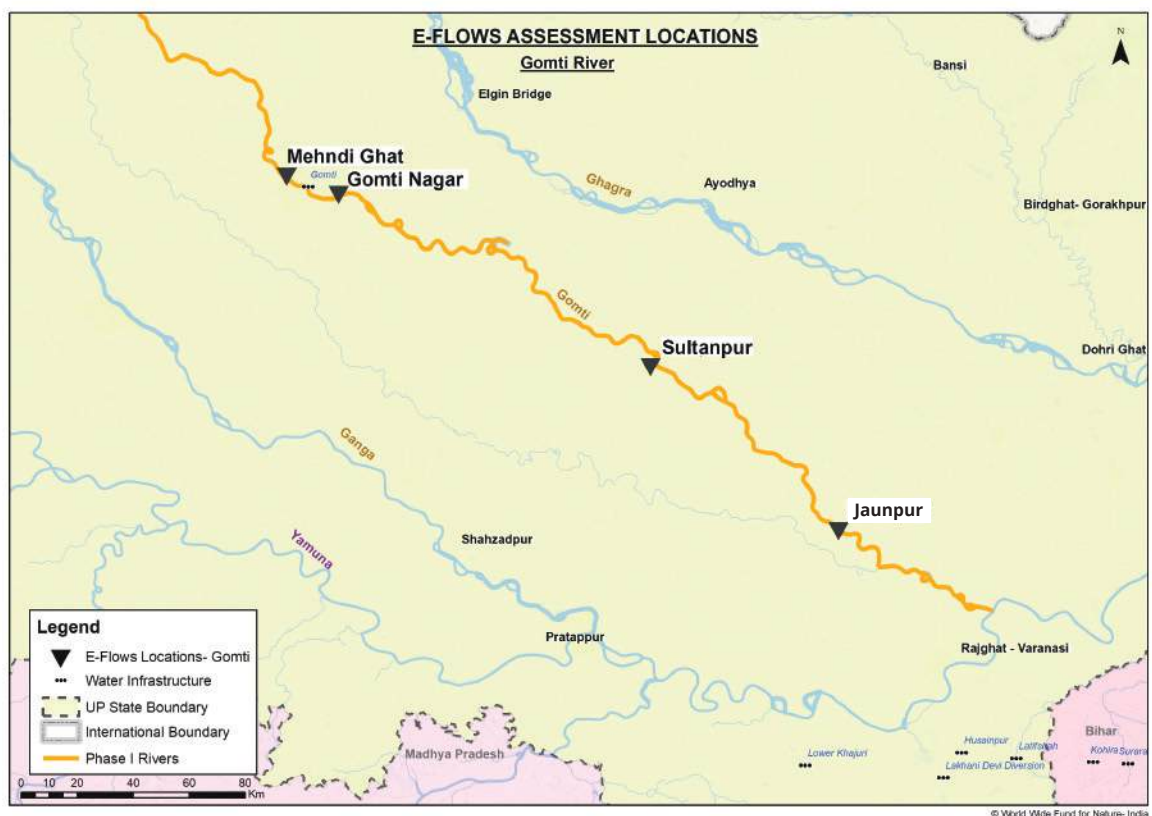
- a. **Zone-1:** The length of the river course is about 179km. The elevation range in the main river stretch is from 215 to 150 metres. This is a relatively free-flowing stretch of the river.
- b. **Zone-2:** The length of the river course is about 139km. The elevation range in the main river stretch is from 150 to 125 metres. This is also a relatively free flowing stretch of the river. However, certain pollution sources are observed in this stretch.
- c. **Zone-3:** The length of the river course is about 203km. The elevation range in the main river stretch is from 125 to 100 metres. This is the most critical zone of the river as the city of Lucknow falls under this zone, where pollution and abstractions become critical issues. Mehndi Ghat, upstream of Gomti Barrage and downstream of Gomti Nagar near aqueduct, are the two E-Flows locations in this zone.
- d. **Zone-4:** The length of the river course is about 271km. The elevation range in the main river stretch is from 100 to 41 metres. This is another critical zone with towns and cities like Sultanpur and Jaunpur on its banks. Both Sultanpur and Jaunpur are the E-Flows locations in this zone.

The Gomti River is relatively free flowing till it reaches Lucknow, where a barrage has been built near Gomti Nagar. Therefore, the team focused much more in the middle to lower reaches of the river. The Gomti river is relatively in better health in upper to middle stretch till Mehndi Ghat, Lucknow in terms of flows, water quality and aquatic biodiversity, after which it gets degraded in terms of flows and water quality.

Fish diversity was estimated at all four E-Flows locations through surveys. In Lucknow, there are two sampling locations - one is upstream of the city (above Peepa Pul and barrage) and the other is downstream of the city at aqueduct. There is one location each in Sultanpur and Jaunpur.



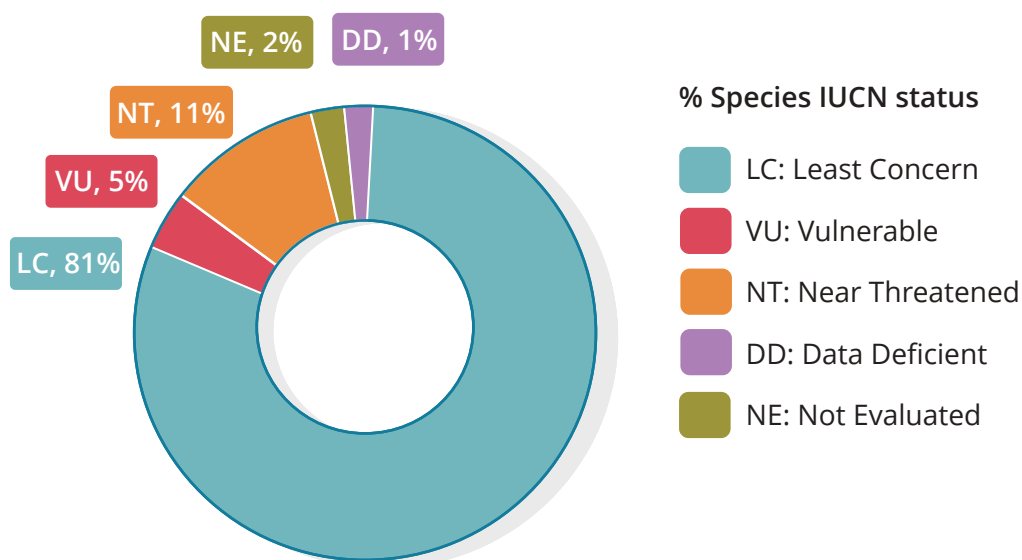
**Figure 77: Homogenous zonation map of the Gomti River depicting four distinct zones**



**Figure 78: Map of the Gomti River with E-Flows locations**

A total of 81 fish species belonging to 53 genera, 24 families and seven orders were recorded in the Gomti River (highest among all the rivers surveyed).

Among these, 72 are native and seven are exotic, i.e. *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *Hypophthalmichthys nobilis*, *Clarias gariepinus*, *Oreochromis mossambicus* and *Oreochromis niloticus*.



**Figure 79: Percentage of species as per IUCN Red Data List 2020-21 in the Gomti River**

During the field surveys, basic hydrological and water-quality parameters were also assessed, the results of the same are shown in Table 19.

| Hydrological and Water-quality Parameters | Lucknow Upstream Barrage near Mehndi Ghat |                  | Lucknow near Aqueduct Downstream of Barrage |                  | Sultanpur             |                  | Jaunpur          |                  |
|-------------------------------------------|-------------------------------------------|------------------|---------------------------------------------|------------------|-----------------------|------------------|------------------|------------------|
|                                           | Summer                                    | Monsoon          | Summer                                      | Monsoon          | Summer                | Monsoon          | Summer           | Monsoon          |
| River Depth (m) Average, (min-max)        | 2.15 (0.76-3.35)                          | 1.14 (0.76-2.62) | Surveys not conducted                       | 1.32 (0.76-1.80) | Surveys not conducted | 1.38 (0.76-2.44) | 1.48 (1.13-1.86) | 1.82 (0.82-2.50) |
| River Width (m)                           | 80                                        | 90               |                                             | 100              |                       | 50               | 50               | 50               |
| Average Current velocity (m/sec)          | 0.100                                     | 0.060            |                                             | 0.08             |                       | 0.47             | 0.133            | 0.070            |
| Water Appearance                          | Clear                                     | Greenish         |                                             | Black            |                       | Black            | Greenish         | Greenish         |
| pH                                        | 8.9                                       | 9.2              |                                             | 8.2              |                       | 9.4              | 8.3              | 9.4              |
| Temperature (°C)                          | 32.4                                      | 2.6              |                                             | 23.5             |                       | 23.1             | 35               | 23.5             |
| Dissolved Oxygen (DO) mg/l                | 7.5                                       | 7                |                                             | 4                |                       | 3.8              | 6.8              | 7                |
| Total Dissolved Solids (TDS) mg/l         | 195                                       | 225              |                                             | 405              |                       | 361              | 240              | 361              |

**Table 19: Hydrological and basic water-quality parameters assessed at various E-Flows locations on the Gomti River**

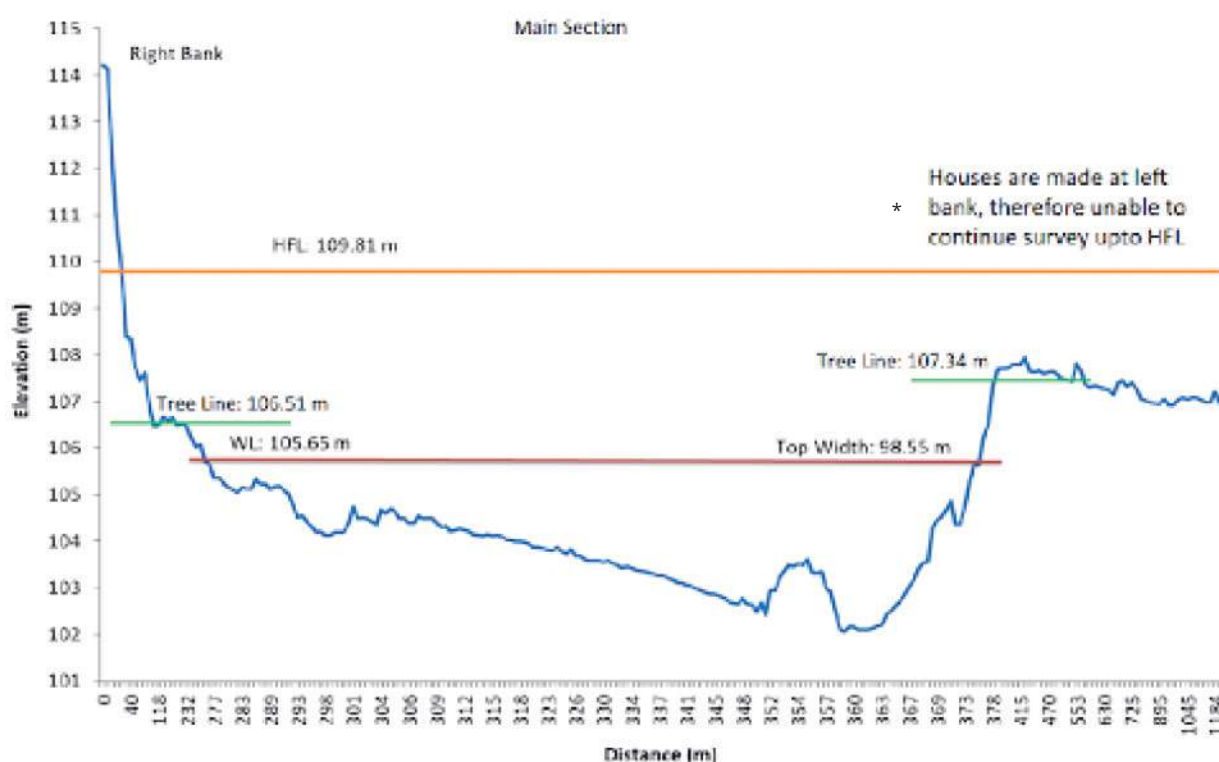


In terms of Fluvial geomorphology, this is a small river and detailed planform mapping is not possible at the scale of freely available satellite images. Also, the river is quite similar in terms of its planform morphology at all locations with only minor variations. The location-wise 'Present' and 'Desired' state of the Gomti River are discussed in the section ahead.

### 4.3.1 Mehndi Ghat – Peepa Pul (Upstream of the Gomti Barrage)

This is the first location on the Gomti River, just above where the river enters the Lucknow city. There is a pontoon bridge (locally known as *Peepa Pul*) here. In addition to people from this location, the team also interviewed people downstream of the location around Hazratganj, to get a sense of the traditional river-linked occupations in the city.

The cross section of the Mehndi Ghat E-Flows location is given in Figure 80 (with water level at the time of survey).



**Figure 80: Cross section of the Mehndi Ghat E-Flows location (upstream of the Gomti Barrage) on the Gomti River**

The Present and Desired states of the river around Mehndi Ghat location is discussed in the upcoming section.

The cross-sectional parameters are shown in Table 20.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 1184*     | 12.2           | 3.6                         | 97.05                    |

**Table 20: Cross-sectional parameters for the Gomti River downstream of Gomti Nagar near Aqueduct**



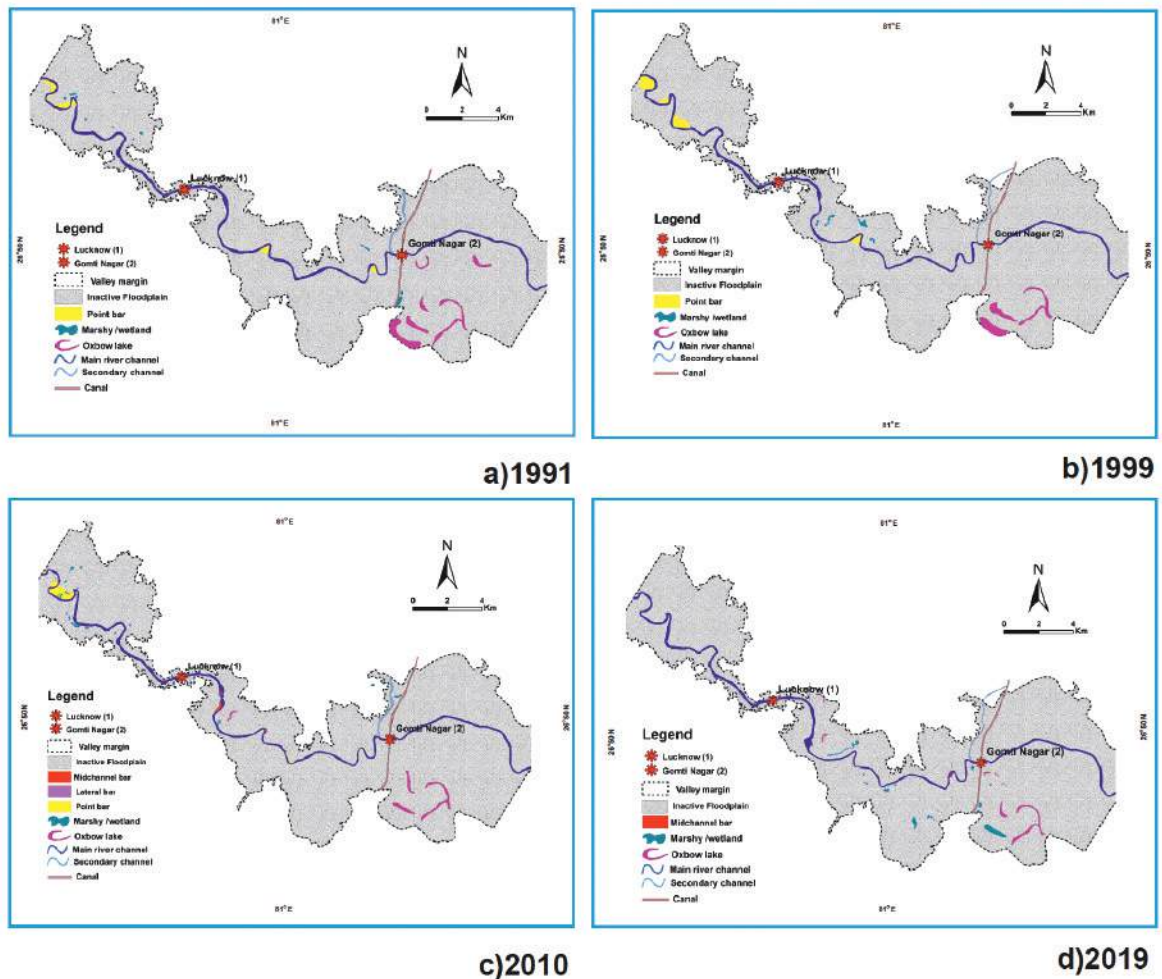
**Figure 81: Mehndi Ghat E-Flows location on the Gomti River**

### 4.3.1.1 Mehndi Ghat (Peepa Pul) – Present State

#### A. Fluvial geomorphology

The river does not show much evidence of dynamics and has remained fixed in its position for the last four decades (Figure 82). A number of meander scars and ox-bow lakes downstream of Lucknow city are noted in a 1991 map, but they have been drying up over the years. The river has practically no active floodplain as most of the channel is confined within the banks. Most of the older floodplain is occupied by urban settlements, implying poor lateral connectivity. The mapping of channel shift and thalweg also confirms the lack of any dynamics, apparently due to the lack of sufficient flow.

The thalweg lies on the left bank with a fairly asymmetric channel in the upstream and main sections. The channel in the downstream section is fairly symmetric. Due to the lack of accessibility towards the left bank, the HFL position could not be traced during the survey.



**Figure 82: Geomorphic maps of the Gomti River around Lucknow in 1991, 1999, 2010, 2019**



## B. Aquatic biodiversity

The maximum number of fish species (28 species) were recorded at this location, as compared to others in the Gomti River. IUCN Red listed species recorded at this location include one Near Threatened (NT) species i.e. *Ompok bimaculatus* and three Vulnerable (VU) species, i.e. *Cyprinus carpio*, which is an exotic species and commonly called “common carp”, *Wallago attu*, which is also an economically important fish species and commonly called “Lanchi” and *Oreochromis mossambicus*, an exotic fish commonly called “Tilapia”.

**Globally, *Cyprinus carpio* fish species is listed as Vulnerable (VU) in IUCN's Red List. However, this fish variety has been recorded in subsequently large numbers in this stretch of the river during the surveys conducted by the team and is an invasive alien fish species. Therefore, this fish species was not considered as a 'flows motivating species' by the aquatic biodiversity thematic team. Rather, the team focused on other critical fish species.**



**Figure 83: *Wallago attu***

Some of the Near Threatened and Vulnerable species were also reported in secondary literature from locations that are close to the survey location (i.e. upstream from Lucknow city).

- a. *Ompok bimaculatus* (NT), *Bagarius bagarius* (NT), *Ailia coila* (NT), *Hypophthalmichthys molitrix* (NT), *Cyprinus carpio* (VU), *Wallago attu* (VU), and *Oreochromis mossambicus* (VU) (Bano and Serajuddin, 2016)<sup>26</sup>
- b. *Channa orientalis* (VU), *Chitala chitala* (NT), *Chela laubuca* (NT), *Labeo pangusia* (NT), *Ompok pabda* (NT), *Ompok pabo* (NT), *Bagarius bagarius* (NT), (Srivastava and Singhal, 2015)<sup>27</sup> and similar species were reported by Sarkar et.al., 2009.<sup>28</sup>

<sup>26</sup> Bano Farah and Serajuddin Mohammad (2016). Biodiversity, Threat Status and Conservation Priority of Ichthyofauna of River Gomti at Lucknow Region, India. Biodiversity Journal, 7 (4): 913–92

<sup>27</sup> Srivastava Archana and Singhal Achintya (2015). Biodiversity, Ecological status and Conservation priority of the fishes of river Gomti, Lucknow (U.P., India). International Journal of Advanced Research (2015), Volume 3, Issue 9, 1471- 1480. ISSN 2320-5407

<sup>28</sup> U. K. Sarkar, B. K. Gupta and W. S. Lakra (2009). Biodiversity, ecohydrology, threat status and conservation priority of the freshwater fishes of river Gomti, a tributary of river Ganga (India). Environmentalist (2010); 30:3–17. DOI 10.1007/s10669-009-9237-1

While there was an abundance of fish species around this location, the river is not well connected longitudinally. There is a barrage downstream of the location and a lot of anthropogenic activities like fishing, washing clothes, presence of dairy and few smaller drains meeting the river, were observed during the surveys.

### C. Socio-cultural aspects

A large community of *Chikan karigars* live downstream of Mehndi ghat and use the river to wash freshly made '*chikan*' clothes for the retail market. Close to them live the dairy keepers who bathe their buffaloes in the Gomti River. These workers are in hundreds. In addition to these primary livelihoods, they also occasionally catch fish for their households and grow vegetables. Further downstream, the Rowing Club has its boathouse. This was established a few decades ago by a professor at the Lucknow University for his students.

Earlier, worshippers would form long lines along the river, standing knee deep in the water and waiting for sunrise. However, the concretisation of the banks within Lucknow has done away with the naturally sloping profile of the river and converted it into a rectangular channel. A small area has been constructed in the traditional *ghat* with steps leading down to the river, especially for the Puja. However, this is inadequate, as reported by the stakeholders. People therefore, come to the river with tubs, ropes and buckets. They use the ropes and buckets to haul water up, pour it into the tubs and stand in it. The river was once a source of solace; its role in rituals was to purify the space and tools used for the rituals.

The water supply system on the Gomti River was established in 1901 to provide water supply for Lucknow and the extraction from the river has been steadily increasing. Despite this, as little as over a decade ago, there were still adequate flows in the river to allow for all the river functions to be carried out – as discussed by local people. People maintain that water in the monsoon covered the entire space between the embankments. In the winter, the water was about twice as much as it is now, and the summer flows then were as much as the winter flows.

The level of flow here does not come into consideration. A respondent said that, even if the water level is raised, it won't make any difference unless the river is cleaned first.

### 4.3.1.2 Mehndi Ghat (Peepa Pul) – Desired State

The 'Desired' state of the Gomti River at the Mehndi Ghat E-Flows location is shown in Table 21.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                                                                                                       | Desired State       |
|--------|-----------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1      | Fluvial Geomorphology | Degraded            | The river around this location lacks any sign of natural geomorphic activity due to insufficient flow. Also, most parts of the floodplain are occupied by urban settlements and the river has practically no floodplain.                                                                                 | Moderately Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | The physical appearance of the water in the river looks satisfactory around this location. There is rich fish diversity observed during river surveys and as reported in secondary literature. Though long-range connectivity is impacted due to barrage gate operations which control flows and depths. | Slightly Modified   |
| 3      | Socio-cultural        | Degraded            | Reduced water levels, lack of access to the river and increasing pollution is noted, especially in the downstream section of Mehndi Ghat.                                                                                                                                                                | Moderately Modified |

**Table 21: Present and Desired state of the Gomti River around the Mehndi Ghat E-Flows location**

### 4.3.2 Gomti Nagar near Aqueduct

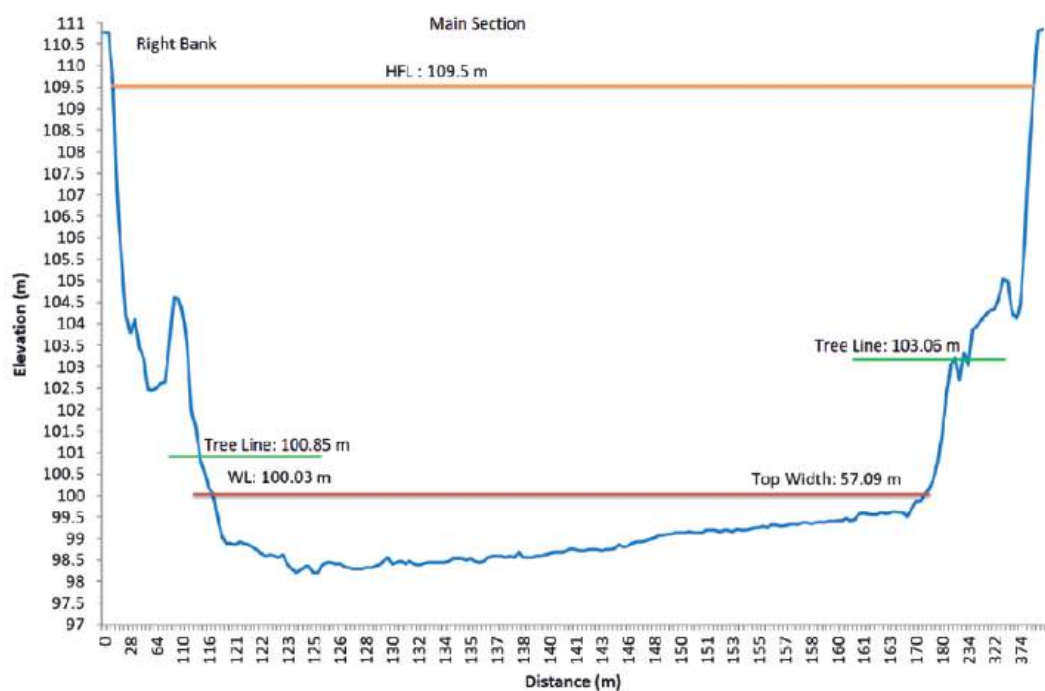
The Gomti River flows beneath the Indira Aqueduct, downstream of Gomti Nagar. Here, the river is obstructed upstream by a barrage, and much of the water appears to be wastewater. According to some local residents, pollution has irrevocably affected the lives of people in this area. They also express resentment towards Lucknow, as they feel they bear the brunt of the pollution generated by the city. One respondent stated, 'Lucknow dumps all its waste into our river, and our village has to deal with the consequences'.





**Figure 84: Gomti River near downstream of the Gomti Nagar (under Aqueduct) E-Flows location. The river is severely polluted around this location.**

The cross section from this location is given in Figure 85 (with water level at time of survey).



**Figure 85: Cross section of the Gomti River at the Downstream Gomti Nagar location, from HFL (Aqueduct)**

The cross-sectional parameters are shown in Table 22.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 374       | 12.5           | 1.8                         | 29.92                    |

**Table 22 Cross-sectional parameters for the Gomti River Downstream of Gomti Nagar near Aqueduct**

The Present and Desired state of the river around Gomti Nagar Aqueduct location is discussed in upcoming sections.

### 4.3.2.1 Gomti Nagar near Aqueduct – Present State

#### A. Fluvial geomorphology

The upstream and downstream sections around this location show fairly symmetrical cross sections, while the main section channel is asymmetric with the thalweg lying closer to the right bank. The geomorphic characteristics are discussed in the last section.

#### B. Aquatic biodiversity

This river stretch harbours a wide range of fish species; a total of 19 fish species were recorded during the surveys. Of these, two species come under the IUCN Red List Category i.e. *Ompok bimaculatus* in Near Threatened (NT) and *Cyprinus carpio* in Vulnerable (VU). In secondary literature, some IUCN Red List species have also been reported from this location, such as *Chitala chitala* (NT), *Ompok pabda* (NT), *Bagarius bagarius* (NT), *Ailia coila* (NT) and *Wallago attu* (VU).

Besides this, Indian major carp species were reported in secondary literature from this location. These include *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. These varieties of IMCs are one of the motivations of flows requirement for this location.



**Figure 86: *Ompok bimaculatus***



**Figure 87: (i) *Catla catla* (ii) *Labeo rohita* (iii) *Cirrhinus mrigala* (in same sequence)**

The sewage and sludge have a deleterious effect on the river. As mentioned earlier, the Gomti River is fed by several springs. Along this stretch of the river too, there were several springs, which fed the river as recently as two decades ago. However, the sludge settling down on the riverbed has effectively blocked all these springs. This also makes the river inhospitable to all aquatic life. Another result has been reduction of base-flow, and a lack of clean drinking water for humans and animals. At present, the only flowing springs are at the temple of Sailani Mata, about 5km downstream of Sikandarpur.

### C. Socio-cultural aspects

On this river stretch, access is not an issue anymore, but water quality is more of a concern. The water is predominantly composed of black sludge, resulting in a complete denial of access. A respondent said, 'Earlier, we used to bathe in the river and even use its water for cooking. Now we cannot even go near the river because it smells so bad'.

One respondent was so incensed by the state of the river that he insisted on taking the team in his boat to estimate the level of sludge at the base of the river and to witness the pollution due to the sewage outfalls. The river is presently much shrunk from what it was just three decades earlier. Here too, the concern of pollution overshadows the quantity of flow. Respondents claim that there is one outfall from the sewage treatment plant, as well as a few drains that directly fall into the river. The team visited the outfall near Chhoti Devariya, where the water is foamy and sludge-like for several metres downstream.

Several people in Sikandarpur have entirely stopped going to the river. Earlier, they would go regularly for festive bathing and with their livestock. However, they claim that now the water gives them skin diseases.

In the case of flows, people unanimously complained of decreased flows. They said that there is no longer any water to wash away the sludge, especially since there are no high flows or floods. The lack of floods also means that there is no more new silt laid across the fields. It is now possible to easily walk across in the summer where once they needed to swim. Winter flows are also now greatly reduced, being less than half of what they once were.



### 4.3.2.2 Gomti Nagar near Aqueduct – Desired State

The 'Desired' state of the Gomti River at downstream Gomti Nagar is shown in Table 23.

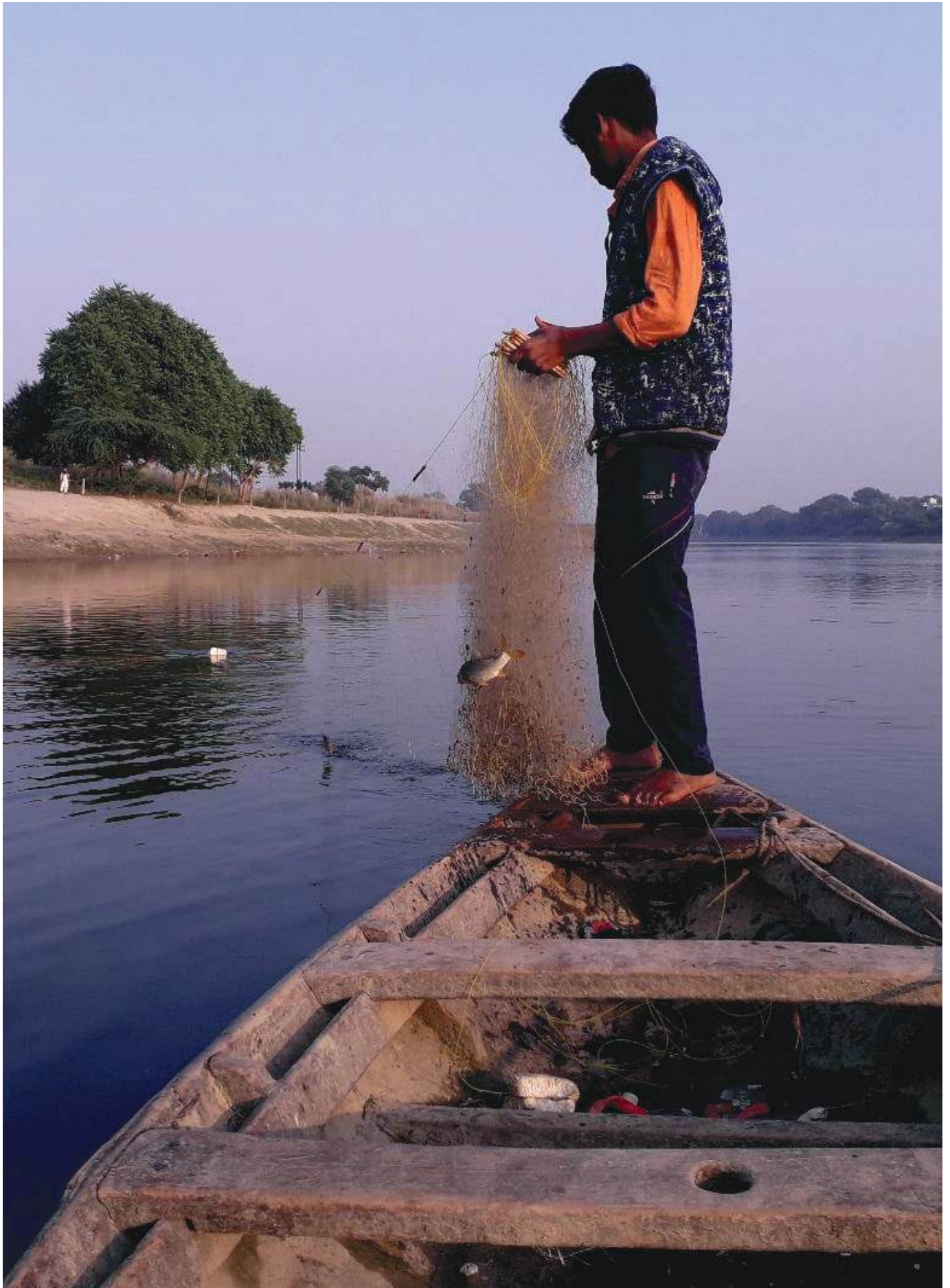
| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                       | Desired State       |
|--------|-----------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1      | Fluvial Geomorphology | Degraded            | The river around this location lacks any sign of natural geomorphic activity due to insufficient flow. Also, most parts of the floodplain are occupied by urban settlements.                             | Moderately Modified |
| 2      | Aquatic Biodiversity  | Critically Degraded | With no long-range connectivity, poor water quality, the river is devoid of any healthy aquatic life around this location.                                                                               | Moderately Modified |
| 3      | Socio-cultural        | Degraded            | While the main concern has been pollution here, there is a sense of unwillingness to venture into the river as well. The flows in all seasons are inadequate for socio-cultural and livelihood purposes. | Moderately Modified |

**Table 23: Present and Desired state of the Gomti River at the downstream location of Gomti Nagar near Aqueduct**

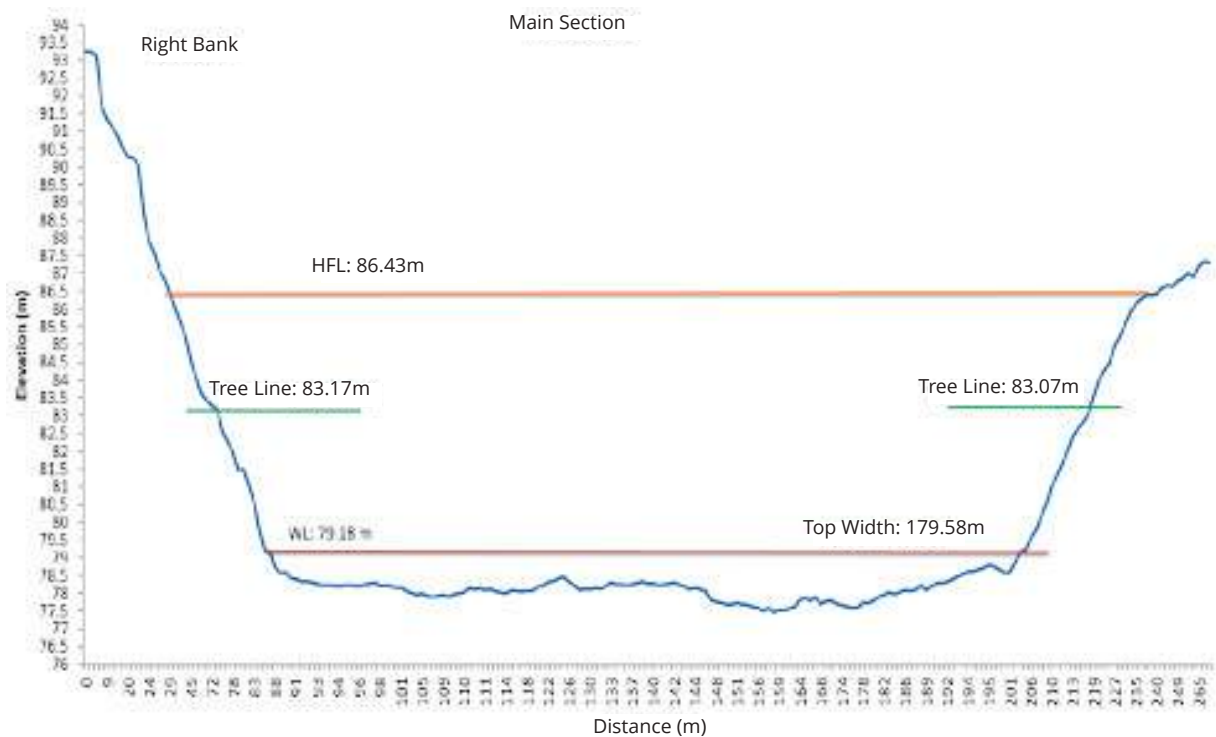
### 4.3.3 Sultanpur

While the distance between Lucknow and Sultanpur is just about 140km by road, the river covers a much greater distance due to its meandering course. A boatman at Indira Aqueduct informed the team that it takes about three to five hours to reach up to Sultanpur. It is believed that, as a result of this extended distance along with a very gentle slope, the sludge carried by the river has a chance to settle before it reaches Sultanpur.

There is a temple on the left bank. The observed habitat types are run and small pools with steep banks. The substrate is largely composed of silt. The cross section of the E-Flows location on the Gomti River in Sultanpur is given as Figure 89.



***Figure 88: The Gomti River at the Sultanpur E-Flows location***



**Figure 89: Cross section of the Sultanpur E-Flows location on the Gomti River**

The cross-sectional parameters are shown in Table 24.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 229       | 10             | 1.7                         | 29.90                    |

**Table 24: Cross-sectional parameters for the Gomti River at Sultanpur**

The Present and Desired state of the Gomti River at the Sultanpur E-flows location is discussed in the upcoming section.

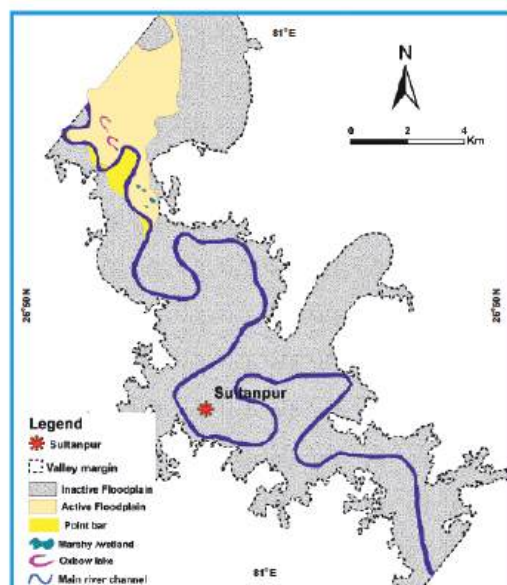
### 4.3.3.1 Sultanpur – Present State

#### A. Fluvial geomorphology

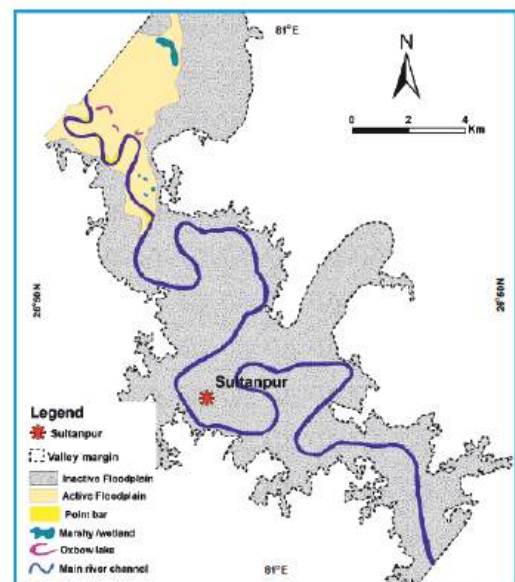
The Gomti River around Sultanpur shows stable planform morphology during the period of investigation. In general, the river is characterised by tight meanders but very few meander scars are mapped from the satellite images. Floodplains are almost negligible, except for a small patch in the upstream reaches, much outside the Sultanpur city area. Most of the geomorphic features within the valley margin have been obliterated by the anthropogenic interventions, mostly in the form of agriculture and settlements.

Detailed mapping of channel width shows a decrease in the channel width from ~150 metres (1990, 2000) to ~80 metres (2019) in certain reaches. The thalweg line between 1990 to 2000 and 2010 to 2019 do not show any significant change (Figure 90). The Sultanpur E-Flows location is representative of a stable single channel.

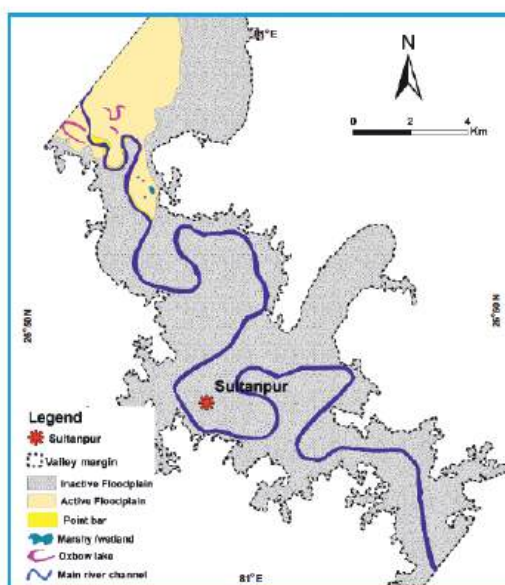




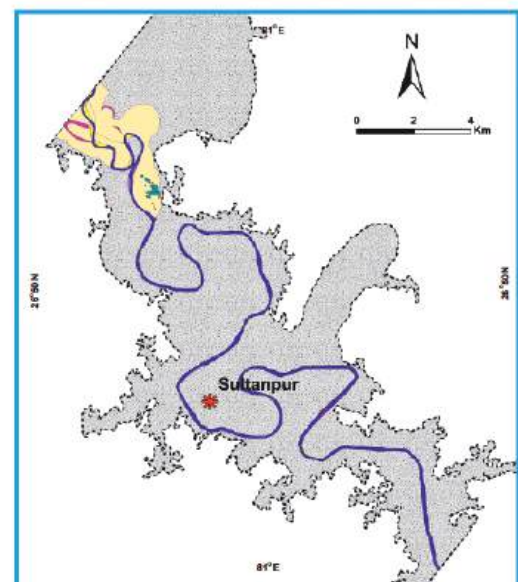
a) 1990



b) 2000



c) 2010



d) 2019

**Figure 90:**  
Planform  
dynamics in  
the Gomti  
River around  
the Sultanpur  
location  
during 1990,  
2000, 2010,  
2019

## B. Aquatic biodiversity

Though fishermen and experts say there is a presence of more than 30 fish species from the stretch (as reported in secondary literature), only three species were recorded from the Sultanpur location during the surveys. Among those, two are in Vulnerable (VU) category of IUCN Red List, i.e. *Oreochromis mossambicus* and *Cyprinus carpio*. Both are exotic fish species. Various fish species are also reported in secondary literature from nearby locations, i.e. *Chitala chitala* (NT), *Ompok bimaculatus* (NT), *Bagarius bagarius* (NT), *Ailia coila* (NT), *Wallago attu* (VU).

Besides this, Indian major carp species are reported in secondary literature from this location. These include *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. As in the case of the previous E-Flows location, these varieties of IMCs are one of the motivations of flows requirement for this location.

### C. Socio-cultural aspects

The location is just below the bridge, which hosts the *Sita kund*. It is believed that when Rama and Sita were returning home from their exile, Sita washed her hair in the Gomti River at this spot. Besides the temple on the right bank, there is also a dargah, *Pancho Peer ka Mazhar* on the left bank. The *dargah* and the temple both attract devotees and shopkeepers along with the priests and the imam. Fishing on the right bank is prohibited by the temple authorities. There are also several boatmen who ferry people across the river and offer joyrides. The sandy bank on the right is a pleasant place to walk.

The priest of the temple says there is a mention of the Sita kund ghat in the scriptures. People visit the temple often and also the river to conduct *Aarti* – where they light lamps and float them down the river. The temple also conducts *Aarti* at dusk. There are several shops and individual vendors near the temple that supply devotees with puja material.

The *dargah* attracts scores of devotees and hosts *urus* (socio-cultural festivities) during the month of *saavan*, which is probably the largest *urus* in Sultanpur district.

While not clean enough for drinking or bathing by usual standards, the river is considered of acceptable quality by the people who live along its banks. It is extensively used for washing and fishing and the team also witnessed one woman devotee take *aachman*.

The devotees who visit the *mazaar* also use this water to perform *wuzu*. But with the state of the water now deteriorating, they use the taps provided by the *Dargah*.

Generally, people informed the WWF team that while they are comfortable bathing and swimming in the river, they do not drink its water as they are aware that it is polluted with Lucknow's waste.

### 4.3.3.2 Sultanpur – Desired State

The 'Desired' state of the Gomti River at the Sultanpur E-Flows location is shown in Table 25.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                                                            | Desired State       |
|--------|-----------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1      | Fluvial Geomorphology | Degraded            | Lack of any natural geomorphic activity and heavily occupied floodplain. Floodplain is non-existent, except for a few patches.<br><br>Also, most geomorphic features have been obliterated due to human interventions and there is practically no floodplain. | Moderately Modified |
| 2      | Aquatic Biodiversity  | Degraded            | A disturbed location, doesn't offer habitat for much critical aquatic life—mainly because of reduced flows and deteriorated water quality.                                                                                                                    | Moderately Modified |
| 3      | Socio-cultural        | Moderately Modified | Whilst low flows and pollution are critical concerns, river regains some life around this location and socio-cultural and livelihood-based interactions of local communities with the river are evident here.                                                 | Slightly Modified   |

**Table 25: Present and Desired state of the Gomti River at the Sultanpur E-Flows location**



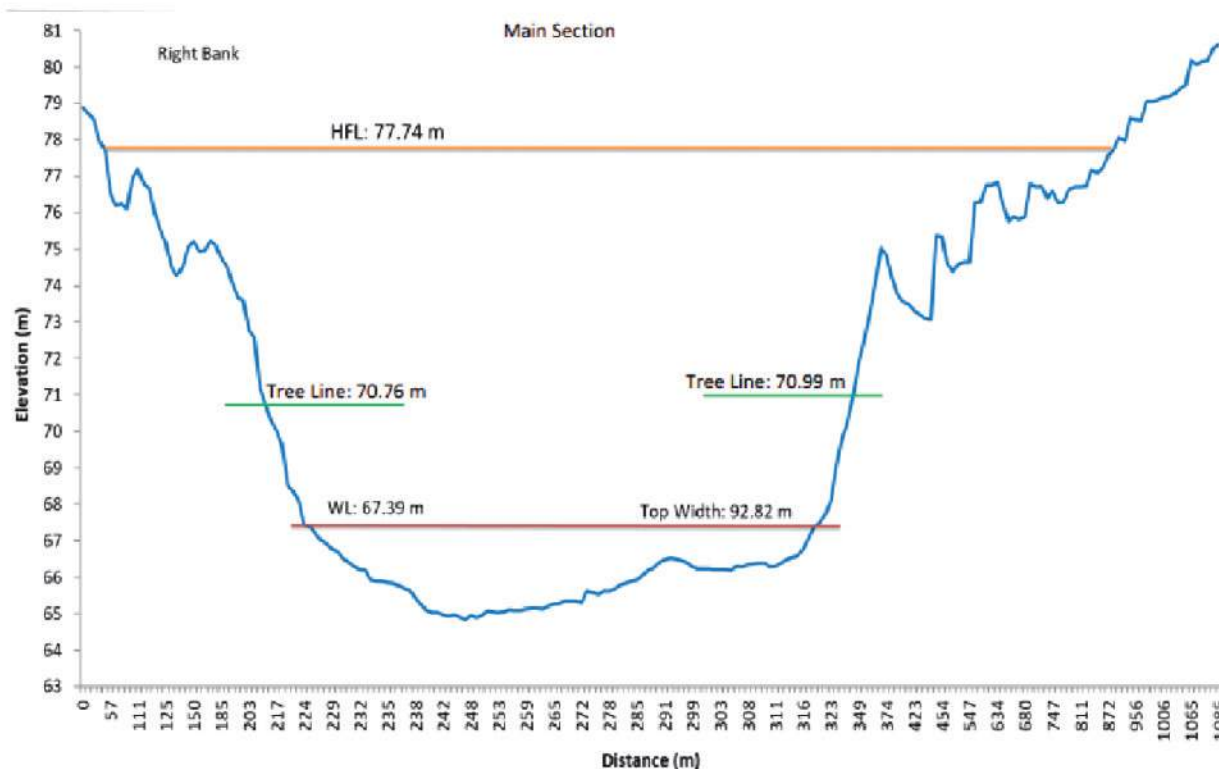
### 4.3.4 Jaunpur

Jaunpur city, on the banks of the Gomti River, was once a desirable kingdom fought over by several dynasties. This E-Flows location is near the 16<sup>th</sup> century *Shahi Pul*, an excellent example of people-friendly architecture with its alcoves serving as resting-places for pedestrians.

Jaunpur is the last location on the Gomti River around 90km via road from the Sultanpur E-Flows location. A number of anthropogenic activities were observed, such as disposal of solid waste, fishing and small drains carrying waste into the river. A temple on the right bank was also observed. The active channel is not very wide due to low flows in the summer. The ghats are constructed on the right bank under *Shahi Pul* (bridge). The river is not fragmented and flowing as a single channel. Substrate include clay and silt and the habitat types are run (in shallow water) and few small pools.



**Figure 91: Jaunpur E-Flows location near Shahi Pul in the city**



**Figure 92: Cross section of the Jaunpur E-Flows location near Shahi Pul**

The cross-sectional parameters are shown in Table 26.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 949       | 14             | 2.5                         | 67.79                    |

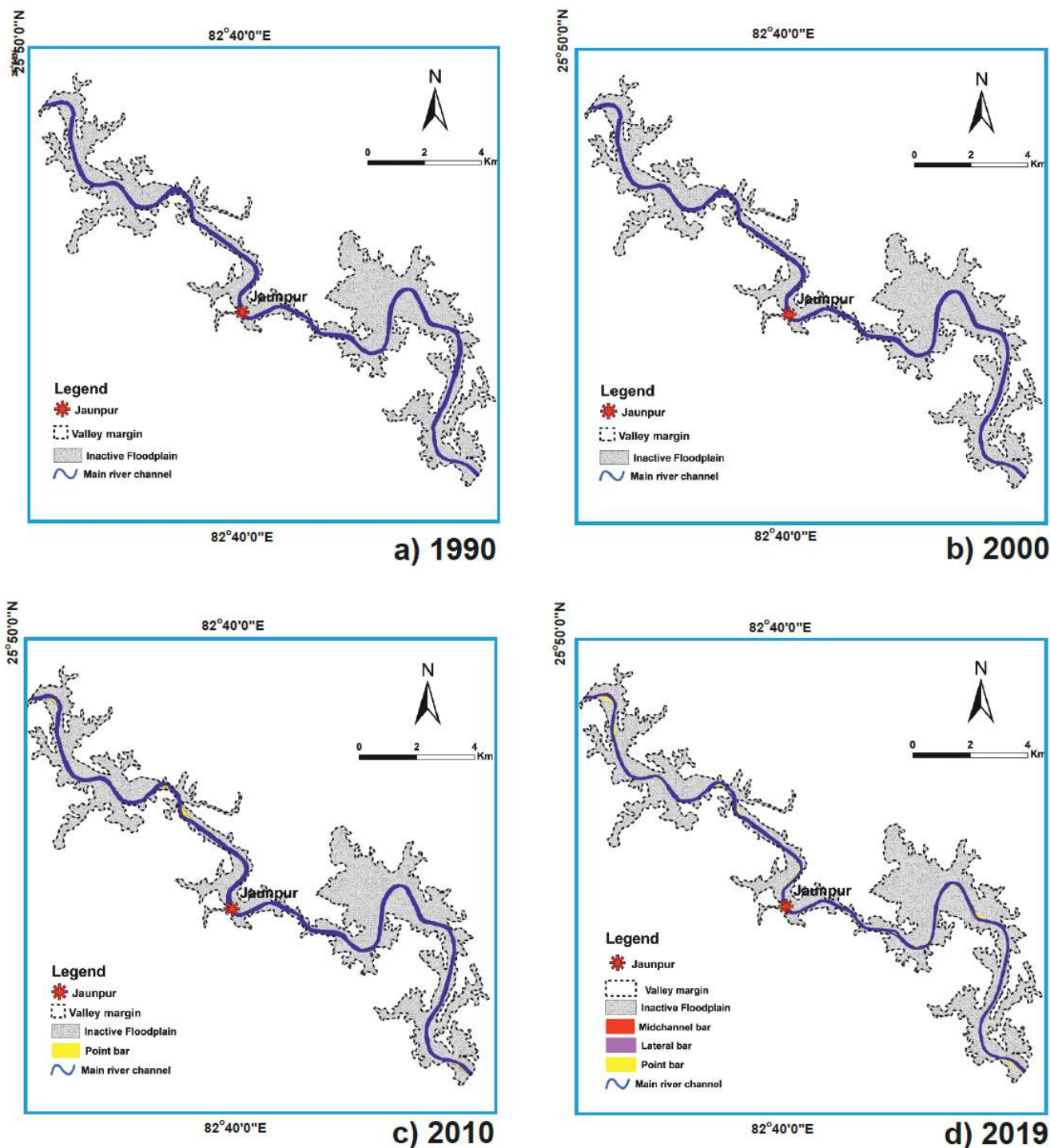
**Table 26: Cross-sectional parameters for the Gomti River at Jaunpur (from HFL)**

The Present and Desired state of the Gomti river for the Jaunpur location is discussed in the upcoming section.

### 4.3.4.1 Jaunpur – Present State

#### A. Fluvial geomorphology

The river has been confined to a narrow single meandering channel throughout the last three decades. In the year 2010, a few point bars developed at the sinuous bend of the river. The year 2019 shows a few more lateral bars and mid-channel bars in the course of the river. No active floodplain is mappable at this scale during the study, although wide patches of inactive floodplain are noted in several reaches. This suggests that the river is totally disconnected from its floodplain. In terms of planform dynamics, the temporal channel width shows no width change in the last three decades, indicating a regulated channel flow. Similarly, the thalweg line also reflects no channel shift during the study period (Figure 93).



**Figure 93: Planform maps of the Gomti River near Jaunpur for 1990, 2000, 2010, 2019**

## B. Aquatic biodiversity

The river stretch around Jaunpur harbours a wide range of fish species, and a total of nine species were recorded during the survey. Of these, *Wallago attu*, *Oreochromis mossambicus* and *Cyprinus carpio* are found to be in the Vulnerable (VU) category as per IUCN Red List data. Both *Cyprinus carpio* commonly known as “common carp” and *Oreochromis mossambicus* commonly called “Tilapia” are exotic species. *Wallago attu* (VU) is one of the economically important fish species. As per secondary literature, at a nearby location, several other species such as *Chela laubuca* (NT), *Ompok bimaculatus* (NT), *Bagarius bagarius* (NT), *Ailia coila* (NT), were reported.



Besides this, Indian major carp species are reported in secondary literature from this location. These include *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. These varieties of IMCs are among the motivations driving the flows requirements for this location.

### C. Socio-cultural aspects

According to the Imperial Gazetteer<sup>29</sup>, the Gomti River frequently floods the low-lying areas, but does not cause serious harm. In 1774, 1871 and 1894, the river rose above the parapet of the Shahi Pul. The river was also navigable, and was used to carry stone, grain, fuel and thatching grass.

There are mosques and temples on either side of the banks, both upstream and downstream of the bridge. People frequent the ghats for recreation in the morning and evening. There is a large population of *mallahs*, the traditional fishing community, who have had to evolve their ways of fishing with the changing nature of the river.

Jaunpur is home to a bustling community of people with varying uses of the river. The ghats along the river, especially on the downstream right side of the bridge, are used extensively for domestic activities. A snapshot count during the surveys revealed that nearly 50 people use the river for washing of clothes and bathing in the morning.

Gomti *aarti* has been initiated by a local organization in order to increase interest in the river and to maintain cleanliness along its banks. At present, the *aarti* is sparsely attended, mainly by the people who are part of this cleanliness campaign. There is a ritual of bathing during festivals, with people coming from the nearby towns and villages. The river ghats also offer people the opportunity to walk and spend some time in the open air.

Pollution, both regular inflow of sewage and occasional dumping of effluents from upstream factories, has led to a decline in the health of the river. Respondents have memories of feeling comfortable drinking the water, but now are reluctant to even wash in it. Even the people who have no option but to use the river water for washing, cannot do so on certain days because of the pollution in it. Several respondents alleged that there are sugarcane factories upstream that release effluents into the river, turning the river black. As a result of this pollution, not only is there a decline in the fish, but also turtles, which were once common.

All the respondents agreed that present flows are much diminished as compared to historic flows, and they fall short of the residents' expectations. The boatmen reported concern about increasing sediment in the center of the channel due to lack of floods. According to them, regular annual floods (up to the top of the ghats) will enable the clearing of the sediment.

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<sup>29</sup> Imperial Gazetteer of India, v. 14, p. 77

### 4.3.4.2 Jaunpur – Desired State

The 'Desired' river state of Jaunpur E-Flows location is shown in Table 27.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                | Desired State       |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1      | Fluvial Geomorphology | Degraded            | Lack of any channel-floodplain connectivity. The river has been almost static for the last four decades and there is very little sign of any geomorphic activity. | Moderately Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | Some revival of river is apparent at this location, as the species diversity has improved at this location.                                                       | Moderately Modified |
| 3      | Socio-cultural        | Moderately Modified | Pollution and low flows during all seasons has been a concern amongst the local people, although great deal of interaction with the river is still evident.       | Slightly Modified   |

**Table 27: Present and Desired state of the Gomti River at the Jaunpur E-Flows location**

## 4.4 Rapti river

The Rapti River originates from the southern direction of a prominent east-west ridgeline, midway between the western Dhaulagiri Himalaya and the Mahabharat Range (1000-3000m) at an elevation of approximately 3200m ASL (above sea level). This river originates from the Himalayas in Nepal, enters India in the district of Bahraich and traverses through the districts of Gonda, Balrampur, Basti, Bahraich, Siddharth Nagar, Gorakhpur, Sant Kabir Nagar and Deoria in Uttar Pradesh. It is a typical meandering river with the most prominent features in the lower Rapti floodplain being ox-bow lakes, alternative channel bars, flood chutes, point bars, swirl pit, swamps or marshes, natural levee, dry channel and branching streams. It joins the Ghaghra River at Kaparwar Ghat in Deoria district, which is downstream of the Dohri Ghat E-Flows location on the Ghaghra River.

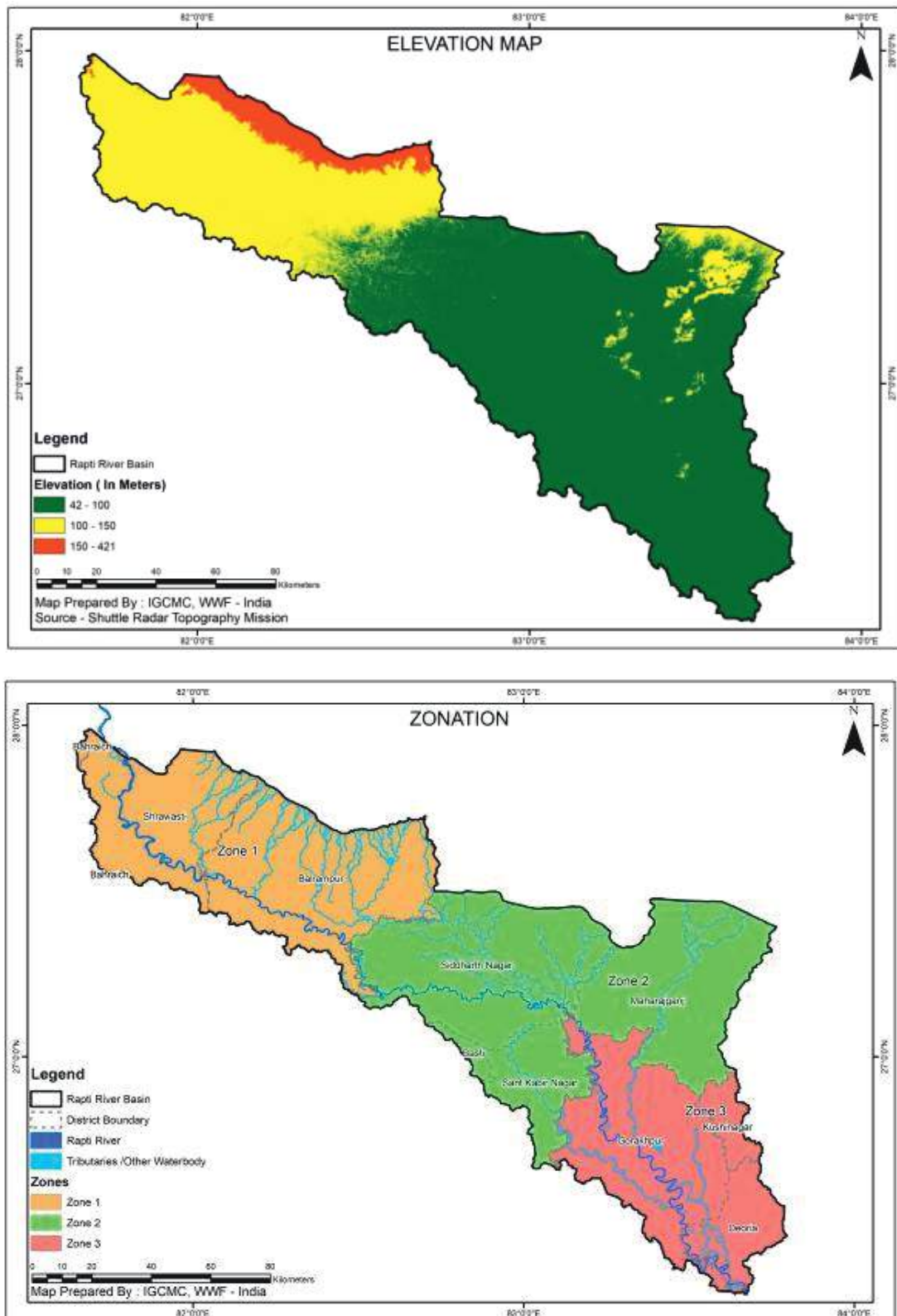
The Gonda Gazetteer mentions that on either side of the Rapti river, the land is cut by innumerable paleo-channels. Floods are common and recede before spring planting is due, benefiting the crops with the rich silt. The high banks mean that the river floods only during very wet seasons, but when it does, it covers the surrounding land with rich loam. The Gonda Gazetteer describes the Rapti River as a large and rapid stream that is navigable throughout its length in that district. It is only the bends in the river that make the navigation difficult. The Rapti River was also navigable for small boats up to Bhinga in Bahraich, and for large boats up to Gorakhpur. There are records of extensive forests both in the upper reaches of the catchment as well as near Gorakhpur, but this has largely been lost now.

***The Rapti River is mentioned to a large extent in ancient literature. In Buddhist literature, it is referred to as Airavati and Ajitavati (Watters, Thomas. On Yuan Chwang's Travels in India, 629-645 AD. Vol. 1. Royal Asiatic Society, 1904). The river's other names also testify to the nature of its flow. The epics refer to it as Sadantara (ever-flowing) and Iravati (refreshing) (Stevenson. Imperial Gazetteer of India, V 21. page 236). The river rises in the foothills of Nepal from the western face of the Dewaligiri mountains where it is known as the Shingrak. It flows south before turning towards the north-west and west for a total distance of about 800km, before it meets with the Ghaghra River. In the upper reaches, it flows through the Tarai, where the subsoil water is close to the surface and the river is prone to flooding.***



Similarly, the Rapti River and its tributaries are recorded to be very well stocked with fish, which were dried and bartered with the people of Nepal.

Based on Homogenous Zonation exercise (Annexure 1D), the river is divided into three distinct homogenous zones, i.e. having elevation ranges of 42-100 metres, 100-150 metres and 150-421 metres (Figure 94 A & B).



**Figure 94 A & B: Elevation Map and Homogenous Zones in the Rapti River**

- A. Zone 1** - This zone falls within Bahraich, Shravasti and Balrampur districts of Uttar Pradesh. The length of the river course is about 218km. The elevation range in the main river stretch is from 421 to 150 metres. Major places are Nawabganj, Balrampur, Bhinga, Sirsa, Bhatpurwa, Tulsipur, Pachperwa, Utraula, etc. Balrampur is the E-Flows location in this zone.
- B. Zone 2** - This zone falls within Siddharth Nagar, Maharajganj, Basti and Sant Kabir Nagar districts of Uttar Pradesh. The length of the river course is about 133km. The elevation range in the main river stretch is from 150 to 100 metres. Major places are Itwa, Domariaganj, Baugarh, Bansi, Anandnagar and Nautanwa, etc. Bansi is the E-Flows location in this zone.
- C. Zone 3** - This zone falls within Gorakhpur, Kushinagar and Deoria districts of Uttar Pradesh. The length of the river course is about 133km. The elevation range in the main river stretch is from 100 to 42 metres. Major places are Gorakhpur, Jagdishpur, Murera, Rudrapur, Unwal, Maghar, Kunraghat, Deoria, etc. Gorakhpur is the E-Flows location in this zone.

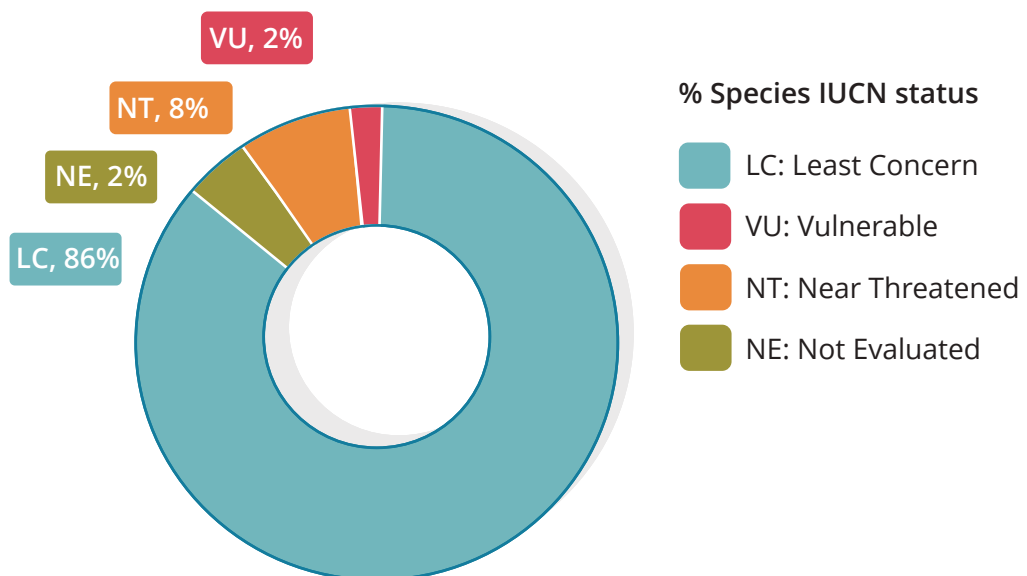
Three E-Flows locations are identified on the Rapti River, which are selected from all three zones (Figure 95).

A total of 49 fish species belonging to 39 genera, 19 family, and seven orders were recorded from the Rapti River. This data is based on secondary literature and primary surveys. The location-wise details of the species are given in Annexure 6 (Starter Document Aquatic Biodiversity). Maximum number of species (20 species) were reported from Gorakhpur during the entire survey, followed by 13 species from Bansi and 11 species from Balrampur. *Cirrhinus reba*, *Labeo bata*, *Labeo calbasu*, *Bagarius bagarius* are some of the commercially important fish species reported from Rapti River.

As per the IUCN Red Data List – 2020-21, 42 species are listed as Least Concern (LC) in the Rapti River, four species are Near Threatened (NT) and one vulnerable (VU). Two species are under Not Evaluated (NE) category. The percentage of fish species under IUCN category are presented in Figure 96.



**Figure 95: E-Flows locations on the Rapti River - Balrampur, Bansi, Gorakhpur**



**Figure 96: Percentage of species as per IUCN Red Data List 2020-21 in the Rapti River**

Basic water quality parameters and hydrological information was also collected during the surveys, the same is given in Table 28.



| Hydrological and Water-quality Parameters | Balrampur           |                     | Bansi                                               |                     | Gorakhpur           |                      |
|-------------------------------------------|---------------------|---------------------|-----------------------------------------------------|---------------------|---------------------|----------------------|
|                                           | Summer              | Monsoon             | Summer                                              | Monsoon             | Summer              | Monsoon              |
| River Depth (m) Average, (min-max)        | 1.45<br>(1.07-1.83) | 1.49<br>(0.76-4.11) | Data not collected, as this site was selected later | 1.59<br>(0.76-2.29) | 1.14<br>(0.76-1.89) | 8.60<br>(0.76-16.22) |
| River Width (m)                           | 60                  | 100                 |                                                     | 120                 | 110                 | 300                  |
| Average Current velocity (m/sec)          | 0.140               | 0.290               |                                                     | 0.370               | 0.140               | 0.380                |
| Water Appearance                          | Clear               | Turbid              |                                                     | Turbid              | Brownish            | Turbid               |
| pH                                        | 7.8                 | 8.4                 |                                                     | Not Available       | 7.2                 | 8.4                  |
| Temperature (°C)                          | 29.6                | 29.2                |                                                     | Not Available       | 31.8                | 28.7                 |
| Dissolved Oxygen (DO) mg/l                | 7.6                 | 7.8                 |                                                     | 6.8                 | 6.5                 | 7.2                  |
| Total Dissolved Solids (TDS) mg/l         | 165                 | 176                 |                                                     | 190                 | 173                 | 212                  |

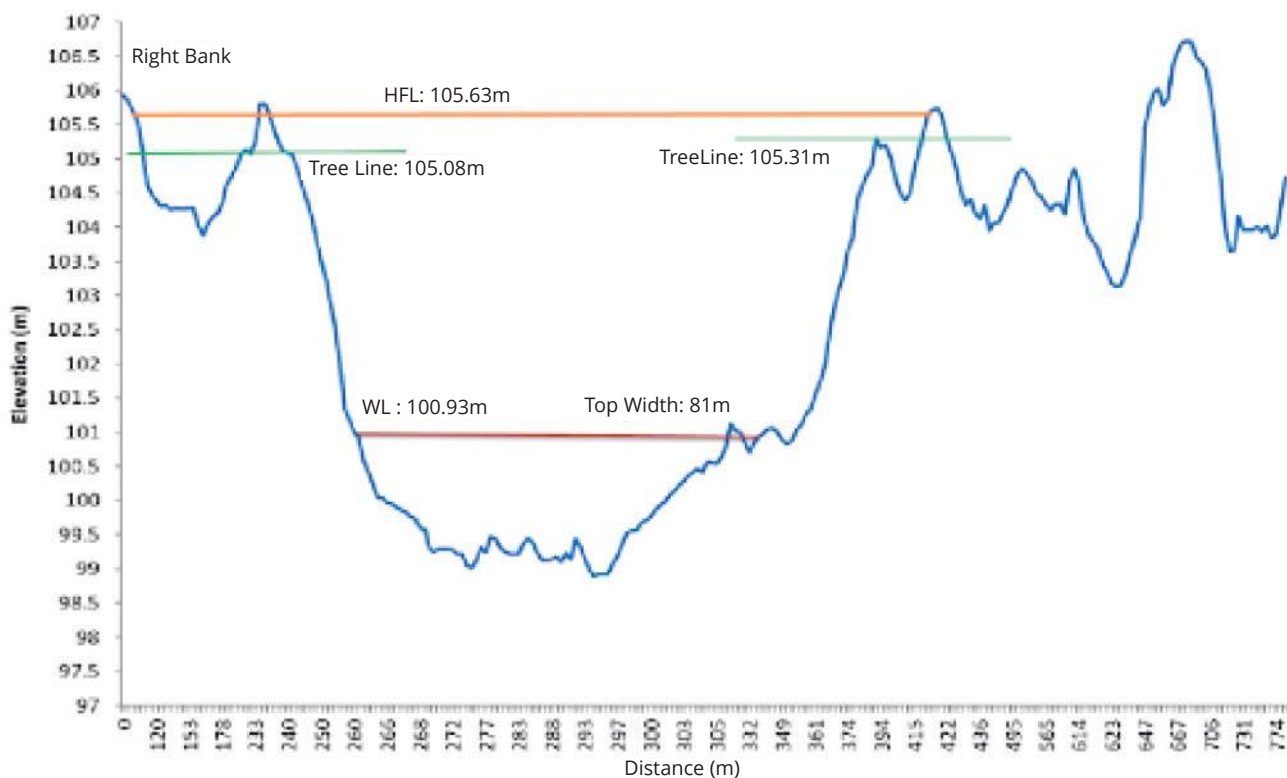
**Table 28: Hydrological and basic water-quality information of the Rapti River at E-Flows locations**

## 4.4.1 Balrampur

Balrampur is located on the right bank of the Rapti River. In the dry season, the river flows remain minimal and it becomes a narrow channel. The E-Flows location is around 6km away from the main city and the banks were free from encroachment.



**Figure 97: Rapti River at Balrampur**



**Figure 98: Cross-section profile of the Balrampur E-Flows location**

The cross-sectional parameters are shown in Table 29.

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 657       | 7               | 2                           | 93.86                    |

**Table 29: Cross-sectional parameters for the Rapti River at the Balrampur**

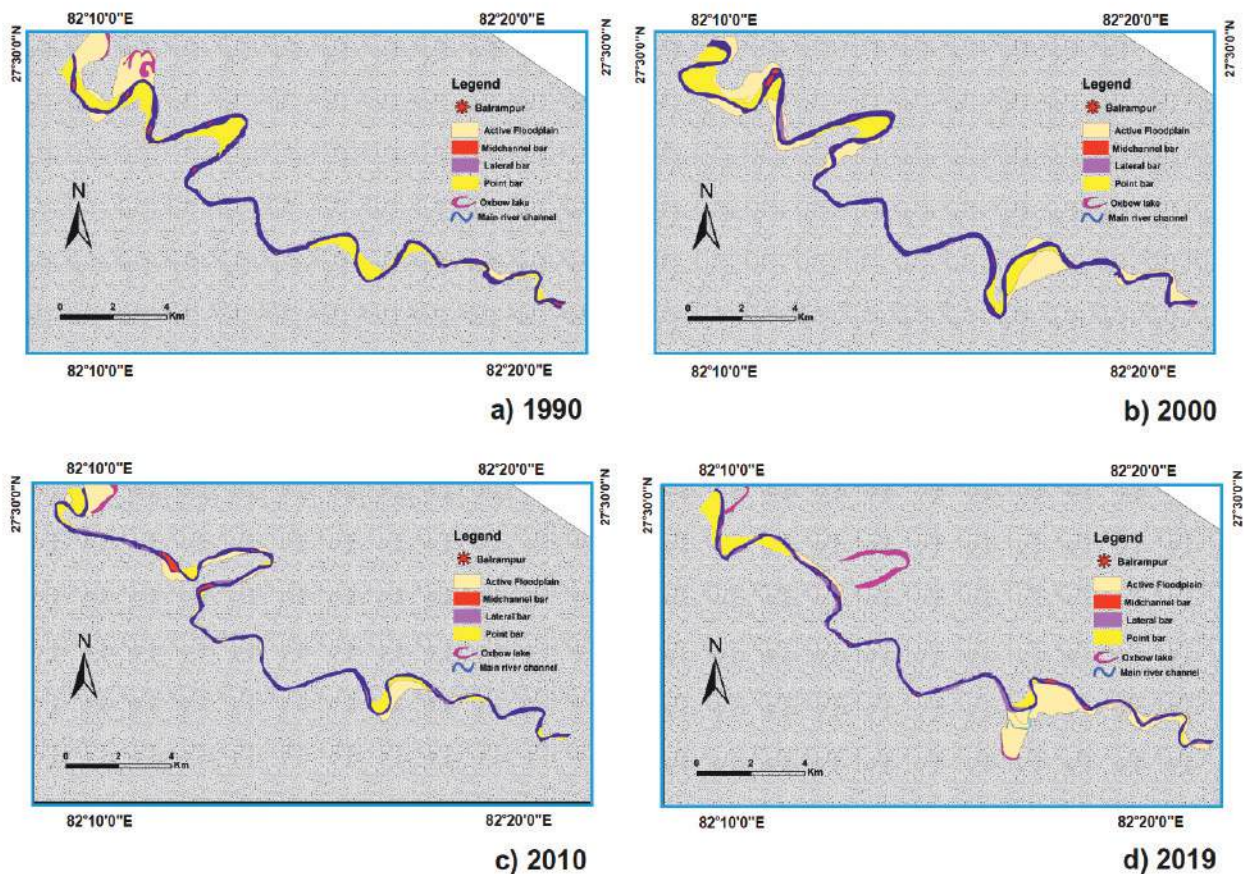
The Present and Desired state of the Rapti River for the Balrampur location is discussed in the upcoming section.

#### 4.4.1.1 Balrampur - Present State

##### A. Fluvial geomorphology

A stretch of 20km, including both upstream and downstream of the Rapti River near Balrampur, was considered for the planform analysis. The entire reach of the Rapti River around Balrampur shows a sinuous channel with patches of floodplain and a large meander scar in the upstream reaches. The channel is narrow and the maximum width is less than 130m in the entire stretch.

Temporal planform maps (Figure 99) show that the river morphology has not changed much in the last three decades except for two major cutoffs of large meanders – one in the upstream reaches and another in the downstream reaches that occurred between 2010 and 2019. The width of the main channel has remained more or less uniform throughout the stretch.



**Figure 99: Changes in planform dynamics around the Balrampur E-Flows location**

## B. Aquatic biodiversity

Twelve fish species were reported during the survey from Balrampur. *Labeo bata*, *Mystus cavasius*, *Wallago attu*, *Rita rita*, *Bagarius bagarius* and *Mastacembelus armatus* are some of the commercially important fishes. As per the IUCN Red List data, *Wallago attu* (Vulnerable) which is commonly called “Lanchi” and *Bagarius bagarius* (Near Threatened) which is commonly called “Goonch” were found here.

As per secondary records, *B. bagarius* is a migratory fish, which moves upstream during summer and monsoon seasons. *Wallago attu* was also reported from Kodhari ghat in secondary literature and *Bagarius bagarius* was reported by Verma 30 et.al. (2019)<sup>30</sup> from Khamariya.

The Ganga river dolphin was neither spotted during the surveys nor reported by local people and fishermen at this location. While there are some human interferences, the water quality appears to be free from noticeable industrial and domestic waste.

<sup>30</sup>Verma Dharmra, Ahmad Tabrez, Bajpai Sandeep, Dixit Vivek Kumar and Singh U.B. (2019). Condition Factor of Fishes of Rapti River in Different Seasons at Balrampur, Uttar Pradesh, India. International Journal of Zoological Investigations Vol. 5, No. 2, 118-128 (2019); ISSN: 2454-3055





**Figure 100: *Labeo bata***



**Figure 101: *Bagarius bagarius***



**Figure 102: *Rita rita***

Besides this, Indian major carp species are reported in secondary literature from this location. These include *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. These varieties of IMCs are also among the motivations driving flows requirements for this location.

### C. Socio-cultural aspects

The town of Balrampur was part of the Balrampur state, and was once the largest *talukdari* estate in the United Provinces, which was acquired by Madoh Singh in 1566. The town was established by his son Balram Das in the first quarter of the 17<sup>th</sup> century. The city is still close to its feudal antecedents, with nearly all the respondents referring to the King and his estate. The last major flood occurred on 15<sup>th</sup> August 2017, with a water level of 105.5m, which is 2m above the standard warning level.<sup>31</sup> The surveys revealed very little *pallage* farming in the area. There are embankments on either side of the river and a limited amount of farming is undertaken. This is a change from historical times, as the Gonda Gazetteer states that in the Balrampur pargana 'almost the whole

<sup>31</sup> <https://sandrp.in/2020/09/16/north-india-cwc-flood-forecasting-sites-2020-new-website-old-problems/#more-37736>

area is taken up by melons, which are somewhat extensively grown during the hot weather in the sandy soil along the Rapti River'.<sup>32</sup> There are records of seven ferries across the Gonda district. At least one of these ferries is still operational just upstream of Balrampur at Shravasti.

The river in this stretch was once the cradle of Buddhist civilisation. Today, the ruins of *Sahet Mahet* have been identified at Shravasti and this has increased the religious importance of the area. *Magh Mela*, *Navratri*, and *Chhat puja* are some of the socio-culturally auspicious festivities that are practised extensively in this stretch.

The cenotaphs of the royal family of Balrampur are located on the river bank. The river continues to be regarded as a source of prosperity as it increases the soil moisture. However, there appears to be a lack of annual floods, interrupting the age-old replenishment of soil. The silt brought down by the river was once of such fine quality that it has been mentioned in nearly every official document of the 19<sup>th</sup> century. During the last flood, the river deposited sand in the fields. Nearly all the respondents maintain livestock, primarily buffaloes. For them, an adequate depth of water is absolutely essential to continue practising this livelihood.

Present day summer flows are extremely low, with the river shrinking to a mere stream in the centre. There are very few pools where the water depth is waist deep, but most of the stream is such that one can easily walk across. In the monsoon, the river channel is filled with water, but regular floods do not occur any more. In addition, there are now unexpected floods in summer, which cause devastating losses to the *pallage* crops.

According to the respondents, the historical flows in the summer were deep enough to submerge a person in the centre. Monsoon flows would completely fill the channel, and annual floods would regularly inundate the surrounding areas.

The main concern for the people was low flows during summer and the lack of monsoon floods, along with untimely summer floods that sometimes occurred. It is possibly the low summer flows, which have the greatest impact on the well-being and livelihoods of the residents. Respondents described their desired flows as being much greater in the summer than at present. A depth of shoulder deep in the centre is considered adequate. The present winter flows are considered adequate though more would be welcomed as it replenishes the soil moisture. In addition, monsoonal floods inundating the surrounding area for three to four days annually are considered essential.

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<sup>32</sup> Nevill HR, 1905. Gonda: A Gazetteer, being volume XLIV of the district gazetteers of the united provinces of Agra and Oudh. Nainital. URL <https://archive.org/details/dli.csl.2951/page/n3/mode/2up>

### 4.4.1.2 Desired State

The 'Desired' state of the Rapti River at the Balrampur E-Flows location is shown in Table 30.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                           | Desired State     |
|--------|-----------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Slightly Modified   | The river is fairly stable with a sinuous morphology and asymmetric channel form. The planform morphology does not show any appreciable dynamics.                                                                            | Near Pristine     |
| 2      | Aquatic Biodiversity  | Slightly Modified   | The river is in satisfactory state, with no major disturbances from the aquatic biodiversity perspective.                                                                                                                    | Near Pristine     |
| 3      | Socio-cultural        | Moderately Modified | Present day summer flows are extremely low, with the river shrinking to a stream in the centre. There are very few pools where the water remains waist deep, but most of the stream is such that one can easily walk across. | Slightly Modified |

**Table 30: Present and Desired state of the Rapti River at the Balrampur E-Flows location**

### 4.4.2 Bansi

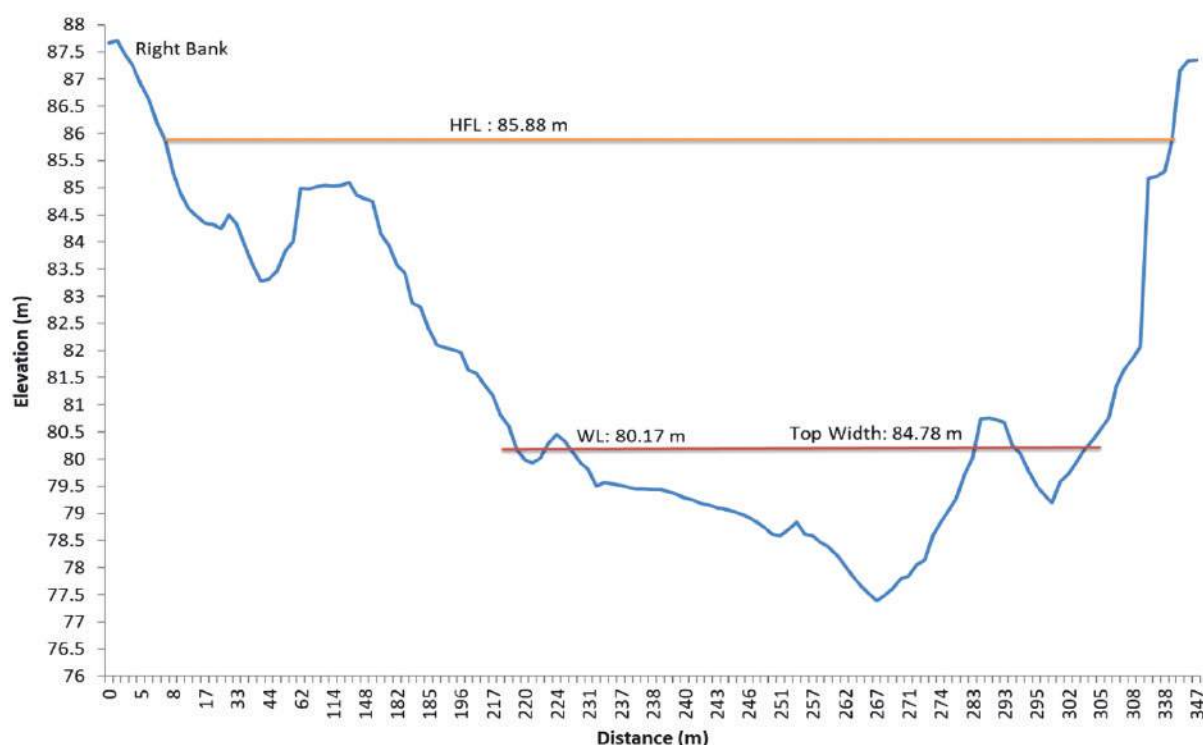
Bansi, a town in the Siddharth Nagar district of Uttar Pradesh, is around 76km downstream from Balrampur, 52km from Basti and 90km from Gorakhpur. The river here was found to have low flows, moves slowly and the substrate is mainly composed of silt and sand.



**Figure 103: The Rapti River at the Bansi E-Flows location**



The cross-section profile of the Bansī E-Flows location on the Rapti River is given in Figure 104 (with water level at time of survey).



**Figure 104: Cross-section profile of the Rapti River at the Bansī E-Flows location**

The cross-sectional parameters are shown in Table 31.

| Cross Section | Width (m) | Max. Depth (m) | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|----------------|-----------------------------|--------------------------|
| Main Section  | 340       | 9.75           | 2.65                        | 34.87                    |

**Table 31: Cross-sectional parameters for the Rapti River at the Bansī E-Flows location**

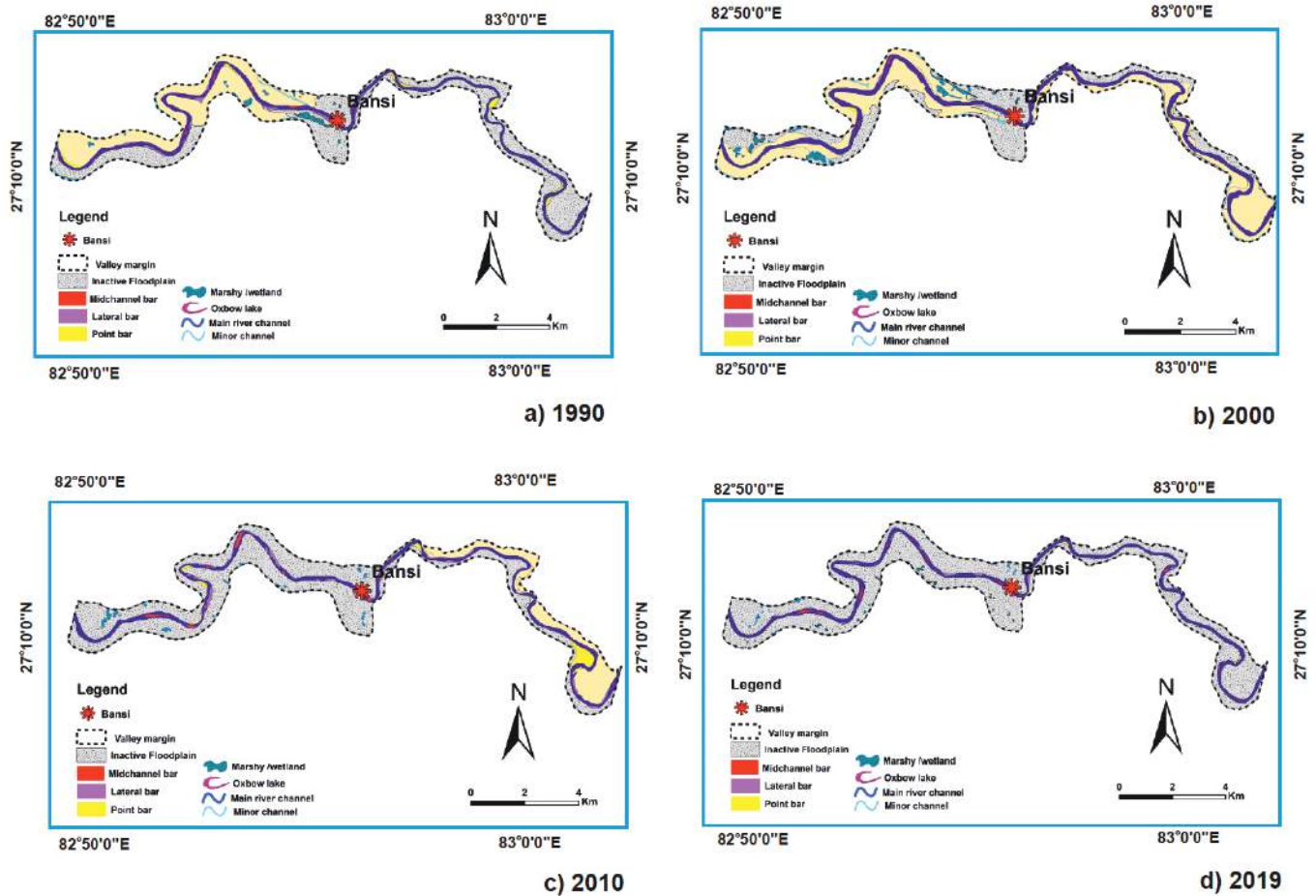
The Present and Desired state of the river at the Bansī E-Flows location is discussed in the upcoming section.

### 4.4.2.1 Bansī-Present State

#### A. Fluvial geomorphology

The Rapti River at Bansī has a morphology very similar to that at Balrampur. The river is fairly sinuous, narrow and deep with almost no active floodplains.

Here, it has not shown much dynamics over the last three decades and almost each and every bend of the river has been stable during this period (Figure 105). The channel width as well as the position of the river has remained nearly fixed throughout the stretch of 20km. Similar is the case of the thalweg, with no change between 1990 to 2019. However, the active floodplain width and extent show appreciable variation over the period between 1990 - 2019. The disappearance of active floodplain suggests that the river has nearly lost the lateral connectivity in recent years.



**Figure 105: Planform dynamics of the Rapti River near Bansi for the years 1990, 2000, 2010, 2019**

## B. Aquatic biodiversity

Thirteen fish species were recorded during the survey from this location. Among these species, *Cirrhinus reba*, *Labeo calbasu*, *Labeo gonius*, *Ompok bimaculatus*, *Wallago attu* and *Clupisoma garua* are commercially important fish. As per the IUCN Red data List, *Ompok bimaculatus* is categorised as Near Threatened and *Wallago attu* is listed under Vulnerable category. *Ompok bimaculatus* was also reported in the Rapti River in secondary literature from Mathura Ghat and Mirzapur Ghat.

Besides this, Indian major carp species are reported in secondary literature from this location. These include *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. These varieties of IMCs are among the motivations that drive the flows requirement for this location.

During the surveys, agriculture was observed close to the floodplain and water quality showed no signs of industrial effluents.

### C. Socio-cultural aspects

Bansi, just downstream of Balrampur, was once part of the Balrampur estate and ruled by the same king. The respondents interviewed during the survey include rice farmers, *pallage* farmers, grass cutters, shopkeepers and goat herders. One of the respondents, a 70-year-old farmer, remembered the times when floods would occur annually, inundating the entire surrounding area. These annual floods would recede within three to four days. The few times that the floods did not recede for a week, the then king of Balrampur, Maharaja Pateshwari Prasad Singh<sup>33</sup>, would open his residence in Bansi—built on a small hillock—to all the flood-affected villagers. Rice and salt would be provided to the livestock and *puri-sabzi* to the humans. Some of the respondents remember staying there in their childhood. At such times, the king would also go along the road to an elevated bridge and address the river, saying ‘This is enough. Now you should go back.’ The villagers believed that less than four days after this ritual the flood would always recede. This corresponds with the documentation in the Imperial Gazetteer about the periodicity and duration of the floods in the Rapti River. However, there have been reduced floods since the construction of the barrage at the India-Nepal border. Consequently, the last two generations of the royal family have not had an occasion to practice this ritual.

Bansi was once a rice-growing area, mainly irrigated by tanks and streams. The rice from here was famous and a major export commodity of the area. This rice was of three types. *Dhan* was the chief rice sown when the rains began, and harvested post-monsoon. *Jarhan* is sown in nursery beds in June, transplanted during the monsoon and harvested in November. The most valuable rice crop was *Boro*, which was summer rice transplanted in January and harvested in May<sup>34</sup>.

Most historical records of Bansi refer to it lying between the Rivers Rapti and the Suwawan, due to which it was often inundated. However, this didn’t last long and the water receded within a few days.

The river is looked upon with affection for the many gifts it brings. The people along this stretch, being subsistence agriculturists, observe the river keenly. The ebb and flow of the river over the seasons allows for the practice of *pallage* farming. The inundation is welcomed for the rich silt and moisture it brings, which allows for two or more crops a year.

The river is used for fishing, collection of grass from its banks and for swimming in the summer. *Maagh Mela* and *Chhat Puja* are celebrated on a large scale at Bansi, just upstream of the E-Flows location. The *Maagh Mela*, especially, is an additional source of income and entertainment for the people of Bansi and the surrounding villages.

The present-day summer flows are extremely low with people being able to walk across the bed. This is unacceptable to animal herders, farmers, and swimmers

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<sup>33</sup> <http://www.indianrajputs.com/view/balrampur>

<sup>34</sup> Clow AG. 1919. Final settlement report of the Basti district United Provinces, 1915-1919. Government Press, United Provinces. Allahabad.



as a threat to their livelihoods and memories of the river. In the winter, the river is not in a better situation, with the water rarely covering the channel bed. It flows in a deeply incised channel, which is often filled during the monsoon. However, it has not overtopped its banks in recent years. The rice farmers interviewed said that at present, the floods rarely reach the embankment, while earlier that would be an annual affair. They clarified that inundation in the field at present do not come from the river, but from the surrounding areas. The embankments do not allow the rainfall to reach the river-course and cause stagnation of the water in the fields.

The historical flows were not as low as it is at present, as per the historical records as well as in people's memories. There are records of cargo boats taking rice from Bansi in the winter. Several country boats would also ply the river at this location. In people's memories, the floods would occur regularly. The oldest respondent mentioned having memories of extraordinary floods (those of greater intensity and duration than the annual floods), occurring three or four times in his childhood. Thus, even six decades ago, regular flooding would occur for three days every year and for up to seven days every few years. Summer flows were high enough that people could swim with ease, indicating chest-level water depth.

The main concern is low summer flows and lack of flooding, which severely impacts farming and other activities.

**Desired flows:** Summer flows need to be ideally chest deep or more at the centre of the river, and waist deep in times of drought. The base of the channel bed needs to be full in winter. Monsoon flows need to fill the channel bed, with annual floods overtopping the channel.

### 4.4.2.2 Desired State

The 'Desired' state of the Rapti River at Bansi E-Flows location is shown in Table 32.

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                                      | Desired State     |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Slightly Modified   | The river is fairly stable with a sinuous morphology and asymmetric channel form. The planform morphology does not show any appreciable dynamics, except some changes in floodplain width and extent.                   | Near Pristine     |
| 2      | Aquatic Biodiversity  | Slightly Modified   | The river is in reasonably satisfactory state, with evident longitudinal connectivity. No major disturbances from the aquatic biodiversity perspective.                                                                 | Near Pristine     |
| 3      | Socio-cultural        | Moderately Modified | The present-day summer flows are extremely low with people being able to walk across the bed. This is unacceptable to animal herders, farmers, and swimmers as a threat to their livelihoods and memories of the river. | Slightly Modified |

**Table 32: Present and Desired state of the Rapti River at the Bansi E-Flows location**

### 4.4.3 Birdghat – Gorakhpur

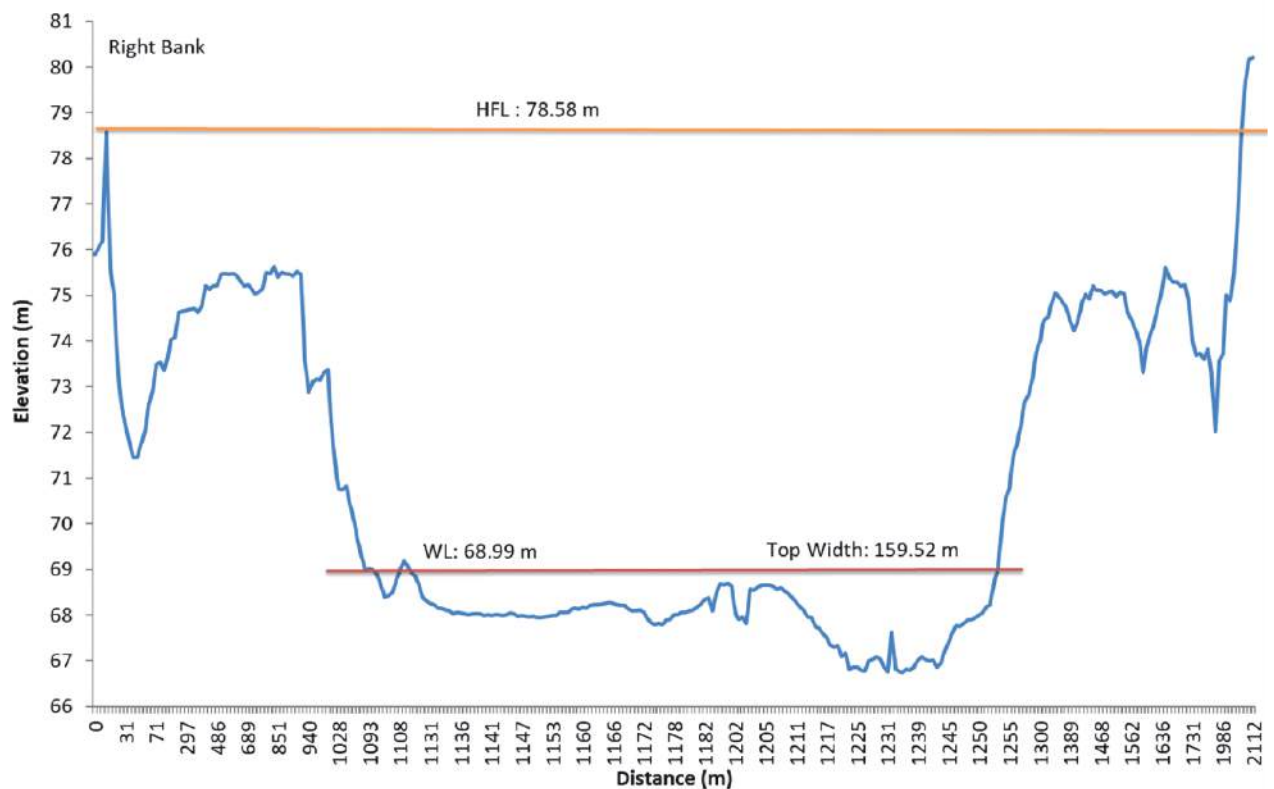
Birdghat–Gorakhpur E-Flows location is over 75km downstream from Bansi on the left bank of the Rapti River, under a bridge on the Lucknow–Gorakhpur highway. The data over the past 100 years show a considerable increase in the intensity and frequency of floods, with extreme events occurring every three to four years. Roughly, 20 percent of the population is affected by floods, which are an annual occurrence in some areas. They cause huge loss of life, health and livelihoods for the poor inhabitants, as well as damage to public and private property.<sup>35</sup> A small fishermen colony is located on the right bank of the Rapti River at the Birdghat–Gorakhpur location and a temple is also located under the bridge. A ghat is noticed at this location. The substratum is mainly composed of sand and silt particles. Deep pools are found during monsoon upstream of the river, making it a good habitat for the Ganga river dolphin. Human interferences were evident, in terms of fishing, bathing and washing of cloths.

<sup>35</sup> [https://cdkn.org/resource/integrating-climate-change-into-disaster-planning-gorakhpur/?loclang=en\\_gb](https://cdkn.org/resource/integrating-climate-change-into-disaster-planning-gorakhpur/?loclang=en_gb)



**Figure 106: Rapti River at the Birdghat-Gorakhpur E-Flows location**

The cross-section profile of the Birdghat-Gorakhpur E-Flows location is given in Figure 107.



**Figure 107: Cross-section profile of the Rapti River at the Birdghat-Gorakhpur E-Flows location**



The section shows that the channel is centrally located and is bound by high banks and secondary channels on both sides. The cross-sectional parameters are shown in Table 33.

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 2050      | 11.75           | 2.2                         | 174.47                   |

**Table 33: Cross-sectional parameters for the Rapti River at the Birdghat–Gorakhpur location**

The Present and Desired state of river at the Birdghat–Gorakhpur E-Flows location is discussed in the upcoming section.

### 4.4.3.1 Birdghat–Gorakhpur-Present State

#### A. Fluvial geomorphology

The river is characterized by asymmetric meanders with a wide active floodplain in most parts that nearly coincides with the valley margin. The active floodplain unit shows several meander scars suggesting some channel dynamics in the past.

The planform morphology of the Rapti River at Birdghat shows some dynamics related to the movement of meanders and abandonment of meander bends over the last three decades (Figure 108). A major change is noted in the extent of active floodplain, which has been increasing steadily since 1991. The channel width of the Rapti River does not show much change over the entire stretch at Birdghat. The thalweg line between the years is also consistent.

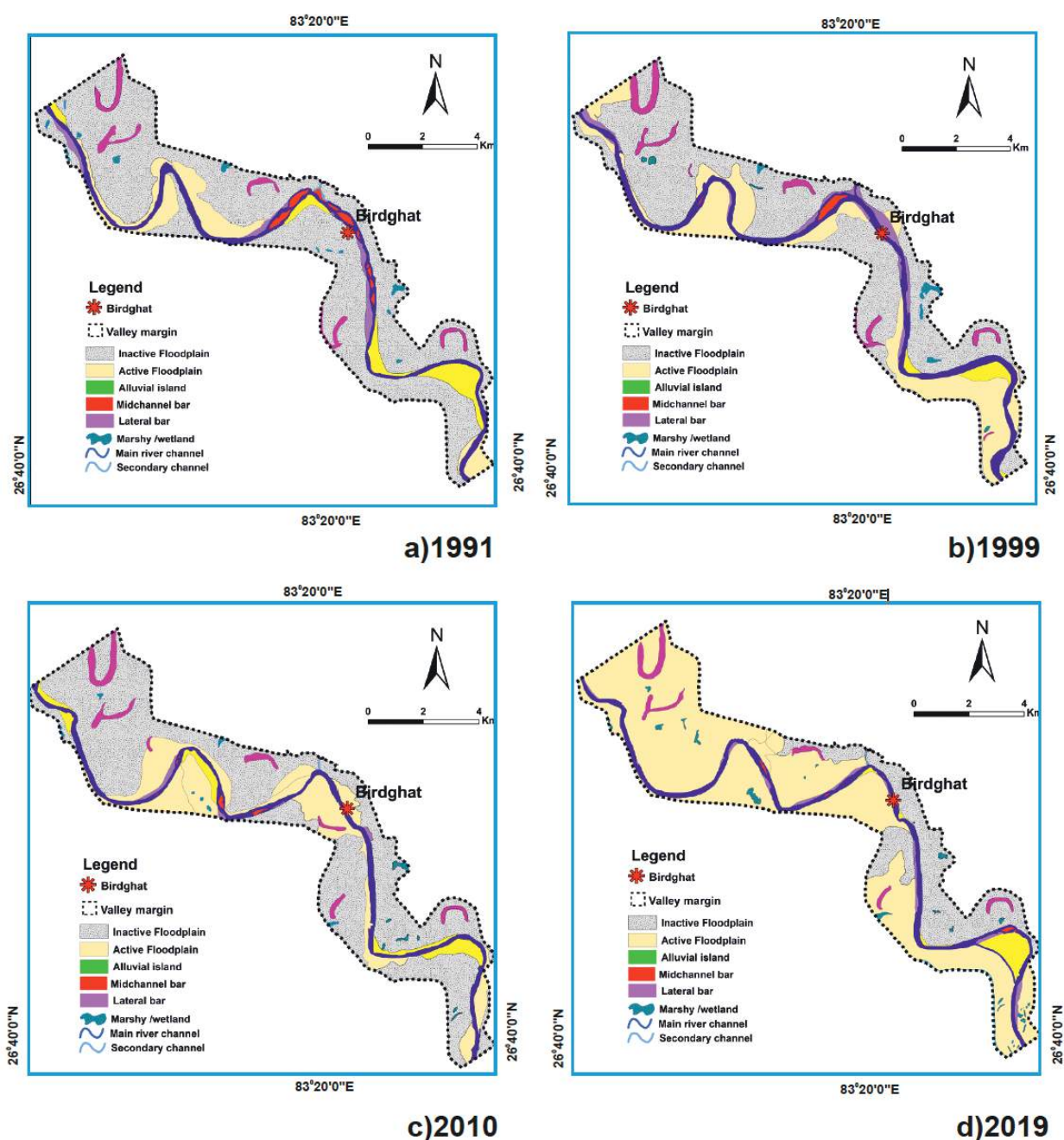
#### B. Aquatic biodiversity

A total of 20 fish species were recorded from this location. As per the IUCN Red data List, only one species, *Wallago attu* was found here, which falls under the Vulnerable category. This is also a commercially important fish species and is commonly called “Lanchi”.

Pollution is not observed or reported by the local communities near this location. The river is well connected longitudinally, and the physical appearance of the water looks good around this location.

A few deep pools were observed here in the river during monsoon, where the Ganga river dolphin was spotted multiple times at the time of the survey. One adult dolphin was spotted swimming in the river. According to the fishermen and locals, they see the Ganga river dolphin during monsoon season.

Besides this, Indian major carp species are reported in secondary literature from this location. These include *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. These varieties of IMCs are among the motivations driving the flows requirement for this location. The Ganga river dolphin is the motivation for wet season flows and IMCs are considered as motivation for the lean season flows.



**Figure 108: Planform dynamics of the Rapti River near Birdghat-Gorakhpur for the years 1990, 2000, 2010, 2019**

### C. Socio-cultural aspects

This is the most downstream E-Flows location on the Rapti River and close to a major city. The city is believed to be founded at the beginning of the 15<sup>th</sup> century and takes its name from a shrine *Gorakhnath*. The city lies almost exclusively on the left bank of the Rapti River, though there are signs that the city

will soon extend across the river to the right bank. There is evidence that at the time of settlement of the city, the Rapti River flowed more to the north-east of its present course, passing through the Ramgarh *Tal*. The Gorakhpur Gazetteer states that evidence of this has repeatedly been furnished by the discovery of driftwood and pieces of boats in excavating wells, and therefore, it seems that the original settlers selected this place because it was protected on two sides by the rivers Rapti and the Rohin.

At present, most of the riverbanks are in a near-natural state with very little construction along the banks. However, one spot immediately below the Rajghat bridge has considerable construction of *ghats* on the right bank as well as an expansion of the cremation grounds on the left bank. The sandy banks upstream of the left side of the cremation grounds are the focus of most of the social and livelihood activities.

*One of the youths exercising on the sandbanks explained how the river had proved a blessing during the times of COVID lockdown. He explained that many of them has lost work during the lockdown. But they were able to come to the river and safely meet in the open air, with adequate distancing. Rather than turn to unhealthy habits during this period of forced inactivity, they set up a club amongst themselves where they visit the river daily and exercise together. During the lockdown, about a hundred people would exercise here. This underlines the importance of open spaces along the river in an urban area.*

Here, the team met buffalo herders, laundry workers, farmers, fisher-folk, as well as people enjoying the open spaces and the fresh air.

Earlier, *pallage* farming was undertaken by migratory farmers. Now, not much of that is evident. At present, only wheat is grown next to the river since the flooding does not allow for paddy. However, the value of the silt is acknowledged.

At this location, respondents felt that the floods have decreased. The last flood at Gorakhpur was in 2000, with an HFL of 82.12m<sup>36</sup>. This was not the case earlier, with records of a large area in the south-west of Gorakhpur tehsil becoming a continuous sheet of water after heavy rains. At present, floods only extend up to the embankment and last for about a week. This year, one respondent reported it reaching her house on the far side of the road.

The Rapti River has always been perennial, which has allowed Gorakhpur to escape the worst of the historical famines. There is only one instance in 1661 when the Rapti River is said to have run almost dry. While there have been other times of scarcity, the issue was more of distribution of rainfall than lack of water (Neville, 1909).

<sup>36</sup> <https://sandrp.in/2020/09/16/north-india-cwc-flood-forecasting-sites-2020-new-website-old-problems/#more-37736>



Festivals are celebrated along the banks of the Rapti River, the most popular one being the *Chhat puja*. Some respondents said that there should be adequate flow in the river throughout the season. This indicates a desire for a healthy river.

The respondents included a *sadhu*, a person accompanying a funeral, laundry workers, fishermen, farmers, recreation, exercise enthusiasts, and buffalo herders. There was a clear demarcation among the respondents upstream and downstream of the cremation ghat. Amongst upstream ones, nearly all the respondents had a close relationship with the river and had interacted with it in many different forms, whether for recreation or livelihoods. On the other hand, most people at the constructed banks were occasional visitors with little or no interactions with the river itself.

The Rapti River around this location is considered as a lifeline for several communities, enabling traditional livelihoods to continue functioning. A buffalo herder explained that the river allows them to continue keeping livestock. Some fishing is done here, but according to the respondents' memories, the fish population has declined. People do imbibe the Rapti River water during rituals. The river flows are not considered satisfactory at the moment, especially in summer. The water levels have lowered in the last couple of decades, inconveniencing recreational swimmers, boatmen, livestock herders, and fishermen.

The present flows for lean season recedes till it is a small stream in the centre. Water is up to knees or less till the festival of *Holi* in March. In some places, it may be up to the waist in the far side, but that is rare. This depth is not enough for swimming or for the buffaloes. In the winter, the flows increase. Water levels in the river during *Chhat puja* is satisfactory and the respondents pointed out that this level of water should be present throughout the winter, and not just for special occasions. In the monsoon, the water rises up to the embankment, bringing new silt to the wheat fields. The floods rise up to about four feet near the embankment on the river-side. This water lasts for about ten days every year.

Historically, the river flows were natural and dependent on rainfall in the immediate catchment area. This enabled residents to predict the river's behavior, unlike the present situation where it may rise unexpectedly. Additionally, floods were more extensive in the past, with monsoon floods submerging the entire area. Summer flows were nearly one meter higher than present levels, which was considered adequate for supporting all livelihood activities.

The Rapti River at Gorakhpur was once used extensively for carrying cargo, with boats carrying up to 100 tons of weight.<sup>37</sup> According to the respondents, not much has changed between historical and present floods, except for the unexpected nature of today's floods.

The main concern is that the summer flows are very low. This causes hardship to the local community. Fishermen also feel visitors are dissatisfied with the visit

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<sup>37</sup> Nevill HR. 1909. Gorakhpur: A Gazetteer, being volume XXI of the district gazetteers of the united provinces of Agra and Oudh. Nainital.

when the flows are low.

**Desired flows:** The monsoon flows are adequate, but the summer flows are inadequate. The water should be up to the neck in the centre of the river, and a minimum of chest deep across the centre of the river in times of drought. Monsoon flows need to submerge the entire channel and the adjoining banks. In addition, annual floods that extend across the present floodplain area up to the embankment are required for about a week.

#### 4.4.3.2 Desired State

The 'Desired' state of the Rapti River at the Birdghat–Gorakhpur E-Flows location is shown in Table 34

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                                                  | Desired State     |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | Fairly stable location in terms of channel morphology, but shows some dynamics in terms of floodplain extent lately, and it might suggest recent vulnerability of the location to floods.                                           | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | The river is in reasonably satisfactory state, with evident longitudinal connectivity. Some human disturbances observed from aquatic biodiversity perspective.                                                                      | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | The present flows for lean season recede till it is a small stream in the centre. Water is up to the knees or less till the festival of Holi in March. In some places in the far side, it may be up to the waist, but that is rare. | Slightly Modified |

**Table 34: Present and Desired state of the Rapti River at Birdghat–Gorakhpur E-Flows location**

## 4.5 Ganga River

Several institutions and organizations have undertaken the E-Flows assessment for the Ganga River, jointly and individually. WWF-India, along with various national and international partners, conducted the first holistic E-Flows assessment for the Ganga River up to Kanpur (2008-12). In 2013, another study was conducted by WWF-India along with partners to assess the E-Flows for Kumbh at Triveni Sangam Prayagraj.

The Consortia of seven IITs (Indian Institute of Technology) developed the Ganga River Basin Management Plan (GRBMP 2015) and as part of this exercise, E-Flows assessment was undertaken for the mountainous stretch of the Ganga River up to Bhimgoda Barrage. Several other institutions contributed to this initiative and WWF-India was one of them. Under another CGIAR-IWMI initiative (2016-17), WWF-India and cGanga IIT Kanpur conducted E-Flows assessment at critical locations downstream of major diversions.

*The Ganga Authority Notification 2016 <sup>(a)</sup> (October 07<sup>th</sup>, 2016) calls for an urgent need, 'to maintain ecological flows in the River Ganga with the aim of ensuring continuous flows throughout its length, so as to restore its ecological integrity that enables it to self-rejuvenate'. Further, while stating that 'Ecological flow of water in River Ganga to be maintained', Point No. 5 of the Notification notes that:*

- *Every State Government shall endeavour to ensure that uninterrupted flows of water are maintained at all times in the River Ganga.*
- *Every State Government shall also endeavour to maintain adequate flow of water in River Ganga in different seasons to enable the river to sustain its ecological integrity. To achieve the goal, all concerned authorities shall take suitable actions in a time-bound manner.*

*It points out that, the National Mission for Clean Ganga shall identify places where the E-Flows of River Ganga has been modified and take measures for correction thereof to maintain the continuous flow of water for rejuvenation, protection and management of River Ganga and its tributaries. It also calls to devise a system to be put in place for continuous monitoring of flow of water and pollution levels in River Ganga and its tributaries. The striking feature of this point is that, it takes into account not only the Ganga river, but also its tributaries and all the rivers.*

*Later on, with an objective to implement some of the aspects of the Ganga Notification 2016, the Government of India came out with a Ganga E-Flows Order 2018 <sup>(b)</sup> (October 09<sup>th</sup>, 2018). This 2018 Order has E-Flows values, which are to be maintained across different seasons at the downstream location of various water resources infrastructure projects (Dams and Barrages).*

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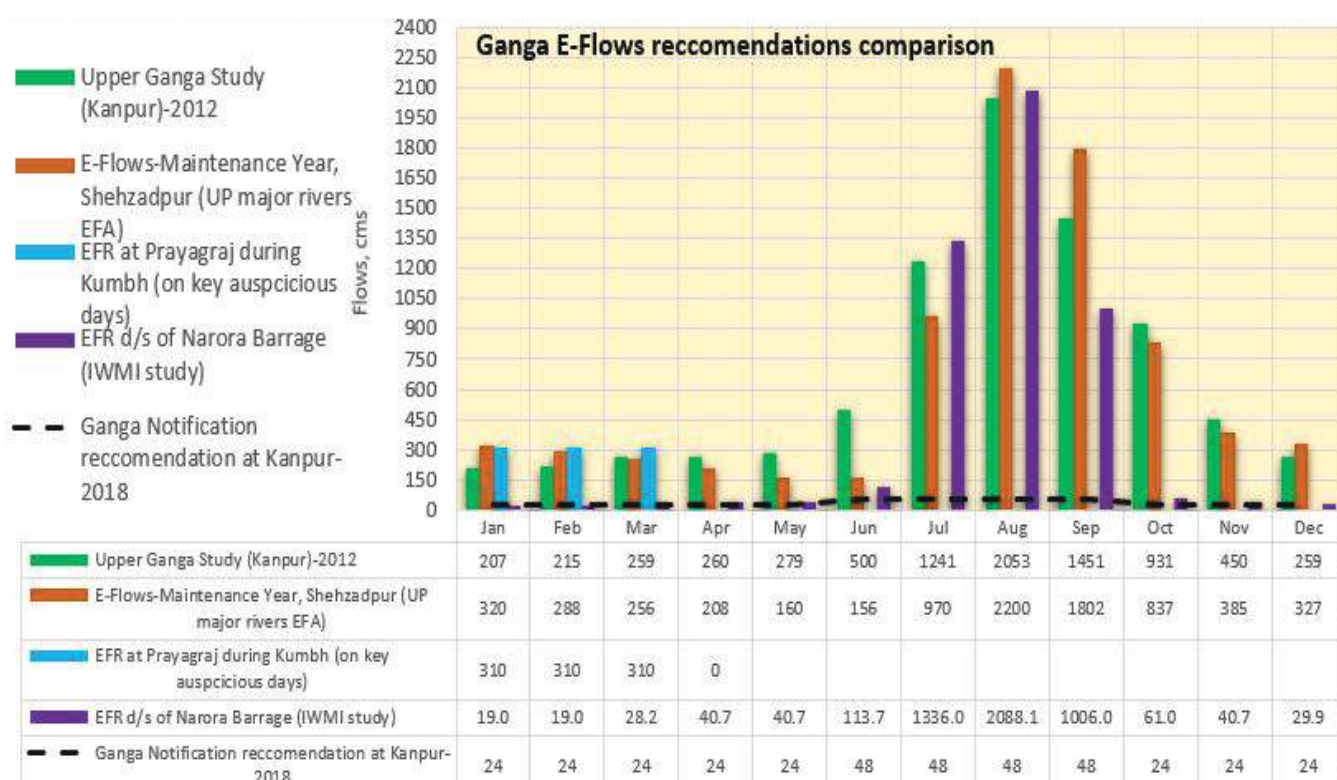
Source:

<sup>a</sup> Ganga Authority Notification 2016 <https://nmcg.nic.in/pdf/AuthorityNotification.pdf>

<sup>b</sup> Ganga E-Flows Order 2018 [https://nmcg.nic.in/writereaddata/fileupload/46\\_Notification.pdf](https://nmcg.nic.in/writereaddata/fileupload/46_Notification.pdf)



The E-Flows values recommended through various studies and initiatives is given in Figure 109.



\* The Ganga E-Flows Order gives recommendations for all key dams and barrages, however Kanpur information is given in above graph

**Figure 109: The E-Flows values from other studies on different locations on the Ganga River**

These studies, or initiatives fairly represent the E-Flows locations on the Ganga River in the state of Uttar Pradesh. The locations are:

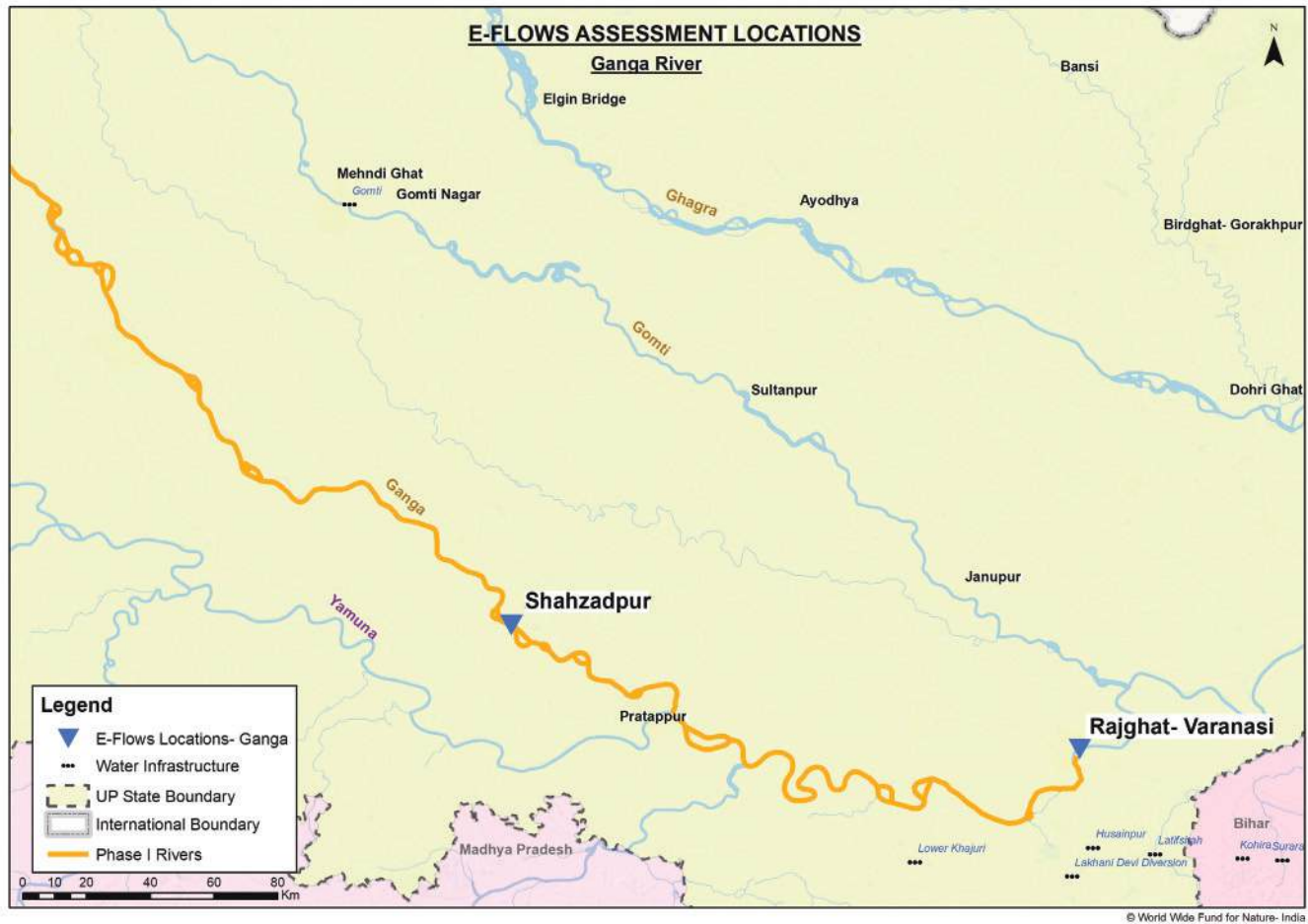
- Downstream of Bhimgoda Barrage – Balawali (Uttarakhand)
- Garhmukteshwar
- Downstream of Narora Barrage
- Kachla Ghat
- Bithoor
- Shastri Bridge–Prayagraj

In view of this work, two more locations on the Ganga River were identified for E-Flows assessment under this study. These are:

- Shahzadpur
- Rajghat–Varanasi

The main reason is that an E-Flows Assessment has not been conducted for these critical locations thus far. The homogenous zonation study for such a short stretch with lesser slope (about 30 metres) is not required.

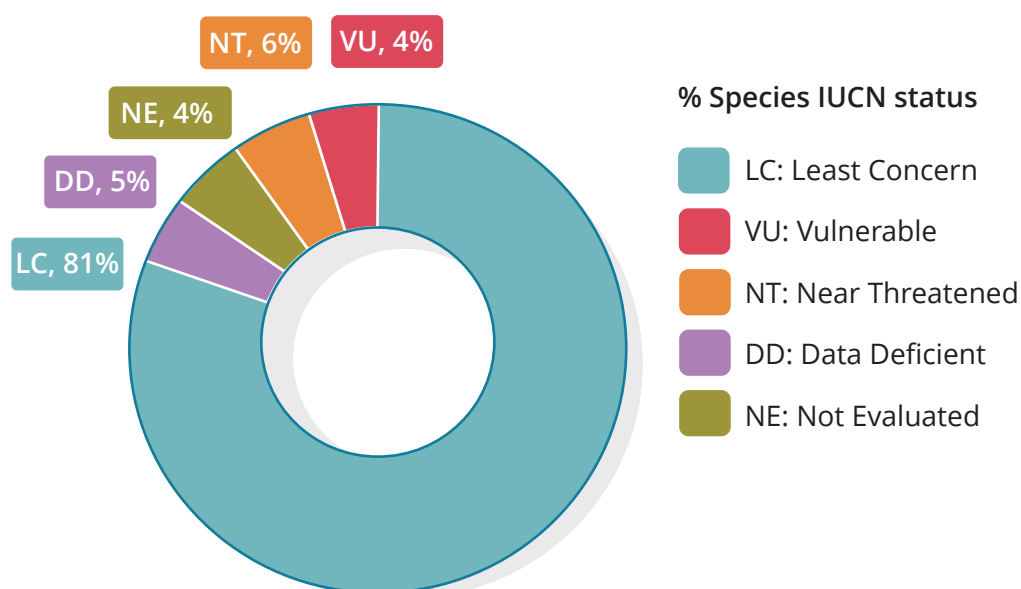
In this report, the E-Flows assessment is discussed for two locations (Shahzadpur and Rajghat–Varanasi).



**Figure 110: The Ganga River and E-Flows locations**

Of the total 69 fish species observed and reported (from secondary literature) from both the locations on the Ganga River, 55 fish species fall under Least Concern category of the IUCN Red List Data. Two species, i.e. *Wallago attu* reported from Shahzadpur; *Cyprinus carpio* reported from Shahzadpur, Varanasi are listed under Vulnerable category as per IUCN. Another Vulnerable category species *Channa orientalis* was reported in the secondary literature in this river stretch. Four species, i.e. *Labeo pangusia*, *Ompok pabda*, *Bagarius bagarius* and *Ailia coila* are categorised as Near Threatened under the IUCN Red List Data. The percentage of various species under IUCN categories is illustrated in Figure 111. For further details, please refer to Annexure 5.

*Cyprinus carpio* and *Oreochromis niloticus* are exotic species reported from both Shahzadpur and Varanasi E-Flows locations.



**Figure 111: Percentage of species as per IUCN Red Data List from the E-Flows locations on the Ganga River**

Basic water-quality parameters and hydrological information was also collected during the surveys for these two locations and are given in Table 35.

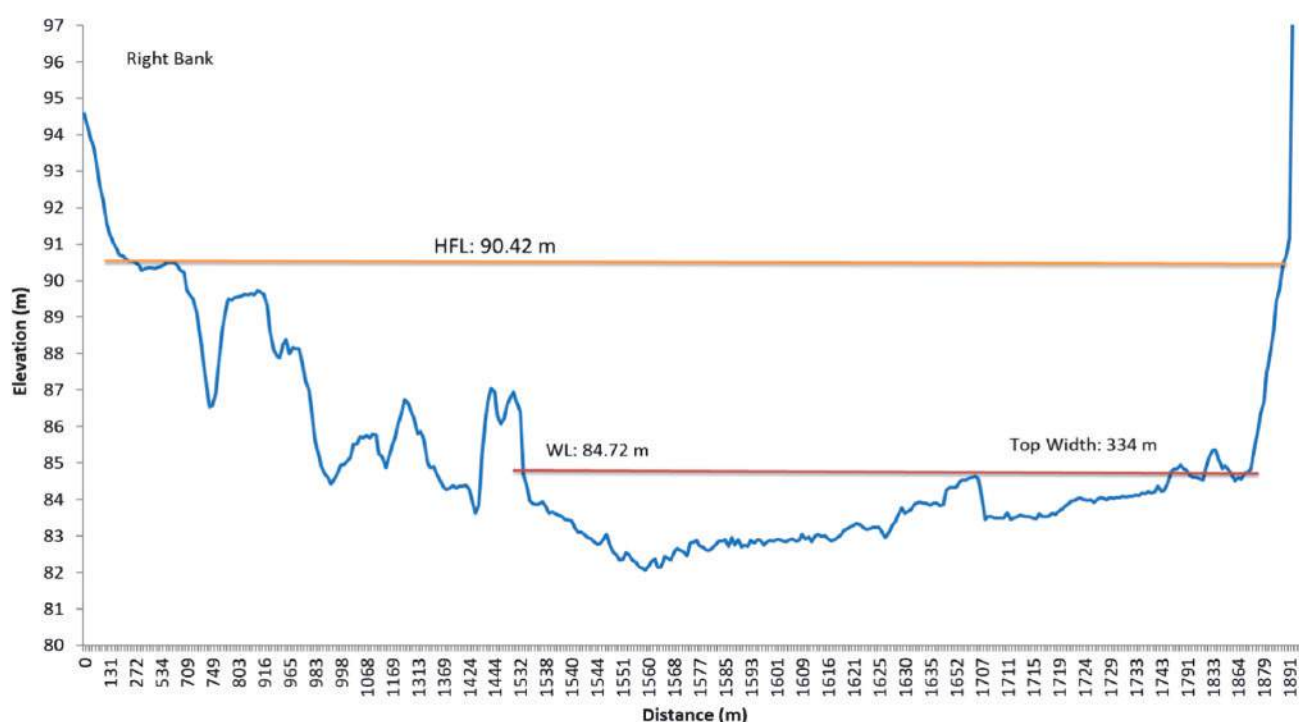
| Hydrological and Water-quality Parameters | Shahzadpur          |                     | Rajghat-Varanasi                                                                                     |                      |
|-------------------------------------------|---------------------|---------------------|------------------------------------------------------------------------------------------------------|----------------------|
|                                           | Summer              | Monsoon             | Summer                                                                                               | Monsoon              |
| River Depth (m) Average, (min-max)        | 1.90<br>(0.67-5.09) | 1.46<br>(0.76-3.60) | Data not collected due to unfavourable conditions for field surveys (COVID 19 Movement Restrictions) | 6.63<br>(0.79-13.08) |
| River Width (m)                           | 120                 | 300                 |                                                                                                      | 700                  |
| Average Current Velocity (m/sec)          | 0.45                | 0.2                 |                                                                                                      | 0.1                  |
| Water Appearance                          | Clear               | Turbid              |                                                                                                      | Turbid               |
| pH                                        | 8.1                 | 9                   |                                                                                                      | 8.4                  |
| Temperature (°C)                          | 30.5                | 24.8                |                                                                                                      | 23.3                 |
| Dissolved Oxygen (DO) mg/l                | 8.6                 | 8.6                 |                                                                                                      | 8.4                  |
| Total Dissolved Solids (TDS) mg/l         | 210                 | 296                 |                                                                                                      | 204                  |

**Table 35: Hydrological and basic water-quality information of the Ganga River at the E-flows locations**



## 4.5.1 Shahzadpur

Shahzadpur is located over 65 km upstream of Prayagraj. *Karenti ghat* in Shahzadpur is the E-Flows location on the left bank of the river, where cremation and fishing are the observed activities. Near this ghat, there is a small village of fishermen, whose alternate livelihood besides fishing is making and selling boats in the nearby areas. During summer and monsoon seasons, fish population was studied at both the above locations and the recorded species are given in Annexure 6. Secondary literature was also reviewed to understand the reported fish species in the past around these locations. The cross-section profile of Shahzadpur location is given in Figure 112. The main section at Shahzadpur is asymmetric towards the left bank and the right bank shows several submerged bars, some of which nearly touch the water surface.



**Figure 112: Cross-sectional profile of the Shahzadpur E-Flows location**

The cross-sectional parameters are shown in Table 36 (with water level at time of survey).

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 1890      | 12.7            | 2.9                         | 148.82                   |

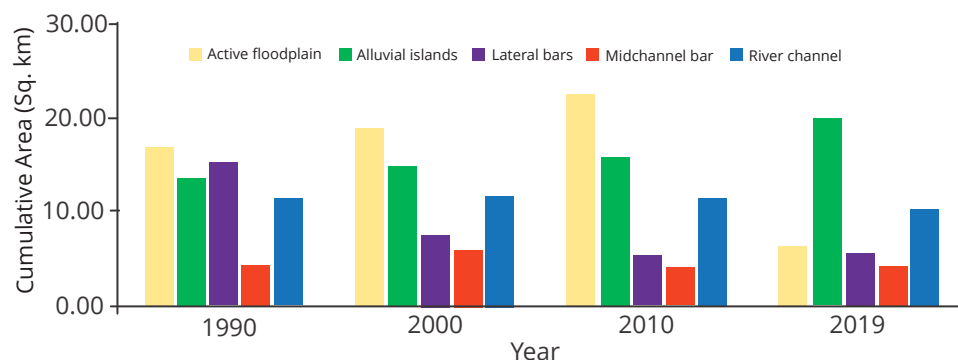
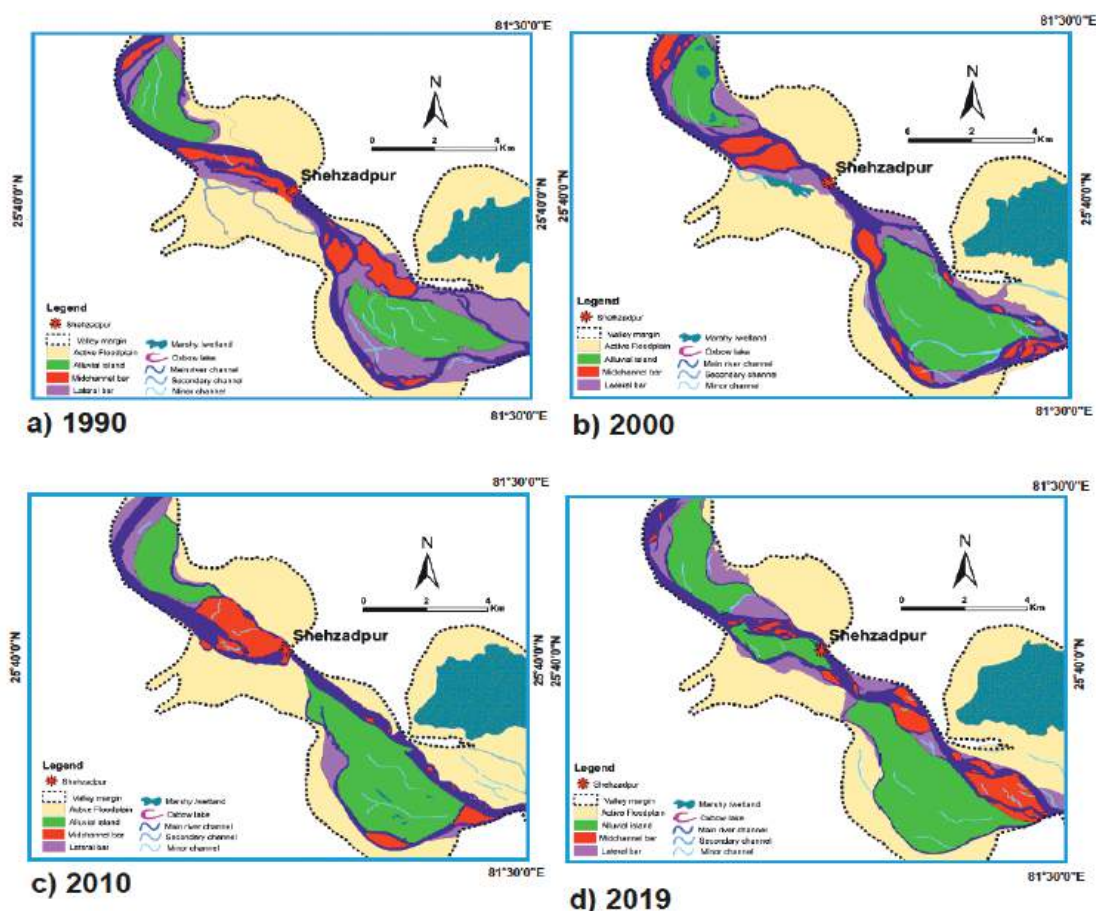
**Table 36: Cross-sectional parameters for the Ganga River at the Shahzadpur E-Flows location**

The Present and Desired state of the river at the Shahzadpur E-Flows location is discussed in the upcoming section.

### 4.5.1.1 Shahzadpur-Present State

#### A. Fluvial geomorphology

The river flows in a northwest-southeast direction around Shahzadpur and is highly braided and anabranching. The river is characterised by multiple branches both upstream and downstream of Shahzadpur and the channel belt is as wide as 1.6km in certain reaches. Large alluvial islands are particularly noted in the entire stretch of the river around Shahzadpur, which are mostly unvegetated and covered with fresh sand. Several abandoned anabranches are also noted, suggesting significant channel dynamics of the river in this stretch. A large wetland is also noted in the downstream reaches along the left bank of the river. The river has a variable extent of active floodplain.



**Figure 113(a, b, c, d): Planform maps of the Ganga River near Shahzadpur for 1990, 2000, 2010, 2019. (e) Temporal changes in area covered by different geomorphic units.**

Shahzadpur, site is mostly unvegetated and covered with fresh sand. Several abandoned anabranches are also noted, suggesting significant channel dynamics of the river in this stretch. A large wetland is also noted in the downstream reaches along the left bank of the river. The river has a variable extent of active floodplain. The temporal maps (Figure 113) of the Ganga River around Shahzadpur suggest an aerial increment of active floodplain region from 16.60 sq. km in 1990 to 18.90 sq. km in 2000 to 22.25 sq. km in 2010. The year 2019 marked a sudden decrease in active floodplain region to 6.24 sq. km., but was marked by the highest increment of the alluvial islands (19.73 sq. km).

## B. Aquatic biodiversity

Although this river stretch harbours a wide range of fish species in general (for details, please refer to the Starter Document Aquatic Biodiversity Annexure 5), only 11 species were recorded during the river surveys. During the summer, the majority of the fish catch consisted of exotic species, with the dominant one being *Cyprinus carpio*. Additionally, the Vulnerable species *Wallago attu*, commonly known as 'Lanchi' or 'Padhan,' according to the IUCN Red List, is also found in this area. *Cyprinus carpio* and *Oreochromis niloticus* are the exotic species recorded here. Apart from these, *Rita rita*, *Sperata seenghala*, *Mastacembelus armatus*, *Labeo bata* are some of the commercially important fish species found here.

Many deep pools were observed in the river during summer and monsoon season, where the Ganga river dolphin was also spotted at the time of the survey. According to the fishermen, the species is occasionally seen in summer and monsoon season, especially at night. They said that the Ganga river dolphin swim around their boats in search of captured fishes.

## C. Socio-cultural aspects

The local people refer to the river as either *Ganga ji* or *Ganga Maa*. Respondents testified to the importance of the river in Hindu culture. Farmers and fishermen are not content with the present state of the river. It is considered to have both diminished in quantity as well as declined in quality. There is an interesting dissonance where people acknowledge that the river is contaminated to the extent that they refrain from using it for drinking, yet consider it pure enough for ceremonial dips and *aachman*.

The river is considered to be much shrunken at present. All the residents stated that they were dissatisfied with the present condition of the river. The winter flows were stated as being less than adequate for soil moisture. The farmers stated that floods are less frequent as compared to earlier times, particularly in their childhood. In the summer, water shrinks to about 30 percent of the present winter flows – this is considered inadequate for soil moisture, bathing and religious rituals.

The decrease in flows is the primary concern for the respondents. They have witnessed a drastic shrinking of the river within their lifetimes; collective memory



indicates a still greater reduction in flows. This affects nearly every aspect of their lives, from livelihoods such as *pallage* and fishing, to religious rituals such as a ceremonial bathing. The appearance of the sandbanks is a visual reminder of these reduced flows.

Respondents unanimously wanted higher flows in all seasons. They emphasized the necessity for summer flows to cover the sandbank present in the river which aligns with devotees' visualization of the river and historical flow patterns. It will also allow for the comfortable carrying out of rituals. The monsoon flows need to fill the channel completely, allowing for a replenishment of moisture for *pallage* farming. Floods need to extend into the fields at least once a year for three to four days.

### 4.5.1.2 Desired State

The 'Desired' state of the Ganga River at the Shahzadpur E-Flows location is shown in Table 37.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                            | Desired State     |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | The floodplain widens slightly in the downstream reaches but its extent has not changed much during the last three decades. Channel shift is also minimal. Overall, this location reflects a fairly stable geomorphic regime. | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | The river is in a satisfactory state, with evident longitudinal connectivity and minimal disturbances from an aquatic biodiversity perspective.                                                                               | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | Respondents unanimously wanted higher flows in all seasons to carry out rituals and livelihood activities. This aligns with the devotees' visualization of the river and historical flow patterns.                            | Slightly Modified |

**Table 37: Present and Desired state of the Ganga River at the Shahzadpur E-Flows location**

## 4.5.2 Rajghat – Varanasi

Varanasi, perhaps the most revered city along the banks of the Ganga River, gets its name from Varuna and Assi – the two tributaries to the Ganga River that once demarcated the boundaries of the city. One of the oldest cities in the world, Varanasi is mentioned in mythology as well as in several travel memoirs. It holds significance in both the Mahabharata and the Ramayana.

*Hseun Tsang, who travelled in India between 629 and 645 AD, referred to the area around the city as Kasi and the city itself as Varanasi (Po-Lo-Na-Se). He refers to the landscape as follows: 'the climate of this district was temperate and the harvests were abundant; fruit and other trees grew densely and there was luxuriant vegetation, thickets of trees gave continuous shade and there were streams of pure water.' The narrative also refers to more than a hundred temples in the area, with 30 in the city alone.*

Besides being the location of the Buddha's first teaching, it is also reputed to be the residence of several past Buddhas<sup>38</sup>. It is in Banaras that Prabhupala Bodhisattva, an earlier reincarnation of the Buddha, is believed to have been born in the Bhadra Kapa. The Buddha is also known to be born here in the form of a six-tusked white elephant, a deer king, and a bird<sup>39</sup>.

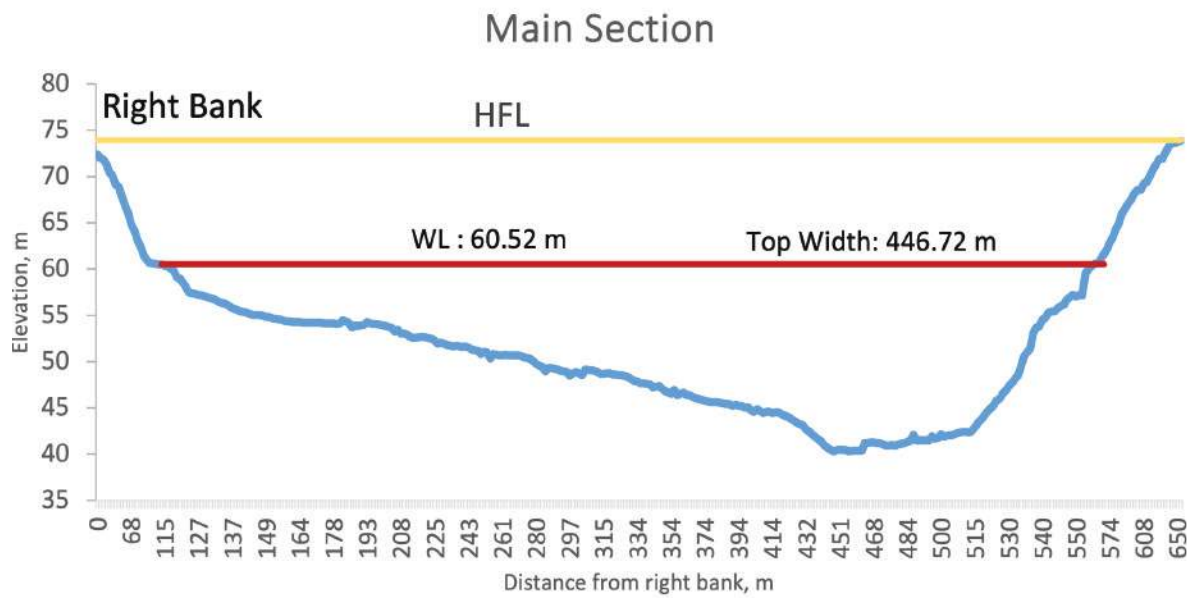
Varanasi, or Benares as it was then known, was one of the holiest places for Hindus and attracted millions of pilgrims. It retains this reputation today, with religious tourism and the temples forming an important part of the city's economy. This activity is nearly entirely concentrated along the right bank of the Ganga River. For centuries, the right bank has been lined with ghats, often donated by royalty and temples.

According to the Imperial Gazetteer, 'the native town lies for four miles along the Kankar ridge on the northwest bank of the Ganges, which forms a slightly curved reach below it, thus permitting the eye to take in a single sweep, the long line of picturesque ghats surmounted by irregular buildings of various styles and proportions'.<sup>40</sup> The left bank is an open sandy plain.

<sup>38</sup> Watters, Thomas. On Yuan Chwang's travels in India.(AD 629-645). Munshiram Manoharlal Publishers (1973), 2018.

<sup>39</sup> Hwui Li and Yen Tsung. The Life of Hieun Tsiang. Trubner and Co, Ludgate Hill. 1888

<sup>40</sup> Steenson, Burn, Cotton and Risley. 1909. The Imperial Gazetteer of India. Vol. 7. p.190. Clarendon Press.



**Figure 114: The cross-section profile of the Ganga River at the Rajghat-Varanasi E-Flows location**



**Figure 115: The Ganga River at the Rajghat-Varanasi E-Flows location. CWC gauges can also be seen.**



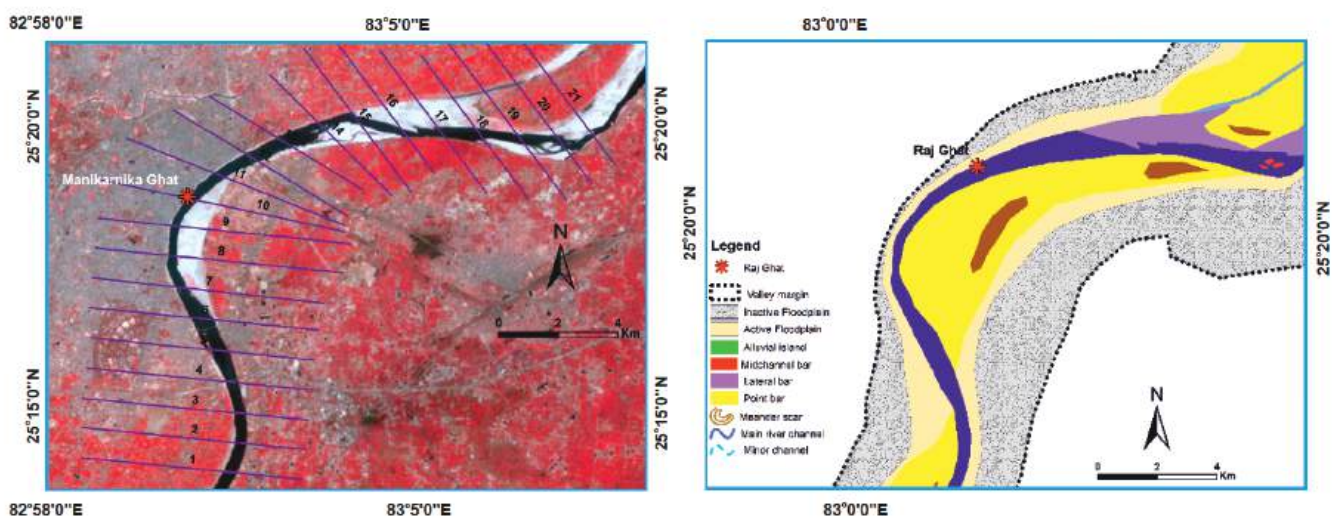
### 4.5.2.1 Rajghat–Varanasi–Present State

#### A. Fluvial geomorphology

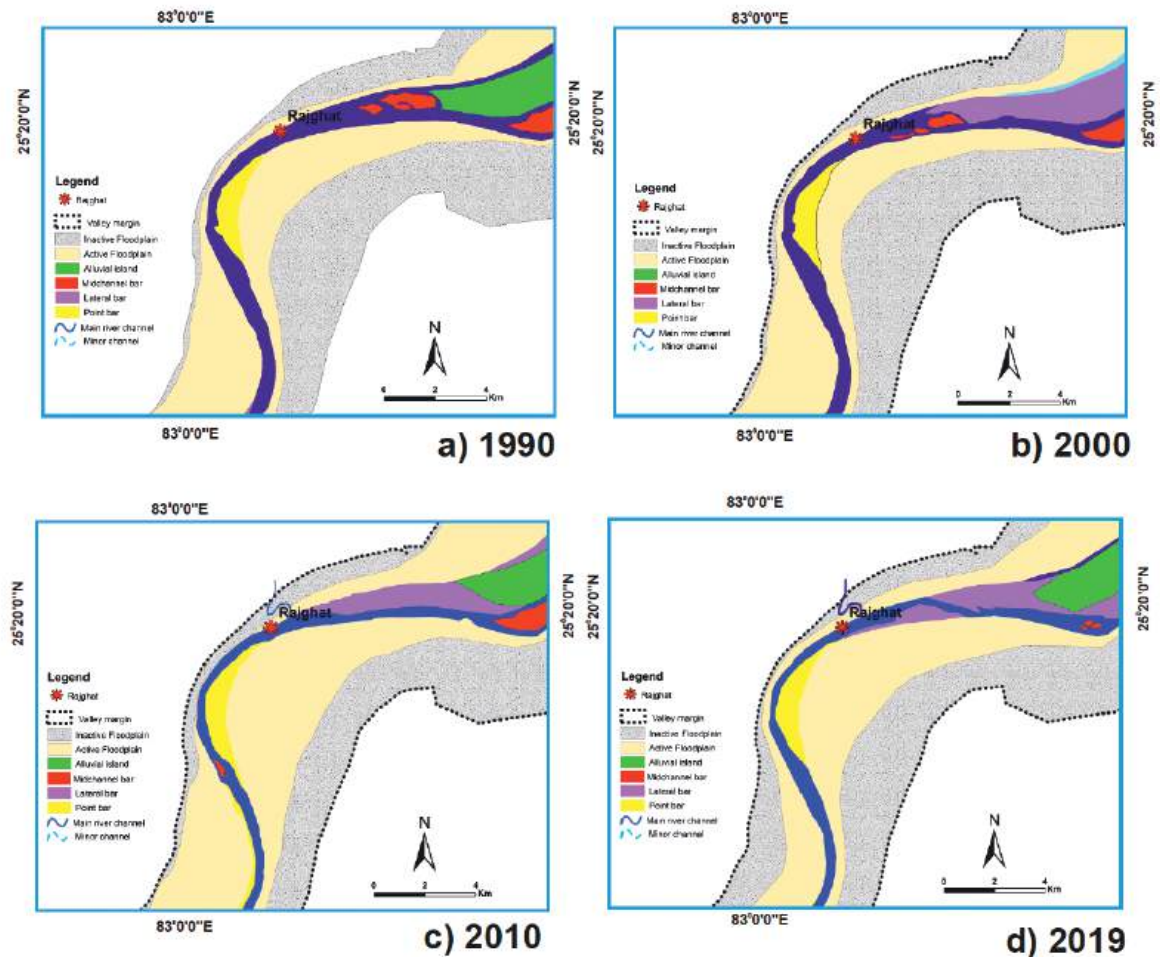
Recently, as a part of the inland waterway project, a jetty has been proposed at this site (near the Ganga bridge) and there are apprehensions that the morphological and ecological entity of this very sensitive stretch will be disturbed. Rajghat is located at the convex bend of the river and a prominent point bar and an abandoned meander belt exists just upstream on the opposite bank.

The channel belt is very wide at this site, but the active floodplain is quite narrow. The valley margin also runs quite close to the left bank, but it is ~10 km away from the main channel along the right bank. Figure 117 shows the temporal planform maps of Rajghat with a stretch of 20 km considering both upstream and downstream of the E-Flows site are occupied by large point bars along the bends of the river. There is an increase in the areal extent of the point bars from the year 1990 (16.04 sq.km) to 22.05 sq.km (2000). Year 2010 and 2018 shows similar distribution of point bar area (~ 32.51 and 31.02 sq.km). The Ganga River in the vicinity of Rajghat shows a gradational increase in the active floodplains from the year 1990 (27.90 sq.km) to 2010 (30.28 sq.km) marked by an appreciable decrease in the year 2018 (19.93 sq.km) (Fig. 118).

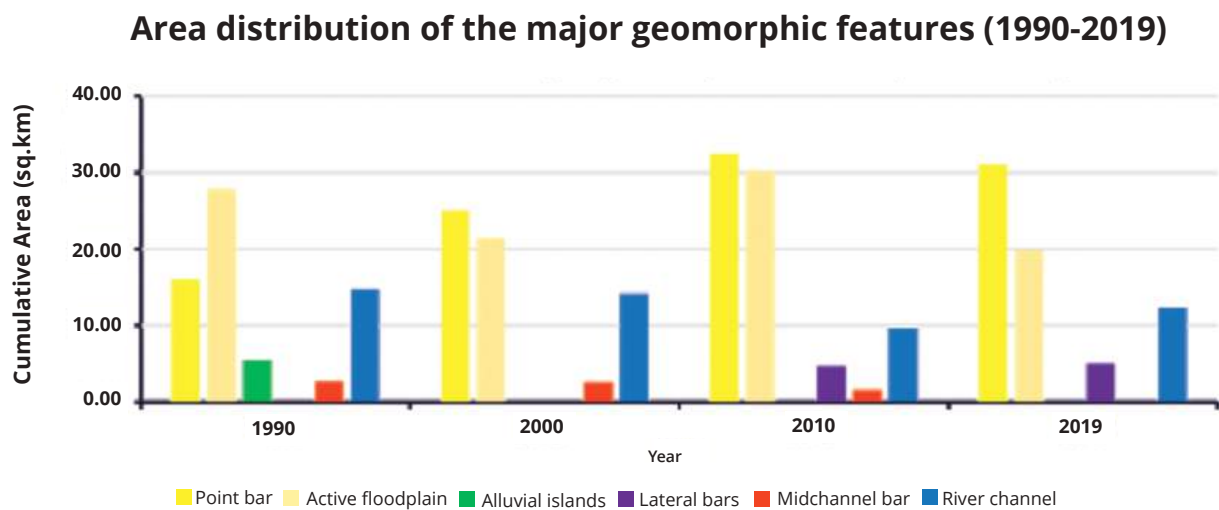
The decrease in the alluvial plain can be seen by the reoccupation of large point bars developed in the bend of the Ganga River occupying a large area of 31.02 sq.km (Fig. 117D). This window is mostly dominated by a single sinuous channel with abundance of point bars. The areal extent of other geomorphic features is negligible in this stretch e.g., an alluvial island is shown in the year 1990 map, but this gradually disappeared because the northern anabranch was abandoned, and the alluvial island became a part of the point bar in 2000.



**Figure 116: Geomorphic characteristics of the Ganga River around the Rajghat-Varanasi E-Flows location.**



**Figure 117: Planform maps of the Ganga River near Rajghat for the year 1990, 2000, 2010, 2019.**



**Figure 118: Temporal changes in area covered by different geomorphic units at the Rajghat-Varanasi E-Flows site on the Ganga River**

## B. Aquatic biodiversity

The substrate around the Rajghat-Varanasi location mainly consists of sand and silt. Deep pools were found during monsoon, which provide good shelter for the Ganga river dolphin and other aquatic species. River channel was found to be vast and the width of the active channel was about 700 metres. Dissolved Oxygen was above the desired limit and recorded at 7.8 mg/l in summer and 8.4 mg/l in monsoon, indicating good water quality for proliferation of aquatic biodiversity. The pH level was slightly higher at 9.1 and the rest of the parameters were within limit.

A total of 12 fish species were recorded from Varanasi during the survey, of which *Cyprinus carpio* was abundantly found and is listed as Vulnerable under IUCN red data list. It is an exotic species and cannot be considered as a desired species for the flow motivation for this location. Apart from this, *Sperata seenghala* and *Eutropiichthys vacha* are commercially important fish species, found at this location.



**Figure 119: *Eutropiichthys vacha***

The Ganga River Dolphin was spotted here during both seasons. During monsoon, deep pools were found in the river which are good habitats for the species. Fishermen informed the team that the Ganga River dolphin is seen usually in the downstream stretches during monsoon season.

**Desired flows:** For the Ganga river dolphin, the minimum requirement of the river depth in dry season is at least 3 metres. Since the water quality here is good in terms of Dissolved Oxygen, the river is in a good state and holds required prey-base for the Ganga river dolphin. While the water depth, velocity and water-quality parameters desired for the species are also highly congenial for growth and propagation of fish species available in the river, the location experiences high human disturbance.

## C. Socio-cultural aspects

In view of the COVID-19 pandemic, there were some limitations to conduct interviews with people, nevertheless, the team was able to interact with pilgrims,







In case of larger or mighty rivers like Ganga (especially middle to lower stretches), the flows must be much higher in comparison to other comparatively smaller rivers or tributaries. This is because the middle and downstream stretches of larger rivers and deep pools hold brooder stocks and large-sized specimens of fishes, which are responsible for auto-stocking/propagation of the critical species in the river. Many of these forms move upstream during monsoon/breeding season and help in planting/stocking of the upstream stretches also. Plus, better water depth in the river is always useful for luxurious growth of fish food organisms, herbivorous fishes, omnivores and carnivorous fishes, other aquatic animals. Therefore, while recommending E-Flows for such rivers, in addition to precise hydraulic habitat requirement of flagship aquatic species, such as Ganga river dolphin, Mahseer, IMCs, etc., due consideration to this aspect is essential and the depth requirements should be proposed accordingly. In fact, enhanced depths and improved flows in a river are always useful for maintaining the ecosystems perpetually. If such considerations are not made, then it is likely to be fatal for sustainability of the aquatic life forms, the ecological health of the river and its biota.

shopkeepers, tourists, farmers, goatherds, boatmen and sanitation workers. Around this location, people refer to the river with an honorific, as either *Ganga ji* or *Ganga Ma*. Respondents testified to the enduring importance of the river in Hindu culture. Ganga, the mother goddess, is seen as all-powerful and enduring even with diminished or polluted flows. Some respondents spoke of the healing qualities of the water of the Ganga River. Of these, two attributed these qualities to the herbs that the water comes in contact with in the Himalayas. The importance of the river for cremation rites is also significant and was mentioned by several respondents. The river is considered holy near Varanasi since there is a belief that five rivers have met in this stretch - the Ganga, Yamuna, Saraswati, Kirna and Dhupa. This adds to the sanctity of the location.

In terms of present-day flows, while the holiness of the Ganga River remains a dominant aspect of both visitor and resident experiences, residents did remark upon a decline in the river's flow. They unanimously lamented the 'shrinking' of the river due to lack of water in it. According to the boatmen, the maximum depth in winter used to be 45 'hands' and in summer about 35 hands. This year especially saw a great decrease in the summer flows, leading to a decrease in *pallage* farming. Fishing too has seen a turn for the worse, with the interviewed fishermen referring to a decline both in the size and number of fish in the day's catch.

In the monsoon, water reaches the steps of all the ghats. Every three years, the monsoon flows should reach the top of the ghats, while the floods reach the watermark on the pillars at the top of the ghat. However, this has not happened for several years. This has impacted *pallage* farming, due to an absence of fresh silt.

In people's memory, the historical flows during the wet season were considerably higher and also longer in duration than they are now. The last significant flood was in 1978 when the water overflowed into the city. Since then, there have been no notable floods. According to the local people, for the last 15 years, there has been a decline in monsoon flows which is evident from

the fact that temporary huts are being constructed along the river bank due to lowering of water levels.

The main concern for the people is the decrease in flows. Respondents attest that in summer, water reduces to a narrow channel only. The boatmen say that while the water in the centre remains deep, it is very shallow across the river.

**Desired flows:** Respondents unanimously want higher flows in all seasons. Summer flows especially are extremely low, causing inconvenience to pilgrims and boatmen. The water needs to at least reach the bottom of the ghats, allowing the pilgrims to access it without great inconvenience while also allowing boatmen a reasonable channel to ply their boats. The monsoon flows need to extend across the ghats, submerging several steps.

#### 4.5.2.2 Desired State

The 'Desired' state of the Ganga River at the Rajghat–Varanasi E-Flows location is shown in Table 38.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                                                                                         | Desired State     |
|--------|-----------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Slightly Modified   | Geomorphologically the river is intact around this location, however, the proposed jetty, as part of Inland Waterways Project, may potentially disturb the geomorphological settings at this location and therefore, downgrade the RHC.                                                    | Near Pristine     |
| 2      | Aquatic Biodiversity  | Moderately Modified | While the water depth, velocity and water quality parameters desired for the Ganga river dolphin are highly congenial for growth and propagation of fish species available in the river, the location has high degree of human disturbance.                                                | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | Respondents have remarked upon a decline in flows. They were unanimous in lamenting the 'shrinking' of the river due to lack of water in it. Fishing too has seen a turn for the worse, as fishermen pointed to a decline both in the size and number of fish that form their day's catch. | Slightly Modified |

**Table 38: Present and Desired state of the Ganga River at the Rajghat–Varanasi E-Flows location**



## 4.6 Yamuna River

The Yamuna River originates from the Yamunotri Glacier near Banderpoonch peaks in the Mussoorie range of the lower Himalayas. It is at an elevation of about 6284 m above msl in Uttarkashi district in the state of Uttarakhand. The Yamunotri, at an elevation of 3300 m above sea level, travels for 1376 km before joining the Ganga at Prayagraj at *triveni sangam* (confluence of Ganga, Yamuna and Mythical Saraswati Rivers). This confluence, known as *Prayag*, is one of the most sacred spots of Hindu pilgrimage. The river traverses through Uttarakhand and Himachal Pradesh in the upper stretch of 200km. The river Yamuna runs parallel to Ganga after entering into the Delhi region, then it passes through Uttar Pradesh and joins the Ganga at Prayagraj drawing water from several major streams (such as Tons, Hindon, Ken, Chambal and Sindh). The Yamuna River is regulated through dams and barrages.

According to the Central Water Commission, the Yamuna River is divided into five independent segments due to hydrologic characteristics and ecological conditions:

| Segment               | Distance                               | Length, Kms |
|-----------------------|----------------------------------------|-------------|
| Himalayan Segment     | From origin to Tajewala Barrage        | (172km)     |
| Upper Segment         | Tajewala Barrage to Wazirabad Barrage  | (224km)     |
| Delhi Segment         | Wazirabad Barrage to Okhla Barrage     | (22km)      |
| Eutrophicated Segment | Okhla Barrage to Chambal Confluence    | (490km)     |
| Diluted Segment       | Chambal Confluence to Ganga Confluence | (468km)     |

**Table 39: Five Segments of the Yamuna River<sup>41</sup>**

Based on the Homogenous Zonation (Annexure X(A)) exercise for the Yamuna River, four distinct Homogenous Zones were identified (Figure 120). Four zones have been generated based on the longitudinal profile of the Yamuna River and with consideration of various other factors such as agro climatic zones, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), temperature, rainfall, population, LULC, soil type, etc.

<sup>41</sup> Central Water Commission (22 September 2019), Yamuna Basin Organisation – New Delhi. Retrieved from [https://cwc.gov.in/ylbo/about\\_basin](https://cwc.gov.in/ylbo/about_basin) )



प. म. पु. ज. ए. म. ला. वा.  
प. म. पु. ज. मो. पु. ल. दा. व.  
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ला. वा. दा. व. न.

# श्री यमुनाष्टक

नमामि यमुनामहं सकल सिद्धि हेतुं मुदा।  
मुरारिपद पंकज स्फुरदुमन्दरेणुत्कटाम् ॥

तटस्थनवकातनप्रकटमोदपुष्पाम्बुना।  
सुरासुपुत्रितस्मरपितुः श्रियं विधत्ते ॥१॥  
कलिन्द गिरि मस्तके पतदुमन्द पूरोज्ज्वला  
विलास गमनोल्लसत प्रगट गण्ड शैलोन्नता ।

सघोष गतिदन्तुरा समधि रुढ दोलोत्तमा  
मुकुन्द रति वर्धनी जयति पद्म चन्द्रोः सुता ॥२॥  
मुव सुवन पावनी मधिगता मनेकस्वनेः

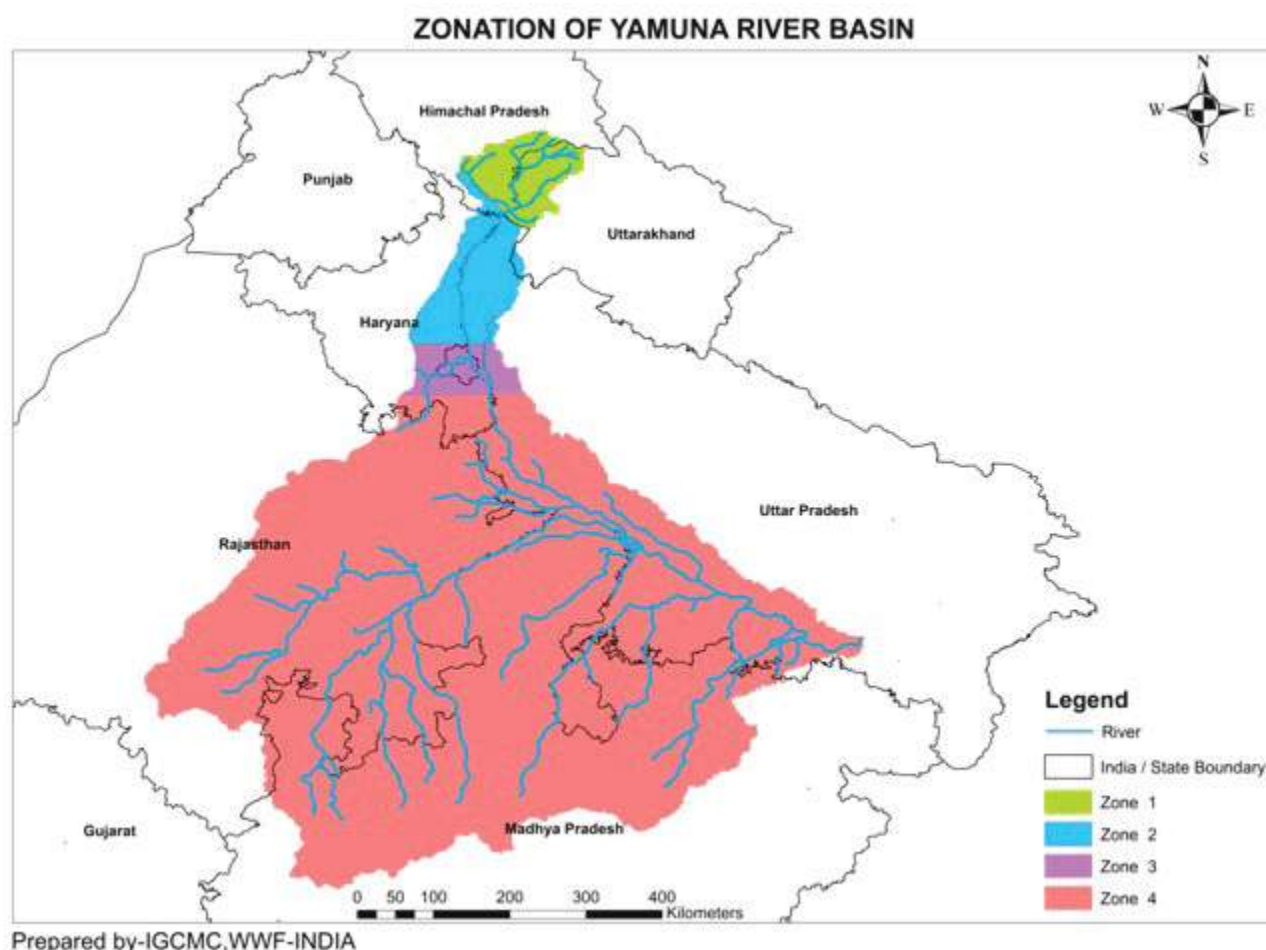
प्रिया मिरिख खेवितां शुक् मयूर हंसादिभिः।  
तस्या मुज कंकण प्रगट मुक्तिका बालुका  
मिर्मन्व तट सुदरी नमत कृष्णः तुयं प्रियाम् ॥३॥

अनंत गुण भूषिते शिव विरंचि देवस्तुते  
घना घन तिमे सदा ध्रुव पराशर अर्भीष्टदे  
विरुद मयुरा तटे सकल गोप गोपी वृते  
कृपा जलधि संश्रिते मम मनःसुखं भावय ॥४॥

यया चरण पद्मजा मुरारियो प्रियं भावुका  
समागमनतोऽभवत्सकलसिद्धिदा सेविताम्  
तया सदृशतामियात्कमलजासपत्नी वयत् ।  
हरि प्रियकलिन्दया मनसि मे सदा स्थीयताम् ॥५॥







**Figure 120: Homogeneous zonation of Yamuna River**

The categorized four zones have distinct features, such as:

- a. **Zone 1** starts from the Yamunotri glaciers and ends at Paonta Sahib, mainly falling in the states of Himachal Pradesh and Uttarakhand. The tributaries Tons and Giri join the main river in the first zone. The Yamuna River in this area has moderate terrain to steep slope in this zone. The distance of the river-course in Zone 1 is about 135 km. The elevation in this zone varies from 201 to 6284 m.
- b. **Zone 2** starts near Paonta Sahib and ends at Sonipat, and mainly falls in Haryana and Uttar Pradesh. The distance of the river course in this zone is about 223 km. The elevation in this zone varies from 104-3638 m. Tajewala Barrage is also found in this zone. Yamuna River is moderately polluted in this zone because of the existence of industries.
- c. **Zone 3** starts near Sonipat and ends at the boundary of Faridabad. It mainly falls in the Delhi-NCR region. The distance of the river course in this zone is about 91km. The majority of the area has a gentle slope and the elevation varies from 62 - 357 m. Wazirabad barrage and Okhla barrage are two important barrages in this zone. The Yamuna River is highly polluted in this zone in comparison to other zones.



- d. **Zone 4** is the largest zone identified in the Yamuna River Basin because of its plain topography. The zone starts near Faridabad boundary and covers the entire remaining part of the river basin, mainly falling in Rajasthan, Uttar Pradesh and Madhya Pradesh. The distance of the river course in this zone is about 902km. The elevation in this zone varies from 90-1323 m (with elevation at Prayagraj of 98 m).

There are many gauge/discharge monitoring sites on the main stem of the river. Based on the Homogeneous-Zonation work, 5 sites were identified on the Yamuna River for an EFA exercise (Table 40).

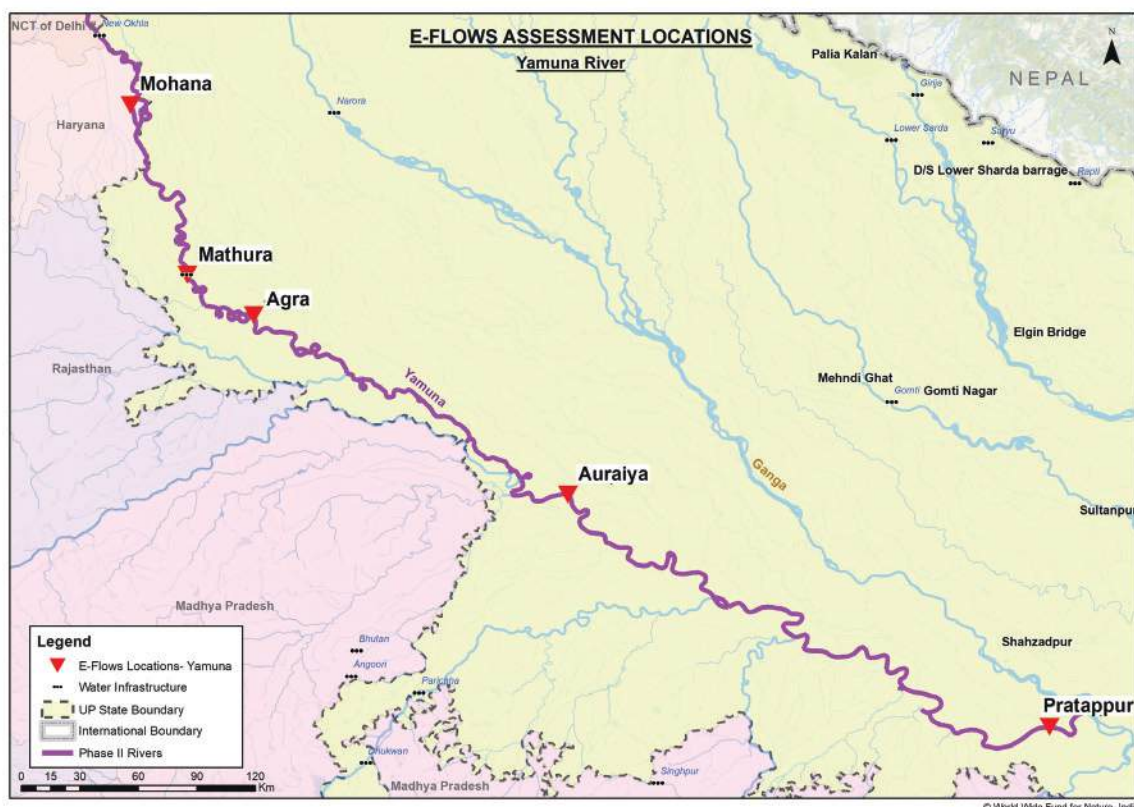
The Yamuna is one of the most critical rivers for the state of Uttar Pradesh. Though after passing through Delhi and Faridabad district of Haryana, the first main city on the banks of Yamuna River is Mathura in Uttar Pradesh; the team felt it should identify an E-Flows site in Haryana as well, just before the river enters Uttar Pradesh. The idea was to ascertain the flows in quantitative terms, before it enters Uttar Pradesh. It is in this context that the Mohana site on the Yamuna River was selected for E-Flows work.

Apart from Mohana, there are four E-Flows sites on the Yamuna River and all of them fall in Uttar Pradesh.

| S. No. | Site Name              | Latitude       | Longitude      | Rationale for selection                                                                                                                                                                                                                                                                                                                               |
|--------|------------------------|----------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.     | Mohana (in Haryana)    | 28°13'27.271"N | 77°27'26.22"E  | <ul style="list-style-type: none"> <li>This is located in Haryana, but after this site, the river enters Uttar Pradesh; so the idea was to ascertain the E-Flows requirement at the start of the Yamuna River stretch in Uttar Pradesh.</li> <li>Availability of observed discharges</li> </ul>                                                       |
| 2.     | Gokul Barrage, Mathura | 27°26'28.277"N | 77°43'10.796"E | <ul style="list-style-type: none"> <li>Water regulation due to the presence of Barrage</li> <li>Urban cluster bringing sewage into river</li> <li>Availability of observed discharges</li> </ul>                                                                                                                                                      |
| 3.     | Agra                   | 27°15'14.414"N | 78°1'32.891"E  | <ul style="list-style-type: none"> <li>Urban cluster bringing raw sewage into river</li> <li>Important world heritage site at Agra</li> <li>Availability of observed discharges</li> </ul>                                                                                                                                                            |
| 4.     | Auraiya                | 26°25'34.143"N | 79°28'27.95"E  | <ul style="list-style-type: none"> <li>Confluence of Chambal and Yamuna</li> <li>Biodiversity hotspot (gharials)<sup>42</sup></li> <li>Availability of observed discharges</li> </ul>                                                                                                                                                                 |
| 5.     | Pratappur              | 25°21'18.422"N | 81°41'48.752"E | <ul style="list-style-type: none"> <li>Downstream of Ken-Yamuna confluence. This location will have contributions from all major tributaries of Yamuna upstream of Triveni Sangam at Prayagraj.</li> <li>E-Flows implementation here can be seen through lens of tributary contributions too.</li> <li>Availability of observed discharges</li> </ul> |

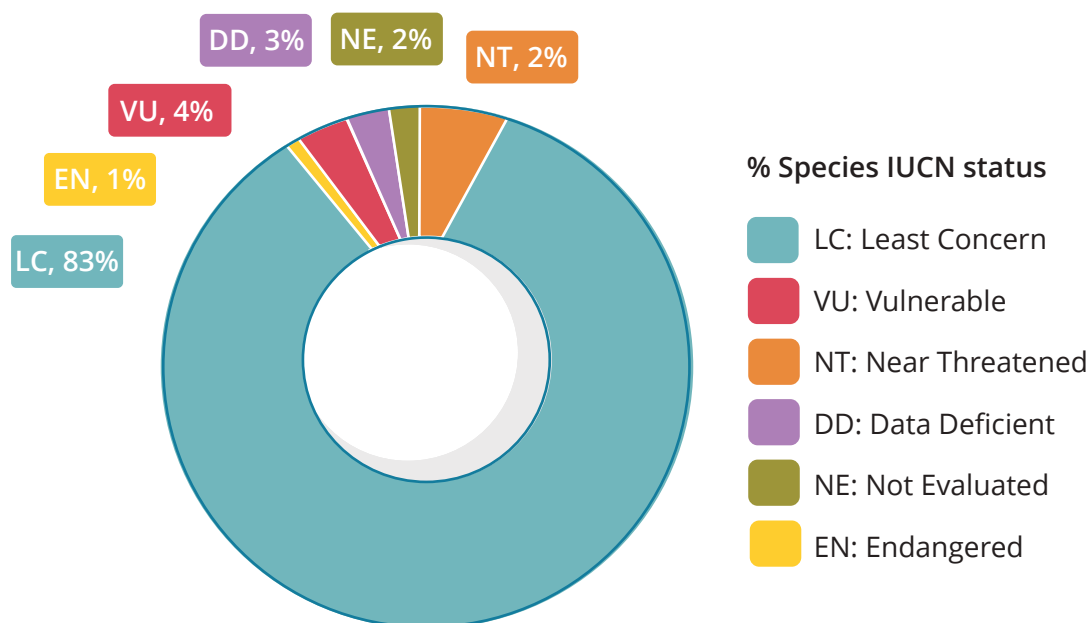
**Table 40: Sites for E-Flows assessment for the Yamuna River.**

<sup>42</sup> <https://www.indiatimes.com/trending/environment/gharial-yamuna-lockdown-516621.html>



**Figure 121: E-Flows sites on the Yamuna River**

A total of 105 fish species belonging to 73 genera, 27 families and 9 orders were observed in the Yamuna River. These species were recorded at different locations in the Yamuna River during the surveys conducted; including the species reported in secondary literature. Under the conservation status as per IUCN Red List, 8 species are categorized as Near Threatened (NT); 4 are Vulnerable (VU) and one is under Endangered (EN) category. The percentages of fish species under IUCN category in Yamuna River are presented in Figure 122.



**Figure 122: Relative percentage of species as per IUCN Red Data List in the Yamuna River.**

The general hydrological and basic water-quality information of the Yamuna River during the survey period, as recorded at location is tabulated in Table 41.

| Parameters                             | Mohana          | Mathura        | Agra            | Auraiya          | Pratappur        |
|----------------------------------------|-----------------|----------------|-----------------|------------------|------------------|
| River Depth in m Average, (min-max)    | 1.06 (0.60-1.2) | 1.37 (0.3-3.8) | 1.73 (0.36-1.9) | 1.61 (0.33-1.99) | 1.76 (0.36-1.99) |
| River Depth in Feet Average, (min-max) | 3.5 (2.1-4.2)   | 4.5 (1-12.5)   | 5.7 (1.2-16.1)  | 5.3 (1.1-3.12)   | 5.8 (1.2-16.4)   |
| River Width (m)                        | 192             | 166            | 194             | 350              | 510              |
| Average Current Velocity (m/sec)       | 0.18            | 0.12           | 0.16            | 0.19             | 0.21             |
| pH                                     | 9.0             | 8.7            | 8.5             | 7.2              | 6.9              |
| Temperature (°C)                       | 16.2            | 18.2           | 18.9            | 18.6             | 18.2             |
| Dissolved Oxygen (mg/l)                | Very Low        | 2.8            | 4.0             | 6.0              | 6.3              |
| Total Dissolved Solids (mg/l)          | 1.190           | 9.14           | 863             | 505              | 425              |
| Physical Appearance                    | Black           | Black          | Black           | Clear            | Clear            |

**Table 41: Hydrological and basic water-quality information of the Yamuna River at the E-Flows locations**

A site-wise description and discussion about the Present and Desired state for various E-Flows sites on the Yamuna River are detailed in the upcoming section. It is evident here that floodplain widths and water quality (especially Dissolved Oxygen) shows increasing trend as river travels downstream primarily due to tributaries like Chambal joining in between.



## 4.6.1 Mohana site

Mohana village is located in Ballabgarh Tehsil of Faridabad district in Haryana, India. The Yamuna River enters the state of Uttar Pradesh after this point. The site is located just below the Mohana- Baghpur Yamuna Bridge. This is also an important CWC site immediately downstream of the heavily populated Delhi-NCR and Faridabad cities, equipped with gauge, discharge, water quality, silt and telemetry measurements.

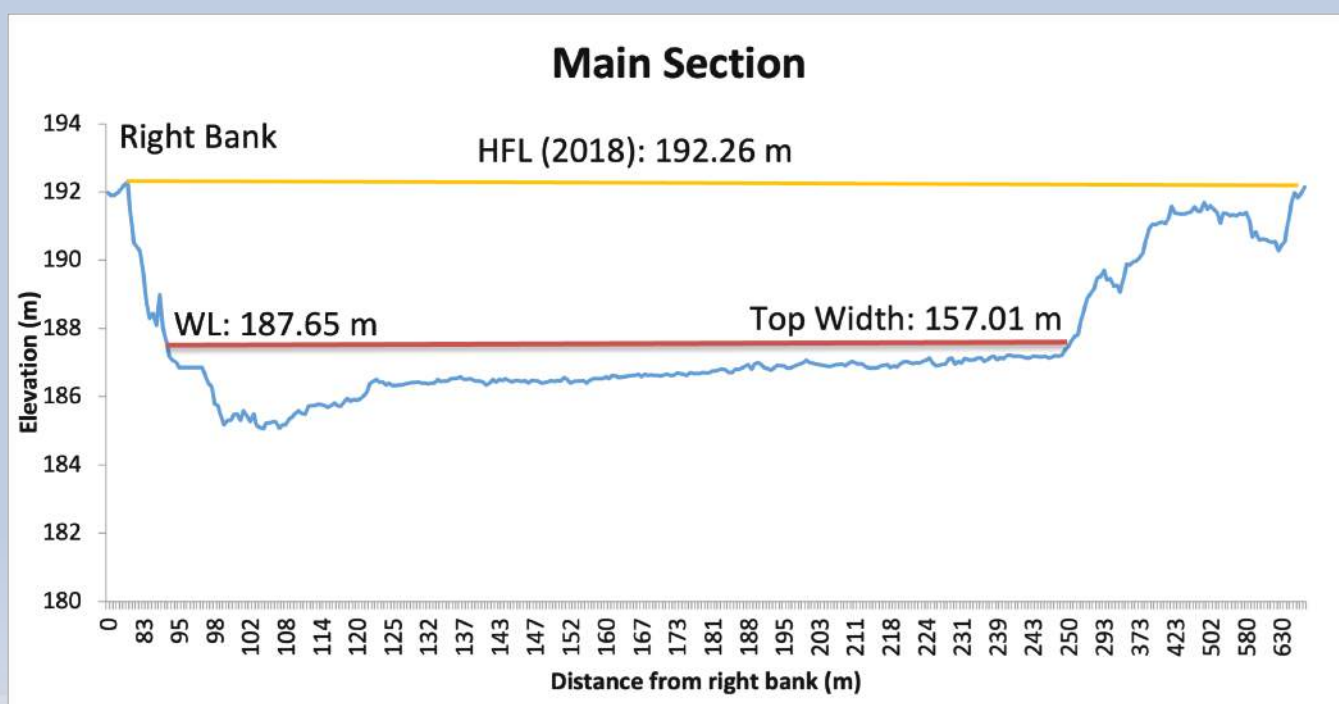


**Figure 123: Mohana site with the cross-sections**



**Figure 124: Mohana E-Flows Site**

The only major confluence, before Yamuna passes through this site, is with the severely polluted Hindon River. The river is slow flowing at this location and the substrate is mainly composed of mud and clay. The salts in the clay have been washed away by the Yamuna, and is available at reasonably shallow depths. This has led to well irrigation in the district being confined to this belt.



**Figure 125: Cross-section profile of the Mohana E-Flows site on the Yamuna River**

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 621       | 7               | 2.4                         | 88.7                     |

**Table 42: Cross-sectional parameters for the Yamuna River at the Mohana site (From HFL).**

The 'Present' and 'Desired' state of the Yamuna River at the Mohana site is discussed in a thematic manner



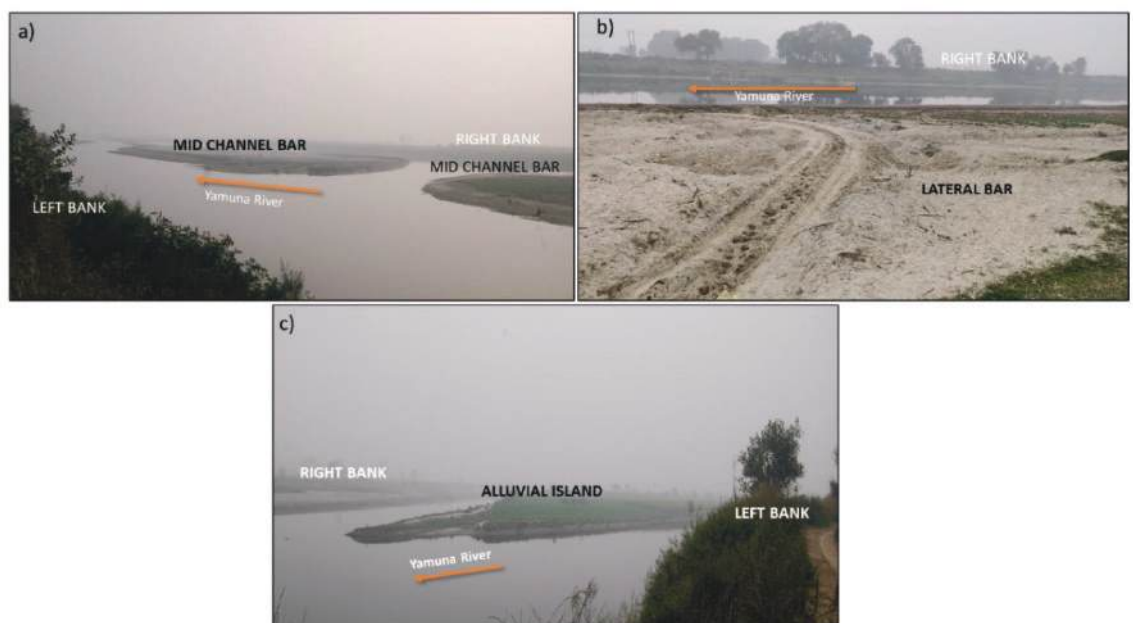


### 4.6.1.1 Mohana – present state

#### A. Fluvial geomorphology

The channel around the Mohana bridge is characterized by an asymmetric form, and high sinuosity in the upstream portion. The river is mostly a single-channel system with some bifurcations caused by alluvial islands and mid-channel bars. The channel substrate is primarily coarse-grained sand. The depositional features such as mid-channel bars and relatively stable alluvial islands, are elongated along the flow direction of the river Yamuna. A well-developed point bar has been noted in the sinuous bend of the upstream reach while the lateral bars have been found in both the upstream and downstream reaches in the vicinity of the Mohana bridge site (Figure 126).

This stretch has a few rural clusters, which are mostly agriculturally dominated. The major crops in this region are paddy, *bajra*, *jowar*, *kharif pulses* and *kharif* vegetables. In the Rabi season, wheat, rabi oilseeds, barley, vegetables and sugarcane are cultivated. Though this stretch is relatively the least urbanized, the contribution from the densely populated cities upstream renders the water unsuitable for direct use with excessive organic loads from sewage, effluents, etc. Pontoon bridges have been observed both upstream and downstream of the Mohana bridge site, in the narrow stretches of the river. Local-scale sand mining has been noted in one of the upstream reaches, in the lateral bar that was emergent in lean season.



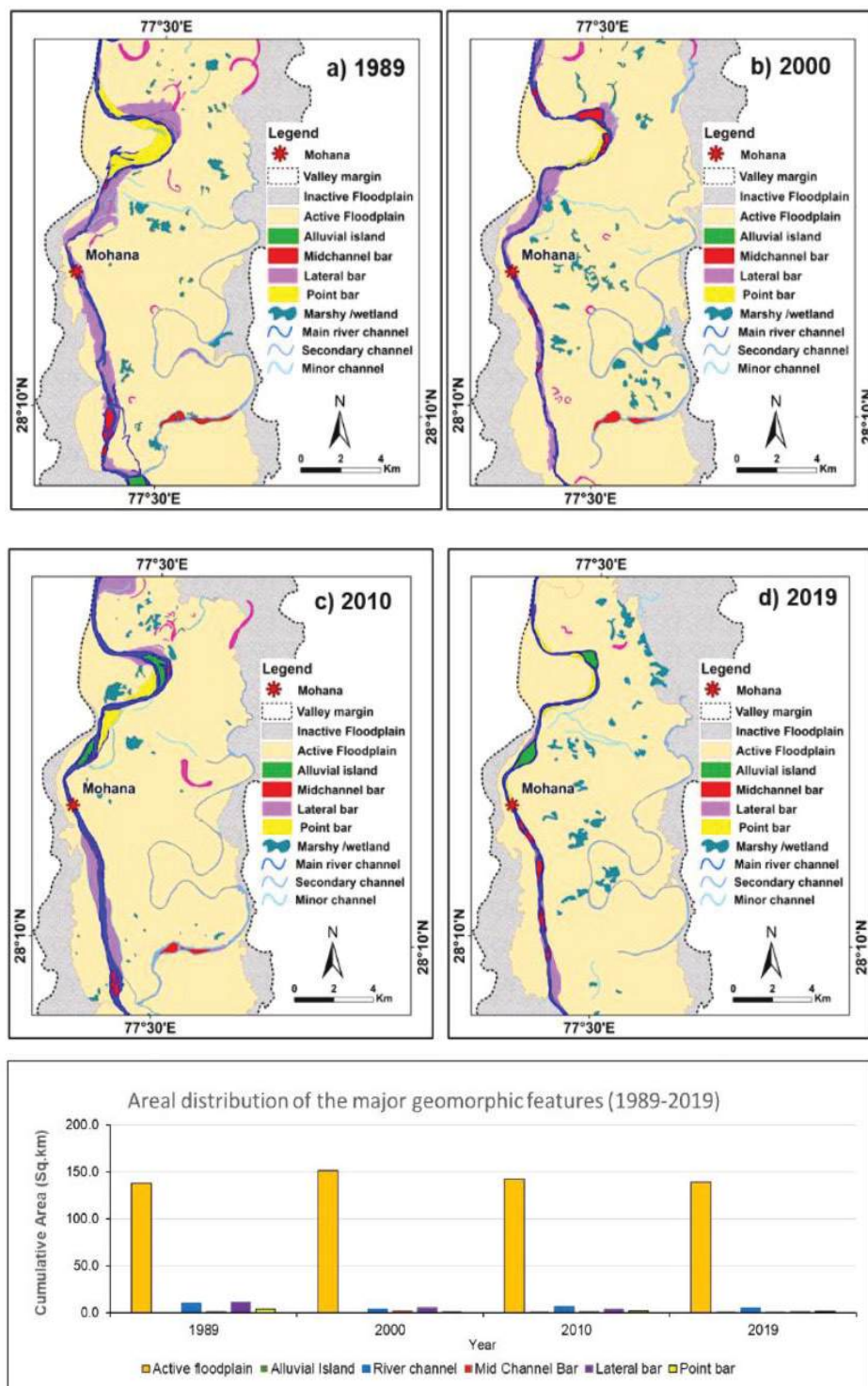
**Figure 126: Geomorphic features of the Yamuna River channel around the Mohana bridge E-Flows site**

Figure 127 shows the planform dynamics of the Yamuna River around Mohana (Haryana) for the years 1989, 2000, 2010 and 2019. The temporal maps do not show any significant change in the planform features. Considering the 20-km stretch, a major part of the study area is dominated by large floodplains, which



increases between 1989 and 2000 and then decreases between 2010 and 2019. Along with the active floodplain, it also shows the dominance of lateral bars. The distribution of lateral bars decreased from 1989 with lowest in the year 2019.

In summary, the Yamuna River at this site is characterized by a sinuous channel, with alluvial island, mid-channel bars and lateral bars. The main channel is incised in nature and presents uniform channel width along its course with no



**Figure 127 (a, b, c, d):** Figure showing the geomorphic map of the Yamuna River near Mohana (Haryana) for the years 1989, 2000, 2010, 2019. **e) Temporal changes in area covered by different geomorphic units in Yamuna River near Mohana (Haryana)**

temporal variability. Floodplain width has been consistent temporally, and a good lateral and longitudinal connectivity can be observed. No significant change both in terms of channel migration and thalweg shift over the entire channel course has been found, with a maximum channel shift of 1 km. A significant decrease in the BA/CA ratio can be observed, with a 78% decrease in point-bar area, a 90% reduction in lateral-bar area, and almost a 50% reduction in mid-channel bars over the last three decades. This decline, evident in most stretches, represents a loss in net aggradation.

## **B. Aquatic bio-diversity**

Netting sessions were not performed at this site due to unavailability of fishes, as informed by locals, except *Clarias gariepinus*, an exotic fish species that is largely found in highly polluted waters, as it can survive with a negligible amount of Dissolved Oxygen. All the water-quality parameters are high above the standard levels, indicating the water is highly polluted. Presence of ammonia and coliforms indicates organic pollution in the river. Turbidity is high due to the presence of suspended solids. This is mainly responsible for the black colour of the water.

## **C. Socio-cultural aspects**

According to the communities, pollution was a significant concern, followed closely by low summer flows. These two issues are linked, as they are both results of increased withdrawal and release of effluents upstream. They significantly impact the quality of life for the communities living along the river. Respondents were also unanimous about the decline in flooding in the recent years. The last major flood seen by the farmer communities was three years ago. There is a great deal of fluctuation in the flows from day to day. This is usually not intense enough to create a problem, but occasionally surges that impact crops do occur. This causes inconvenience to the farmers. The fisher folk had a tradition of taking a new bride and groom to the river for its blessing after the wedding; the bride and groom would bathe there. However, this practice has had to be modified due to the pollution; now the bride and groom bathe after returning from the river.

### 4.6.1.2 Mohana - Desired state

The 'Desired' state of the Yamuna River for the location Downstream of the Mohana bridge is tabulated in Table 43.

| S. No. | Thematic area         | Present State | Reasoning/ Remarks – Present state                                                                                                                                                                                                                                                                                                                                                                             | Desired State       |
|--------|-----------------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 1      | Fluvial Geomorphology | Degraded      | The main channel is incised in nature and presents uniform channel width along its course with no temporal variability. A significant decrease in Bar Area- Channel Area ratio can be observed: 78% decrease in point bar area, 90% reduction in lateral bar area and almost 50% reduction in mid-channel bars in the last three decades. This decline in most stretches represents a loss in net aggradation. | Moderately Modified |
| 2      | Aquatic Biodiversity  | Degraded      | The reduction in fish abundance is attributed to riverbed congestion caused by sedimentation and low flows, with increased pollution, which is placing stress on aquatic species.                                                                                                                                                                                                                              | Slightly Modified   |
| 3      | Socio-cultural        | Degraded      | Pollution was a significant concern, followed closely by low summer flows. This led to fish mortality, noxious odours and decreased soil moisture. Decline in flooding in recent years and daily fluctuation in the flows create problems for farmers. People's rituals have also changed due to pollution.                                                                                                    | Slightly Modified   |

**Table 43: The Present and Desired state of the Yamuna river at the Mohana E-Flows location**



## 4.6.2 Mathura-Gokul Barrage

Mathura is located approximately 50 kilometres north of Agra, and 145 kilometres south-east of Delhi; about 11 kilometres from the town of Vrindavan, and 22 kilometres from Govardhan. Mathura is a sacred city according to Hindu mythology. The Lord *Krishna* is said to have been born on the site of Sri Krishna *Janma Bhoomi*. The E-Flows site is located just below the Gokul Barrage, one of the six important barrages on the river Yamuna. This barrage facilitates domestic water, largely to the population of Mathura and Vrindavan.



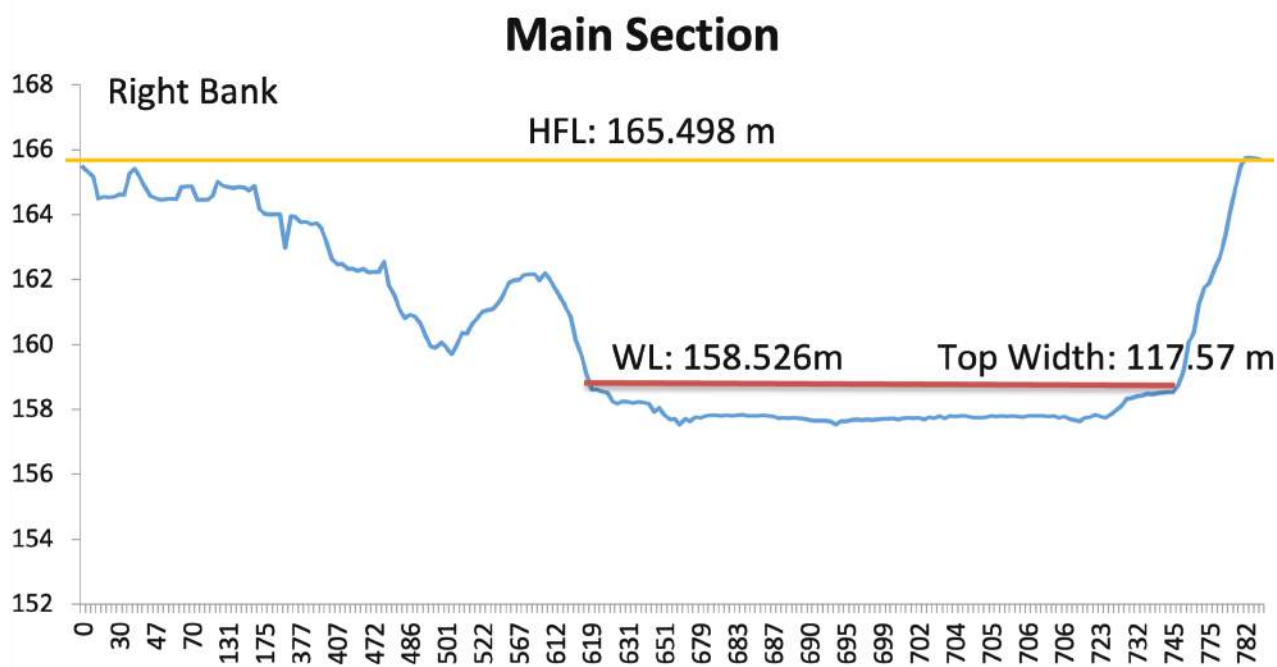
**Figure 128: Mathura site with the cross-sections**

Cross sectional parameters and on site view of the Yamuna river at the Mathura E-Flows location



**Figure 129: Yamuna River stretch near the E-Flows site at the Gokul Barrage, Mathura**

The cross-section morphology of the Yamuna River at the Gokul Barrage is shown in Figure 130. The main channel shows asymmetric channel form with a deeper part along the left bank. This site is primarily characterized by coarse sand substrate.



**Figure 130: Cross-section profile of the Mathura E-Flows site on the Yamuna River**

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 780       | 8               | 1                           | 97.5                     |

**Table 44: Cross-sectional parameters for the Yamuna River at the Mathura site**

The 'Present' and 'Desired' state of the Yamuna River at Mathura is discussed in a thematic fashion.

### 4.6.2.1 Mathura–Present State

#### A. Fluvial geomorphology

Floodplain development is quite low adjacent to the bridge site and mostly in the downstream stretch. A variable channel belt width and floodplain width can also be observed. The main channel around the Gokul Barrage is characterized by an asymmetric form, low sinuosity and low multiplicity. The thalweg of the primary channel mostly runs closer to the left bank. Immediately upstream of the barrage site, a relatively stable large alluvial island can be observed, which seems to have formed after the construction of the barrage. Mostly, this stretch has numerous mid-channel bars elongated along the direction of the flow of the river. Sand mining has been observed on a local scale in the lateral bars of the lower reaches, mostly using non-mechanized modes of transport, near the Barrage site (Figure 131).

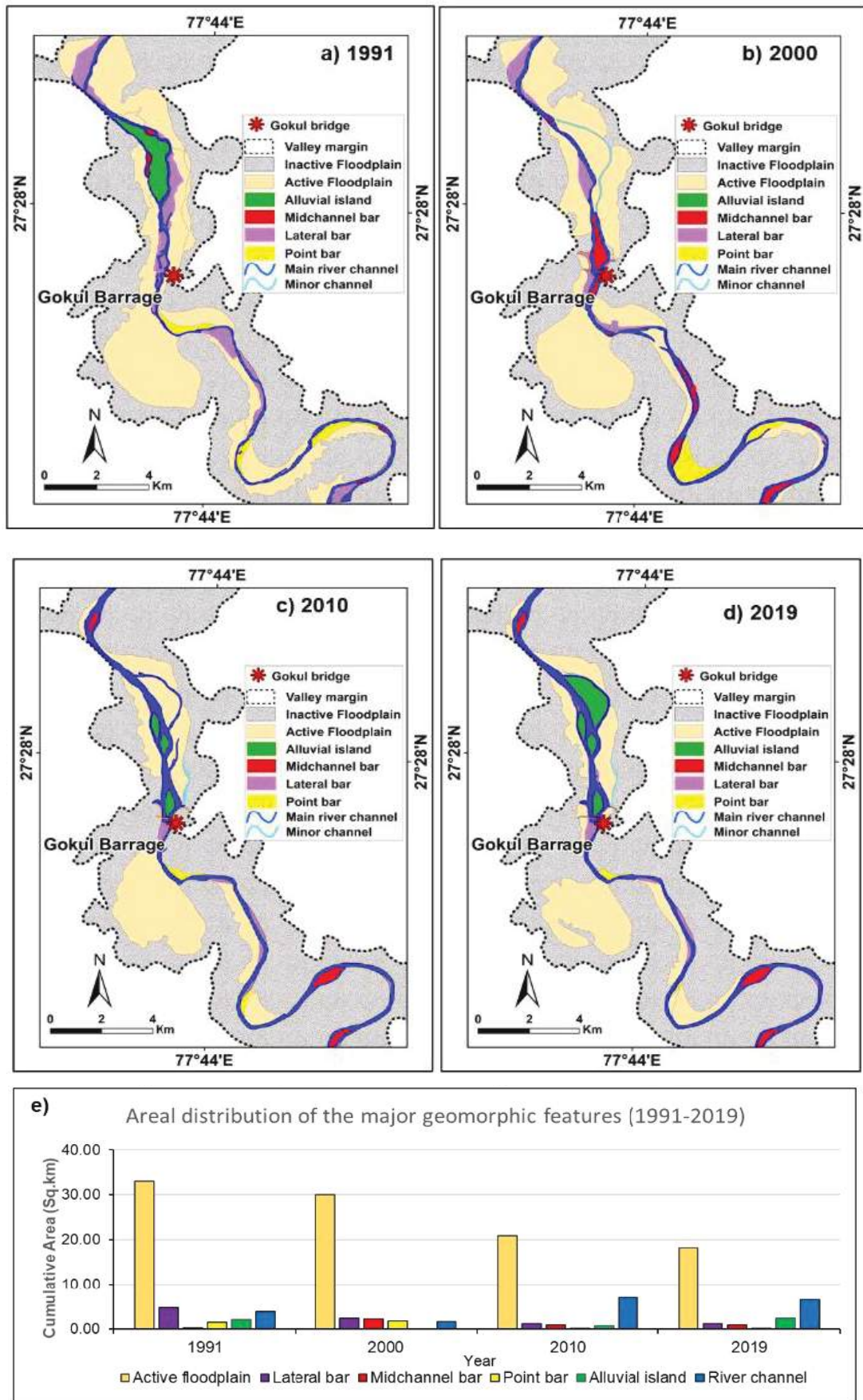
Figure 132 (a-d) shows the temporal planform maps of the Yamuna River at the Gokul Barrage, Mathura. The main channel shows a prominent meandering pattern downstream of the Gokul Barrage. Based on the temporal maps and the statistics, the study reach shows a decrease in the area of the active floodplain region from 1991 to 2019. In terms of channel dynamics, the main channel migrated from east to west during 1991–2000 and remained stable between 2010 and 2019 in the reaches upstream of the Gokul Barrage. To its downstream, the main channel does not show any significant channel migration over the entire period. The main channel is incised in nature with no change in the channel width. The thalweg shift of the Yamuna River near the Gokul Barrage shows a similar trend to that of the main channel. In terms of floodplain dynamics, the floodplain width shows a temporal decline from 1991 to 2019 throughout the stretch.



**Figure 131: (a) U/S of Gokul Barrage. Alluvial Island can be observed; (b) Swampy/Marshy area in the proximity of the Barrage; (c) Intake well.**

In summary, the Yamuna River at this site is characterized by a sinuous channel, hosting mid channel bars, few lateral bars and large alluvial islands. The most significant observation is the decrease of active floodplain area from 1991 to 2019. This suggests a loss in lateral connectivity, while the longitudinal connectivity is satisfactory. The net increase in the area of alluvial islands is observed with a 75% decrease in the percentage of lateral bars and almost 95% decrease in the point bar area. Though there is an overall increase in area of wetted channel upstream of the barrage site, which can be attributed to water storage, there is a significant decrease in depositional area and most importantly a loss of lateral connectivity.





**Figure 132: (a, b, c, d). Figure showing the geomorphic map of the Yamuna River at the Gokul bridge, Mathura for 1991, 2000, 2010, 2019 and e) Temporal changes in area covered by different geomorphic units in the Yamuna River at the Gokul Barrage, Mathura.**

## B. Aquatic biodiversity

Netting sessions were not performed at this site due to the unavailability of fishes, as informed by locals, besides *Clarias gariepinus*. This is an exotic fish species and is largely found in polluted waters as it can survive with a negligible amount of Dissolved Oxygen. Secondary survey literature indicated the presence of IMCs (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) in this river stretch.

All the water-quality parameters are high above the standard levels indicating the waters are highly polluted. Presence of ammonia and coliforms indicated organic pollution in the river. Turbidity was high due to the presence of suspended solids. This was responsible for the black colour of the water. Local reports suggest poor quality of irrigation water; mostly saline, alkaline and/or oily. Evidence of severe pollution can be distinctly observed with thick trails of toxic foam left by the pollutants and effluents, immediately downstream of the Gokul Barrage.

## C. Socio-cultural aspects

Gokul and Mathura remain important pilgrimage centres due to their connection with the life of Krishna. However, the condition of the river is a source of dissatisfaction to the residents as well as some visitors. The primary concern, as is the case upstream, is that of the quality of the water. People attest that they no longer are comfortable bathing in the water let alone drinking from it. The very devout continue to regard the river as a mother and bathe in it. The barrage has also resulted in the complete absence of sand deposition by the river during the monsoon. This has severely affected *pallage* farming in the area. The sudden changes in water level and velocity caused by the operation of the barrage also impact farmers and livestock owners. In summer, the river shrinks to a width of 15 to 20 feet with an average depth of around 5 feet; if not for the occasional deep pools, the river would be fordable. In the monsoon, the river extends across the channel bed with the exception of some islands in the middle of the bed.

Low flows in the summer exacerbate the issue of polluted water, with some people likening the river in the summer to a black thread. These also cause dissatisfaction among both pilgrims and residents as the water no longer can be accessed from the ghats. People need to trudge for quite a distance before they can touch the water, which is polluted. This decreases the level of satisfaction amongst visiting pilgrims and therefore impacts the revenue that the boatmen, tour guides and *purohits* (priests) might obtain from the practice of visiting the river and performing the socio-cultural activities.

Several long-time residents claimed that in the past, the availability of water in summer would be the same as the present time (post monsoon). In the monsoon, the water would fill the entire channel bed coming half way to the top of the ghats; there would be an annual flood up to the road that runs along the top of the ghats with an occasional flood entering the city of Gokul.

### 4.6.2.2 Mathura-Desired state

The 'Desired' state of the Yamuna River for Downstream of the Mathura Gokul Barrage site is tabulated in Table 45.

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                                                                                                                                                                                                                                           | Desired State     |
|--------|-----------------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | The most significant observation is the decrease in the active floodplain area. This suggests a loss in lateral connectivity, while the longitudinal connectivity is satisfactory. There is an overall increase in area of wetted channel upstream of the barrage site, which can be attributed to water storage. There is a significant decrease in depositional area and most importantly, a loss of lateral connectivity. | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | Fish abundance has reduced due to riverbed congestion. This is because of sedimentation and the low flows due to increased pollution. The water level is controlled by the barrage operations, which is putting stress on aquatic species.                                                                                                                                                                                   | Slightly Modified |
| 3      | Socio-cultural        | Degraded            | Pollution was a significant concern, followed closely by low summer flows. Summer flows are considered grossly inadequate. Every single respondent expressed unhappiness with the level of water as well as its quality in the summer. This decreases the pilgrim satisfaction of visiting the river.                                                                                                                        | Slightly Modified |

**Table 45: Present and Desired state of the Yamuna River at the Mathura E-Flows location**



### 4.6.3 Agra-Poiyaghat

Agra is 378 kilometres west of the state capital, Lucknow, 206 kilometres south of the national capital New Delhi, 58 kilometres south from Mathura and 125 kilometres north of Gwalior. Agra is one of the most populous cities in Uttar Pradesh, and the 24<sup>th</sup> most populous city in India. Agra is renowned for the Taj Mahal and other monuments along the bank of the Yamuna and is of prime socio-cultural and historical significance. The CWC site is located at the Poiyaghat site. *Pallage* farming along the river was observed and is a practice throughout the year. Cultivation is observed on both the banks.

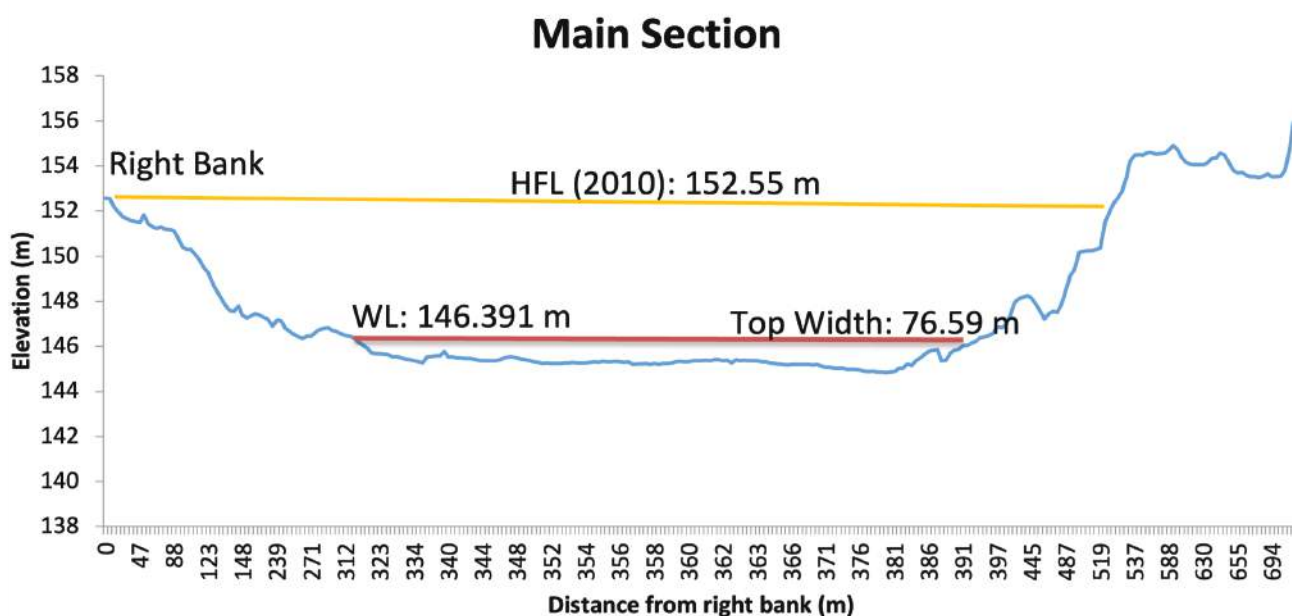


**Figure 133: Agra (Poiyaghat) site with the cross-sections locations**



**Figure 134: Agra (Poiyaghat) E-Flows site at CWC flow observation station**

The cross sections across the Yamuna River at Agra shows that the deepest part of the primary channel is centrally placed in the main section, but the channel has migrated towards the right bank in the upstream and downstream sections. The cross section is essentially a trapezoidal shaped profile. The HFL recorded in 2010 is 152.55m, whereas the present water level is 146.39m with an average water depth of 1.03m in the main section, as per the survey.



**Figure 135: Cross-section profile of Agra E-Flow site on the Yamuna River**

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 530       | 7.7             | 1.5                         | 68.83                    |

**Table 46: Cross-sectional parameters for the Yamuna River at the Agra site**

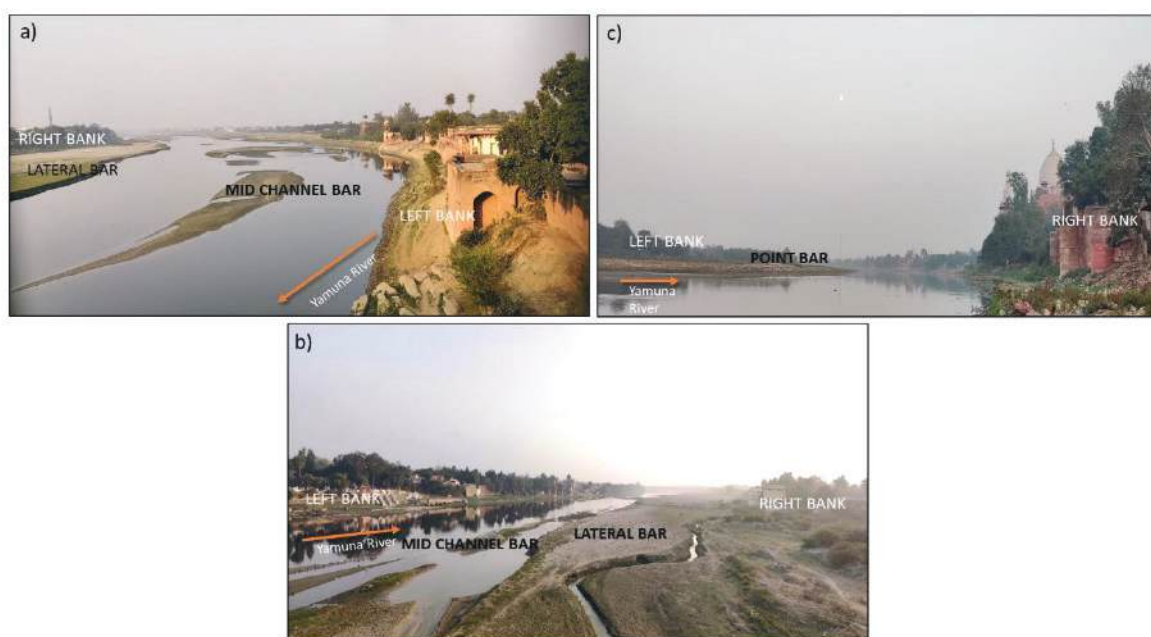
The ‘Present’ and ‘Desired’ state of the Yamuna River at Agra is discussed in a thematic fashion.

### 4.6.3.1 Agra–Present State

#### A. Fluvial geomorphology

The entire reach of the Yamuna River around Agra is narrow and highly sinuous in nature, and roughly follows a North West-South East trend, with numerous lateral bars and patches of floodplain upstream of Poiyaghat. The floodplain is unconfined in both the upstream and downstream locations of the bridge. The width of the channel belt seems to be consistent in both the upstream and downstream reaches. The channel around the site is characterized by an asymmetric form, meandering with a high sinuosity upstream and low multiplicity. The primary channel mainly flows alternating between the left and right banks and

bifurcates in case of mid-channel bars and the alluvial islands. Numerous unvegetated bedforms such as mid-channel bars, that are elongated in the direction of the flow, and lateral bars have been observed (Figure 136).

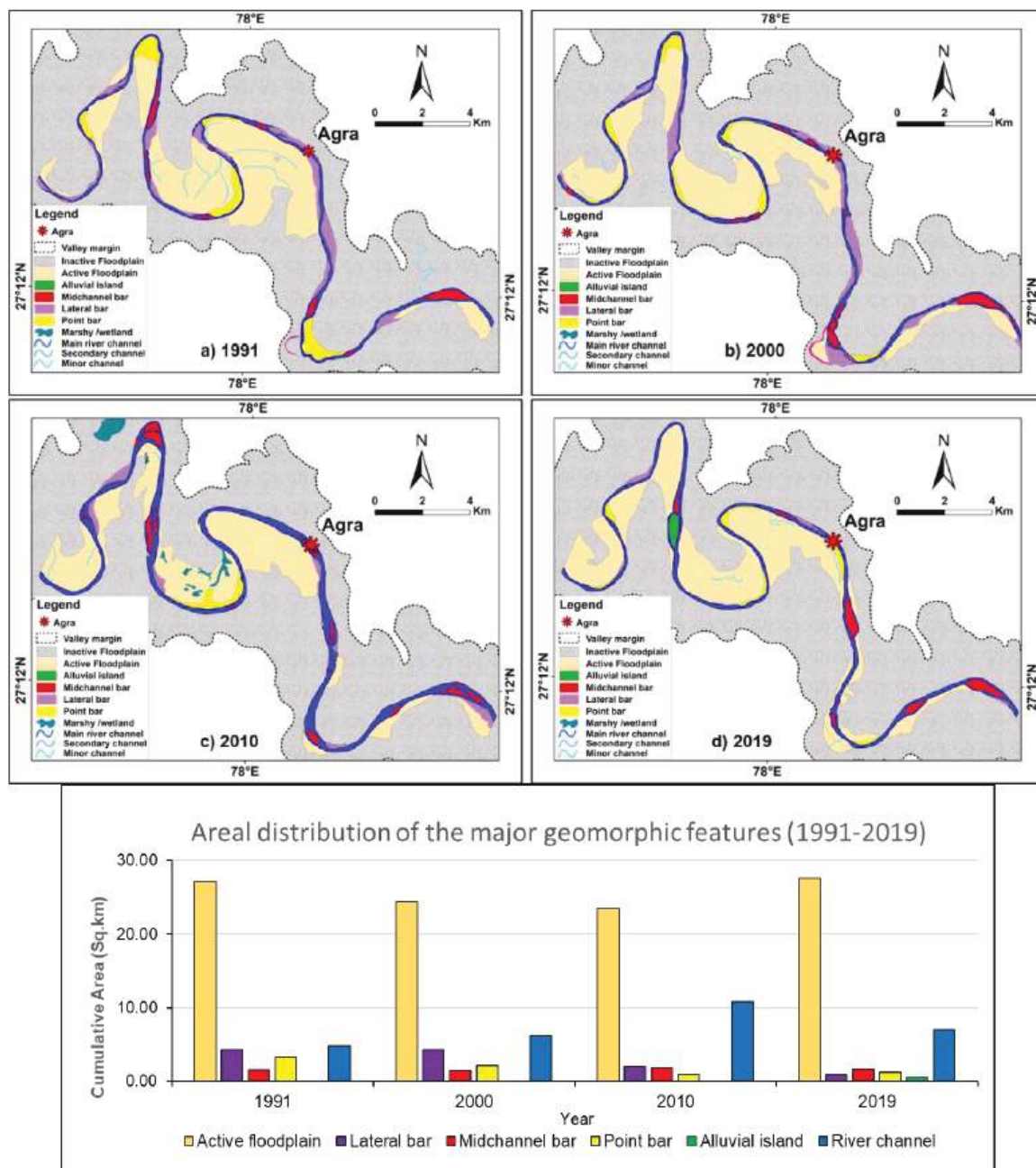


**Figure 136 (a): Well-developed mid-channel bar upstream of the Jawahar. Lateral bar towards the right bank; (b) Mid-channel bars, lateral bar and active flood plain area downstream of the Jawahar Bridge, (c) The primary channel has migrated and become confined towards the left bank**

Figures 137 (a-d) show the temporal planform maps of the Yamuna River around the Agra site. It shows no change in the planform features over the entire study period. Throughout the study reach of 20km, the upstream reach of the Agra site is dominated by an active floodplain in all the years. It shows a decreasing trend between 1991 to 2010 and a similar area in 2019 as in 1991. The main channel is incised in nature but shows an increase in area between 1991 to 2010 and then a decrease in 2019. The temporal planform map also shows a continuous decrease in the lateral bar area from 1991 to 2019. The main channel is incised and shows a sinuous pattern downstream of the study stretch. It does not show any significant variation in the channel width except in 2010. The channel thalweg also shows a similar pattern to that of main channel migration with no spatial and temporal shift. The temporal floodplain width also shows no major change over the entire study stretch, except at some reaches.

In summary, the Yamuna River at this site is characterized by high sinuosity, low multiplicity and depositional features such as point bars, numerous mid-channel bars and lateral bars. The upstream reaches of the Agra site are dominated by an active floodplain in all the years, with consistency and good lateral connectivity. Overall, the longitudinal connectivity is satisfactory, though there has been ~ 87% reduction in the lateral bar area and 2.6-fold decrease in point bar area. The channel thalweg shows no spatial and temporal shift.





**Figure 137 (a, b, c, d): Figure showing the geomorphic map of the Yamuna River at Agra (U.P.), for the year 1991, 2000, 2010, 2019; (e) Temporal changes in area covered by different geomorphic units in the Yamuna River at Agra (U.P.).**

## B. Aquatic biodiversity

In this site, a total of two species were recorded. Among those, one is in Vulnerable (VU) category of the IUCN Red List, i.e. *Cyprinus carpio*, and the other is in LC category, i.e. *Clarias gariepinus*. Both of these are exotic fish species and is largely found in polluted waters, as it can survive with a negligible amount of Dissolved Oxygen. Secondary survey literature indicated the presence of IMCs (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*) in this river stretch. Most of the water-quality parameters are high above the standard levels, indicating the water is moderately polluted. Presence of ammonia and coliforms indicated organic pollution in the river. Turbidity is more than 25 NTU, this may be due to suspended particles present in the river.

### C. Socio-cultural aspects

Poiyaghat shares a history with Agra but is itself of little historical or mythological significance. The banks of the river Yamuna extend as far back as the legends of Krishna and the heroes of the Mahabharata. In AD 1558, there was a modern city founded on the right bank of the river with Agra as the capital. At this section, the river flows in a channel with well-defined banks. Extensive farming as well as maintaining livestock on both sides of the riverbank is carried out. The cremation ghat, used by the people of Dayalbagh as well as the surrounding villages, is located in this section. The section also has an operational ferry, which is a country boat that carries people and farm products. The section is also a popular spot for visitors who come to breathe the fresh air and enjoy the open space. There is a *Nishad* community in Kashpur, who operate boats and are engaged in fishing for subsistence. *Pallage* farming is done once the water recedes around Diwali. However, the *pallage* farmers have suffered losses in the last two years due to unseasonal releases.

In the monsoon, the water fills the channel bed, barely touching the edges. Occasional releases from upstream raise the water by around a metre so that it fills the channel bed. Floods do occur but very rarely, with the last major flood occurring in 2010 when water came up past the gate to the cremation ground. Sudden surges of water in summer and winter severely impact farmers by endangering both livestock and crops. Low summer flows are a matter of concern for both farmers and visitors for several reasons. It is then also quite shallow except for some deep pools. These deep pools are also present within the stream-bed which causes them to stagnate. The situation is aggravated by the highly polluted condition of the water in the stream. The sight of an almost dried-up river, accompanied by a slender stream of dark sludge some distance from the bank, leaves visitors both disheartened and perplexed. Farmers are faced with increasing salinity, lower soil moisture and an almost complete unavailability of water to bathe their livestock in.

### 4.6.3.2 Agra - Desired state

The 'Desired' state of the Yamuna River for Downstream of Agra site is tabulated in Table 47.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                            | Desired State     |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | There is a variation in longitudinal connectivity and there has been 87% reduction in the lateral bar area and 2.6-fold decrease in point bar area.                                                                           | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | There is a reduction in fish abundance because of their confinement to a very narrow bed, in addition to increased pollution. The water level is controlled by upstream releases, which is putting stress on aquatic species. | Slightly Modified |
| 3      | Socio-cultural        | Degraded            | Sudden surges of water in summer and winter severely impacts farmers by endangering both livestock and crops. Low flows in summer concern the villagers due to the unavailability of water to bathe their livestock.          | Slightly Modified |

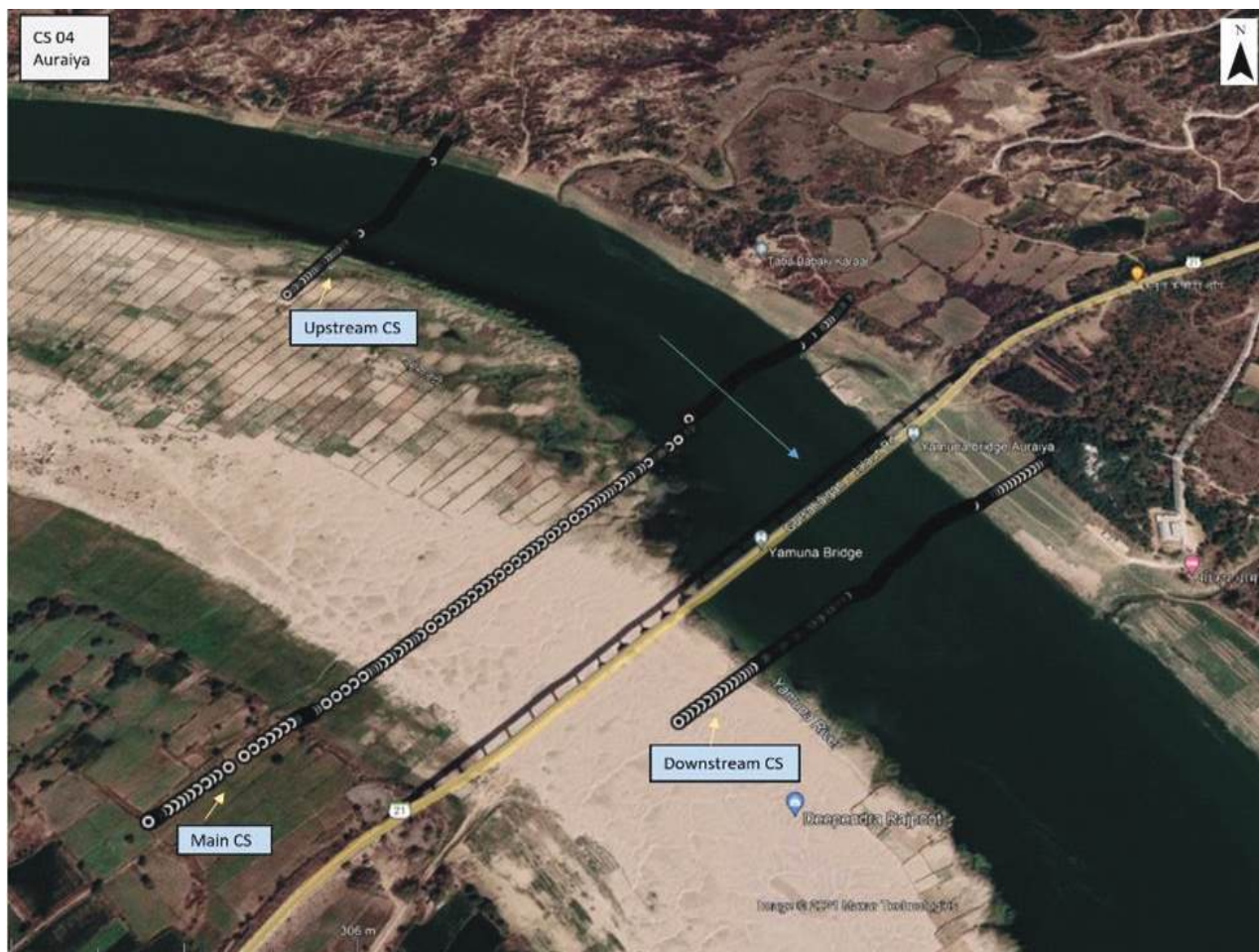
**Table 47: Present and Desired State of the Yamuna River at the Agra E-Flows location**

### 4.6.4 Auraiya site

Auraiya is situated 64km in the east of district headquarters of Etawah and 105km to the west of the Kanpur city. This E-Flows site is located near the Yamuna Bridge, downstream of the confluence of the Yamuna with the Chambal River. The Yamuna at this site receives contributions from two major rivers, the Sindh and Chambal, the latter being the dominant contributor in terms of discharge. There is also an important CWC site at this location involved in gauge, discharge, sediment concentration and water quality. This site is well known for massive flooding during the monsoon period<sup>43</sup> and causing misery to the human and animal population. The river stretch bears continuous high cliffs on one side of bank; the other side, though, is well leveled with the ground. Each side takes turns to perform fishing and selling activities on a bigger scale.

<sup>43</sup> <https://floodlist.com/asia/india-floods-uttar-pradesh-august-2021>



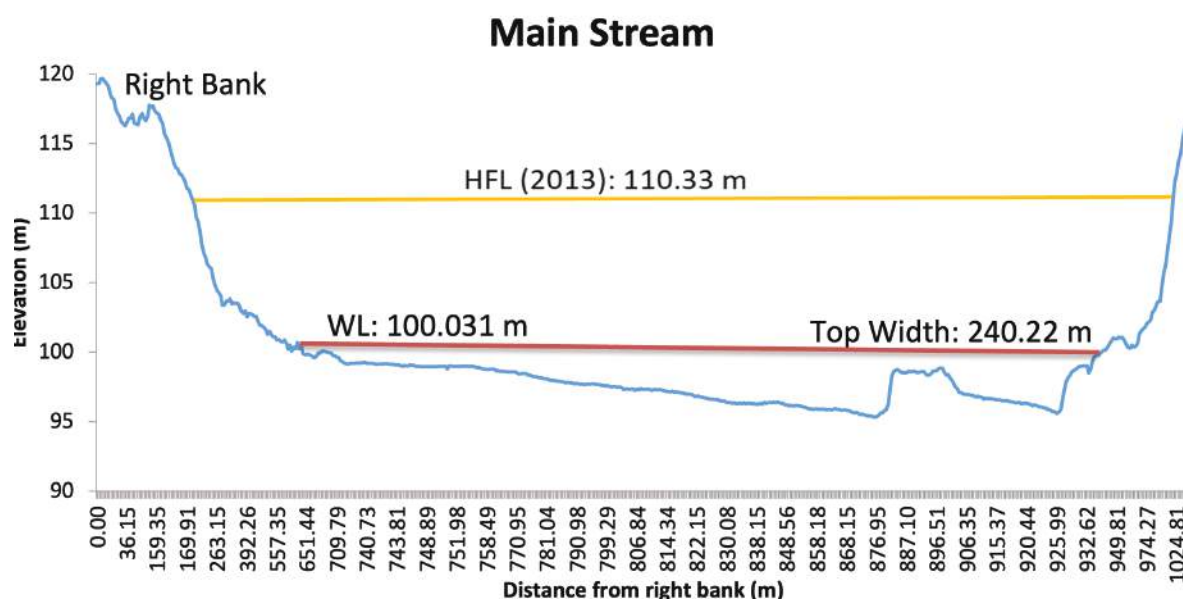


**Figure 138: Auraiya site and the cross-sections location**



**Figure 139: Yamuna River at the Auraiya site during monsoon**

The cross sections at the site shows that the channel has an asymmetric form. The maximum depth is observed in the main section of the Yamuna River at Auraiya towards the left bank. The HFL was recorded as 118.19m (water level) for the 25.08.1996 flood.



**Figure 140: Cross-section profile of Auraiya E-Flows site on the Yamuna River**

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 880       | 20.7            | 4.7                         | 42.51                    |

**Table 48: Cross-sectional parameters for the Yamuna River at the Auraiya site**

The 'Present' and 'Desired' state of the Yamuna River at Auraiya is discussed in a thematic fashion.

### 4.6.3.1 Auraiya–Present state

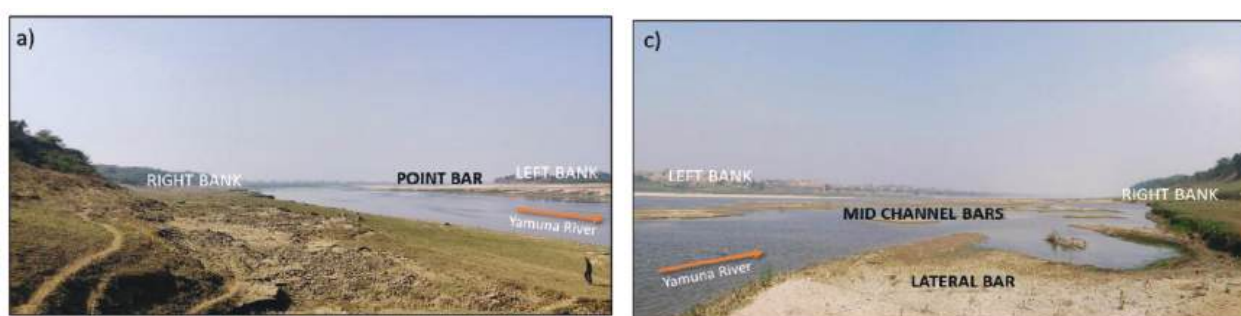
#### A. Fluvial geomorphology

The river at this site is mostly sinuous and shows low multiplicity. The only major intervention is the bridge site built in the year 1994, on the stable meander belt, where the left bank has developed a cliff. The floodplain along the left bank has developed a classical topography consisting of ravine land.

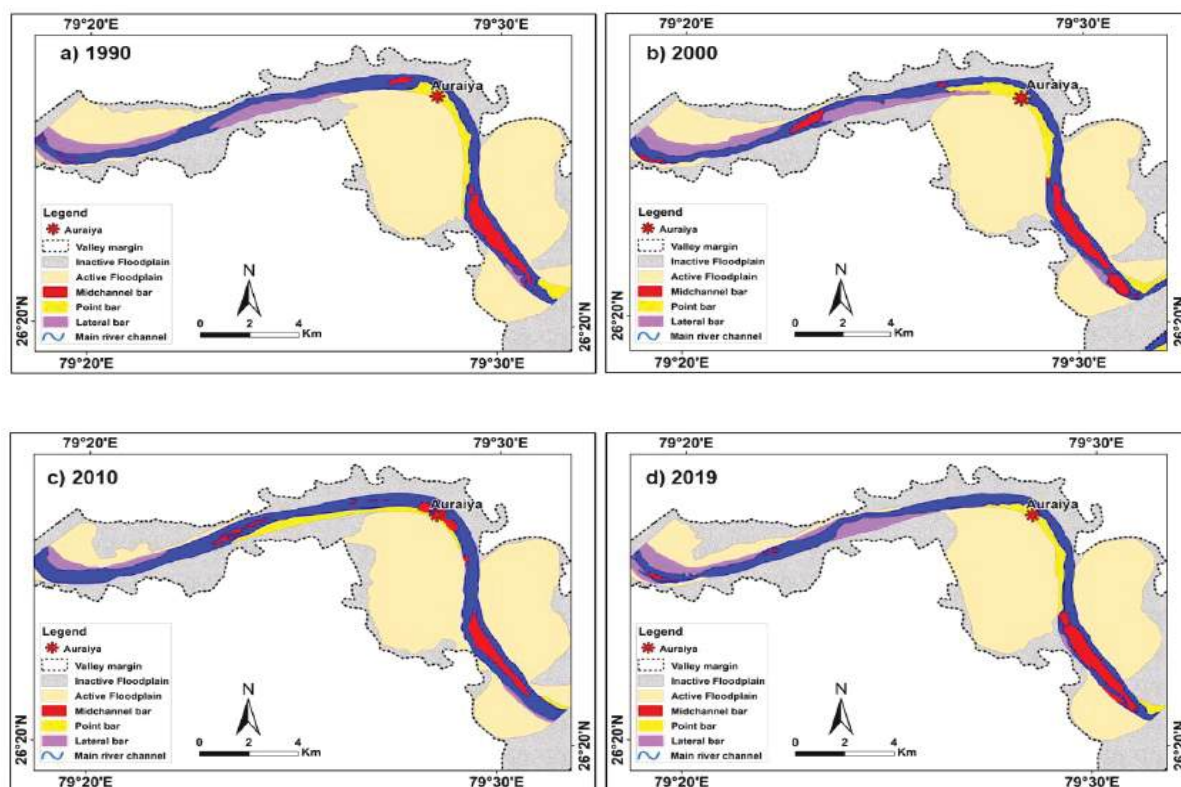
This site is characterized by partially confined floodplains in the upstream and downstream reaches. This site has a typical point bar towards the right bank of the bridge. Similarly, large lateral bars and mid-channel bars have also been noted in the upstream and downstream stretches, respectively (Figure 141). The active floodplain area towards the downstream reaches is wider near the bridge site, compared to the upstream stretches.

This site is of agricultural importance with the main crops of the district being Paddy, Wheat, Bajra, Pulses and Mustard. Mango, Aonla, Guava, Papaya, Potato, Tomato, Garlic and Petha are also cultivated here. A few sand-mining sites have been observed in the upstream reaches.

The temporal maps of the Yamuna River at the Auraiya site are marked by a single-thread incised main channel with few depositional bars. Floodplains dominate a major part of the study site, but its area has decreased consistently from 1990 to 2019. The lateral bars decreased from 1990 to 2010, but marked a sudden increase in 2019. The mid-channel bars show a gradual shift from 1990 to 2000 and then decrease in 2010 and 2019. The study reach has a prominent point bar visible in all the years. The main channel at this site does not show any considerable change between 1990 and 2019, but a slight increase in 2010 is noted (Figure 142).

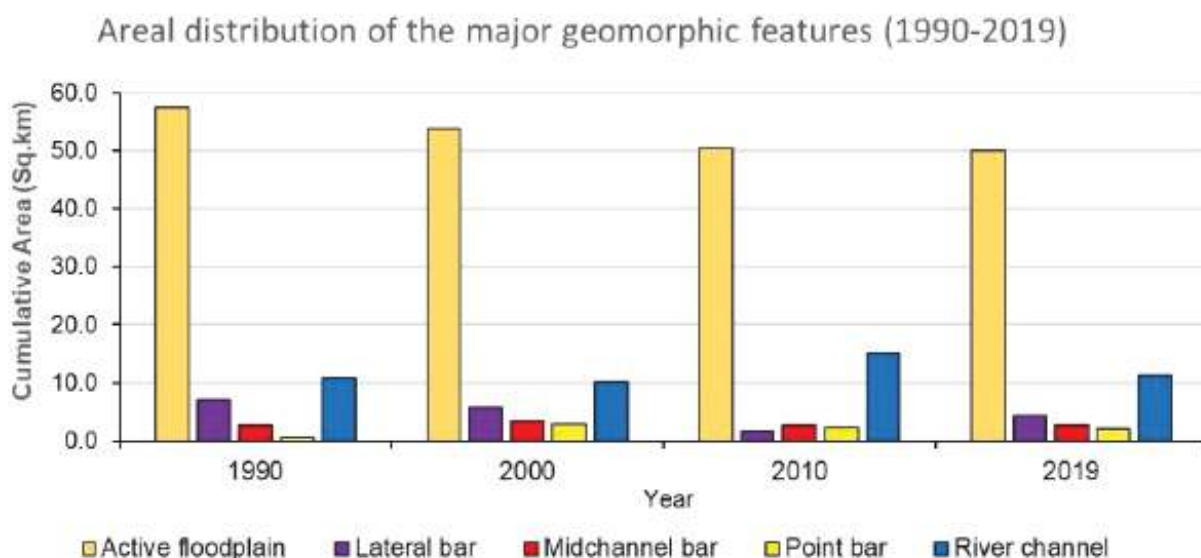


**Figure 141 (a): Well-developed point bar in the meander bend; (b) Multiple riffles and pools, fish-spawning site**



**Figure 142: (a, b, c, d): Figure showing the geomorphic map of the Yamuna River near Auraiya for the year 1990, 2000, 2010, 2019; (e) Temporal changes in area covered by different geomorphic units in the Yamuna River near Auraiya**





**Figure 142: (e) Temporal changes in area covered by different geomorphic units in the Yamuna River near Auraiya**

The channel width as well as the position of the Yamuna River at Auraiya have remained stable during the entire study period (20 years). Upstream of the Auraiya site, the river thalweg remains stable in all the years. But, in some stretches, the river thalweg has migrated to the southwest during 1990–2000. The floodplain width has no temporal change over the entire study stretch of Auraiya, except in very few stretches.

In summary, the Yamuna River at this site is sinuous, having low channel multiplicity and characterized by a large point bar, mid-channel bars and lateral bars. The active channel area has reduced by 13% from 1990 to 2019. Overall, in the middle and lower reaches, the lateral connectivity is good. Longitudinal connectivity is also very good in this region. Pedogenic calcrete bed substrate is observed at certain locations, and mostly the channel is flowing towards the left bank in the vicinity of the bridge site. The depositional area and the river channel area have also been consistent, showing a relatively stable reach. The floodplain width shows no temporal change over the entire study stretch of Auraiya except in few reaches.

## B. Aquatic biodiversity

A total of eight species were recorded from this site. Among those, one is in Vulnerable (VU) category of the IUCN Red List, i.e. *Cyprinus carpio* and the others are in LC category, i.e. *Mystus aor*, *Oreochromis niloticus*, *Channa punctata*, *Osteobrama cotio*, *Labeo bata*, *Xenentodon cancila*, and *Cabdio morar*. Secondary survey literature indicated the presence of IMCs in the Etawah stretch of the river.

Besides these, gharials and dolphins are found at a site 5km downstream of Auraiya site (Jitamau) even in the current period. Dolphins are seen in good numbers on a daily basis in the middle of the water body, as informed by the locals. The dolphins swim down in the depths and hide behind rocks during this season.

Water appearance was clear and normal for this river stretch. Most of the water-quality parameters are within the standard limits. Absence of ammonia and coliforms indicated no organic pollution in the river. Turbidity is more than 25 NTU. This may be due to suspended particles present in the river.

### C. Socio-cultural aspects

The river here is regarded as an important contributor to the sustenance and livelihood of the people that live alongside it. Fishing is practised here to a very large extent, with the survey team witnessing several people sitting on the shores of the river and angling for fish. Downstream of the section, there were several boats stocked with fishing nets along the sandbank. The respondents belonged to the *Kewat* community that traditionally depended exclusively on fishing and ferrying for their livelihood. However, since the bridge was constructed, they have adopted farming. Some of them would also manually extract sand from the river, however, that too has stopped now.

People spoke with some pride about the quality and extent of the crops grown here. Melons and watermelon are both planted here along with lesser cucurbits such as cucumbers and bottle gourds. Most of the residents also practice farming in permanent fields. Vegetables are also grown here. Residents attest that the water quality is better here than in Agra, and the river also has more fish. The monsoon flows and floods are considered to be adequate. Nevertheless, the daily fluctuations result in dissatisfaction, as it becomes challenging to predict the timing and extent of water passage. This uncertainty also raises concerns about the safety and security of livestock population when they are in the water. One or two cremations are held on the left bank of the river on a daily basis.

There is a desire for increased flows in summer to improve fish stocks. Despite an awareness of the diminishing quality and quantity of flows in the river, the residents of the villages around this section are not too dissatisfied with the river.

### 4.6.3.2 Auraiya - Desired state

The 'Desired' state of the Yamuna River for the Auraiya site is tabulated in Table 49.

| S. No. | Thematic Area         | Present State     | Reasoning/ Remarks – Present State                                                                                                                                                                            | Desired State |
|--------|-----------------------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 1      | Fluvial Geomorphology | Slightly Modified | There is a variation in longitudinal connectivity and there has been 87% reduction in the lateral bar area and 2.6-fold decrease in point bar area.                                                           | Near Pristine |
| 2      | Aquatic Biodiversity  | Slightly Modified | Fish abundance is reducing due to summer lean flows and diurnal variation. The water level is controlled by the upstream releases, which is putting stress on the aquatic species.                            | Near Pristine |
| 3      | Socio-cultural        | Slightly Modified | Sudden surges of water in summer and winter severely impact farmers by endangering both livestock and crops. Low flows in the summer is a concern. Increasing salinity and low soil moisture affects the crop | Near Pristine |

**Table 49: Present and Desired state of the Pratappur E-flows site on the Yamuna River**

### 4.6.5 Pratappur site

The Pratappur site is located 50km upstream of the Yamuna-Ganga confluence at Prayagraj. This site falls in Handia Tehsil in the Prayagraj district. Prayagraj is one of the oldest cities in India. It is called 'Prayag' or 'Teertharaj' in ancient scriptures and is considered the holiest of pilgrimage centres of India. It is situated at the confluence of three rivers – Ganga, Yamuna and the mythical Saraswati. The meeting point is known as Triveni and is very sacred to Hindus. The Kumbh held every six years and Mahakumbh every 12 years at Prayagraj (Sangam) are the largest gatherings of pilgrims on earth. The Yamuna River at the Pratappur site receives contributions from two major cratonic rivers, the Ken and Betwa. In this section, there are two sets of water abstraction infrastructures built on the Yamuna: one serving the NTPC thermal power plant and the other facilitating an irrigation canal.

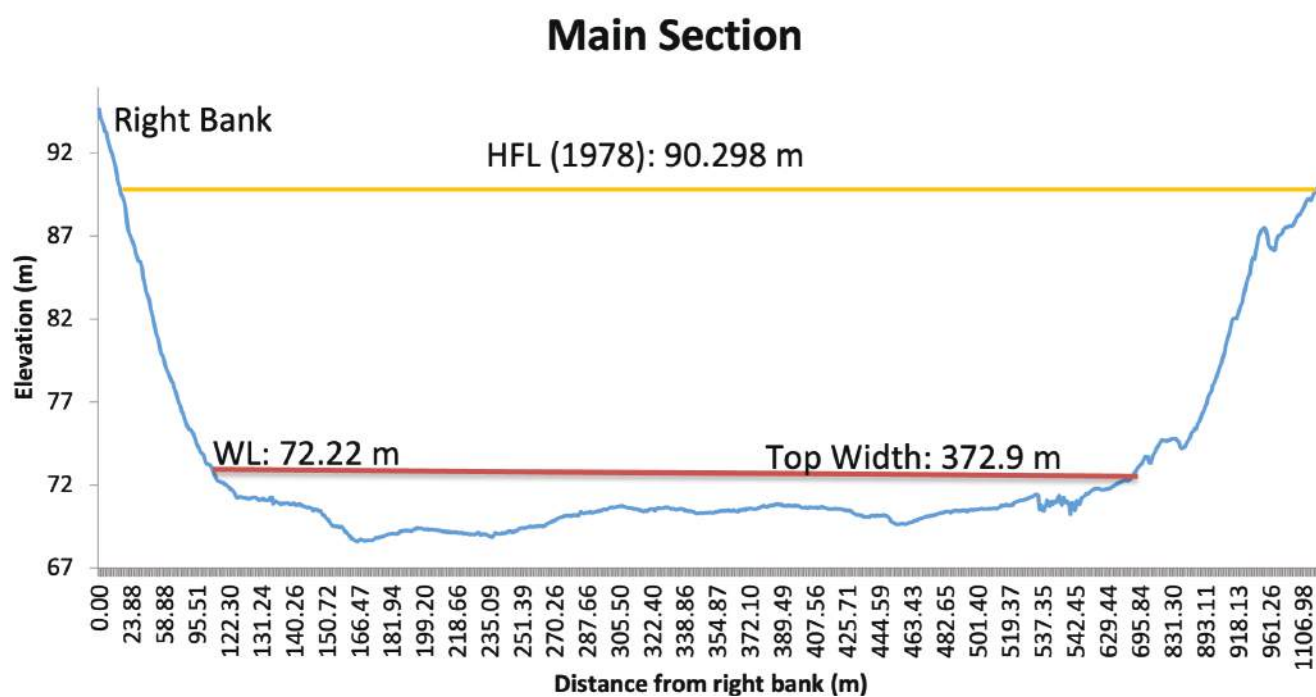
The cross sections at the site shows that the channel has an asymmetric form, and the thalweg lies more towards the right bank. The maximum width (1120 m) and depth (22 m) are associated with the main section. The substrate type is



mostly quartz-rich and coarse-grained cratonic-type sand. A major sand-mining site was located downstream of the E-Flows site on the lateral and mid-channel bar.



**Figure 143: Pratappur E-Flows location at CWC hydro-observation site**



**Figure 144: Cross-section profile of Pratappur E-Flow site on Yamuna River**

| Cross Section | Width (m) | Max. Depth (m)* | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|--------------------------|
| Main Section  | 880       | 20.7            | 42.51                    |

**Table 50: Cross-sectional parameters for the Yamuna River at the Pratappur site**

The 'Present' and 'Desired' state of the Yamuna River at Pratappur is discussed in a thematic fashion.

### 4.6.5.1 Pratappur – Present state

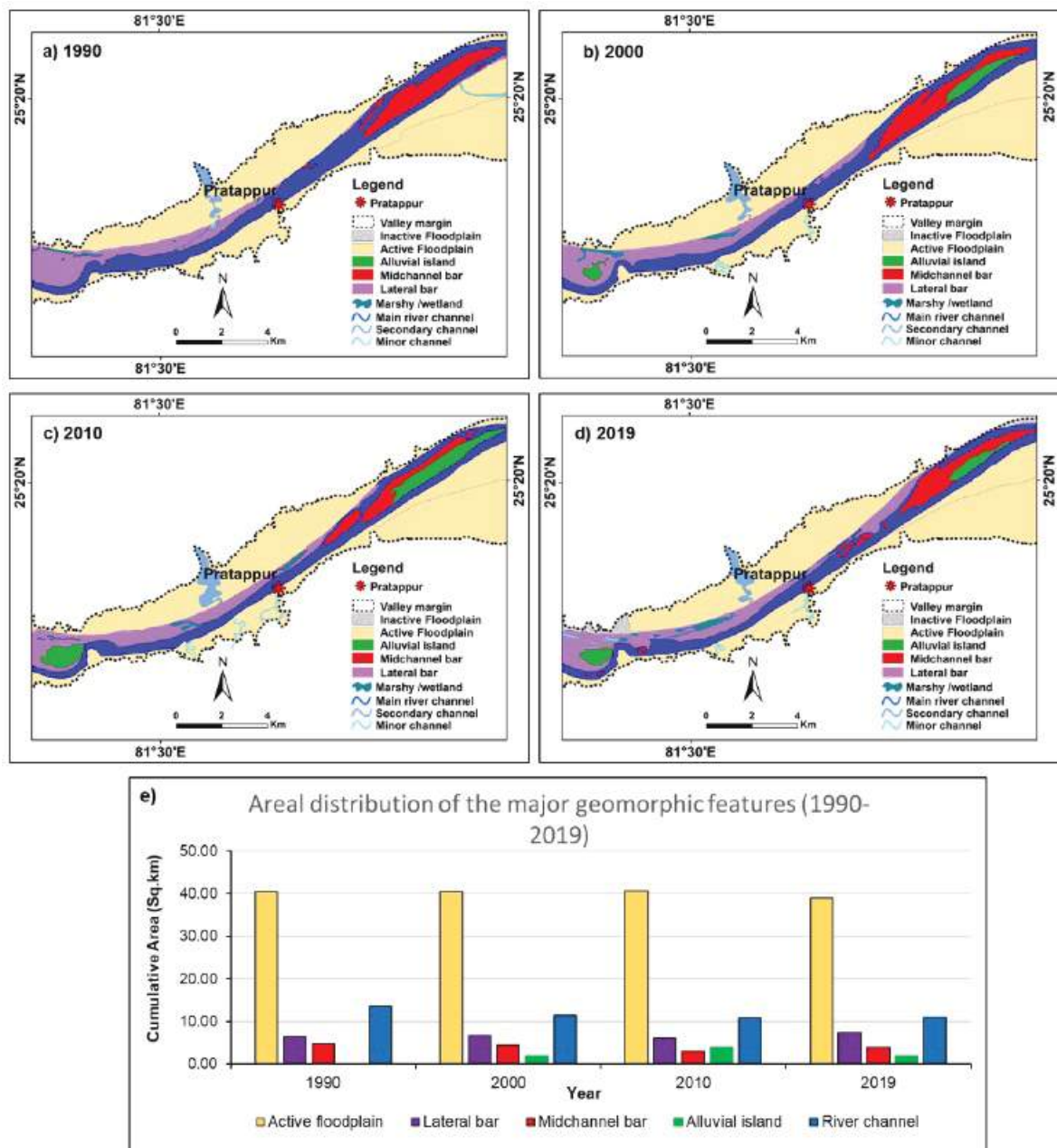
#### A. Fluvial geomorphology

The Yamuna River at this site is incised, asymmetric and the thalweg runs closer to the right bank. The major depositional features in this stretch include the large lateral bars, large mid-channel bars and an alluvial island towards the down-stream region. The bar forms, including the mid-channel bars and alluvial islands, are elongated along the direction of the flow. The alluvial islands are relatively new but stable features that trap the instream sediments. Most of the mid-channel bars and lateral bars are typically un-vegetated. The active floodplain region is well developed towards the left bank near the E-Flows site and mostly towards the right bank side in the downstream region. A pontoon bridge has been noted immediately upstream of the E-Flow site. A few rural settlements are noted which are mostly dependent upon agriculture, with the major crops being Paddy, Arhar, Dal and Moong. Mustard is also grown as a mixed crop. (Figure 145)



**Figure 145 (a) Large mid-channel bar and alluvial islands (b) Lateral Bar to the the left back side and sand-mining can also be seen (c) Pontoon bridge near the site on the Yamuna River**

Figure 146 a-d show the temporal planform maps of the Yamuna River extending 20km both upstream and downstream of the Pratappur site. A major part of the study stretch is dominated by active floodplain and single thread main channel with few depositional bars. Upstream of the Pratappur site, large lateral bars are observed throughout the study period (1990-2019), part of which get stabilized in consequent years and form the alluvial island. Major planform features such as floodplain, mid-channel bars and lateral bars do not show any major change in area over the period. The floodplain shows an overall decrease between 1990 and 2019. The temporal maps and statistics of the main channel record a continuous decrease in area during 1990-2019. The main channel does not show any shift in its course over the entire study stretch between 1990 and 2019. Similar is the case of thalweg shift with no temporal change along the river course. Also, the floodplain area remains more or less similar in all the studied years.



**Figure 146 (a, b, c, d): The year 1990, 2000, 2010, 2019; (e) Temporal changes in area covered by different geomorphic units in the Yamuna River at Pratappur**



In summary, the Yamuna River at this site is characterized by a sinuous channel with relatively low channel multiplicity and large bar forms such as mid-channel bars and lateral bars, respectively. The channel form is mostly asymmetric and consistent with no notable thalweg shift observed in the last four decades. The channel area has reduced by 20% in the last four decades. Although the river is partially confined, the area in the zones of active floodplains has consistently remained unchanged. This indicates no loss in lateral connectivity in the last four decades. Overall, the depositional area has been consistent, and there is a major trade-off that lies between the lateral bar and the mid-channel bar area with a net increase in channel aggradation in a few reaches. Also, a notable feature in the post-2000 period is the formation of a stable alluvial island in some reaches.

## B. Aquatic biodiversity

A total of 12 species were recorded from this site. Among those, one is in Vulnerable (VU) category of IUCN Red List, i.e. *Cyprinus carpio* and the others belonged to LC category i.e., *Mystus cavasius* (Petwara), *Sicamugil cascasia* (Banna), *Pethia conchonius*, *Glossogobius giuris* (Chitra), *Cirrhinus reba*, *Johnius coitor* (Pathri), *Macrognathus pancalus*, *Mastacembelus armatus*, *Cabdio morar* (Chilwa), *Gonialosa manmina*, and *Eutropiichthys vacha*. Besides these, locals told the team that gharials are found during the monsoon. Ganga river dolphin is also spotted from this location.

Water appearance was clear and normal for this river stretch. The water-quality parameters are within the standard limits. Absence of ammonia and coliforms indicated no organic pollution in the river. The Chlorides, Nitrates, Phosphorus and Total Hardness was recorded within the prescribed range.

## C Socio-cultural aspects

This section of the river is the site of a conflict over water sharing. Two intake wells pump out water into two canals – one leads to the nearby NTPC thermal plant and other to an irrigation canal. The NTPC canal has priority over the irrigation canal. The respondents feel that the water during lean season is not as clean as it used to be and the water levels are also reduced now-a-days. Earlier, people used to drink the water from the river. These days, the water turns black when the levels are low. This happens at least three to four times a year.

People practice *pallage* farming at this site. Bottle gourds, pumpkin and melons are the popular crops. There is some sand extraction going on at present. Here too, sometimes water increases suddenly in the low seasons and causes the *pallage* fields to be washed away. Fishing is also carried out at this site. However, the species composition of the fish has changed. Earlier Tongra (*Mystus seenghala*) and Gogra were found in adequate quantities; these days the fish are primarily China (*Common carp*), Rohu (*Labeo rohita*), etc. A cremation ghat is also present on the banks and is used by people from the surrounding villages.



#### 4.6.5.2 Pratappur-Desired state

| S. No. | Thematic area         | Present State     | Reasoning/ Remarks – Present state                                                                                                                                                                                                                                        | Desired State |
|--------|-----------------------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 1      | Fluvial Geomorphology | Slightly Modified | The channel area has reduced by 20% in the last four decades. Though the river is partly confined, in the zones of active flood-plains, the area has remained consistent, indicating no loss in lateral connectivity. Overall, the depositional area has been consistent. | Near Pristine |
| 2      | Aquatic Biodiversity  | Slightly Modified | Fish abundance is reducing due to river behaviour during the summers. The water level is being controlled by the upstream releases, which is putting stress on the aquatic species.                                                                                       | Near Pristine |
| 3      | Socio-cultural        | Slightly Modified | The water levels in summer are lower than before. In addition, the water is no longer clean, so people cannot drink from the river.                                                                                                                                       | Near Pristine |

**Table 51: Present and Desired state of the Yamuna River at the Pratappur E-Flows location**



## 4.7 Gandak River

The Gandak River rises in the mountains of Nepal where its sources lie between the Dhaulagiri and Gosainath mountains also known as the Sapt Gandaki. Three distinct affluents converge in the lower foothills of the Himalaya before entering India<sup>44</sup>. The Burhi Gandak and the Trisuli Gandak unite on the south side of the Great Himalaya, and after flowing as one river, they join the Kali Gandak at Deb Ghat, a place of pilgrimage<sup>45</sup>. The Gandak is also known as the Narayani, beyond this confluence and as Salgrami in Nepal. Greek travellers have referred to it as the Kondochates. Tellingly, in Indian epics, it is known as the *Sadanira*, or the 'ever flowing'<sup>46</sup>.

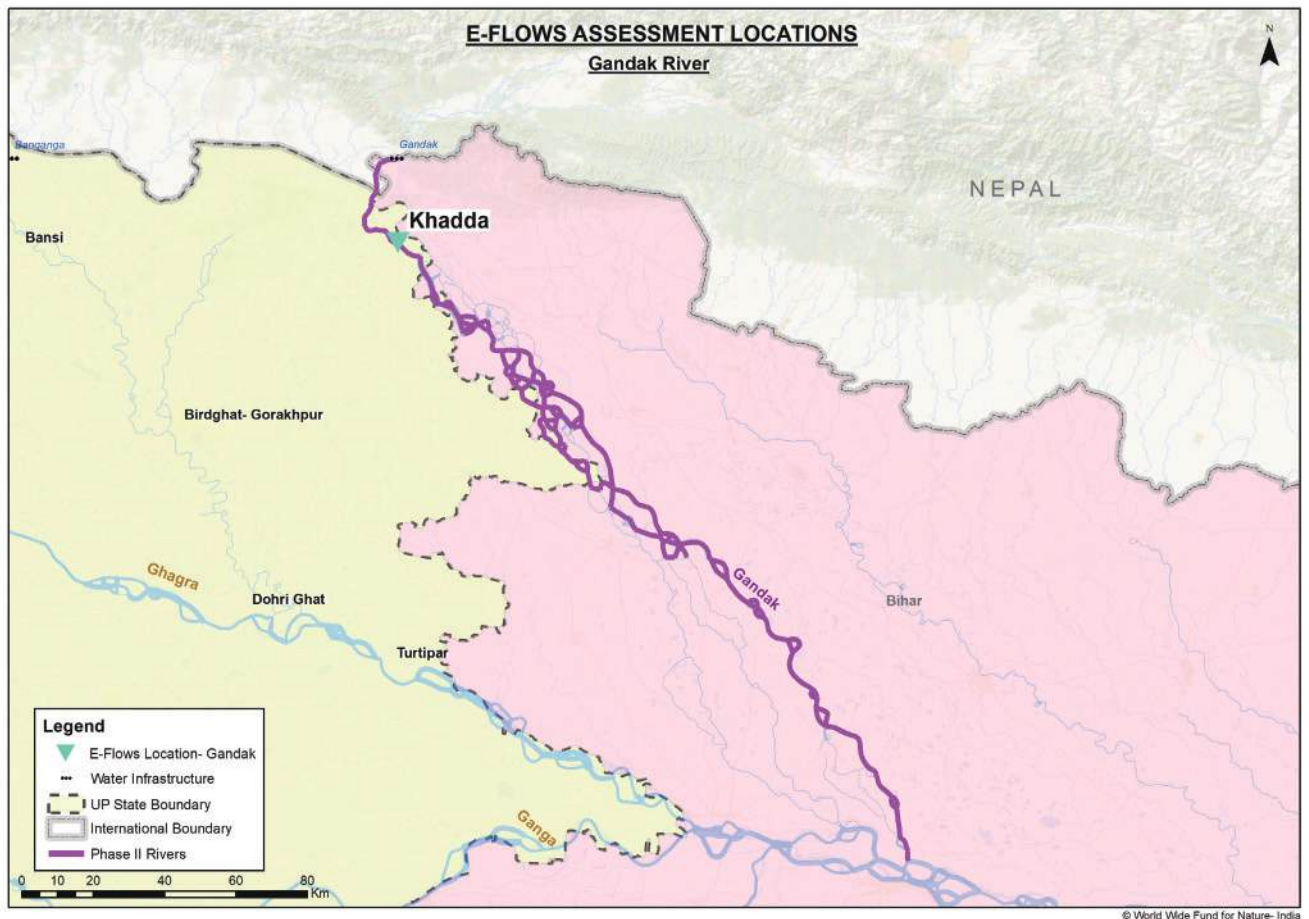
The Gandak River originates at an altitude of 7620 m above MSL in the north of Dhaulagiri in Tibet near Nepal border. Starting from the Himalayas, the river stretches over a length of 630 km, with 445 km running through India and 185 km in Nepal. The Gandak River has a total drainage basin area of 29,705 sq. km. The river flows through the Indian states of Bihar and Uttar Pradesh, and joins the Ganga near Patna just downstream of Hajipur. The major tributaries of the Gandak River include the Mayangadi, Bari, Trisuli, Panchand, Sarhad, Budhi Gandak. Valmiki National Park in Bihar is located on the banks of this river.

As the Gandak River flows for only 40km within Uttar Pradesh, no river zonation exercise was carried out and one site, Khadda, was identified for E-Flows assessment. The rationale for selecting Khadda as an E-Flows site is that it has a stable, confined cross section. Moreover, observed information is also available, as this site is maintained by Central Water Commission and is categorised as a flood-forecasting site where only water levels are being recorded.

The river shows high geomorphological dynamic characteristics with heavy sediment loads during the monsoon season leading to a change in its course at several places. There is a water resource infrastructure-Valmikinagar Barrage, constructed on the Gandak River at the India-Nepal boundary, which diverts water for irrigation (for Uttar Pradesh) and has partially altered the natural stream power. The river provides several livelihood opportunities to riparian communities in terms of floodplain agriculture, fishing, activities during socio-cultural events, tourism, etc. Fishing continues to be practised along this stretch, though there is a decrease in the overall size of the catch as well as a decrease in the size of individual fish.

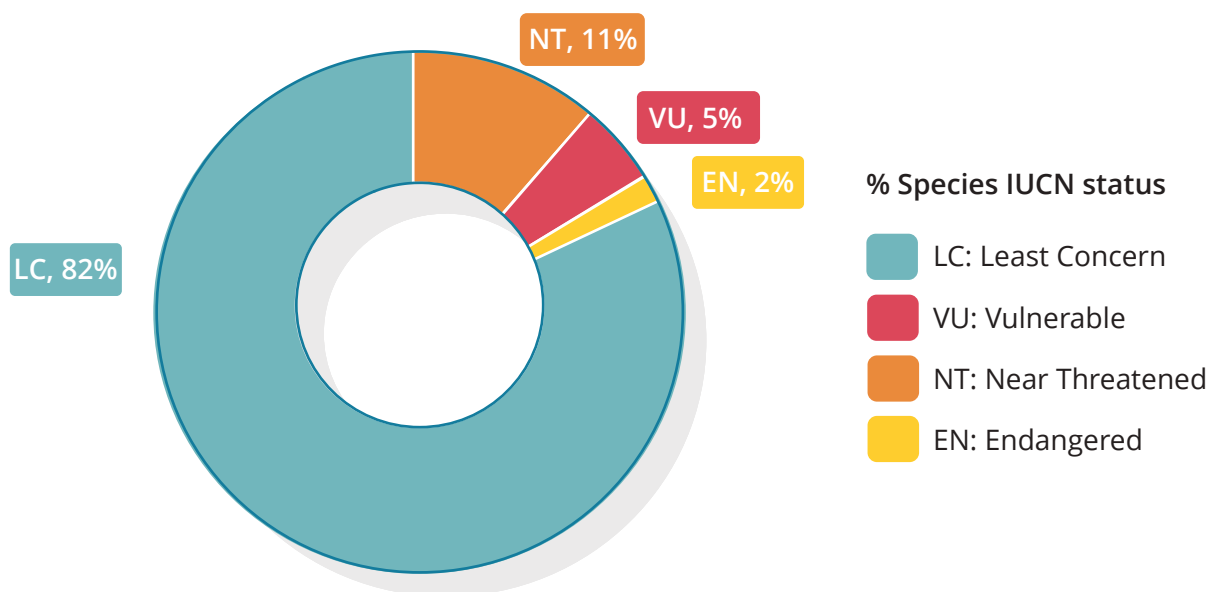
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<sup>44</sup>Tanner. 1891. Our present knowledge of the Himalaya Proceedings of the Royal Geographical Society. Vol. XIII. 1891



**Figure 147: E-Fows site location on the Gandak River**

A total of 61 fish species belonging to 41 genera, 20 families and 8 orders were recorded in the Gandak River during primary surveys and from secondary literature. Under the conservation status as per the IUCN Red List, 7 species are categorized as Near Threatened (NT); 3 are Vulnerable (VU) and one is under Endangered (EN) category. The percentages of fish species under IUCN category in the Gandak River are presented in Figure 148.



**Figure 148: Relative percentage of species as per IUCN Red Data List 2020 in the Gandak River**

The general hydrological and basic water-quality information about the Gandak River was taken during the survey and is tabulated in Table 52.

This section discusses the 'Present' and 'Desired' state of the river at the Khadda

| Parameters                             | Khadda           |
|----------------------------------------|------------------|
| RiverDepth in m Average, (min-max)     | 1.22 (0.64-2.10) |
| River Depth in feet Average, (min-max) | 4.03 (2.1-6.9)   |
| River Width (m)                        | 720              |
| Average Current velocity(m/sec)        | 0.21             |
| pH                                     | 7.2              |
| Temperature (°C)                       | 24.8             |
| Dissolved Oxygen (mg/l)                | 7                |
| Total Dissolved Solids (mg/l)          | 180              |
| Physical Appearance                    | Clear            |

**Table 52: Hydrological and Hydraulic information of the Khadda site during survey (July 2021)**

## 4.7.1 Khadda site

This site is located at the border of Uttar Pradesh and Bihar. This site is free from any industry and hence no effluents were observed. Dolphins and Gharials are present, as reported by locals. The Gharial migrates to Nepal during the summer season and returns to Uttar Pradesh during monsoon. It is an important site from a tourism and socio-cultural perspective. A crematorium is present near this site. The site is located at the Panihawa bridge which is 850m in length (within the confined bund on both sides).

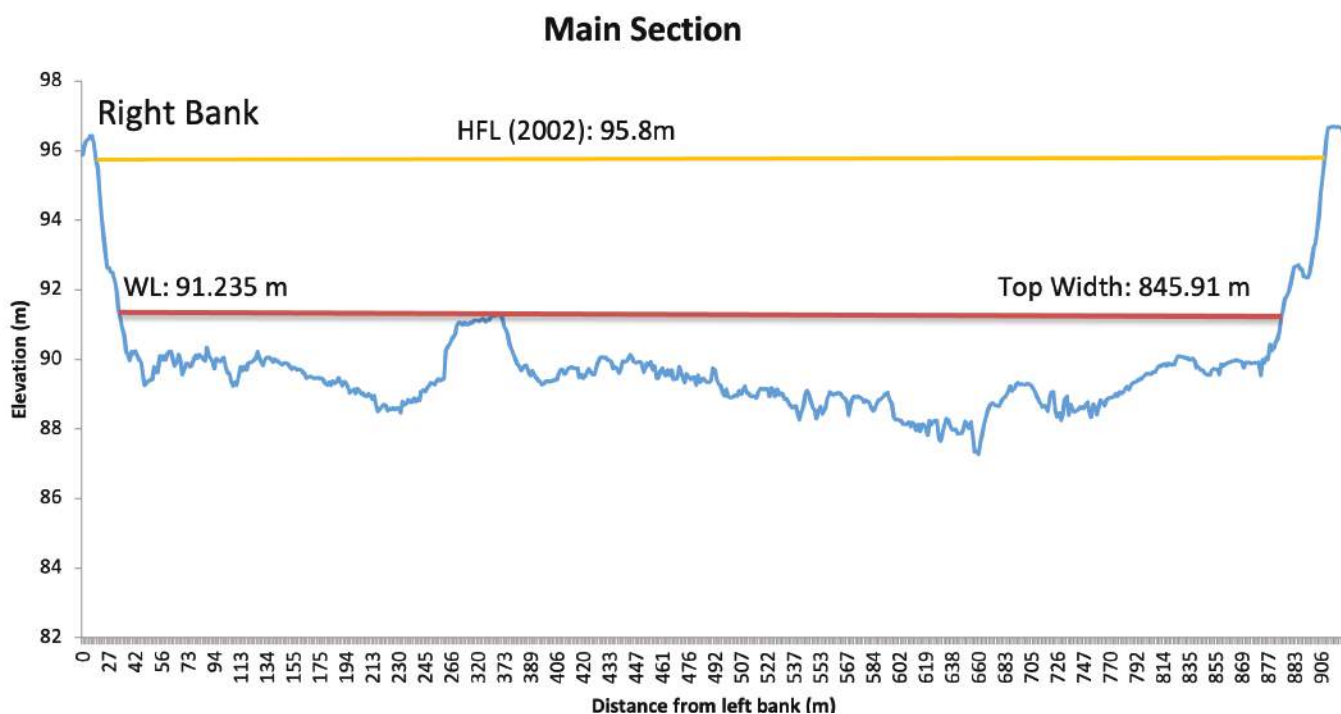
The cross sections at the site shows that the channel has an asymmetric form, and the thalweg lies more towards the right bank. The maximum width (1120m) and depth (22m) are associated with the main section. The substrate type is mostly quartz-rich and coarse-grained cratonic-type sand. A major sand-mining site was located downstream of the E-Flows site on the lateral and mid-channel bar.

The river is fast flowing at this location with riffles and pools and the substrate is mainly composed of silt and clay.





**Figure 149: E-Flows site on the Gandak River**



**Figure 150: Cross-section profile of Khadda E-Flows site on the Gandak River.**

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 889.33    | 6.67            | 3.98                        | 133.33                   |

**Table 53: Cross-sectional parameters for the Gandak River (From HFL).**

The 'Present' and 'Desired' state of the Gandak River at Khadda is discussed in a thematic fashion.

### 4.7.1.1 Khadda - Present state

#### A. Fluvial geomorphology

The Gandak River passes through the boundary between Uttar Pradesh and Bihar. The E-Flows site is located upstream of the Kushinagar-Paniyawaha road bridge and Northern railway bridge. The channel at this site is confined by the oblique bank stabilization structures, such as groins or dykes. The channel belt, as well as the active floodplain, have variable widths with a wider active floodplain along the right bank of the river. The lowest portion of the river runs closer to the right bank near the bridge. Many ephemeral streams join in the upstream and downstream regions. The river at this site has an asymmetric form, has high sinuosity and high multiplicity owing to its typical braided morphology. The multiple anabranches are connected to the main channel and are reactivated during a high-flow event. The Gandak River immediately downstream of the bridge site is highly sinuous and the point of bifurcation between the noticeable large anabranch and the primary channel is also a potential site of avulsion. The Valmiki Tiger Reserve is located on the left bank of the river, upstream of the site. Several mid-channel bars can be identified, both upstream and downstream of the bridge site. A large alluvial island can be identified immediately upstream of the bridge site (Figure 151). Also, relatively large lateral bars have been noted downstream of the bridge site. The channel substrate is primarily mica-rich coarse sand. The bar forms are elongated along the direction of the flow. The banks have been jacketed with rip-rap blocks to prevent erosion immediately upstream and downstream of the bridge site. Large marshy wetland bodies developed adjacent to the bridge site can be attributed to the construction of the embankments to protect the bridge site from erosion.

The Gandak River at this site is characterized by a primarily braided morphology and anabranches with large alluvial islands and large mid-channel bars and lateral bars. The channel is mostly asymmetric with a wide main channel near the bridge site and a high sinuosity downstream of the bridge site. Several reaches of the river in this stretch are identified as hotspots of aggradation. Planform dynamics indicates that the river is highly susceptible to in-channel migration (Figure 152). The maximum channel depth observed is 9.2m and maximum width observed is 895 m. In general, the longitudinal and lateral connectivity is very good for the Gandak River.



**Figure 151: (a) and (b) The geomorphic features at the Khadda site on the Gandak River**

## B. Aquatic biodiversity

In the Gandak river, a total of nine species were recorded from this site. Among those, one is in the Near Threatened (NT) category of the IUCN Red List, i.e. *Labeo pangusia*, one in the Vulnerable category (VU), i.e. *Wallago attu* and the other belonged to LC category, i.e. *Devario devario*, *Mystus vittatus*, *Macrognathus pancalus*, *Rita rita*, *Channa punctata*, *Mystus cavasius*, *Mystus aor*, etc. Ganga River Dolphins are also observed around this location.

The river lacks the sufficient amount of flows during lean season. Since the Valmikinagar barrage, the velocity of the river at Khadda has decreased. As a result of this, and also due to the deposition of sand, the river spreads out. In the summer, the river consists of deep pools linked by shallow channels.

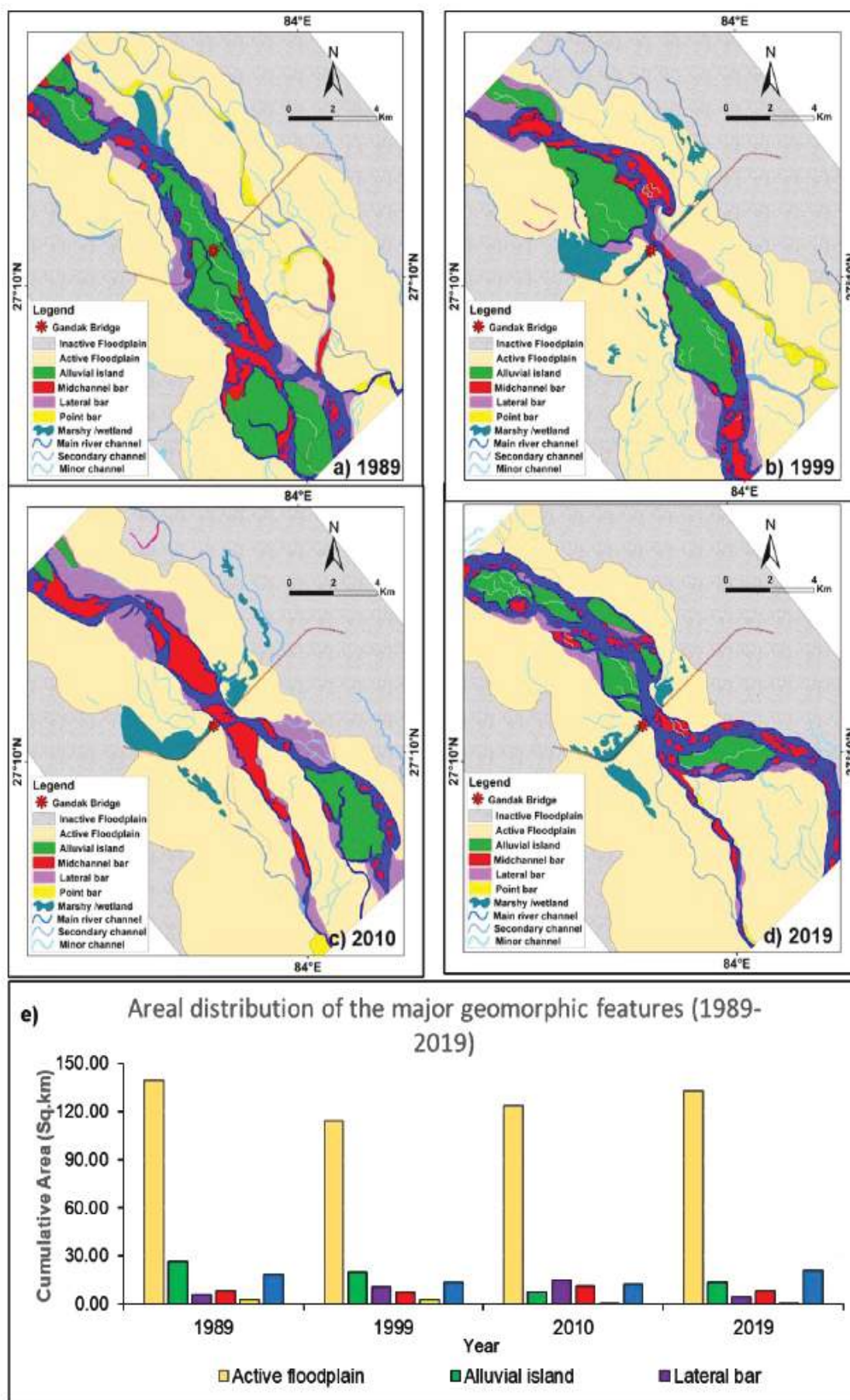
Water appears clear around this stretch and the water-quality parameters are within the limits (to satisfy Outdoor Bathing Water Quality Standards). This site is free from major pollution since there are no industries. Absence of ammonia and coliforms indicated no organic pollution in the river. The Chlorides, Nitrates, Phosphorus and Total Hardness were recorded within the prescribed range.

## C. Socio-cultural aspects

In recent years, the occurrence of yearly floods has reduced and the behaviour of the river has also become permeant.

Most of the land downstream of the section is given over to growing bananas. Some intercropping with broad beans, garlic, potatoes and other vegetables is also followed. People here have learnt to live with the floods; according to them,





**Figure 152(a, b, c, d):** Figure showing the geomorphic map of the Gandak River near the Gandak bridge for the years 1989, 1999, 2010, 2019; **(e)** Temporal changes in the area covered by different geomorphic units in the Gandak River near the Gandak bridge.

the crop immediately following a flood is ruined, but it improves the year after next. However, the farmers have witnessed a change in the nature of the flood deposits. Where earlier, the deposits would be a mixture of sand and silt, now it is mainly sand. Despite the diminished flows, several livelihoods continue to be practised along the river.

Fishing continues to be practised along this stretch, though nearly all the respondents mentioned that there is a decrease in the overall size of the catch as well as a decrease in the size of individual fish. Tourism also has a role to play in this site; several tourists visit the river from Gorakhpur and also travel to the National Park. There is a boating service, which ferries tourists partway across the river. They cannot go completely across due to low flows, but go as far as possible.

Searching for the *Shaligrams* (a special auspicious fossilized stone collected from the riverbed, used in worshipping God *Vishnu* in *Hinduism*) is an occupation that the team has witnessed here, a few kilometres upstream of the actual site. People mark out their territory and select suitable cylindrical stones, which are black with white markings. These are then sold wholesale for further shaping and polishing. *Shaligrams* are created when pebbles roll against each other along the bed of a swift-flowing river.

There are also quite a few socio-cultural ritual-based occupations that are practiced along this site. Several priests near the site make a living by carrying out rituals along the river. There is a cremation *ghat* at the site, which is used by the local and visiting people. In normal times, about 7-10 cremations take place at the site every day.



### 4.7.1.2 Khadda - Desired state

The 'Desired' state of the Gandak River downstream of the Gandak Barrage at Khadda is tabulated in Table 54.

| S. No. | Thematic Area         | Present State       | Reasoning/ Remarks – Present State                                                                                                                                                                                                                                                                                                                                                    | Desired State     |
|--------|-----------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | Primarily braided morphology and wandering/anabranching channels with large alluvial islands both upstream and downstream, respectively, hosting large mid-channel bars and lateral bars. The longitudinal connectivity is good, and the lateral connectivity is very good. Planform dynamics indicate that the river is highly susceptible to in-channel migration and bank erosion. | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | Long-range connectivity for species migration is hampered by barrages upstream; however, the water quality is good with no industrial and domestic effluent. The water level is getting controlled by the barrage operations, which is putting stress on the aquatic species.                                                                                                         | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | Lowest flows are in late-winter/early summer, around March. Then the flows continue to increase through summer. Annual floods have disappeared recently. The regulated flows are affecting the communities and their livelihood.                                                                                                                                                      | Slightly Modified |

**Table 54: Thematic desired state of the Gandak river downstream of the Gandak barrage at the Khadda site**



## 4.8 Sone River

The Sone river at Amarkantak in the Maikal range, with its nominal source being known as Sonmunda. It joins the Ganga River above Dinapore, after a course of just over 780 km. The E-Flows site at Chopan is close to the confluence of three rivers – the Tijul, Ren and Sone. The confluence is considered to be holy and is a popular bathing place. A mela is also held annually. Before the dams were constructed, the river had a pebble-laden bed. People believe that earlier, precious stones would sometimes be found among these pebbles and this led to the river being called the 'golden' or Sone river (from *Suvarna*).

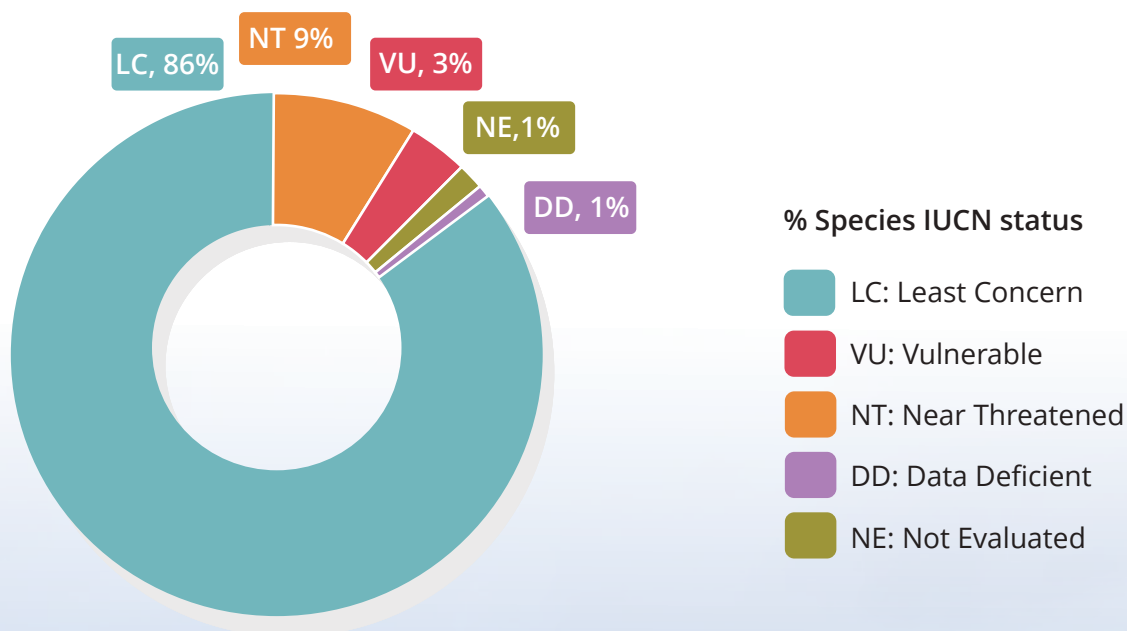
The zonation study has not been conducted because the river stretch within Uttar Pradesh boundary is only 90km, therefore only one site was selected at Chopan, which is also a Central Water Commission's hydro-observation site.



**Figure 153: E-Flows site in the Sone River**

A total of 90 fish species belonging to 62 genera, 25 families and 9 orders were recorded in the Sone River during primary surveys and in secondary literature. Under the conservation status as per the IUCN Red List 2020-3, 8 species are categorized as Near Threatened (NT) and 3 are in the Vulnerable (VU) category. The percentages of fish species under IUCN category in Sone River are presented in Figure 154.





**Figure 154: Relative percentage of species as per IUCN Red Data List in the Sone River**

The general hydrological and basic water-quality information about the Sone River during the survey is tabulated in Table 55.

| Parameters                             | Khadda           |
|----------------------------------------|------------------|
| River Depth in m Average, (min-max)    | 0.94 (0.61-1.29) |
| River Depth in feet Average, (min-max) | 3.1 (2.02-4.29)  |
| River Width (m)                        | 497              |
| Average Current Velocity(m/sec)        | 0.20             |
| pH                                     | 7.2              |
| Temperature (°C)                       | 23               |
| Dissolved Oxygen (mg/l)                | 6.3              |
| Total Dissolved Solids (mg/l)          | 87               |
| Physical Appearance                    | Clear            |

**Table 55 : Hydrological and hydraulic data collected during Aquatic biodiversity surveys (July 2021)**

The Present and Desired state for the Chopan E-Flows site on the Sone River is discussed in the upcoming section.

## 4.8.1 Chopan site

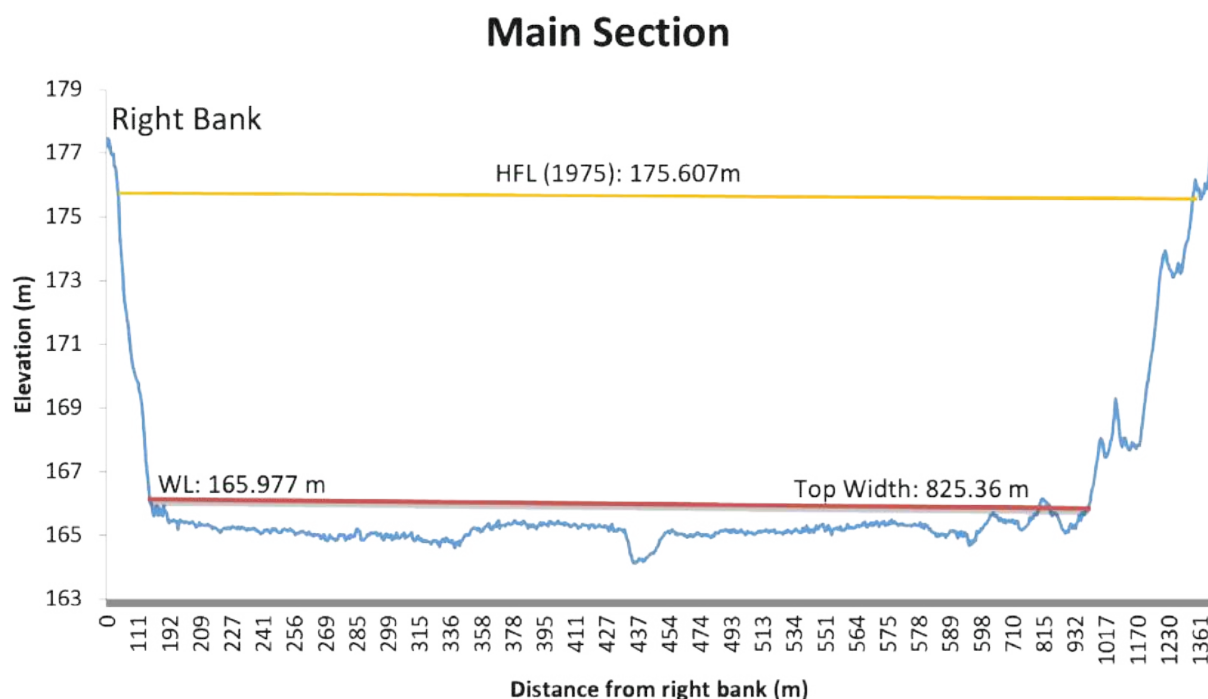
This site is located along the Sone River at the Chopan Bridge site. The E-Flows site is between two road bridges and a railway bridge. The river is looked upon as a diminished or reduced river. It was once known for its abundant flow with high stream power. The flows in the river are much reduced due to fragmentation and regulation of river waters by the Rihand and Obra dams upstream. In summer, the flows are reduced to half of those in winter, and the river flows as a thin, narrow stream with very occasional deep pools. At the Chopan Bridge, this stretch is the conjugation of three rivers i.e., Renu, Bijul and Sone.



**Figure 155: E-Flows site at Chopan on the Sone River**

The site is experiencing issues of pollution because of the effluents coming from factories. The accumulation of sediment is causing congestion in the riverbed, reducing its carrying capacity which is then degrading the habitats of fishes and their abundance. The water surface is covered by ash giving the river bed a blackish colour. Cultivation is being observed on the right bank. Locals bathe and wash clothes on the banks. This site is considered for E-Flows Assessment, as it was the only representative location on the Sone River within UP with the availability of observed flow data that can be used to cross validate the model outputs.





**Figure 156: Cross-section profile of the Chopan E-Flows site on the Sone River.**

| Cross Section | Width (m) | Max. Depth (m)* | Depth at time of survey (m) | w/d <sub>max</sub> ratio |
|---------------|-----------|-----------------|-----------------------------|--------------------------|
| Main Section  | 1400      | 13.3            | 1.77                        | 105.26                   |

**Table 56: Cross-sectional parameters for the Sone River (From HFL).**

The 'Present' and 'Desired' state of the Sone River at the downstream Chopan location is discussed in a thematic fashion.

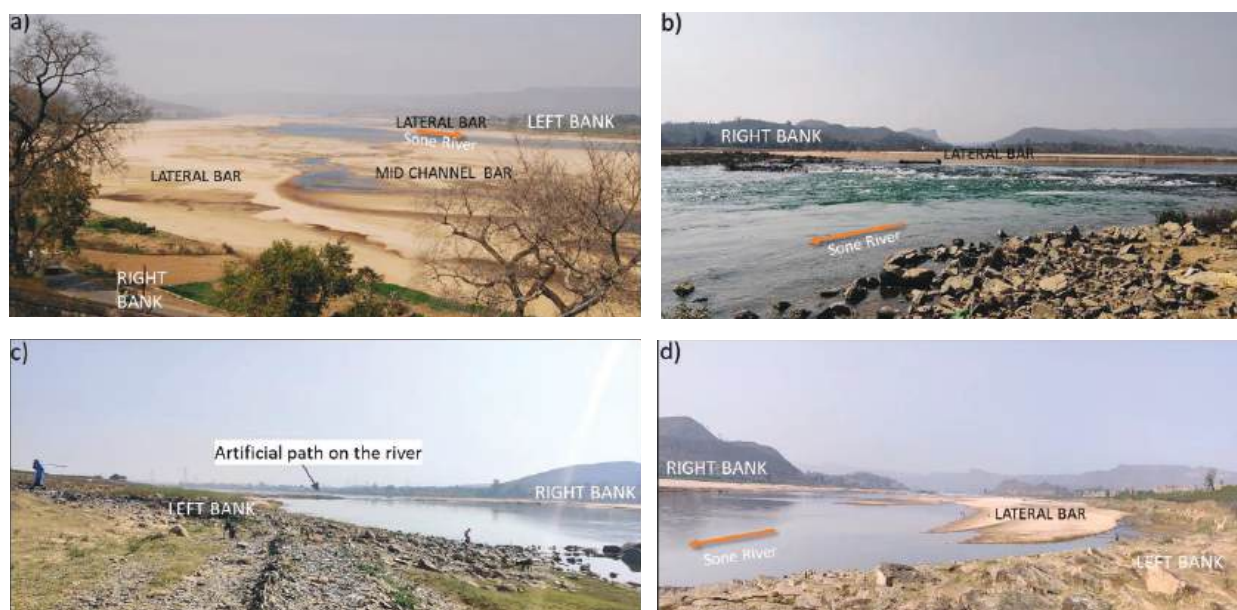
### 4.8.1.1 Chopan–present state

#### A. Fluvial geomorphology

The E-Flows site is between two road bridges and a railway bridge and this region is surrounded by hard undulating rock and hilly table land topographic features, of the geological Kaimur ranges. River Sone, Kanhar and Rihand are main perennial rivers in this stretch. The Kanhar and the Rihand Rivers both originate from Chhattisgarh and meet the Sone River on the right bank, upstream of the Chopan road bridge.

The Rihand Dam is the largest dam in India in terms of volume, located 40km upstream of the confluence. The other anthropogenic interventions on the river in this stretch are three bridges and Sone barrage, in the proximity of the E-Flows site. The channel around the road bridge site is characterized by an asymmetric form, sinuosity and high multiplicity. The primary channel flows towards the right bank near the bridge site. Large mid-channel bars and lateral bars are found in

both the upstream and downstream portions of the bridge site (Figure 157). Vegetated mid-channel bars and lateral bars have also been spotted in the downstream reaches. Since this is a classical braided river system, a major dependence on the river is for the unique coarser variety of sand highly suitable for sand mining.

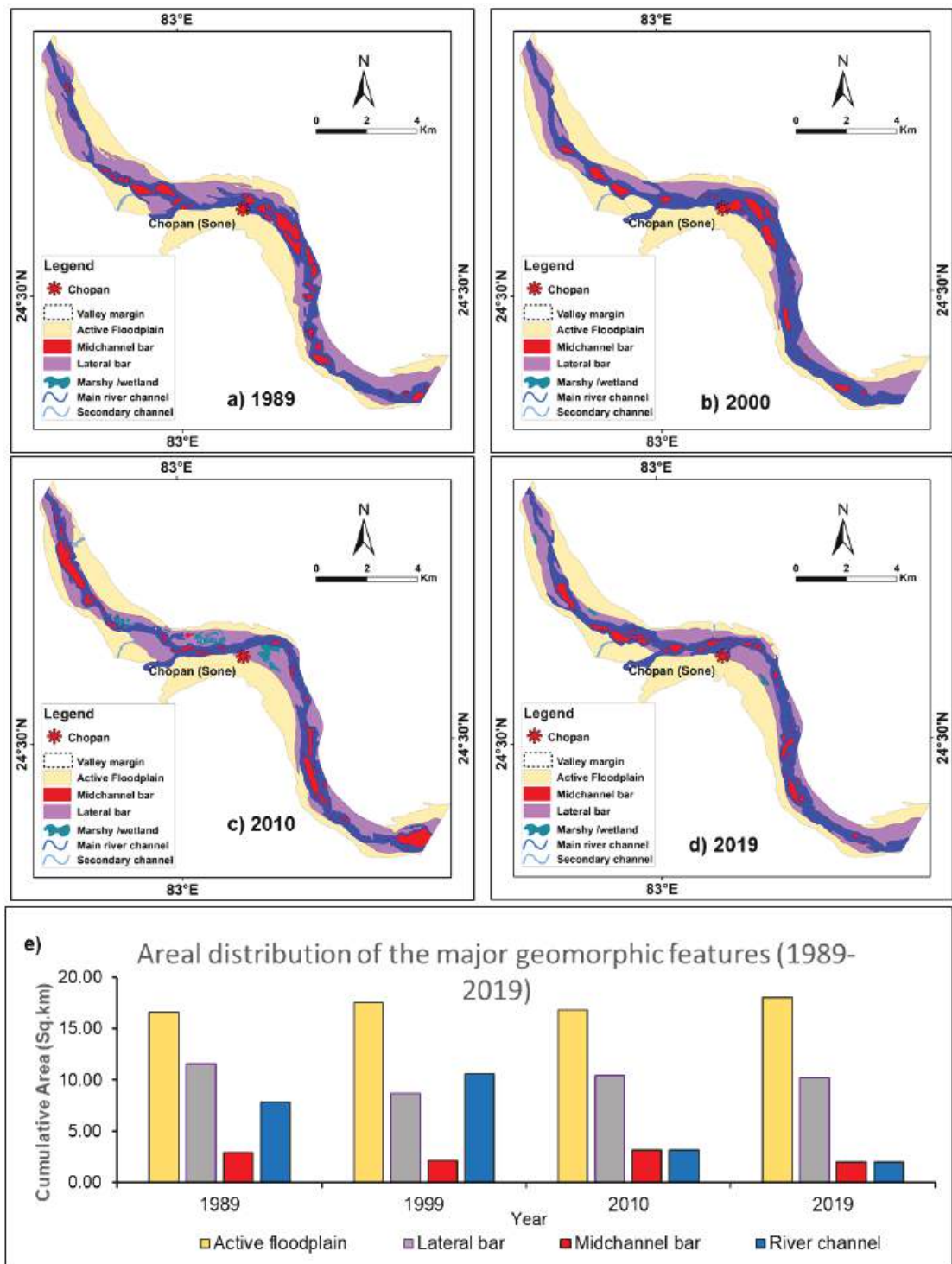


**Figure 157 (a & b): Mid-channel bar upstream of the Sone River bridge. Blasted limestone dust can be observed having settled on the channel substrate, considered to be detrimental to fish spawning; (c & d) downstream of the Sone River bridge, large lateral bar and numerous mid-channel bars can be observed.**

An interesting observation is the deposition of limestone dust generated from the mining and blasting activities, carried down by the Rihand River. This gets deposited in the channel substrate, and as per the local information, it is severely detrimental for fish spawning. Apart from limestone dust, blasted angular debris was also identified in the river channel. These are also used as a pathway to access the river for the transport of sand using mechanized vehicles.

The temporal planform maps of the Sone River near Chopan for the years 1989, 2000, 2010, 2019 are shown in Figure 158. The main channel is partly confined with discontinuous floodplains and depositional bars along the study stretch. Generally, the active floodplain area increased and the bar area decreased between 1989 and 2019.

In summary, the Sone River at this site is characterized by a braided pattern, with high multiplicity mostly in the upstream reaches and is partly confined by the valley setting. The channel form is mostly asymmetric and has variable widths while the floodplain width has remained consistent over the last three decades. There is a net increase in aggradation, reduction in channel area and good longitudinal connectivity. The main channel is partly confined with discontinuous floodplains and depositional bars along the study stretch. The main channel at Chopan does not show any major channel shift as the river is partly confined and the thalweg shows only minor shifts.



**Figure 158 (a, b, c, d): Figure showing the geomorphic map of the Sone River near Chopan for 1989, 2000, 2010, 2019; (e) Temporal changes in area covered by different geomorphic units in the Sone River near Chopan**

## B. Aquatic biodiversity

In the Sone River, a total of eight species were recorded from this site. Among those, one is in the Vulnerable (VU) category of the IUCN Red List, i.e. *Cyprinus carpio*, and the others are in the LC category, i.e. *Eutropiichthys vacha*, *Bangana dero*, *Xenentodon cancila*, *Raiamas bola*, and *Cabdio morar*. A market survey was carried out by the team in which they surveyed three fish species, viz. *Labeo rohita*, *Cirrhinus mrigala*, and *Cabdio morar*.



This E-Flows site is after the confluence of the three rivers. Upstream of the site the water is unpolluted, but downstream the water becomes polluted due to factory effluents, which joins the Sone River half kilometer upstream of the site. The factory effluents come from Renu nadi, which arises from a thermal plant, situated 11.3km upstream of the site. According to the locals, Gharials used to be seen on Karghara gaon (8km upstream) along with turtles, on a large scale previously, but their numbers have dwindled now. Sediment deposition is happening in this stretch, which impacts the abundance of fish. Local sand mining is present in this stretch.

Water appearance was clear and normal for this river stretch. The water-quality parameters are within the standard limits. The presence of ammonia indicated a slight trace of organic pollution in the river; probably because of the factory effluents. The Chlorides, Nitrates, Phosphorus and Total Hardness were recorded within the prescribed range.

### C. Socio-cultural aspects

The three rivers' confluence being an important spot for ceremonial bathing, days such as *Kartik Purnima* offer opportunities to many people living close to the river. Several cultural fairs are also held at this spot. *Chhath puja* is gaining in popularity at this section. The participants of a women's focus group discussion reported that earlier very few people performed this ceremony. However, the puja celebrations have attracted crowds for the last 7-8 years. *Ram Leela* and *Durga Puja* are also organized at the Ram Leela ground next to the river. There is also a ritual of introducing a bride to the river. When a bride arrives in her marital village, she is brought to the river where she offers prayers to Ganga. So, this site is critical from the socio-cultural perspective.

The water from the river is also used extensively for domestic purposes. The communities who live alongside the river access it directly for bathing, washing, cooking and drinking. Livestock herders graze their animals on the banks of the river and bring their buffaloes to bathe. *Pallage* farming (riverbed farming) is also observed on the banks of the river but they mostly rely on soil moisture and don't need any irrigation from the river.

According to the locals, the present flows have reduced due to the infrastructure built across the river. In the monsoon, the water stays within the channel bed. Floods go as far as the embankment downstream of the bridge but then recede almost immediately. In summer, the flows are a thin narrow stream and much more polluted than before.

### 4.8.1.2 Chopan - Desired state

The 'Desired' state of the Sone River Downstream of the Chopan bridge at Chopan is tabulated in Table 57.

| S. No. | Thematic area         | Present State       | Reasoning/ Remarks – Present state                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Desired State     |
|--------|-----------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| 1      | Fluvial Geomorphology | Moderately Modified | Characterized by a braided pattern in the upstream location and partly confined by the valley setting. The channel form is mostly asymmetric and of variable widths but the floodplain width has remained consistent. There has been a four-fold reduction in the active channel because of the dams constructed upstream. The longitudinal connectivity and lateral connectivity seem fair. The depositional area has been consistent; however, there are hotspots of aggradation. | Slightly Modified |
| 2      | Aquatic Biodiversity  | Moderately Modified | Fish abundance is reduced due to riverbed congestion, caused by sedimentation, low flows and increased pollution. The water level is controlled by the dam operations, which is putting stress on aquatic species.                                                                                                                                                                                                                                                                  | Slightly Modified |
| 3      | Socio-cultural        | Moderately Modified | In summer, the water flows as a thin narrow stream with occasional deep pools. In the monsoon, the water stays within the channel bed. Floods go as far as the embankment downstream of the bridge but then recede almost immediately. The regulated flows are affecting the communities and their livelihood.                                                                                                                                                                      | Slightly Modified |

**Table 57:**  
**Present and**  
**Desired state**  
**of the Sone**  
**River at the**  
**Chopan**  
**E-Flows**  
**location**

# 5. Environmental Flows Recommendations

The main motivation of E-Flows recommendations is to enhance the present River Health Class (RHC) of each river at every location. The description of various types of RHCs is given in Chapter 5. In Chapter 4, the River Health Class of each of the locations, along with the rationale was discussed. Table 58 lists location and theme-wise 'Present' and 'Desired' River Health Class. Along with that, a collective and agreed River Health Class (consolidated) is also mentioned. The purpose of this table over here is to give a quick snapshot of various RHCs of the E-Flows locations across the rivers.





| River   | Location                 | Thematic River Health Class(RHC)                           |                                                              |                                                            | Consolidated RHC                                                                                 |
|---------|--------------------------|------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|         |                          | RHC — Fluvial Geomorphology                                | RHC — Aquatic Biodiversity                                   | RHC — Socio-Cultural                                       |                                                                                                  |
| Sharda  | D/S Banbasa Barrage      | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                       |
|         | Palia Kalan              | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Slightly Modified<br>DESIRED: Near Pristine         | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified to Slightly Modified<br>DESIRED: Slightly Modified to Near Pristine |
| Ghaghra | D/S Lower Sharda Barrage | PRESENT: Moderately Modified<br>DESIRED: Near Pristine     | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                       |
|         | Elgin Bridge             | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Slightly Modified<br>DESIRED: Near Pristine         | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                       |
|         | Ayodhya                  | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Degraded<br>DESIRED: Slightly Modified            | PRESENT: Moderately Modified to degraded<br>DESIRED: Slightly Modified                           |
|         | Dohri Ghat               | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                       |
|         | Turtipar                 | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Slightly Modified<br>DESIRED: Near Pristine         | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                       |
| Gomti   | Mehndi Ghat              | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Moderately Modified to Degraded<br>DESIRED: Slightly Modified to Moderately Modified    |
|         | D/S Gomti Nagar          | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Critically Degraded<br>DESIRED: Moderately Modified | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Degraded<br>DESIRED: Moderately Modified                                                |
|         | Sultanpur                | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Degraded<br>DESIRED: Moderately Modified            | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified to Degraded<br>DESIRED: Slightly Modified to Moderately Modified    |
|         | Jaunpur                  | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified to Degraded<br>DESIRED: Slightly Modified to Moderately Modified    |
| Rapti   | Balrampur                | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Slightly Modified<br>DESIRED: Near Pristine         | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Slightly Modified<br>DESIRED: Near Pristine                                             |
|         | Bansi                    | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Slightly Modified<br>DESIRED: Near Pristine         | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Slightly Modified<br>DESIRED: Near Pristine                                             |
|         | Birdghat — Gorakhpur     | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified   | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                       |

| River  | Location                | Thematic River Health Class(RHC)                           |                                                               |                                                            |                                                                                               |
|--------|-------------------------|------------------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
|        |                         | RHC —<br>Fluvial<br>Geomorphology                          | RHC —<br>Aquatic<br>Biodiversity                              | RHC —<br>Socio-<br>Cultural                                | Consolidated<br>RHC                                                                           |
| Ganga  | Shahzadpur              | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified    | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                    |
|        | Rajghat—<br>Varanasi    | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified    | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                    |
| Yamuna | Mohana                  | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Degraded<br>DESIRED: Moderately Modified             | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Degraded<br>DESIRED: Moderately Modified                                             |
|        | Mathura (Gokul Barrage) | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified    | PRESENT: Degraded<br>DESIRED: Moderately Modified          | PRESENT: Moderately Modified to Degraded<br>DESIRED: Slightly Modified to Moderately Modified |
|        | Agra (Poiyaghat)        | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified    | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                    |
|        | Auraiya                 | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Slightly Modified<br>DESIRED: Near Pristine          | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Slightly Modified<br>DESIRED: Near Pristine                                          |
|        | Pratapapur              | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Slightly Modified<br>DESIRED: Near Pristine          | PRESENT: Slightly Modified<br>DESIRED: Near Pristine       | PRESENT: Slightly Modified<br>DESIRED: Near Pristine                                          |
| Gandak | Khadda                  | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified    | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                    |
| Sone   | Chopan                  | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modifiedvav | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified | PRESENT: Moderately Modified<br>DESIRED: Slightly Modified                                    |

**Table 58: Present and Desired River Health Class of each of the locations on every river in a theme-wise consolidated manner**

# 5.1 The E-Flows setting exercise

It is critical to understand the process followed to arrive at the E-Flows recommendations under this initiative. There are standard approaches that WWF-India and partners have been jointly working upon for over a decade.

Before the beginning of the E-Flows Setting exercise, the objective-setting was done by the aquatic biodiversity, socio-cultural & livelihoods and fluvial geomorphology thematic teams. The thematic teams set the desired objective for each of the E-Flows locations from every river. The purpose recommend suitable conditions to reach the objective. The objective-setting allows the thematic groups to concentrate on the integration of specific objectives into a final set of for E-Flows requirements at each of the study sites.

After reaching a consensus about the River Health Class, the general Hydrology and Hydraulic aspects for each site were presented. The 'Flows Motivation Forms' were filled by specific thematic groups (Fluvial Geomorphology, Biodiversity, Socio-cultural & Livelihood) (i) for each of the seasons, and (ii) for both Maintenance & Drought years requirement. They provided required depth and velocity for specific item/ activity/ process/ species. The highest value was debated, and clarity was reached regarding the rationale behind why such water depths are necessary and what the implications are of not achieving those levels.

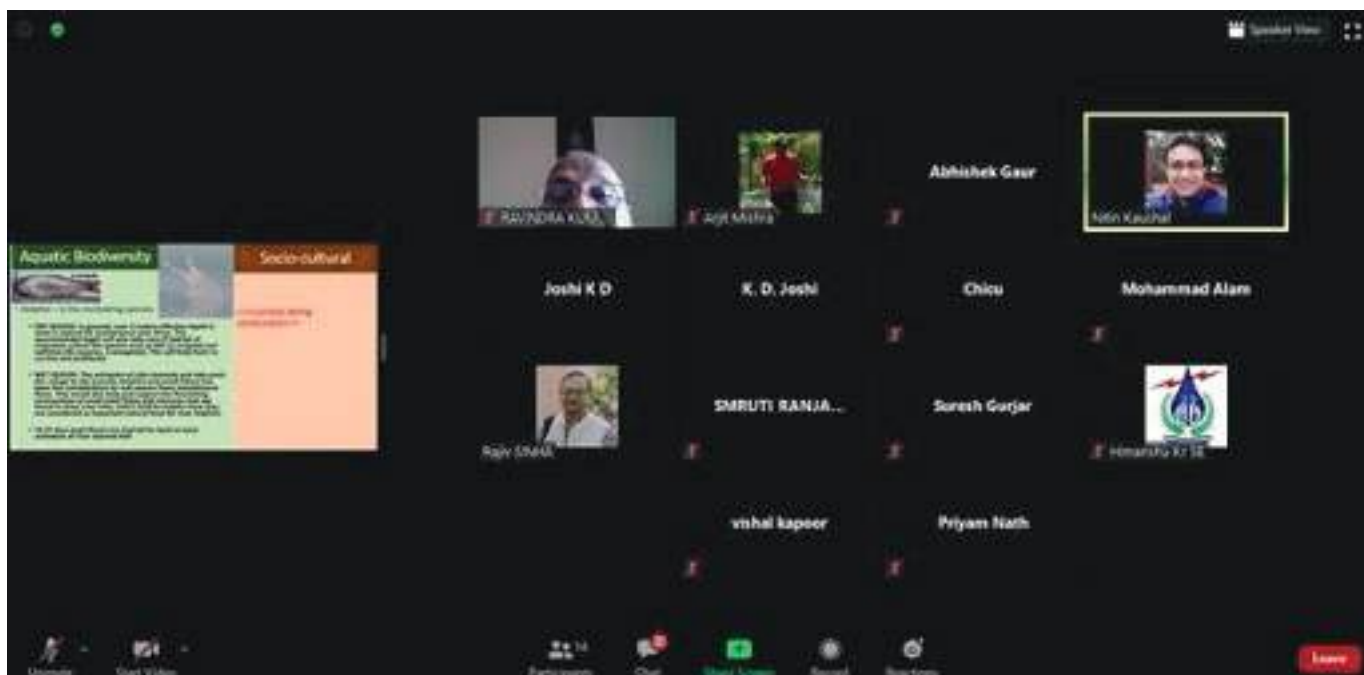
The value thus agreed upon was then converted into flows (cumec) and cross-checked against the available information about the hydrology at that site and for that season, i.e. whether that flow would be practically possible. After the validation of this flow value for a given site, the same was considered as an E-Flows recommendation for that season and for that scenario.

In general, the E-Flows Setting process is a highly iterative and deliberative process, which deserves physical sessions with the entire team. However, in view of the COVID-19 pandemic, this was not possible. Therefore, the team decided to conduct online E-Flows Setting Sessions. This required the thematic teams to do a lot of preparatory work before coming together for the virtual E-Flows Setting Sessions. The thematic teams were requested to fill respective 'Flows Motivation Forms' (Annexure 2A to 2C) for each of the E-Flows locations and for each of the seasons (Lean and Wet). This was done for both kind of years, i.e.

- a. Maintenance Year: a normal year which is neither, very wet, nor very dry
- b. Drought Year: when the situation is not like a normal year, but still some fundamental riverine ecosystem functions and processes are required to take place

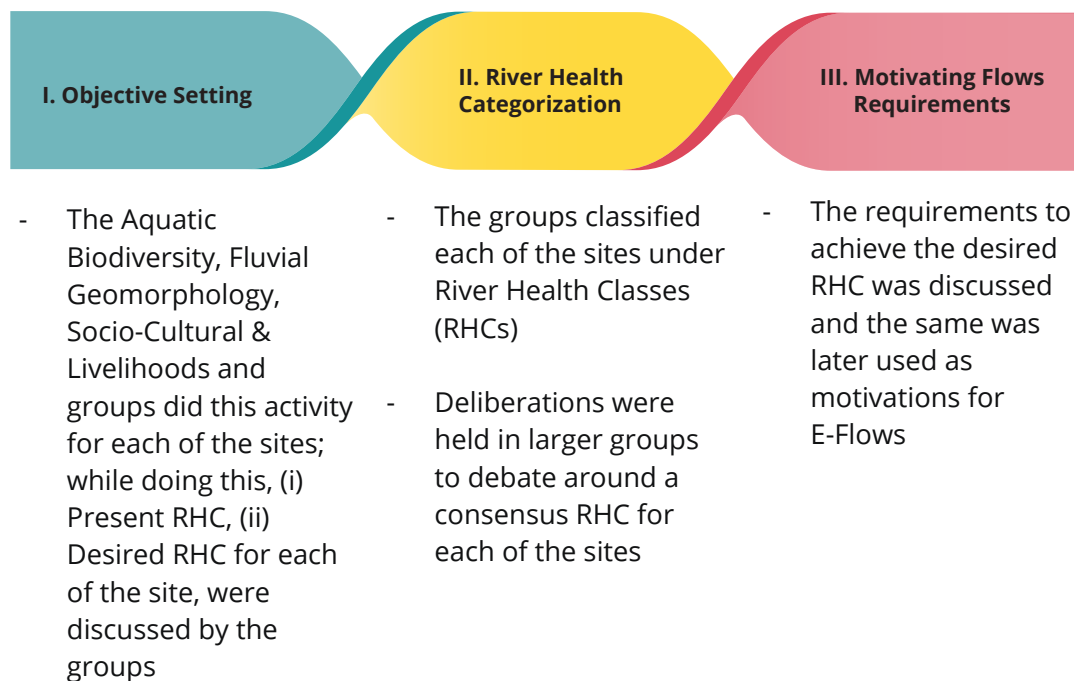
The virtual E-Flows Setting Sessions were conducted on September 21, 22 and October 8, 2020 and August 1, 2023.





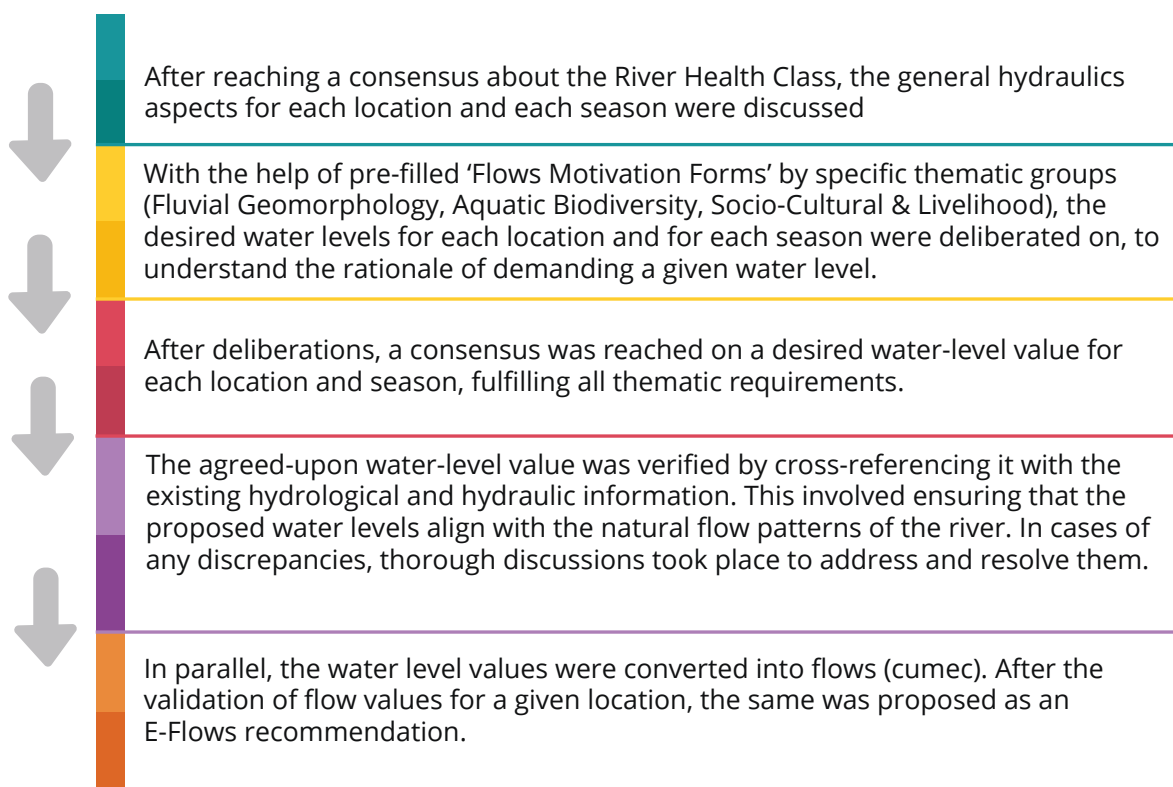
**Figure 159: Virtual E-Flows Setting Sessions on September 21 and 22, 2020 and on August 1, 2023**

The key steps in the E-Flows Setting Sessions are illustrated in Figure 160.



**Figure 160: Sequence of activities during E-Flows Setting Sessions**

Figure 161 illustrates the step-by-step process to arrive at E-Flows recommendations, once the 'Present' and 'Desired' state of the river was decided by various thematic groups on the basis of River Health Classes (Table 58).



**Figure 161: Step-by-step process chart to arrive at E-Flows recommendations**

The recommended water levels<sup>48</sup> were deliberated upon and validated with the historical hydraulics and hydrological information for that specific location and for that specific season. After conducting these checks, the E-Flows were determined for both the 'leanest' and 'wettest' months. These values were extrapolated for other months of the year by taking ratios of monsoon months with reference to the wettest month value and non monsoon months with reference to the leanest flow month, to draw a monthly regime of flows. Some manual adjustments at few locations were done so that it should mimic natural/present day flow hydrographs. The graphs generated from this exercise are presented as E-Flows recommendations for various locations. The desired 'water-levels' or 'depth' for each season and each location of the rivers is given with rationale in the tables under the sub-section on E-Flows recommendations. The rationale or motivation (in detail) for desiring such water levels are discussed in Flows Motivation Forms (Annexure 2A to 2C).

In the case of some of the E-Flows locations, the reliable gauge versus discharge information was either not available or inadequate. Therefore, arriving at E-Flows recommendations was not possible for some locations. Besides, during the process of input data processing and cleaning for hydraulic modelling, it was observed that the Gauge-Discharge data at same water levels have large variations. This was a bottleneck in generating simulated hydraulic parameters at seven locations. In light of this, the team could only recommend 'desired water levels' at seven such locations, i.e.

- a. Downstream of the Banbasa Barrage – Sharda River
- b. Downstream of the Lower Sharda Barrage – Sharda River
- c. Dohri Ghat – Ghaghra River
- d. Mehndi Ghat – Gomti River
- e. Rajghat Varanasi - Ganga River
- f. Khadda – Gandak River
- g. Chopan – Sone River

Amongst these seven locations, the Mehndi Ghat (Upstream of barrage in Lucknow city) location on the Gomti River is an even more complex location in terms of recommending E-Flows. This is because the flows and velocity are influenced by the operation of the downstream barrage near Gomti Nagar in Lucknow. Under such conditions, it would be better to recommend desired water level instead of flows, as there could be inherent issues.

For the rest of the locations, the E-Flows recommendations are made in terms of flows (cumec). It is proposed that while E-Flows graphs on a monthly flows pattern would be presented for all the locations, except the above eight locations; for these eight locations, gauges should be installed and a joint mechanism to monitor water levels should be devised for E-Flows monitoring.

While formulating E-Flows recommendations for the Yamuna River in Uttar Pradesh, two scenarios are considered:

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<sup>48</sup> The water level is calculated from the deepest part of the river channel looking at the specific Cross Section.



1. Target Scenario: This scenario focuses on immediate goals, striving to achieve defined objectives with acceptable trade-offs. It addresses questions related to healthy biodiversity, biophysical processes, and the provision of ecological services for people and nature.

2. Improved Scenario: It is a visionary scenario, which is likely to be achieved in the long run, as the river is substantially impacted; therefore, a systematic and gradual approach is better. It is also expected that, in order to achieve the Improved Scenario, we first need to achieve the Target Scenario for the river at a given site.

The sites where these two scenarios were generated are:

- a. Mohana site – Yamuna River
- b. Mathura site – Yamuna River
- c. Auraiya site – Yamuna River
- d. Pratappur – Yamuna River

At the Mathura site on the Yamuna River, the long-term data shows a discrepancy in the water level and discharge values. So, in order to gain confidence, the team held deliberations with the Mathura Barrage authorities (U.P. Irrigation & Water Resources Department) and obtained reliable information from them, and the same has been used for the analysis.

## 5.2 E-Flows Recommendations

This section presents the E-Flows recommendations for each of the locations. The full suite of explanations with respect to the need for desired flows and consequences of not having desired flows are available in the Flows Motivation Forms (Annexure 2A to 2C). Here, key thematic motivations have been captured to explain the rationale behind a given E-Flows recommendation.

### 5.2.1 Sharda River

As noted earlier, the gauge versus discharge (flows) information for two out of the three locations on the Sharda River is not usable. Therefore, the team proposed desired water levels for these locations. However, with robust and credible gauge versus discharge information, these values can be converted into flows. Nevertheless, the proposed E-Flows as part of this study are elaborated in the sections ahead.

## 5.2.1.1 Downstream of the Banbasa Barrage

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 59.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                  | <p><i>Tor putitora</i> is the motivating species. Recommended flows will also take care of required habitat for original resident fish species such as <i>Bangana dero</i>, <i>Labeo dyocheilus</i>, <i>Chagunius chagunio</i>, and <i>Crossocheilus latius</i>. During dry season, the desired flows are required to maintain a conducive hydraulic depth for the species to survive. During wet season, the desired flows would ensure inundation of side channels. This will allow smaller fishes, young ones and juveniles to move there for spawning/breeding purposes and return to the mainstream channels later on. This means survival and proliferation for the species. The desired conditions are essential for movement of biota for breeding, feeding and maintaining an exchange of rich nutrients.</p> |
| Drought Year     | <p>During dry season, the recommended water level is the bare minimum depth in which the fish species are likely to survive and withstand the stress caused by drought. The depth recommended for wet season would help in inundation of lateral side channels. This depth for extreme drought conditions will help in the survival of the fish stocks and protection of species from adverse conditions. This will also be helpful for the survival and growth of the desired fish food organisms. The depth during the wet season is desired for the influx of nutrients, survival and growth of organisms, and for breeding purposes.</p>                                                                                                                                                                           |

**Table 59: Desired water levels/depths along with rationale for the Downstream Banbasa Barrage E-Flows location on the Sharda River**

|                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                           | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                | Socio-cultural Aspects                                                                                                                                                                                    | <p>Dry season: 2 m<br/>Wet season: 4 m</p> <p>[The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity, mainly for <i>Tor putitora</i> fish species. Although Fuvial Geomorphology and Socio-cultural thematic also desired similar water levels for wet season.]</p> |
| <p>The desired flows would maintain the longitudinal connectivity of the river during the dry season. The primary channel will be inundated, which runs closer to the right-bank side of the channel belt. During the wet season, the desired flows will maintain continuity in less dominant secondary channels. The desired flows will also maintain the lateral connectivity.</p> | <p>The revival of the river profile was desired over more flows. A narrower and deeper profile of the river was desired. Present flows cause inconvenience to the worshippers, boatmen and villagers.</p> |                                                                                                                                                                                                                                                                                                      |
| <p><i>An additional requirement is a depth of 4.65m for a period of 10-15 days in the months of July-August-September This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p>                                                                                                                            |                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                      |
| <p>The recommended water levels would aid in maintaining the longitudinal connectivity during the lean season. The recommended wet season flows would not really help in achieving absolute lateral connectivity, but an enhanced active width of the channel will aid some level of lateral connectivity.</p>                                                                       | <p>The river profile is a critical issue from this perspective, nevertheless the present-day flows are accepted as desired flows for a Drought Year.</p>                                                  | <p>Dry season: 1.5m<br/>Wet season: 2.5m</p> <p>[The motivating thematic for desired depth for both seasons is Aquatic Biodiversity, mainly for <i>Tor putitora</i> fish species]</p>                                                                                                                |



Figure 162 illustrates the various depth requirements for different seasons at the cross-section profile of the Downstream Banbasa Barrage E-Flows location.

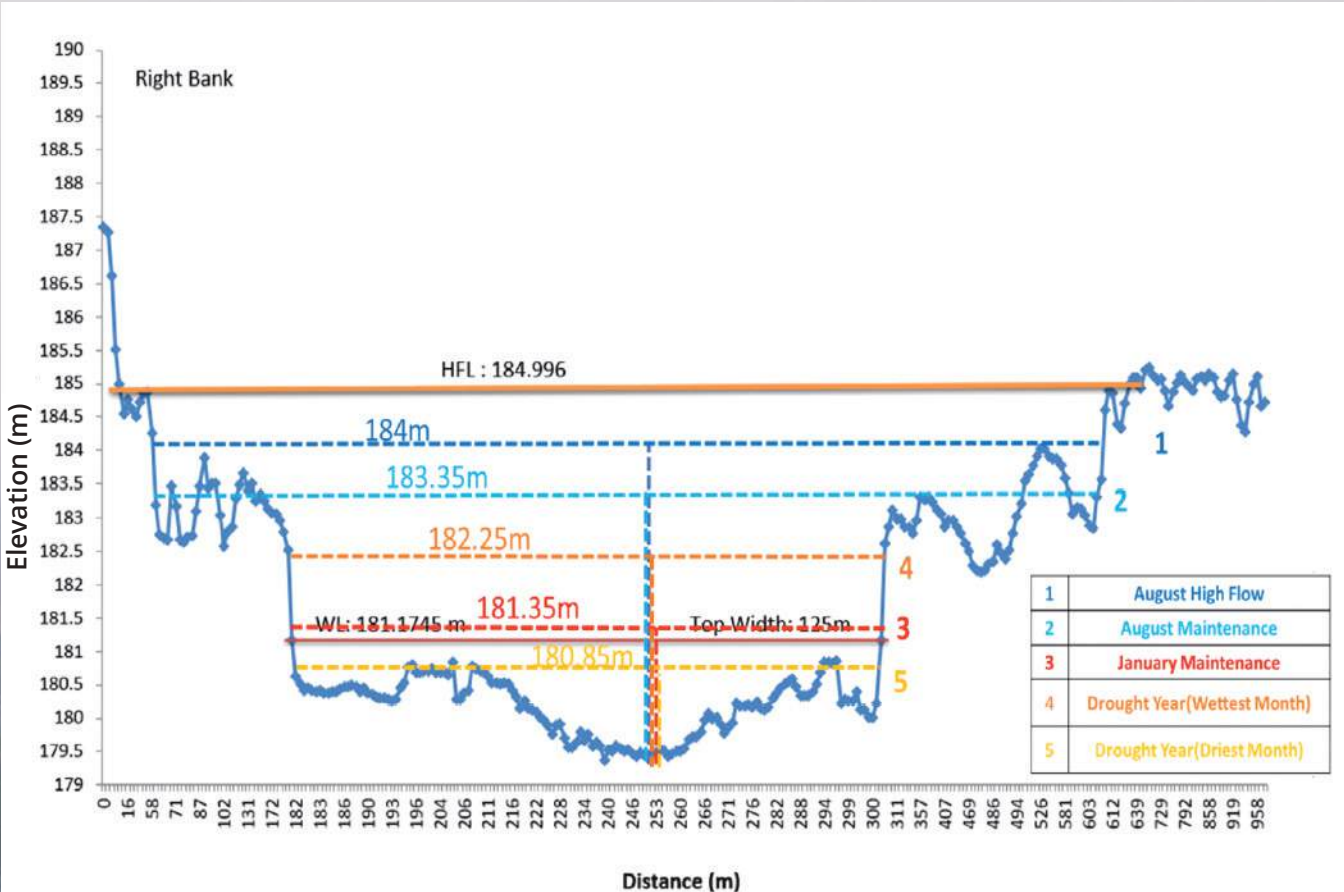
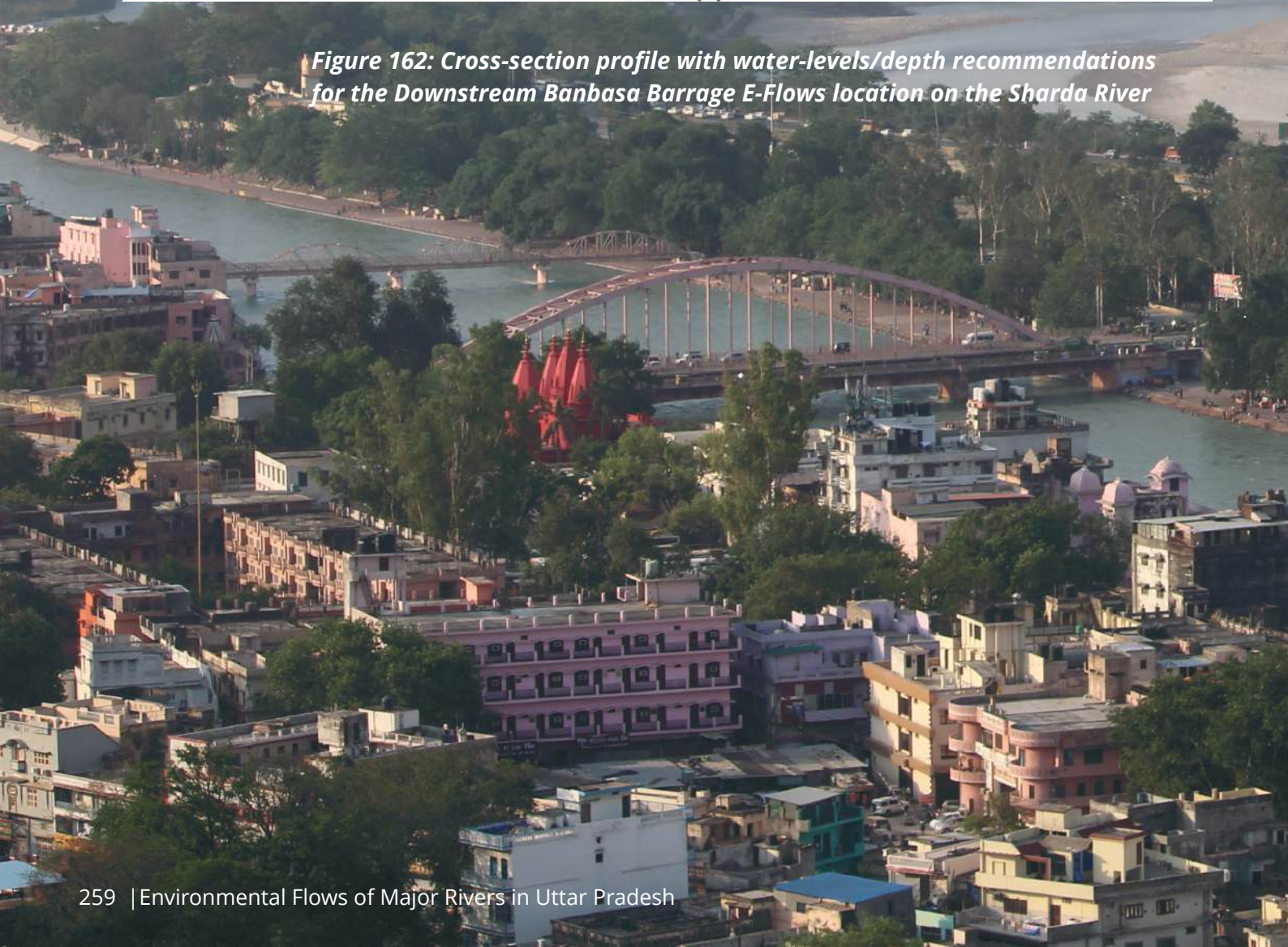


Figure 162: Cross-section profile with water-levels/depth recommendations for the Downstream Banbasa Barrage E-Flows location on the Sharda River









## 5.2.1.2 Palia Kalan

The consensus values for the desired water levels or depths for various seasons for Palia Kalan location along with the rationale is given in Table 60.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | Aquatic Biodiversity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                  | During the dry season, the recommended depth is essential for providing space for the Ganga river dolphin's normal body movement and prey. Feeding grounds increase with increasing depth. River dolphins tend to spend a majority of their time in areas with abundant food supply. During the wet season, the recommended water levels would aid in the formation of side pools/wetlands, which would also help and support the flourishing communities of small-sized fishes and minnows to flourish. The recommended depth would support complete inundation of side channels during wet season. |
| Drought Year     | The recommended depth is essential for the survival of the Ganga river dolphin population during stress conditions, This will also provide required width of the river bed, which is necessary as per the substratum condition at the location.                                                                                                                                                                                                                                                                                                                                                      |

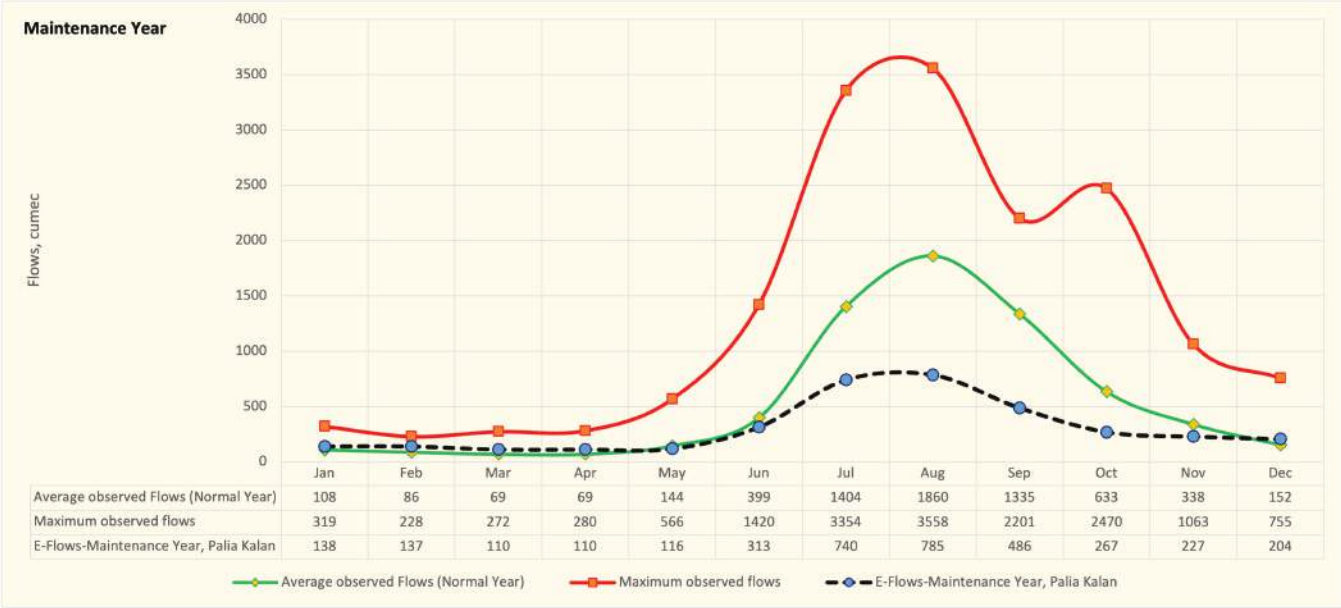
**Table 60: Desired water levels/depths along with rationale for the Palia Kalan E-Flows location on the Sharda River**



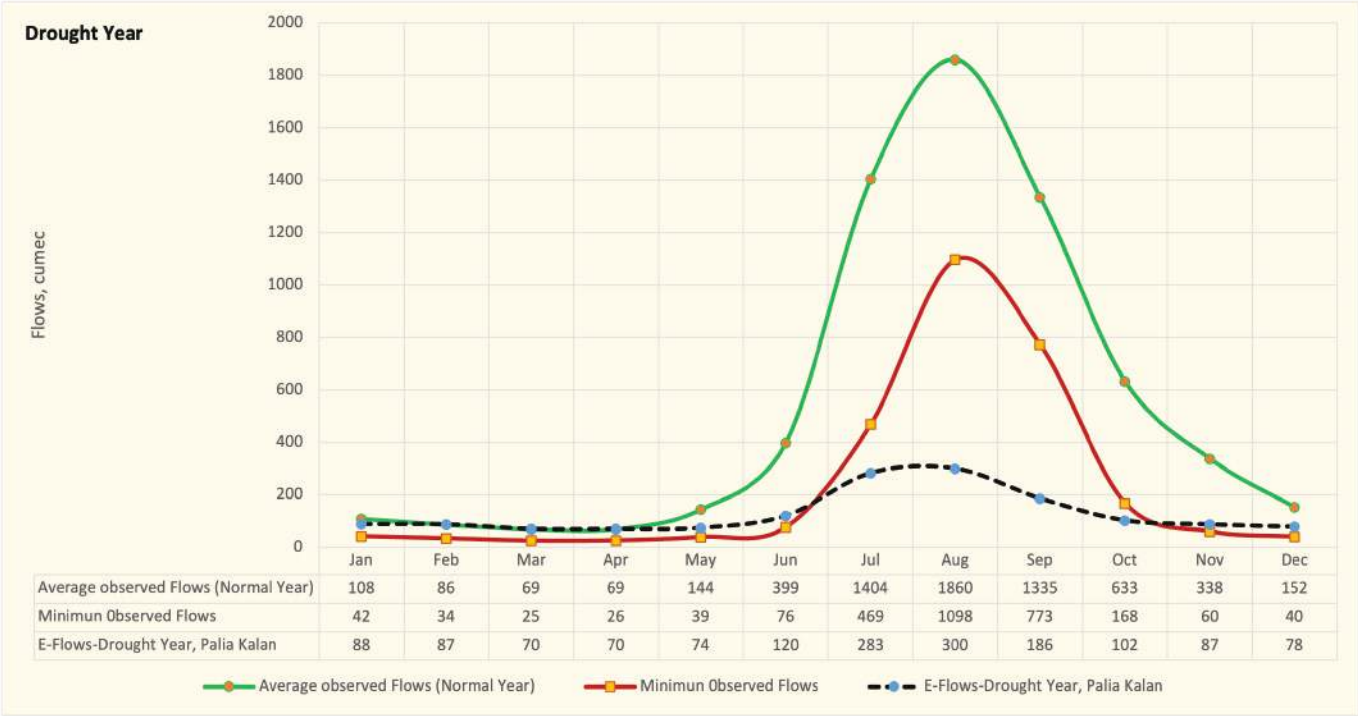
|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                               | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                            |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Socio-cultural Aspects                                                                                                                                                                        | <p>Dry season: 3.1 m<br/>Wet season: 4.8 m</p> <p>[The motivating thematic for desired depth for dry season are Aquatic Biodiversity (Ganga river dolphin). Fluvial Geomorphology (Longitudinal Connectivity) and Socio-Cultural (Ritual Bathing). The wet season desired depth is motivated by Fluvial Geomorphology thematic.]</p> |
|  | <p>The dry season recommendations will partially inundate the bars and maintain the longitudinal connectivity of the channel, and also ensure some flow in the secondary channel which lies closer to the right bank of the channel belt. The wet season recommendations will maintain lateral connectivity of the river at this location and keep the bar forms submerged.</p> <p><i>An additional requirement is a depth of 5.4 m (1000 cumec) for a period of 10-15 days in the months of July, August, and September, which will maintain lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p> | <p>Convenient ritual bathing is critical from this perspective and the recommended depth would ensure the same.</p>                                                                           |                                                                                                                                                                                                                                                                                                                                      |
|  | <p>The recommended water levels are the least that are required for ensuring longitudinal connectivity during dry season. Some level of lateral connectivity is the prime motivation for drought year</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <p>The group concluded that waist-deep water is the minimum depth required for convenient bathing. In a drought year, people are willing to wade further from the banks for a ritual dip.</p> | <p>Dry season: 3 m<br/>Wet season: 3.8 m</p> <p>[The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity, mainly for the Ganga river dolphin. Though Fluvial Geomorphology desired similar depth for the wet season.]</p>                                                                             |



The observed hydrology for this location was available. Therefore, the modelled flows could be validated and calibrated. Based on this, and in light of the water levels recommendations made by the team, the E-Flows graphs for both Maintenance Year and Drought Year have been developed (Figure 163 & 164).



**Figure 163: E-Flows recommendations in a monthly flows pattern-  
Palia Kalan location (Maintenance Year)**



**Figure 164: E-Flows recommendations in a monthly flows pattern-  
Palia Kalan location (Drought Year)**



### 5.2.1.3 Downstream of the Lower Sharda Barrage

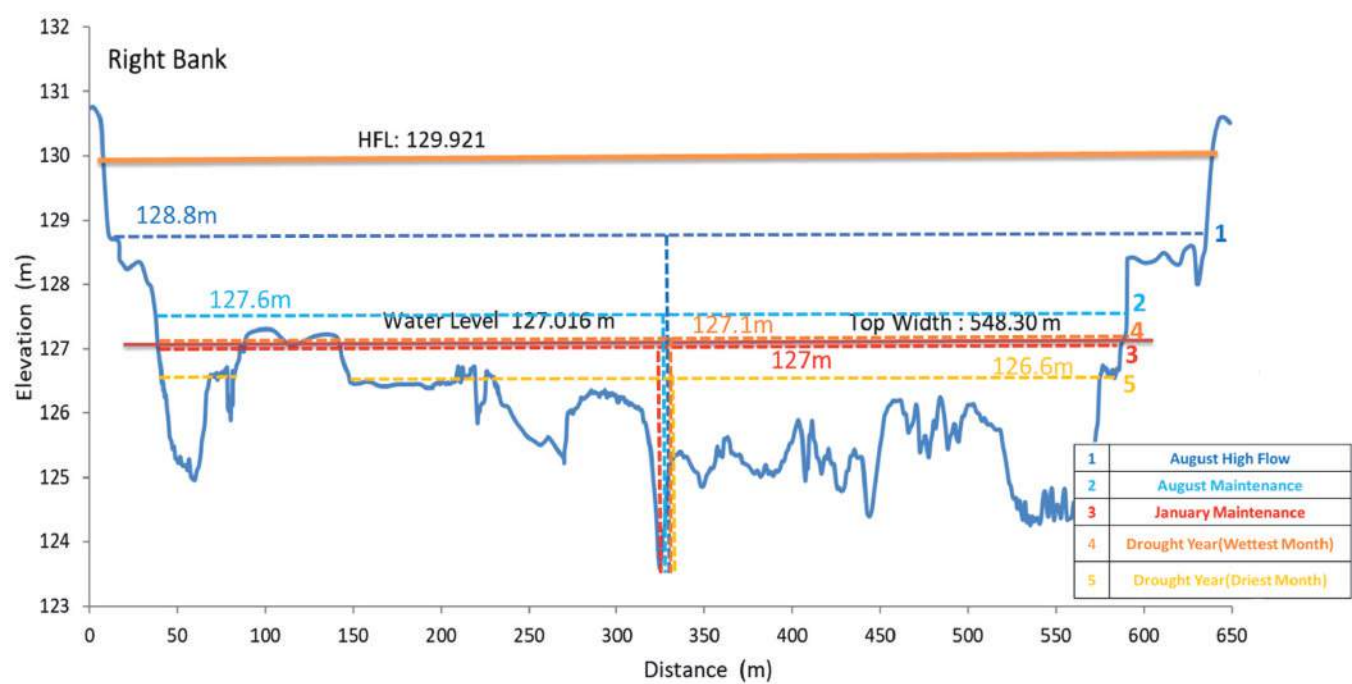
As noted earlier in Section 5.2, water levels are recommended for this location. The water levels/depth desired as E-Flows are based on thematic motivations, which are shown in Table 61.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | Aquatic Biodiversity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                  | During the dry season, the recommended depth is essential for providing space for the Ganga river dolphin's normal body movement and ensuring food base. Feeding grounds increase with increasing depth. River dolphins tend to spend a majority of their time in areas with abundant food supply, which include extended depth. During the wet season, the recommended water levels would aid in the formation of side pools. Wetlands formed would also help and support the flourishing communities of small-sized fishes and minnows. This will be helpful since they are considered an important natural food for the Ganga river dolphin. The recommended depth would support complete inundation of side channels during the wet season. |
| Drought Year     | The minimum desired depth and river width is necessary for the survival of the Ganga river dolphin population during extreme conditions. The recommended depth would also ensure the required width of the river-bed, which is necessary according to the substratum condition of the location, in addition to providing sufficient depth during drought years.                                                                                                                                                                                                                                                                                                                                                                                 |

**Table 61: Desired water levels/depths along with rationale for the Downstream Lower Sharda Barrage E-Flows location on the Sharda River**

|  |                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                      | Desired Water Level<br>(consensus values)                                                                                                                                                                                                    |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                     | Socio-cultural Aspects                                                                                                                                                                                                               | Dry season: 3.4 m<br>Wet season: 4 m<br><br>[The motivating thematic for desired depth for both seasons is Aquatic Biodiversity, mainly for the Ganga river dolphin. Though Fluvial Geomorphology desired similar depth for the wet season.] |
|  | The desired water levels during the dry season will maintain the longitudinal connectivity of the river. While in the wet-season, recommended water levels will inundate the primary channel along with the submergence of the bar forms. | The recommended water levels during the dry season would provide convenient waist-deep water near the bank for ritual bathing. For the wet season, the group aspired that the river should regain its 'swift, narrow, deep' profile. |                                                                                                                                                                                                                                              |
|  | An additional requirement is a depth of 5.2m for a period of 10-15 days in the months of July-August-September. This will maintain lateral connectivity completely inundating the channel belt and a portion of the floodplain region     |                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                              |
|  | The recommended water levels represent the minimum necessary for ensuring longitudinal connectivity during the dry season, while maintaining some degree of lateral connectivity is the primary motivation during drought years.          | Fishing would be impacted during the lean season due to reduced water levels. However, the recommended water levels would ensure satisfactory ritual bathing.                                                                        | Dry season: 3 m<br>Wet season: 3.5 m<br><br>[The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity, mainly for the Ganga river dolphin.]                                                                    |

Figure 165 illustrates the various depth requirements for different seasons at the cross-section profile of the Downstream Lower Sharda Barrage E-Flows location.



**Figure 165: Cross-section profile with water-levels/depth recommendations for the Downstream Lower Sharda Barrage E-Flows location on the Sharda River**

### 5.2.2 Ghaghra River

Looking at the available hydrological information, prima facia this river exhibits a reversal of flows regime, i.e. more flows in the upstream locations and lesser flows in the downstream locations. This could be because of many reasons:

- (i) Stretches of the river are losing water to the ground and thus become 'losing' in between locations one and four. Neither of the reasons can be conclusively established and therefore, the E-Flows recommendations should be viewed in light of these possibilities.
- (ii) These may be floodplain wetlands or deep pools along the way from one site to the next site. Some portion of water from the first site may get filled into these wetlands or deep pools before reaching the next site.
- (iii) Data discrepancies







### 5.2.2.1 Elgin Bridge

The water levels/depth desired as E-Flows requirements based on thematic motivations are shown in Table 62.

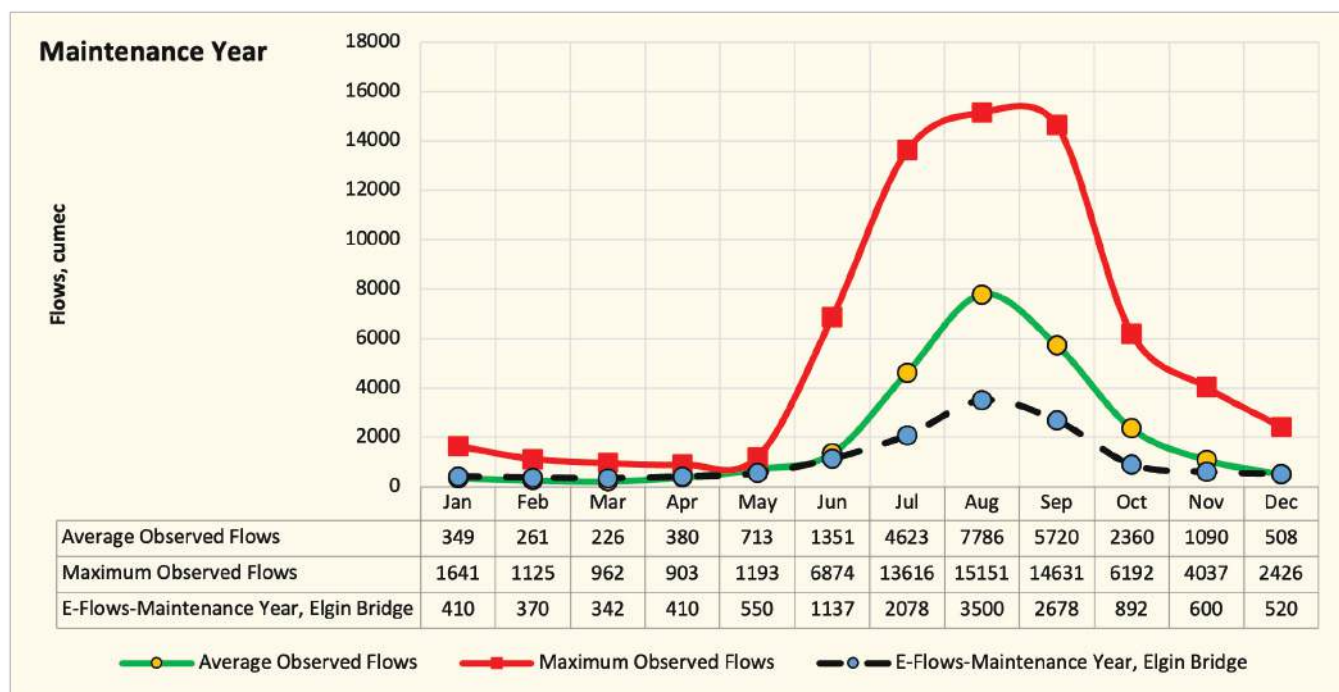
| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                  | As the river-bed and substratum conditions, the recommended depth during the dry season would be adequate for the survival of the Ganga river dolphin. This recommended depth is essential for providing space for its normal body movement and prey base. Feeding grounds increase with increasing depth. River dolphins tend to spend majority of their time in areas with abundant food supply, which include extended depth. The recommended depth for the wet season is likely to ensure formation of side pools/wetlands, and that would help and the support the flourishing communities of small-sized fishes and minnows. This is helpful since they are considered as important food for the Ganga river dolphin. |
| Drought Year     | The recommended depth for the dry season will support the survival of the Ganga river dolphin's population during extreme conditions. Width is a critical factor, and therefore, the recommended depth has been chosen with this in mind. Similarly, the recommended depth for the wet season will ensure the bare minimum hydraulic habitat requirements for the species' survival.                                                                                                                                                                                                                                                                                                                                        |

**Table 62: Desired water levels/depths along with rationale for the Elgin Bridge E-Flows location on the Ghaghra River**

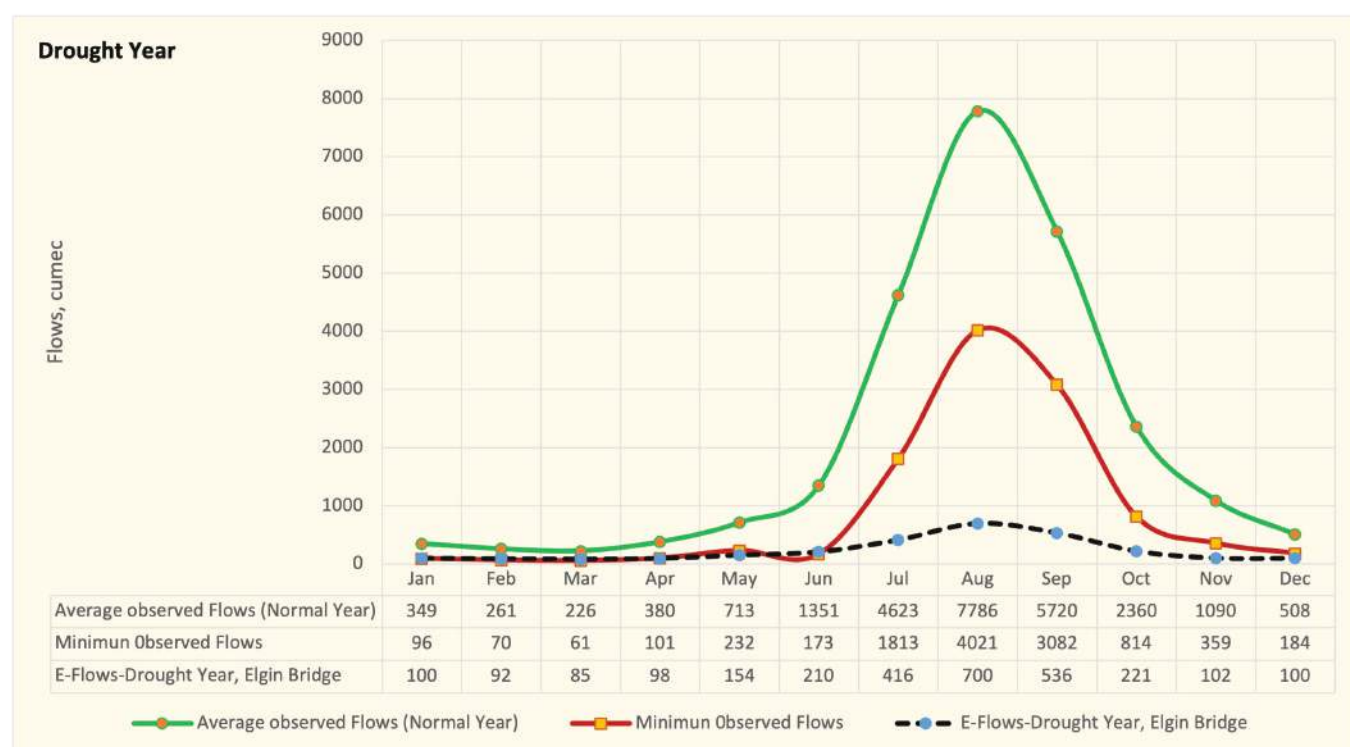
|  |                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                     | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                                                                                      |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                     | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                              | <p>Dry season: 4.9 m<br/>Wet Season: Depth cannot be presented here as model could not simulate the flows of such magnitude.</p> <p>[The motivating thematic for desired depth for dry season is Socio-cultural (mainly for carrying out rituals).]</p> <p>[The motivating thematic for desired depth for wet season is Fluvial geomorphology for maintaining lateral connectivity and sediment flushing.]</p> |
|  | <p>The dry season requirement will maintain the longitudinal connectivity and partially inundate the bar forms. The primary channel, closer to the left bank, will be inundated and also provide some flow to the Chauka River that runs closer to the right bank. The recommended wet-season depth will keep the secondary and primary channels submerged during the monsoon months.</p> | <p>The recommended depth during the dry season corresponds to the historical flows in people’s mind. This will also provide enough soil moisture for farming. The current flows during the wet season are adequate, but local communities hope to avoid sudden fluctuations in water levels caused by sudden releases from upstream structures.</p> |                                                                                                                                                                                                                                                                                                                                                                                                                |
|  | <p><i>An additional requirement is a depth of 9.6 m (&gt;1500 cumec) for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p>                                                                                                               |                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                |
|  | <p>The longitudinal connectivity would be maintained in the stress condition during the dry season, whereas some level of lateral connectivity would be achieved with recommended water levels during the wet season.</p>                                                                                                                                                                 | <p>Present-day water levels are aspired for by the local communities and they feel that the religious rituals will continue to be carried out under prevailing conditions, with some inconvenience, however.</p>                                                                                                                                    | <p>Dry season: 3.5 m<br/>Wet season: 6.2 m</p> <p>[The motivating thematic for desired depth in dry season is Aquatic Biodiversity (Ganga river dolphin)]<br/>[The motivating thematic for desired depth for wet season is Fluvial geomorphology for maintaining lateral connectivity and sediment flushing.]</p>                                                                                              |



Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Elgin Bridge location on the Ghaghra River (Figure 166 & 167). It is to be noted that due to high variability in observed Gauge-Discharge data points, the hydraulic model simulation could not provide satisfactory and confident outcomes for the wet season (mid of June to mid of October) discharge values for a Maintenance Year. Therefore, the recommended depth (8.6m) should be considered as an indicator of wet season E-Flows requirements for a Maintenance Year.



**Figure 166: E-Flows recommendations in a monthly flows pattern – Elgin Bridge location (Maintenance Year)**



**Figure 167: E-Flows recommendations in a monthly flows pattern – Elgin Bridge location (Drought Year)**



## 5.2.2.2 Ayodhya

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 63.

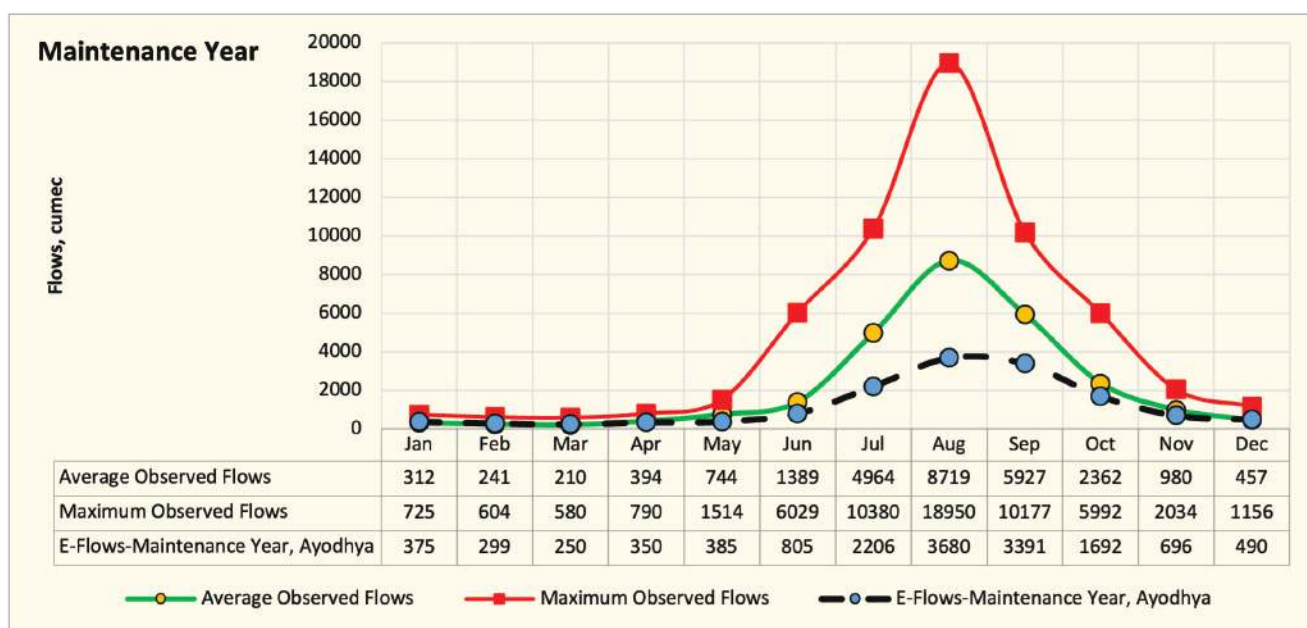
| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                  | As per river-bed and substratum conditions, the recommended depth the dry season would be adequate for the survival of the Ganga river dolphin. This recommended depth is essential for providing space for normal body movement and prey base. Feeding grounds increase with increasing depth. River dolphins tend to spend majority of their time in areas with abundant food supply, which can include extended depth. The recommended depth for wet season is likely to ensure the formation of side pools/wetlands, and that would help to support the flourishing communities of small-sized fishes and minnows. This is helpful since they are considered important food for the Ganga river dolphin. |
| Drought Year     | The recommended depths for a drought condition will at least ensure the survival of the Ganga river dolphin. Here, the width is a critical factor which has been taken into account while recommending depth.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

**Table 63: Desired water levels/depths along with rationale for the Ayodhya E-Flows location on the Ghaghra (Saryu) River**

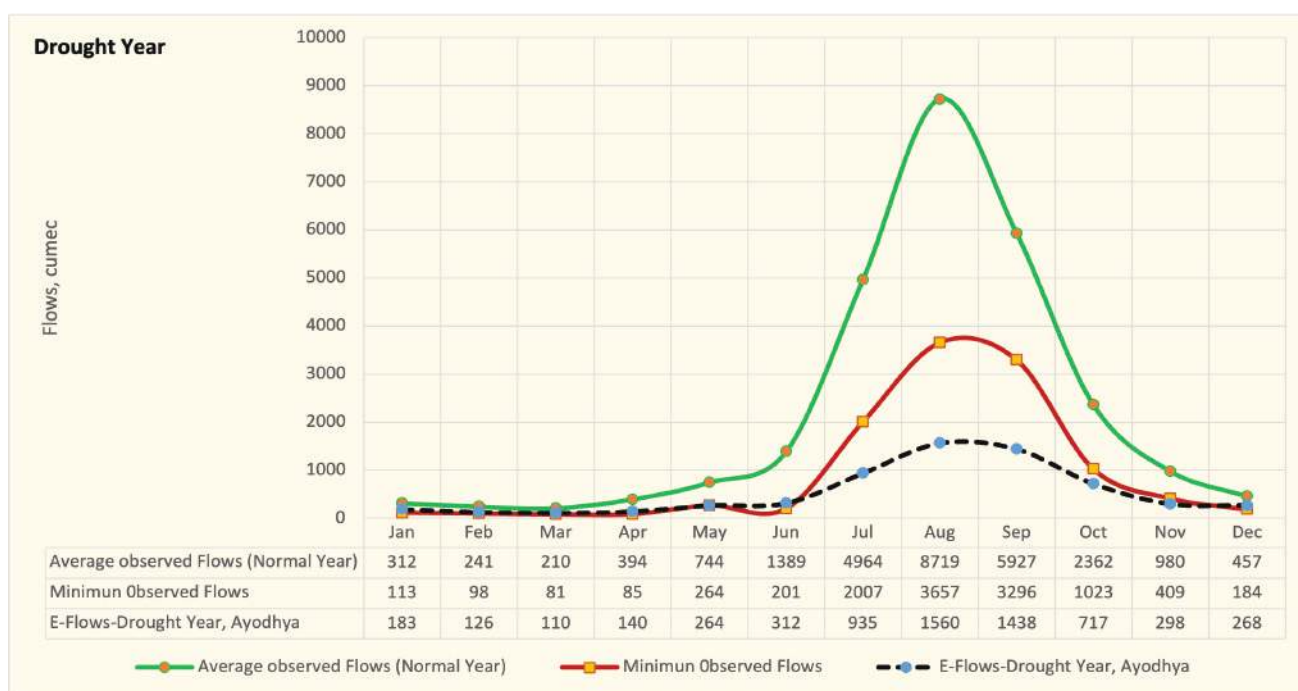


|  |                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                 | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                                                                        |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                  |
|  | <p>The recommended depth for the dry season will maintain the longitudinal connectivity and partially inundate the bars. The recommended depth for the wet season will keep the bar forms submerged throughout the monsoon period.</p>                               | <p><b>Ayodhya is the most important location on the Ghaghra River, which is also called Saryu in this stretch.</b> The recommended depth is required for satisfactory Socio-cultural rituals, including bathing. The pilgrims are dissatisfied with the current water levels in the river, as it does not match their memories of the flowing and resounding Ghaghra River.</p> | <p>Dry season: 4.3 m<br/>Wet season: 8.6 m</p> <p>[The motivating thematic for desired depth in the dry season is both Fluvial geomorphology and Socio-cultural (mainly for maintaining lateral connectivity and carrying out rituals.)</p> <p>[The motivating thematic for the desired depth in the wet season is Fluvial geomorphology for maintaining lateral connectivity and sediment.]</p> |
|  | <p><i>An additional requirement is a depth of 9.5m (5000 cumec) for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity, completely inundating the channel belt and portion of the floodplain region.</i></p> |                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                  |
|  | <p>During the dry season, longitudinal connectivity would be maintained even under stress conditions, while recommended water levels during the wet season would allow for some level of lateral connectivity to be achieved.</p>                                    | <p>The recommended depth will ensure ritual bathing at certain points (where the depth of water is more than that at the cross-section) and performing other Socio-cultural activities. This is not ideal, but will be acceptable during a drought year.</p>                                                                                                                    | <p>Dry season: 3.5 m<br/>Wet season: 7 m</p> <p>[The motivating thematic for desired depth for the dry season is Aquatic Biodiversity mainly for the Ganga river dolphin and the survival of IMCs). The motivating thematic for desired depth for the wet season is Socio-cultural (mainly for carrying out rituals).]</p>                                                                       |

Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Ayodhya location on the Saryu River (Figure 168 & 169).



**Figure 168: E-Flows recommendations in a monthly flows pattern- Ayodhya location (Maintenance Year)**



**Figure 169: E-Flows recommendations in a monthly flows pattern- Ayodhya location (Drought Year)**







### 5.2.2.3 Dohri Ghat

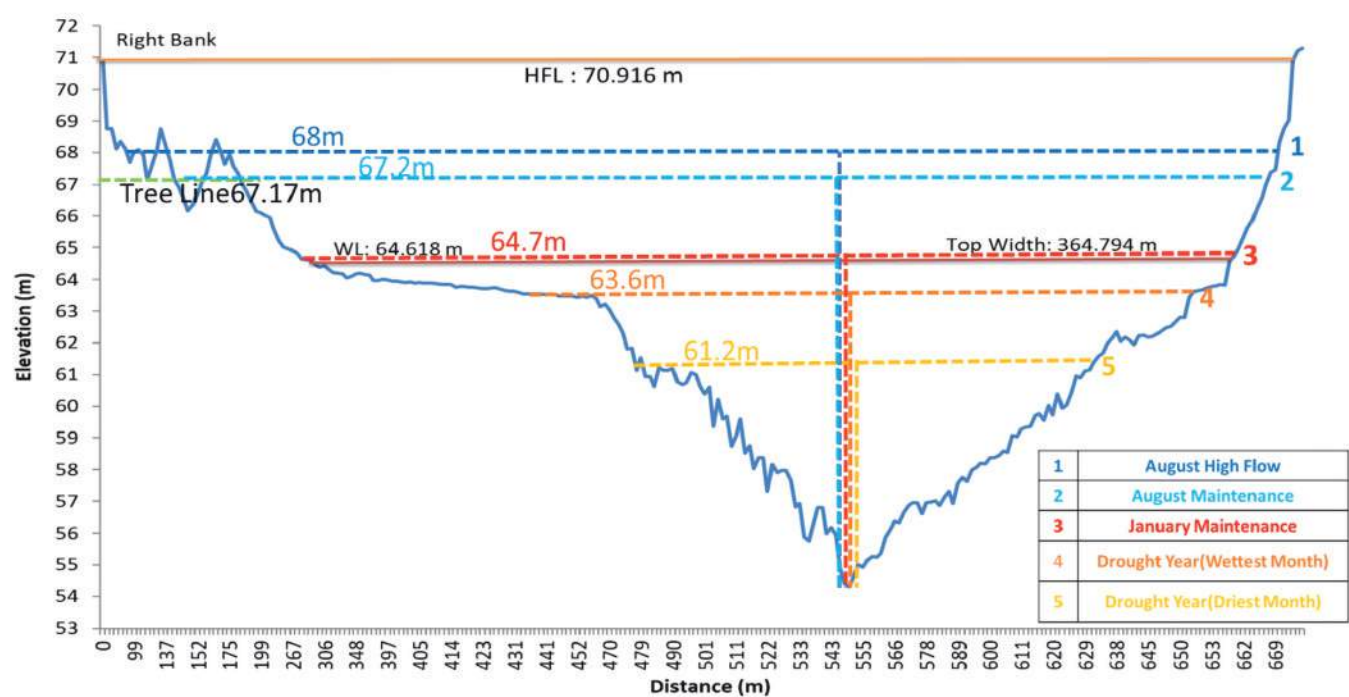
As noted earlier in Section 5.2, only water levels are recommended for this location. The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 64.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                  | The Ganga river dolphin is the motivating species here. The recommended depth during the dry season will provide space for normal body movement and adequate prey base. Feeding grounds increase with increasing depth. Adequate width is also a factor here, a consideration while recommending the depth. River dolphins tend to spend a majority of their time in areas with abundant food supply, which include extended depth. The wet season depth would ensure the formation/inundation of side-pools/wetlands. This would also help and support the flourishing communities of small-sized fishes and minnows that are found in these river locations, which shall be helpful since they are considered to be natural food for the Ganga river dolphin. |
| Drought Year     | The recommended depth will aid the survival of the Ganga river dolphin during extreme conditions. While recommending the depth, the width is also taken into account as that is another prerequisite for a conducive hydraulic habitat for the species.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

**Table 64: Desired water levels/depths along with rationale for the Dohri Ghat E-Flows location on the Ghaghra River**

|  |                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                          | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                             |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                    | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                   | Dry season: 11 m<br>Wet season: 13 m<br><br>[The motivating thematic for desired depth for the dry season is Socio-cultural (ritual bathing) and for the wet season, the desired depth was motivated by Fluvial Geomorphology (inundation of primary and secondary channels).]        |
|  | The recommended depth during dry season will maintain the longitudinal connectivity, and partially inundate the bar form (lateral/point bar) in the right bank side of this sinuous and asymmetric channel belt. The recommended depth during wet season will inundate the primary and secondary channel and establish connectivity in the channel belt. | The recommended depth will aid in matching people’s aspiration of a healthy river and will allow the carrying out of rituals without hesitation. People are distressed by present water levels, as they do not match their recollections of the river.                                                                                   |                                                                                                                                                                                                                                                                                       |
|  | <i>An additional requirement would be a depth of 25 m for a period of 10-15 days in the months of July-August-September. This will maintain lateral connectivity; inundating the channel belt and a portion of the active floodplain.</i>                                                                                                                |                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                       |
|  | With the recommended depth, longitudinal connectivity would be maintained even in stressful conditions during the dry season, while some level of lateral connectivity would be achieved with the recommended water levels during the wet season.                                                                                                        | The recommended water depth will allow carrying out of Socio-cultural rituals, but in limitation. This is acceptable in a drought scenario. The recommended water levels will also support some livelihoods, including boating. The issue of stagnation of water along the banks may still persist, but are tolerable in a drought year. | Dry season: 7 m<br>Wet season: 9.4 m<br><br>[The motivating thematic for the desired depth for dry seasons is Aquatic Biodiversity (The Ganga river dolphin). Though Fluvial Geomorphology thematic motivated wet season depth, mainly to ensure some level of lateral connectivity.] |

Figure 170 illustrates the various depth requirements for different seasons at the cross-section profile of the Dohri Ghat E-Flows location on the Ghaghra River.



**Figure 170: Cross-section profile with depth recommendations for the Dohri Ghat E-Flows location on the Ghaghra River**





## 5.2.2.4 Turtipar

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 65.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                  | The recommended depth during the dry season will provide space for normal body movement and adequate prey for the Ganga river dolphin. Feeding grounds increase with depth. River dolphins tend to spend a majority of their time in areas with abundant food supply, which include extended depth. Like some of the previous locations, width is a critical consideration while recommending depth. The recommended depth during wet season will inundate/form side-pools/wetlands and support the flourishing communities of small-sized fishes and minnows, which shall be helpful since they are considered as important natural food for the Ganga river dolphin. The recommended depth for the wet season will also support lateral movement, movement of biota and to the maintenance of rich nutrients. |
| Drought Year     | The riverbed is relatively flat and the recommended depth is essential for the survival of the Ganga river dolphin during extreme conditions. The recommended wet-season depth will allow some inundation in the side channels, which is not highly appropriate, but acceptable in stress conditions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

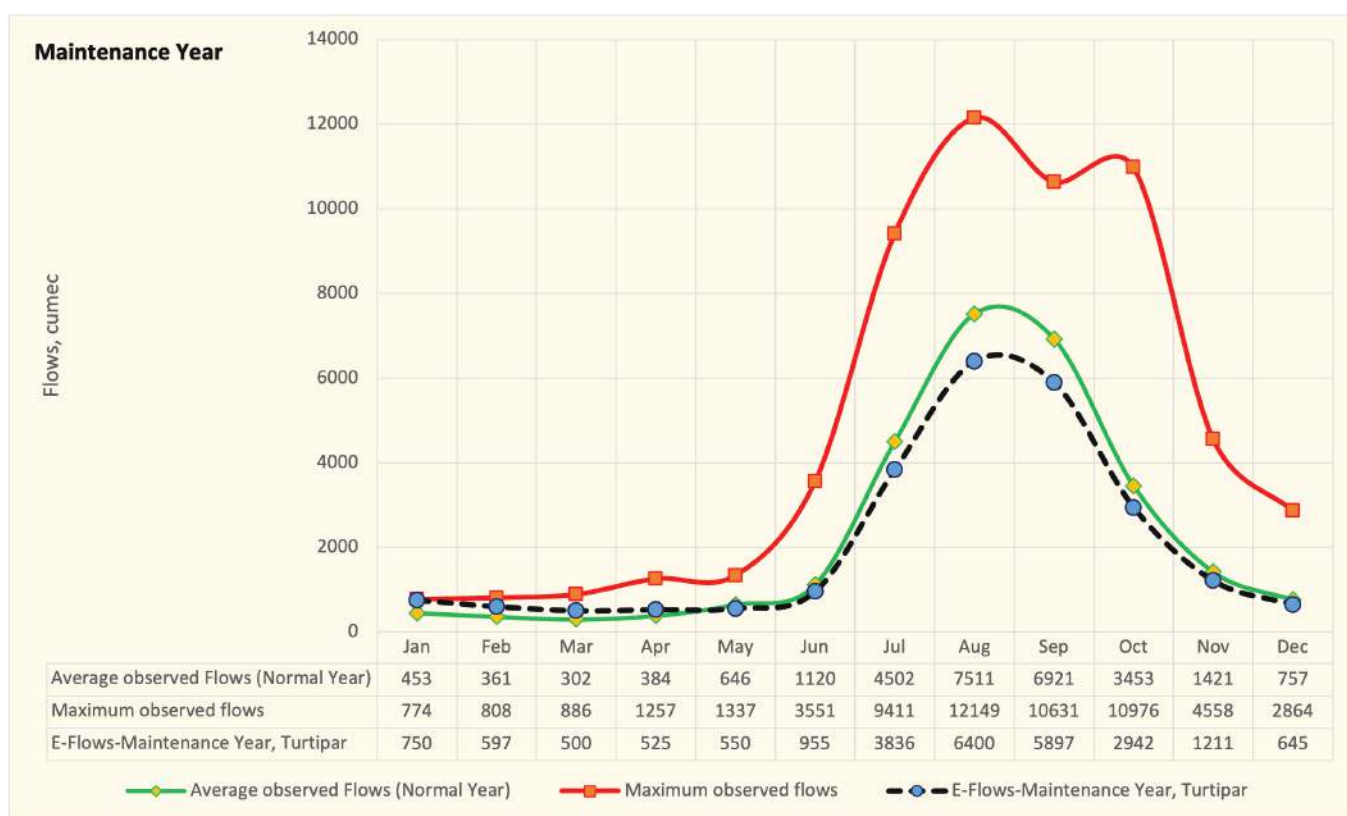
**Table 65: Desired water levels/depths along with rationale for the Turtipar E-Flows location on the Ghaghra River**



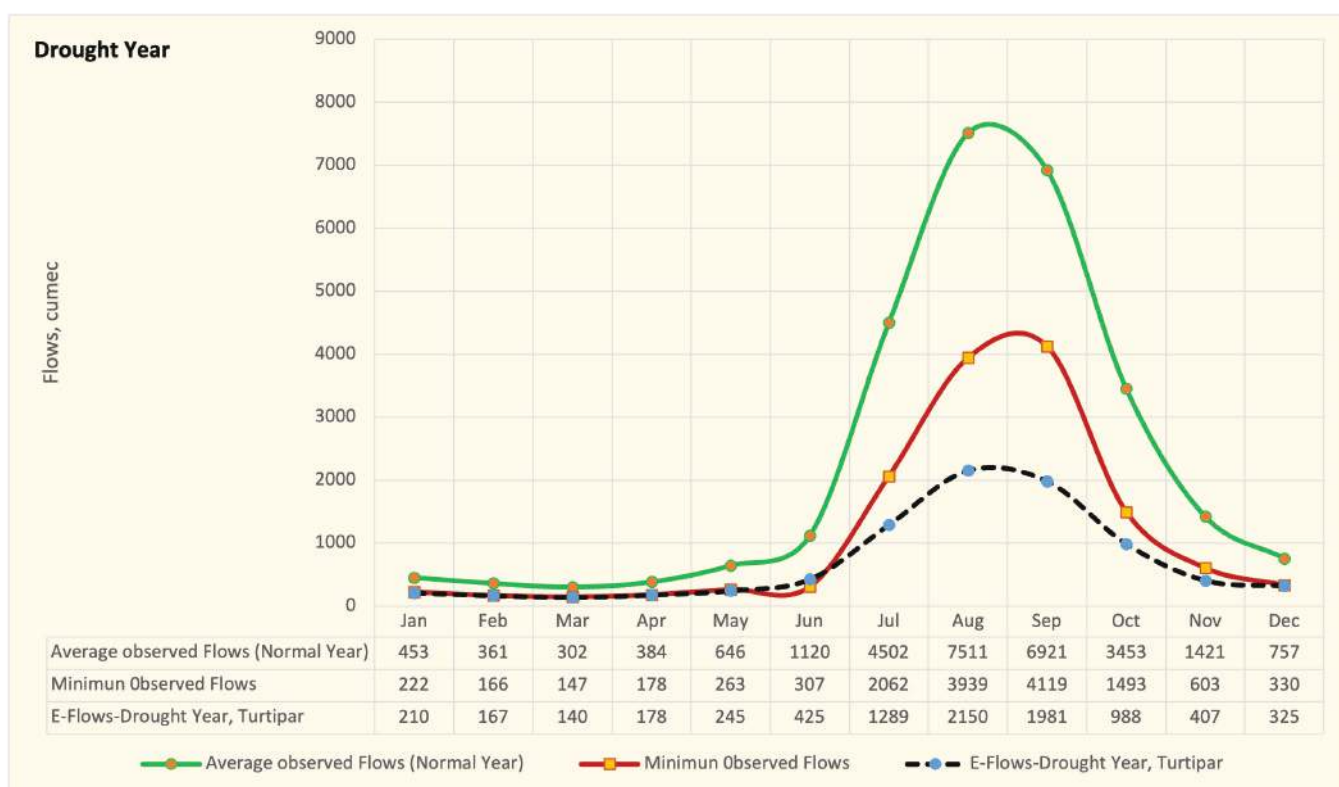
|  |                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                        | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                         |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                               | Socio-cultural Aspects                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                   |
|  | <p>The recommended depth during the dry season will maintain the longitudinal connectivity and partially inundating the main channel that lies closer to the right bank. The recommended wet-season depth will keep the lateral/side bar form submerged for the monsoon period.</p> | <p>The recommended depth during the dry season would reduce the hardship of local communities in terms of fulfilment of their socio- cultural aspirations and livelihood activities. However, the wet season flows are satisfactory to the people.</p> | <p>Dry season: 4.0 m<br/>Wet season: 7.95 m</p> <p>[The motivating thematic for desired depth for both seasons is Aquatic Biodiversity (Ganga river dolphin) and Fluvial Geomorphology (longitudinal connectivity and submergence of lateral and side bars).]</p> |
|  | <p><i>An additional requirement is a depth of 9.25 m (6950 cumec for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity. completely inundating the channel belt and a portion of the floodplain region.</i></p>             |                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                   |
|  | <p>With the recommended depth, the longitudinal connectivity would be maintained in stress conditions during the dry season. Some level of lateral connectivity would also be achieved with recommended water levels during the wet season.</p>                                     | <p>Since it is a drought scenario, communities are willing to cope with the stress conditions imposed on them by nature, as they understand and appreciate that such conditions are temporary phenomenon and next year will be better.</p>             | <p>Dry season: 3 m<br/>Wet season: 6 m</p> <p>[The motivating thematic for desired depth for both seasons is Aquatic Biodiversity (Ganga river dolphin).]</p>                                                                                                     |



Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for Turtipar location on the Ghaghra River (Figure 171 & 172).



**Figure 171: E-Flows recommendations in a monthly flows pattern–Turtipar location (Maintenance Year)**



**Figure 172: E-Flows recommendations in a monthly flows pattern–Turtipar location (Drought Year)**

### 5.2.3 Gomti River

The flows regime in the first two locations on the Gomti River shows a reverse trend, i.e. the downstream location at Indira Aqueduct, near Gomti Nagar shows lesser flows than the upstream location (before the Gomti Barrage) in Lucknow at Mehndi Ghat. The cause for this pattern is attributed to the presence and operation of the barrage. The locations further downstream show normal trend of flows, i.e. flows are increasing from upstream (Sultanpur) to downstream (Jaunpur) location.



### 5.2.3.1 Mehndi Ghat

As noted earlier, only water levels are recommended for this location. The desired water levels/depth based on thematic motivations are shown in Table 66.

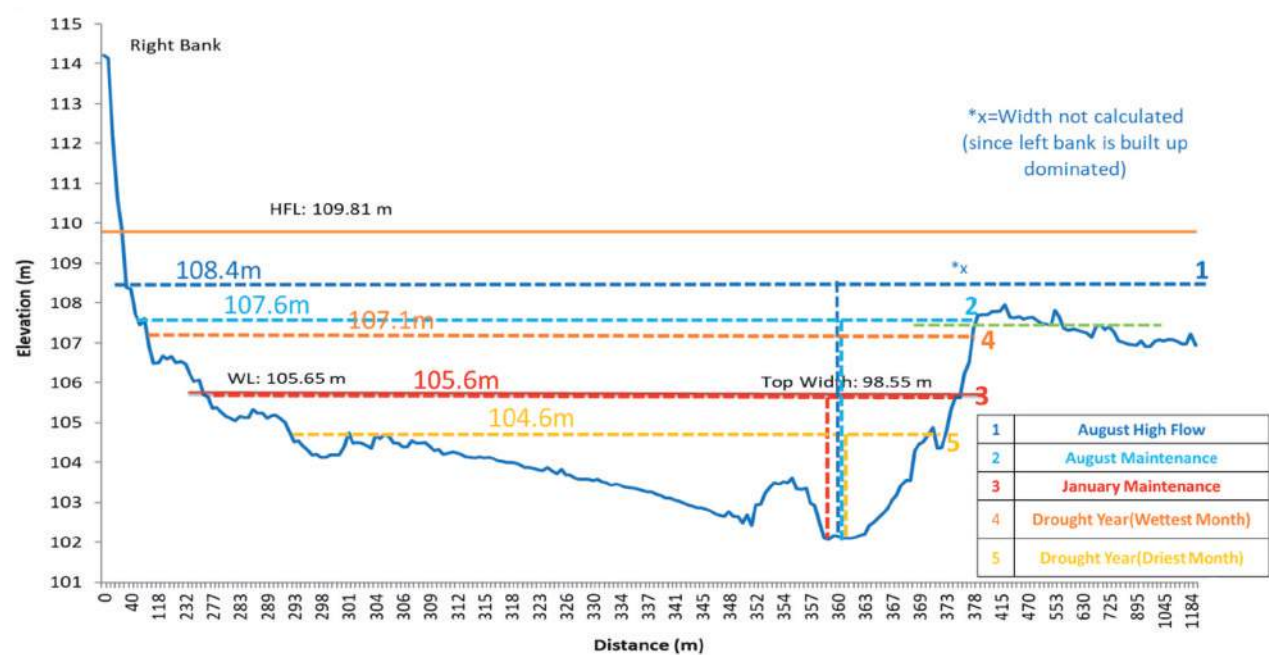
| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                  | <p>The recommended dry-season depth is required to maintain a congenial thermal profile for the fish (particularly to the brooders). It is also required to maintain the desired Dissolved Oxygen levels during varying weather conditions, and the growth of fish food organisms (plankton, periphyton, benthos). This is essential to safeguard the stocked fish. The size and weight of fish are significantly affected by lower depths. The recommended wet-season depth is suitable for temperature variations, plankton production, etc. The present water-quality parameters of the river at the mentioned location are not suitable for the survival and growth of IMC, but suitable for other opportunist species and hardy alien fishes (common carp, tilapia, etc). The presence of enormous composition of alien fish species indicates that the water quality is not suitable for the survival and proliferation of native fish species during lean season. The water-quality issues need to be dealt separately.</p> |
| Drought Year     | <p>The recommended water depth during dry season is the minimum for maintaining the fish base around this location. The recommended wet-season depth is required to ensure a minimum depth in side channels for the revival of side/connected pools, which are useful for the flow of nutrients, growth of fish food organisms (plankton, periphyton, benthos) and for the development of nursery grounds for fish juveniles. Lateral side channels will be inundated. Movement of biota and rich nutrition exchange is made possible if the recommended depth is attained.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

**Table 66: Desired water levels/depths along with rationale the Mehndi Ghat E-Flows location on the Gomti River**



|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                  | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                        |
|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Socio-cultural Aspects                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                  |
|  | <p>The recommended depth during dry season will maintain the longitudinal connectivity of the river, where the deeper section of the asymmetric channel lies closer to the left bank. Currently, the river does not show any sign of natural geomorphic activity in the form of erosion and deposition. Also, the flow velocity was too low to perform the function of sediment transport. The recommended wet-season flows would sustain some geomorphic activity in the form of sediment transport.</p> | <p>The recommended water depth would correspond to the farmers' memories of the historical flows. It will also improve soil-moisture levels and encourage fishing-based livelihoods.</p>                         | <p>Dry season: 3.5 m<br/>Wet season: 5.5 m</p> <p>[The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity (Indian major carps) and Fluvial Geomorphology (longitudinal connectivity and to aid sediment transport).]</p>                                                         |
|  | <p><i>An additional requirement is a depth of 6.3 m for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p>                                                                                                                                                                                                                                                |                                                                                                                                                                                                                  | <p>Dry season: 2.5 m<br/>Wet season: 5 m</p> <p>[The motivating thematic for desired depth for dry season is Socio-cultural (mainly for carrying out rituals); whereas for the wet season, Fluvial Geomorphology motivated desired depth (to maintain some level of lateral and longitudinal connectivity).]</p> |
|  | <p>The recommended flows would help in maintaining longitudinal connectivity and some level of lateral connectivity, though only partially.</p>                                                                                                                                                                                                                                                                                                                                                           | <p>The present-day lean season flows are acceptable as drought year flows by the local communities, as some rituals and livelihood practices can be carried out at this water level, though with difficulty.</p> |                                                                                                                                                                                                                                                                                                                  |

Figure 173 illustrates the various depth requirements for different seasons at the cross-section profile of the Mehndi Ghat location, which is upstream of the Gomti Barrage in Lucknow city.



**Figure 173: Cross-section profile with water-levels/depth recommendations for the Mehndi Ghat E-Flows location on the Gomti River**









## 5.2.3.2 Indira Aqueduct near Gomti Nagar

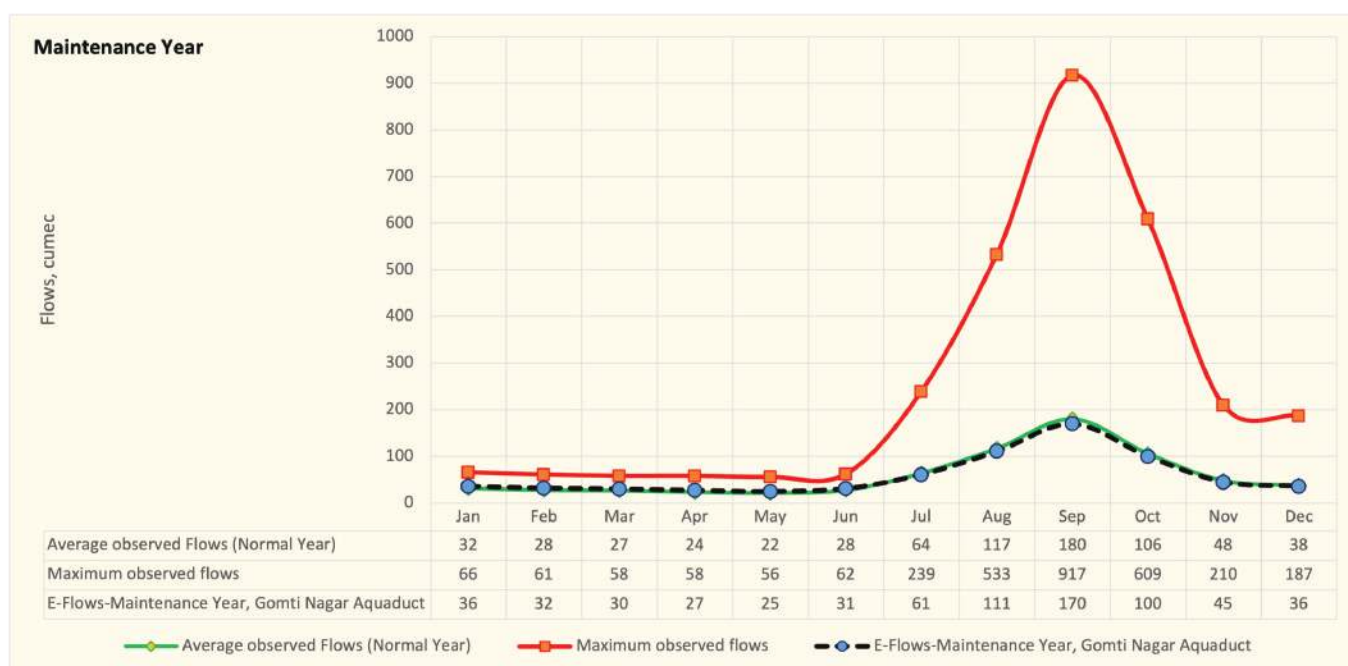
The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 67.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                  | <p>The recommended dry-season depth is required to maintain congenial thermal profile for the fish (particularly the brooders); this depth is also required to maintain the desired Dissolved Oxygen level during extreme weather conditions. This will also aid the growth of fish food organisms (plankton, periphyton, benthos). The recommended depth is mandatory to safeguard the stocked fish from extreme weather conditions. Size and weight of fish are significantly affected by lower depths. Fishes cultivated at low depth of water yielded lower weight, and were shorter in length in contrast to the fishes cultivated at higher depth.</p> <p>The recommended wet-season depth is required for the development of suitable nursery grounds (flooding of side pools and connected wetlands) for IMC. The recommended depth is suitable for temperature variations, plankton production, etc.</p> <p>The present water-quality parameters of the river at the mentioned location are not suitable for survival and growth of IMC, but suitable for other opportunist species and hardy alien fishes (common carp, tilapia, etc). Presence of enormous composition of alien fish species indicates water quality is not suitable for survival and proliferation of native fish species during the lean season. This needs due attention and is beyond the scope of E-Flows; the water-quality issues need to be dealt with separately.</p> |
| Drought Year     | <p>The recommended dry-season depth will ensure conducive hydraulic habitat requirement in terms of depth and channel width for motivating fish species, i.e. species of IMCs.</p> <p>The recommended wet-season depth will provide minimum depth in side channels for the revival of side/connected pools, which are useful for the flow of nutrients, growth of fish-food organisms (plankton, periphyton, benthos) and for development of nursery grounds for fish juveniles. Lateral side channel also gets inundated during wet season. Further movement of biota and rich nutrition exchange is made possible if this depth is attained.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

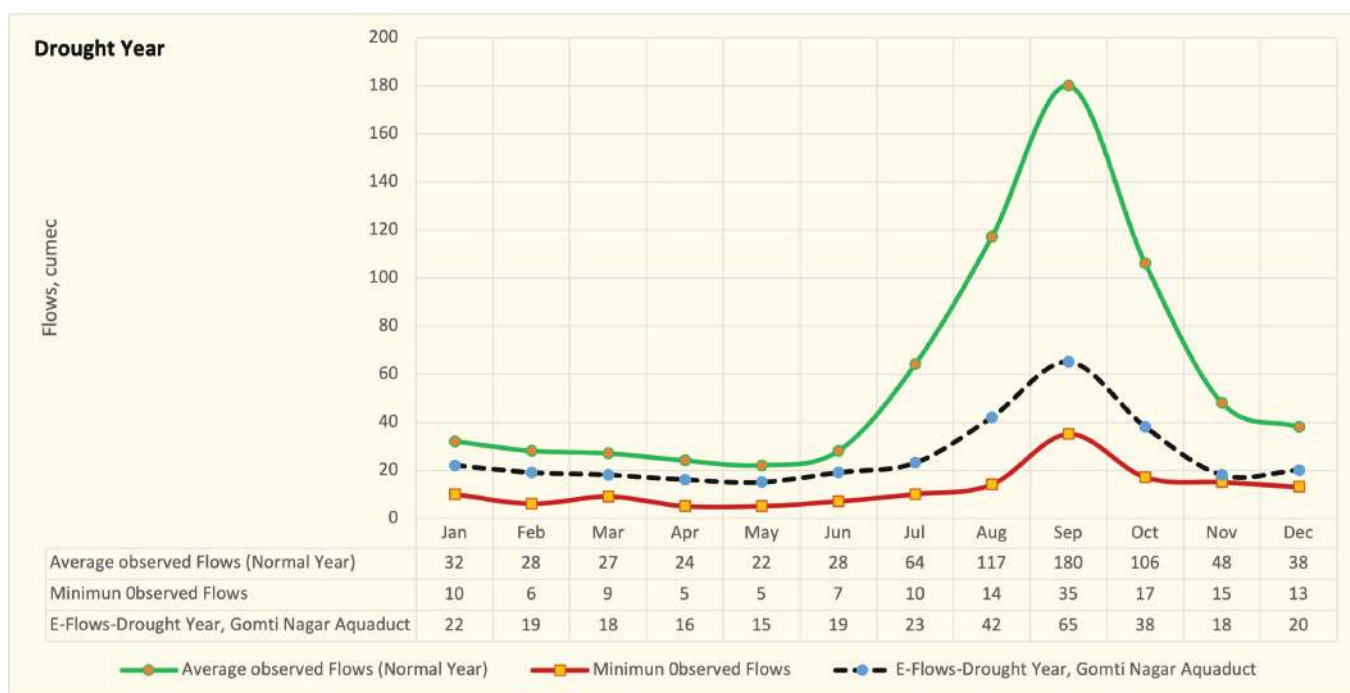
**Table 67: Desired water levels/depths along with rationale for Indira Aqueduct**

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                     |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Dry season: 2.5 m<br>Wet season: 5.26 m<br><br>The motivating thematic for desired depth for dry and wet season is Fluvial Geomorphology.                                                                                                                                                                     |
|  | The recommended dry-season depth will maintain the longitudinal connectivity of the river. Currently the river does not show any sign of natural geomorphic activity in the form of erosion and deposition and the flow velocity was too incredibly low to perform the function of sediment transport. The recommended wet- season depth will sustain some geomorphic activity in the form of sediment transport and also inundate the flanked secondary channel towards the right bank. | Though much less than the historic flows during summers, this recommended dry season depth is still considered the bare minimum requirement to keep the river flowing. The river is at present critically degraded, with practically no influx of freshwater Either from the catchment or groundwater in terms of baseflows. This state of affairs is already unacceptable & the condition will only worsen if desired depths and resolution to water-quality issues are not ensured.                                                    |                                                                                                                                                                                                                                                                                                               |
|  | An additional requirement is a depth of 6.8 m (310 cumec) for a period of 10-15 days in the months of July-August-September.<br>This will maintain the lateral connectivity, completely inundating the channel belt and portion of the floodplain.                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                               |
|  | The recommended flows would aid in maintaining longitudinal connectivity and some level of lateral connectivity, though only partially.                                                                                                                                                                                                                                                                                                                                                  | The sludge drying up and forming an impermeable crust is linked to the decline in flow. The recommended dry-season depth will just barely prevent the sludge from settling. It is considered necessary to scour the river bed, so that the accumulated sludge will be taken away and the spring contribution to river flows gets reactivated again. At present, the river is highly toxic and a source of great inconvenience. The recommended hydraulic conditions will not really scour the bed, but will prevent additional deposits. | Dry season: 2.1 m<br>Wet season: 3.5 m<br><br>[The motivating thematic for desired depth for the dry season is Socio-cultural (mainly for carrying out rituals); whereas for wet season Fluvial Geomorphology motivated the desired depth (to maintain some level of lateral and longitudinal connectivity).] |

Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for Gomti Nagar near the Aqueduct E-Flows location on the Gomti River (Figure 174 & 175).



**Figure 174: E-Flows recommendations in a monthly flows pattern–Indira Aqueduct, near Gomti Nagar location (Maintenance Year)**



**Figure 175: E-Flows recommendations in a monthly flows pattern–Indira Aqueduct, near Gomti Nagar location (Drought Year)**





### 5.2.3.3 Sultanpur

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 68.

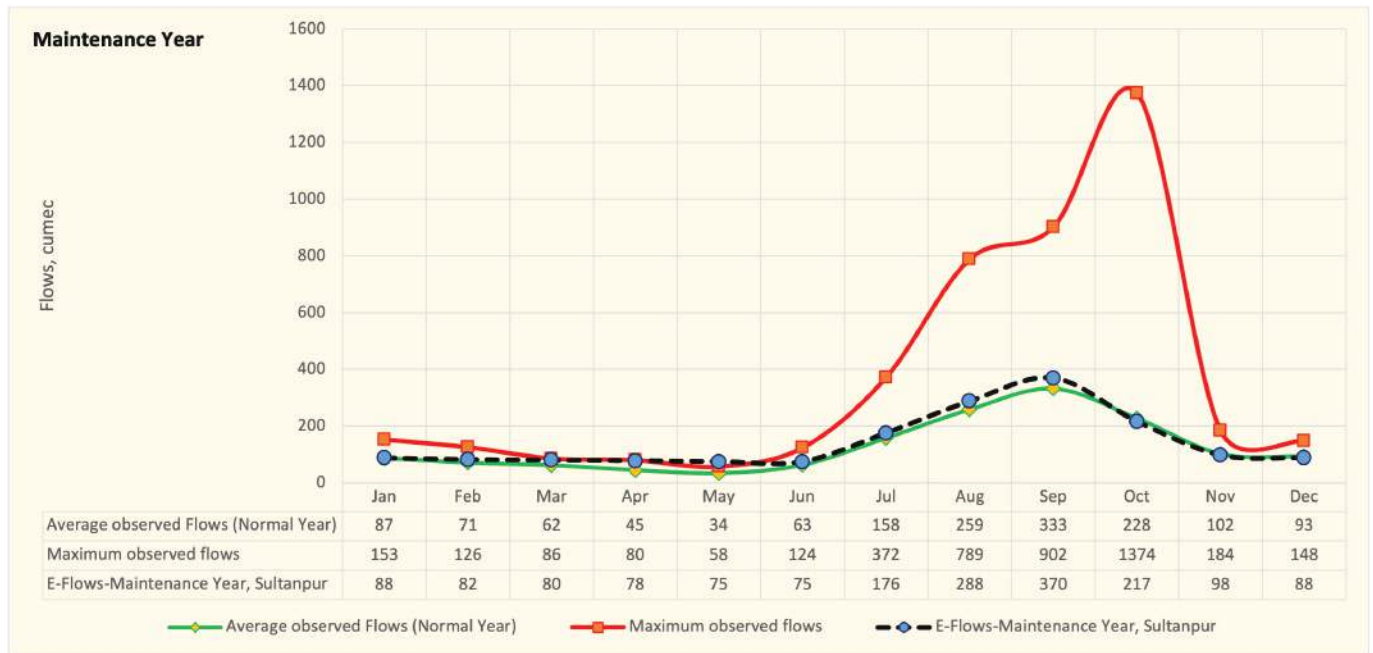
| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                  | <p>The recommended depth for the dry season will maintain congenial thermal profile for the fish (particularly to the brooders). The desired depth is also essential to maintain desired Dissolved Oxygen level during extreme weather conditions, growth of fish-food organisms (plankton, periphyton, benthos). The recommended depth will also safeguard the stocked fish from extreme weather conditions. Lower depths significantly affect size and weight of the fish.</p> <p>The depth recommended for the wet season are required for the development of suitable nursery grounds (flooding of side-pools and connected wetlands) for IMCs. The depth recommended for wet season is suitable for temperature variations, plankton production, etc.</p> <p>The present water-quality parameters of the river at this location are not suitable for the survival and growth of IMCs, but suitable for other opportunist species and hardy alien fishes (common carp, tilapia, etc). This needs due attention and is beyond the scope of E-Flows assessment, as the water-quality issues need to be dealt separately.</p> |
| Drought Year     | <p>The recommended dry-season depth will ensure conducive hydraulic habitat requirement in terms of depth and channel width for motivating fish species, i.e. species of IMCs. The recommended wet-season depth will provide minimum depth in side channels for the revival of side/connected pools, which are useful for the flow of nutrients, growth of fish-food organisms (plankton, periphyton, benthos) and for the development of nursery grounds for fish juveniles. Lateral side channels also get inundated during the wet. Further movement of biota and rich nutrition exchange is made possible if this depth is attained.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

**Table 68: Desired water levels/depths along with rationale for the Sultanpur E-Flows location on the Gomti River**

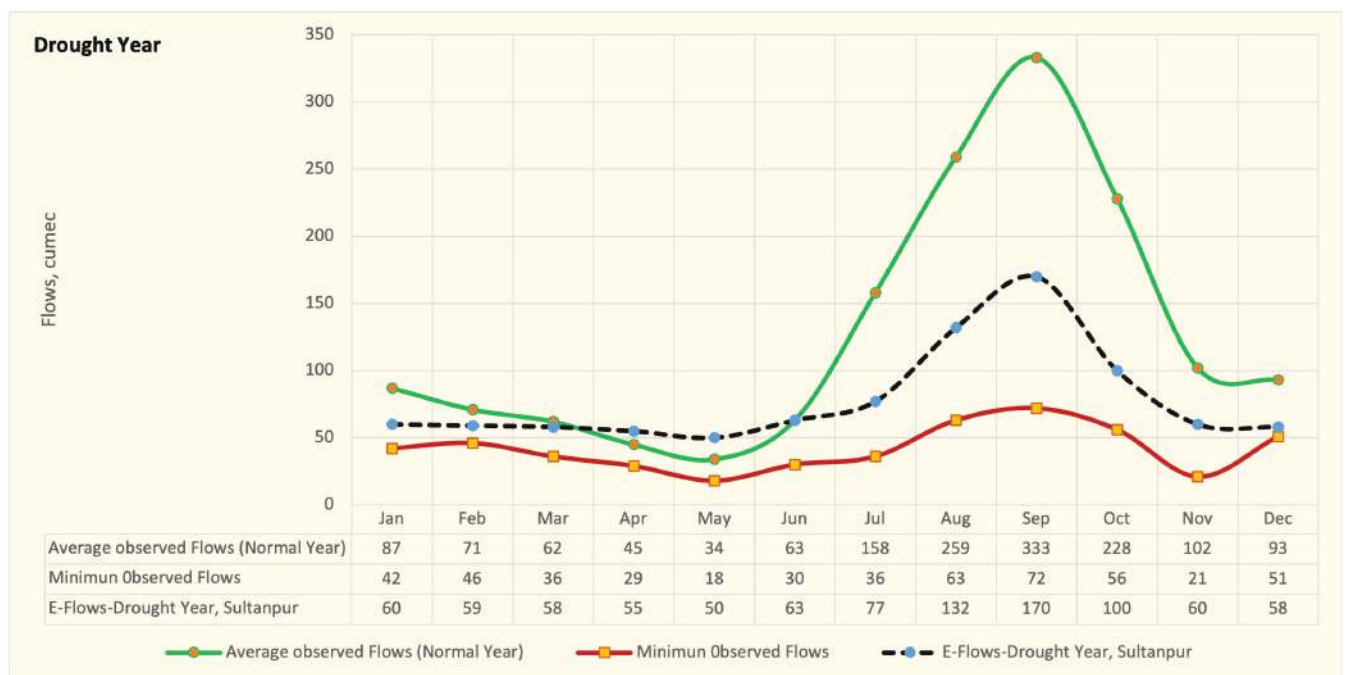
|  |                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                        |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                                      | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                         | Dry season:2 m<br>Wet season:4.4 m<br><br>[The motivating thematic for desired depth for the dry and wet seasons is Fluvial Geomorphology for maintaining lateral connectivity and sediment flushing.]                                                                           |
|  | The recommended depth for dry season will maintain the longitudinal connectivity of the river. Currently the river does not show any sign of natural geomorphic activity in the form of erosion and deposition. The flow velocity was too low to perform the function of sediment transport. The recommended depth for wet season will sustain some geomorphic activity in the form of sediment transport. | The recommended depth for dry season will allow satisfactory rituals, including bathing. This depth would also allow boatmen to ply with ease. The recommended depth for wet season is likely to prevent accumulation of silt and sludge, as per the local people. The local people find it convenient to worship from the concrete steps of the old ghats. As per the residents, the floods are necessary to maintain the shape and integrity of the channel. |                                                                                                                                                                                                                                                                                  |
|  | <i>An additional requirement is a depth of 9 m (1370 cumec) for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i>                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                  |
|  | The recommended flows would aid in maintaining longitudinal connectivity and some level of lateral connectivity, though only partially.                                                                                                                                                                                                                                                                    | The recommended depth will alleviate a certain degree of inconvenience for worshippers and boatmen while still permitting the performance of rituals and livelihood activities.                                                                                                                                                                                                                                                                                | Dry.season: 1.62 m<br>Wet season: 3 m<br><br>[The motivating thematic for desired depth for the dry seasons is Aquatic Biodiversity (Indian major carps)]<br><br>[The motivating thematic for desired depth for wet season is Socio-cultural (mainly for carrying out rituals).] |



Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Sultanpur E-Flows location on the Gomti river (Figure 176 & 177).



**Figure 176: E-Flows recommendations in a monthly flows pattern- Sultanpur location (Maintenance Year)**



**Figure 177: E-Flows recommendations in a monthly flows pattern- Sultanpur location (Drought Year)**



### 5.2.3.4 Jaunpur

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 69.

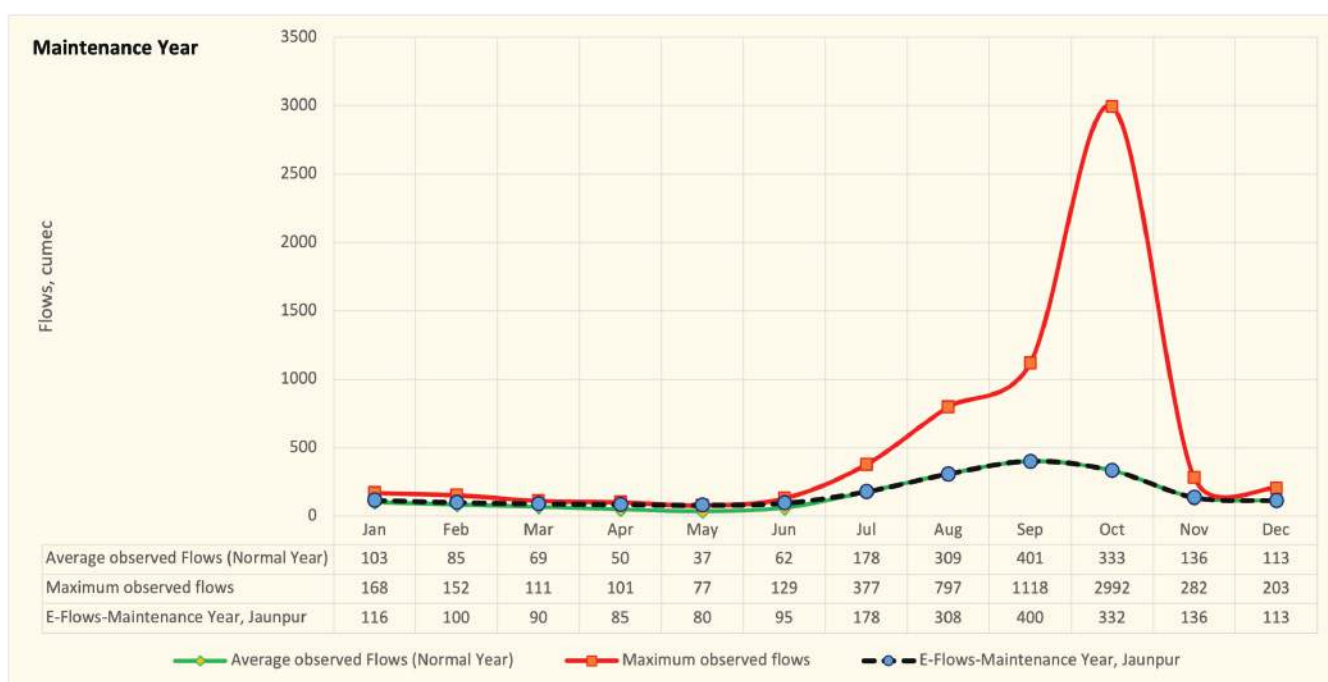
| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                  | <p>The recommended depth for the dry season will maintain a congenial thermal profile for the fish (particularly for the brooders). This depth is also required to maintain the desired Dissolved Oxygen level during extreme weather conditions, growth of fish-food organisms (plankton, periphyton, benthos). It will also safeguard the fish from extreme weather conditions. Lower depths significantly affect the size and weight of the fish.</p> <p>The recommended depth for the wet season is required for the development of suitable nursery grounds (flooding of side-pools and connected wetlands) for IMCs. This depth is suitable for temperature variations, planktons, etc. during the wet season.</p> <p>The present water-quality parameters of the river at this location are not suitable for the survival and growth of IMCs, but suitable for other opportunist species and hardy alien fishes (common carp, tilapia, etc). This needs due attention and is beyond the scope of this E-Flows assessment exercise. The water-quality issues need to be dealt separately.</p> |
| Drought Year     | <p>The recommended water depth for the dry season will ensure that the fish species (IMCs) can sufficiently thrive, although fresh recruitment of fish population may be minimal.</p> <p>The recommended depth for the wet season will provide minimum depth in side channels for the revival of side/connected pools, which are useful for the flow of nutrients, growth of fish-food organisms (plankton, periphyton, benthos) and for the development of nursery grounds for fish juveniles. Lateral side channels are inundated and activation of lateral side channels is achieved. Further movement of biota and rich nutrition exchange is made possible if this depth is attained.</p>                                                                                                                                                                                                                                                                                                                                                                                                      |

**Table 69: Desired water levels/depths along with rationale for the Jaunpur E-Flows location on the Gomti River**

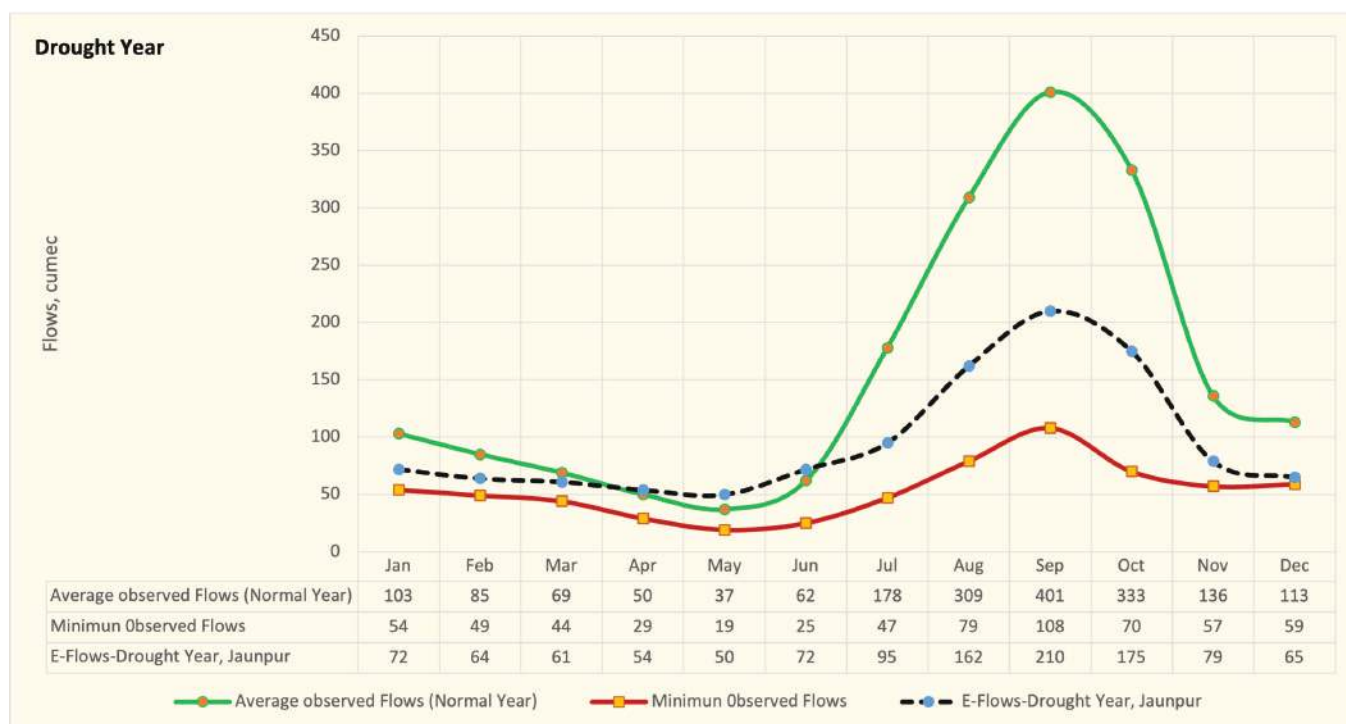


|  |                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                         |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                                                                        | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <p>Dry season: 2.75 m<br/>Wet season: 5 m</p> <p>[The motivating thematic for desired depth for the dry and wet seasons is Fluvial Geomorphology for maintaining lateral connectivity and sediment flushing.]</p>                                                                                                                 |
|  | <p>The recommended depth for the dry season will maintain the longitudinal connectivity of the river. Currently, the river does not show any sign of natural geomorphic activity in the form of erosion and deposition and the flow velocity was too low to perform the function of sediment transport. The recommended depth for the wet season will partially inundate the flanked portion of the channel belt for the monsoon period.</p> | <p>The recommended depth for the dry season will allow comfortable ritual bathing and livelihoods. The desired depth is considered necessary to scour the riverbed, so that the accumulated sludge will be taken away and the springs will flow again. At present the river is highly toxic and a source of great inconvenience to the riparian communities. The recommended depth for the wet season corresponds to the historical reach of the river in the monsoon. It also enables people to access the river safely and cleans the steps of the ghats of accumulated sand and silt. The desired water depth is considered adequate and not likely to cause inconvenience to the visitors, while also allowing the river to carry out its functions.</p> |                                                                                                                                                                                                                                                                                                                                   |
|  | <p><i>An additional requirement is a depth of 11 m (2450 cumec) for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity; completely inundating the channel belt and a portion of the floodplain region.</i></p>                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <p>Dry season: 2.3 m<br/>Wet season: 3.6 m</p> <p>The motivating thematic for the desired depth during dry seasons is Aquatic Biodiversity (mainly for the survival of IMCs), whereas Fluvial Geomorphology motivates the desired depth for the wet season (to maintain some level of lateral and longitudinal connectivity).</p> |
|  | <p>The recommended depth would aid in maintaining longitudinal connectivity and some level of lateral connectivity, though only partially.</p>                                                                                                                                                                                                                                                                                               | <p>Although the recommended water depth is less desirable, it will allow for ritual bathing, worshipping and continuation of livelihood activities. These flows will allow people to access the river and at least partly allow the river to carry out its scouring function. The recommended depth will alleviate a certain degree of inconvenience for worshippers and boatmen while still permitting the performance of rituals and livelihood activities.</p>                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                   |

Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Jaunpur E-Flows location on the Gomti River (Figure 178 & 179)



**Figure 178: E-Flows recommendations in a monthly flows pattern-Jaunpur location (Maintenance Year)**



**Figure 179: E-Flows recommendations in a monthly flows pattern-Jaunpur location (Drought Year)**



## 5.2.4 Rapti River

There are three E-Flows locations on the Rapti River, which are Balrampur, Bansi and Birdghat. The E-Flows are recommended for all three locations.





## 5.2.4.1 Balrampur

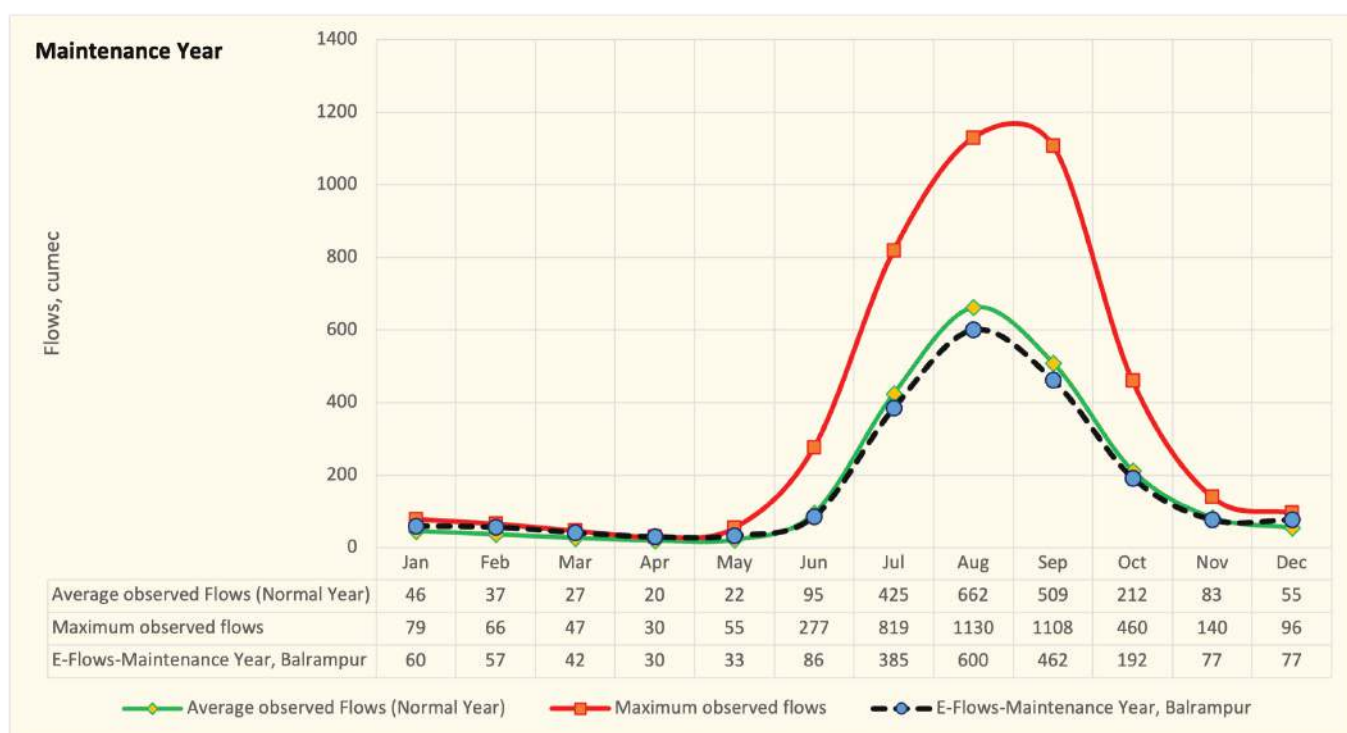
The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 70.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                  | The recommended depth is required to maintain a congenial thermal profile for the IMC fish species (particularly for the brooders of <i>C.mrigala</i> and <i>L.rohita</i> ). It is also required to maintain the required Dissolved Oxygen level and to ensure the growth of fish-food organisms (plankton, periphyton, benthos). Therefore, the recommended depth is critical to safeguard the stocked fish. The recommended depth for the wet season is required for development of suitable nursery grounds (water in side pools and connected wetlands) for IMC. It is also suitable for temperature variations, planktons, etc. during the wet season. |
| Drought Year     | The recommended water depth will support the fish population and aid lateral migration. It would help in the revival of side-channels/connected-pools, which are useful for the flow of nutrients, growth of fish-food organisms (plankton, periphyton and benthos) and for the development of nursery grounds for fish juveniles. The recommended depth during wet season is likely to inundate side channels. Further movement of biota and rich nutrition exchange will be possible with this recommended depth.                                                                                                                                         |

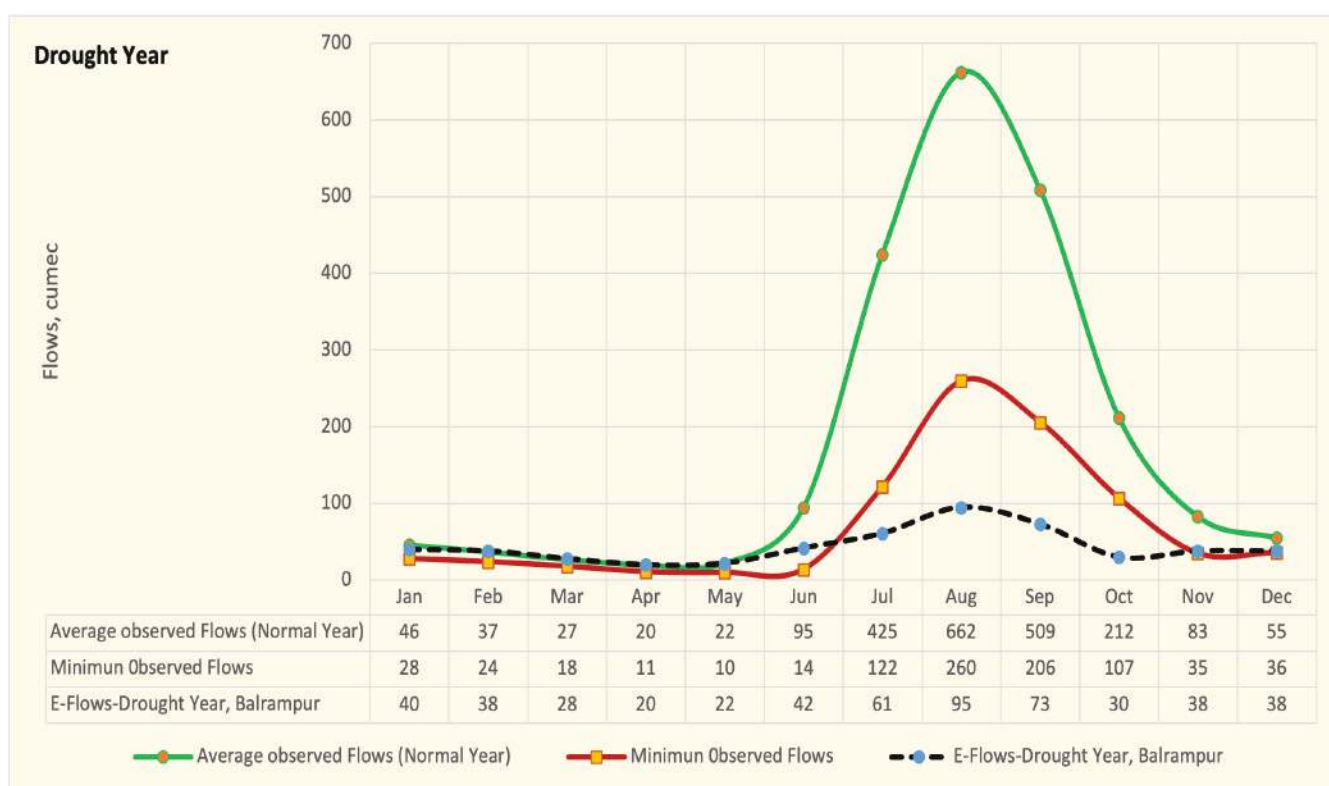
**Table 70: Desired water levels/depths along with rationale for the Balrampur E-Flows location on the Rapti River**

|  |                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                                                 |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                    | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <p>Dry season: 2.5 m<br/>Wet season: 4.9 m</p> <p>The motivating thematic for the desired depth during the dry season is Aquatic Biodiversity (Indian major carps), while the desired depth for the wet season is motivated by Fluvial Geomorphology (to inundate primary and flanked areas suitable for temperature variations, plankton, etc., during wet seasons).</p> |
|  | <p>The recommended dry-season depth will maintain the longitudinal connectivity and partially inundate the main channel and the lateral bar that lies closer to the left bank. The recommended wet season depth will inundate the primary channel and flanked channels adjacent to the main channel.</p> | <p>The desired water levels would satisfy people's perception of a healthy river during the summer season. The recommended flows would allow satisfactory fulfilment of Socio-cultural rituals and the sustenance of livelihood activities with ease.</p>                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                           |
|  | <p><i>An additional requirement is a depth of 7 m (&gt;1300 cumec) for a period of 10-15 days in the months of July-August-September. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p>                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                           |
|  | <p>The recommended flows would help to maintain longitudinal connectivity and some level of lateral connectivity, though only partially.</p>                                                                                                                                                             | <p>The drought scenario is a stress condition and local communities fully recognise and appreciate this. They are fine with the stress condition as they know that the following year would be a better one and they can resume their normal day-to-day activities pertaining to livelihood and Socio-cultural rituals. Nevertheless, the recommended water levels would certainly help them better carry out the different activities pertaining to their livelihood and Socio-cultural lives.</p> | <p>Dry season: 2 m<br/>Wet season: 3 m</p> <p>[The motivating thematic for the desired depth for both the seasons is Aquatic Biodiversity (Indian major carps).]</p>                                                                                                                                                                                                      |

Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Balrampur E-Flows location on the Rapti River (Figure 180 & 181).



**Figure 180: E-Flows recommendations in a monthly flows patter-Balrampur location (Maintenance Year)**



**Figure 181: E-Flows recommendations in a monthly flows pattern-Balrampur location (Drought Year)**





## 5.2.4.2 Bansi

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 71.

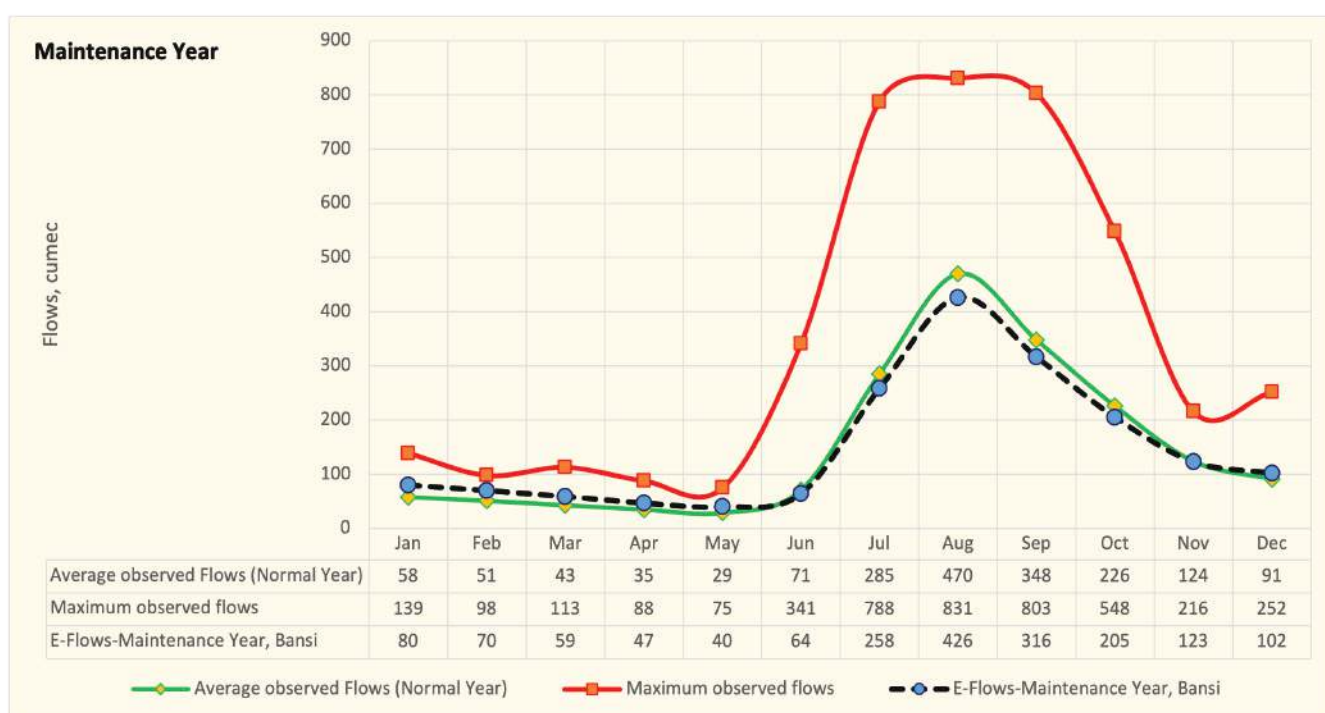
| Year                    | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Maintenance Year</b> | <p><b>Aquatic Biodiversity</b></p> <p>The recommended depth for the dry season is required to maintain a congenial thermal profile for the IMC fish species (particularly to the brooders of <i>C.mrigala</i> and <i>L.rohita</i>). It is also required to maintain the desired Dissolved Oxygen level and for the growth of fish food organisms (plankton, periphyton, benthos). Therefore, the desired water level will safeguard the stocked fish. The depth recommended for wet season are required for development of suitable nursery grounds for IMC. The desired water depth is suitable for temperature variations, planktons, etc. during the wet season.</p> |
| <b>Drought Year</b>     | <p>The recommended depth will ensure minimum depth in side channels for the revival of side/connected pools, which are useful for the flow of nutrients, growth of fish food organisms (plankton, periphyton and benthos) and for the development of nursery grounds for fish juveniles. At this depth, the side channel is inundated, leading to activation of side channels during the wet season. Further movement of biota and rich nutrition exchange will be possible, if this depth is attained.</p>                                                                                                                                                             |

**Table 71: Desired water levels/depths along with rationale for the Bansi E-flows location**

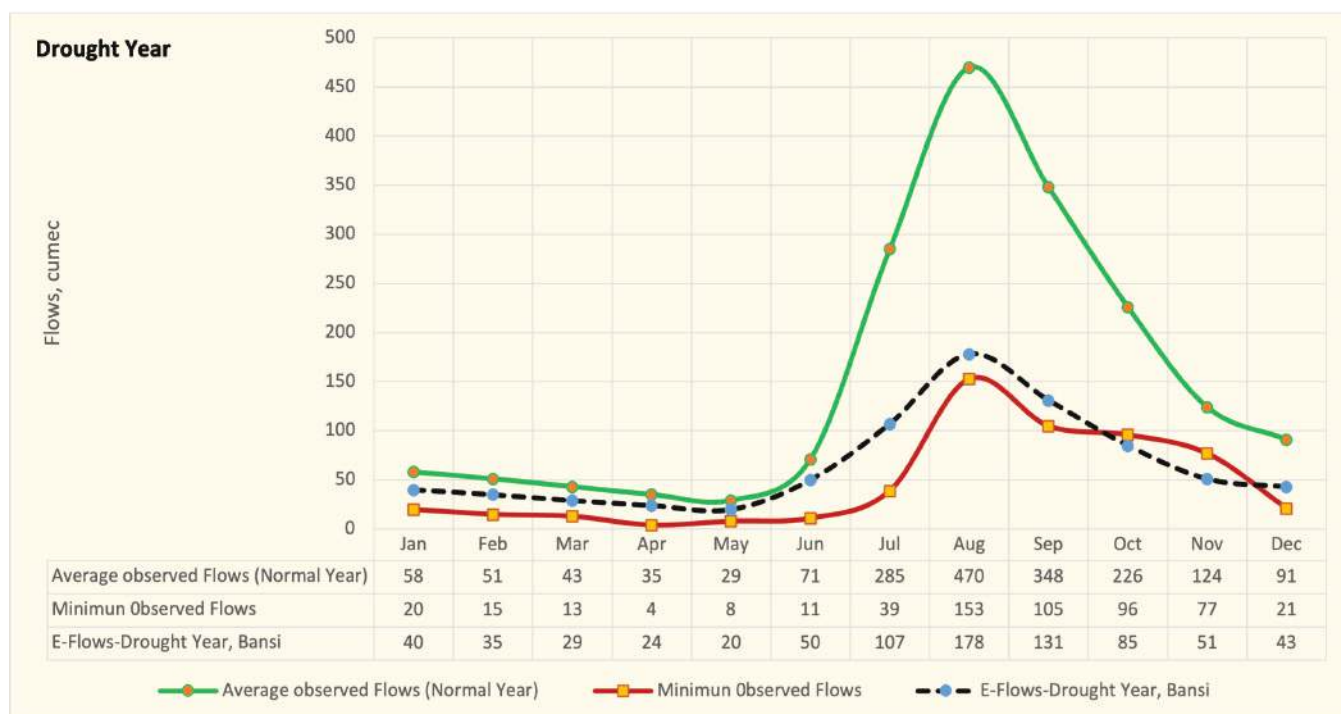
|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                          |
|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                    |
|  | <p>The recommended depth for the wet season will inundate the primary channel and the portion adjacent to the floodplain.</p>                                                                                                                                                                                                                                                                                                                                         | <p>The recommended water levels are well above the requirement from the Socio-cultural perspective. Various livelihood activities and Socio-cultural rituals can be conducted satisfactorily. The recommended flows, once achieved, would lead to appreciation of a healthy river by the local communities.</p>                                                                                                                                                                                 | <p>Dry season: 2.4 m<br/>Wet season: 5.9 m</p> <p>The motivating thematic for the desired depth for the dry season is Aquatic Biodiversity (Indian major carps) and the wet-season desired depth is motivated by Fluvial Geomorphology (to inundate primary and flanked channels).]</p>                            |
|  | <p><i>An additional ask is to attain a depth of 7.75 m for a period of 10-15 days in the months of July-August-September, which will completely inundate the channel belt and the floodplain region crossing the levee region. Recent planform imageries show a loss of lateral connectivity in certain reaches in the form of reduction of active floodplain area since the 1990s, therefore it is of prime importance to maintain the lateral connectivity.</i></p> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                    |
|  | <p>The recommended flows would help to maintain longitudinal connectivity and some level of lateral connectivity, though only partially.</p>                                                                                                                                                                                                                                                                                                                          | <p>The drought scenario is a stress condition and the local communities fully recognise and appreciate this. They are fine with the stress conditions, as they know that the following year will be a better one and they can resume their normal day-to-day activities pertaining to livelihood activities and Socio-cultural rituals. The recommended depth will alleviate a certain degree of inconvenience while still permitting the performance of rituals and livelihood activities.</p> | <p>Dry season: 2 m<br/>Wet season: 3.35 m</p> <p>[The motivating thematic for the desired depth for the dry season is Aquatic Biodiversity (Indian major carps) and for the wet season, the Fluvial Geomorphology thematic motivated the desired depth (mainly to ensure some level of lateral connectivity).]</p> |



Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Bansi E-Flows location on the Rapti River (Figure 182 & 183).



**Figure 182: E-Flows recommendations in a monthly flows pattern- Bansi location (Maintenance Year)**



**Figure 183: E-Flows recommendations in a monthly flows pattern- Bansi location (Drought Year)**



### 5.2.4.3 Birdghat–Gorakhpur

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 72.

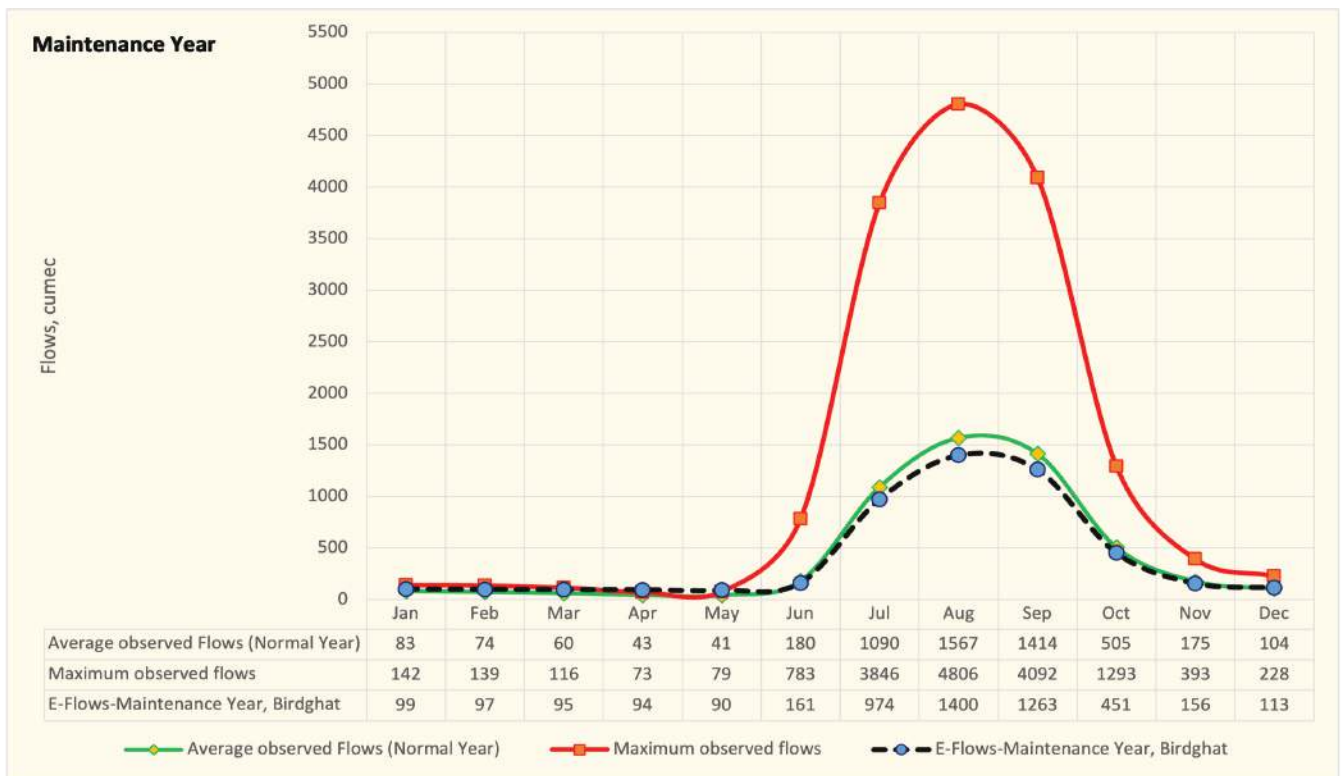
| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                  | <p>The recommended depth for the dry season will take care of habitat requirement of IMC species. The recommended depth for the wet season is essential for providing space for normal body movement for the Ganga river dolphin. The feeding grounds increase with increasing depth. River Dolphins tend to spend a majority of their time in areas with abundant food supply. The recommended depth during wet season will aid in formation and activation of side-pools/floodplain-wetlands. This would also help and support the flourishing communities of small- sized fishes and minnows that are found, which shall be helpful since they are considered an important natural food for the Ganga river dolphin.</p> |
| Drought Year     | <p>The recommended depth is a bare minimum requirement for the existence of IMC fish species at this location, though not really conducive. However, at this depth, the species is likely to survive the stress conditions posed by the Drought Year.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

**Table 72: Desired water levels/depths along with rationale for the Birdghat Gorakhpur E-Flows location on the Rapti River**

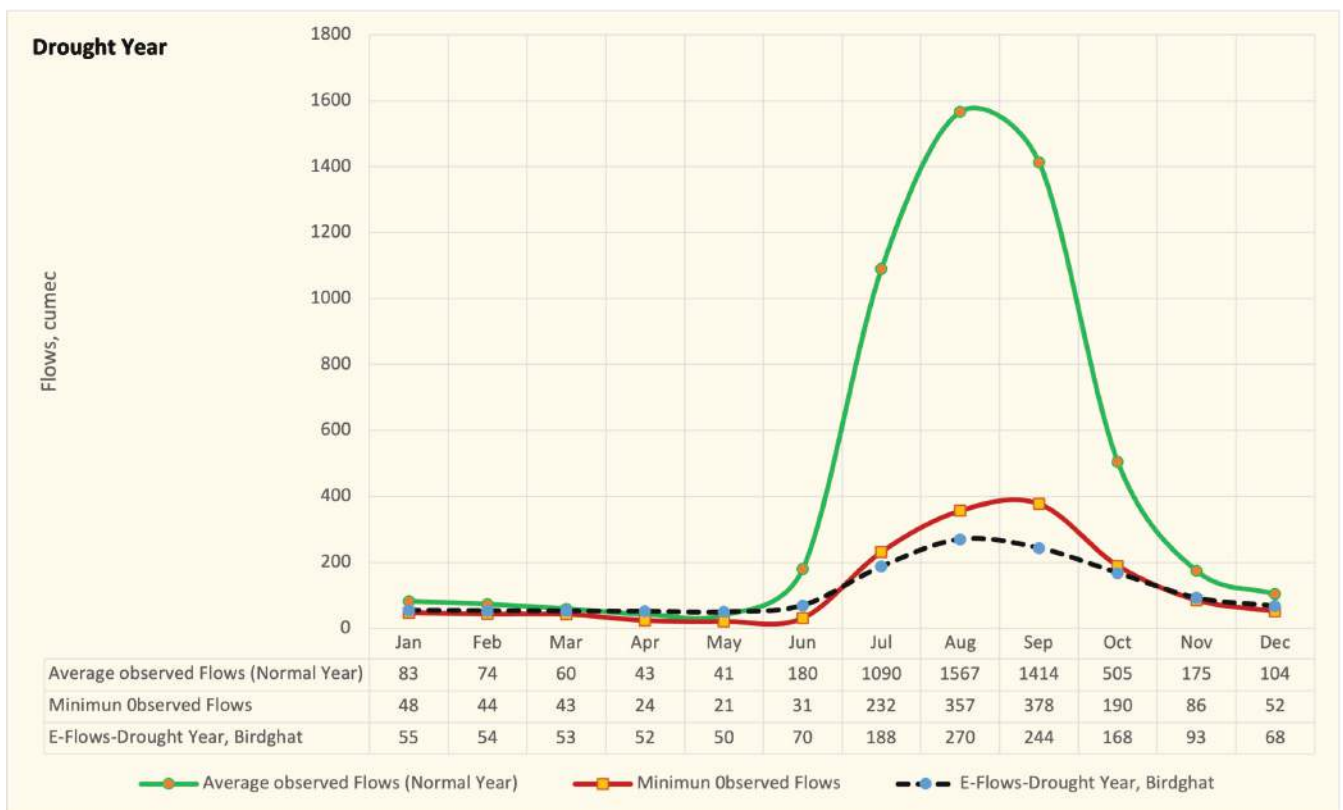


|  |                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Desired Water Level<br>(consensus values)                                                                                                                     |
|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                           | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Dry season: 2 m<br>Wet season: 6.4 m<br><br>[The motivating thematic for the desired depth for the wet season is Aquatic Biodiversity (Ganga river dolphin).] |
|  | <p>The recommended depth for the dry season will maintain longitudinal connectivity by partially inundating the primary channel and the lateral bar that lies closer to the right bank.</p> <p>The recommended depth for the wet season will inundate the primary channel and flanked portion adjacent to the main channel.</p> | <p>The recommended depth or water levels at this location will take care of satisfactory conduct of livelihood activities and Socio-cultural rituals. With the attainment of these water levels during summers, the memory of a healthy river would be revived in the minds of local communities.</p> <p>The wet season flows are not a critical issue at this location. The recommended flows, once achieved, would lead to the appreciation of a healthy river by the local communities.</p>        |                                                                                                                                                               |
|  | <p><i>An additional requirement is a depth of 8.9 m for a period of 10-15 days in the months of July-August-September. This depth will maintain the lateral connectivity, inundating the minor channels flanking the main channel and therefore suitably inundating the channel belt and portion of the floodplain.</i></p>     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                               |
|  | <p>The recommended flows would help to maintain longitudinal connectivity and some level of lateral connectivity, though partially.</p>                                                                                                                                                                                         | <p>The drought scenario is a stress condition and local communities fully recognise and appreciate this. They are fine with the stress condition as they know that the following year would be a better one and they can resume their normal day-to-day activities pertaining to livelihood and Socio-cultural rituals. Nevertheless, the recommended water levels would certainly help to reduce their hardships in regard to carrying out the livelihood activities and Socio-cultural rituals.</p> | Dry season: 1.5 m<br>Wet season: 3 m<br><br>[The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity (IMC).]                   |

Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Birdghat–Gorakhpur E-Flows location on the Rapti River (Figure 184 &185).



**Figure 184: E-Flows recommendations in a monthly flows pattern–Birdghat Gorakhpur location (Maintainance Year)**



**Figure 185: E-Flows recommendations in a monthly flows pattern–Birdghat Gorakhpur location (Drought Year)**



## 5.2.5 Additional locations on Ganga

As noted earlier in section 4.5, as part of this exercise, the E-Flows are being recommended for two locations, Shahzadpur and Rajghat-Varanasi.





## 5.2.5.1 Shahzadpur

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 73.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                  | <p>The Ganga river dolphin is sighted at this location. The recommended depth during the dry season will ensure appropriate hydraulic habitat for the species in terms of depth and active channel width. The river stretch at this location also holds a number of other fish species (mostly small-sized species, minnows and catfishes). Among the fishes found, exotic species like common carp (<i>Cyprinus carpio</i>) and Nile tilapia (<i>Oreochromis niloticus</i>) form sizeable populations. The Indian major carps (IMC) are negligible in this stretch. Prey base of the Ganga river dolphin is almost intact as small-sized fishes like <i>Cabdio morar</i>, <i>Chela cadius</i> are found which are important natural food for the species.</p> <p>The recommended depth for the dry season is essential for providing space for normal body movement and adequate prey base. Feeding grounds increase with increasing depth. River dolphins tend to spend the majority of their time in areas with abundant food supply. The recommended depth during wet season will form/inundate side-pools/wetlands. This would also help and support the flourishing communities of small-sized fishes and minnows, which are considered food for the Ganga river dolphin.</p> |
| Drought Year     | <p>The recommended depths are the bare minimum requirement for the survival of the Ganga river dolphin population during extreme conditions. While recommending depth, the width is also a critical factor for this location.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

**Table 73: Desired water levels/depths along with rationale for the Shahzadpur E-Flows location on the Ganga River**

|  |                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                  |
|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                 | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Dry season: 3 m<br>Wet season: 6 m                                                                                                                                                                                                                                         |
|  | <p>The recommended depth during the dry season will maintain the longitudinal connectivity and partially inundate the bar forms (mid-channel bars) and the primary channel which lies closer to the left bank.</p> <p>The recommended wet-season depth is required to maintain some flows in the flanked secondary channel on the right bank side for most of the monsoon period.</p> | <p>The appearance of sandbanks is a source of concern and a visual reminder of the decreased flows in the river, according to the local communities. The recommended depth, while it cannot affect the large sandbanks on the right bank, will allow for an ‘uncluttered’ expanse of water on the left bank. It will also allow for the comfortable carrying out of rituals. The respondents attested that farming has been affected by the lack of floods entering the fields. According to them, floodwater reaching the fields will both replenish the farms and also possibly, redistribute the sandbanks in the river.</p> | [The motivating thematic for the desired depth for the dry season is Aquatic Biodiversity (Ganga river dolphin). whereas for the wet season the motivating thematic is Fluvial Geomorphology (to maintain some flows in the flanked secondary channel on the right bank).] |
|  | <p><i>An additional requirement would be a depth of 7.8 m for a period of 10-15 days in the months of July-August-September. This will maintain lateral connectivity, inundating channel belt and a portion of active floodplain.</i></p>                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                            |
|  | <p>With the recommended depth, the longitudinal connectivity would be maintained in the stress condition during dry season. Some level of lateral connectivity would be also achieved with recommended water levels during wet season.</p>                                                                                                                                            | <p>It is understood that hardships and loss of livelihood will need to be borne during Drought Years. This recommended depth during summer will allow for the carrying out of a few rituals and domestic activities, but with discomfort. This recommended water level during the wet season allows for the upkeep of livestock, some minimal winter cultivation, and some basic rituals, though other livelihoods and social activities will be diminished.</p>                                                                                                                                                                | Dry season: 2.5 m<br>Wet season: 4 m                                                                                                                                                                                                                                       |
|  |                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | [The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity (Ganga river dolphin).]                                                                                                                                                            |

Based on the recommended water levels or depths, the E-Flows graphs were created for both Maintenance Year and Drought Year for the Shahzadpur E-Flows location on the Ganga River (Figure 186 & 187).

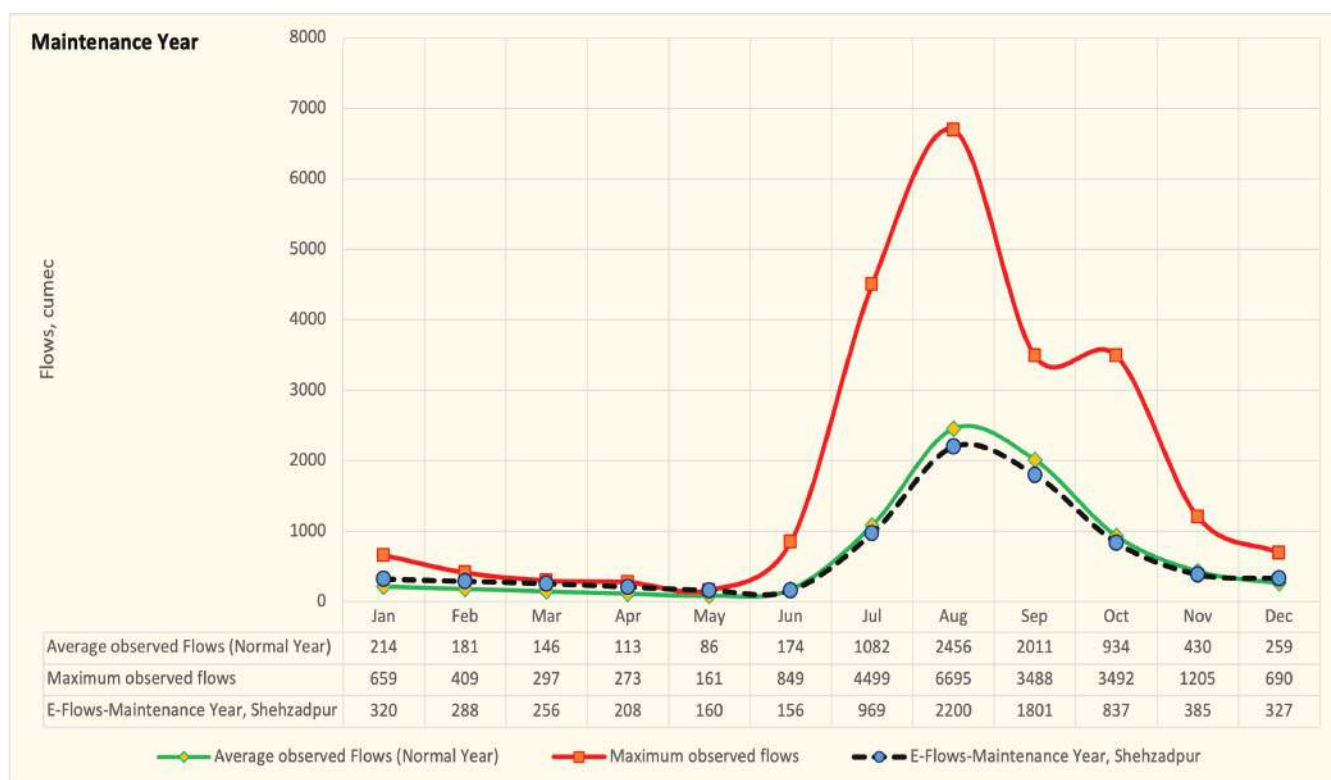


Figure 186: E-Flows recommendations in a monthly flows pattern–Shahzadpur location (Maintenance Year)

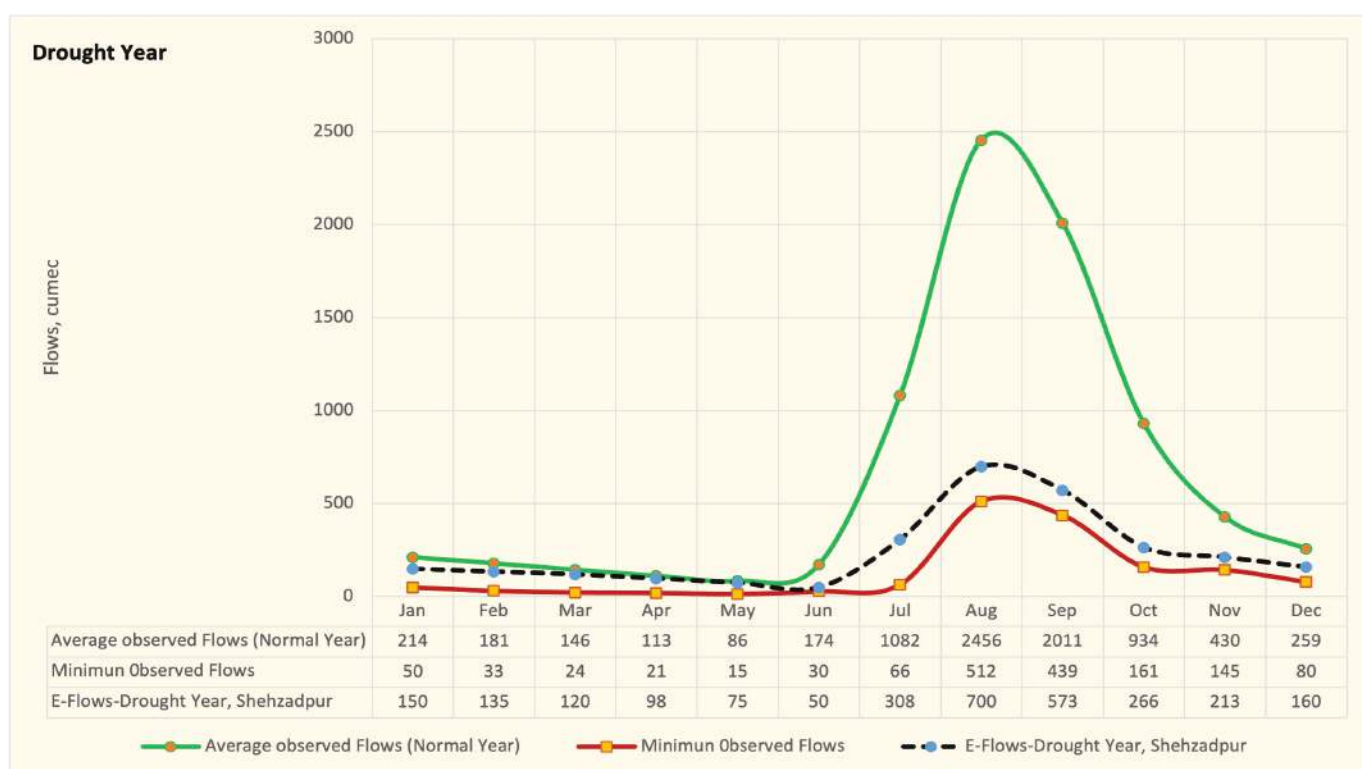


Figure 187: E-Flows recommendations in a monthly flows pattern–Shahzadpur location (Drought Year)





## 5.2.5.2 Rajghat- aranasi

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are shown in Table 74.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                  | <p>The Ganga river dolphin is sighted at this location. The recommended depth during the dry season will ensure appropriate hydraulic habitat for the species in terms of depth. At this section channel, width is a critical factor; hence the recommended depth should be seen in that light. The river stretch at this location also holds a number of other fish species (mostly small-sized species, minnows and catfishes). Among the fishes caught, exotic species like common carp (<i>Cyprinus carpio</i>), <i>Sperata seenghala</i> and <i>Eutropiichthys vacha</i> form sizeable populations.</p> <p>The recommended depth for the dry season is essential for providing space for normal body movement and adequate prey base. The feeding ground increases with increasing depth. River dolphins tend to spend the majority of their time in areas where they have access to an abundant food supply, which include extended depth. The recommended depth during wet season will form/inundate side-pools/wetlands. This would also support the flourishing communities of small-sized fishes and minnows, which are considered food for the Ganga river dolphin.</p> <p><i>In case of larger or mighty rivers like Ganga (especially middle to lower stretches), the flows must be much higher in comparison to other comparatively smaller rivers or tributaries. This is because the middle and downstream stretches of larger rivers and deep pools hold brooder stocks and large-sized specimens of fishes, which are responsible for auto-stocking/propagation of the prized species in the river.</i></p> |
| Drought Year     | <p>The recommended depths are a bare minimum requirement for the survival of the Ganga river dolphin population during extreme conditions. While recommending depth, the width is also a critical factor for this location.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

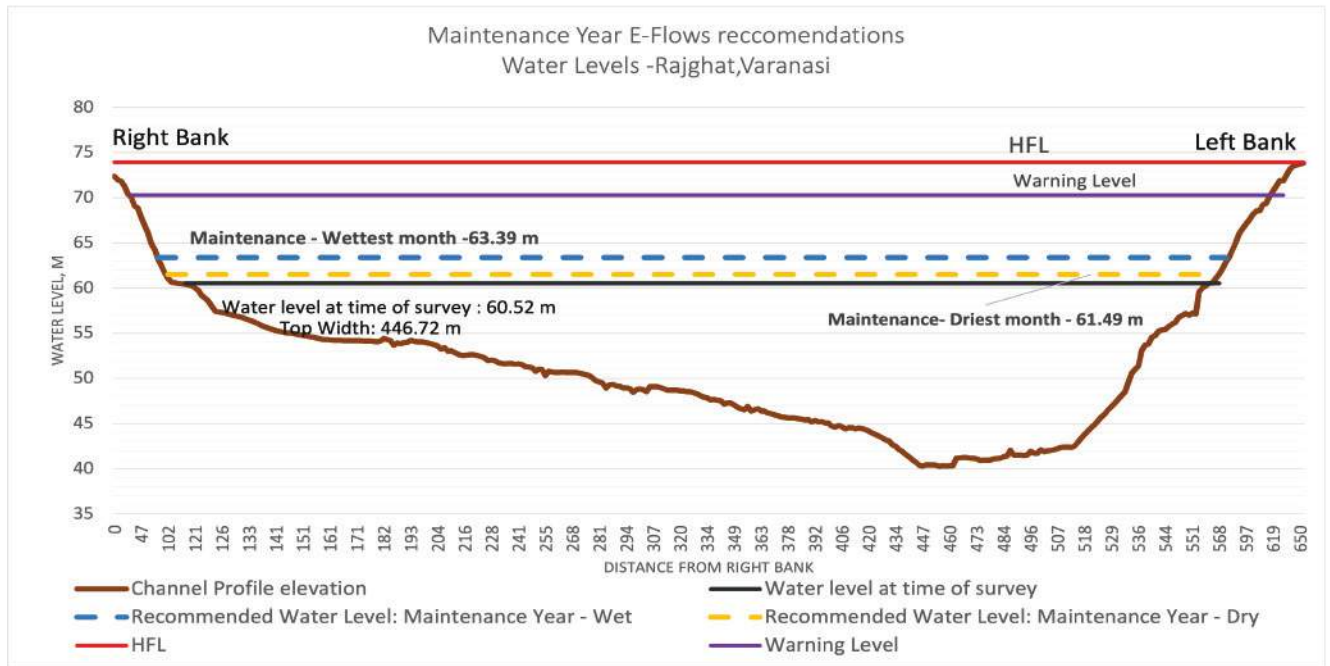
**Table 74: Desired water levels/depths along with rationale for the Rajghat-Varanasi E-Flows location on the Ganga River**



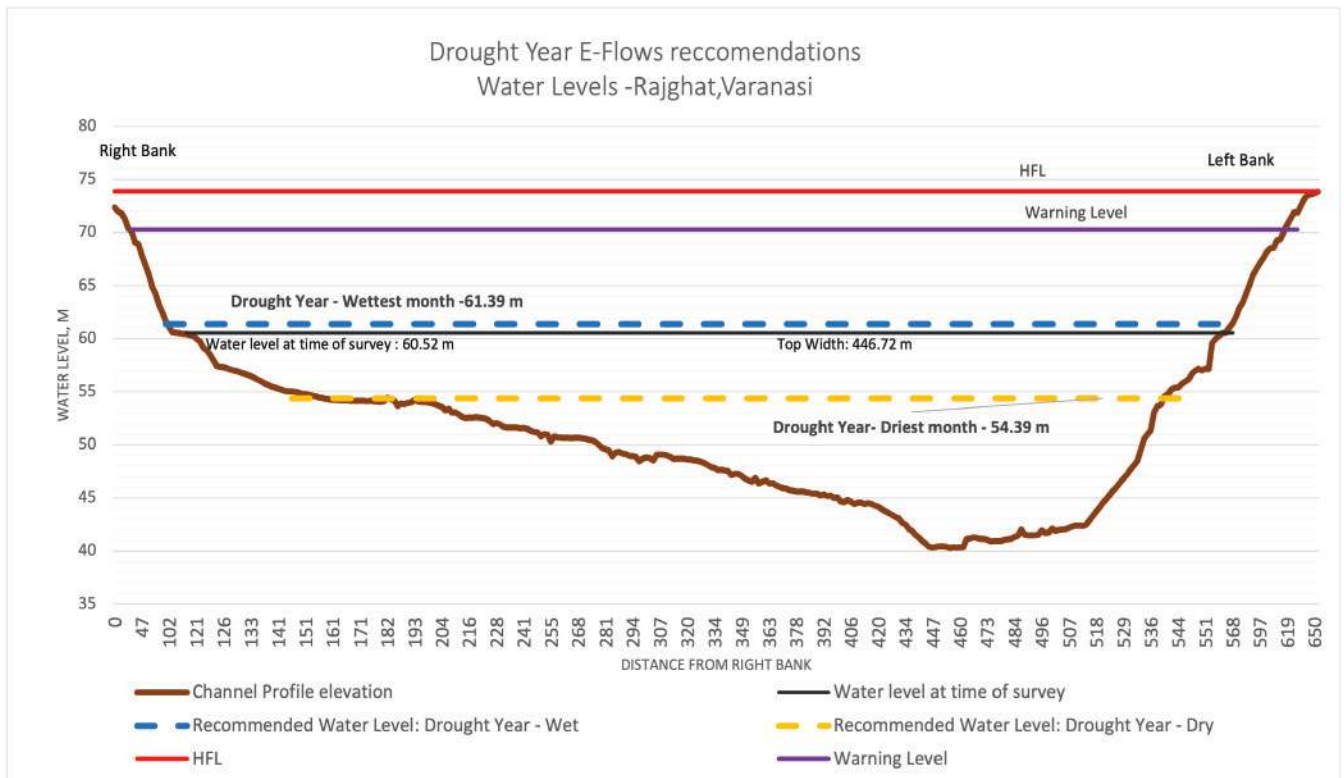
|                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                              | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                    | Fluvial Geomorphology                                                                                                                                                                                                                                                         | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                       | Dry season: 21.3 m<br>Wet season: 23 m<br><br>[The motivating thematic for the desired depth for the dry season is Aquatic Biodiversity (Ganga River Dolphin), whereas for the wet season the motivating thematic is Fluvial Geomorphology (to maintain some flows in the flanked secondary channel on the right bank).] |
|                                                                                                                                                                                                                                    | The dry-season recommended water levels will maintain longitudinal connectivity and partially inundate the main channel closer to the left bank. The wet season recommended water levels will maintain lateral connectivity by completely inundating the channel belt.        | The recommended water levels would comfortably allow the water to reach the bottom of the ghats, allowing the pilgrims to access it without inconvenience while also allowing boatmen a reasonable channel to ply their boats.                                                                                                                               |                                                                                                                                                                                                                                                                                                                          |
| An additional requirement would be a depth of 25 m for a period of 10-15 days in the months of July-August-September. This will maintain lateral connectivity; inundating the channel belt and a portion of the active floodplain. |                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                          |
|                                                                                                                                                                                                                                    | At the recommended depth for dry season the minimum longitudinal connectivity will be maintained, that is essential to carry the suspended sediments along with nutrients. The recommended depth for the wet season will maintain both longitudinal and lateral connectivity. | It is understood that hardships and loss of livelihood will need to be borne during Drought Years. This recommended depth during summer will allow for the carrying out of a few rituals and domestic activities, but with some level of discomfort. But this discomfort is acceptable – as the people hope that next year would be a normal and better one. | Dry season: 14 m<br>Wet season: 21 m<br><br>[The motivating thematic for the desired depth for both seasons is Aquatic Biodiversity (Ganga River Dolphins).]                                                                                                                                                             |



Based on the recommended water levels or depths, an exercise was conducted (like other sites where E-Flows were recommended, in terms of monthly flows pattern) to arrive at E-Flows graphs for the Rajghat-Varanasi site as well. However, the model outputs have several assumptions and limitations, and therefore the team did not find it to be appropriate to use for estimation of depth and corresponding discharges. In view of this, the team only recommend water levels/depth desired as E-Flows for Maintenance and Drought Year for Rajghat-Varanasi. The water-level graphs depicting E-Flows requirements for the Rajghat-Varanasi site are given as Figure 188 and 189.



**Figure 188: E-Flows recommendations in terms of water levels for the Rajghat-Varanasi location (Maintenance Year)**



**Figure 189: E-Flows recommendations in terms of water levels for the Rajghat-Varanasi location (Drought Year)**

## 5.2.6 Yamuna River

There are five designated E-Flows locations along the Yamuna River under this study, making it one of the most crucial rivers for the state. Despite Mathura being the first major city on the riverbanks within Uttar Pradesh, it was deemed necessary to identify an E-Flows site in Haryana, right before the river enters the state. The objective was to assess the river flows quantitatively before it reaches Uttar Pradesh. In this context, the Mohana site on the Yamuna River was chosen for E-Flows assessment.

Apart from Mohana, there are four E-Flows sites on the Yamuna River and all of them fall in Uttar Pradesh.



### 5.2.6.1 Mohana site

The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 75.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                  | <p>Indian major carps are the motivational species and the recommended depth is mandatory to safeguard the stocked fish from extreme weather conditions. The pollution level and lower depth caused the disappearance of the species. Size and weight of fish are significantly affected by lower depths.</p> <p>The recommended wet-season depth is required for the development of suitable nursery grounds (flooding of side pools and connected wetlands) for IMC. The recommended depth is beneficial for temperature variations, better oxygen, plankton productions, etc.</p> |
| Drought Year     | For the survival of the IMC population during stress conditions, the recommended depth is essential.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

**Table 75: Desired water levels/depths along with rationale for the Mohana site on the Yamuna River**

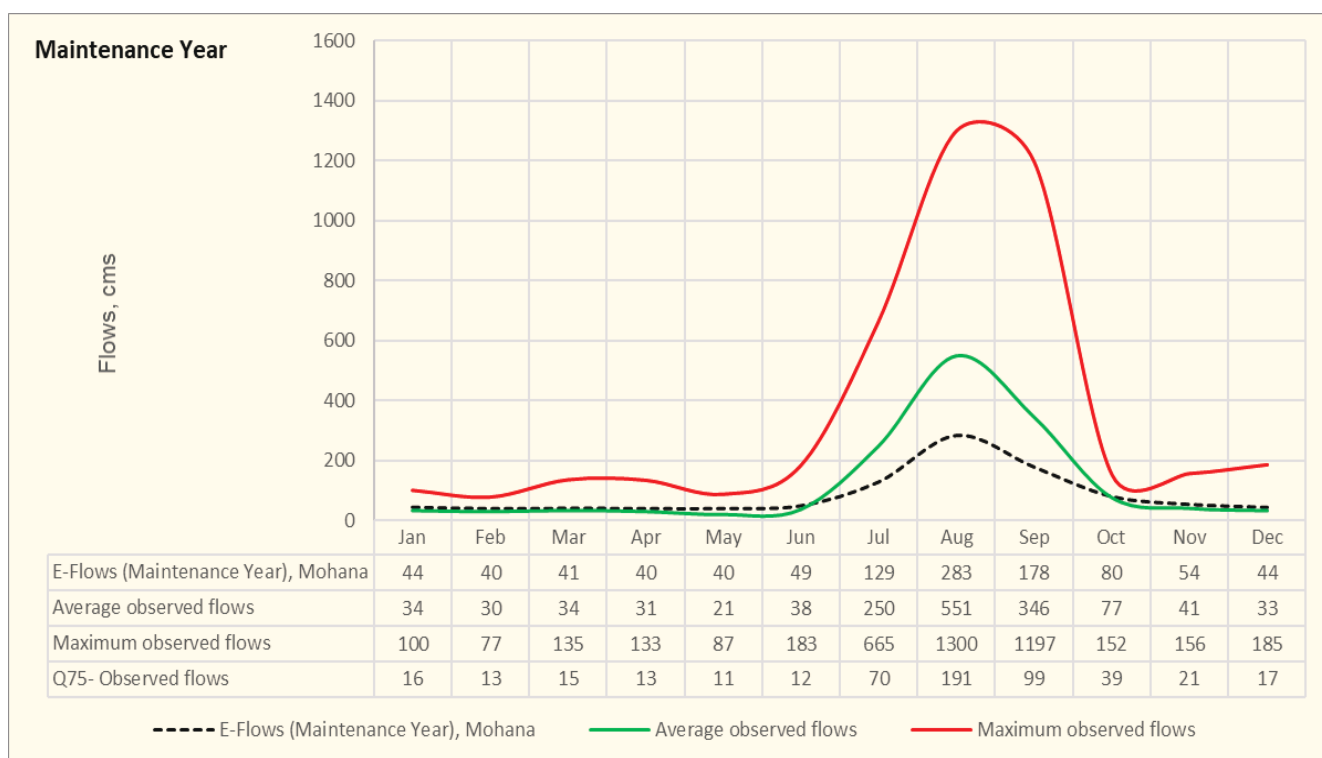


|  |                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                       | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                         |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                  | Socio-cultural Aspects                                                                                                                                                                                                                                                                | <p>Dry season: 2.8 m<br/>Wet season: 4.5 m</p> <p>Motivating thematic for desired depth for both dry and wet season is Fluvial Geomorphology (Inundation of primary and secondary channels and to aid sediment transport).</p>                                                                                                                    |
|  | <p>The desired flows would maintain the longitudinal connectivity of the river during the dry season. The primary channel will be inundated, which runs closer to the right bank of the channel belt.</p> <p>During the wet season, the desired flows will maintain continuity in the dominant secondary channels.</p> | <p>Respondents desire reduction in fish mortality and noxious odours. Stagnation of water should be avoided by connecting the pools, and thereby allowing some aquatic life to thrive in summers and winters. In monsoon, the water needs to reach at the top of the channel bed.</p> |                                                                                                                                                                                                                                                                                                                                                   |
|  | <p><i>An additional requirement is a depth of 6.8 m (&gt;1600 cumec) for 10-15 days during the monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p>                                                                     |                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                   |
|  | <p>The recommended water levels are the least that are required for ensuring longitudinal connectivity during the dry season. Some level of lateral connectivity is the prime motivation for drought year.</p>                                                                                                         | <p>Respondents desire the river to flow continuously without any bad odour.</p>                                                                                                                                                                                                       | <p>Dry season: 2.0 m<br/>Wet season: 3.1 m</p> <p>Motivating thematic for desired depth for both dry and wet season is Fluvial Geomorphology (Inundation of primary and secondary channels and to aid sediment transport) and Socio-cultural (For livelihood aspects; reduce fish mortality, noxious odours and also increase soil moisture).</p> |



**Figure 190: Cross-section profile with water-levels/depth recommendations for the downstream E-Flows site at Mohana.**

Based on the recommended water levels or depths (Figure 190), the E-Flows graphs were created for both Maintenance Year and Drought Year for the Mohana E-Flows site on the Yamuna River (Figure 191 & Figure 192).



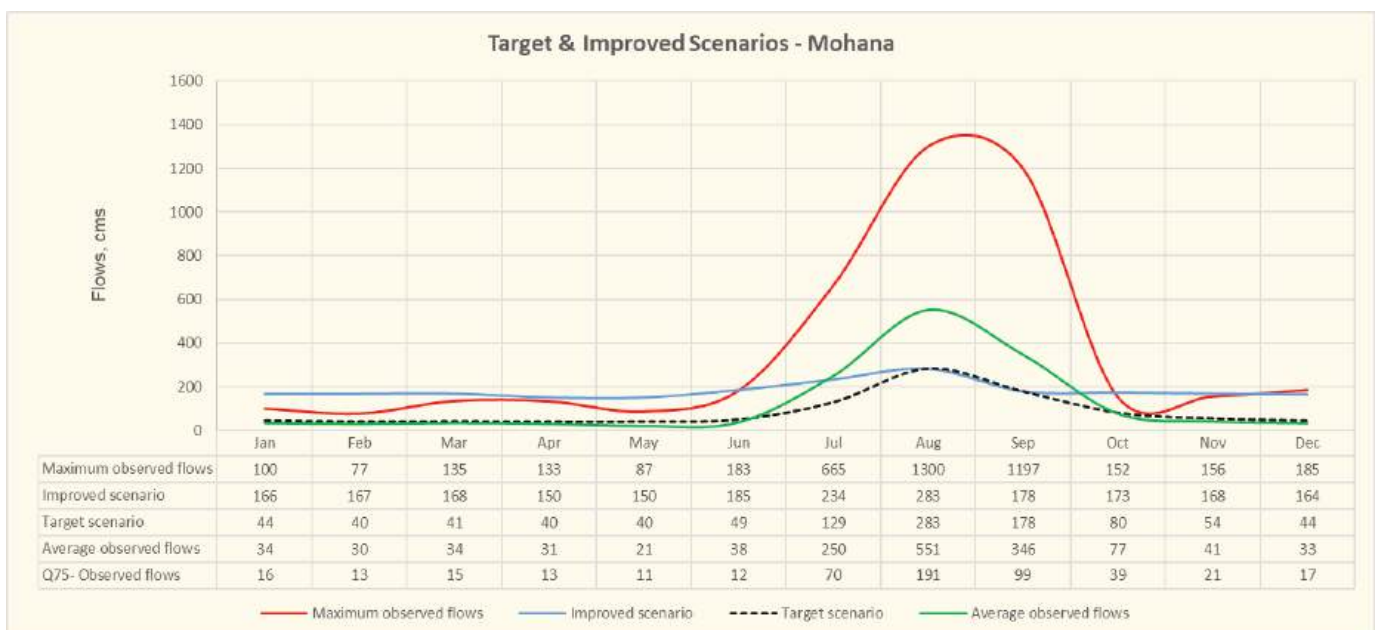
**Figure 191: E-Flows recommendations in a monthly flows pattern–Mohana site (Maintenance Year)**



**Figure 192: E-Flows recommendations in a monthly flows pattern–Mohana site (Drought Year)**

The Q75 values (monthly flows at 75% dependability) is presented in above graphs for reference.

Some of the locations along the Yamuna River are impacted in terms of flows and water quality. This means that overall health improvement for the Yamuna River at such locations would be a long-term goal. However, as an immediate goal, one would aim for some improvement in the river's health at these locations. Keeping this in mind, the team developed two distinct scenarios for water managers and decision-makers to consider: the Target Scenario, which should be achieved in a shorter time duration, and the Improved Scenario, which could be a long-term goal. Mohana is one such E-flows location on the Yamuna River; therefore, an additional graph (Figure 193) has been created to illustrate the flow requirements to achieve both the Target and Improved scenarios.



**Figure 193: Mohana E-Flows Recommendations–Improved Scenario**



The Mohana E-Flows site is located downstream of the Okhla Barrage (in the National Capital Region (NCR) and marks the confluence with the Hindon River. The site faces significant challenges of infrastructural fragmentation and pollution, leading to a notable degradation of the river in this stretch. This degradation hampers the river's ability to support the ecosystem and local communities, posing a threat to the health of aquatic species and people. The NCR contributes to direct pollution as the river passes through the city, and indirectly through its connection with the Hindon River. The releases from the Okhla Barrage are insufficient to meet the ecological and Socio-cultural needs downstream, and the low flows exacerbate pollution levels at the E-Flows site.

The immediate goal for the E-Flows requirement (Target Scenario) is to address ecological and Socio-cultural needs based on historical flow patterns at the site. The lean season flows are a major concern, and recommendations have been formulated by examining thematic recommendations and the E-Flows study conducted by the National Institute of Hydrology at the 'Palla' site, which is upstream of the NCR region. It is recommended to maintain a minimum flow of 40 cumec at the Mohana site during the lean season of the Maintenance Year. The target scenario will provide 2.8 m depth and improved scenario will provide 3.6 m depth in the lean season of the Maintenance Year.

The lean season flows needed aren't consistently available throughout the studied hydrological cycle. There are very old structural interventions and water management practices, which has altered the flows for a long time. Meeting the ultimate desired state of river is ambitious and should be approached as a long term goal, the same is depicted in the Improved Scenario.

As noted earlier, at the Mohana site, one more scenario (Improved Scenario) was developed, which is a kind of long-term aspirational goal where flows would be enhanced after working on all main avenues, release from dams, sectoral demand management (reducing footprint), reduction in groundwater abstractions, etc.



## 5.2.6.2 Mathura site

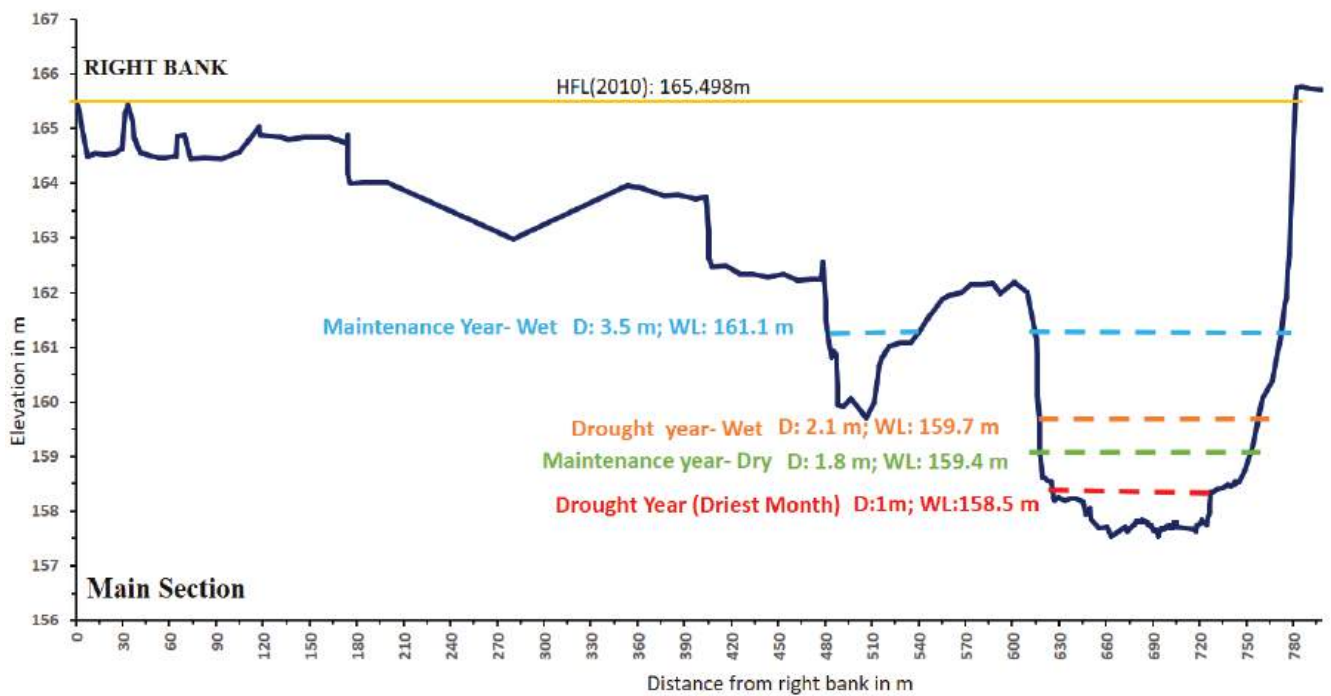
The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 76.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                  | <p>Indian major carps are the motivational species and the recommended depth is mandatory to safeguard the stocked fish from extreme weather conditions. The pollution level and lower depth caused the disappearance of the species.</p> <p>The recommended wet-season depth is required for the development of suitable nursery grounds (flooding of side pools and connected wetlands) for the IMC. It is desirable that water-quality parameters remain within the standard limit for the survival of the species.</p> |
| Drought Year     | For survival of the IMC population during stress conditions, the recommended depth is essential.                                                                                                                                                                                                                                                                                                                                                                                                                           |

**Table 76: Desired water levels/depths along with rationale for the Mathura site on the Yamuna River**

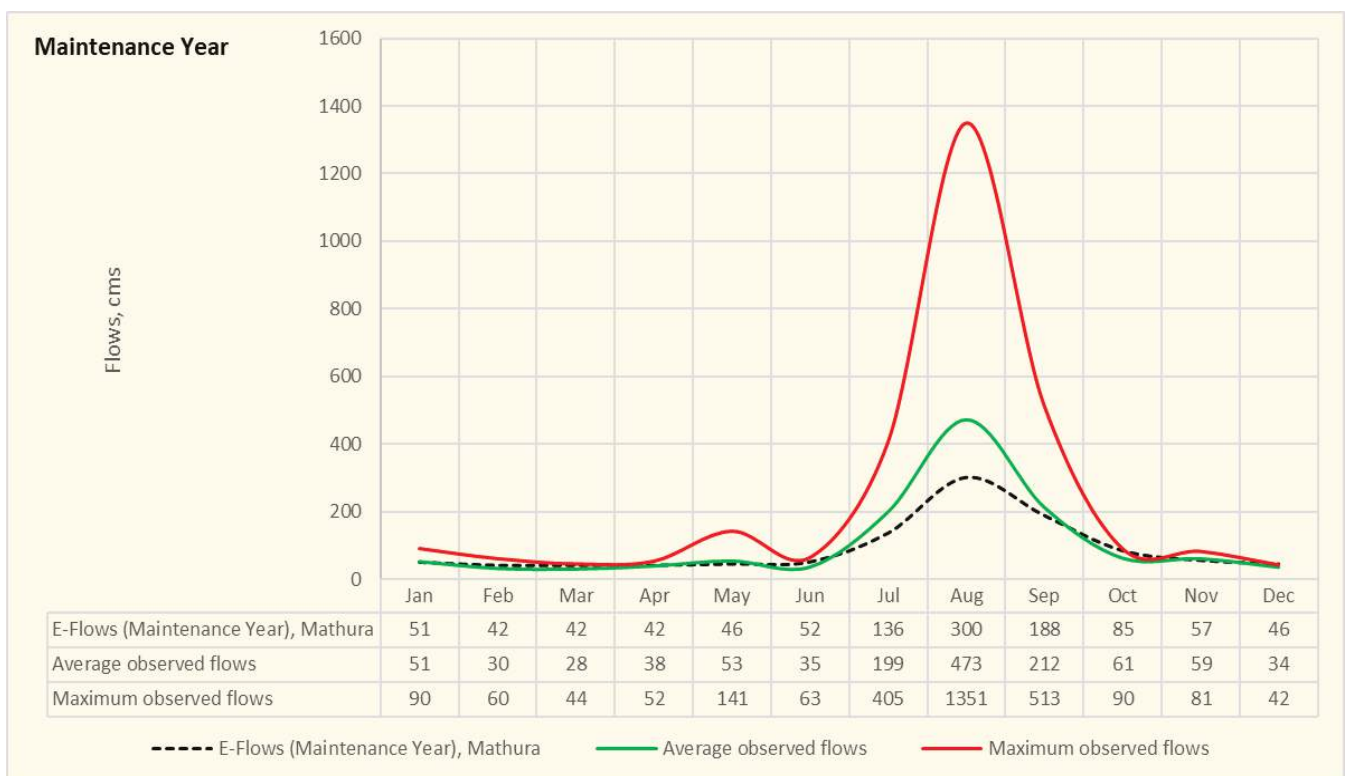


|  |                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                            | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                            |
|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                         | Socio-cultural Aspects                                                                                                                                                                                                                                                     | Dry season: 1.8 m<br>Wet season: 3.5 m                                                                                                                                                                                                                                                               |
|  | The desired flows would maintain the longitudinal and lateral connectivity of the river during dry season. The primary channel will be inundated, which runs closer to the left bank side of the channel belt. During the wet season, the desired flows will maintain continuity in the dominant secondary channels.                                          | People are adapted to the no-flood condition. In monsoon, the desired water level is touching the base of the Thakurani ghat or higher. In summers, one gate of the barrage on the extreme right should be left open to allow for adequate flows, at least near the Ghats. | Motivating thematic for desired depth for dry season is Fluvial Geomorphology (to maintain some level of lateral and longitudinal connectivity and to aid the sediment transport), and motivating thematic for the desired depth for wet season is Socio-cultural (mainly for carrying out rituals). |
|  | <i>An additional requirement is a depth of 6.8 m (&gt;4300 cumec) for 10-15 days at some point in the entire monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region. Annual flood up to the road that runs along the top of the ghats, but in the flood season 6-7 m.</i> |                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                      |
|  | The recommended water levels are the least that are required to ensure longitudinal connectivity during the dry season. Some level of lateral connectivity is the prime motivation for drought year.                                                                                                                                                          | Respondents desire the river to flow continuously, at least near the Ghats.                                                                                                                                                                                                | Dry season: 1.0 m<br>Wet season: 2.1 m<br><br>Motivating thematic for desired depth for the dry season is Aquatic biodiversity (for Indian major carps) & Socio-cultural (for carrying out rituals) and for wet season is Aquatic biodiversity (for Indian major carps).                             |

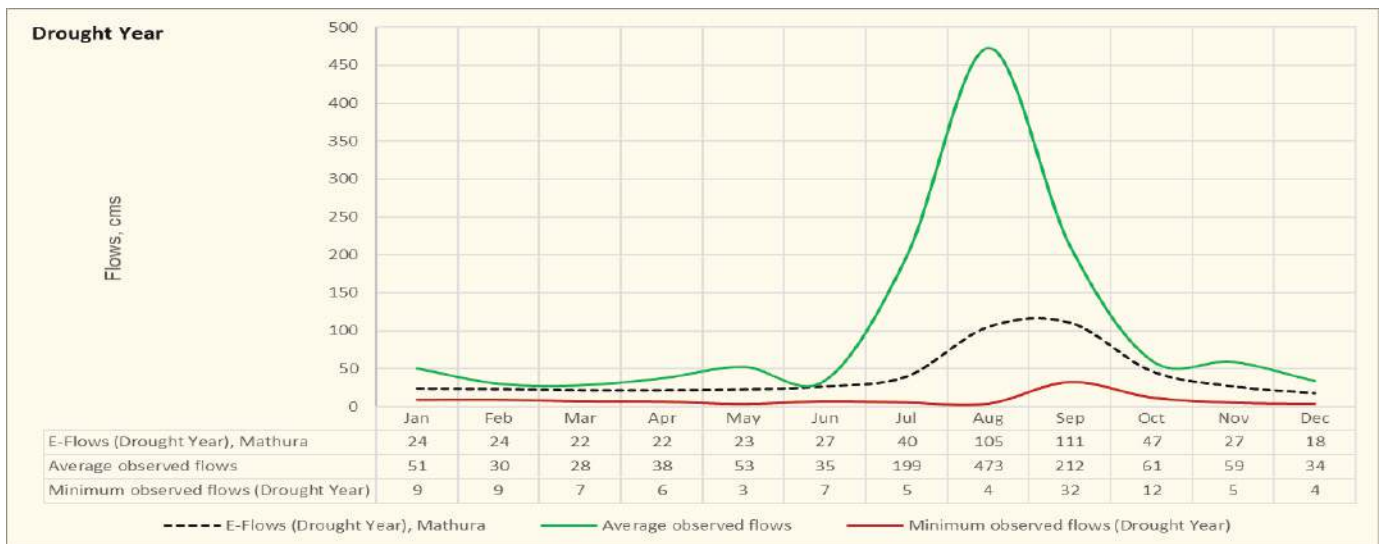


**Figure 194: Cross-section profile with water-levels/depth recommendations for the downstream E-Flows site at Mathura.**

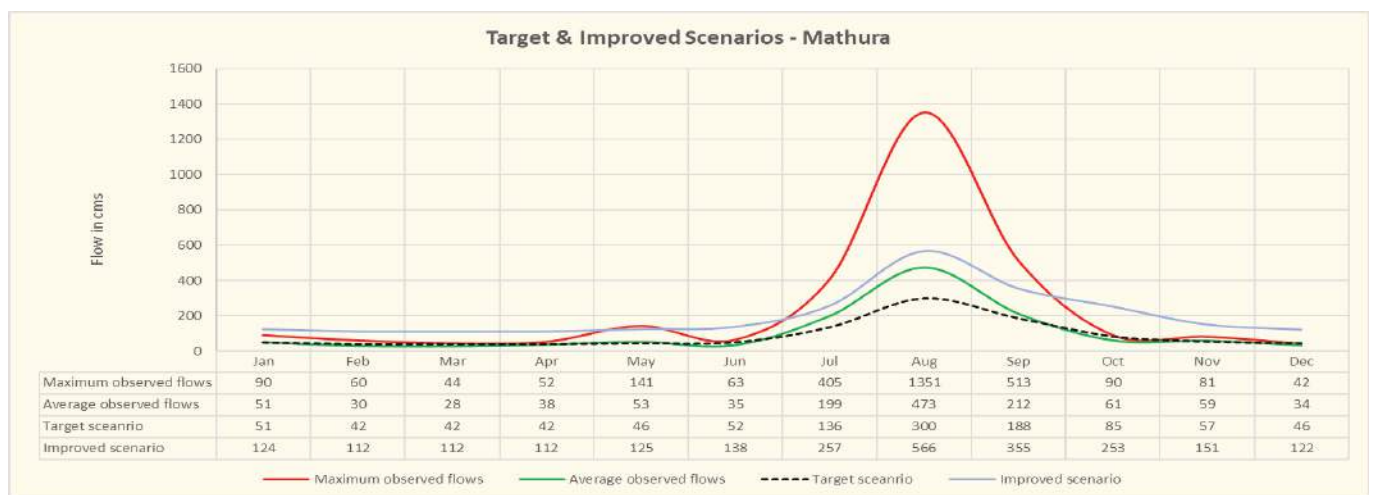
Based on the recommended water levels or depths (Figure 194), the E-Flows graphs were created for both Maintenance Year and Drought Year for the Mathura E-Flows site on the Yamuna River (Figure 195 & Figure 196).



**Figure 195: E-Flows recommendations in a monthly flows pattern–Mathura site (Maintenance Year)**



**Figure 196: E-Flows recommendations in a monthly flows pattern–Mathura site (Drought Year)**



**Figure 197: Mathura E-Flows Recommendations–Improved Scenario**

Mathura site is located 131 km downstream of the Mohana site and the pressures from the Mohana site are extended to this site. The Gokul Barrage also has an impact on the flows downstream of this site. The low flows and the pollution are major concerns for the site. The recommendations are largely influenced by the upstream and downstream conditions, given the unavailability of long-term data at this site.

The E-Flows requirement (Target Scenario) is an immediate goal to fulfil the ecological and Socio-cultural requirements to a certain extent. The lean season flows are a major concern at this site as well. The recommendations are made by considering both the thematic recommendations and the upstream-downstream conditions. The team recommended that a minimum of 42 cumec flow be maintained in the river during the lean season of Maintenance Year. The Target scenario will provide 1.8 m depth and Improved scenario is to provide 2.2 m depth in the lean season of the Maintenance Year.

The required depth is not available for a longer time due to the altered flows in the river. So, achieving the complete recommendations is an ambitious process and could be pursued as a long-term goal (improved Scenario).



### 5.2.6.3 Agra site

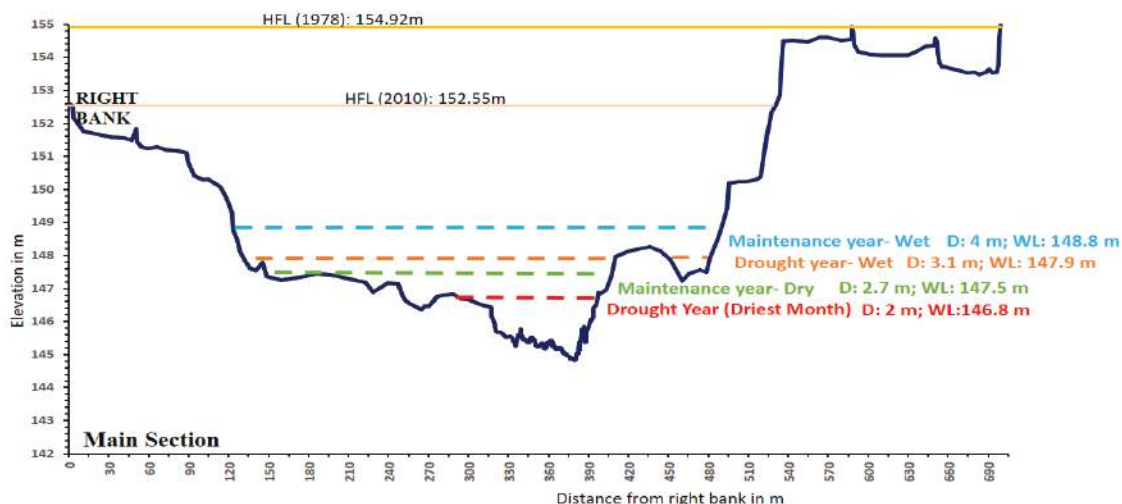
The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 77.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                  | Indian major carp is the motivational species and the recommended depth is mandatory to safeguard the stocked fish from extreme weather conditions. The desired depth is also required to maintain the desired Dissolved Oxygen level and for the growth of fish food organisms. Therefore, the desired depth will safeguard the stocked fish from mortality. Fishes cultivated at low depth of water yielded lower weights and shorter lengths in contrast to the carps cultivated at higher depth. The depth recommended for the wet season are required for the development of suitable nursery grounds for IMC. |
| Drought Year     | The recommended depth will ensure minimum depth in side channels for the revival of side/connected pools, which are useful for the flow of nutrients, growth of fish food organisms and for development of nursery grounds for fish juveniles.                                                                                                                                                                                                                                                                                                                                                                      |

**Table 77: Desired water levels/depths along with rationale for the Agra site on the Yamuna River**

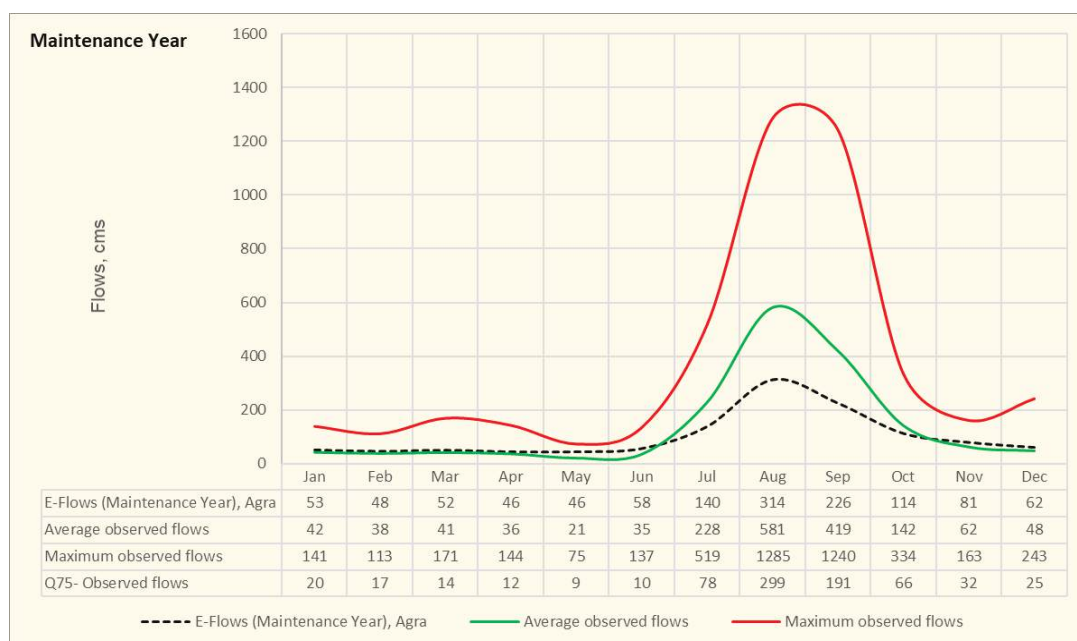
|  |                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                      | Desired water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                    | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|  | <p>The desired flows would maintain the longitudinal connectivity of the river during the dry season. The primary channel will be inundated, which runs through the middle of the channel belt. During the wet season, the desired flows will maintain continuity in the dominant secondary channels.</p>                                | <p>The thematic group recommends maintaining the long-term historical flows during the summers for establishing longitudinal connectivity. In monsoon, water should fill the canal bed and should reach the path near the river. People do not desire unpredictable releases from upstream. Additionally, an extra metre in depth of water is desired in winters</p> | <p>Dry season: 2.7 m<br/>Wet season: 4.0 m</p> <p>All three thematics have recommended similar depths for the dry season therefore all three of them are motivating thematics. (FGM: to maintain lateral and longitudinal connectivity, to fill the secondary channels and to aid the sediment transport. Aquatic biodiversity( for Indian major carps) and Socio-culture (for tourists and pilgrimages and aiding the livelihood).</p> <p>Motivating thematic for the desired depth for the wet season is Fluvial geomorphology (to maintain some level of lateral and longitudinal connectivity and to aid the sediment transport).</p> |
|  | <p><i>An additional requirement is a depth of 6.9 m (&gt;1560 cumec) for 10-15 days sometime in the entire monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region. A flood every 5 years that reaches the village on the right is preferred.</i></p> |                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|  | <p>The recommended water levels are the minimum necessary to ensure longitudinal connectivity during the dry season. This is the prime motivation for drought year.</p>                                                                                                                                                                  | <p>Respondents desire the river to flow for longitudinal connectivity and some level of lateral connectivity.</p>                                                                                                                                                                                                                                                    | <p>Dry season: 2.0 m<br/>Wet season: 3.1 m</p> <p>Motivating thematic for desired depth for both dry and wet seasons are Aquatic biodiversity (for indian major carps) and Socio-cultural (for tourists and pilgrimages and aiding the livelihood).</p>                                                                                                                                                                                                                                                                                                                                                                                   |

**Figure 198:**  
Cross-section  
profile with  
water-levels/depth  
recommendations  
for the downstream  
E-Flows site at  
Agra.

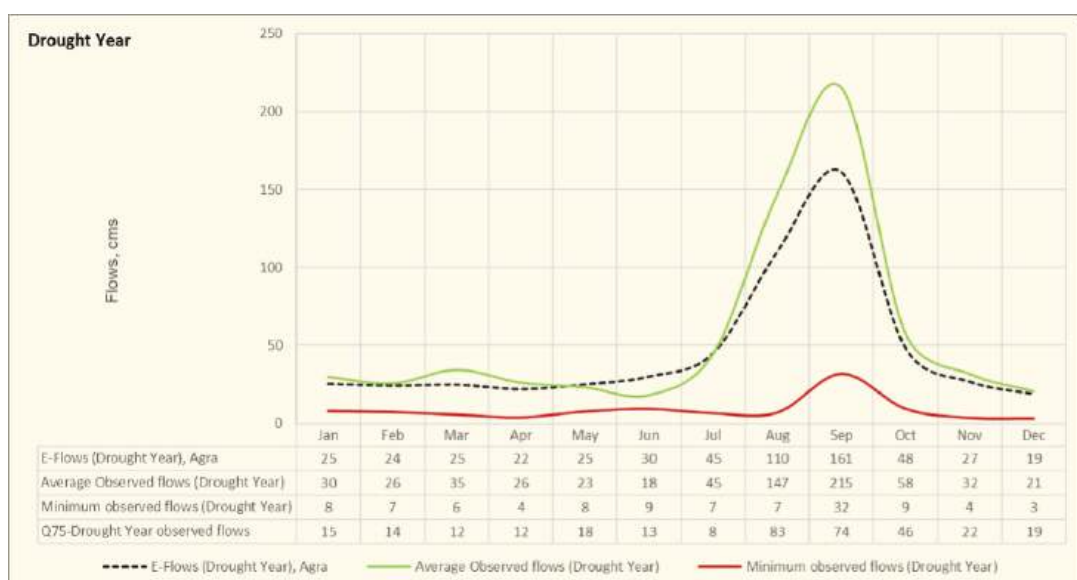


Based on the recommended water levels or depths (Figure 198), the E-Flows graphs were created for both Maintenance Year and Drought Year for Agra E-Flows site on the Yamuna River (Figure 199 & Figure 200).

**Figure 199: E-Flows  
recommendations in  
a monthly flows  
pattern-Agra site  
(Maintenance Year)**



**Figure 200:**  
E-Flows  
recommendatio  
ns in a monthly  
flows pattern-  
Agra site  
(Drought Year)

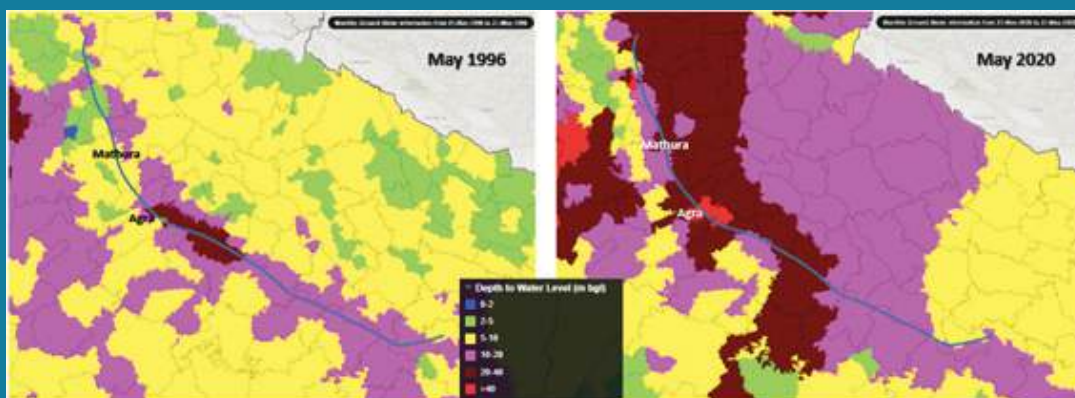


The Q75 values (monthly flows at 75% dependability) is presented in above graphs for reference.



## River-Aquifer interactions

It has been observed that the stretch of the Yamuna river between Mathura and Agra is experiencing a loss of water to groundwater (a losing stretch), resulting in lower flow volumes at the downstream Agra site compared to Mathura. Further research and data analytics have indicated that one of the main reasons for this phenomenon is the over-abstraction of groundwater in this stretch, leading to a significant decline in groundwater levels (20 m in the last 15 years).



Groundwater levels map of Ganga Basin (India-WRIS)

The flows in Yamuna in this stretch are being largely influenced by upstream releases and contributions from groundwater as baseflows. The over abstraction of groundwater for various sectoral uses is one of the leading factors in the decline of baseflows contribution. Due to this nature of stream flows, the depth recommendations at Mathura are also greater than the Downstream Agra site considering the historically observed and available flow regime. Therefore, E-Flows realization will not only involve releases from upstream but will also have to work on demand management, groundwater recharge, wetland restoration, etc. to stabilize aquifers.

## 5.2.6.4 Auraiya site

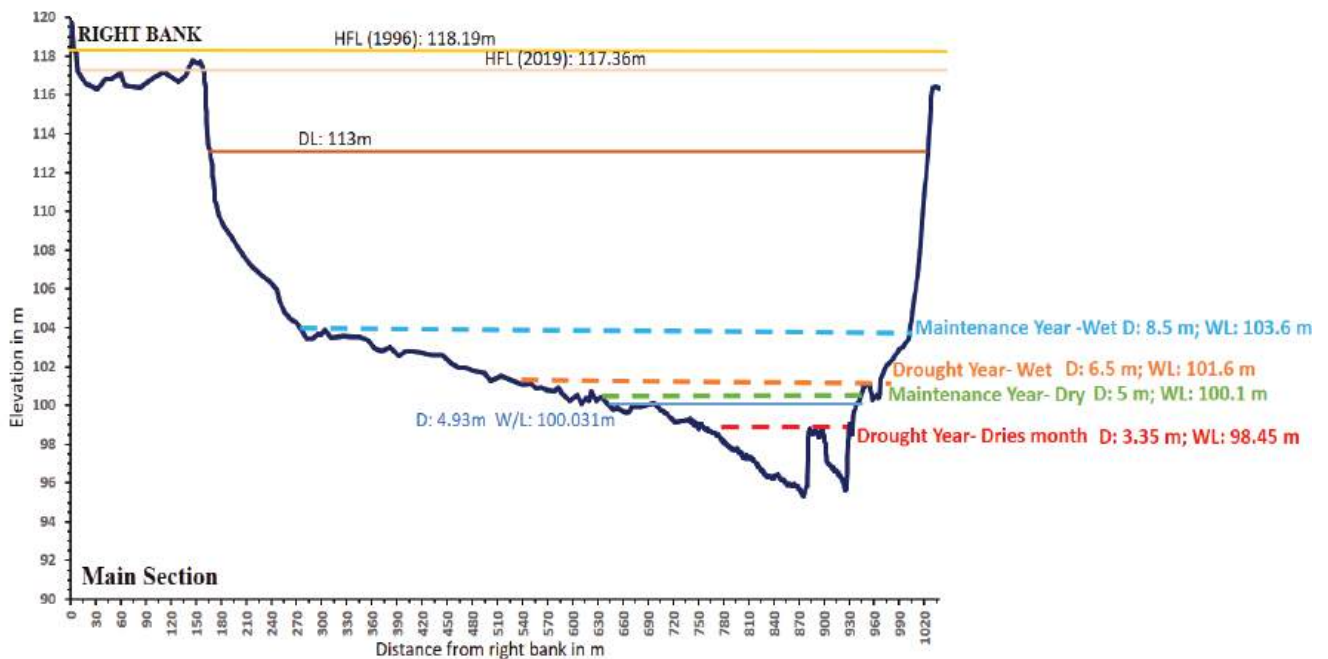
At Auraiya site, the flows get enhanced substantially as compared to the flows at Agra due to the Chambal River joining Yamuna between these two sites, which brings lots of freshwater flows into Yamuna, improving its river health to some extent. The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 78.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | Aquatic Biodiversity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                  | Indian major carps, Gharials and Dolphins are the motivational species. The recommended depth is mandatory to safeguard the stocked fish from extreme weather conditions. <i>Cyprinus carpio</i> , in Vulnerable (VU) category of the IUCN Red List, is also found at this site. The recommended depth for the dry season is essential for providing space for the dolphins' normal body movement. The feeding ground increases with increasing depth. River dolphins tend to spend a majority of their time in areas where they have access to an abundant food supply, which include extended depth. |
| Drought Year     | The recommended depth is a bare minimum requirement for the dolphins' existence in this location, though not really conducive, but with this depth, the dolphins are likely to survive the stress conditions posed by Drought Year.                                                                                                                                                                                                                                                                                                                                                                    |

**Table 78: Desired water levels /depths along with rationale for the Auraiya site on the Yamuna River**

|  |                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                              | Desired Water Level<br>(consensus values)                                                                                                                                                                                                    |
|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                               | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                       | Dry season: 5 m<br>Wet season: 8.5 m                                                                                                                                                                                                         |
|  | Longitudinal and lateral connectivity is good. The desired flows would maintain the longitudinal connectivity of the river during the dry season. During the wet season, the desired flows will maintain continuity in the dominant secondary channels.                                                                                             | The monsoon flows and floods are considered adequate. However, the daily fluctuations lead to difficulties for the local communities in their day-to-day activities, such as interactions with the river for cattle, livelihood, and recreational purposes. The communities desire that summer flows be at least a meter in depth, which is more than the present-day flows. | Motivating thematic for the desired depth for both dry and wet seasons is Fluvial Geomorphology ( to maintain the good lateral and longitudinal connectivity and to fill the secondary channels).                                            |
|  | Annual floods up to the temple on the right bank. An additional requirement is a depth of 17m (>12800 cumec) for 10-15 days at some point in the entire monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.                                                 |                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                              |
|  | The recommended water levels are the minimum required to ensure longitudinal connectivity during the dry season. Some level of lateral connectivity is the primary motivation for drought years. The water level fills the secondary side channels during the monsoon and submerges the mid-channel bars in the primary channel during the summers. | There is a desire for increased flows in summer to improve fish stocks. Respondents desire the river to flow continuously without any bad odours.                                                                                                                                                                                                                            | Dry season: 3.35 m<br>Wet season: 6.5 m                                                                                                                                                                                                      |
|  |                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                              | Motivating thematic for desired depth for the dry season is Socio-cultural (for livelihood and rituals), and motivating thematic for desired depth for the wet season is Fluvial Geomorphology (for filling primary and secondary channels). |





**Figure 201: Cross-section profile with water-levels/depth recommendations for the downstream E-Flows site at Auraiya.**

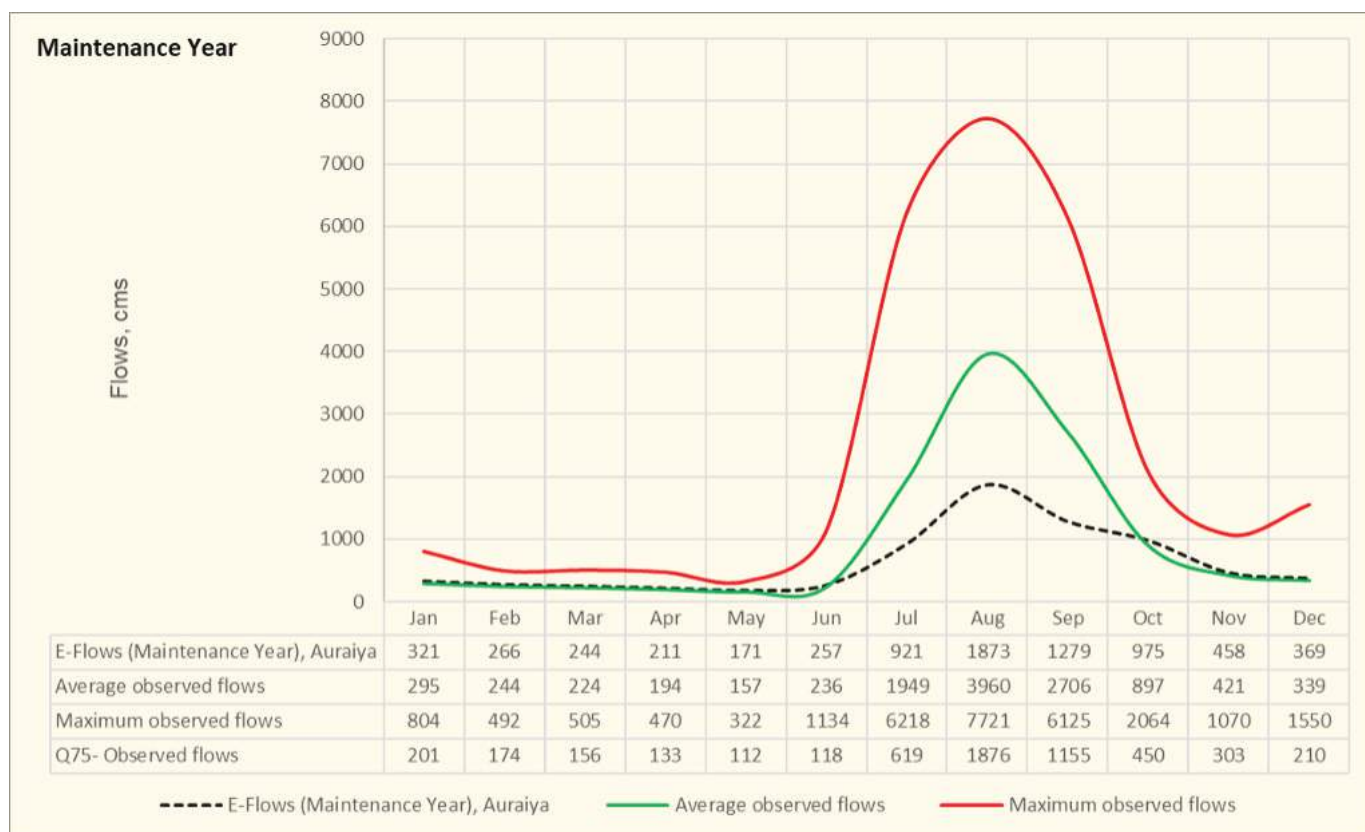
Based on the recommended water levels or depths (Figure 201), the E-Flows graphs were created for both Maintenance Year and Drought Year for the Auraiya E-Flows site on the Yamuna River (Figure 202 & Figure 203).

The Auraiya site is located 260 km downstream of the Agra site and Chambal, Gambhiri and Sindh rivers join in this stretch. The river health, in terms of flows and water quality, is in a better condition at this site due to the contribution of the tributaries. The thematic requirements for the site are different from the upstream site; the motivating species at this site is Dolphin (IMC was for the upstream sites).

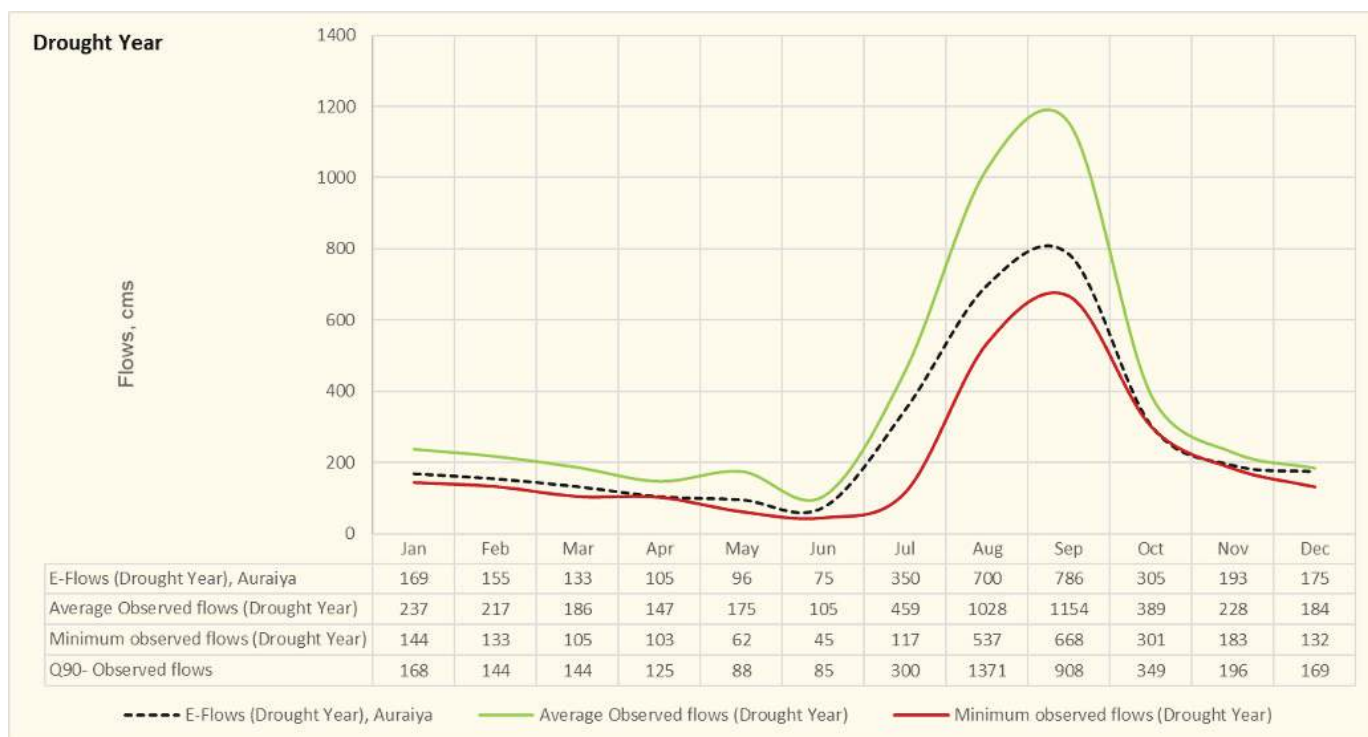
The E-Flows requirement (Target Scenario) is an immediate goal to fulfil the ecological and Socio-cultural requirement to an extent. The lean season (post monsoon and summer) flows and diurnal variations are a major concern at this site; recommendations are made considering the thematic recommendations and the upstream-downstream consistencies. The team recommended a minimum flow of 160 cumec in the river during the lean season of a Maintenance Year. The target scenario will provide 4.95 m depth and Improved scenario is to provide 5.5 m depth in the lean season of the Maintenance Year to be maintained.

The duration for which observed data was available, the recommended depth/flows is not available, mainly due to the altered upstream flow regime in the river. So, achieving the recommendations is an ambitious and complex process, hence could be considered as a long term goal, i.e. an Improved Scenario. It is also suggested to compare the Improved Scenario flow recommendations with additional historical data.

Nevertheless, Figure 204 illustrates the flows requirements for both Target and Improved scenarios. This allows the water-manager to understand the deficit that needs to be met, when the aspiration is to move from Target to Improved scenario.



**Figure 202: E-Flows recommendations in a monthly flows pattern–Auraiya site (Maintenance Year)**



**Figure 203: E-Flows recommendations in a monthly flows pattern–Auraiya site (Drought Year)**

The Q75 and Q90 values (monthly flows at 75% and 90% dependability) is presented in above graphs for reference.



**Figure 204: Auraiya E-Flows Recommendations–Improved Scenario**







## 5.2.6.5 Pratappur site

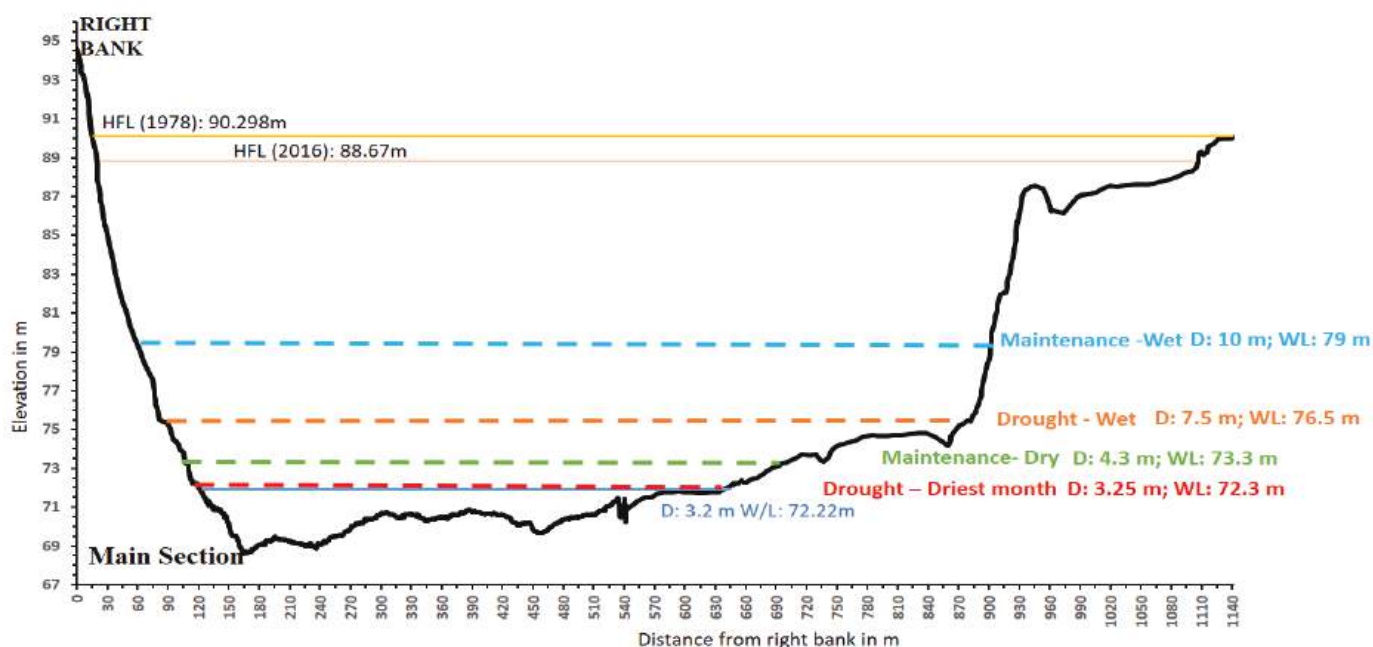
The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 79.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                  | <p>Dolphins are sighted at this location. The recommended depth during the dry season will ensure an appropriate hydraulic habitat for dolphins in terms of depth and active channel width. <i>Cyprinus carpio</i>, in Vulnerable (VU) category of the IUCN Red List, was also found in this site.</p> <p>The recommended depth for the dry season is essential for providing space for normal body movement and adequate dolphin food. Feeding ground increases with increasing depth. River dolphins tend to spend the majority of their time in areas where they have access to an abundant food supply, which include extended depth.</p> <p>The recommended depth during the wet season will form/inundate side-pools/wetlands; this would also help and support the flourishing communities of small-sized fishes and minnows, which are considered food for dolphins.</p> |
| Drought Year     | <p>The recommended depth for the dry season is essential for providing space for normal body movement and adequate dolphin food. The feeding ground increases with increasing depth. While recommending depth, the width is also a critical factor for this location.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

**Table 79: Desired water levels/depths along with rationale for the Pratappur site on the Yamuna River.**

|  |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                               | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                              |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                | Socio-cultural Aspects                                                                                                                                                                                                                        | <p>Dry season: 4.3 m<br/>Wet season: 10.0 m</p> <p>Motivating thematic for desired depth for both dry and wet season is Fluvial Geomorphology (to maintain the good lateral and longitudinal connectivity and to fill the secondary channels).</p>                                                     |
|  | <p>The desired flows would maintain the longitudinal connectivity of the river during the dry season. During the wet season, the desired flows will maintain continuity in the dominant secondary channels. In monsoon, bank-to-bank channel flows are desired.</p>                                                                  | <p>The monsoon flows need to extend to the CWC monitoring station. In the winter, flows are required to be at least a metre higher than at present. In the summer, the water needs to equal the levels present at the time of the survey.</p> |                                                                                                                                                                                                                                                                                                        |
|  | <p><i>An additional requirement is a depth of 19 m (&gt;9500 cumec) for 10-15 days at some point in the entire monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region. Requirement of depth 21 m (&gt;11800 cumec) for a short duration.</i></p> |                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                        |
|  | <p>The recommended water levels are the least that are required for ensuring longitudinal connectivity during the dry season. Some level of lateral connectivity is the prime motivation for a drought year.</p>                                                                                                                     | <p>The recommended flows need to be increased to maintain the connectivity and increase the assimilative capacity of the river.</p>                                                                                                           | <p>Dry season: 3.25 m<br/>Wet season: 7.5 m</p> <p>Motivating thematic for desired depth for the dry season is Socio-cultural (for livelihood and rituals).</p> <p>Motivating thematic for desired depth for the wet season is Fluvial Geomorphology (for filling primary and secondary channels).</p> |





**Figure 205: Cross-section profile with water-levels/depth recommendations for the downstream E-Flows site at Pratappur**

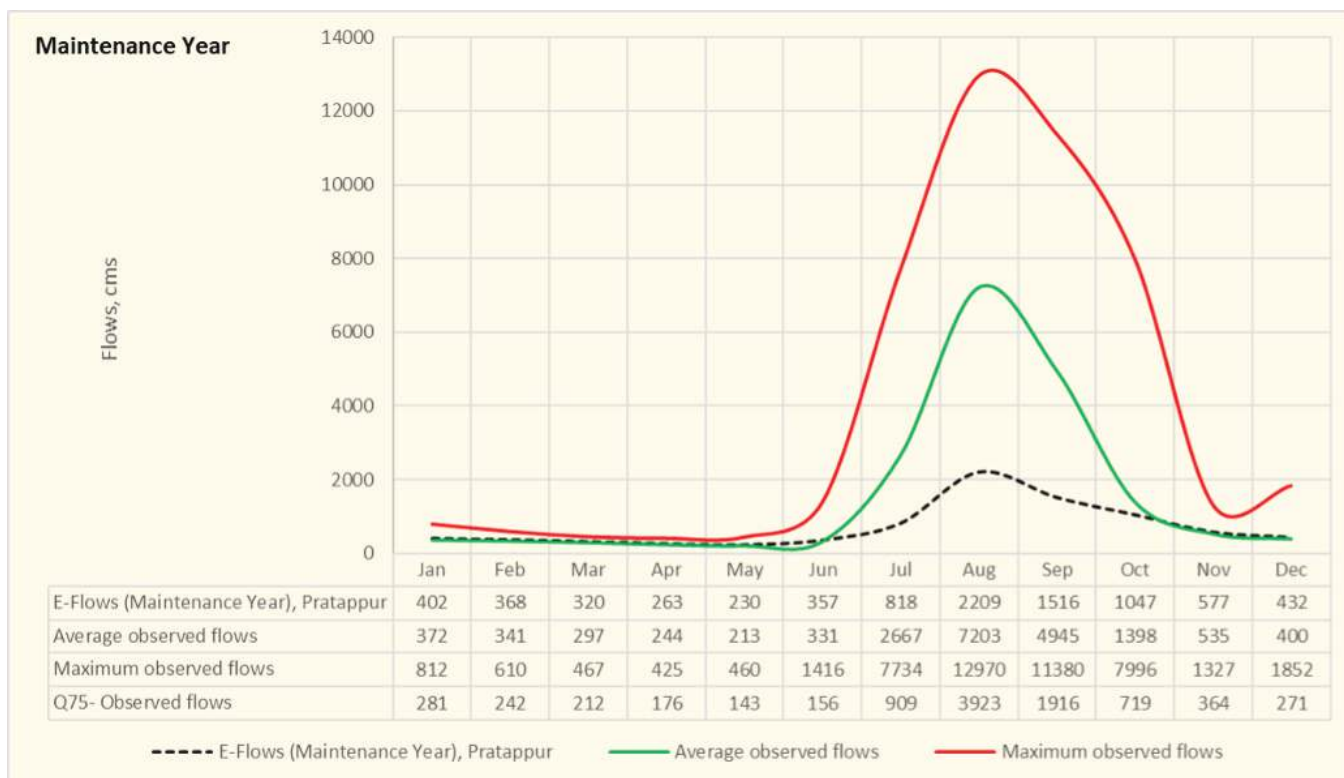
Based on the recommended water levels or depths (Figure 205), the E-Flows graphs were created for both Maintenance Year and Drought Year for the Pratappur E-Flows site on the Yamuna River (Figure 206 & Figure 207).

The Pratappur site is located 360 km downstream of the Auraiya site; the Betwa and Ken Rivers join in this stretch. The river health in terms of flows and water quality are in a good condition at this site due to the flow contribution from tributaries. The thematic requirements for the site are similar to the upstream site; our concerned species is olphins (IMC was for the three upstream sites) and fluvial geomorphic recommendations also demanded more flows at this site in the lean season.

The E-Flows requirement (Target Scenario) is an immediate goal to fulfil the ecological and Socio-cultural requirement to an extent. The lean season (post monsoon and summer) flows and diurnal variations are a major concern at this site as well. The recommendations are made by considering both the thematic recommendations and the upstream-downstream conditions. The team recommended that a minimum of 171 cumec flow be maintained in the river during the lean season of the Maintenance Year. The Target Scenario will provide 4 m depth and Improved scenario is to provide 5.5 m depth in the lean season of the Maintenance Year.

The duration for which observed data was available, the recommended depth/flows is not available, mainly due to the altered upstream flow regime in the river. So, achieving the recommendations is an ambitious and complex process, hence could be considered as a long term goal, i.e. an Improved Scenario. It is also suggested to compare the Improved Scenario flow recommendations with additional historical data.

Nevertheless, Figure 208 illustrates the flows requirements for both Target and Improved Scenarios. This allows the water-manager to understand the deficit that needs to be met, when the aspiration is to move from Target to Improved Scenario.

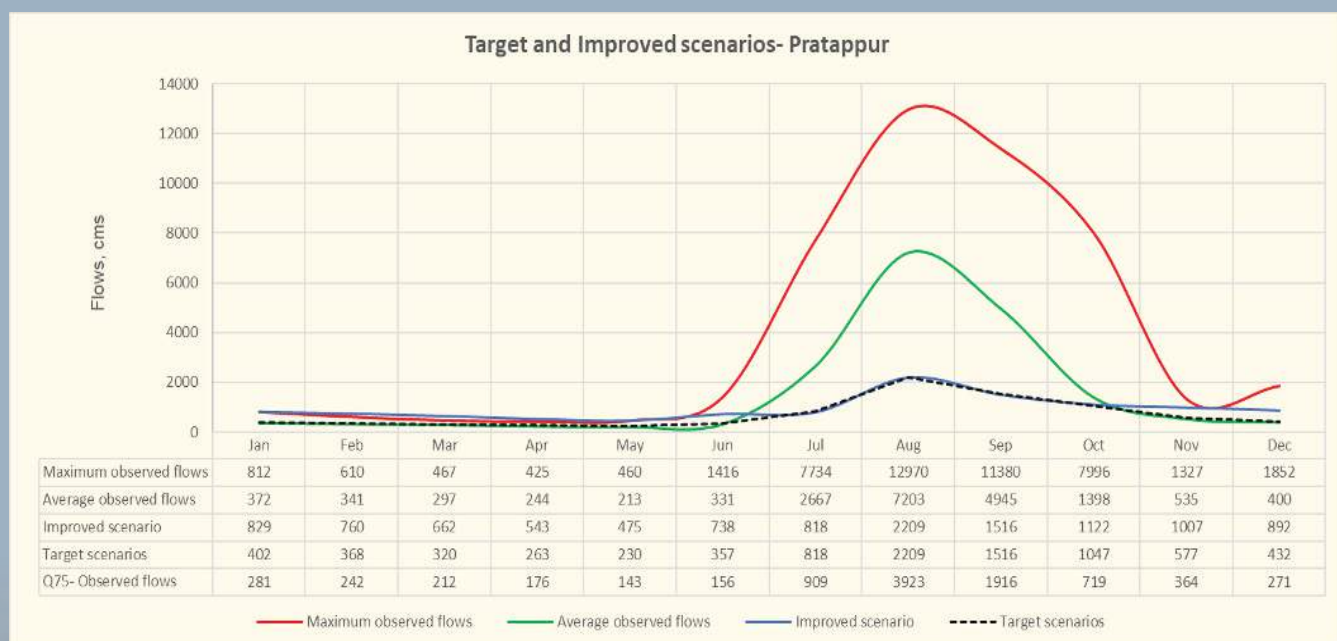


**Figure 206: E-Flows recommendations in a monthly flows pattern–Pratappur site (Maintenance Year)**



**Figure 207: E-Flows recommendations in a monthly flows pattern–Pratappur site (Drought Year).**

The Q75 and Q90 values (monthly flows at 75% and 90% dependability) is presented in above graphs for reference.



**Figure 208: Pratappur E-Flows Recommendations–Improved Scenario**





## 5.2.7 Gandak River

As mentioned earlier, the observed gauge-versus-discharges information for the site on the Gandak River is not available and therefore, the team proposed desired water levels for these locations, which will achieve the desired targets in terms of meeting the motivations set out by thematic groups. For all practical purposes, the achievement/maintaining of recommended water levels, will ensure a healthy river state, from the perspective of water quantity. On the other hand, going forward, in the wake of robust and credible hydraulic information, these values pertaining to water levels can be converted into flows.



## 5.2.7.1 Khadda site (Downstream of the Gandak barrage)

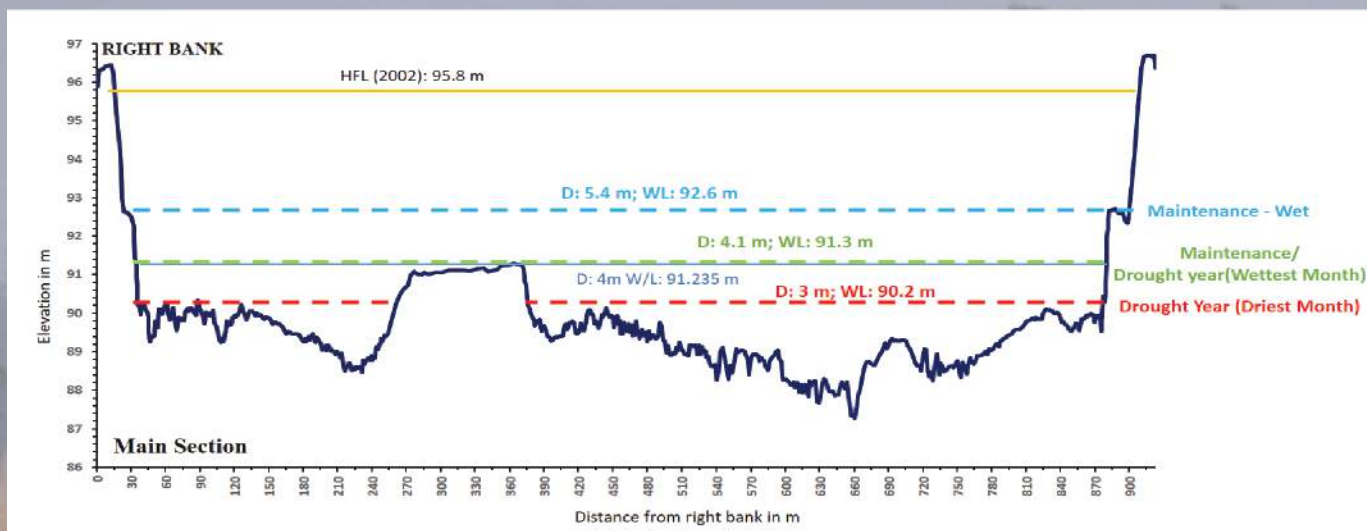
As discussed in Section 5.2, the water levels would be recommended for this location. The water levels/depth desired as indicators of E-Flows requirements are based on thematic motivations, which are tabulated in Table 80.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                  | During the dry season, the recommended depth is essential for providing space for dolphins' normal body movement and their food. Feeding grounds increase with increasing depth. River dolphins tend to spend the majority of their time in areas where they have access to an abundant food supply. During the wet season, the recommended water levels would aid the formation of side pools/wetlands. This would also help and support the flourishing communities of small-sized fishes and minnows that are found in this site, which is crucial since they are considered important natural food for dolphins. The recommended depth would support complete inundation of side channels during the wet season. |
|                  | <i>An additional requirement is a depth of 6.8 m for 10-15 days during the monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Drought Year     | For the survival of the dolphin population during stress conditions, the recommended depth is essential.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

**Table 80: Desired water levels/depths along with rationale for the E-Flows site on the Gandak River**

|                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                   | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fluvial Geomorphology                                                                                                                                                                                                                                                                                                                                                                | Socio-cultural Aspects                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <p>The desired flows would maintain the longitudinal connectivity of the river during dry season. The primary channel will be inundated, which runs closer to the right bank side of the channel belt. During the wet season, the desired flows will maintain continuity in the less dominant secondary channels. The desired flows will also maintain the lateral connectivity.</p> | <p>Respondents desire that the water in the summer should be enough to submerge the central island. This will consequently provide enough water in the side channels for boats to ply and livestock to bathe.</p> | <p>Dry season: 4.1m<br/>Wet season: 5.4 m</p> <p>Motivating thematic for desired depth for the dry season are Fluvial Geomorphology (longitudinal-lateral connectivity and submergence of lateral and mid-channel bars) and Socio-cultural (for rituals and livelihood), and motivating thematic for desired depth for the wet season is Fluvial Geomorphology (for longitudinal-lateral connectivity and filling primary secondary channels).</p> |
| <p>The recommended water levels are the least that are required for ensuring longitudinal connectivity during dry season. Some level of lateral connectivity is the prime motivation for drought year.</p>                                                                                                                                                                           | <p>People desire water that is enough to submerge the central island.</p>                                                                                                                                         | <p>Dry season: 3 m<br/>Wet season: 4.1m</p> <p>Motivating thematic for desired depth for the dry season is Socio-cultural (for rituals and livelihood) , and motivating thematic for desired depth for the wet season is Fluvial Geomorphology (for longitudinal-lateral connectivity and filling primary secondary channels).</p>                                                                                                                 |





*Figure 209: Cross-section profile with water-levels/depth recommendations for the downstream Gandak Barrage E-Flows site at Khadda on the Gandak river*



## 5.2.8 Sone River

As discussed earlier, it was noted that the observed gauge-versus-discharge data for the Sone River site is unavailable. Consequently, the team has put forward specific water level recommendations for these locations. These recommendations are designed to fulfill the objectives outlined by thematic groups, ensuring that their motivations are met.



### 5.2.8.1 Chopan site

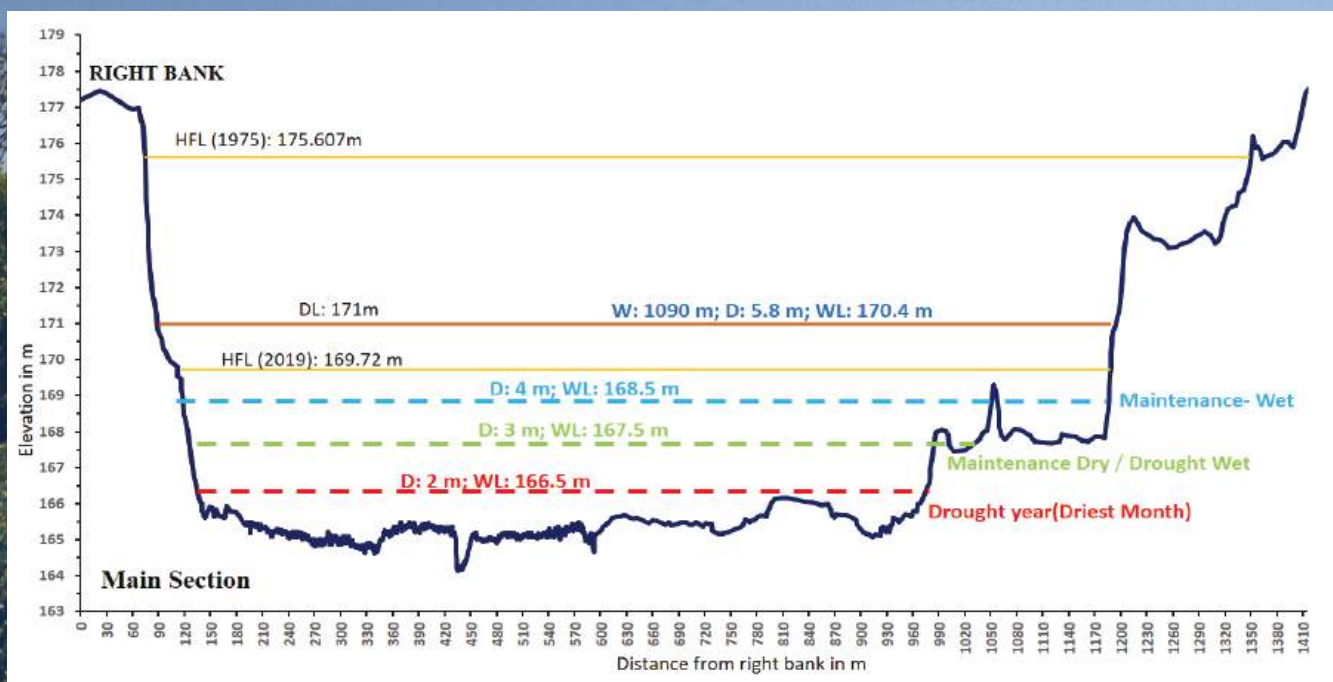
As noted earlier in Section 5.2, for this location, only water levels are recommended. The water levels/depth desired as E-Flows requirements are based on thematic motivations, which are tabulated in Table 81.

| Year             | Motivation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintenance Year | <b>Aquatic Biodiversity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                  | <p>Indian major carps are the motivational species and the recommended depth is mandatory to safeguard the stocked fish from extreme weather conditions. Size and weight of fish are significantly affected by lower depths. Fishes cultivated at low depths of water yielded lower weight, and were shorter in length in contrast to the carps cultivated at higher depth of pond water.</p> <p>The recommended wet season depth is required for the development of suitable nursery grounds (flooding of side pools and connected wetlands) for IMC. The recommended depth is suitable for temperature variations, oxygen, plankton production, etc.</p> |
| Drought Year     | For survival of IMC population during stress conditions, the recommended depth is essential.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

**Table 81: Desired water levels/depths along with rationale for the E-Flows site on the Sone River**



|                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                              | Desired Water Level<br>(consensus values)                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fluvial Geomorphology                                                                                                                                                                                                                                                                                        | Socio-cultural Aspects                                                                                                                                                                                                                                                                                                                                                                                                       | <p>Dry season: 3 m<br/>Wet season: 4 m</p> <p>Motivating thematic for desired depth for the dry season are Socio-cultural (for rituals and livelihood), and motivating thematic for desired depth for the wet season is Fluvial Geomorphology (for longitudinal-lateral connectivity and filling secondary channels) and Socio-cultural (for rituals and livelihood).</p> |
| <p>The desired flows would maintain the longitudinal connectivity of the river during the dry season. The primary channel would be inundated, closer to the right bank of the channel belt.</p> <p>During the wet season, the desired flows will maintain continuity in the dominant secondary channels.</p> | <p>The local community desired that at a minimum, water should flow up to the second pillar from the marker. This is less than historical flow, but is considered to be enough to sustain life. The respondents also expressed a desire that the river remain within the bounds of the riverbed.</p>                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                           |
| <p><i>An additional requirement is a depth of 5.8 m for 10-15 days during the monsoon season. This will maintain the lateral connectivity, completely inundating the channel belt and a portion of the floodplain region.</i></p>                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                           |
| <p>The recommended water levels are the minimum required to ensure longitudinal connectivity during the dry season. Some level of lateral connectivity is the primary motivation for drought years.</p>                                                                                                      | <p>At present, in summer, the water flows as a thin narrow stream with very occasional deep pools. These summer flows are frequently too shallow to allow buffaloes to bathe comfortably. This low flow also exacerbates the pollution in the river.</p> <p>The recommended flows will not only provide water to livestock and riparian communities for their needs but also improve river health impacted by pollution.</p> | <p>Dry season: 2 m<br/>Wet season: 3 m</p> <p>Motivating thematic for desired depth for the dry season are Socio-cultural (for rituals and livelihood), and motivating thematic for the desired depth for the wet season is Aquatic Biodiversity (for Indian major carps) and Socio Cultural (for rituals and livelihood).</p>                                            |



*Figure 210: Cross-section profile with water-levels/depth recommendations for the downstream E-Flows site at Chopan on the Sone River*













## 6. Towards E-Flows Implementation

The report, thus far, captures the approach and results of the E-Flows assessment in all the major rivers in Uttar Pradesh. This chapter will discuss broad actions needed for restoring E-Flows in these rivers.

**The Government of India and the National Mission for Clean Ganga have recognized ‘aviral dhara’ or uninterrupted flows as one of the visions of the flagship Namami Gange programme which aims at the rejuvenation of the Ganga river. In this regard, the Ganga Notification of 2016 is a positive step, which calls for maintaining E-Flows in Ganga and its tributaries.**

Later on, the ‘Ganga Vision’ document of December 2017 (a joint policy document of the National Mission for Clean Ganga – the implementing agency of *Namami Gange* programme of the Government of India and cGanga – Centre for Ganga River Basin Management Studies), categorically stressed on the implementation of the E-Flows regime in Ganga and its tributaries. In 2018, the Government of India came out with E-Flows Order for the Ganga River, stipulating E-Flows values and percentages downstream of water-resource infrastructure (dams and barrages).

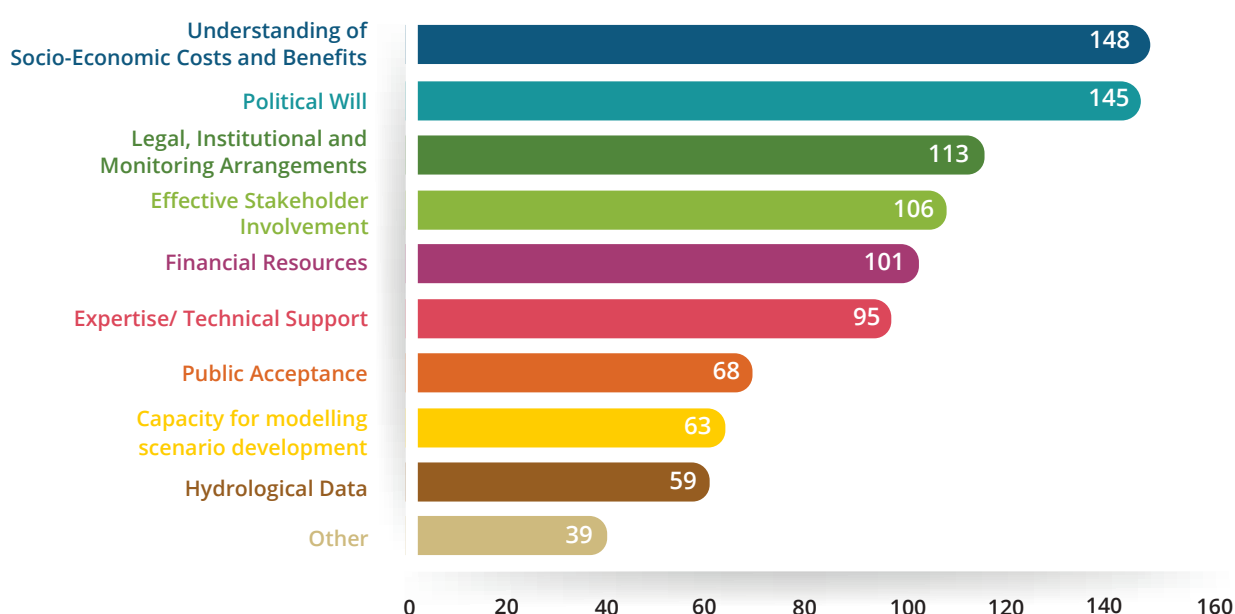
More recently, this joint study by the Uttar Pradesh Water Management and Regulatory Commission (UP WaMReC) in partnership with WWF-India is another milestone. The recommendations coming out of this study is likely to enrich and strengthen the ongoing River Basin Management Planning exercise by the Uttar Pradesh State Water Resources Agency (UP SWaRA) for all the major rivers of the state.

All these are steps in the right direction and one would hope that, this will go a long way in long-term E-Flows realization across Ganga and its tributaries.

This chapter attempts to build on the experiences of E-Flows restoration and river rejuvenation for enhancing flows across the globe, with an objective to suggest a few pointers and next steps in terms of E-Flows maintenance in these rivers.

## 6.1 E-Flows restoration

Through the Brisbane Declaration, the delegates to the 10<sup>th</sup> International River Symposium and Environmental Flows Conference in 2007 called upon “all governments, development banks, donors, river basin organizations, water and energy associations, multilateral and bilateral institutions, community-based organizations, research institutions, and the private sector across the globe” to commit to a set of actions for restoring and maintaining E-Flows. Despite the fact that many countries now have some form of policy or legal recognition of the E-Flows, the implementation has been limited across geographies. A number of international reviews (Moore, Hirji and Davis, and Le Quesne *et al.*) have assessed E-Flows implementation challenges and identified principal obstacles (see Figure 211):



**Figure 211: E-Flows Implementation Challenges: Principal Obstacles**

On the 10<sup>th</sup> anniversary of the Brisbane Declaration in 2017, WWF released a report titled *Listen to the River* which showcased success stories, since 2007, of governments and water-management authorities across the globe in developing policies and regulations, and undertaking activities to protect and restore E-Flows. These successes were not without obstacles and challenges, which ranged from a lack of political will and stakeholder support, to insufficient resources and capacity, competition for water use among sectors, institutional barriers and conflicts of interest. These stories also illustrate that there are numerous ways for achieving success in E-Flows restoration, which are both dependent on system-specific and jurisdiction-specific concerns and relate to legal, political, institutional, social, economic and ecological contexts.



Further, these examples testify to Le Quesne's conclusion that there cannot be a single approach towards E-Flows implementation, and that any attempt at E-Flows restoration must be carefully tailored to the context. However, one cannot also ignore some common truths that came out with every success story.

- Enact clear and effective legislation and regulation, and maintain the political will to implement and enforce those legislations and regulations;
- Engage meaningfully with stakeholders to properly understand the issue and to garner support for E-Flows implementation;
- Secure sufficient resources and capacity for E-Flows design (including stakeholder engagement), implementation and monitoring;
- Consider how E-Flows implementation will affect not just the ecology, but also economic and social conditions of different groups of people;
- Implement some level of protection as early as possible, since it is easier to restrict allocation than attempt to re-allocate water;
- Keep E-Flows prescriptions as scientific as possible, taking into account the level of risk and intensity of water use, while also considering financial and human resource constraints. However, there is a need to balance this science with clear communication to stakeholders, ensuring that the recommendations are only as complex as the context allows;
- Monitor ecological, social and economic outcomes of E-Flows implementation and manage adaptively.

These lessons reinforce and complement the conclusions of the previous case study reviews of E-Flows implementation. The Brisbane Declaration of 2017 on Environmental Flows went a step further and called upon all governments, development banks, donors, water and energy associations, multilateral and bilateral institutions, community-based organizations, research institutions, indigenous groups and the private sector across the globe to commit to protecting and restoring E-Flows as a central element of water resources management, and as a foundation for the achievement of water-related Sustainable Development Goals (SDGs). There is a larger recognition of the fact that E-Flows are required to protect not only aquatic ecosystems, but also the social, economic and cultural benefits that humans draw from rivers and interconnected lakes, wetlands and aquifers, and to enhance water security.

## 6.2 Implementation Framework for Long-term E-Flows in the Major Rivers of Uttar Pradesh

The Implementation Framework for Long-term Environmental Flows (E-Flows) Maintenance includes a structured plan and set of procedures to ensure the sustainable and effective management of river systems including basins and processes through multi-stakeholder engagement and collective action. The long-term E-Flows implementation across these rivers would call for application of multiple measures, including technical, social and institutional. With an objective to arrive at plausible management scenarios, the team has looked at some key issues and challenges and then come up with suggestions in regard to long-term E-Flows implementation.

The team emphasized that achieving long-term implementation and realization of Environmental Flows (E-Flows) goes beyond simply releasing water from dams or barrages at all river sites. Instead, it requires collaborative efforts from diverse stakeholders and thematic areas to actively participate in the sustainable management and conservation of freshwater resources. This involves adopting holistic river basin management approaches that consider the interconnectedness of various elements (wetland restoration, groundwater management, conjunctive use of water, overall water demand side management across sectors and so on) within the river ecosystem. The collective actions of stakeholders are integral to ensuring the effectiveness and sustainability of E-Flows initiatives.

Some of the key aspects are discussed in the following sub-section.

### 6.2.1 Technical

#### 6.2.1.1 Demand and supply side management

- **Sustainable water management practices in agriculture:** Agriculture being the highest user of freshwater, has huge scope of improving the water use efficiencies which is currently at a very low range of 20-40%<sup>1</sup> in India. In fact, Goal 4 of the National Water Mission is to “increase water-use efficiency by 20 per cent”. The government is also making efforts for sectoral water-use efficiency. The National Commission on Integrated Water Resources Development Plan (NCIWRDP) had assessed the water requirement for irrigation as 78 per cent, 72 per cent and 68 per cent of the total water

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<sup>38</sup> [https://www.iima.ac.in/sites/default/files/2022-11/2020-21\\_1.pdf](https://www.iima.ac.in/sites/default/files/2022-11/2020-21_1.pdf)

requirement for the years 2010, 2025 and 2050, respectively. In light of these facts, the water-use efficiency targets look essential. Therefore, the government's ask for improved water-use efficiency would have dual benefits; it can lead to securing water resources from irrigation (thereby achieving the target envisaged by the government) and also benefit the movement towards rejuvenation and conservation of the Ganga River system. There are several good initiatives and success stories, which can be looked upon and scaled up to achieve the goal.

- **Systematic promotion of conjunctive use:** It has been observed that a majority of the farmers in the canal commands use ground water to supplement canal irrigation. Besides, the use of groundwater in comparison to canal water is very high. Our experience and interaction with scores of farmers spread across 55,000 hectare in Ramganga canal command (Ramganga Basin) and Bachhmai canal command (Kali Basin) indicate heavy reliance on ground water and this may be attributed to (i) designed partial coverage of command area for irrigation by the canal, (ii) changes in cropping pattern, and (iii) unreliable, unequitable canal water supplies. This leads to avoidable extraction of groundwater and consumption of fossil fuel and energy.
- **Groundwater management for enhanced baseflows:** During the lean season, when overall river flows are reduced, baseflows become especially significant as they contribute substantially to the total flow. Here it is important to understand the linkages between ground water and river flows. There is a knowledge-gap in comprehensive information on surface-groundwater interaction in these rivers. The objective should be to assess the stretches where the river is losing its waters to aquifer and vice versa. This would eventually assist in narrowing down to the areas where aquifer management needs to be taken up, so that groundwater levels can be enhanced through demand management and other water conservation measures, such as rejuvenation of wetlands, demand management in agriculture to reduce abstractions etc.
- **Pricing of water:** At present, there are no incentives for the farmers to reduce their water consumption as the irrigation water charges are 100 per cent subsidised by the state government, as a welfare measure. The canal irrigation systems within the state, like in the other parts of the country, are designed for protective irrigation in a defined command area. However, over a period of time, farmers have diversified into water-intensive crops and have also enhanced the area under irrigation, in certain cases; this is mainly (i) due to the need to grow more food supported by market drivers, (ii) due to the quest to grow cash crops, and (iii) in the absence of an effective pricing. Once the institutional arrangements under the UP PIM Act 2009 are implemented across the state, the irrigation water charges may be rationalised by the state government through UPWaMReC, UP SWaRA and UP I&WRD
- **Water balance and tradeoff analysis at control structures:** All water resources infrastructure in the river needs a thorough tradeoff analysis



through assessment of water availability (under various climatological and management scenarios), sectoral demand vis-à-vis E-Flows requirements. In this regard, a thorough field-based assessment of all reservoirs including trade-off analysis in the river basins may be done to ascertain the prospects of securing E-Flows in these rivers through revising dam/barrage operation schedules and plans. This work would be a useful input to advocate for E-Flows implementation.

- **Small tributary rejuvenation initiatives:** Smaller tributaries that feeds the larger river systems are of critical importance in terms of hydrological health. Though much focus is on rejuvenation of bigger river systems like Ganga, Ramganga, Gandak, Ghaghra etc, there is need to focus on their sub tributaries which contributes in rejuvenating flows and can help sustaining the long term E-Flows recommendations. NMCG is now also focussing of these smaller tributaries through active engagement with district administrations within Uttar Pradesh, through respective District Ganga Committees. Currently these smaller tributaries are facing huge threats like encroachment, over abstractions of groundwater, pollution, wetland degradation etc. The conservation and rejuvenation of these smaller rivers and tributaries is something that the state of Uttar Pradesh has also taken up as part of its initiative under, reviving one river in each district. WWF-India through multi-stakeholder engagement with district administration, line departments, technical experts under its various initiatives is also working on tributary rejuvenation through channel rehabilitation, catchment treatment, demand side management in agriculture, institutional strengthening to enhance flows in rivers like Karula, Aril, Gaagan (Ramganga basin) and Kali (Ganga basin).
- **Wetland Restoration and Conservation:** Conserving and safeguarding floodplain wetlands not only contributes to the enhancement of biodiversity and local water security but also plays a critical role in sustaining the base-flows in rivers via groundwater recharge and river-wetland connectivity. It has been observed that over a period of time, the wetlands have been degrading at a rapid state due to pressures like encroachment, pollution, inlet channel degradation, invasive weeds etc. MoEF&CC through their 'Save My Wetlands' campaign are focusing on the rejuvenation of wetlands and raising awareness on its conservation. Uttar Pradesh government is also actively working towards the conservation of wetlands with aims to improve local water security, groundwater recharge and enhance base-flows. WWF-India through multi-stakeholder engagement has effectively showcased the augmentation of flows in the Aril River within the Ramganga basin through floodplain wetland restoration in Bareilly and Moradabad districts. WWF-India is technically supporting various district administrations (Uttar Pradesh) in baseline data collection and developing and implementation of restoration activities on conservation of such wetlands.

## 6.2.2 Social

- **Community Awareness:** Public awareness campaigns to educate local communities about the importance of E-Flows and their role in sustaining river ecosystems including awareness drives on reducing their water footprint, role and participation in river and wetland conservation initiatives.
- **River health assessment-** As part of promoting citizen science, training and capacity building of community needs to be scaled up to all river systems. Under this activity, community members are trained on monitoring of health of river and wetlands through a simple “Jal Tara Kit” which provides information on various water quality parameters, catchment health, bio-indicators etc. WWF-India is actively carrying out similar river health assessment in various rivers and wetland and imparting training to community members, Mitra groups and Nodal officers in District Ganga Committees.
- **Water footprint campaigns-** With ever increasing population and expanding urban cities, stress of freshwater resources are also increasing. With higher rates of abstractions and excess water usages, not only the rivers and wetlands are getting degraded due to pollution loads from cities, but pressure water withdrawals from aquifers and rivers are also increasing. There is a need to raise awareness among urban citizens on reducing their water footprint through simple measures and contribute to the rejuvenation of freshwater resources. WWF-India is working with 50,000 plus citizens from Bareilly, Moradabad and Kanpur to reduce their water footprint by measuring their daily water usages in various activities through the Water footprint app and change their practices to save water.



## 6.2.3 Institutional

An assessment of some of the relevant stakeholding institutions, departments, ministries and organizations has been undertaken to ascertain the linkages and potential roles of such entities with respect to furthering the cause of E-Flows in these rivers. The key points of this assessment are given in Table 82.

| Stakeholder                                                     | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                                                                                          | Support desired for the E-Flows implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | What can be achieved and impact                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UTTAR PRADESH</b>                                            |                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>UP Irrigation and Water Resources Department</b>             | It is the custodian of major water-resources infrastructure on river Ganga and its tributaries. In-charge of providing irrigation in Uttar Pradesh and also, water resources management at the state level.                                                                                                                                                                                      | <p>The UPI&amp;WRD should conduct a thorough analysis of trade-offs, taking into account sectoral demands, long-term river flow availability, and E-Flows requirements.</p> <p>Revise the barrage/reservoir operations to account for E-Flows releases downstream of these structures is needed.</p> <p>Encourage and incentivize farmers to adopt efficient irrigation practices.</p> <p>Establish WUAs and strengthen them through technical and administrative support. Implement revised water allocations.</p> | It will become one of the pioneering irrigation departments in the country to secure E-Flows in the river, while sustaining all other committed uses.                                                                                                                                                                                                                                    |
| <b>Farmers, Water Users Associations, Krishi Vigyan Kendras</b> | <p>Major water users; State-wide Water User Associations (WUAs) establishment is under process. Overall, there is substantial scope of improvement in agricultural water use efficient, due to conventional agricultural practices which mainly include flood irrigation.</p> <p>The mandate of KVK is Technology Assessment and Demonstration for its Application and Capacity Development.</p> | <p>Adoption of efficient irrigation practices. Contribute towards formation of WUAs and actively participate in its activities. Contribute towards river's rejuvenation initiatives undertaken by the government by using less water for irrigation. Suggest and promote efficient and sustainable agriculture technologies and practices in various crops. Support in training and capacity building of farmers through imparting training and exposure visits.</p>                                                | <p>It will help the government to achieve its targets of 20 per cent water-use efficiency in irrigation.</p> <p>Effective agriculture water management technologies and capacity building can help farmers improve their water use efficiencies, reduce input costs, and increased yields. This will eventually reduce pressure on freshwater resources like rivers and groundwater.</p> |



| Stakeholder                                                                                               | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                                             | Support desired for the E-Flows implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | What can be achieved and impact                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>District Administration</b>                                                                            | The district administration in India plays a crucial role in implementing government policies and programs at the local level. The primary mandate of district administration includes law and order, civil administration, disaster management, revenue administration, development initiatives, implementation of Central and State Policies etc. | Develop District Ganga plans for all riparian districts in Ganga basin including tributaries restoration plans and implement, monitor conservation actions through multi-stakeholder engagement. Leverage funds from various government schemes and implement through District Ganga Committees platform.                                                                                                                                                                                                      | It will become the country's leading water resources institution to account for E-Flows in water-allocation processes at the state level.                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Related line departments to support restoration and rejuvenation (Revenue Department, MNREGA cell)</b> | <p>Revenue department's mandate is to document, map, register land records including ownerships, transfer for various activities.</p> <p>MNREGA cell's mandate is to provide livelihood opportunities/employment to rural communities by carrying out various developmental and conservation activities.</p>                                        | <p>Revenue departments can contribute in river rejuvenation and E-Flows realization and monitoring activities through landuse planning and regulations, surveys and mapping of floodplains, channel encroachments, river and wetlands space prevention from encroachments etc.</p> <p>Various developmental and river/wetlands conservation actions like wetland restoration/creation of new ponds, inlet channel creation, desilting work have been actively carried out by various district MNREGA cell.</p> | <p>Revenue department can help in supporting conservation and restoration of rivers, channels, wetlands through mapping, surveys, establishing ownerships, demarcation of boundaries, mapping inlets and identifying the lost river stretches, which had been encroached.</p> <p>Through various restoration activities, the District MNREGA cell can support in various conservation and restoration activities like channel rehabilitation, desilting, deweeding, construction of new ponds etc. by engaging local communities (MNREGA card holders)</p> |
| <b>UP WaMReC and UP SWaRA</b>                                                                             | <p>It is responsible for planning of surface water resources in the state of Uttar Pradesh.</p> <p>Develop the policy and legal framework for water resources management in an integrated way at a river-basin scale and at state-level.</p>                                                                                                        | Drafting rationalised water-allocation principles. Draft revised water allocations and publicise it to seek comments from the stakeholders. Bring in measures to curb the practice of water wastage and over-use across all sectors. Appraise the Government of UP and the Irrigation Department to seek their support towards the above-mentioned reforms.                                                                                                                                                    | It will become the country's leading water resources institution to account for E-Flows in water-allocation processes at the state level.                                                                                                                                                                                                                                                                                                                                                                                                                  |

| Stakeholder                                       | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                                     | Support desired for the E-Flows implementation                                                                                                                                                                                                                                                                                                          | What can be achieved and impact                                                                                                                                                                                                                                                      |
|---------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Decision Makers</b>                            | Generally, it sets the agenda for various activities and plays a vital role as they represent the masses. Their decisions are orders for the executives.                                                                                                                                                                                    | It will understand the steps of UPWamReC, SWaRA, UP Irrigation Department and other organizations towards river rejuvenation and take informed decisions in the favour of society, nature and natural resources, including rivers. Support and incentivise water-use efficiency across all sectors.                                                     | Political support is a must for river rejuvenation. Implementation of these steps has the potential to get the project recognised at the national and international levels as a leader in E-Flows initiatives; as part of the mission for rejuvenation of Ganga and its tributaries. |
| <b>Groundwater Department</b>                     | Monitoring of groundwater levels, managing groundwater resources, improving groundwater recharge, and planning.                                                                                                                                                                                                                             | Increase monitoring network with more frequency of samples, carry out detailed gaining-losing stretch mapping and develop an understanding on river-groundwater flow linkages, identify potential catchment areas to carry out demand and supply side management, carry out recharge activities in stressed areas with support from other stakeholders. | Through various monitoring, planning and aquifer recharge initiatives, not only river base-flows can be enhanced but will also help enhance local water security.                                                                                                                    |
| <b>Uttar Pradesh Pollution Control Department</b> | <p>Identification and assessment of industrial and municipal pollution sources and control .</p> <p>Assessment of the quality of inland surface waters.</p> <p>Mass awareness programmes.</p> <p>Notification of effluent and emission standards.</p> <p>Development of pollution control technologies.</p> <p>Instituting legal action</p> | <p>Expand monitoring network to smaller tributaries.</p> <p>Demonstrate effective technologies in pollution abatement with focus on various nature-based solutions.</p> <p>Curb pollution through legal actions.</p>                                                                                                                                    | Various actions will help in pollution abatement and improve river health and habitats for aquatic biodiversity.                                                                                                                                                                     |
| <b>Forest Department</b>                          | The department looks after various forest reserves, national parks and sanctuaries within the state limits. It has interest in maintaining E-Flows in the rivers, improving health of wetlands and conservation actions etc.                                                                                                                | It can play a crucial role in the monitoring of river flows and its benefits vis-à-vis aquatic species like: Dolphins, Indian major carps, Gharial, Otters and key aquatic species.                                                                                                                                                                     | It will become one of the correlations between river flows and habitat viability.                                                                                                                                                                                                    |

| Stakeholder                                                                                   | Mandate/<br>Goal/ Interest                                                                                                                                                                                                                                                                                        | Support desired for<br>the E-Flows<br>implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | What can be<br>achieved and<br>impact                                                                                                            |
|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>GOVERNMENT OF INDIA</b>                                                                    |                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                  |
| <b>Ministry of<br/>Jal Shakti</b>                                                             | <p>Responsible for laying down policy guidelines and programmes for the development and regulation of country's water resources.</p> <p>Responsible for Ganga Rejuvenation. The NMCG works under this ministry, hence both these entities are critical for E-Flows work across the entire Ganga River system.</p> | <p>The Ministry can incentivise efforts and the application of efficient ways to use water for irrigation by providing additional financial support and packages. As part of implementation of Ganga Notification 2016 and Ganga E-Flows Order 2018, the Ministry can incentivise the state's initiatives for the rejuvenation of the tributaries of Ganga. The revised water allocation (taking into account the E-Flows requirements) should be provided with additional support (from the Ministry) in terms of share and quota of financial resources for water resources management.</p> | <p>The Ministry becomes one of the rare governmental entities, on a global scale, that supports the cause of E-Flows and river rejuvenation.</p> |
| <b>Ministry of<br/>Environment,<br/>Forests and<br/>Climate<br/>Change<br/>(MoEF&amp; CC)</b> | <p>It is the nodal agency in the administrative structure of the Central Government for the planning, promotion, co-ordination and for overseeing the implementation of India's environment and forest policies and programmes.</p>                                                                               | <p>The implementation of E-Flows will improve the health of the river and help in ensuring conducive habitats for aquatic species. Therefore, the Ministry should provide additional incentives to state entities or departments that are making efforts towards E-Flows implementation, aiming for river rejuvenation.</p>                                                                                                                                                                                                                                                                   | <p>It will become one of the leading government entities to support E-Flows in the river system.</p>                                             |



| Stakeholder                           | Mandate/ Goal/ Interest                                                                                                                                                                                                                                                                                                                                                                                        | Support desired for the E-Flows implementation                                                                                                                                                                                                                                                                            | What can be achieved and impact                                                                                                                                                  |
|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Central Water Commission (CWC)</b> | <p>Monitoring of hydrological data, including – river flows, water levels and maintain a data repository.</p> <p>Initiates, coordinates and leads project sanctions and consultations between concerned State Governments for control, conservation and utilisation of water resources; mainly for the purpose of flood control, irrigation, navigation, drinking water supply and hydropower development.</p> | <p>CWC's support to access hydro-meteorological data is critical for the E-Flows work. Going forward, CWC can play a key role in monitoring of flows regime and sharing the results with the concerned stakeholders.</p> <p>It can develop policies and guidelines for E-Flows implementation in other river systems.</p> | <p>It becomes the leading state-of-the-art agency to deal with water resources management in a holistic manner, taking into account the environmental and social dimensions.</p> |

**Table 82: Key ministries/ departments/agencies that has a role in implementation of E-Flows**

An effective 'role-play' by these entities would complement the initiatives that could be taken up under earlier components, i.e., technical and social ones.

## 6.3 Next steps

In comparison to E-Flows assessment, its implementation has always been a much more complex, challenging and time-intensive task. This gets even more cumbersome in case of committed river systems (whose water resources are committed/allocated to various uses, including irrigation, domestic supplies and industrial use).

*This section, by no means makes concluding remarks about E-Flows implementation in the river systems for which the E-Flows assessment and recommendations are made in this report. As a matter of fact, like any other robust E-Flows assessment process, this has been a socio-technical and scientific process, while considering all practical natural boundaries (in terms of possibilities of flows) of a given river. On the other hand, the implementation of E-Flows will need to take into account various scenarios of water resources management, including – planning, allocations and use (better management practices in agriculture, urban and industrial use). Therefore, the deliberations around recommended E-Flows need to be broad-based across various stakeholders. This will ensure support from them and therefore, aid in the implementation.*

***The releases from the storages and diversions alone are not the answer to maintaining the E-Flows regime in these river systems. The heavy reliance on groundwater, leading to unregulated groundwater exploitation, is another critical issue that needs to be tackled for maintaining E-Flows in the river systems in a sustainable manner. Diminishing and deteriorating wetlands is another critical aspect that needs to be addressed for maintaining base-flows in the rivers and to ensure year-round local water security for the communities.***

This section gives a general commentary around the key issues being faced by these rivers and potential avenues that can and should aid E-Flows implementation in these river systems. However, precise suggestions around E-Flows implementation at each location would require much deeper studies and analysis of the situation on the ground.

Table 83 to 90 lists site-wise and river-wise E-Flows shortfalls vis-à-vis average present-day flows and various issues that the respective river faces. The table also lists next steps (based on the suggestions), which can aid the E-Flows implementation across these rivers.

| S. No. | River  | Site                       | Shortfall in Maintenance Year |              | Shortfall in Drought Year   |              | Key Issues (prima facie)                                                                                    |
|--------|--------|----------------------------|-------------------------------|--------------|-----------------------------|--------------|-------------------------------------------------------------------------------------------------------------|
|        |        |                            | Dry Season                    | Wet Season   | Dry Season                  | Wet Season   |                                                                                                             |
| 1      | Sharda | Downstream Banbasa Barrage | Only Water Levels suggested   |              | Only Water Levels suggested |              | Reduced lean season flows due to water diversions at the upstream barrage to cater to sectoral water demand |
| 2      |        | Palia Kalan                | December to March             | No shortfall | February to April           | No shortfall |                                                                                                             |
| 3      |        | D/S Lower Sharda Barrage   | Only Water Levels suggested   |              | Only Water Levels suggested |              |                                                                                                             |

**Table 83: List of issues for E-Flows implementation on the Sharda River**

## Suggestions

- Reservoir/Barrage re-operation to be discussed and planned
- Wetland rejuvenation in losing stream catchments
- Demand management in agriculture/domestic/industrial
- Joint rejuvenation initiatives of smaller contributing tributaries

## Next Steps

- Trade-offs analysis study to assess the potential of releases into the river and committed allocations against various management actions
- Scoping study to assess the potential of demand management in agriculture through promotion and implementation of Package of Practices for enhancing water-use efficiency, organic farming, improved seed varieties, etc.
- Mapping and restoration of wetlands
- Hydrogeology study to identify and map gaining and losing streams for prioritizing implementation of demand and supply side measures (Gaining streams are those which receive water from groundwater, while losing streams lose river water to recharge aquifers as they flow downstream)

| S. No. | River   | Site         | Shortfall in Maintenance Year |              | Shortfall in Drought Year   |            | Key Issues (prima facie)                                                                                    |
|--------|---------|--------------|-------------------------------|--------------|-----------------------------|------------|-------------------------------------------------------------------------------------------------------------|
|        |         |              | Dry Season                    | Wet Season   | Dry Season                  | Wet Season |                                                                                                             |
| 1      | Ghaghra | Elgin Bridge | January to April              | No shortfall | No shortfall                |            | Reduced lean season flows due to water diversions at the upstream barrage to cater to sectoral water demand |
| 2      |         | Ayodhya      | December to April             | No shortfall | No shortfall                |            | Reduced lean season flows due to water diversions at the upstream barrage to cater to sectoral water demand |
| 3      |         | Dohri Ghat   | Only Water Levels suggested   |              | Only Water Levels suggested |            |                                                                                                             |
| 4      |         | Turtipar     | January to April              | No shortfall | Only Water Levels suggested |            | Reduced lean season flows due to water diversions at the upstream barrage to cater to sectoral water demand |

**Table 84: List of issues for E-Flows implementation on the Ghaghra River**



## Suggestions

- a. Barrage re-operation to be discussed and planned
- b. Wetland rejuvenation in losing stream catchments
- c. Demand management in Agriculture/Domestic/Industrial sectors
- d. Joint rejuvenation initiatives of smaller contributing tributaries

## Next Steps

1. Trade-offs analysis study to assess the potential of releases into the river, with minimal impact on the committed allocations
2. Scoping study to assess the potential of demand management in agriculture to reduce water use, increase yields through promotion and implementation of Package of Practices to enhance water-use efficiency, organic farming, improved seed varieties, etc.
3. Mapping of wetlands and restoration activities in the catchment
4. Hydrogeology study to identify and map Gaining and Losing streams for prioritizing implementation of demand and supply side measures (Gaining streams are those which receive water from groundwater while Losing streams lose river water to recharge aquifers as they flow downstream)



| S. No. | River | Site            | Shortfall in Maintenance Year |                   | Shortfall in Drought Year |              | Key issues (prima facie)                                                                                                                                                   |
|--------|-------|-----------------|-------------------------------|-------------------|---------------------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|        |       |                 | Dry Season                    | Wet Season        | Dry Season                | Wet Season   |                                                                                                                                                                            |
| 1      | Gomti | Mehndi Ghat     | Only Water Levels suggested   |                   |                           |              |                                                                                                                                                                            |
| 2      |       | Indira Aqueduct | January to June               | No shortfall      | No shortfall              |              | Excessive groundwater exploitation, making the river a 'losing' stream in the stretch downstream of the Lucknow city                                                       |
| 3      |       | Sultanpur       | January to May                | June to September | April to May              | No shortfall | Excessive groundwater exploitation, making the river a 'losing' stream in the stretch around the Jaunpur town. Degradation of smaller contributing tributaries and streams |
| 4      |       | Jaunpur         | January to June               | No shortfall      | April to June             |              |                                                                                                                                                                            |

**Table 85: List of issues for E-Flows implementation in the Gomti River**

## Suggestions

- a. Regulate groundwater exploitation to align with the rates of groundwater withdrawal and replenishment.
- b. Enhance artificial and natural groundwater recharge in and around the Lucknow city through rainwater harvesting and wetland rejuvenation
- c. Water demand management initiatives in various sectors; including – promotion of better management practices in agriculture to reduce water use
- d. Smaller rivulets/streams rejuvenation initiatives

## Next Steps

1. Scoping/literature review about the state of groundwater and its exploitation over the recent past (last 30 years)
2. Introduce and make water footprint work mainstream across the residential, industrial and institutional area in and around the Lucknow city
3. Scoping study to assess the potential of demand management in agriculture through the promotion and implementation of Package of Practices for enhancing water-use efficiency, organic farming, improved seed varieties, etc in the command of Sharda and Sharda Sahayak Irrigation System (that falls in the Gomti River basin) and pass on saved water into nearby rivulets/wetlands
4. Hydrogeology study to identify and map Gaining and Losing streams to prioritize the implementation of demand and supply side measures





| S. No. | River | Site      | Shortfall in Maintenance Year |              | Shortfall in Drought Year |              | Key Issues (prima facie)                                                                              |
|--------|-------|-----------|-------------------------------|--------------|---------------------------|--------------|-------------------------------------------------------------------------------------------------------|
|        |       |           | Dry Season                    | Wet Season   | Dry Season                | Wet Season   |                                                                                                       |
| 1      | Rapti | Balrampur | December to May               | No shortfall | February to March         | No shortfall | Degradation of smaller contributing tributaries and streams                                           |
| 2      |       | Bansi     | December to May               | No shortfall | No shortfall              |              |                                                                                                       |
| 3      |       | Birdghat  | December to May               | No shortfall | February to March         | No shortfall | Excessive groundwater exploitation<br><br>Degradation of smaller contributing tributaries and streams |

**Table 86: List of issues for E-Flows implementation on the Rapti River**

### Suggestions

- Rejuvenation of tributaries/streams joining Rapti upstream of this site
- Promotion of Package of Practices in agriculture in canal commands within the Rapti Basin to reduce water usage.
- Rejuvenate and conserve local wetlands and ponds to ensure year-round water security and to recharge the aquifers.

### Next Steps

- Scoping study to assess the potential of demand management in agriculture through promotion and implementation of Package of Practices for enhancing water-use efficiency, organic farming, improved seed varieties, etc
- Assessing the health of stream/tributaries joining Rapti and developing tributary rejuvenation plans
- Mapping and identifying the critical floodplain wetlands and low lying areas and reviving them

| S. No. | River | Site               | Shortfall in Maintenance Year |              | Shortfall in Drought Year |            | Key Issues (prima facie)                                                                                         |
|--------|-------|--------------------|-------------------------------|--------------|---------------------------|------------|------------------------------------------------------------------------------------------------------------------|
|        |       |                    | Dry Season                    | Wet Season   | Dry Season                | Wet Season |                                                                                                                  |
| 1      | Ganga | Shahzadpur         | December to May               | No shortfall | No shortfall              |            | Excessive groundwater exploitation<br><br>Reduced lean season flows due to abstractions at the upstream barrages |
| 2      |       | Rajghat – Varanasi | Only water level suggested    |              |                           |            |                                                                                                                  |

**Table 87: List of issues for the E-Flows implementation at the Shahzadpur and Varanasi sites on the Ganga River**

### Suggestions

- Regulate groundwater exploitation to align with the rates of groundwater withdrawal and replenishment.
- Demand management in agriculture/domestic/industrial sectors
- Joint rejuvenation initiatives of smaller contributing tributaries
- Canal irrigation water-use efficiency leading to enhancing flows in Ganga/ tributaries/drains (leading to Ganga River)

### Next Steps

- Scoping study to assess the potential of demand management in agriculture through the promotion and implementation of Package of Practices for enhancing water-use efficiency, organic farming, improved seed varieties, etc
- Trade-offs analysis study to assess the potential of releases from water resources infrastructure into the river, with or without impacting the committed allocations

| S. No. | River  | Site           | Shortfall in Maintenance Year            |              | Shortfall in Drought Year |              | Key Issues (prima facie)                                                                                                                                                                                                                                                                                |
|--------|--------|----------------|------------------------------------------|--------------|---------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|        |        |                | Dry Season                               | Wet Season   | Dry Season                | Wet Season   |                                                                                                                                                                                                                                                                                                         |
| 1      | Yamuna | Mohana         | October to June                          | No shortfall | No shortfall              | No shortfall | Over-abstraction of groundwater, diversions from upstream barrages, heavy pollution loads from Delhi-NCR and the Hindon River (tributary of Yamuna)                                                                                                                                                     |
| 2      |        | Mathura        | October – December, February–April, June | No shortfall | No shortfall              | No shortfall | Diversions and regulation from upstream barrages and Gokul barrage. Heavy pollution loads (Yamuna, Gaunchhi drain (right bank). Patwaha nala (left bank), Over-abstraction of groundwater. Degradation of small tributaries like Gaunchhi drain, Patwaha nala joining Yamuna between Mohana and Mathura |
| 3      |        | Agra-Poiyaghat | November–June                            | No shortfall | May–June                  | No shortfall | Huge groundwater abstractions and decline in groundwater levels observed. River losing flows to groundwater between Mathura and Agra. Huge pollution loads from upstream and Agra city                                                                                                                  |



|   |        |           |                          |              |              |              |                                                                                                                                 |
|---|--------|-----------|--------------------------|--------------|--------------|--------------|---------------------------------------------------------------------------------------------------------------------------------|
| 4 | Yamuna | Auraiya   | November-June (marginal) | No shortfall | No shortfall | No shortfall | Pollution loads from upstream sites (though river health marginally improves due to freshwater from Sindh, Gambhir and Chambal) |
| 5 |        | Pratappur | No shortfall             | No shortfall | No shortfall | No shortfall |                                                                                                                                 |

**Table 88: List of issues for the E-Flows implementation on E-Flows assessment sites on the Yamuna River**

### Suggestions

- Regulate groundwater exploitation to align with the rates of groundwater withdrawal and replenishment.
- Implement recharge measures including wetland restoration to improve groundwater scenario in contributing catchment.
- Demand management in agriculture/domestic/industrial. Promote adoption of better management practices in agriculture water management.
- Joint rejuvenation initiatives of smaller contributing tributaries
- Improving canal irrigation water-use efficiency that can contribute saved water to enhance flows in Yamuna and its tributaries.
- Addressing pollution loads and improving water quality by treating polluted water at various levels before discharging into river.

### Next Steps

- Scoping study to assess the potential of demand management in agriculture through promotion and implementation of Package of Practices for enhancing water-use efficiency, organic farming, improved seed varieties, etc.
- Hydrogeological studies to assess gaining and losing streams and potential areas of interventions
- Trade-offs analysis study to assess the potential of releases from water resources infrastructure into the river, with or without impacting the committed allocations
- Mapping of wetlands/ponds/lakes in the catchment and prioritization for rejuvenation through multistakeholder engagement (District administration, line departments, community, thematic experts and NGOs)

| S. No. | River  | Site                               | Shortfall in Maintenance Year |            | Shortfall in Drought Year |            | Key Issues (prima facie)                                                                                                                                                     |
|--------|--------|------------------------------------|-------------------------------|------------|---------------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|        |        |                                    | Dry Season                    | Wet Season | Dry Season                | Wet Season |                                                                                                                                                                              |
| 1      | Gandak | Khadda (downstream Gandak barrage) | Only water levels recommended |            |                           |            | Regulations and diurnal variations in releases from the Gandak barrage to downstream impacting habitats of aquatic biodiversity, livelihoods of communities and bank erosion |

**Table 89: List of issues for E-Flows implementation on the Khadda site of the Gandak River**

| Suggestions                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>a. Effectively managing barrage operations to minimize diurnal fluctuations in water levels and mitigate the loss of habitats and damage to riparian communities caused by sudden releases.</p>                                                                                                                                                                                          |
| Next Steps                                                                                                                                                                                                                                                                                                                                                                                  |
| <p>a. Engagement with concerned officials (Gandak Barrage) of Uttar Pradesh Irrigation &amp; Water Resource Department on exploring ways and means to minimize the diurnal fluctuations</p> <p>b. Trade-offs analysis study to assess the potential of releases from water resources infrastructure downstream of the Gandak River, with or without impacting the committed allocations</p> |

| S. No. | River | Site   | Shortfall in Maintenance Year |            | Shortfall in Drought Year |            | Key Issues (prima facie)                                                                                                                                                                                                                          |
|--------|-------|--------|-------------------------------|------------|---------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|        |       |        | Dry Season                    | Wet Season | Dry Season                | Wet Season |                                                                                                                                                                                                                                                   |
| 1      | Sone  | Chopan | Only water levels recommended |            |                           |            | <p>Regulations and diurnal variations in releases from Rihand dam, barrage operated by UPJVNL, Obra.</p> <p>Slurry release from Thermal Power Plant operated by (UPJVNL) damaging habitats of aquatic biodiversity and impacting river health</p> |

**Table 90: List of issues for E-Flows implementation on the Chopan site of the Sone River**

| Suggestions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>a. Effectively managing barrage operations to reduce diurnal fluctuations in water levels and mitigate the loss of habitats and damage to riparian communities caused by sudden releases.</p> <p>b. Slurry/ash management at thermal plant to minimize the impact on river health and habitats of biodiversity</p>                                                                                                                                                                                       |
| Next Steps                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <p>c. Engagement with the concerned officials of Rihand dam (Uttar Pradesh Irrigation &amp; Water Resource Department) to explore barrage reoperations in order to minimize diurnal variations, and officials at thermal plant (UPJVNL) on exploring ways and means to implement better slurry/ash management</p> <p>d. Trade-offs analysis study to assess the potential of releases from water resources infrastructure downstream of Rihand dam, with or without impacting the committed allocations</p> |

In next section, few brief case studies are discussed, which could serve as motivating examples for initiatives aimed at enhancing flows in rivers, thereby supporting the realization of E-Flows in rivers.





# Successful Initiatives and Best Practices in River Rejuvenation and E-Flows

## 1. Ramganga E-Flows assessment, implementation and impacts

The Ramganga is a microcosm of the Ganga River in many ways, encountering similar challenges as the Ganga; albeit at a smaller scale, however with a potentially similar severity of impacts. The Ramganga River faces obstruction, irrigation abstractions and diversions, pollution, besides excessive groundwater exploitation in the basin for the purpose of irrigation, domestic and industrial use.

Through its decade long journey WWF-India carried out various activities in phases from assessment to implementation of E-Flows in Ramganga River. This includes E-Flows assessment at 8 locations (2013-15), Tradeoff analysis downstream of Hareoli Barrage location (2015-18), engagement for E-Flows implementation with UPI&WRD (2018-2021) and impact assessment (2021-24). The Ramganga E-Flows assessment was carried out with contributions from various partner organizations, institutions, departments and experts (IIT-Kanpur, IIT-Delhi, ICAR- CIFRI, PSI, INRM and other technical experts) that worked with WWF-India. In this process various thematic aspects were studied, which includes Hydrology-Hydraulics, Fluvial geomorphology, Aquatic biodiversity, water quality, river health, socio-cultural and livelihoods.

Through scientific assessment and sustained engagement on tradeoff analysis for downstream Hareoli Barrage site, UPI&WRD issued an Office-Order to release 140 cusec of water from Kalagarh Dam downstream in Ramganga for the lean season (January to June). Similar initiatives can be undertaken in other river systems. The preliminary impact assessment shows that river depth in the lean season has increased by 2-3 feet, thereby improving river health, which is also reflected in the increased diversity of fishes.





Thematic field surveys and E-Flows assessment at 8 key locations on Ramganga



E-Flows releases (144 cusec) downstream of Hareoli Barrage site and impact monitoring



## 2. River rejuvenation to support E-Flows in Ramganga and Ganga through agriculture water management in canal command areas (Karula-Gaagan and Kali rivers catchments)

The pressure on freshwater resources is leading to diminishing flows in some of the critical river systems including Ganga basin, agriculture being the largest freshwater user (80-90%). To cater to the ever-growing irrigation water requirements, there have been more diversions of riverine waters and over abstraction of groundwater. This is leading to diminished flows in rivers impacting dependent communities and biodiversity. While graduating from the concept of Environmental Flows and its assessment methodologies in India, the water-managers, the researchers and the conservationists are now moving towards answering the next question i.e., if the rivers are to be revived, then where will the water come from, especially in the case of over-allocated rivers, including the river Ganga? The logical way is to look at the biggest user of water, i.e. irrigation.

### Approach

WWF-India along with various partners and stakeholders is working on the realization of E-Flows through a two pronged approach – i) Releases from dams/barrages ii) River rejuvenation through agriculture water management in canal command areas. E-Flows releases from dams have been successfully demonstrated downstream of the Hareoli Barrage as discussed in the previous section. River rejuvenation through agriculture water management in canal command areas was successfully piloted in a 380 ha canal command area of Khanpur minor canal with 300 plus farmers to work on improving their water use efficiencies in sugarcane crop in Bijnor district, UP. This was a joint initiative involving farmers, the Uttar Pradesh Irrigation and Water Resources Department, Bijnor District Administration and WWF-India to enhance flows in a rivulet, called Karula River, which is part of the Ramganga River system. A three pronged approach was adopted

- i. Demand-side Interventions – Introduction, demonstration, upscaling of water-efficient irrigation techniques (across the command farmers) along with organic fertilizers, organic pesticides, micronutrients. Since the command area predominantly grows sugarcane, so this crop was targeted for irrigation water-use efficiency
- ii. Supply-side Interventions – Rehabilitating the canal to ensure the designed irrigation discharge from the head of the canal and the formation of a passage from the tail-end of the canal to the Karula riverbank.

- i. Institutional Support – Capacity building of command farmers in regard to (i) functioning of WUA, (ii) the roles and responsibilities of farmers as WUA members. Plus, facilitate setting-up of Khanpur Minor Water Users Association to sustain the Karula river initiative

## Impacts

Through collective sustained efforts from all stakeholders, in May 2019 , first time the saved water from irrigation was discharged into Karula river, thereby rejuvenating it. Between 2019-2023 about 90 million litres of saved and available water from irrigation was discharged into the Karula River, thus augmenting its flows. In addition to this, the water use efficiency increased by 17% in single cropping and 34% in multi-cropping and productivity was enhanced by average 24% in demonstration farms.

This pilot study was scaled up to 55,000 hectare connecting 1.4 lakh farmers in canal command of Ramganga (Karula and Gaagan river) and Bachhmai distributary (Lower Ganga Canal system) in Kali River catchment. The coverage extends across districts like Bijnor, Moradabad, Amroha, Kasganj.

Till December 2023, this approach has led to the release of over 2000 million litres of saved and available water into Kali, Karula-Gaagan rivers and its tributaries/drains through passages connecting various canal-ends with the rivers.



***Trench-based sugarcane cultivation underway***



***Saved water leading towards Karula river***



***A healthier Karula river***

### 3. Multi-stakeholder-led river-wetland co-management in the Aril River(Ramganga basin) for river rejuvenation through floodplain wetland restoration

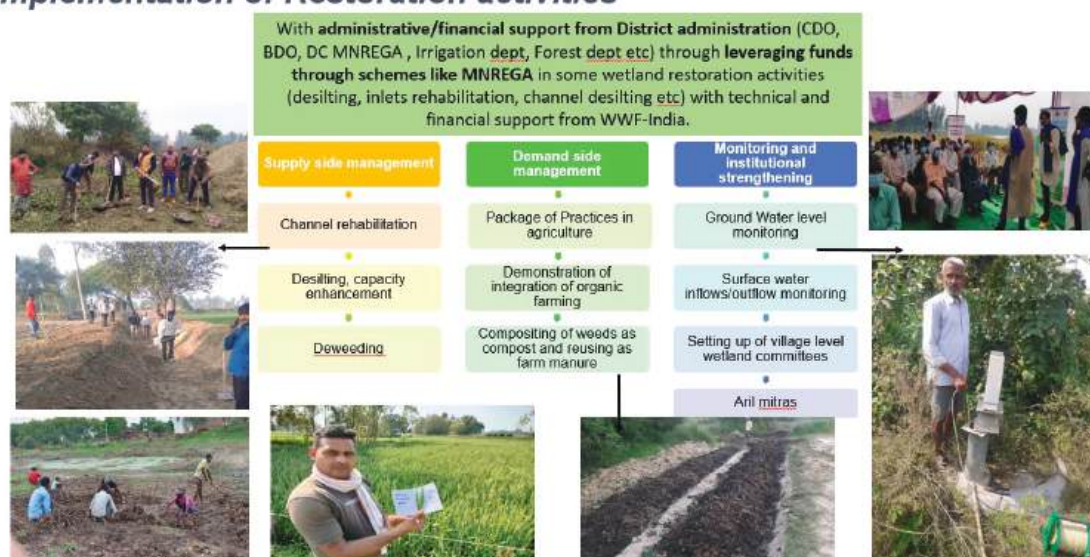
Ramganga and its tributaries are aquifer fed river systems that are being subjected to loss of connectivity and degradation of river health (flows, water quality, biodiversity) due to over-abstraction of groundwater, diversion of surface water, unsustainable agriculture practices, pollution, land use change, encroachment etc. To improve river health, maintaining its 3-dimensional connectivity viz. lateral (floodplain), Longitudinal (upstream to downstream) and vertical (river-groundwater) connectivity is essential.

Wetlands are crucial in supporting the base flows in the river system through groundwater replenishment apart from providing a myriad of ecosystem services to communities and biodiversity including flood cushioning, groundwater replenishment, habitat for avian and aquatic flora/fauna, water security to riparian communities, cultural values, recreation and tourism through aesthetic value.

#### Approach

WWF-India along with its partner IIT- Kanpur mapped all the wetlands (>2.5 ha) in the Ramganga basin and assessed their degradation status over the last 3-4 decades. Ramganga tributary catchments were scanned and Aril river basin (a right bank tributary) was selected to showcase river-wetland co-management work. A multi-stakeholder-led collective action approach was adopted where the District Administration, various line departments, District Ganga Committee, Bareilly/Moradabad, riparian community and WWF-India are working together to improve the ecological health of the river through river-wetland co-management.

#### Implementation of Restoration activities





Based on the wetland's status and connectivity to river floodplains, more than 20 wetlands were field surveyed to collect baseline information. The survey indicated several major threats to the wetlands, including excess weed growth, siltation, choked inlets/outlets, sewage, fragmentation, intensive chemical usage in agriculture, and land use/land cover changes, as well as issues related to ownership.

Using a prioritization matrix, four wetlands were selected viz. Khangawa Shyam (10.6 hectares (ha), Lilaaur Lake (42 ha), Bahoda Kheda (7.42 ha) in Bareilly district and Devari wetland (2.5 ha) in Moradabad district. The wetland restoration plan was developed for all four wetlands. While community mobilization, engagement of 'Aril Mitras', technical support in planning, training, and capacity building along with restoration activities like de-weeding and sustainable agriculture and monitoring of impacts were done by the WWF-India team and Mitras, synergies were also built with various government schemes like MNREGA for carrying out various restoration activities desilting, channel rehabilitation etc.

The District Administration, Bareilly, and WWF-India collaborated and brought stakeholders together including line departments, representatives from 5 villages, and 500 plus community members under the Aril Mitra platform to spread awareness and enhance community participation in restoration activities.

### **Impacts of collective action**

- Synergies with government schemes like MNREGA were built and through leveraging funds, 8 new inlets were created and 4 inlet channels were rehabilitated which brought more surface water inflows into wetlands
- To improve wetland health and promote organic farming in the wetland zone of influence, 2500 quintals of wet weed was removed and turned into 700 quintals of compost, which is being used by farmers in their crops. Apart from this, 500 plus farmers were trained on the preparation and adoption of bio-fertilizers and bio-pesticides (Amrit Paani and Amrit Khaad) and follow better management practices in agriculture through the customised Package of Practices (PoP). Farmers reported an increase in the length of the wheat spike, improved plant health, 20-25% reduction in water requirement, and substantial reduction in chemical application, through the adoption of PoP.
- Increase in surface water inflows into wetlands and Aril river
  - About 1600 million litres of additional water flowed into three wetlands (post restoration interventions) during monsoon season of 2022 and 2023 exceeding their maximum capacity.
  - About 150 million liters of water have been discharged into the Aril River from the restored Khangawa Shyam wetland outlet (2022 and 2023).

- The increased water availability in the wetlands led to an increase in groundwater levels by 5 feet thereby improving aquifer health and water security for communities, which in long run can help in enhancing base-flows.
- The improvement in wetland health provided conducive habitats for aquatic species and avian fauna.



Wetland restoration of Lilaaur wetland



Rejuvenated Aril river through wetland restoration

There would be a need to collate and popularize such initiatives across the masses, to not only make them aware about the the positive and success stories around them, but also to sensitize them towards the need to have healthy rivers, of which E-Flows is a critical element.

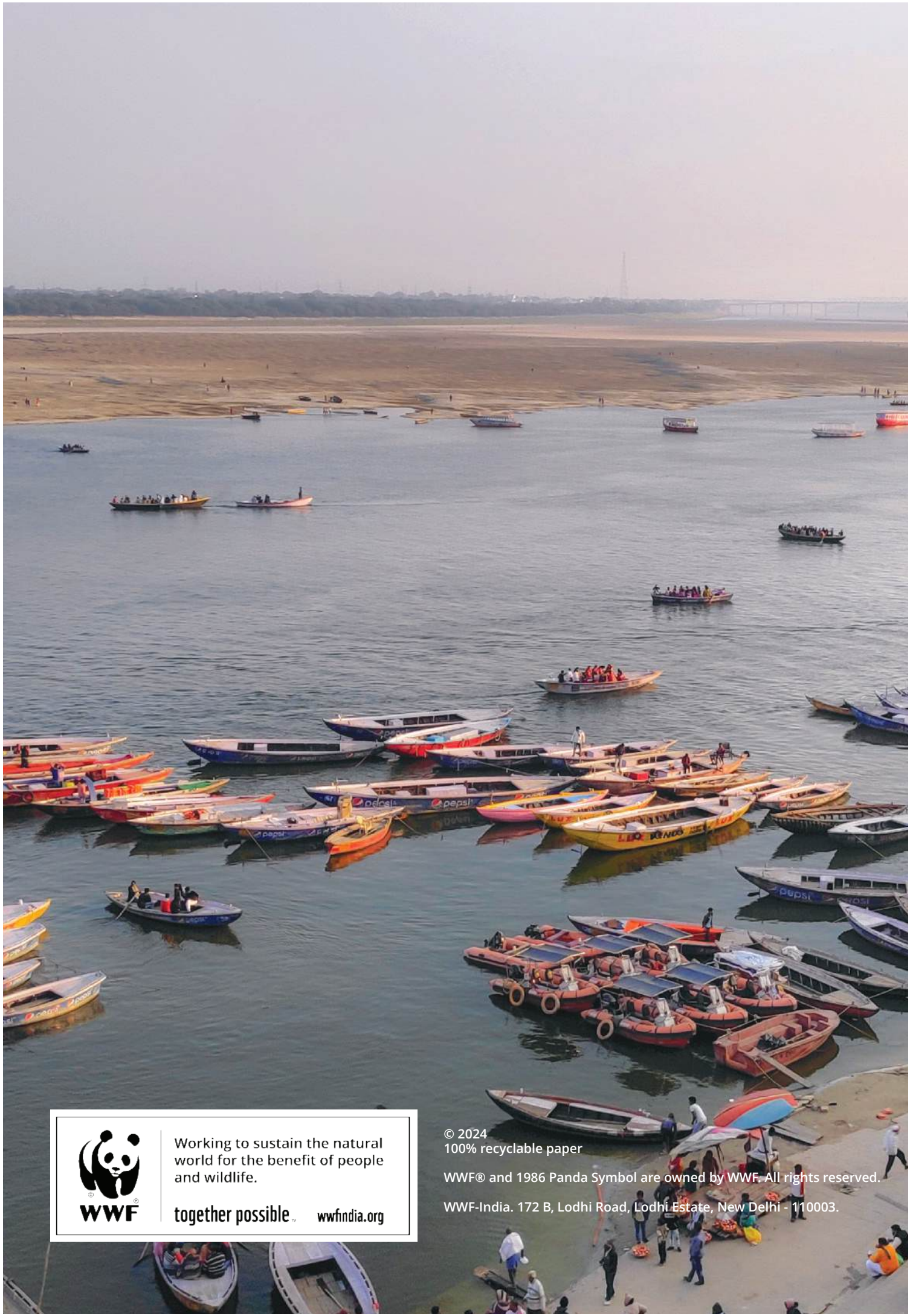
At the end of the day, it needs to be remembered that, the scores of stakeholders (ranging from local communities, farmers, cities, government departments, industries, local civil society) residing in or dependent on the river basin are critical to the well-being of the basin and the river. Therefore, it is a collective responsibility and all of us has a role to play.

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