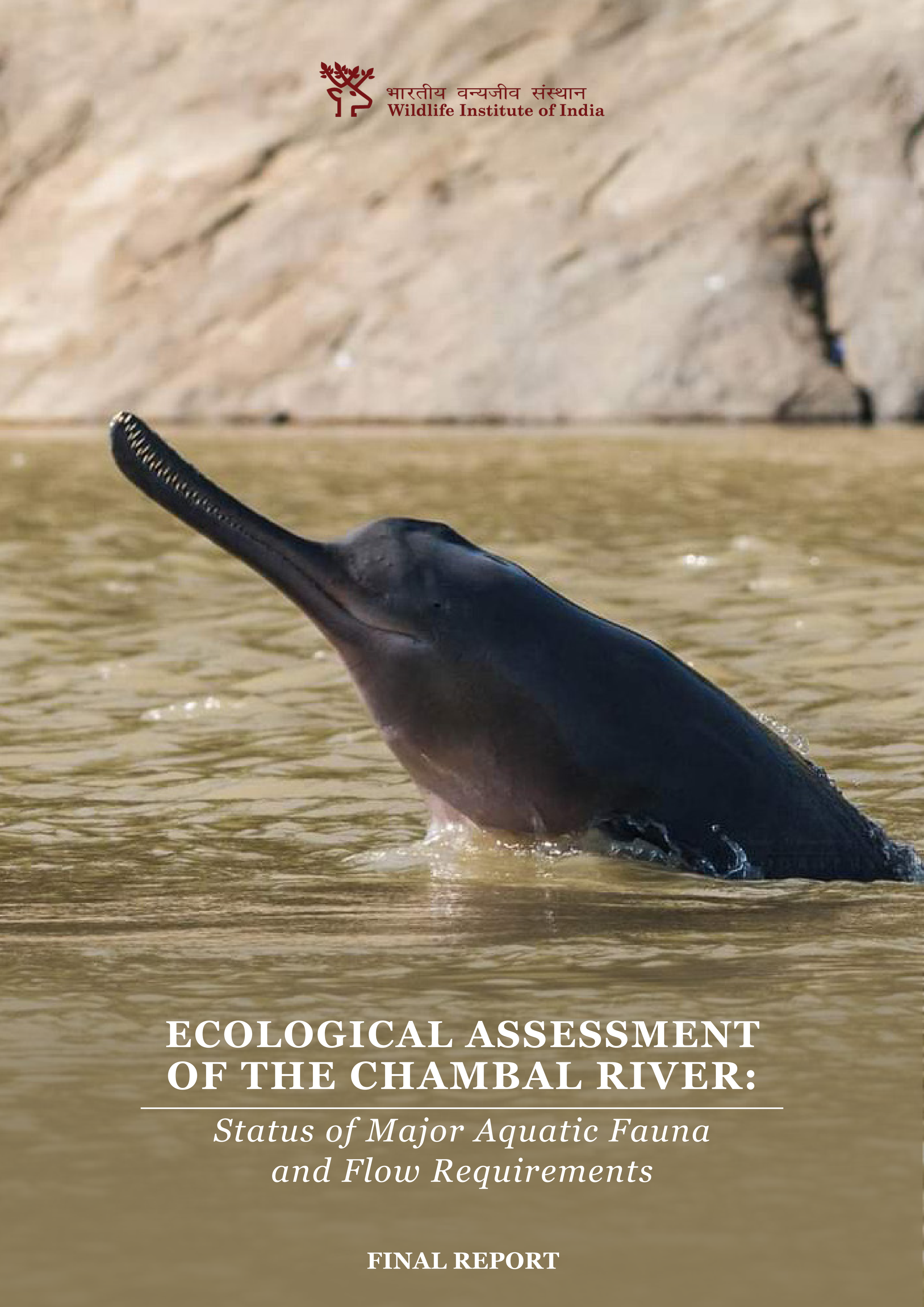
भारतीय वन्यजीव संस्थान
Wildlife Institute of India



ECOLOGICAL ASSESSMENT OF THE CHAMBAL RIVER:

Status of Major Aquatic Fauna and Flow Requirements

FINAL REPORT

Cover photo: Naba Choudhury

CONTENTS

LIST OF MAPS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

At the 70th meeting of the Standing Committee of the National Board for Wildlife (NBWL), held on 13th October 2022 and chaired by the Hon'ble Minister of Environment, Forest and Climate Change (MoEFCC), it was decided to prescribe a minimum environmental flow for the Chambal River. This decision was taken to ensure the sustained health of the river ecosystem and to support the conservation of the Ganges River Dolphin (*Platanista gangetica*) and other aquatic species.

The Wildlife Institute of India (WII), in coordination with the Central Water Commission (CWC), was assigned the responsibility of conducting a comprehensive study on various aquatic species present in the Chambal River, their status, flow, and water level requirements for their survival, and also to identify species of conservation importance.

In line with this mandate, and as referenced in file no. 6-76/2022 WL dated 27th February, WII submitted an interim report on "Status of Major Aquatic Fauna of Chambal River and Effect of Water Flow" through letter no. WII/VK/Chambal-NBWL/Dolphin/2023-2024 dated 14th July, 2023.

For preparing the final report, WII has collated information and undertaken biodiversity assessments since then. However, additional information regarding historical flow, current water availability at Parvati and Ramsagar dam sites, year-wise demand data for the past ten years or since dam construction, Hydraulic Simulation and Flow Assessment was required for a detailed analysis, this was communicated to the respective authorities. Since no response was received, this report is based on the data received from CWC and the biodiversity assessment carried out by WII, which comprises details on identified species of conservation importance, their status, minimum depth and flow requirements for their survival and trends in flow of the Chambal river.

The Chambal River holds a major population of Endangered Ganges River Dolphin, Critically Endangered Gharial, and Vulnerable Mugger crocodile. Also, it supports a wide range of other aquatic biodiversity, including 78 species of water birds, 8 species of turtles and the smooth-coated otter (Sharma & Singh, 1986; Hussain, 1993; Hussain, 1996; Hussain & Choudhury, 1997; Sharma, 2006; Rao, 1991; Taigor & Rao, 2010; Nair & Krishna, 2013). The sanctuary also provides nesting habitats for various island nesting birds. Our findings highlight that several aquatic species in the Chambal River depend on specific flow regimes and water depths. During the range-wide river dolphin estimation exercise carried out for the country, dolphin presence was maximally detected in areas where depth was greater than 3 m, however, it is a known observation that they may navigate to shallower areas (~2 m) when needed. This however does not define optimal habitat. In experiments conducted by WII, depths greater than 3m were the most used in any given area. Gharials use depths ranging from 1 m to over 4 m based on age or size (Hussain, 2009), while muggers also favour deep waters for security and reduced human disturbance (Bhattarai *et al*., 2022). Hussain *et. al*., 2011 estimated minimum lean-season flow requirements to be151–164.34 m^3/s for gharials and 266.4–289.67 m^3/s for dolphins. However, it is important to acknowledge that this is the "minimum" flow required and levels below these may not be able to sustain these species of conservation importance.

There are two crucial aspects with respect to flow, in the context of Chambal river. Firstly, during the flow required to maintain ecological river connectivity with achieving a minimum depth. For the assessment, a depth of 3 m has been considered the minimum required to maintain ecological connectivity across the river, while a depth of approximately 5 m is regarded as necessary to provide optimal habitat conditions for large aquatic fauna such as dolphins, turtles, and crocodilians. Considering the average width of the Chambal River, the flow requirements are estimated at 998.52 m^3/s and 2,324.38 m^3/s for water depths of 3 m and 5 m, respectively. However, during the lean season, the river's width reduces substantially, thereby reducing the corresponding flow requirements. To account for seasonal channel constriction, discharge requirements were modelled for reduced river widths. Based on ecological and geomorphological criteria, a minimum channel width of 150 m is recommended during the lean season to sustain fundamental hydraulic and ecological functions. Using Manning's equation minimum flows required to maintain different target depths were computed across varying width scenarios. Considering a river width of 150 m during the lean period, the flows required to maintain depths of 3 m and 5 m, were calculated as 368.46 m^3/s and 848.79 m^3/s, respectively (Table 12).

Analysis of 10-daily average flow data from 1990 to 2022, provided by the Central Water Commission (CWC), reveals a significant declining trend in river discharge during the lean season (Figure 6). Additionally, we employed a hydraulic modelling approach for monthly flow simulations using HEC-RAS software over the 2012–2022 period with the data provided by CWC, in all the five Gauging and Discharge Stations. This simulation further demonstrates a progressive reduction in flow beginning in November and approaching near-zero conditions by June. Current monthly flow regimes shows only during the monsoon months (July to October) river discharge is sufficient to maintain the depth required for suitable habitat conditions for the aquatic wildlife of Chambal river. This trend raises critical concerns about the ability to maintain minimum environmental flows necessary to support riverine ecosystems. The decline is largely attributed to increased upstream water abstraction projects, functional during the lean season, either on the Chambal River or its tributaries, could further compromise ecological integrity and biodiversity. As tributaries contribute significantly to the overall flow and ecological function of the river, their protection and restoration are vital for sustaining and rehabilitating the health of the Chambal River. Also, during lean season, deeper pools of more than 5m depth present across the river plays crucial role in maintaining the aquatic wildlife.

During recent surveys, the dolphin population hotspot was observed to have shifted downstream, towards the confluence of the Yamuna, due to decreased water depth in the upper stretch. Additionally, lowering of water levels makes the islands exposed to Jackals, stray dogs and cattle, leading to the destruction of nests of these endangered fauna (Jha & Pandav, 2021).

Therefore, the current water flow in chambal is below minimum requirement during lean season, and any additional withdrawal of water from the Chambal River or its tributaries from November onwards may have detrimental effects on the riverine ecosystem. It is thus recommended that water extraction be restricted to the monsoon months when river flow is at its peak. A balanced approach is essential to align developmental needs with long-term environmental sustainability.

INTRODUCTION

Freshwater ecosystems, encompassing rivers, their floodplains, deltas, estuaries, ponds, lakes, and various types of temporary and permanent inland wetlands, are fundamental to both the planet's biodiversity and human well-being (Díaz *et al*.,2018; Dudgeon, 2019). The Anthropocene is an era of unprecedented pressure on Earth's natural ecosystems. This pressure is particularly acute in freshwater ecosystems where aquatic biota face an extinction crisis caused by a continually growing mix of human-induced threats (Dudgeon, 2019; Reid *et al*., 2019). These ecosystems support a substantial portion of global freshwater biodiversity and provide essential services to billions of people. Despite their critical importance, they are currently among the most undervalued, overexploited, and degraded ecosystems worldwide (Arthington *et al*., 2023). Freshwater ecosystems are under unprecedented pressure, leading to an extinction crisis for aquatic life. This environmental degradation is largely driven by a range of human activities, with hydrological alteration and resource exploitation being among the most significant. Hydrological changes are mainly carried out to meet demands for water supply through barrages and water-lifting projects, for generating hydropower using dams, and for modifying river channels to support navigation and transportation. While linear river structures like dams and barrages play a vital role in supporting irrigation, electricity generation, and broader socio-economic development, they also bring unintended consequences (Vaidya *et. al*., 2008). One of the major concerns is their impact on river ecosystems. When free-flowing rivers are fragmented by dams and impoundments, the natural flow and connectivity of the river are disrupted, leading to fundamental changes in how the ecosystem functions. Rivers that were once healthy and diverse now frequently only support species tolerant to drought or pollution (Palmer & Ruhi, 2019).

Historically, efforts to protect river health often focused on identifying and maintaining a **"minimum flow"** in rivers and streams. The idea was to ensure that a basic amount of water remained in the river. So, initially, the environmental flow concept was focused on maintaining minimum flow level as it was generalised as one single river health problem, which is low flow, and as long as the critical level is maintained, the river was considered to be conserved. However, it has been recognised now that all elements of flow regime, viz, flood, medium and low flows; is essential for the natural flow regime (Poff *et. al*., 1997; Hill & Bascheta, 1991; Junk *et. al*., 1989) and any changes in this will impact the river ecosystem in some way. In mid 70s various methods were developed to estimate the e- flow (Wesche & Rechard, 1985; Reiser, 1989; Dunbar *et. al*., 1998; Tharne, 2003; Acreman & King, 2003) with certain advantages and disadvantages and are applicable to certain set of circumstances (Acreman & Dunbar, 2004).

Environmental flows (e-flows)

Environment flows describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems that, in turn, support human cultures, economies, sustainable livelihoods, and well-being. (Arthington *et.al*., 2018; Acreman,2016). Or in simple words, E flows are about providing the right amount of water, at the right times, and with the right quality, to support healthy aquatic ecosystems and the human communities that depend on them. The core idea behind e-flows is that humans benefit greatly from healthy rivers, not just by directly taking water for drinking or farming, but also indirectly through things like recreation, cultural identity, and overall quality of life (Arthington *et al*., 2023; Acreman,2016).

E-flows emphasise the **"flow regime"**(Opperman,2018). This means considering all the different characteristics of how water naturally moves through a river system over time. These characteristics are:

Magnitude: How much water is flowing. This is the volume of water.

Frequency: How often a particular flow event happens, such as a small flush or a larger flood.

Duration: How long a certain flow event last. For example, how many days a flood remains at a certain level.

Timing: When these flow events occur, especially in relation to seasons. Many species have evolved to rely on specific flow events at particular times of the year for their life cycles, like fish spawning during a spring flood.

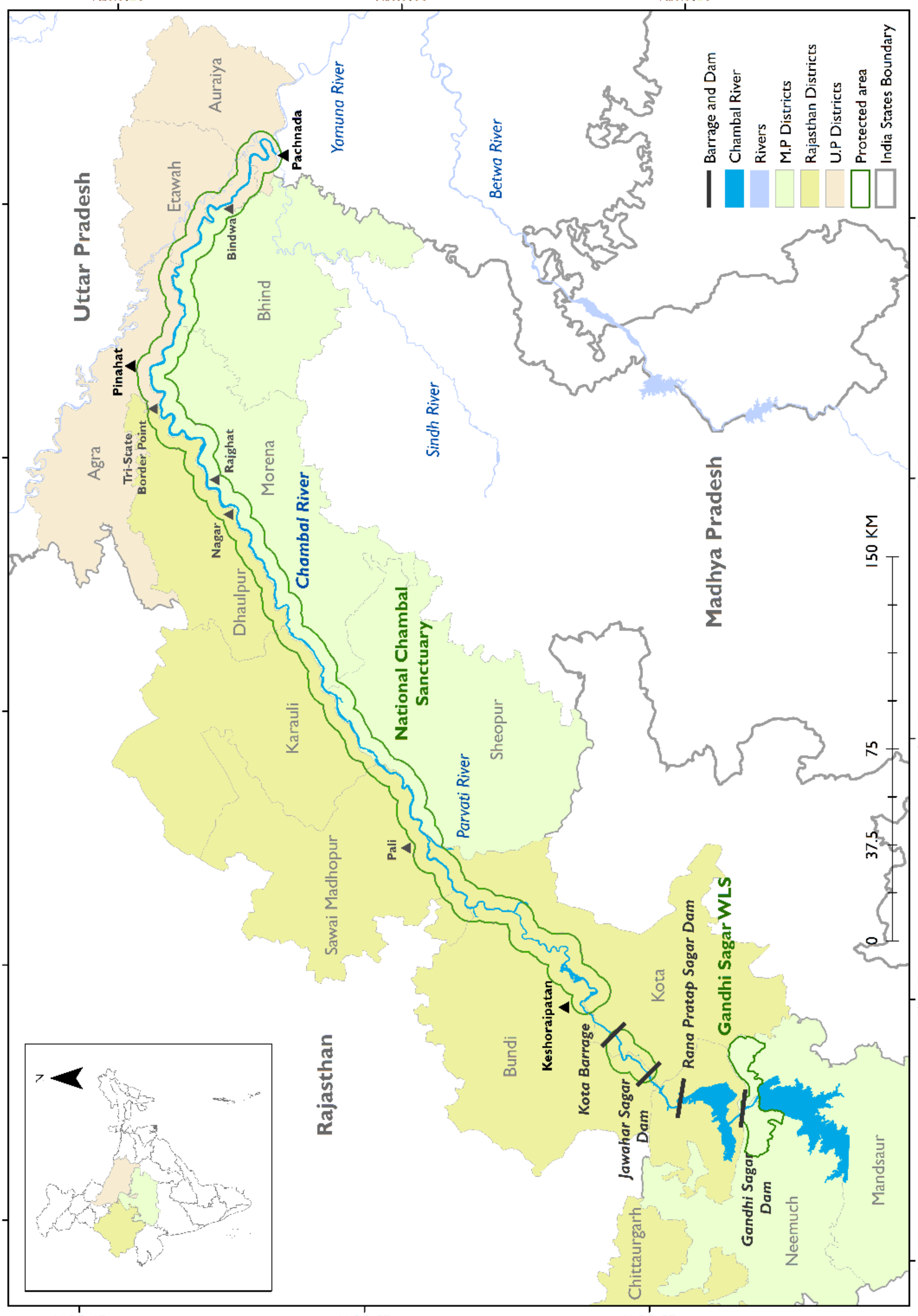
Rate of Change: How quickly the water levels rise or fall

Different aspects of the flow variation have been known to be a key driver of a river's structure and functioning, the characteristic magnitude, frequency, duration, timing, and rate of change in river flows shaped the life history strategies of plants and animals over evolutionary time scales of both aquatic and riparian organisms (Palmer & Ruhi, 2019). For example, certain fish species might rely on specific flood pulses at particular times of the year for spawning. The more a river's flow deviates from its natural regime, the greater the loss of ecosystem (Acreman,2016).

Chambal River

The Chambal River is a relatively unpolluted river that originates in the Singar Chouri peak in the Vindhya range near the Mhow district of Madhya Pradesh and passes through the boundaries of three Indian states, Rajasthan, Madhya Pradesh, and Uttar Pradesh (Katdare *et. al.*, 2011; Hussain, 2013). The river has a course of 965 km, of which 600 km of the river is protected as the National Chambal Sanctuary, established in 1979 (Singh & Rao, 2012). The Sanctuary extends over the Chambal River from Jawahar Sagar Dam to Kota barrage and after a gap of 18 km free zone, from Keshoraipatan (Rajasthan) through Pali to Pachanada, Uttar Pradesh where it forms a common confluence with the Yamuna along with the Kunwari, Pahuj and Sindh rivers (Meshram, 2010). The Chambal River is characterised by an undulating floodplain, gullies, forests, ravines, and a mosaic of land-use types (Hussain & Badola, 2001; Gopal & Srivastava, 2008). The vegetation is classified as ravine and thorn forest (Champion & Seth, 1968). Evergreen riparian vegetation is absent, with only sparse ground cover along the severely eroded river banks and adjacent ravine lands (Hussain 1999, 2009). The tributaries of the Chambal include Shipra, Choti Kalisindh, Sivanna, Retam, Ansar, Kali Sindh, Banas, Parbati, Seep, Kuwari, Kuno, Alnia, Mej, Chakan, Parwati, Chamla, Gambhir, Lakhunder, Khan, Bangeri, Kedel and Teelar (Jain *et. al.*, 2007; Gopal & Srivastava, 2008). The climate of the basin is influenced by its location with respect to the Tropic of Cancer and the presence of the Vindhyan ranges in the upper reaches. The area is semiarid, and the temperature in the region varies from 2° to 48°C during winter and summer, respectively. The Chambal River has an average width of 400 m and a depth of 1–26 m (Hussain and Choudhury, 1992). The riverbanks are rocky in the upstream areas, leading to muddy and sandy banks further downstream and characterised by forest, shrub, and grasses (Singh, 2010; Taigor & Rao, 2010a).

The Chambal river system harbours the largest population of critically endangered Gharial, which is endemic to the Indian subcontinent (Hussain, 1993), and also houses endangered Ganges river dolphins. Apart from these, the major fauna of the sanctuary on the Chambal River include the vulnerable Mugger Crocodile, seven species of freshwater turtles, and 78 species of wetland birds (Hussain, 1993; Singh, 2008). However, this sanctuary suffers from hydrological modifications due to dams, the diversion of river water for irrigation, and from activities like sand-mining, fishing, and the persistent presence of livestock and humans (Hussain, 2009). A series of multipurpose dams constructed on the upper reaches of the river in the early 1970s have reduced its normal discharge. There are 7 major (Gandhi Sagar, Rana Pratap Sagar, Jawahar Sagar, Kota Barrage, Parwati Pick-up Weir, Harish Chander Sagar, and Gudha Dam), 12 medium, and 134 minor irrigation projects operating in the Chambal River basin, all of which have greatly reduced river flow, and erratic water releases in the past have inundated several nesting sites (Hussain & Badola, 2001). These existing projects notwithstanding, 52 new irrigation projects are under construction, and 376 projects have been planned in the basin (Hussain, 2009). As recorded between 1996 and 2004, the average maximum discharge of water of the Chambal River is 2074.28 m3/s/and the minimum is 58.53 m3/s (Hussain and Choudhury, 1992). Studies also show a strong correlation between water flow and the density of aquatic species. It was observed that the water depth increases with the increase in discharge rate. Thus, depending on the flow, the percentage of river stretch optimal for Ganges dolphins observed was 22.8% and 2.9% respectively during the months of February (winter), and June (lean season), 2010. A similar trend is seen in the case of Gharial, where the percentage of river stretch optimal for adult gharial was 53.9%, and 19.2% respectively during the months of February and June 2010 (Hussain *et. al.*, 2011).



Map 1: *Map of Chambal river showing various dams and barrages, along with boundaries of National Chambal Sanctuary*

Objectives

To understand the ecological flow requirement and health status of the Chambal river following key questions needed to be answered:

a. What is the average monthly flow of the Chambal River
b. What are the various water columns used by different aquatic mammals and reptiles
c. What is the seasonal abundance and distribution of aquatic fauna and river birds (Ganges dolphin, Gharial, Mugger, Otters, Turtles and Skimmers)
d. What is the of primary productivity (plankton study)
e. What is the seasonal variations in water quality
f. What is the pollution load in the downstream of dams and mining sites

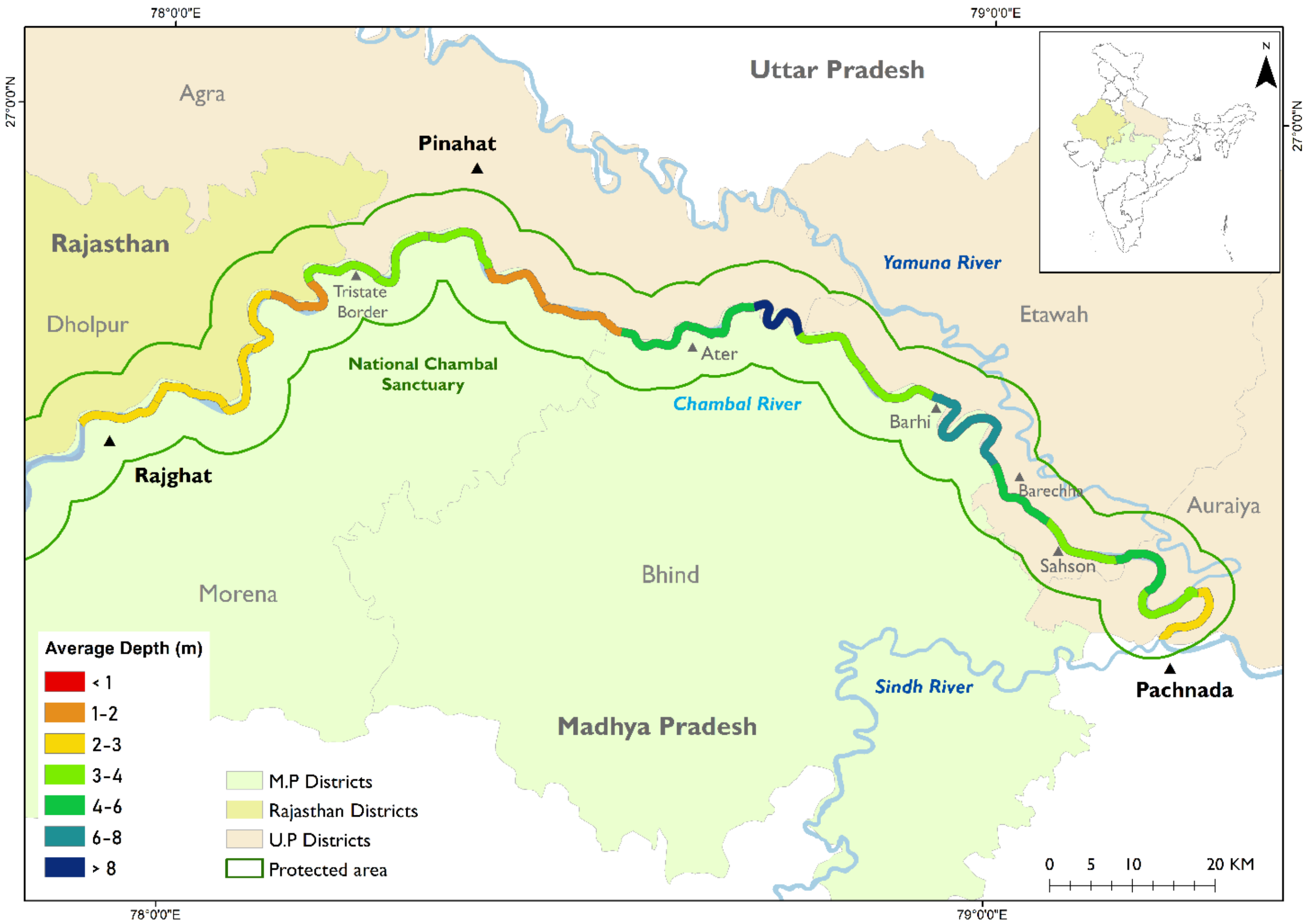
DEPTH DURING THE LEAN PERIOD IN THE LOWER CHAMBAL RIVER

River depth is a key hydrological parameter that plays a critical role in shaping riverine ecology. It directly influences habitat availability, water temperature, flow velocity, sediment transport, and the distribution of aquatic organisms (Allan & Castillo, 2007). For aquatic fauna such as river dolphins, turtles, and fish, adequate depth ensures suitable habitats for feeding, breeding, and movement.

During the WII survey in June 2024, water depth was measured at 500-meter intervals using a handheld depth sounder, along a 233 km stretch from Rajghat, MP, to Pachnada, UP.

Average Depth

The river stretch from Rajghat to Pachnada was found to have an overall average depth of 4m (SD ± 3.65), with a range varying from 0.42 m to 22.02 m, both minimum and maximum depth was recorded from the stretch passing through Madhya Pradesh and Uttar Pradesh. The stretch of the river, sharing the border of MP and UP (from the tri-state border to Barecha), had the highest average depth of 4.86m (SD ± 4.48). The part of the river that lies in the state of Uttar Pradesh (from Barecha to Pachnada), was found to have an average depth of 3.64m (SD ± 2.37), ranging between 0.66m-8.73m. The stretch that lies on the border of Madhya Pradesh and Rajasthan (from Rajghat to the tri-state border) has the lowest average depth of 2.53m (SD ± 1.64), ranging between 0.57m-7.50m (Table 1, Table 2 and Figure 1).



Map 2: *Map showing Average Depth for every 10 km segment of Chambal River from Rajghat, Madhya Pradesh to Pachnada, Uttar Pradesh during June 2024 survey.*

***Table 1:** Average depth across 22 segments of the Study stretch during WII June 2024 survey*

Segment no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Mean of Average Depth	2.91	2.82	2.49	2.87	1.13	3.14	3.81	3.11	1.84	1.55	5.89	4.06	13.07	3.75	3.08	6.28	7.14	4.77	3.11	4.85	3.35	2.22
SD of Average depth	1.43	2.7	1.44	1.17	0.51	1.59	1.6	2.38	1.49	0.54	1.4	2.84	6.73	2.65	3.04	4.59	5.69	2.18	2.96	3.12	1.53	0.53

***Table 2:** Average depth of the river stretch (State-wise) from June 2024*

Average Depth	Rajasthan and Madhya Pradesh	Madhya Pradesh and Uttar Pradesh	Uttar Pradesh
Stretch	Rajghat to Tristate border	Tristate border to Barecha	Barecha to Pachnada
Mean	2.52	4.861	3.64
Range	0.57-7.49	0.41-22.02	0.65-8.73
Standard Deviation	1.63	4.47	2.36

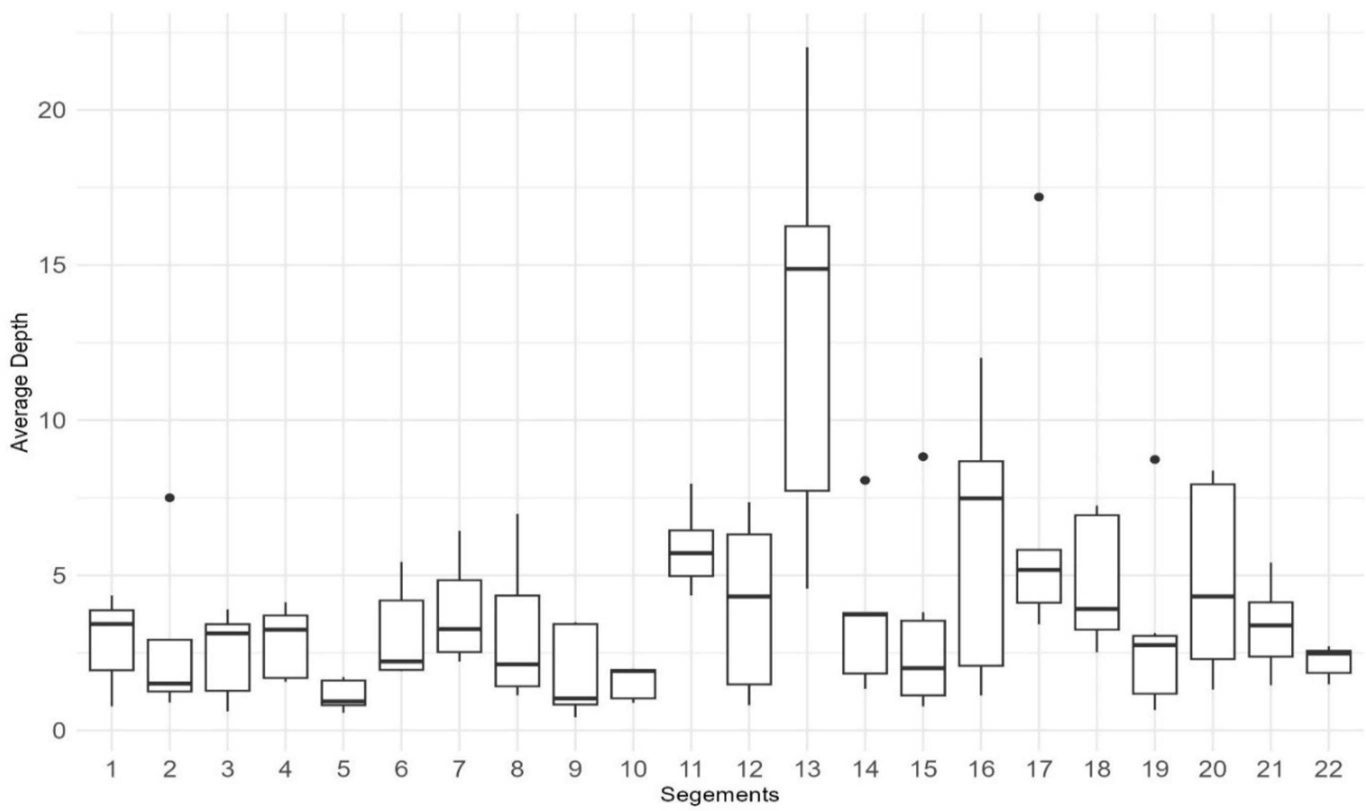


***Figure 1:** Boxplot showing average depth (in meters) for every 10 km segment of Chambal River, June 2024 survey*

Minimum Depth

Depth plays a crucial role in dolphin movement, and the study stretch shows very low average minimum depth (0.43-1.15). These measurements, taken in dry season depict how majority of the segments have water level far below the requirement of dolphins, gharials and muggers.

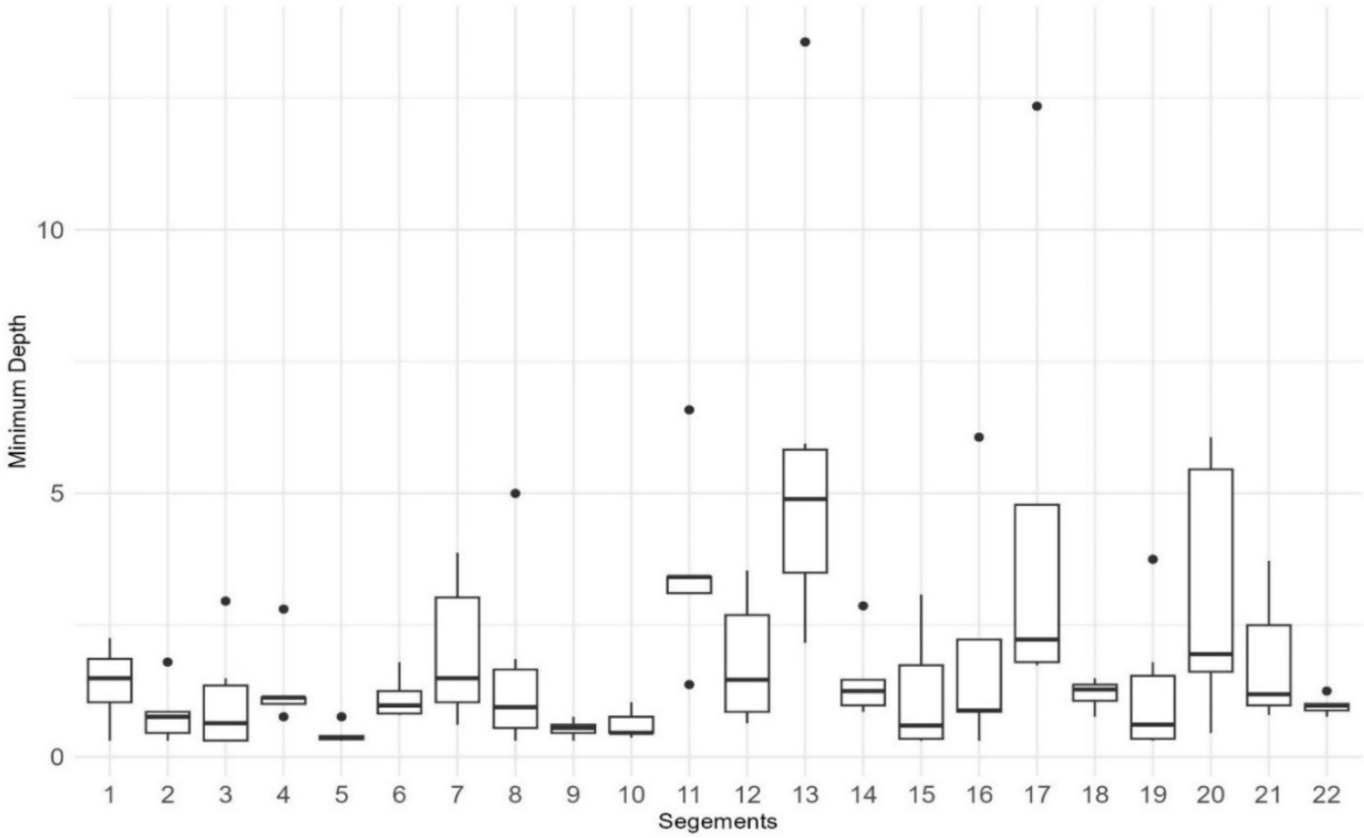


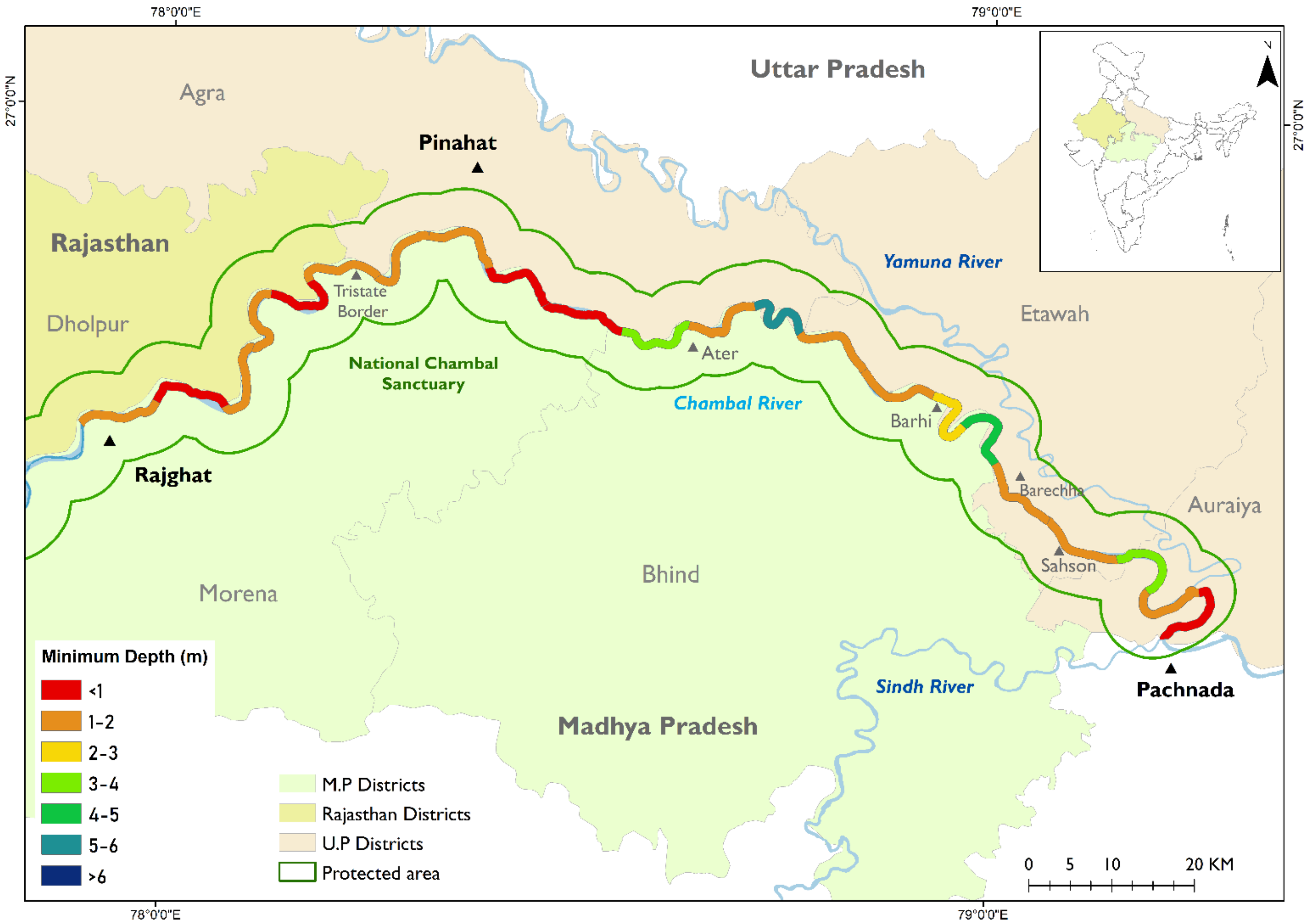
Figure 2: *Boxplot showing average minimum depth (in meters) for every 10 km segment of Chambal River, June 2024 survey*

ABUNDANCE AND DISTRIBUTION OF AQUATIC FAUNA

Abundance and distribution of target species is one of the most fundamental information required for successful monitoring of its status and management interventions, if needed for its revival. The Chambal River represents a critical freshwater ecosystem in India, supporting a wide range of aquatic fauna. Given its ecological importance and conservation value, it is essential to understand the seasonal abundance and spatial distribution of these aquatic species.

Ganges river Dolphin *(Platanista gangetica)*

Ganges river dolphins, locally known as susu (*Platanista gangetica*), one of the four obligatory freshwater species, are found across the Ganges–Brahmaputra–Meghna and Karnaphuli–Sangu river systems in Nepal, India, Bangladesh, and possibly Bhutan (Mohan *et al*., 1997; Sinha *et al*., 2000; Smith *et al*., 2001). As an adaptation to a fluviatile environment, they use echolocation for navigation and foraging and are practically blind, as they have eyes without crystalline lenses (Herald *et al*., 1969). The Ganges dolphin is listed in Schedule I of the Indian Wildlife (Protection) Act 1972 in India, and was declared the National Aquatic Animal of India.



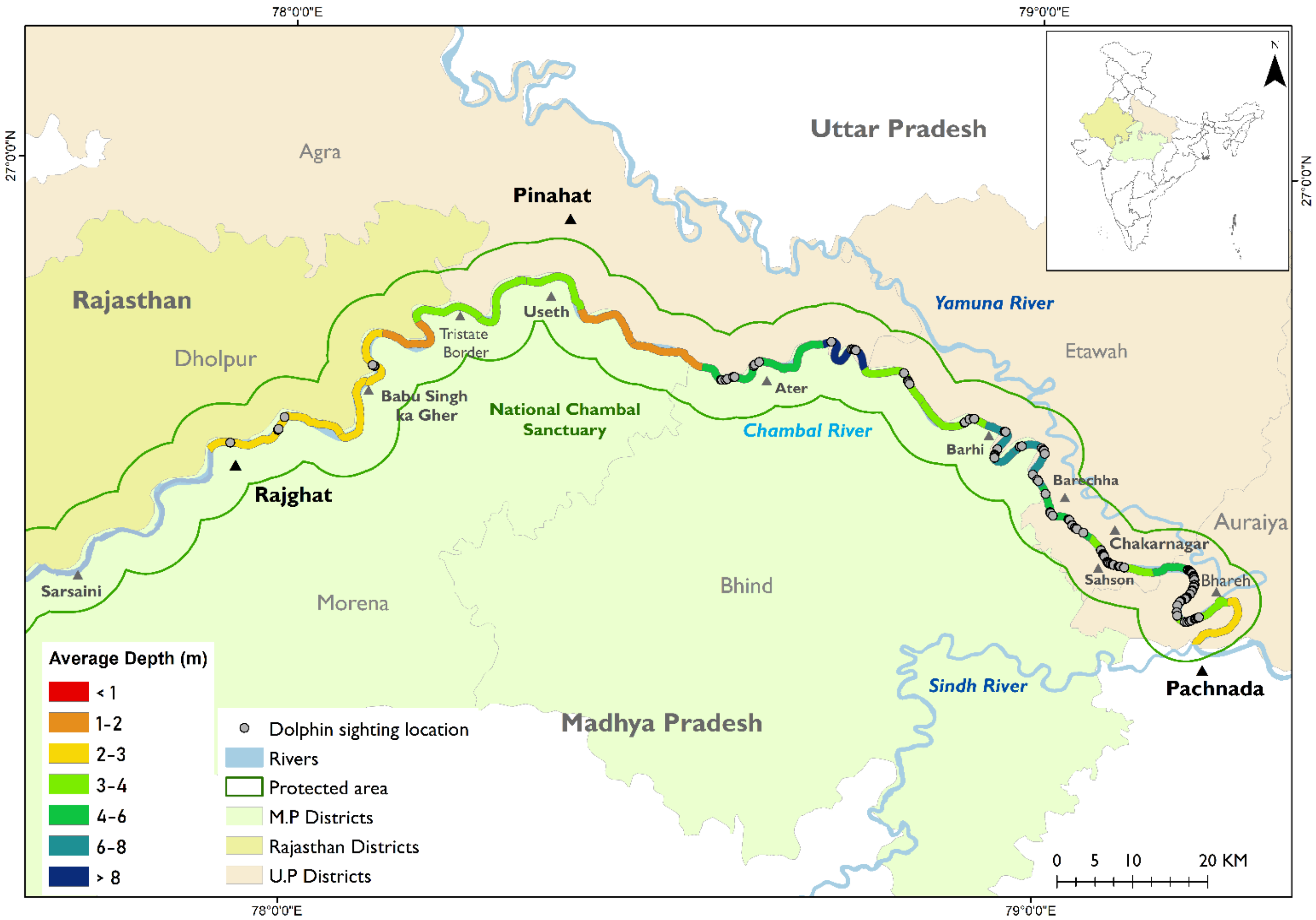
Map 3: *Map showing Average Minimum depth for every 10 km segment from Rajghat, Madhya Pradesh to Pachnada, Uttar Pradesh, during June 2024 survey.*

Previous Studies

In 1983-85, a total of 45 dolphins were counted over a 320 km stretch between Batesura and Pachhnada, through Chakarnagar and Chambal-Yamuna confluence (Singh & Sharma, 1985). In 1988–1989, Rao *et.al*. (1989) surveyed the Chambal River and recorded 59 dolphins (ER 0.18) over 320 km from Batesura to Pachhnada, and 43 dolphins (ER 0.16) over 265 km from Batesura to Chakarnagar. The highest number of dolphins was recorded in the year 2002, with a count of 93 (ER 0.3) dolphins. Thereafter, the number fluctuated between 56 and 91 (Sharma & Singh, 2014)(Appendix 3).

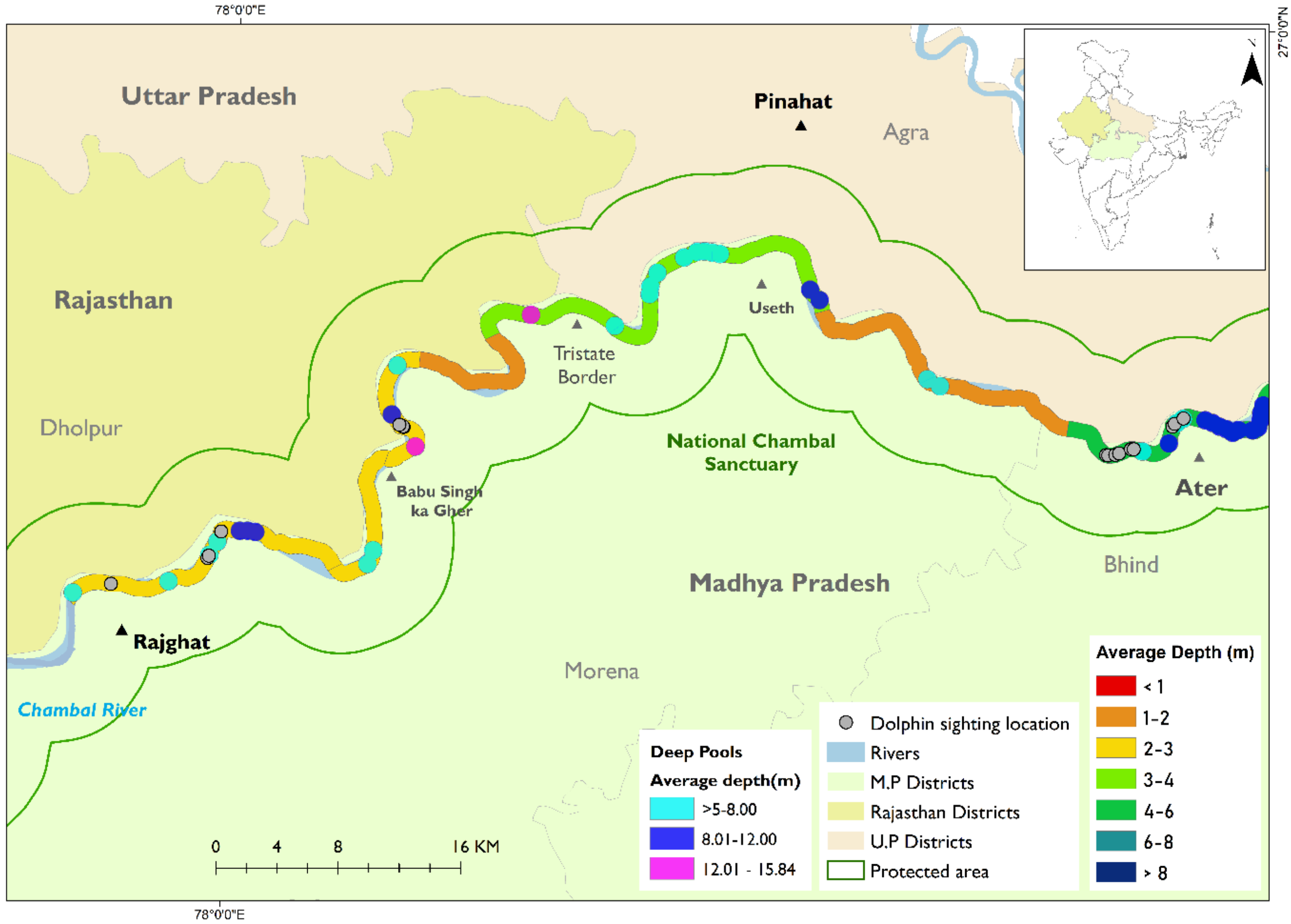
Under WII, during Rangewide River Dolphin Estimation, a Survey was conducted in January 2022 (Winter) along the Chambal River stretch from Nagar, Rajasthan-Madhya Pradesh to Pachhnada, Uttar Pradesh, covering a distance of 242 km. The survey employed the boat-in-tandem method. The survey results revealed an estimated 298 (278-320) dolphins with an encounter rate of 1.2/Km and a least count of 243 dolphins in the stretch (Qureshi *et.al*.,2024).

Later, in a study conducted by WII in June 2024, from Rajghat, Madhya Pradesh to Pachhnanda, Uttar Pradesh (233 km). A total of 226 (207-243) dolphins were estimated, with an encounter rate of 0.97/ km and a least count of 146. In this survey, a single boat was used to perform a dolphin survey where a single team of three researchers, consisting of two observers (positioned on the left and right sides) and one data recorder (at the centre), was used for data collection. This approach was employed in the Chambal River due to the survey being conducted during the lean season when the river's depth was significantly low, making it impractical for larger boats to navigate. Consequently, more robust estimation methods, such as the Tandem Boat or Double Observer techniques, could not be applied.

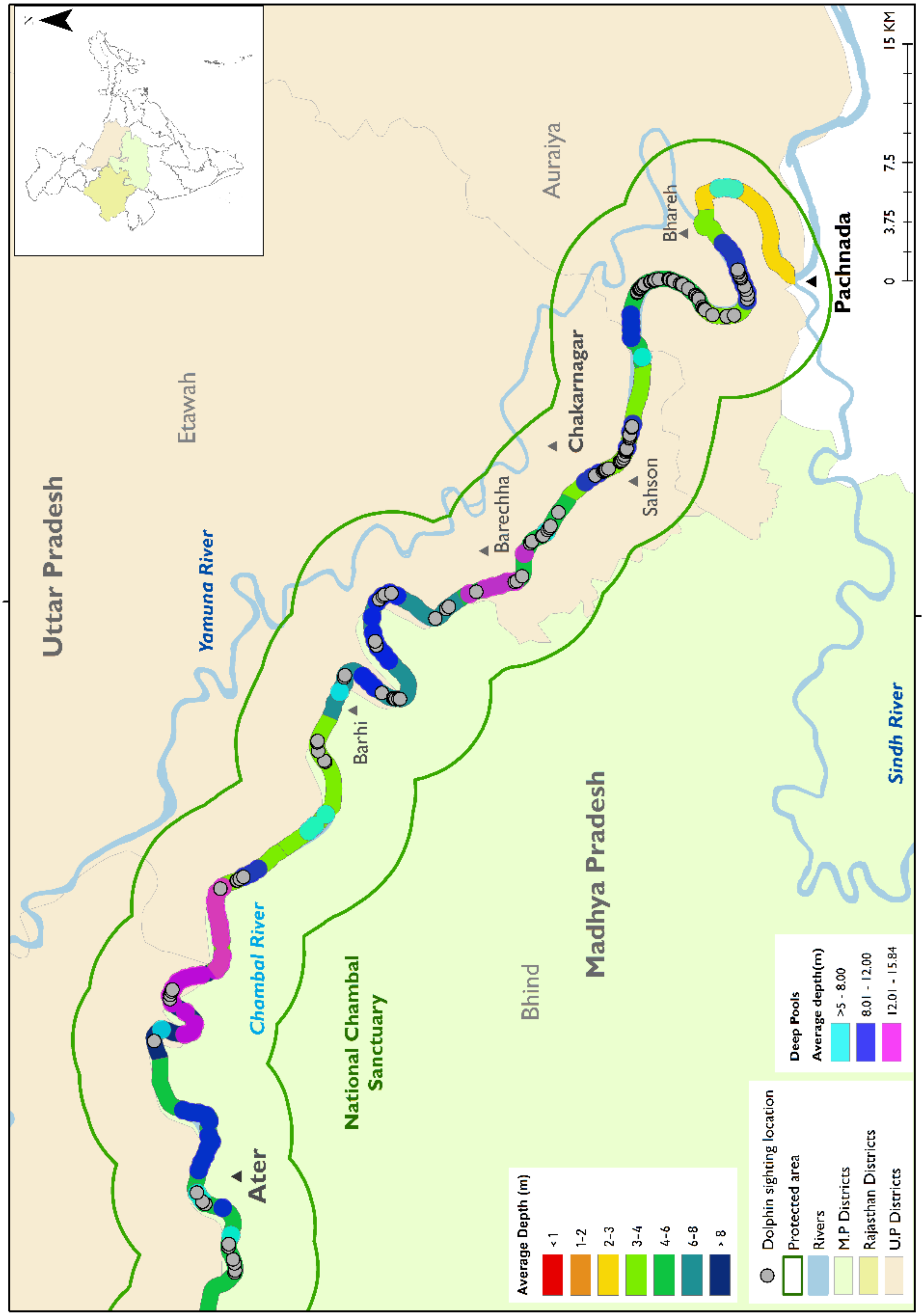


Map 4: *Map Showing the Dolphin sighting locations in study stretch along Chambal river during WII June 2024 Survey*

Image 1: *Dolphin Surfacing in Chambal River on two different Occasions*



Map 5: *Map Showing the Dolphin sighting locations along with deep pools from Rajghat to Ater in study stretch along Chambal river during WII June 2024 Survey*



Map 6: *Map Showing the Dolphin sighting locations along with deep pools from Ater to Pachnada in the study stretch along Chambal river during WII June 2024 Survey*

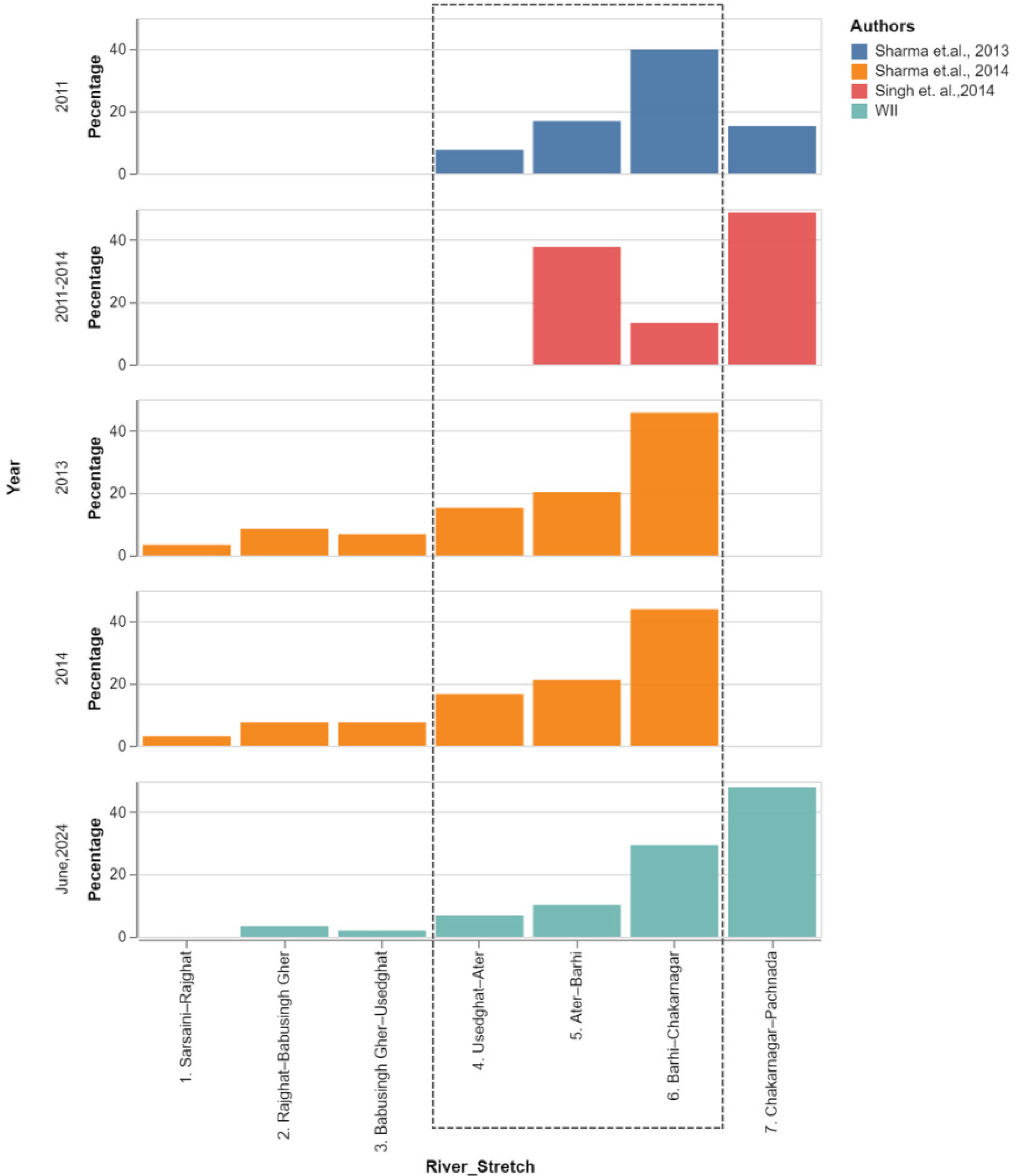


Figure 3: *This bar graph shows the percentage of dolphins recorded in each stretch during different surveys and time periods. The box highlights the overlapping stretches — areas that were included in all the surveys, even though each survey covered different stretches.*

The dolphin distribution map (Map 4) clearly shows that dolphins are largely distributed in the lower stretch of the Chambal River, where the water depth is adequate (more than 3-4m). However, also revealed that even within this lower stretch, no dolphins were recorded between Bhareh (Confluence of Chambal and Yamuna) and Pachnada, likely due to shallower water in this section (less than 3m)with minimum depth less than 1m).

Both previous studies and our current research indicate that dolphins are now mostly found in the deeper parts of the lower Chambal, where water depth is generally more than 3 meters. Earlier studies recorded a fair number of dolphins between Rajghat and Ater (Figure 3). But in our recent survey, June 2024, this section had very few dolphins. Most of the dolphin population is now found downstream of Ater, particularly concentrated between Barhi(Udi) and Bhareh. This indicates that dolphins are gradually moving from the middle stretch of the Chambal River (between Sarsaini and Ater) toward its lower stretch (from Ater to Pachnada). This shift is likely due to insufficient water depth and a lack of deep pools in the middle section, which are crucial for dolphin survival. Therefore, it is essential to ensure that enough water is released into the river to maintain a steady flow and adequate depth, especially in the middle stretch, to support a healthy dolphin population.

Water Column (Depth) Utilisation by the Ganges River Dolphin

Sinha & Kannan (2014) found that "The greatest influence on the presence and abundance of dolphins is exerted by the area of water depth below one meter", noting that dolphins avoid shallow channels with small cross-sectional areas. This indicates that areas with less than 1-meter depth significantly reduce dolphin presence and abundance. Wakid (2009) reported dolphins preferring water depths between 4.1 and 6 meters. In another study conducted in West Bengal, dolphins were observed at depths as shallow as 3.5 to 4 meters, marking the minimum recorded during the survey. However, the majority of sightings occurred at depths ranging from 6 to 10 meters (Mitra *et. al.*,2015). Observations from the WII range wide river dolphin survey further reinforce that dolphins thrive in river sections with sufficient water depth and minimal anthropogenic disturbances. Dolphins have been observed foraging in water less than 1 meter deep in confluence zones, but this represents temporary foraging behaviour rather than sustained habitat use (Kelkar *et. al.*,2018). Maintaining river stretches with depths of at least 2 meter is essential for river connectivity and movement of dolphins, while depths of 4 meters or more are necessary for optimal habitat conditions.

Based on the available scientific evidence, 2 meters represents the critical minimum depth threshold below which Ganges river dolphins cannot survive. However, for healthy breeding populations, depths of 4 meters or more are strongly preferred.

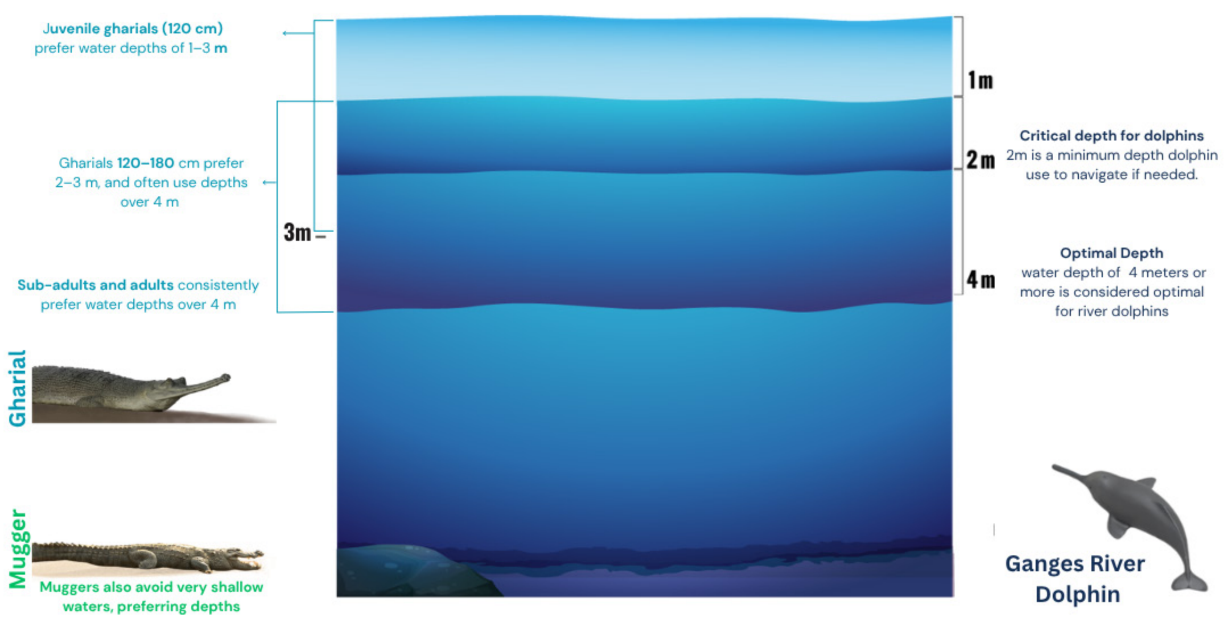


Figure 4: *Illustration showing preferred water depths of Dolphins, Gharials, and Muggers. (Souces: Hussain, 2009; Nishan et.al., 2023; Bhattarai et. al.,2022)*

Gharial (*Gavialis gangeticus*)

The gharial (*Gavialis gangeticus*) is one of the most unique and distinctive of the crocodilians, and are also known as Fish-eating crocodiles, having a very specialised diet, predominantly consisting of fish. They are characterised by their long and narrow snout with interlocked, razor-sharp teeth, which are best suited for catching slippery fish, making them one of the most adept piscivores among crocodilians. Gharials are endemic to the Indian subcontinent, occurring in the Indus, Ganges, Brahmaputra, and Mahanadi River systems (Groombridge, 1987; Singh, 1978a; Smith, 1939; Whitaker, 1987). Once the species was on the verge of extinction (the 1970s) due to habitat loss, indiscriminate hunting, and intensive use of nylon fishing nets, causing net entanglement and drowning, leading to large-scale mortalities (Choudhury & Bustard, 1979; Choudhury & Chowdhury, 1986; Daniel, 1970; Honegger, 1971; Whitaker, 1987)

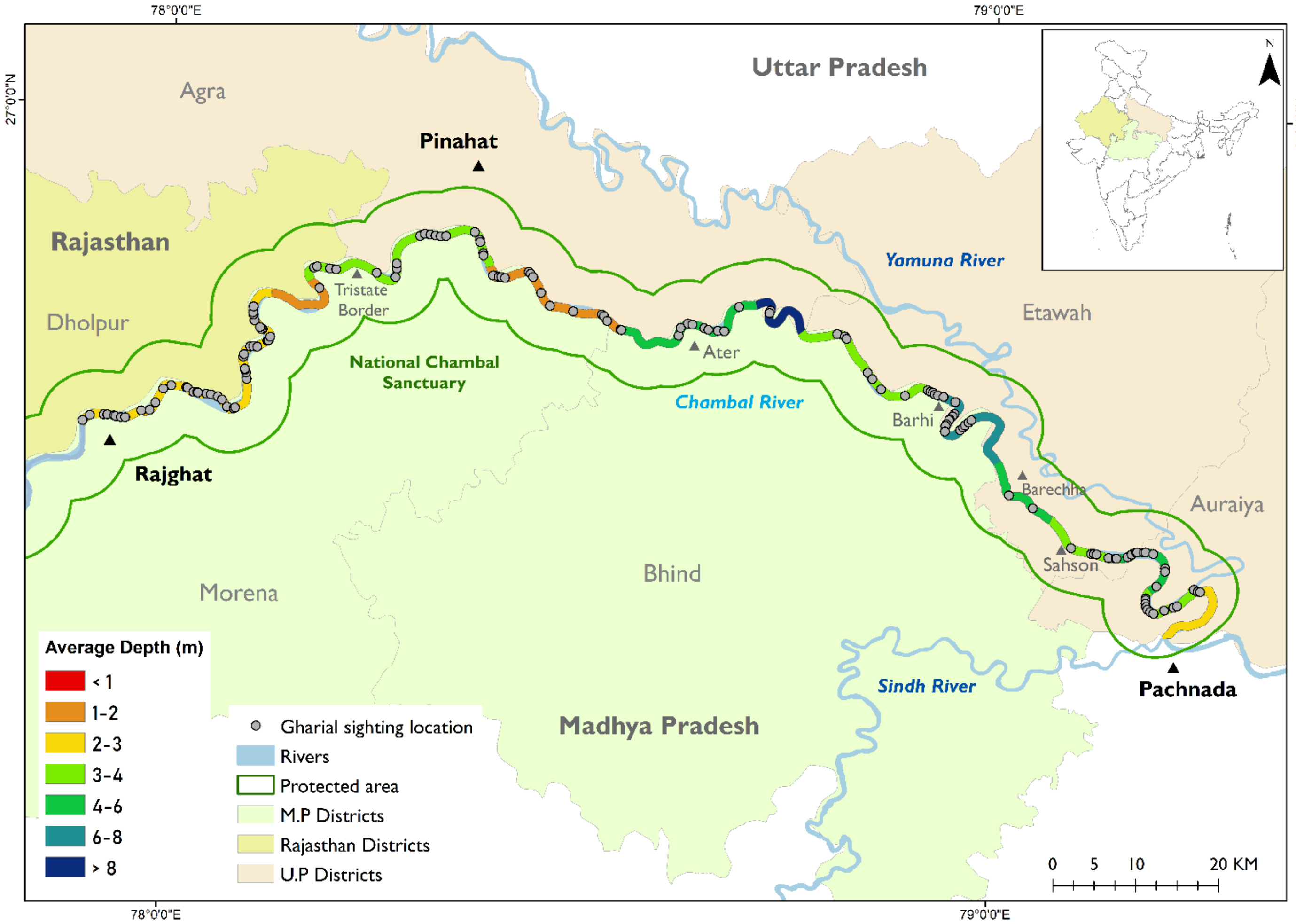
Previous Studies

A total of 83 adult Gharials (*Gavialis gangeticus*) were recorded along approximately 200 kilometres of the Chambal River in Uttar Pradesh in 1977 (Singh, 1978). Followed by the release of captive-reared individuals by 1981, Gharials of all size classes in Chambal increased from 451 individuals in 1983-84 to 982 in 1990 (Choudhury & Hussain, 1991). From 1993 to 1997, Gharials of Chambal increased from 898 to 1242, including 226 breeding adults. 81 nests were recorded in the same year (Sharma, 1999). Since 1997, no survey for Gharial was conducted in Chambal until in 2003. In 2003, Sharma & Basu (2004) reported a total of 552 Gharials, of which 158 were adults, 276 were juveniles and sub-adults, and 118 were hatchlings (Appendix 3). The Chambal Gharial population was reduced by almost half in the period of five years. Sharma & Dasgupta (2013) studied the population trend of Gharial in around 400 km stretch of Chambal River from 2003 to 2013 and have reported total 512 Gharial including 150 adults, 264 sub adult and juveniles and 98 yearlings and hatchlings in 2003, while in 2013 total 948 Gharials including 430 adults, 367 sub adult and juveniles, 150 yearlings and hatchling were reported. In 2017, in a Boat survey of 414 km of the Chambal river, a total of 541 gharial, consisting of 38 males, 376 females, 41 subadults, 59 juveniles, and 27 yearlings, were recorded, whereas two stationary surveys from the same study tallied 861 and 789, respectively (Lang & Kumar, 2017). As of 2021, around 1700 Gharials were counted in the Chambal River, which is 80-90% of the global Gharial population. Some Gharials are also reported to seasonally migrate to the Kuno River in the Kuno National Park. Head-started Gharials are now being released in the Kuno National Park (Lang, 2021).

During the Rangewide River Dolphin Estimation survey in January 2022, 348 Gharials were recorded from Nagar to Pachhnada (Qureshi *et.al.*,2024).During the June 2024 survey conducted by WII, a total of 1361 Gharials, including 1003 hatchlings, were recorded from Rajghat to Pachnada. Our observations include gharials of different age classes, as shown in Table 3. Additionally, as the survey was conducted during June, which is the hatching time of gharial nests, we recorded 12 gharial nesting sites as shown in Map 8.

Table 3: *Count of gharial recorded in different stretches across different age groups during the boat-based ABT survey conducted in June 2024*

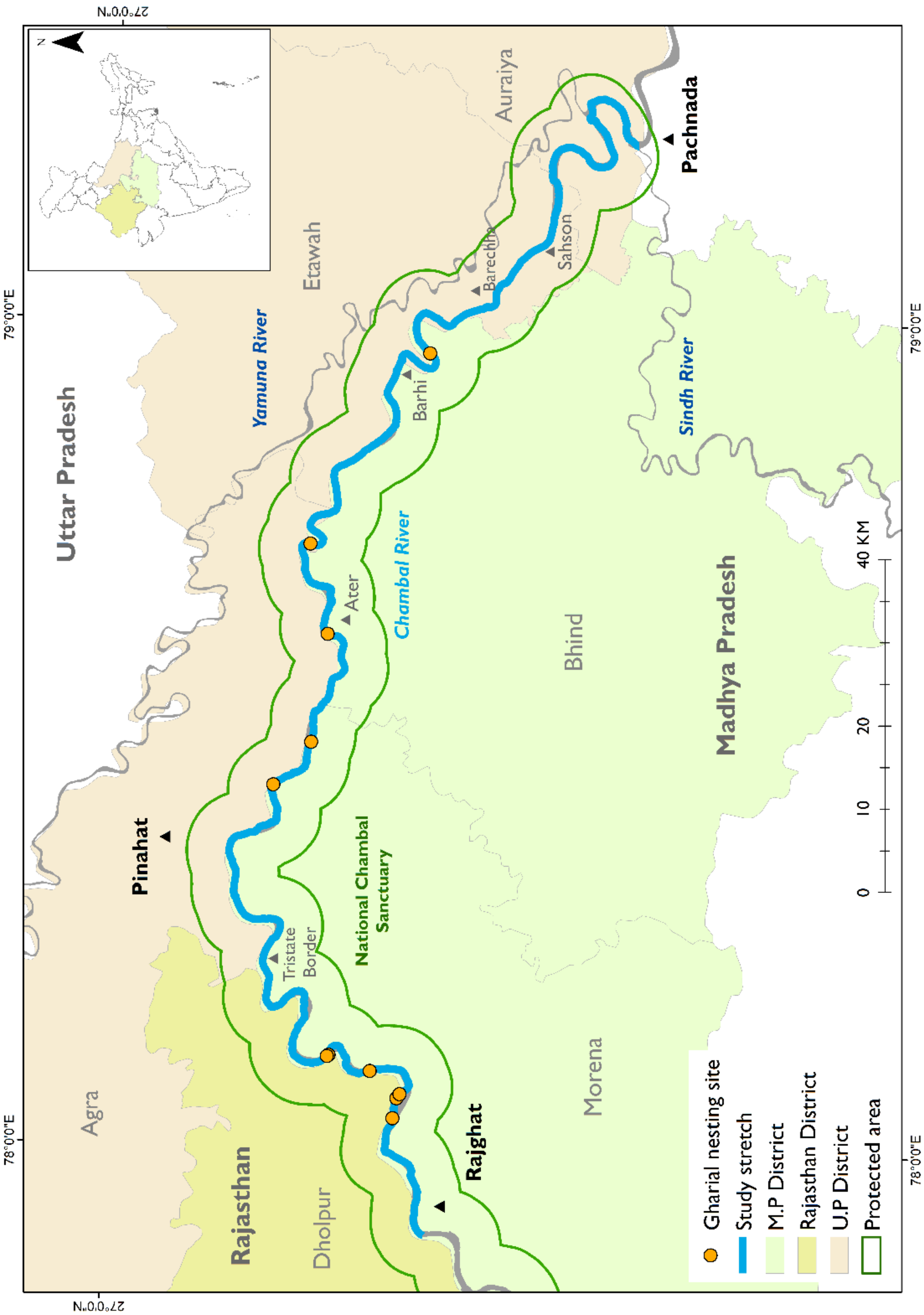
Stretch	Length (Km)	Adult		Hatchling	Subadult	Young	Total
		Male	Female				
Rajghat to Kuthiyana	26.12	4	15	153	7	33	212
Kuthiyana to Garhi Jafar	27.86	1	7	390	10	35	443
Garhi Jafar to Pinahat	25.8	-	8	-	2	21	31
Pinahat to Kenjra ghat	22.53	1	3	150	2	16	172
Kenjra ghat to Dinnpura	24.74	-	2	30	2	26	60
Dinnpura to Barhi(Udi)	31.02	1	3	30	-	33	67
Barhi(Udi) to Sahson	36.4	1	13	250	9	20	293
Sahson to Pachnada	38.58	3	9	-	17	54	83
Grand Total	233.05	11	60	1003	49	238	1361



Map 7: *Map showing sighting locations of gharial along the Chambal river, recorded during a boat-based aquatic biodiversity survey conducted in June 2024, along with depth profile of the stretch in 10 km segments*

Image 2: *Hatchlings of gharial near a nesting site in the Chambal river*

Image 3: *Sub-adult gharial basking on the sand bank in the Chambal river*



Map 8: *Map showing nest locations of gharial along the Chambal river, recorded during boat-based ABT survey*

Water Column (Depth) Utilisation by the Gharial

According to a study in the National Chambal sanctuary by Hussain (2009), Gharials (Gavialis gangeticus) exhibit specific preferences for water depth (Fig. 4), which vary by their size class, reflecting different ecological needs such as foraging and cover. Understanding these preferences is crucial for effective conservation strategies. This study has detailed depth preferences across different gharial size classes:

Juvenile gharials (<120 cm) predominantly prefer water depths of 1–3 meters and tend to avoid depths greater than 3.0 meters. This preference is linked to their feeding habits, as young gharials primarily consume small fish and seek shallow water for both foraging and cover (Hussain, 2009)..

Gharials between 120 and 180 cm show a preference for 2–3 meters. They also frequently utilise depths greater than 4.0 meters when available. This size class largely consists of captive-bred and reintroduced individuals, which sometimes display inconsistencies in selecting favourable water depths, possibly due to their tendency to move over long distances and settle in areas with less competition (Hussain, 2009),

Larger gharials (>180 cm), including sub-adults and adults, consistently prefer water depths greater than 4 meters. Specifically, sub-adult gharials prefer depths of more than 2 meters, while adults prefer depths of more than 4 meters. Deeper water provides sufficient cover for these larger individuals. The range of depth selection by gharials may also be influenced by the relative abundance of different prey sizes (Hussain, 2009).

Mugger (*Crocodylus palustris*):

The Mugger or Marsh crocodile (*Crocodylus palustris*) is a freshwater species of crocodile majorly distributed in the Indian subcontinent, though its range stretches from southern Iran, and it is one of the most adaptable crocodilian species found in India (Da Silva & Lenin, 2010). The species has become locally extinct over large parts of its range, and viable populations only occur in protected areas (Santiapillai & Silva, 2001). Currently, India and Sri Lanka retain the majority of the population. The Mugger is legally protected in India under Schedule I of the Wildlife Protection Act, 1972, and categorized as 'Vulnerable' under the IUCN Red List of Threatened Species (Choudhury & De Silva, 2013).

The Mugger is a medium-sized crocodile reaching a maximum length of up to 4-5 m, and possesses the broadest snout of any living member of the genus Crocodylus (Da Silva & Lenin, 2010). Muggers are generally gray to light brown with darker bands or spots on the body and tail, camouflaging them in murky waters and marshy habitats. This species is found in various freshwater habitats, including rivers, lakes, reservoirs, hill streams, village ponds, and man-made tanks, and it may also be found in coastal saltwater lagoons (Choudhury & De Silva, 2013). The mugger is an opportunistic carnivore, its diet includes fish, reptiles, birds, and larger mammals. As an apex predator of freshwater ecosystems, its presence is crucial for maintaining ecological balance, helping to regulate populations of other species and supporting the overall health of its habitat. Major threats include Habitat destruction, fragmentation, and transformation, mortality due to increased Fishing activities.

Previous Studies

Several studies over the past decades have documented a significant increase in the population of the Mugger crocodile (Crocodylus palustris) in the Chambal River. Early records by Whitaker and Daniel (1980) reported fewer than 20 individuals in the Chambal River and some isolated water tanks in Rajasthan. Subsequently, Rao and Sharma (1985) recorded only 9 individuals between Rajghat and Chakarnagar in the river. By 1988, Rao and Choudhury (1992) noted a rise to 38 Muggers.

This upward trend continued, with Sharma (1993) reporting 86 individuals along a 435 km stretch of the Chambal River. A year later, Sharma *et.al*. (1995b) observed 105 individuals in a 425 km segment of the river. Further surveys by Rao (1999) recorded 120 individuals in 1996, and by 2006, Taigor and Rao (2008) reported 194 Muggers in a 465 km stretch of the river. A comprehensive study by Sharma and Singh (2015) analysed population trends over a 30-year period, showing that the Mugger population in a 395 km section of the Chambal increased from just 19 individuals in

1984 to over 356 in 2014, a more than twelvefold increase. Most recently, a 2019 survey revealed a further rise in the population, with 674 individuals recorded in the Chambal River (Sharma *et.al.*, 2024).

Additionally, 16 Mugger crocodiles were also recorded in 2015 in Parvati River, an upstream tributary of Chambal River (Khandal *et al.*, 2017).

During the WII Rangewide River Dolphin Estimation survey in January 2022, 341 Muggers were recorded in 240 km stretch of Chambal River from Nagar to Pachhnada (Qureshi *et.al.*,2024).

In June 2024 survey conducted by WII, a total of 164 mugger crocodiles were recorded from Rajghat to Pachnada. Of these, 58 were identified as adults, 76 as sub-adults, and 30 as young/juvenile. The majority of muggers were observed basking along the riverbanks, while others were observed swimming or resting in river water. The highest encounter rate was observed in the Rajghat to Kuthiyana (M.P. & Rajasthan) stretch as given in Table 4. Although this number can be an underestimate of the actual population, due to less availability of basking individuals because of the survey season, which was conducted in peak summer.

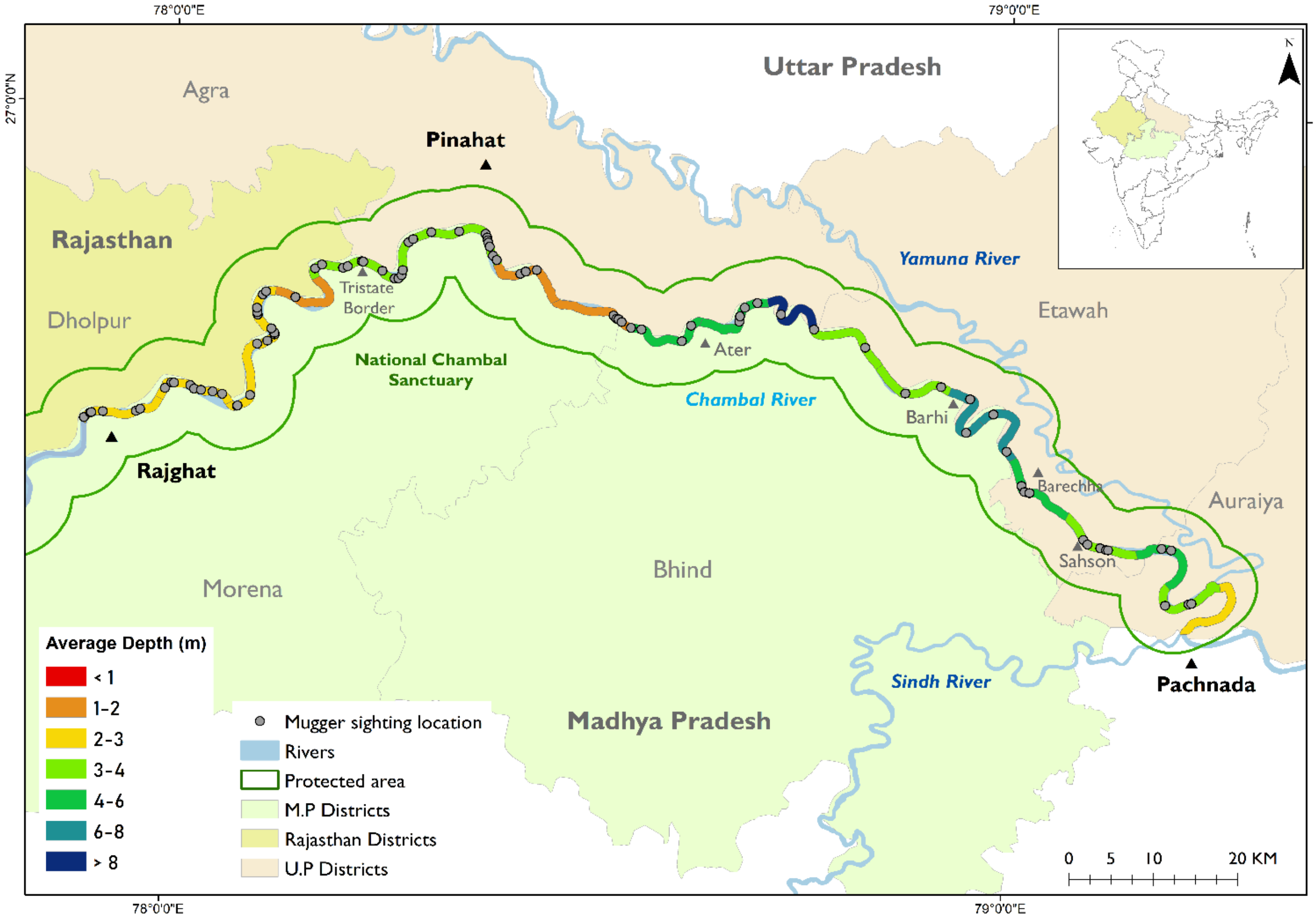
Table 4: *Table showing the Mugger count (age groups) and Encounter rate per Km in different stretches across the Chambal River, recorded during the June 2024 Survey*

River stretch	Length (Km)	Adult	Subadult	Young	Total	Encounter rate (per Km)
Rajghat to Kuthiyana	26.12	17	10	6	33	1.26
Kuthiyana to Garhi Jafar	27.86	5	15	4	24	0.86
Garhi Jafar to Pinahat	25.8	12	12	3	27	1.05
Pinahat to Kenjra ghat	22.53	5	8	4	17	0.75
Kenjra ghat to Dinnpura	24.74	7	9	6	22	0.89
Dinnpura to Barhi(Udi)	31.02	4	1	3	8	0.26
Barhi(Udi) to Sahson	36.4	4	10	1	15	0.41
Sahson to Pachnada	38.58	4	11	3	18	0.47
Grand Total	233.05	58	76	30	164	0.70

Water Column (Depth) Utilisation by the Mugger

The use of water depth by Mugger crocodiles (*Crocodylus palustris)* varies across different habitats, with studies in Nepal highlighting both significant and insignificant relationships between depth and mugger occurrence.

In a study by Nishan *et.al.*, 2023 in the Rapti River of Chitwan National Park (CNP), researchers investigated mid-river depth as one of eight habitat characteristics potentially influencing mugger occurrence. During the study, the majority of observed muggers (45.7%) were found at a mid-river depth of 1.01–1.5 meters, with the mean mid-river depth at mugger observation sites being 1.46 ± 0.35 meters. Despite its inclusion in the best-fitted models, mid-river depth was ultimately found to be an insignificant predictor for the probability of meters.



Map 9: *Map showing sighting locations of mugger crocodile along the Chambal river, recorded during boat-based ABT survey conducted in June 2024.*

However, this is statistically inappropriate for Rapti River, which is a rain-fed system with a smaller range of mid-river depths (0.3–2.1 m) and minimal fluctuations, contrasts with findings from other areas.

Conversely, a study conducted by Bhattarai *et. al.*,2022 in and around Koshi Tappu Wildlife Reserve (KTWR), where water depth was also assessed as a habitat predictor, revealed a significant association between water depth and the probability of observing muggers. In this region, the probability of a mugger sighting increases with increased water depth. The water depth in the KTWR study ranged from 1.7 to 10 meters. This finding aligns with the understanding that deeper water provides greater security for crocodilians, allowing them to immediately retreat into the water when they detect nearby threats. Additionally, areas with higher water depth may experience fewer human interventions like washing or bathing, further contributing to their suitability for muggers.

The contrasting results regarding the statistical significance of water depth in mugger habitat selection between the Rapti River and Koshi Tappu Wildlife Reserve may be attributed to differences in the hydrological characteristics of these river systems. The Rapti River is rain-fed, potentially leading to more stable, albeit shallower, depth ranges compared to a snow-fed river system like Koshi Tappu, where variations in depth might be more pronounced and thus a more influential factor.

Despite these differences, both studies indicate that muggers avoid very shallow waters, preferring depths that offer security and potentially reduce human disturbance.

Indian Skimmer

Indian Skimmer (*Rynchops albicollis*) is a tern-like bird belonging to family Laridae and order Charadriiformes. The bird is mostly black on the above with white colour on the forehead and collar, while white on the below, characterized by the specialized beak: where the lower mandible is much larger than the upper one and the beak is red or deep orange with yellow tip. The species gets its name from its feeding mechanism; as while foraging for food the bird flies low over water with its bill open and the lower mandible skimming through water. It is one of the three species of skimmers found worldwide. Indian Skimmer is listed as an Endangered species, as it has a small global population size and is suffering a continuing decline of over 20% in 11 years (two generations) (IUCN), but before 2020 and since 1994 it was listed as a vulnerable species.

The current distribution of Indian Skimmer is restricted to India and Bangladesh with very few records from Pakistan (Roberts, 1991). And very rarely recorded in Nepal (Inskipp *et al*., 2016). Currently, the Indian skimmer exclusively breeds in India with occasional breeding in Bangladesh (Kabir *et al*., 2016). Although the Indian Skimmer has been reported across different major rivers and lakes throughout the country, its distribution is majorly confined to the northern regions including Punjab, Uttar Pradesh, Madhya Pradesh, West Bengal, and up to Odisha (Rahmani, 2012). Its known breeding sites in India include National Chambal Wildlife Sanctuary (Sundar 2004, Das 2015) and Narora Ramsar site (Siddiqui *et a*l., 2007) in Uttar Pradesh, the Pong Dam Wildlife Sanctuary in Himachal Pradesh (Fernandes & Besten, 2013), the Son Gharial Wildlife Sanctuary in Madhya Pradesh (Dilawar & Sharma, 2016), Mahanadi River in Odisha, (Rajguru, 2017; Debata *et al*., 2017) and most recently discovered breeding site along the Ganga river in Prayagraj (Ankit *et.al*.,2024).

The Population decline of Indian skimmers is due to very low nesting success because of predation (especially by feral dogs and egg-collection) and hydrological changes due to dams and abstraction along breeding rivers (Debata et al., 2019; Shaikh *et al*., 2018; Shaikh & Mendis, 2019; Shaikh, 2020).

Previous Studies

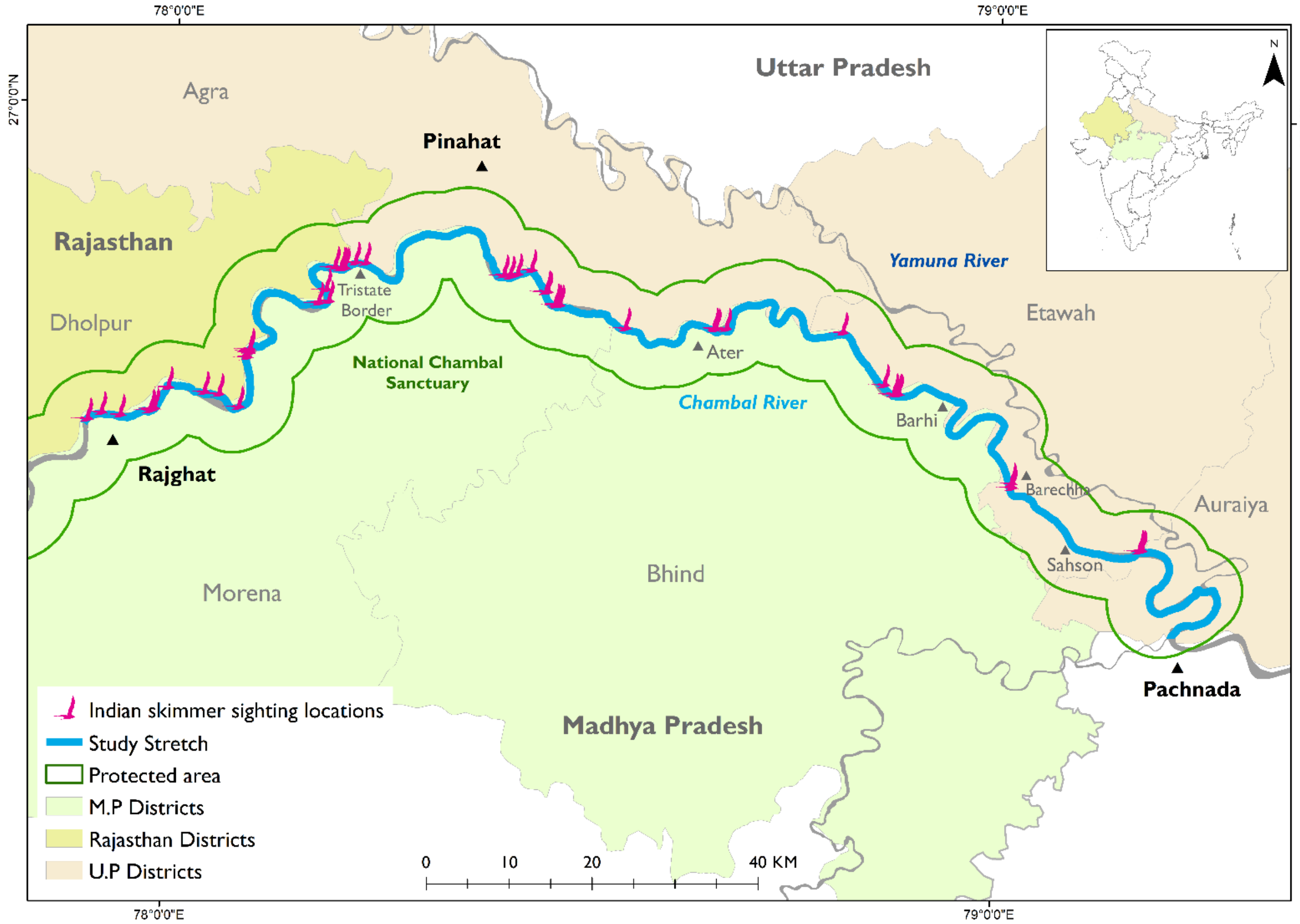
103 Indian skimmers were reported by Sharma and Singh in the ecological study conducted on Gharials in NCS in 1986. 341 of skimmers were tallied during a five-day survey conducted there by Sundar in 2004. A winter survey was conducted on the status, distribution, and breeding of the skimmers in NCS from February to July 2017. A Total of 412 skimmers were observed from 25 locations (Shaikh et al., 2018).

202 Indian Skimmers were recorded during the Rangewide River Dolphin Estimation survey conducted in January 2022 (Qureshi *et.al*.,2024).

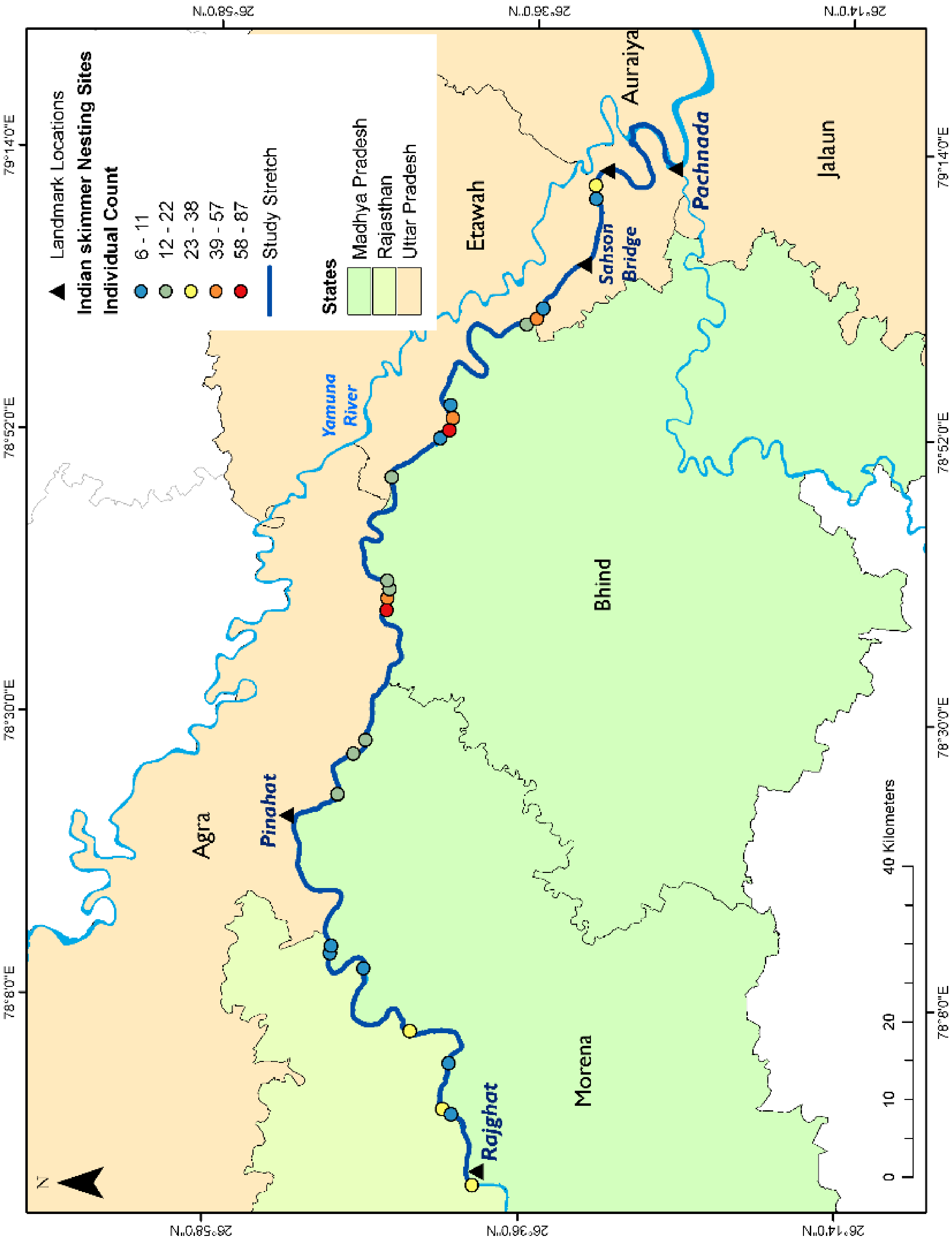
During the survey in June 2024 from Rajghat to Pachnada (233 km), a total of 888 individuals of Indian skimmers were recorded, including 654 adults, 233 juveniles, and only one hatchling (Table 5). Notably, the juveniles were full-grown, and most of them were also observed flying, indicating successful breeding, crucial for the conservation of this species. The single hatchling observed could be the result of late nesting, a behaviour that is a natural response to the loss of earlier clutches, and an important adaptive strategy to ensure reproductive success (Arnold *et. al*., 2010; Morrison *et. al,* 2019; Swift et. al., 2020; De la Cruz *et. al*., 2022).

Table 5: *Table showing the count of Indian skimmers recorded in different stretches across different age groups during the boat-based ABT survey conducted in June 2024.*

River stretch	**Length (Km)**	Adult	Juvenile	Hatchling	Total
Rajghat to Kuthiyana	26.12	91	17	0	108
Kuthiyana to Garhi Jafar	27.86	50	1	0	51
Garhi Jafar to Pinahat	25.8	77	24	0	101
Pinahat to Kenjra ghat	22.53	58	27	1	86
Kenjra ghat to Dinnpura	24.74	108	67	0	175
Dinnpura to Udi	31.02	151	87	0	238
Udi to Sahson	36.4	76	6	0	82
Sahson to Pachnada	38.58	43	4	0	47
Grand Total	233.05	654	233	1	888



Map 10: *Map showing sighting locations of Indian skimmers along the Chambal river, recorded during boat-based ABT survey conducted in June 2024*



Map 11: *Nesting locations of Indian skimmer during ABT survey conducted in June 2024*

Image 4: *A) Indian Skimmers nesting on Sand bar near Rajghat in Chambal river; B) Indian Skimmer flying over Chambal river*

Image 5: *Indian Skimmers nesting on a sandy island in the lower Chambal, while sand mining machinery operates ominously in the background. The photo shows how this rare bird is struggling to survive near human activity.*

Turtles

The Chambal River remains a critical stronghold for various freshwater species of turtles. Home to **eight species of freshwater turtles including**, *Batagur dhongoka*(Three-striped roofed turtle), *Batagur kachuga* (Red-crowned roofed turtle), *Chitra indica* (Indian narrow-headed softshell turtle), *Hardella thurjii* (Crowned river turtle) , *Lissemys punctata* (Indian flapshell turtle), *Nilssonia gangetica* (Indian softshell turtle) , *Nilssonia hurum* (Indian peacock softshell turtle), *Pangshura tentoria* (Indian tent turtle) (Rao,1991; Taigor & Rao, 2010; Nair & Krishna, 2013).

Among these, the Red-crowned Roofed Turtle (*Batagur kachuga*) and the Three-striped Roofed Turtle (*Batagur dhongoka*) are of particular conservation concern, both listed as critically endangered. The Chambal sustains the largest remaining known wild populations of both species (Rhodin *et al*., 2011).

Table 6: *List of Turtles of Chambal river*

Species	Scientific Name	IUCN Status	Population trends
Red-crowned Roofed Turtle	*Batagur kachuga*	Critically Endangered	<400 adult females globally
Three-striped Roofed Turtle	*Batagur dhongoka*	Critically Endangered	Declining; exact numbers unknown
Indian Narrow-headed Softshell	*Chitra indica*	Endangered	Not quantified
Indian Softshell Turtle	*Nilssonia gangetica*	Endangered	Widespread but declining
Indian peacock softshell turtle	*Nilssonia hurum*	Endangered	Decreasing
Indian tent turtle	*Pangshura tentoria*	Least Concern	Decreasing
Indian Flap shell turtle	*Lissemys punctata*	Vulnerable	Decreasing
Crowned river turtle	*Hardella thurjii*	Endangered	Decreasing

Indian Softshell turtle

Indian Softshell turtle (*Nilssonia gangetica*) is a freshwater turtle characterized by a soft, flat, and leathery carapace that is olive green to dark brown. Unlike hard-shell turtles, they lack scutes (hard keratinous plates). The turtle's long, flexible neck and tubular nostrils allow it to breathe while submerged in water. The species exhibits sexual dimorphism, where females are larger than males. Adult males can grow up to 70-90 cm in carapace length, while females grow even bigger (Sarkar *et.al*., 2019)

They are distributed throughout the northern plains of the Indian Subcontinent, inhabiting the Indus, Ganga, Narmada Mahanadi, and Brahmaputra river basins, as well as most of their tributaries and intervening drainages in Bangladesh, India, Nepal, Pakistan, and Afghanistan (Schneider & Djalal, 1970; Das 1995; Iverson, 1992; Praschag & Gemel, 2002).

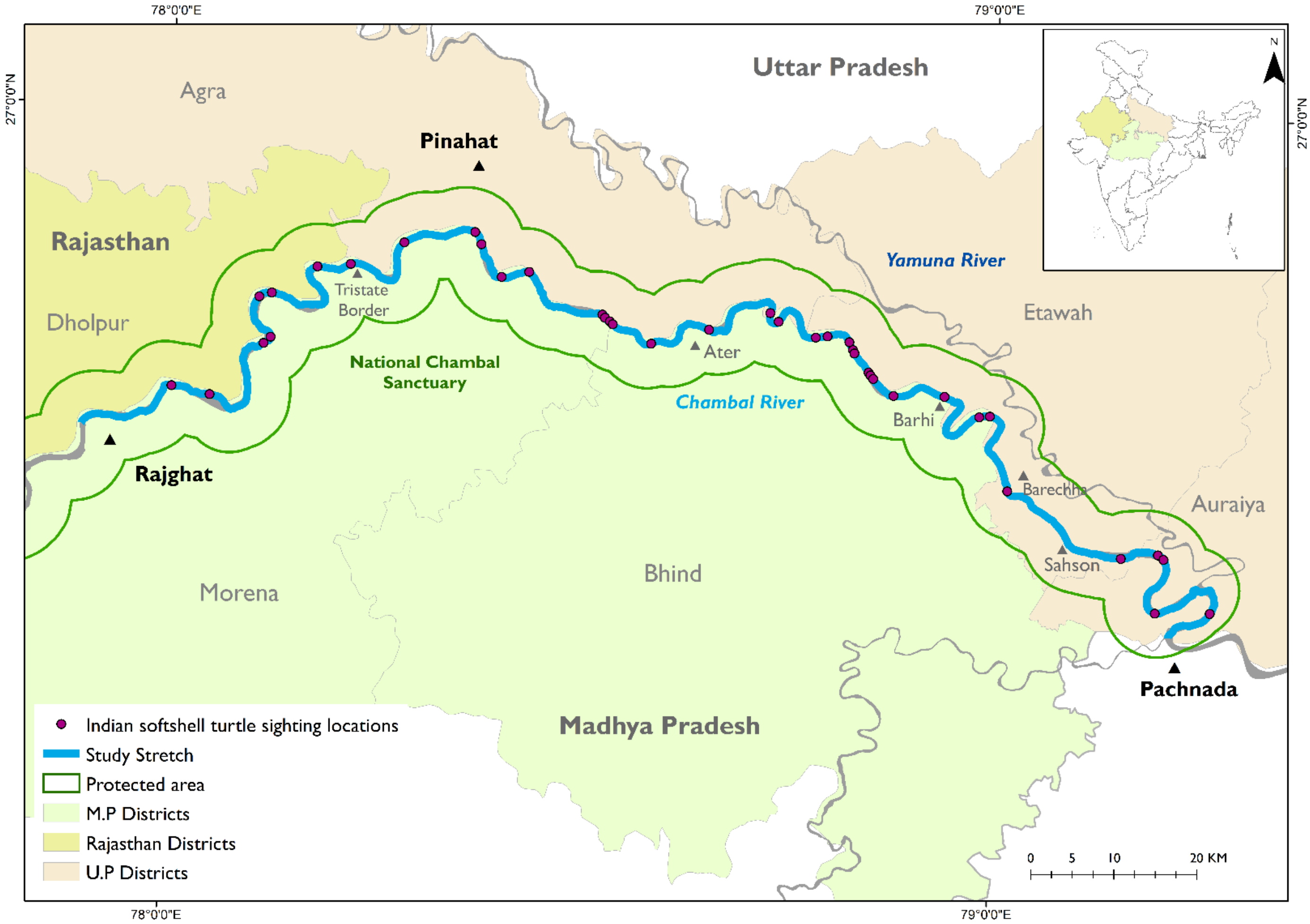
The Indian softshell turtle is an omnivore with a broad diet that includes fish, aquatic vegetation, insects, mollusks, and carrion. Hence, this species plays an essential ecological role as a predator and a scavenger. It is listed under Schedule I of the Wildlife (Protection) Act, 1972, and is classified as Endangered in the IUCN Red List.

During the WII June 2024 survey, a total of 48 Indian Softshell turtles were recorded, mostly basking on islands or riverbanks, and a few were observed while surfacing in river water. The highest number of Indian Softshell turtle(n=13) was observed in the Dinnpura to Udi stretch (31.02 Km) with an encounter rate of 0.42/km (Table 7).

Table 7:*Table showing the count of Indian softshell turtles in different stretches of study area across the Chambal river during June 2024 ABT Survey*

River Stretch	Length (Km)	Count	Encounter Rate
Rajghat to Kuthiyana	26.12	3	0.11
Kuthiyana to Garhi Jafar	27.86	5	0.18
Garhi Jafar to Pinahat	25.8	3	0.12
Pinahat to Kenjra ghat	22.53	6	0.27
Kenjra ghat to Dinnpura	24.74	8	0.32
Dinnpura to Udi	31.02	13	0.42
Udi to Sahson	36.4	4	0.11
Sahson to Pachnada	38.58	6	0.16
Grand Total	233.05	48	0.21

Image 6: *Indian softshell turtle basking on a river island in the Chambal River*



Map 12: *Map showing sighting locations of Indian softshell turtle along the Chambal river, recorded during boat-based ABT survey conducted in June 2024*

Water Column (Depth) Utilisation by the Turtles

India currently lacks dedicated studies specifically focused on the depth preferences of its freshwater turtle species, leaving a critical void in ecological understanding. Although detailed research is limited, field observations indicate that freshwater turtles inhabiting Indian rivers such as the Ganga and Chambal exhibit distinct depth preferences, with large softshell species like *Nilssonia gangetica* and *Chitra indica* relying on deep mid-channel pools (typically 3–6 meters), while hard-shelled turtles like *Pangshura tecta* and *Batagur kachuga* utilise mid-depth channels (2–5 meters) and adjacent shallow sandbars for nesting (WII, 2018; Tripathi & Lang, 2017).

From an ecological perspective, depth likely plays a critical role in shaping the behaviour and habitat use of freshwater turtles in Indian rivers, influencing their thermoregulation, predator avoidance, foraging efficiency, and reproductive behaviours. Deep thalweg pools in the dry season also work as refugia for various species of turtles.

CHAMBAL RIVER WATER QUALITY

The Chambal River is widely recognised as one of the cleanest major rivers in India, a distinction supported by decades of scientific monitoring and comparative water quality assessments (Gupta *et.al.*, 2022a). Stretching over 965 km from its origin in the Vindhya Range to its confluence with the Yamuna River near Etawah, the Chambal traverses largely rural and protected landscapes, including the National Chambal Sanctuary, which helps shield it from the intense urban and industrial pressures that afflict many other Indian rivers (Saksena *et.al.*, 2008).

Scientific studies confirm that the Chambal's water quality parameters, such as dissolved oxygen, turbidity, and total dissolved solids (TDS), are consistently within or better than national and international standards for river health (Saksena *et.al.*, 2008). However, this pristine status is compromised after the Chambal river merges with the Yamuna river at Chakarpura, Etawah, Uttar Pradesh. The Yamuna, particularly in its downstream stretch from Delhi to the Chambal confluence, is among the most polluted rivers in India (CPCB, 2006; Sharma & Kansal, 2011; Singh *et.al.*, 2024). This segment is characterised by extremely high organic loads, nutrient enrichment, severe oxygen depletion, and high bacteriological contamination, primarily due to untreated sewage and industrial effluents from the Delhi NCR region. Central Pollution Control Board data and multiple independent studies highlight that the Yamuna's water quality does not meet even basic standards for bathing or aquatic life in this stretch (Naithani & Pande, 2015; Singh *et.al.*, 2024).

As a result, the Chambal's water quality shows marked deterioration at and after the confluence with the Yamuna. There is a sharp increase in TDS, conductivity, and turbidity, along with a decline in dissolved oxygen and overall ecological health. This transition is so pronounced that it is frequently cited in national water quality reports as a case of a clean river being impacted by the inflow of a highly polluted tributary. The dilution effect temporarily improves Yamuna's water quality, but at the expense of the Chambal's previously pristine status(Hussain & Gupta, n.d.).

This report provides a comprehensive assessment of the Chambal River's water quality based on field data collected with the help of YSI multiparameter probe and benchmarks the results against Bureau of Indian Standards (BIS) and World Health Organisation (WHO) guidelines for riverine ecosystems. The analysis covers key water quality parameters, their ecological roles, observed values, compliance with standards, and implications for aquatic biodiversity.

Table 8: *Comparison of Chambal river water quality with BIS/WHO Standards.*

Parameter	**Chambal Mean (Range)**	**BIS/WHO Standard**	**Compliance/Deviations**
DO (mg/L)	10.47 (5.88–12.07)	≥5.0	Compliant
pH	8.34 (7.85–8.64)	6.5–8.5	Mostly compliant; rare exceedance
Temp (°C)	17.04 (15.17–18.89)	<25 (preferred)	Compliant
Conductivity	708 (365–1271)	<1500	Compliant
Turbidity (NTU)	5.82 (2.82–12.39)	≤5 (BIS); ≤5 (WHO)	Mostly compliant; rare exceedance
TDS (mg/L)	548.8 (281–1028)	≤500 (BIS); <300 (WHO)	Often exceeds BIS/WHO

Table 9: *Comparative Table: Chambal Upstream vs. Confluence.*

Parameter	Chambal Upstream (Mean)	At Confluence (Pachnada)	Change/Implication
Dissolved Oxygen	>10 mg/L	~6 mg/L or lower	Sharp decline, risk of hypoxia
TDS (mg/L)	500–600	1000+	Doubling indicates pollution input
Conductivity (µS/cm)	600–700	1200+	Doubling reflects ionic/ organic influx
Salinity (psu)	0.4	0.7–0.8	Approach the upper freshwater threshold
Turbidity (FNU)	4–6	10–12	Major increase, more s uspended solids
pH	8.3–8.4	7.8–8.0	More variable, sometimes suboptimal

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is a critical parameter for assessing the health and sustainability of aquatic ecosystems. It refers to the amount of oxygen that is present in water in a dissolved form, which is essential for the survival of most aquatic organisms. Fish, macroinvertebrates, and aerobic microorganisms all require adequate DO levels for respiration and metabolic processes. High DO concentrations are indicative of a well-oxygenated and healthy river, supporting a diverse and productive biological community (Wetzel, 2001).

According to the Bureau of Indian Standards (BIS), DO levels in river water should be at least 5.0 mg/L to support aquatic life (BIS IS 2296:1982), and the World Health Organisation (WHO) also recommends a minimum DO concentration of 5.0 mg/L for the protection of aquatic ecosystems. In the Chambal River, observed DO values are notably high, with a mean of 10.47 mg/L and a range from 5.88 to 12.07 mg/L. These results indicate that the Chambal maintains excellent oxygenation throughout most of its course, with DO levels consistently well above the minimum standards necessary for healthy aquatic life. Even at the lower end of the observed range, DO remains at or just above the critical threshold, suggesting only localised or short-term stress. This robust oxygen regime is a primary factor supporting the Chambal's rich biodiversity, including endangered species such as the gharial and river dolphin (Gupta *et.al*., 2022b; Rao, 2008). In contrast, major Indian rivers like the Ganga often experience DO levels below 5 mg/L in urban stretches such as Kanpur and Varanasi due to heavy organic pollution, while the Yamuna in the Delhi segment frequently records DO below 2 mg/L, indicating severe hypoxia. The Brahmaputra, by comparison, generally maintains DO between 6.5 and 8.5 mg/L in its cleaner stretches, levels similar to those found in the healthiest parts of the Chambal (Gupta *et.al*., 2022).

pH

The pH of river water is a fundamental parameter that reflects the balance between acidic and basic substances dissolved in the water. It plays a crucial ecological role by regulating the solubility and bioavailability of nutrients and toxic substances, such as heavy metals and ammonia. For most aquatic organisms, a pH range of 6.5 to 8.5 is considered optimal, as extreme deviations can disrupt physiological processes including respiration, reproduction, and growth. Outside this range, the toxicity of certain chemicals, like ammonia and heavy metals, increases, potentially leading to stress or mortality in sensitive species (Boyd, 2020; Wetzel, 2001).

According to the BIS and the WHO, the desirable pH range for river water is 6.5 to 8.5. This range supports both aquatic life and suitability for most human uses. In the Chambal River, the observed pH values are consistently within or very close to this optimal range, with a mean of 8.34 and a range from 7.85 to 8.64. These values indicate a slightly alkaline environment, which is typical for rivers flowing through regions rich in carbonate rocks and with minimal industrial pollution. The stable and favourable pH conditions in the Chambal contribute to its ability to support a diverse and healthy aquatic ecosystem, including sensitive and endangered species.

In comparison, other major Indian rivers such as the Ganga and Yamuna often exhibit greater fluctuations in pH, especially in urban and industrial zones, where values may occasionally fall outside the recommended range due to pollution (CPCB, 2022).

Conductivity (Cond, µS/cm)

Electrical conductivity (EC) is a key indicator of water quality that measures the ability of water to conduct an electrical current, which is directly related to the concentration of dissolved ions such as sodium, potassium, calcium, magnesium, chloride, sulfate, and bicarbonate (Boyd, 2020). Ecologically, conductivity provides a rapid assessment of the total ionic content of river water and can be used as a proxy for salinity and overall mineralization. While moderate conductivity is natural and even necessary for aquatic life, excessively high values can signal pollution from anthropogenic sources or natural salinization, both of which can negatively affect sensitive aquatic organisms, alter community structure, and reduce biodiversity (Boyd, 2020; Chapman, 1992).

The BIS (BIS IS:2296) recommends that EC in riverine waters should ideally remain below 1000 µS/cm for the propagation of fish and wildlife. Values below this threshold are generally considered suitable for healthy aquatic ecosystems, while values above 1000 µS/cm may indicate anthropogenic impacts such as pollution from urban, industrial, or agricultural sources, or natural salinisation (Chapman, 1992).

In the Chambal River, the observed mean EC is 708 µS/cm, with a range from 365 to 1271 µS/cm. For most of its course, the Chambal's EC values are well within the BIS recommended limit, reflecting the river's passage through regions of mixed geology, limited urban and industrial development, and relatively low agricultural runoff compared to more intensively farmed or urbanized catchments. This suggests that, overall, the river is largely free from significant salinization or ionic pollution.

However, it is important to note that in the lower stretch of the Chambal, after the confluence with the polluted Yamuna river, EC values exceed the 1000 µS/cm threshold at several points. This increase is directly linked to the influx of highly contaminated water from the Yamuna, which carries elevated levels of dissolved ions and pollutants from urban and industrial discharges, particularly those originating in the Delhi NCR region. The rise in EC in these downstream sections of the Chambal signals localized degradation of water quality and highlights the impact of polluted tributaries on even relatively pristine river systems.

In contrast, rivers such as the Yamuna and Ganga often show much higher conductivity values, especially downstream of major urban and industrial centres, where values may exceed 2000 µS/cm due to heavy pollution loads (CPCB, 2022; Sharma & Kansal, 2011). The Brahmaputra, with its pristine upper stretches, typically exhibits lower conductivity, reflecting minimal anthropogenic influence (Barbulescu *et.al.*, 2021).

Turbidity (NTU)

Turbidity is a measure of the cloudiness or haziness of water, caused by the presence of suspended particles such as silt, clay, organic matter, plankton, and other microscopic organisms. Ecologically, turbidity is a critical parameter because high turbidity levels can significantly reduce light penetration in the water column, thereby limiting the photosynthetic activity of aquatic plants and phytoplankton (Davies-Colley & Smith, 2001). Reduced photosynthesis can lower oxygen production and disrupt the base of the aquatic food web. Elevated turbidity can also physically harm aquatic life: it may clog the gills of fish and macroinvertebrates, impairing their ability to respire, and can smother fish eggs and benthic organisms by settling on the riverbed (Rodrigues *et.al.*, 2023). Prolonged high turbidity is associated with declines in fish populations, especially for species that require clear water for spawning or feeding.

The WHO recommends a maximum of 5 NTU for drinking water to ensure safety and palatability (WHO, 2017). While these standards are oriented toward human use, they also serve as useful benchmarks for ecological health, as excessive turbidity can be detrimental to aquatic life.

In the Chambal River, observed turbidity values measured as Nephelometric Turbidity Unit, NTU, show a mean of 5.82 NTU and a range from 2.82 to 12.39 NTU. These values indicate that while the river is generally less turbid than many other major Indian rivers, it frequently exceeds the recommended standards, especially during periods of high flow or after rainfall events. The elevated turbidity in some stretches may be attributed to localized sand mining, erosion, runoff, or the pollution load carry by Yamuna river.

By comparison, rivers such as the Yamuna and Ganga often exhibit much higher turbidity levels, particularly in urban and agricultural regions, sometimes exceeding 50–100 NTU during the monsoon (CPCB, 2021; Sharma *et.al.*, 2013). The Brahmaputra also experiences high turbidity during flood seasons due to intense catchment erosion or landslides in the upstream of Siang river (Sivasankar *et.al.*, 2020).

Total Dissolved Solids (TDS, mg/L)

TDS is a measure of the combined content of all inorganic and organic substances dissolved in water, including minerals, salts, and small amounts of organic matter (WQA, 2013). TDS is a crucial indicator of water quality because it directly affects the health and functioning of aquatic ecosystems. High TDS levels can disrupt the osmoregulation processes in aquatic organisms, particularly fish and amphibians, making it difficult for them to maintain the balance of salts and water in their bodies (Boyd, 2020). Elevated TDS can also reduce water clarity, alter taste, and affect the suitability of water for drinking, irrigation, and industrial uses. In river systems, persistently high TDS may signal the presence of pollution from anthropogenic sources or excessive mineral leaching from the catchment area.

The BIS IS:10500 specifies an acceptable TDS limit of ≤500 mg/L for drinking water, with a permissible limit of up to 2000 mg/L in the absence of alternate sources. For riverine and aquatic ecosystem health, lower TDS is generally preferred. The WHO recommends an ideal TDS of <300 mg/L for drinking water, with a permissible limit up to 1000 mg/L. While these standards are primarily for human consumption, they are also indicative of water quality suitable for aquatic life.

In the Chambal River, the observed mean TDS is 548.8 mg/L, with a range from 281 to 1028 mg/L. These values indicate that, for much of its course, the Chambal's TDS is slightly above the BIS acceptable limit and the WHO ideal value, but remains well below the maximum permissible limits. The higher TDS values are typically observed in the lower stretches of the river, particularly after the confluence with the polluted Yamuna River, where the influx of dissolved pollutants and salts is more pronounced. For the majority of the river, TDS levels suggest relatively low pollution and a healthy aquatic environment, though localized increases may warrant attention, especially for sensitive species.

In comparison, major Indian rivers such as the Yamuna and Ganga often exhibit much higher TDS levels in urban and industrial regions, frequently exceeding 1000 mg/L due to substantial pollution loads (Sharma & Kansal, 2011).

Salinity (PSU)

Salinity refers to the concentration of dissolved salts in water, typically measured in practical salinity units (psu). It is a fundamental parameter influencing the composition, diversity, and functioning of freshwater ecosystems. Most freshwater species are adapted to low salinity conditions, and even moderate increases can disrupt physiological processes such as osmoregulation, leading to stress, reduced growth, impaired reproduction, or mortality (Dugan & Arnott, 2023). Elevated salinity can also alter the structure of aquatic communities, favouring salt-tolerant species over sensitive ones, and may reduce overall biodiversity. In river systems, high salinity can affect not only aquatic life but also the suitability of water for irrigation, drinking, and industrial uses.

There is no strict regulatory limit for salinity in riverine waters, but freshwater ecosystems are generally characterised by salinity levels below 0.5 psu. Levels above this threshold may indicate the onset of salinisation and can be harmful to most freshwater organisms (Boyd, 2020; Dugan & Arnott, 2023).

In the Chambal River, the observed mean salinity is 0.41 psu, with a range from 0.21 to 0.79 psu. For most of its course, the Chambal maintains salinity levels well within the typical freshwater range, supporting a diverse array of aquatic life and indicating minimal salinisation. However, values approaching or exceeding 0.5 psu, particularly in the lower stretches of the river after the confluence with the polluted Yamuna, may signal localised impacts from anthropogenic sources such as urban runoff, sewage, or agricultural return flows.

The Chambal River generally supports good water quality for aquatic life, with strong oxygenation and moderate temperatures. However, persistent turbidity and TDS issues, especially downstream and near confluences, pose risks to biodiversity and river health. Targeted management and continuous monitoring are essential to safeguard this vital river ecosystem.

TRENDS IN FLOW OF CHAMBAL RIVER (1990-2022)

Central Water Commission shared ten daily series of data from 1990 to 2022, available at 5 sites (see Annexure 3) of this report. Based on this information, it was observed that the monsoon water flow does not have a significant change, but has experienced severe fluctuations (Figure 5).

In contrast, the summer water availability has shown a significant declining trend in recent years (Figure 6). This persistent reduction in summer flows is a cause for concern, as it coincides with the period of highest ecological vulnerability. Low flows during summer months can lead to elevated water temperatures, reduced dissolved oxygen levels, and restricted habitat availability for aquatic and riparian species (Rolls *et.al.*, 2012; Null *et.al.*, 2017; Stappert *et.al.*, 2025; Brooks *et.al.*,2025). If the trend continues, it may result in long-term degradation of the river's ecological integrity and diminished ecosystem services for dependent communities. This reduction in dry-season flows can be primarily attributed to intensified water extraction for agriculture and urban use, as well as flow regulation by dams and barrages that retain monsoon flows and reduce downstream releases during summer.

Hussain and Choudhury (1992) and Hussain *et.al.* (2011) reported similar observations, noting that the construction of four multipurpose dams on the Chambal River has significantly reduced (almost to nil) downstream water flow below the Kota Barrage, especially during the lean seasons. As a result, the gharial habitat between Keshoraipatan and the Chambal-Parvati confluence has declined, and the dolphin habitat between the confluence and Rahu Ka Gaon has also decreased. Additionally, the reduction in water flow has caused habitat fragmentation and has altered the composition and structure of riverine fish communities.

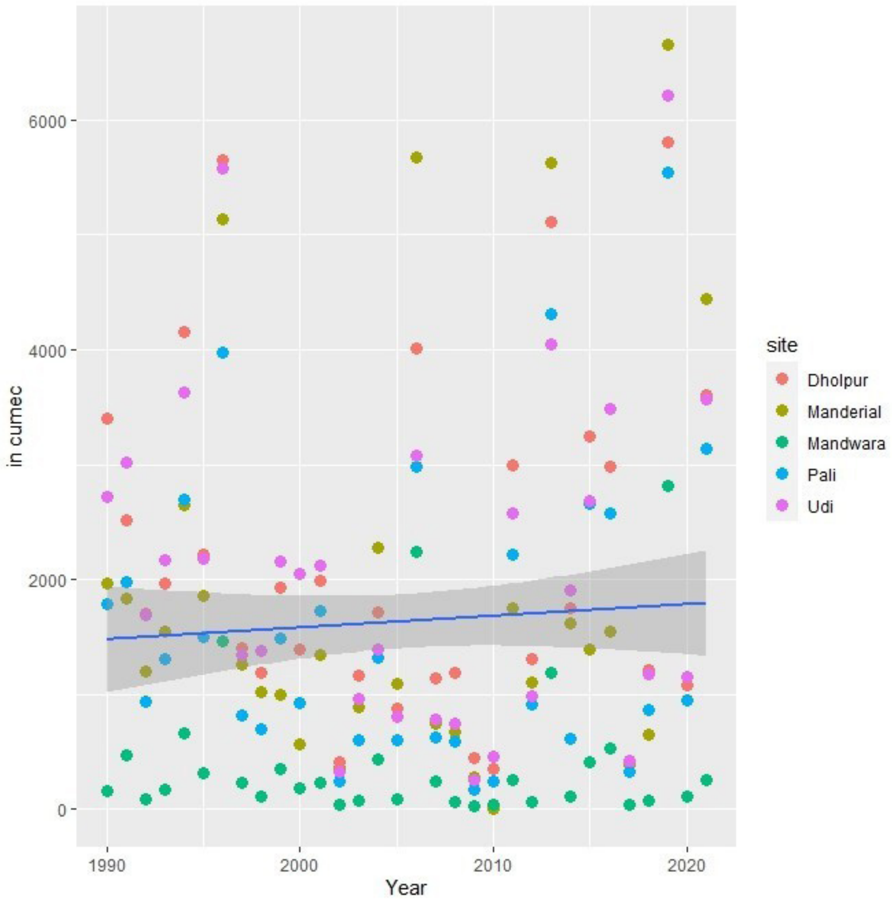


Figure 5: *Trend of water flow in Chambal River (aggregate of ten daily series data) from 1990 – 2021, suggesting no significant change (p = 0.428). Source: CWC*

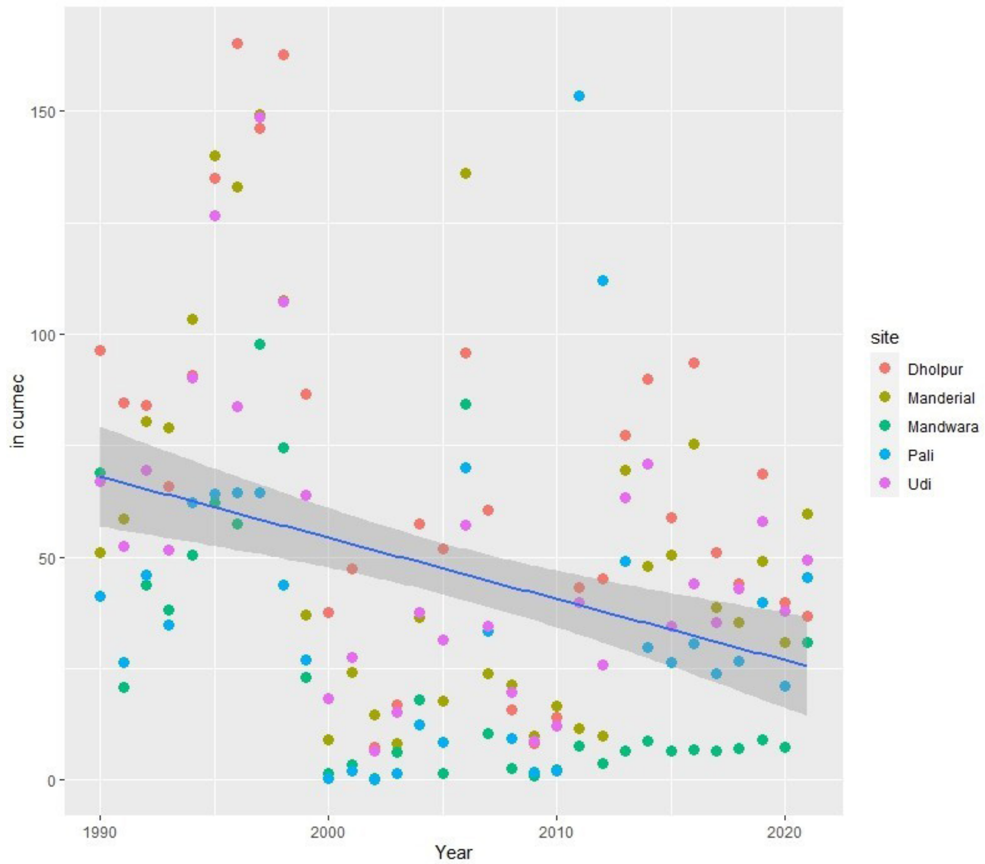


Figure 6: *Trend of water flow in Chambak River (aggregate of ten daily series data) from 1990 – 2021 suggests significant decline (p = 0.001) Source: CWC.*

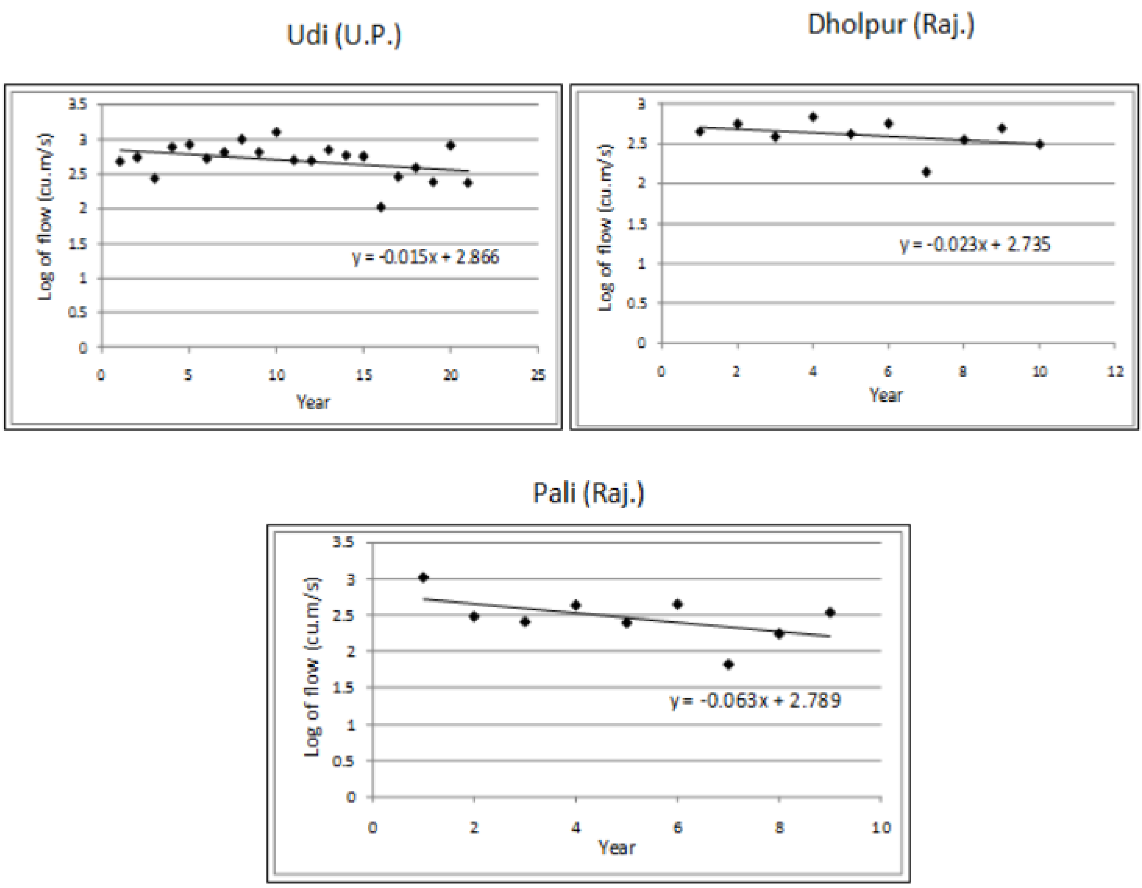


Figure 7: *State of flow in Chambal River from 1996- 2004 in three stations (two in Rajasthan, Pali and Dholpur and one in Uttar Pradesh, Udi) have shown a decreasing trend (6.3% in Pali, 2.3% in Dholpur and 1.5% at Udi). (Source: Hussain. et. al., 2011)*

We also employed a hydraulic modelling approach using the Hydrologic Engineering Centre's River Analysis System (HEC-RAS, version 6.6) developed by the U.S. Army Corps of Engineers, to evaluate monthly flow characteristics across five selected river stations. The objective was to simulate and analyse flow patterns for twelve months using decadal average flow data.

The geometric data for the river reach were prepared using cross-sectional profiles provided by CWC. Channel and overbank roughness coefficients (Manning's n) were assigned based on standard values for natural streams, with a uniform value of 0.030 for Channel and 0.25 for both left and right overbanks applied across all sections to represent moderate vegetation and channel irregularity. And reach lengths were delineated through geospatial analysis using high-resolution satellite imagery and digital elevation models (DEMs). These inputs were integrated and processed within HEC-RAS to develop a detailed geometry file representing the river's physical characteristics.

Discharge data provided by CWC for GD stations (Madwara, Pali, Manderial, Dholpur and Udi)along the river was added. For each station, monthly mean flow values were computed based on data spanning ten years (2012–2022). The monthly mean flows were calculated by averaging the observed flows for each calendar month across all years. This decadal averaging approach minimises interannual variability and captures the central tendency of natural flow regimes, as recommended in environmental flow assessments (Tharme, 2003).

The resultant dataset consisted of 60 flow scenarios (12 months × 5 stations), representing the average monthly discharge conditions. These flows were input as steady flow boundary conditions into the HEC-RAS model to perform one-dimensional steady-state hydraulic simulations.

Each of the 60 flow scenarios was modelled separately. For each simulation, Boundary conditions were specified using the computed average monthly flow for the upstream station, the downstream boundary condition was set using a normal depth, with a slope value of 0.000211. This slope was derived from the elevation difference at the deepest points of the cross-sections between the upstream-most (5^{th}) and downstream-most (0^{th}) stations, divided by the distance between them. Steady flow analysis was selected for the simulation type, as the focus was on evaluating hydraulic parameters under average conditions rather than transient events.

The outputs were visualised using HEC-RAS's built-in plotting tools and exported. For each station, 12 monthly plots were generated, showing key hydraulic characteristics, thereby yielding a total of 60 plots across all sites (Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12). These plots facilitate the interpretation of seasonal variability in hydraulic conditions, essential for identifying ecologically meaningful low-flow periods and high-flow events.

MANDWARA

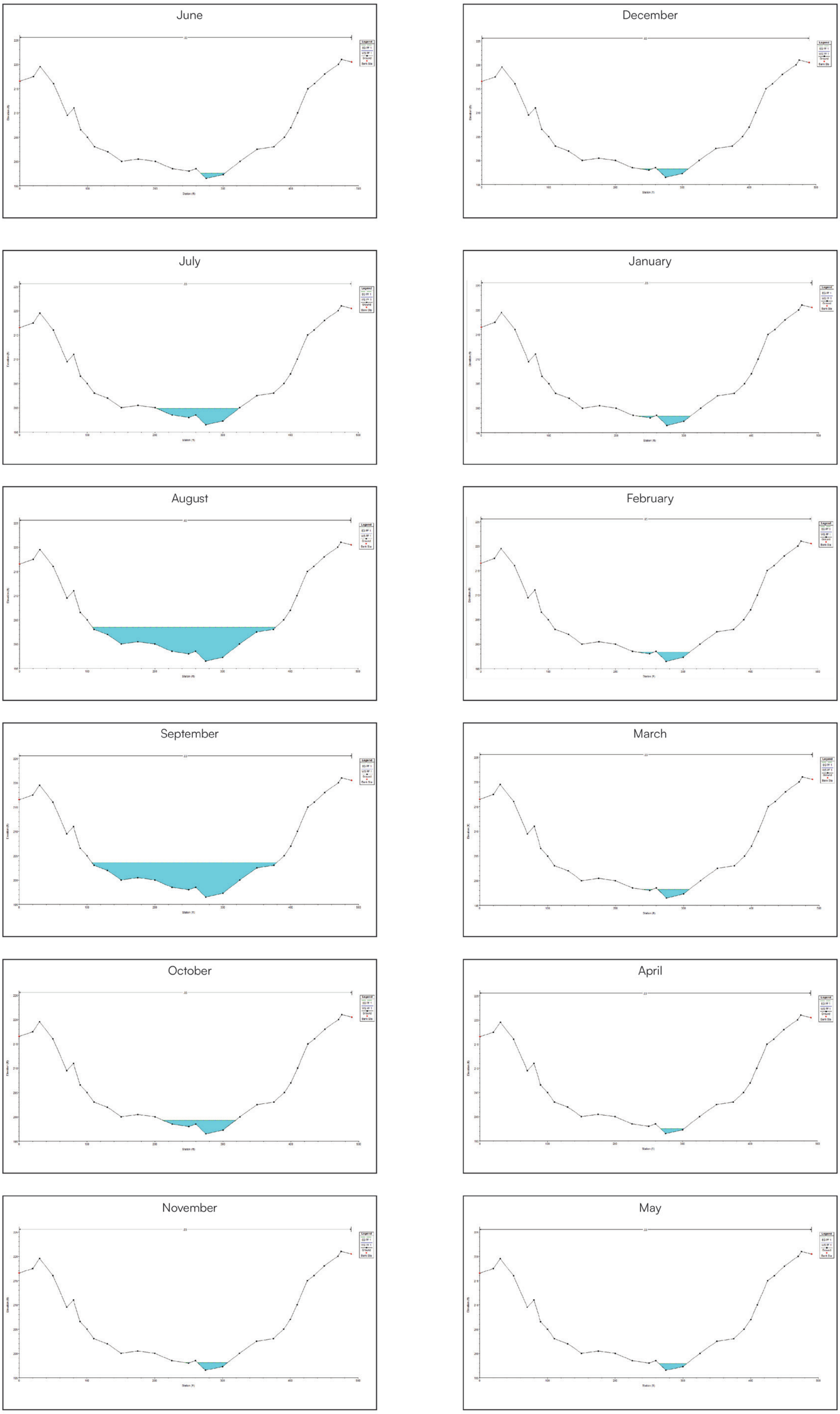


Figure 8: *Hydrological Simulation of Monthly average flow pattern at Mandwara GD site using HEC-RAS model*

PALI

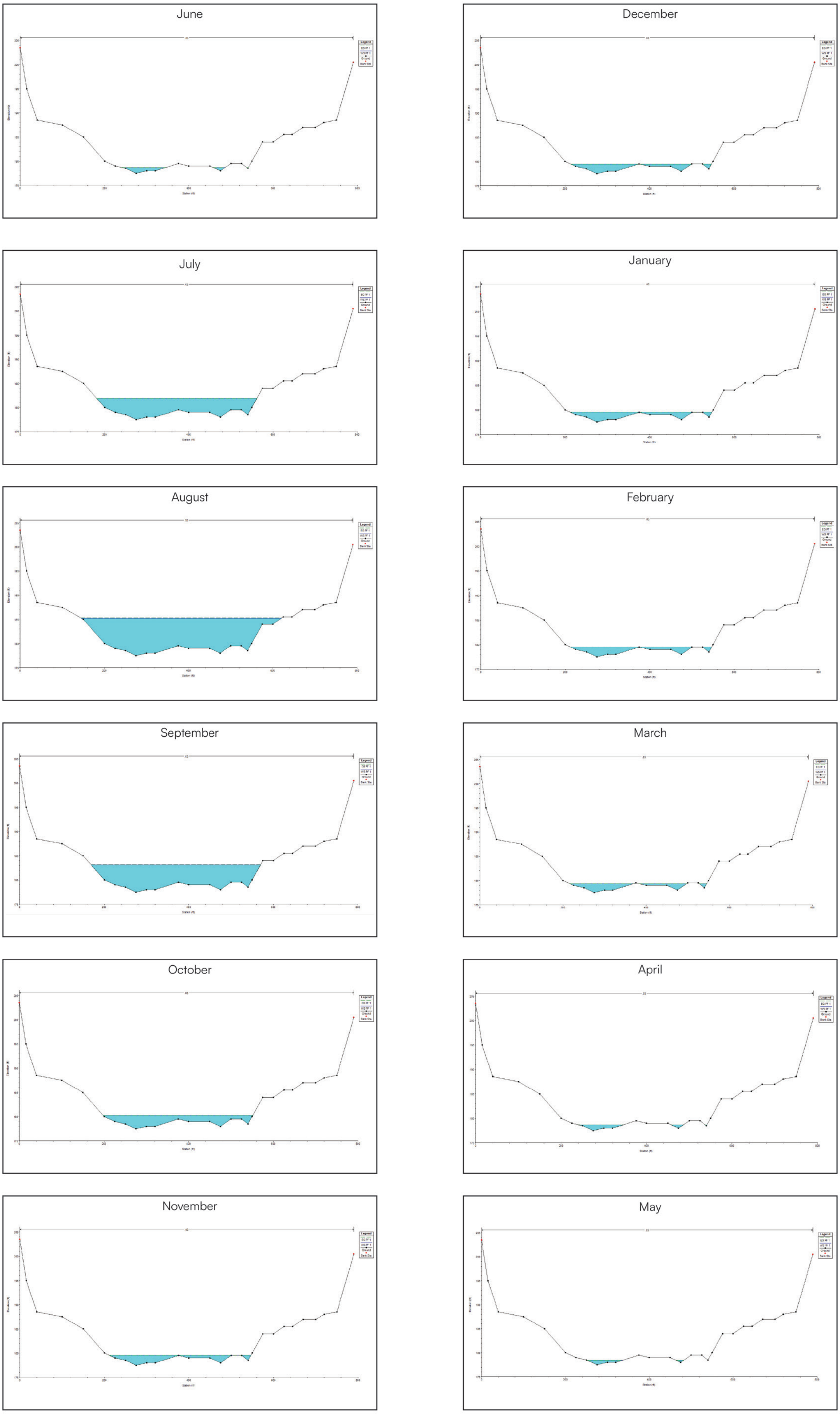


Figure 9: *Hydrological Simulation of Monthly average flow pattern at Pali GD site using HEC-RAS model*

MANDERIAL

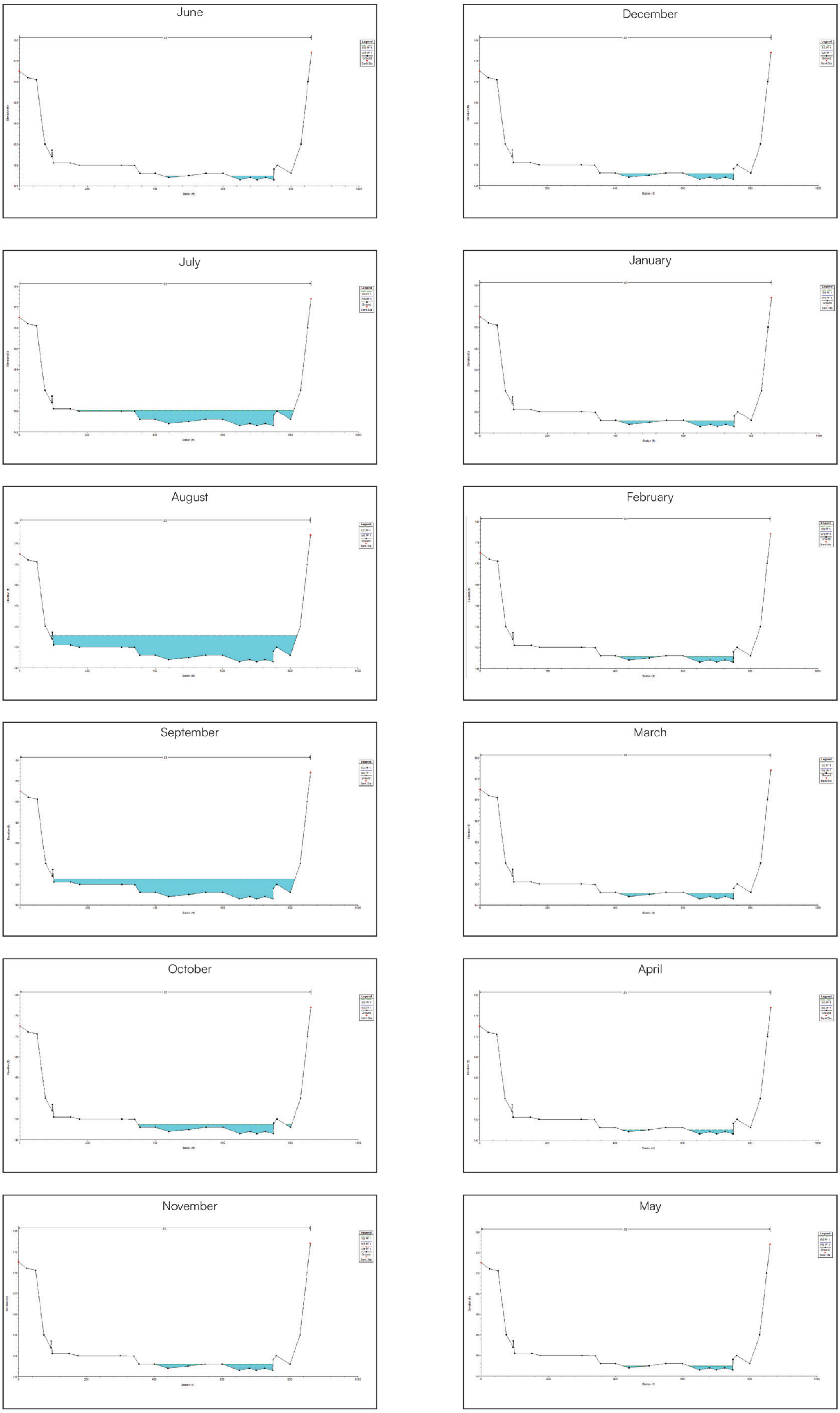


Figure 10: ***H****ydrological Simulation of Monthly average flow pattern at Manderial GD site using HEC-RAS model*

DHOLPUR

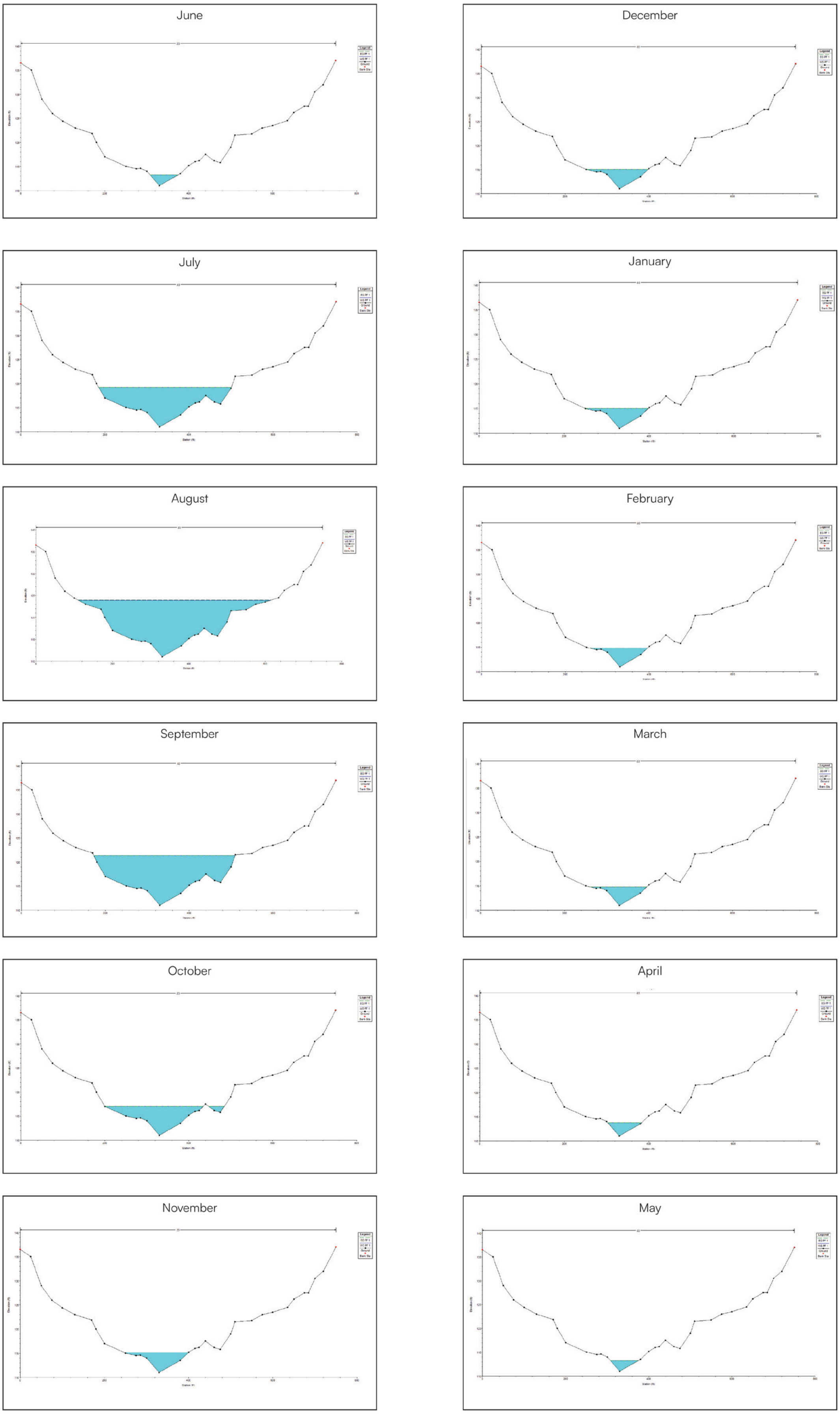


***Figure 10: H**ydrological Simulation of Monthly average flow pattern at Dholpur GD site using HEC-RAS model*

UDI

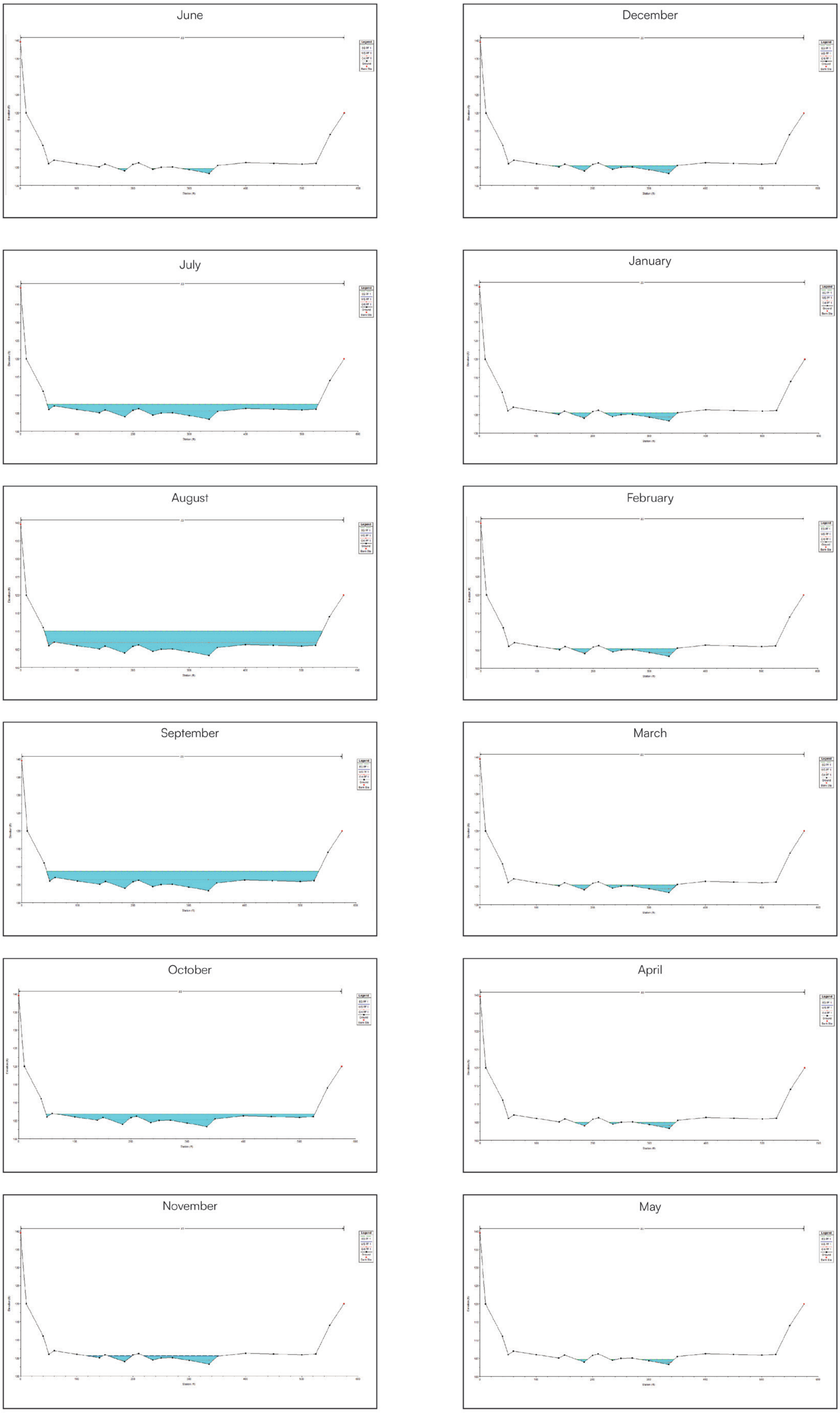


Figure 10: *Hydrological Simulation of Monthly average flow pattern at Udi GD site using HEC-RAS model*

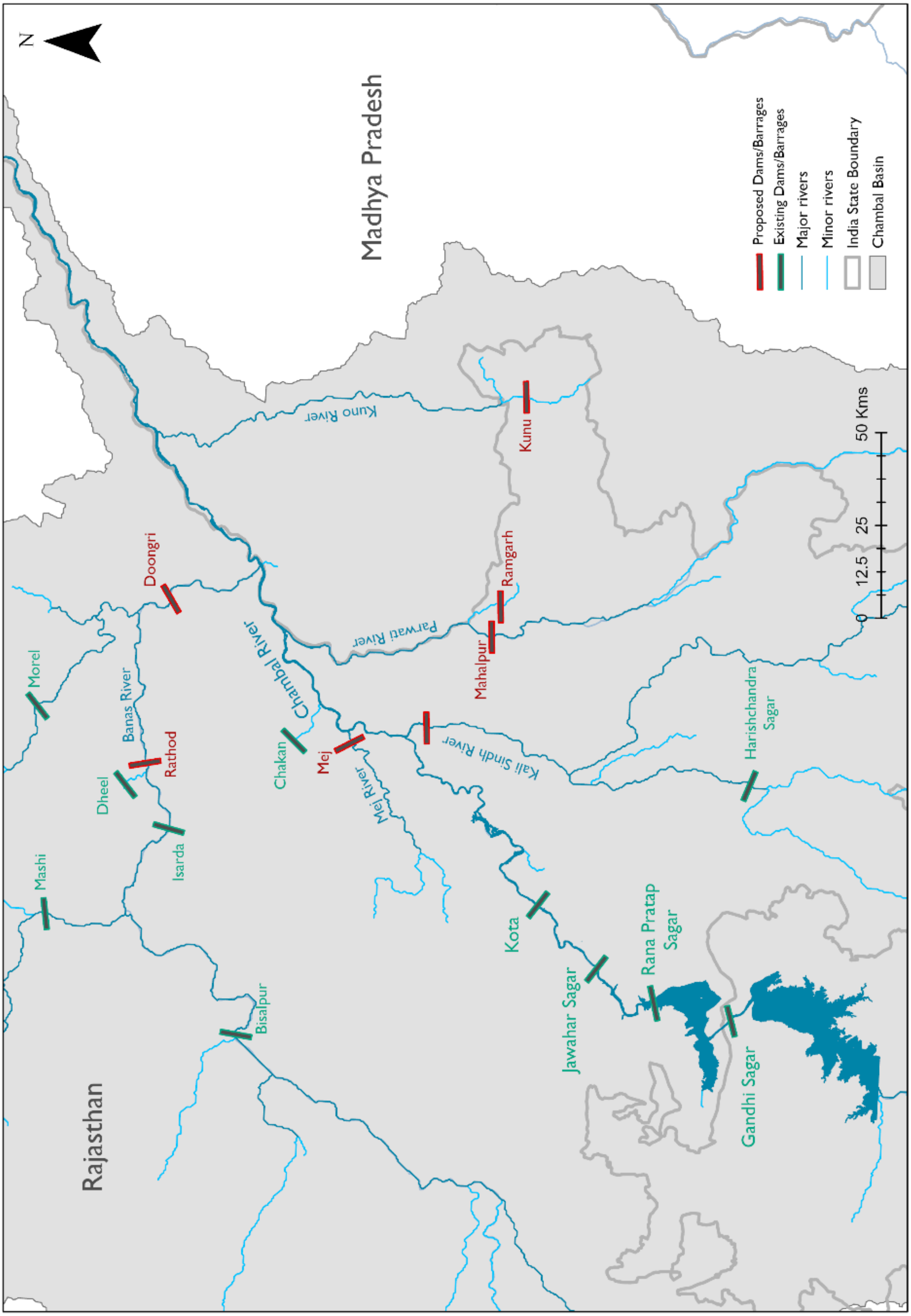
This modeling indicates that the river does not sustain adequate depth throughout the year to support mega aquatic fauna such as the Ganges river dolphin, gharial, and large softshell turtles, as previously discussed in this report. Analysis of current monthly flow regimes reveals that only during the monsoon months (July to October) river discharge is sufficient to maintain the depth required for suitable habitat conditions for these species in all the GD stations. From November onwards, discharge levels begin to decline, culminating in near-zero flow conditions by June (Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12), which barely meets the expected flow conditions to maintain required depth. Field observations corroborate these findings, showing that during the dry summer months, the river becomes highly fragmented. This fragmentation significantly restricts the movement and distribution of aquatic fauna, further compromising habitat connectivity and ecological resilience. The deeper pools (>5m in depth) distributed across the river plays crucuial role in maintaining the aquatic wildlife in lean season, which extends from November to June.

Under Current flow regime scenario, any envisioned projects, which are planned for Chambal or its tributaries, especially involving extraction during the lean seasons, will jeopardise the aquatic biodiversity. The release from upstream dams and barrages from November onward is minimal and cause fragmentation (Map 14), The Chambal's year-round flow is sustained almost entirely by its tributaries (Kalisindh, Banas, Kuno, Parvati, Mej), especially during the lean summer months. The current flow itself barely sustains biodiversity, any further abstraction especially from November onward will compromise the aquatic life of Chambal.

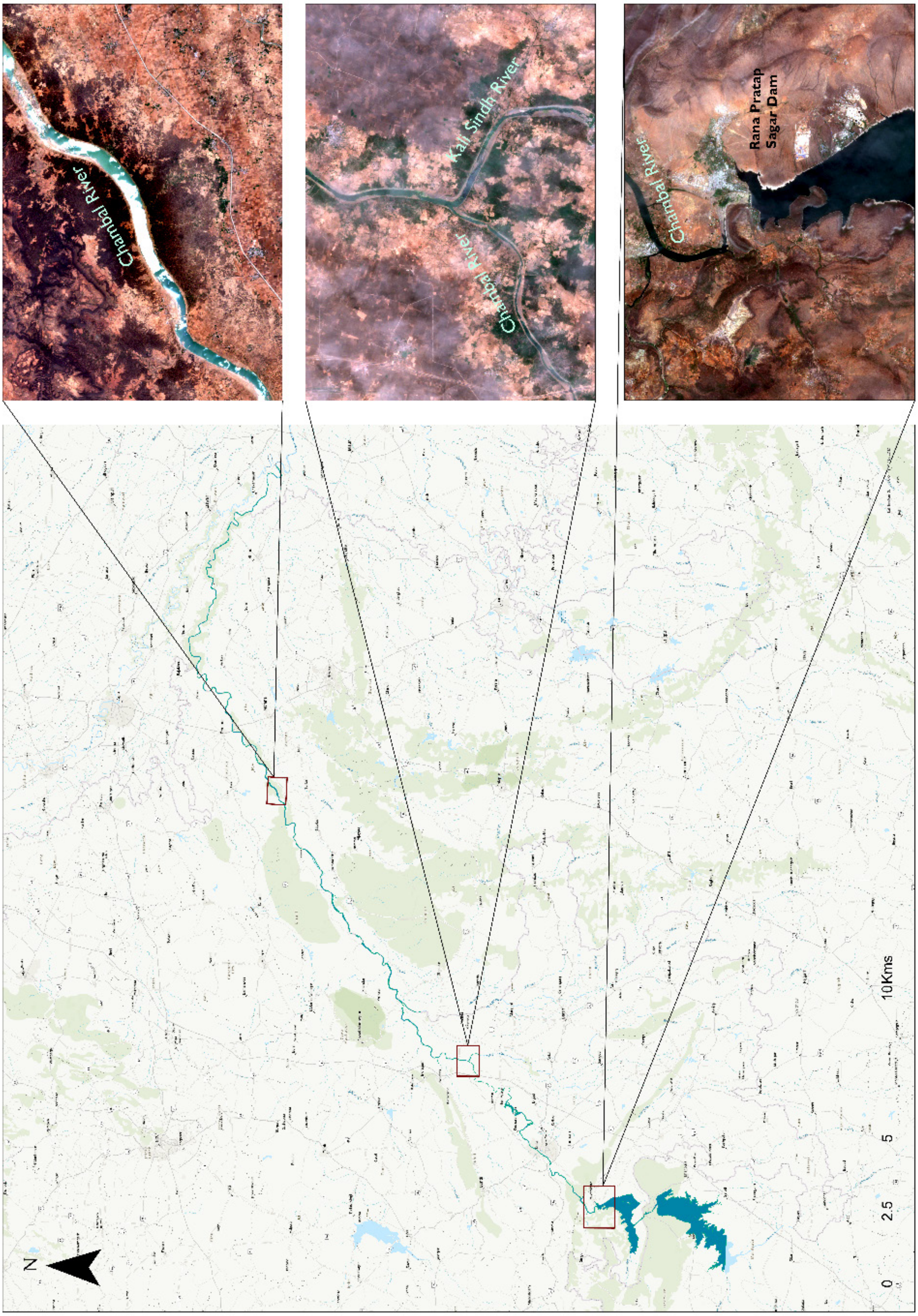
The Chambal River is one of India's last free-flowing and relatively unpolluted river systems. The Chambal's year-round flow is sustained almost entirely by its tributaries, especially during the lean summer months. By intercepting these tributaries at their source, the future projects threaten to cut off critical water inflows, pushing the Chambal toward seasonal drying and ecological fragmentation. Already under stress from upstream water abstraction from Gandhi Sagar dam, Rana Pratap Sagar dam, Jawahar Sagar dam and the Kota Barrage, the Chambal cannot withstand further disruptions. Such changes could have devastating consequences for its rich biodiversity, including endangered fauna such as the Ganges River dolphin, gharial, and various freshwater turtles, all of which depend on a continuous and clean water flow. While these structures aim to provide water security for the neighbouring states, it does so at the cost of ecological damage and biodiversity loss. Therefore, related policies must be re-evaluated with environmental safeguards at the forefront. If implemented without due ecological consideration, these constructions could reduce the Chambal to a seasonal canal, a relic of the past where vibrant biodiversity once thrived in the river ecosystem.

Table 10: *List of Water Diversion structures (Dams/Barrages) proposed to be constructed in ERCP*

Name	River	Village	District	Height (m)	Live Storage (MCM)
Kunu Barrage	Kunu River	Hanotiya	Baran	20	56.88
Ramgarh Barrage	Kul River (tributary of Parwati)	Ramgarh	Baran	26	50.49
Mahalpur Barrage	Parwati River	Mahalpur	Baran	29	160.98
Navnera Barrage	Kalisindh River	Navnera	Kota	26	226.59
Doongri Dam	Banas River	Doongri	Sawai Madhopur	28	1921.74
Rathod Barrage	Banas River	Rathod	Sawai Madhopur	15	143.09
Mej Barrage	Mej River	Balwan	Bundi	20	50.5



Map 13: *Map showing existing and proposed Dams/Barrages in the Chambal River Basin*



***Map 14:** Lean season satellite imagery (June 2024) of various sections of the Chambal River under low-flow conditions. (A) Fragmented stretches of the Chambal River indicating severe flow reduction; (B) Confluence of the Chambal and Kalisindh Rivers, where the Kalisindh significantly contributes to reviving the depleted Chambal flow, emphasizing the hydrological role of tributaries; (C) Downstream section below Rana Pratap Sagar Dam showing absence of water release into the Chambal River.*

MINIMUM FLOW ESTIMATE FOR THE CHAMBAL RIVER

To estimate the flow for Chambal, we have used Manning's Equation, which is one of the most widely used empirical formulas in hydraulic engineering for estimating the velocity and discharge of flow in open channels (Whatmore & Landström, 2010; Song *et.al.*, 2017). Originally developed by **Robert Manning** in 1889, it relates the flow characteristics to channel geometry and roughness (Manning, 1891). We used this method for estimating flow as it is meaningful to apply with basic parameters: channel slope, roughness, and geometry, and with limited data availability.

Minimum Flow estimate for ecological connectivity of the river

To estimate the minimum flow required for the ecological connectivity for the river, we considered minimum depth needed to maintain the habitat connectivity of gharial, dolphin and many turtle species to be 3 meters, The calculation is done considering the average width of the Chambal River as 400 m (Hussain, 1990; Hussain and Choudhury, 1992).

So, using Manning's equation, we estimated the minimum flow required (Q) using the following formula:

$$Q = A \times V$$

Where
V = average flow velocity (m/s)
A = Cross-sectional area

Flow velocity V can be calculated as:
$V = (1 / n) \times R^{(2/3)} \times S^{(1/2)}$

Where
n = Manning's roughness coefficient (dimensionless)
R = hydraulic radius (m), which is flow area A divided by wetted perimeter P
S = river bed slope (m/m)

Assuming the river is rectangular for simplicity:
b =400 m (river width)
d = 3 m (water depth). The flow has been calculated for both cases
Cross-sectional area, $A = b \times d$
Wetted perimeter (P) for a rectangular channel: $P = b + 2 \times d$
Hydraulic radius (R): $R = A / P = (b \times d) / (b + 2 \times d)$
Typical roughness n for a natural river with some stones and vegetation is around 0.03 to 0.05.
Manning's roughness coefficient n= 0.035 (medium roughness)

Assuming a gentle slope in the river Chambal
Slope = 0.0002 (a reasonable gentle slope)

Putting the values in the formula, we calculated 3m depth,
Thus,
For 3 m depth: $V = 28.57 \times 2.0595 \times 0.01414 \approx 0.8321$ m/s

Calculate Flow discharge Q=A
For 3 m depth: $Q=1200 \times 0.8321=$ **998.52 m3/s**

So, to maintain a depth of 3 meters in the Chambal River, the flow should be approximately 998.52 m^3/s. This will ensure the ecological connectivity in the river, and enable aquatic and semi-aquatic species, including Dolphins, Gharials, freshwater turtles, fish, and invertebrates, to move freely between critical habitats such as feeding grounds, nesting sites, and seasonal refugia. This uninterrupted movement is essential for sustaining life cycles, genetic diversity, and overall ecosystem resilience in dynamic river systems like the Chambal.

Using the same method and assuming 5 m as an optimum depth required for most of the mega aquatic fauna (Dolphin, Gharial and large turtle species) required flow is calculated as 2324.38 m3/s for Chambal River.

Lean Season Analysis for Minimum Flow

Recognising that river widths constrict considerably during the lean season, we extended the analysis by modelling discharge requirements for reduced river widths of 50 m (Figure 13), 100 m (Figure 14), 150 m (Figure 15) and 200 m (Figure 16), respectively. Given ecological and geomorphological concerns, we recommend a minimum width of 150 m during the lean period to maintain basic hydraulic and ecological function.

Manning's equation was applied again to determine the minimum flow necessary to maintain depths of 3m, 4m, 5m and 6m under these different width scenarios (Table 11). To evaluate the adequacy of the current flow regime in meeting these ecological depth targets, we compared the modelled discharge requirements with the observed monthly average river flows over a 10-year baseline period (2012–2022, data received from CWC). The results were visualised through a series of plots, where Solid lines represent the observed monthly average discharge under the current flow regime at each station. Dashed lines indicate the minimum flow thresholds required to maintain depths of 3 m, 4 m, 5 m, and 6 m for the corresponding width scenario (Figure 13, Figure 14, Figure 15 and Figure 16). Thus, five separate plots were generated, each corresponding to one of the five river widths considered. Each plot captures the interaction between depth-specific flow requirements and the existing hydrological regime, thus providing an evidence-based foundation for guiding environmental flow prescriptions, seasonal water allocation planning, and riverine habitat management strategies under lean flow conditions.

This visualisation framework enabled a direct comparison between actual and required flows, allowing for the identification of months and locations where flow deficits occur, i.e., periods when the flow fails to provide the minimum depth required.

Table 11: *Estimated flow requirements for different depth and width conditions of the River (in m3/s)*

Depth	Width (m)			
	50	100	150	200
3m	116.90	242.54	368.46	494.45
4m	184.45	386.90	590.10	793.51
5m	261.56	554.37	848.79	1143.67
6m	346.78	742.26	1140.71	1540.02

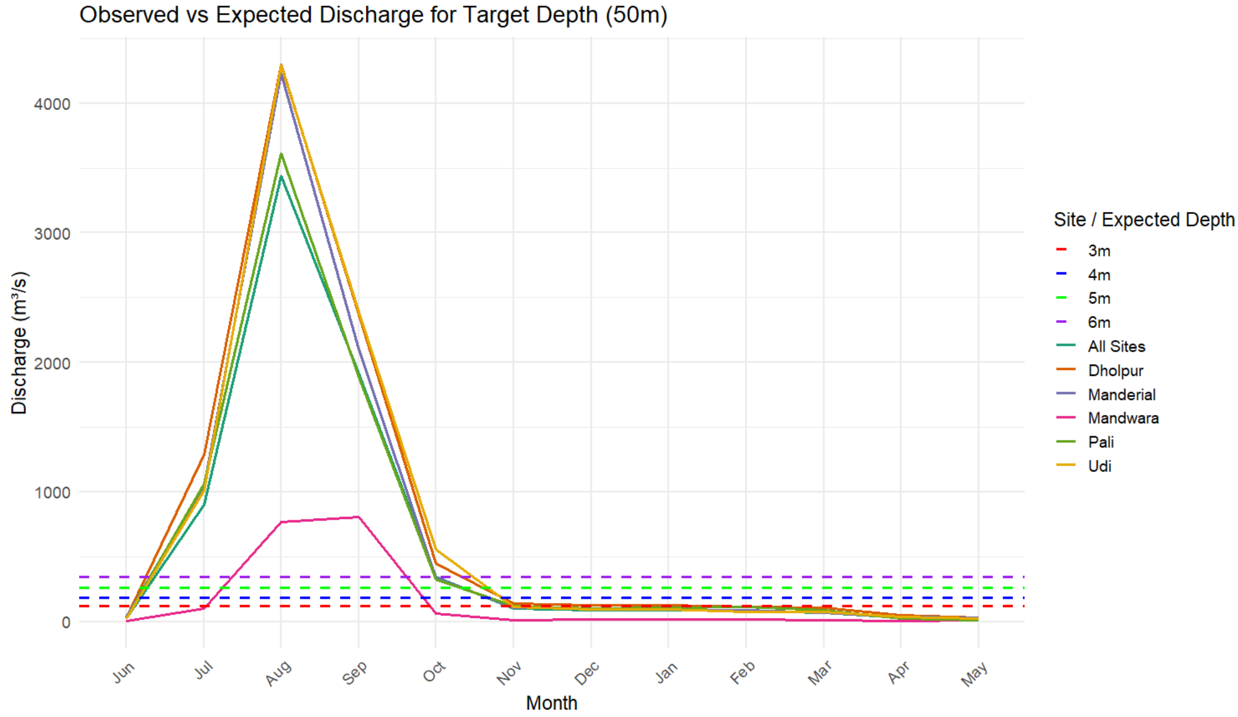


Figure 13: *Graph showing monthly observed discharge vs minimum flow thresholds required to maintain depths of 3 m, 4 m, 5 m, and 6 m for 50m width of River*

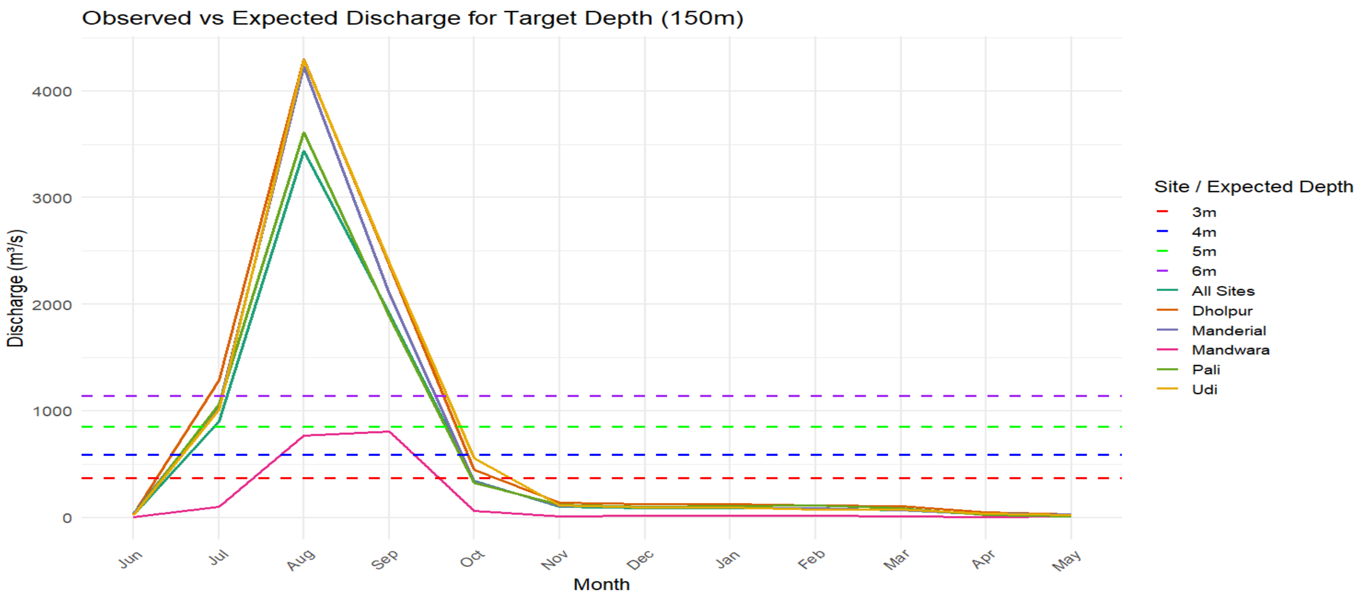


Figure 14: *Graph showing monthly observed discharge vs minimum flow thresholds required to maintain depths of 3 m, 4 m, 5 m, and 6 m for 150m width of River in the five GD stations*

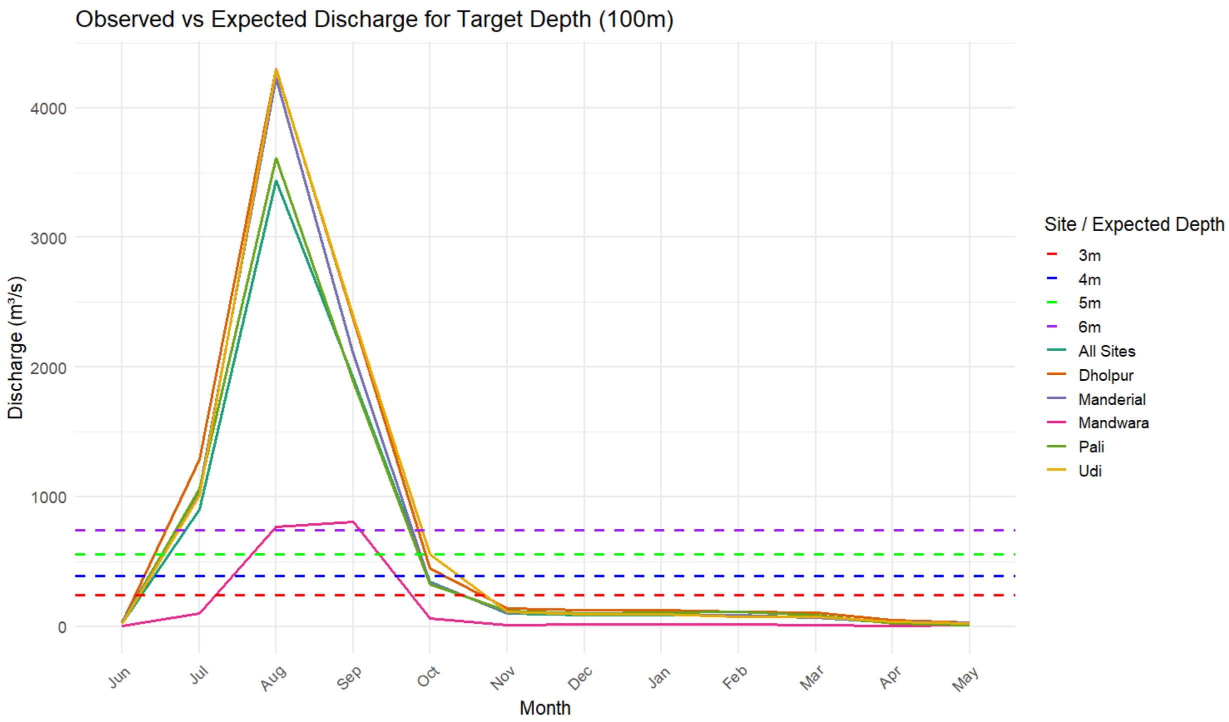


***Figure 15:** Graph showing monthly observed discharge vs minimum flow thresholds required to maintain depths of 3 m, 4 m, 5 m, and 6 m for 100m width of River in the five GD stations*

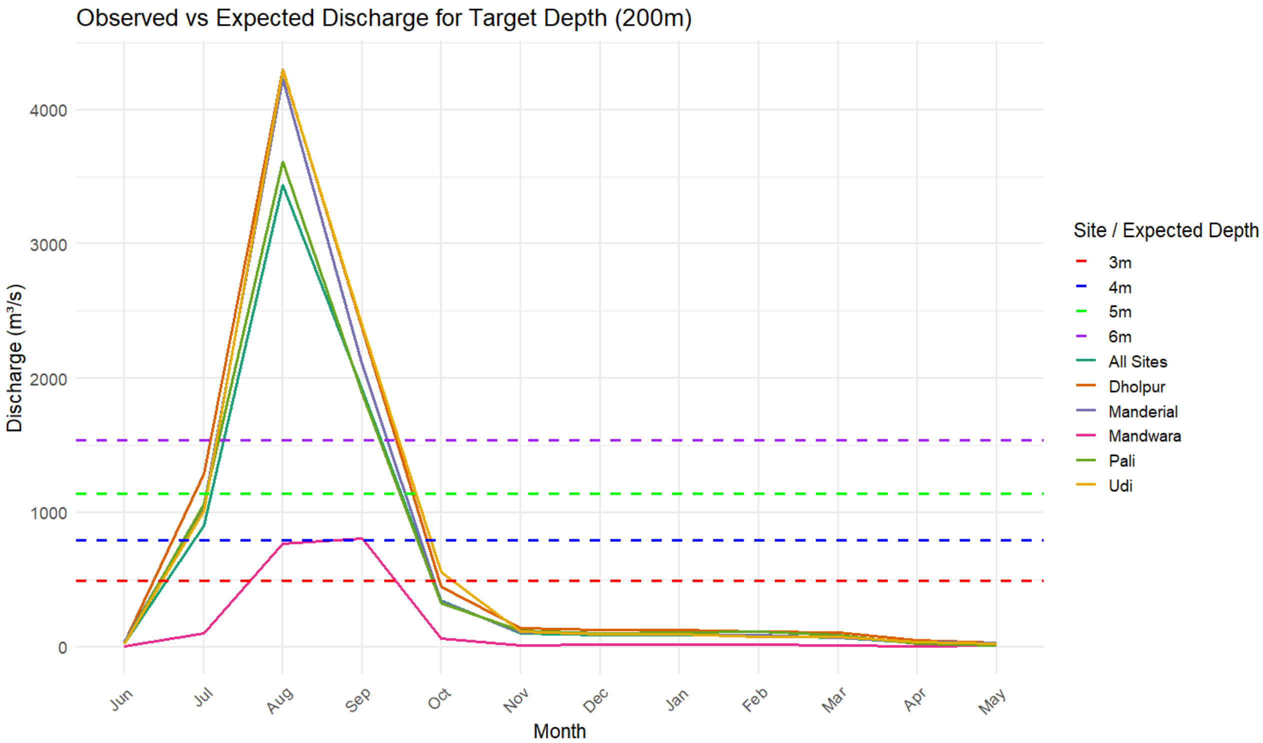


***Figure 16:** Graph showing monthly observed discharge vs minimum flow thresholds required to maintain depths of 3 m, 4 m, 5 m, and 6 m for 200m width of River in the five GD stations*

Our analysis indicates that from November to June, none of the GD stations, regardless of the minimum assumed channel width, receive sufficient discharge to sustain a minimum water depth of 3 m (Figure 13, Figure 14, Figure 15 and Figure 16). This threshold is achieved only during the high-flow months of July to October. This prolonged period of inadequate depth poses a serious threat to aquatic fauna, as reduced flow leads to fragmented habitats, limit movement of certain fauna and also exposing to threats like predators in nesting habitats. Maintaining environmental flows year-round is essential to sustain river connectivity and overall river health.

DISCUSSION

The Chambal River, a tributary of the Yamuna River in central India, is among the ecologically significant rivers in the subcontinent, known for its relatively unpolluted waters and the presence of several endangered aquatic species, including the Ganges river dolphin (*Platanista gangetica*), gharial (*Gavialis gangeticus*), Indian skimmer (*Rynchops albicollis*), and a diversity of freshwater turtles and fishes. Our findings emphasise that multiple aquatic species in the Chambal River are directly dependent on specific flow regimes and water depths. The Ganges River dolphin typically prefers water depths greater than 4 meters (Wakid, 2005), although it may occasionally utilise shallower areas around 2 meters deep for navigation, when necessary, while gharials require water depths ranging from one meter to over 4 meters, depending on their size or age class; the subadults and adult gharials require depth above 4 meters (Hussain, 2009). Muggers also prefer deep waters that offer security and potentially reduce human disturbance (Bhattarai *et. al.*,2022). According to Hussain *et. al.*, 2011, the minimum flow required for the long-term survival of the gharial is around 151 – 164.34 m^3/s, while the dolphin requires a minimum flow of 266.4 –289.67 m^3/s in the lean season, but this is the bare minimum flow and does not address the issue of river fragmentation due to low water depth. Similarly, aquatic invertebrates and fish depend on steady base flow to support breeding, feeding, and larval development (King *et. al.*,2016; Rolls *et. al.*, 2012). Using the empirical Manning's equation, we estimated the flow required to sustain ecological river connectivity at a water depth of 3 meters, as well as the flow necessary to maintain an optimal depth of approximately 5 meters for the habitat requirements of large aquatic fauna such as dolphins, turtles and crocodilians. The flow required to maintain a minimum depth of 3 meters was estimated to be 998.52 cubic meters per second (m^3/s). Further, Recognising the substantial narrowing of river widths during the lean season, we extended our analysis to model discharge requirements under reduced river width scenarios of 50 m, 100 m, 150 m, and 200 m (Figures 13–16), which is crucial as the width across the river is variable, and reduces considerably during lean season. These scenarios were designed to reflect plausible channel constriction extents during seasonal low flows. In ecological and geomorphological considerations, we recommend a minimum lean season channel width of 150 m to maintain the hydraulic and ecological functionality. Manning's equation was re-applied to calculate the flow required to maintain depths of 3 m, 4 m, 5 m, and 6 m across all four width scenarios. Considering a river width of 150 m during the lean period, the flows required to maintain depths of 3 m, 4 m, 5 m, and 6 m were calculated as 368.46 m^3/s, 590.10 m^3/s, 848.79 m^3/s, and 1140.71 m^3/s, respectively. This comparison was visualised using a series of flow-depth interaction plots (Figures 13–16).

However, Data analysis of 10 daily average flow data from 1990 to 2022 (Provided by CWC) indicates a significant declining trend in river flow in the lean season. Also, monthly flow simulations using HEC-RAS software, from a dataset over 10-year period (2012–2022) show a clear and consistent decline in water levels through the year, beginning in November, eventually leading to almost near-zero flow conditions by June (Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12), raising urgent concerns regarding the maintenance of minimum flow essential for sustaining the riverine ecosystem. This also highlight a critical limitation in the river's ability to sustain adequate water depth year-round, particularly in relation to the ecological requirements of large aquatic fauna such as the Ganges river dolphin, gharial, and large softshell turtles. These findings are reinforced by field observations, which indicate that during the dry summer months, the river becomes highly fragmented. This fragmentation impedes species movement and access to critical habitats, particularly affecting depth-dependent fauna like river dolphins. The trend can be attributed to the increased upstream water abstraction for irrigation, dam operations, and irregular release schedules from hydrological structures.

In the case of the Chambal River system, already under significant hydrological stress due to existing water abstraction projects, any additional projects on the Chambal or its tributaries pose a serious risk to the river's ecological integrity and biodiversity. Given that tributaries contribute substantially to the river's flow and support the ecological functioning of the system especially during the lean summer months, their conservation and restoration are essential for sustaining and potentially revitalising the ecological health of the Chambal River.

The declining trend in river flow in the lean season has directly impacted the movement patterns of dolphins, with downstream shifts observed in their distribution (Figure 3), likely as a response to reduced water levels and increasing habitat unsuitability upstream. Such displacement not only limits their breeding opportunities but also increases interspecific competition in denser habitats. Another critical consequence of low water level is the exposure of islands and sandbars, which are essential nesting grounds for island nesting birds, including threatened species like Indian skimmers and black bellied terns. When water levels drop unnaturally or prematurely, land bridges form between these islands and the mainland, allowing terrestrial predators (e.g., jackals and dogs) and cattle to access and destroy nests (Jha &Pandav, 2021).

The lean season is very stressful for the wildlife of the Chambal River. The current flow in this season itself barely sustains biodiversity, so, any further abstraction especially during this period (November till June) will compromise the biodiversity of Chambal. While water abstraction projects are intended to enhance water security for neighboring states, they often come at the expense of ecological damage. Therefore, these should be implemented with due ecological consideration, as these constructions could risk transforming the Chambal from a living river into a seasonal canal, stripping it of the rich biodiversity and ecological vitality that have defined it for generations. Restoring and maintaining environmental flow will be vital for preserving the Chambal's unique biodiversity and supporting sustainable development goals in the region. Integrating environmental flow requirements into water management policies is essential. Such integrated approaches will not only safeguard biodiversity but also foster resilience and sustainability in the face of growing anthropogenic and climatic pressures.


© Sergio Capuzzimati

REFERENCES

- Acreman, M. (2016). Environmental flows—basics for novices. WIREs Water, 3: 622-628. https://doi.org/10.1002/wat2.1160
- Acreman, M. C., & Dunbar, M. J. (2004). Defining environmental river flow requirements–a review. Hydrology and Earth System Sciences, 8(5), 861-876.
- Acreman, M.C. & King, J. (2003). Defining water requirements. In: Flow: the essentials of environmental flows, M. Dyson, G. Bergkamp and J. Scalon (Eds), IUCN, Gland Switzerland and Cambridge, UK.
- Ali, S., Ripley, S. D., & Dick, J. H. (1987). Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. 2nd ed. Delhi:Oxford University Press. Pp. i–xlii, 1 l., 1–737, 52 ll.
- Allan, J. D., & Castillo, M. M. (2007). Stream Ecology: Structure and Function of Running Waters. Springer.
- Ankit, K.,V. Ranjan, M.Ahmad, S. Kumar, S. Hussain & G.V. Gopi (2018). Newly discovered breeding colonies of Indian Skimmer Rynchops albicollis in middle Ganges, India. BirdingASIA 30:99–100
- Arnold, T.W., Devries, J. H., & Howerter, D.W. (2010). Factors that affect renesting in mallards (Anas platyrhynchos). The Auk, 127(1), 212-221.
- Arthington, A. H., Tickner, D., McClain, M. E., Acreman, M. C., Anderson, E. P., Babu, S., ... & Yarnell, S. M. (2023). Accelerating environmental flow implementation to bend the curve of global freshwater biodiversity loss. Environmental Reviews, 32(3), 387-413.https://doi.org/10.1139/er-2022-0126.
- Arthington, A.H., Bhaduri, A., Bunn, S.E., Jackson, S.E., Tharme, R.E., Tickner, D., et al. (2018). The Brisbane Declaration and global action agenda on environmental flows (2018). Front. Environ. Sci. 6: 45.doi:10.3389/fenvs.2018.00045.
- Banyal, H. S., & Kumar, S. (2015). Fish diversity of Chambal River, Rajasthan State. Aquatic Ecosystem: Biodiversity, Ecology and Conservation, 271-281.
- Barbulescu, A., Barbes, L., & Dumitriu, C. S. (2021). Assessing the Water Pollution of the Brahmaputra River Using Water Quality Indexes. Toxics, 9(11), 297. https://doi.org/10.3390/TOXICS9110297
- Bashir, T., Khan, A., Gautam, P., & Behera, S. K. (2010). Abundance and prey availability assessment of Ganges river dolphin (Platanista gangetica gangetica) in a stretch of upper Ganges River, India. Aquatic Mammals, 36(1), 19.
- Behera, S.K.1995. Studies on Population Dynamics, Habitat Utilisation and Conservation Aspects of Gangetic Dolphins (*Platanista gangetica*) in a Stretch of Ganga River from Rishikesh to Kanpur.PhD Thesis, Gwalior: School of Studies in Zoology,Jiwaji University.
- Bevilacqua, M.S., Vitório, A., Felix, R.W. et al. Small is better: comparing the efficiency of two Surber samplers' sizes for biomonitoring programs in tropical headwater streams in the Amazon region. Environ Monit Assess 192, 708 (2020). https://doi.org/10.1007/s10661-020-08676-6
- Bhattarai, D., Lamichhane, S., Pandeya, P., Bhattarai, S., Gautam, J., Kandel, R. C., & Pokheral, C. P. (2022). Status, distribution and habitat use by Mugger crocodile (*Crocodylus palustris*) in and around Koshi Tappu Wildlife Reserve, Nepal. Heliyon, 8(8).
- BirdLife International (2023). Species factsheet: Rynchops albicollis.http://www.birdlife.org/
- Boyd, C. E. (2020). Water Quality- An Introduction. https://doi.org/10.1007/978-3-030-23335-8
- Brooks, J. L., Lédée, E. J. I., Larocque, S. M., Cooke, S. J., Brown, E., & Midwood, J. D. (2025). The influence of thermal and hypoxia induced habitat compression on walleye (Sander vitreus) movements in a temperate lake. Movement Ecology, 13(1), 1.
- CENTRAL POLLUTION CONTROL BOARD (MINISTRY OF ENVIRONMENT & FORESTS)in; Website: www.cpcb.nic.in. (2006). www.cpcb.nic.in
- Champion, H. G., & Seth, S. K. (1968). A Revised Survey of the Forest Types of India. Government of India Press.
- Chandra, K., & Gajbe, P. U. (2005). An inventory of herpetofauna of Madhya Pradesh and Chhattisgarh. ZOOS ' PRINT JOURNAL, 20(3), 1812-1819.
- Chapman, D. (1992). Water Quality Assessments-A Guide to Use of Biota, Sediments and Water in Environmental Monitoring-Second Edition. E&FN Spon. http://www.earthprint.com
- Choudhary, S.K., B.D. Smith, S. Dey, S. Dey, & S. Prakash. (2006). Conservation and biomonitoring in the Vikramshila Gangetic dolphin sanctuary, Bihar, India. Oryx 40: 189–197.
- Choudhury BC, Hussain SA. (1991). Gharial survey of Chambal river. Crocodile Specialist Group Newsletter. 10(1): 4.

- Choudhury, B.C. & de Silva, A. (2013). Crocodylus palustris. The IUCN Red List of Threatened Species 2013: e. T5667A3046723. HTTP://DX.DOI.ORG/10.2305/IUCN.UK.2013- 2.RLTS.T5667A3046723.EN
- Correa-Araneda, F.; Nunez, D.; Diaz, M.E.; Gomez-Capponi, F.; Figueroa, R.;Acuna, J.; Boyero, L.; Esse, C., (2021). Comparison of sampling methods for benthic macroinvertebrates in forested wetlands. Ecol. Indic., 125(107551): 1-11
- CPCB. (2022). REPORT ON WATER QUALITY OF RIVER YAMUNA, PRE AND POST IDOL IMMERSION ON GANESH CHATURTHI AND DURGA PUJA, 2021. www.cpcb.nic.in;
- Da Silva, A. & J. Lenin (2010). Mugger Crocodile Crocodylus palustris. In: Manolis S.C. & C. Stevenson (eds.). Crocodiles. Status Survey and Conservation Action Plan. 3rd Edition. Crocodile Specialist Group, Darwin, Australia.
- Das, D. K. (2015). Breeding status of Indian Skimmer Rynchops albicollis in the National Chambal Sanctuary, India. Indian BIRDS 10(2): 53–54.
- Das, I. 1995. Turtles and Tortoises of India. World Wide Fund for Nature– India/Oxford University Press, Bombay, 176 pp.
- Davies-Colley, R. J., & Smith, D. G. (2001). Turbidity, suspended sediment, and water clarity: A review. Journal of the American Water Resources Association, 37(5), 1085–1101. https://doi.org/10.1111/J.1752-1688.2001. TB03624.X;REQUESTEDJOURNAL:JOURNAL:17521688;JOURNAL:JOURNAL:17521688;WGROUP:STRING:PUBLICATION
- De la Cruz, C., Valencia, J., Exposito-Granados, M., Solis, E., Jimenez, O., Alarcos, S., ... & Gutierrez, J. S. (2022). Helpers during replacement clutches buffer the impacts of late breeding on a cooperative bird. Animal Behaviour, 184, 43-53.
- Debata, S., Kar, T., Palei, H. S., & Swain, K. K. (2019). Breeding ecology and causes of nest failure in the Indian Skimmer Rynchops albicollis. Bird Study 66: 243-250.
- Debata, S., Kar, T., Swain, K. K. & Palei, H. S. (2017). The Vulnerable Indian Skimmer Rynchops albicollis Swainson, 1838 (Aves: Charadriiformes: Laridae) breeding in Odisha, eastern India. J. Threatened Taxa 9(11): 10961–10963.
- Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., ... & Shirayama, Y. (2018). Assessing nature's contributions to people. Science, 359(6373), 270-272.
- Dilawar, M., & Sharma, V. (2016). A new breeding location of Indian Skimmer Rynchops albicollis, and notes on other birds in Son Gharial Wildlife Sanctuary, Madhya Pradesh, India. Indian BIRDS 11(2): 35–38.
- Dudgeon, D. (2019). Multiple threats imperil freshwater biodiversity in the Anthropocene. Current Biology, 29(19), R960-R967.
- Dugan, H. A., & Arnott, S. E. (2023). The ecosystem implications of road salt as a pollutant of freshwaters. Wiley Interdisciplinary Reviews: Water, 10(2), e1629. https://doi.org/10.1002/WAT2.1629;WEBSITE:WEBSITE:WIRES;WGROUP:STRING:PUBLICATION
- Dunbar, M.J., Acreman, M.C., Gustard, A., and Elliot, C.R.N., (1998). Overseas Approaches to setting river flow oblectives. Phase 1 Report to the environment agency. Environment Agency R&D Technical Rport W6-161. 82pp.
- Dyson, M., Bergkamp, G., & Scanlon, J., (2003). Flow: the essentials of environmental flows. IUCN, Gland, Switzerland and Cambridge, UK, 20.
- Eastern Rajasthan Canal Project- Feasibility Report. (n.d.). WRD, Govt. of Rajasthan. https://environmentclearance.nic.in/DownloadPfdFile.aspx?FileName=tQgaJFHvgEs9OCvKGzrtGzGGjxgBuJcZspV7suAL6GLr81mDjBIiuY5KnEXHo4Jv4QNa2CmpPVB5NX4o20IkkX4Q0jyz823L4y85jM4g4dIN6mLFTf0HEtuuv9Q1oZjlbWfai5ditFhAERIm1qy1Uw==&FilePath=93ZZBm8LWEXfg+HAIQix2fE2t8z/pgnoBhDIYdZCxzXmG8GIihX6H9UP1HygCn3pCkAF2zPFXFQNqA4krKa1Aw==
- Fernandes, M. & Besten, J.W.D. (2013). Some interesting breeding records for Pong Dam Wildlife Sanctuary, Himachal Pradesh, India. Forktail 29: 141-143.
- Garg, R. K., Rao, R. J., & Saxena, D. N. (2002). Water quality and conservation management of Ramsagar reservoir, Datia, Madhya Pradesh. Journal of Environmental Biology, 30(5), 909.
- Gopal, L. & V.C. Srivastava (2008). History of Agriculture in India (up to c. 1200 A.D.). History of Science, Philosophy and Culture in Indian Civilization. Project of History of Indian Science, Philosophy and Culture. Centre for Studies in Civilizations, New Delhi, xxxiv+912pp.
- Grimmett, R., Inskipp, C., & Inskipp, T. (1998). Birds of the Indian Subcontinent. 1st Editio. A&C Black, 548, 549.
- Gupta, M. K., Kumar, R., Banerjee, M. K., Gupta, N. K., Alam, T., Eldin, S. M., & Khan, M. Y. A. (2022a). Assessment of Chambal River Water Quality Parameters: A MATLAB Simulation Analysis. Water 2022, Vol. 14, Page 4040, 14(24),

4040. https://doi.org/10.3390/W14244040

- Gupta, M. K., Kumar, R., Banerjee, M. K., Gupta, N. K., Alam, T., Eldin, S. M., & Khan, M. Y. A. (2022b). Assessment of Chambal River Water Quality Parameters: A MATLAB Simulation Analysis. Water 2022, Vol. 14, Page 4040, 14(24), 4040. https://doi.org/10.3390/W14244040
- Hails, J.R. (1982). Grab samplers. In: Beaches and Coastal Geology. Encyclopedia of Earth Sciences Series. Springer, New York, NY. https://doi.org/10.1007/0-387-30843-1_212
- Hays, G. C., Richardson, A. J., & Robinson, C. (2005). Climate change and marine plankton. In Trends in Ecology and Evolution (Vol. 20, Issue 6 SPEC. ISS., pp. 337–344). Elsevier Ltd. HTTPS://DOI.ORG/10.1016/J.TREE.2005.03.004
- Herald, E. S. (1969). Field and aquarium study of the blind river dolphin Platanista gangetica, p 53, Steinhart Aquarium, California Academy of Sciences, San Francisco, CA.
- Hill, M.T. and Baschta, R.L. (1991). Ecological and geomorphological concepts for instream and out – of- channelflow requirements. Rivers 2, 198-210.
- Hussain, J., & Gupta, S. K. (n.d.). COVID-19 and River Water Quality: Impact of Lockdown on Water Quality of River Yamuna, India. Retrieved July 12, 2025, from http://uyrb.gov.in/
- Hussain, S.A. (1990). Ecology of gharial in National Chambal Sanctuary. Unpublished M. Phil. thesis. Centre for Wildlife and Ornithology, Aligarh Muslim University, Aligarh.
- Hussain, S.A. (1993). Aspects of the ecology of smooth-coated Indian otter Lutra perspicillata in National Chambal Sanctuary (Doctoral dissertation, Ph. D. Thesis, Aligarh Muslim University, Aligarh).
- Hussain, S.A. (1996). Group size, group structure and breeding in smooth-coated otter Lutra perspicillata Geoffroy (Carnivora, Mustelidae) in National Chambal Sanctuary, India.
- Hussain, S. A. (2013). Activity pattern, behavioural activity and interspecific interaction of smoothcoated otter (Lutrogale perspicillata) in National Chambal Sanctuary, India. IUCN Otter Specialist Group Bulletin, 30(1), 5-17.
- Hussain, S. A., & Badola, R. (2001, August). Integrated conservation planning for Chambal River basin. In National Workshop on Regional Planning for Wildlife Protected Areas. India Habitat Centre, New Delhi, Wildlife Institute of India, DehraDun (pp. 1-20).
- Hussain, S.A., & Choudhury, B. C. (1992, August). The Gangetic river Dolphin and the status of its habitat in National Chambal Sanctuary. In Proceedings of the Seminar on conservation of river Dolphins of the Indian subcontinent (pp. 18-19).
- Hussain, S. A., & Choudhury, B. C. (1997). Distribution and status of the smooth-coated otter Lutra perspicillata in National Chambal Sanctuary, India. Biological Conservation, 80(2), 199-206.
- Hussain, S.A., Badola, R., Sharma, R., & Rao, R. J. (2013). Planning conservation for Chambal River basin taking gharial Gavialis gangeticus and Ganges River dolphin Platanista gangetica as umbrella species. Faunal Heritage of Rajasthan, India: Conservation and Management of Vertebrates, 135-156.
- Hussain, S., Sharma, R. K., Dasgupta, N., & Raha, A. (2011). Assessment of minimum water flow requirements of Chambal River in the context of Gharial (Gavialis gangeticus) and Gangetic Dolphin (Platanista gangetica) conservation. Wildlife Institute of India.
- Hussain, S.A. (2009). Basking site and water depth selection by gharial Gavialis gangeticus Gmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary, India and its implication for river conservation. AquatConserv Mar FreshwEcosyst 19:127–133
- Inskipp, C., Baral, H.S., Phuyal, S., Bhatt, T.R., Khatiwada, M., Inskipp, T., Khatiwada, A., Gurung, S., Singh, P.B., Murray, L., Poudyal, L. & Amin, R. (2016). The Status of Nepal's Birds: the National Red List series. Zoological Society of London.
- Iverson, J. B. (1992). A revised checklist with distribution maps of the turtles of the world.Richmond, Indiana: Privately Printed.
- Jain, R. K., Goyal, R., & Goldar, D., (2022, March). Study of Sustainability Aspects of Chambal River Linking System Using Reservoir Simulation Techniques. In Environmental Restoration: Proceedings of F-EIR Conference 2021 (pp. 209-229). Cham: Springer International Publishing.
- Jain, S.K., Agarwal, P.K., & Singh, V.P. (2007). Hydrology and Water Resources of India - Volume 57 of Water Science and Technology Library - Tributaries of Yamuna River. Springer, 350pp.
- Jha, R.R.S. & Pandav, B. (2021). Community participation to enhance nest survival for threatened avian riverine fauna in the National Chambal Sanctuary, Uttar Pradesh. Wildlife Trust of India, New Delhi. Pp. 26.
- Johnson, J. A., George, A., Sharma, M., Kavin, D., Sreelekha Suresh, P. C., Gopi, G. V., & Hussain, S. A. (2021). Status of wildlife between Kota Barrage and Jawahar Sagar Dam, Rajasthan, Wildlife Institute of India, Dehradun 59p. Rapid Assessment Report, 4.

- Junk, W. J., Bayley, P. B., & Sparks, R. E. (1989). The flood pulse concept in river-floodplain systems. Canadian special publication of fisheries and aquatic sciences, 106(1), 110-127.
- Kabir, M. T., Chowdhury, S. U., Tareq, O., Alam, A. B. M. S., Ahmed, S., Shahadat, O. & Foysal, M. (2016). New breeding records of riverine birds in Bangladesh. BirdingASIA 26: 39-42.
- Katdare, S., Srivathsa, A., Joshi, A., Panke, P., Pande, R., Khandal, D., & Everard, M. (2011). Gharial (Gavialis gangeticus) populations and human influences on habitat on the River Chambal, India. Aquatic Conservation: Marine and Freshwater Ecosystems, 21(4), 364-371.
- Kelkar, N., Dey, S., Deshpande, K., Choudhary, S. K., Dey, S., & Morisaka, T. (2018). Foraging and feeding ecology of Platanista: an integrative review. Mammal Review, 48(3), 194-208.
- Khandal, D., Sahu, Y. K., Dhakad, M., Shukla, A., Katdare, S., & Lang, J. W. (2017). Gharial and Mugger in upstream tributaries of the Chambal River, north India. Crocodile Specialist Group Newsletter, 36(4), 11-16.
- King, A. J., Gwinn, D. C., Tonkin, Z., Mahoney, J., Raymond, S., & Beesley, L. (2016). Using abiotic drivers of fish spawning to inform environmental flow management. Journal of Applied Ecology, 53(1), 34-43.
- Kumar, A., Singh Yadav, N., & Sharma, M. (2015). Ecological Health Assessment of Chambal River, India. India Article in Journal of Materials and Environmental Sciences, 6(3), 613–618. HTTPS://WWW.RESEARCHGATE.NET/PUBLICATION/272825426
- Lang, J. W. (2021). Gharial Ecology Project---Update 2019-2021. Und. https://www.academia.edu/47005174/Gharial_Ecology_Project_Update_2019_2021
- Lang, J.W. & Kumar, P. (2017). Gharial Ecology Project: Chambal Population & Nest Counts.
- Leonardo Tejerina-Garro, F., Maldonado, M., Ibañez, C., Pont, D., Roset, N., & Oberdorff, T. (2005). BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY Effects of Natural and Anthropogenic Environmental Changes on Riverine Fish Assemblages: a Framework for Ecological Assessment of Rivers. Brazilian Archives of Biology and Technology, 48(1), 91–108.
- Mackie, A. & Coggan, R. &Heteren, S. (2007). Grab sampling.
- Manning, R. (1891). On the flow of water in open channels and pipes. Transactions, Institution of Civil Engineers of Ireland, 20, 161.
- Meshram, P. K. (2010). Diversity of some fauna in National Chambal Sanctuary in Madhya Pradesh, India. Biodiversitas Journal of Biological Diversity, 11(4).
- Mitra, S., Sultan, S., & Sen, S. (2015). Occurrence records of Ganges River Dolphin (Platanista gangetica) in Southern West Bengal and impact of anthropogenic interferences in its habitat. IOSR Journal of Pharmacy and Biological Sciences, 10(3), 76-83.
- Mohan, R.S.L., S.C. Dey, S.P. Bairagi, & S. Roy. (1997). On a survey of the Ganges River dolphin Platanista gangetica of Brahmaputra River, Assam. The Journal of the Bombay Natural HistorySociety 94: 483–495.
- Mohanty, T. R., Tiwari, N. K., Das, B. K., & Kumari, S. (2022). Plankton diversity and ecology of the river Ganga. Science and Culture, 88 (November-December). HTTPS://DOI.ORG/10.36094/SC.V88.2022.PLANKTON_DIVERSITY_AND_ECOLOGY_OF_RIVER_GANGA.MOHANTY.379
- Morrison, C. A., Alves, J. A., Gunnarsson, T. G., Þórisson, B., & Gill, J. A. (2019). Why do earlier-arriving migratory birds have better breeding success?. Ecology and Evolution, 9(15), 8856-8864.
- Naiman, R. J., Decamps, H., & Pollock, M. (1993). The role of riparian corridors in maintaining regional biodiversity. Ecological applications, 3(2), 209-212.
- Nair, A. K. (2009). The status and distribution of major aquatic fauna in the National Chambal Gharial Sanctuary in Rajasthan with special reference to the Gangetic Dolphin Platanista gangetica gangetica (Cetartiodactyla: Platanistidae). Journal of Threatened Taxa, 141-146.
- Nair, T., & Krishna, Y. C. (2013). Vertebrate fauna of the Chambal River basin, with emphasis on the National Chambal Sanctuary, India. Journal of Threatened Taxa, 5(2), 3620-3641.
- Nair, T., (2010). Ecological and anthropogenic covariates influencing gharial Gavialis gangeticus distribution and habitat use in Chambal River, India. Unpublished master's thesis, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore.
- Naithani, R., & Pande, I. P. (2015). Comparative analysis of the trends in river water quality parameters: A Case study of the Yamuna River. International Journal of Scientific Research Engineering & Technology. www.ijsret.org
- Narain, S., Tripathi, A., & Mishra, S. B. (2006). Population ecology of a freshwater turtle Kachuga tentoria near Panchnada(Etawah: U. P.) and its role as water purifier. Journal of Environmental Biology, 27(3), 589-596.
- Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., (2005). Fragmentation and flow regulation of the world's large

river systems. Science 308:405–408

- Nishan, K. C., Neupane, B., Belbase, B., Dhami, B., Bist, B. S., Basyal, C. R., & Bhattarai, S. (2023). Factors influencing the habitat selection of mugger crocodile (Crocodylus palustris) and its conservation threats in the Rapti River of Chitwan National Park, Nepal. Global Ecology and Conservation, 42, e02406.
- Null, S. E., Mouzon, N. R., & Elmore, L. R. (2017). Dissolved oxygen, stream temperature, and fish habitat response to environmental water purchases. Journal of environmental management, 197, 559-570.
- Opperman JJ, Kendy E, Tharme RE, Warner AT, Barrios E and Richter BD (2018) A Three-Level Framework for Assessing and Implementing Environmental Flows. Front. Environ. Sci. 6:76. doi: 10.3389/fenvs.2018.00076
- Palmer, M., & Ruhi, A. (2019). Linkages between flow regime, biota, and ecosystem processes: Implications for river restoration. Science, 365(6459), eaaw2087
- Poff, N. L., Allan, J.D., Bain, M.B., Karr, J.R., Pretegaard, K.L., Richter, B.D., et al (1997). The natural flow regime. Bioscience 47, 769-784.
- Praschag, P. and Gemel, R. 2002. Identity of the black softshell turtle Aspideretes nigricans (Anderson1875) with remarks on related species. Faunistische Abhandlungen Staatliches Museum für Tierkunde Dresden 23: 87–116.
- Qureshi, Q., Kolipakam, K., Wakid, A., Dasgupta, S., Yadav, S.P., Tiwari, V.R., Ranjan, B. (2024). Population Status of River Dolphins in India, 2021 – 23. Ministry of Environment, Forest and Climate Change, New Delhi and Wildlife Institute of India, Dehradun. ISBN No. (Print): 978-81-972769-3-4, ISBN No. (Electronic): 978-81-972769-1-0
- Qureshi, Q., Kolipakam, V., Wakid, A., Deori, S., Gayathri, A., Jacob, M., Gautam, Bettaswamy, A., Roy, K., Jhala, H., Das, S., Sharma, S., Dutta, A., Singh, V., Roy, G., Phukan, A., Sarma, H., Negi, R., Prasad, L., . . . Amin, R. (2021). Monitoring Ganges and Indus River Dolphins, Associated Aquatic Fauna and Habitat: Field Guide.
- Rahmani, A. R. (2012). Threatened birds of India: their conservation requirements. Mumbai: Indian Bird Conservation Network; Bombay Natural History Society; Royal Society for the Protection of Birds; BirdLife International; Oxford University Press. Pp. i–xvi, 1–864.
- Rajguru, S.K. (2017). Breeding biology of Indian Skimmer Rynchops albicollis at Mahanadi River, Odisha, India. Indian BIRDS 13: 1–7
- Rao, K. S., Kartha, K. N., Gupta, D. R., Pandya, S. S., & Iyer, H. K. (1988). Studies on morphometry and hydrology of Gandhisagar reservoir with special reference to its fisheries.
- Rao, R. J. (2008). Water quality and pollution status of Chambal river in National Chambal sanctuary, Madhya Pradesh. Journal of Environmental Biology. https://www.academia.edu/51537392/Water_quality_and_pollution_status_of_Chambal_river_in_National_Chambal_sanctuary_Madhya_Pradesh
- Rao, R. J., & Choudhury, B. C. (1992). Sympatric distribution of gharial Gavalis gangeticus and mugger Crocodylus palustris in India. Journal of the Bombay Natural History Society, 89(3), 312-315.
- Rao, R. J., & Sharma, R. K. (1987). Annual gharial census in north National Chambal Sanctuary, 1985. Tigerpaper (FAO/RAPA), 14(1).
- Rasmussen, P. C., & Anderton, J. C. (2005). Birds of south Asia: the Ripley guide (Vol. 2, pp. 1-378).
- Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P.A., Johnson, P.T., ... & Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. Biological Reviews, 94(3), 849-873.
- Reiser, D.W., Wesche, T.A., and Estes, C., (1989). Status of Instream flow legislation and Practices in North America, Fisheries, 14, 22-29.
- Rhodin, A.G.J., Walde, A.D., Horne, B.D., Van dijk, P.P., Blanck, T., AND Hudson, R. (EDS.). 2011. Turtles in trouble: the world's 25þ most endangered tortoises and freshwater turtles—2011. IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Turtle Conservation Fund, Turtle Survival Alliance, Turtle Conservancy, Chelonian Research Foundation, Conservation International, Wildlife Conservation Society and San Diego Zoo Global Workshop Proceedings, 54 pp.
- Rodrigues, J. N., Ortega, J. C. G., Petsch, D. K., Padial, A. A., Moi, D. A., & Figueiredo, B. R. S. (2023). A meta-analytical review of turbidity effects on fish mobility. Reviews in Fish Biology and Fisheries, 33(4), 1113–1127. https://doi.org/10.1007/S11160-023-09785-4
- Rolls, R. J., Leigh, C., & Sheldon, F. (2012). Mechanistic effects of low-flow hydrology on riverine ecosystems: ecological principles and consequences of alteration. Freshwater Science, 31(4), 1163-1186.
- Sahu, Nosad& GANESH, Thiruchitrambalam& Lakra, Raj. 2021. Efficiency of sampling gears (Quadrate and Core) and Taxonomic Resolution on the Soft Bottom Intertidal Macrobenthic community of Port Blair coast. RESEARCH JOURNAL OF CHEMISTRY AND ENVIRONMENT. Vol. 25(11). 10.25303/2511rjce93103.

- Saksena, D. N., Garg, R. K., & Rao, R. J. (2008). Water quality and pollution status of Chambal river in National Chambal Sanctuary, Madhya Pradesh. Journal of Environmental Biology, 29(5), 701–710. https://www.jeb.co.in/journal_issues/200809_sep08/paper_10.pdf
- Sarkar, D., Mital, A., Mondal, R., Kumar, R. S., & Talukdar, G. (2019). 'Community ponds: a tool for conservation'. A case study of Nilssonia gangetica (Cuvier, 1825) in Kashipur village, Uttar Pradesh, India. Herpetology Notes, 12, 631-636.
- SCHNEIDER, VP, & Djalal, AS (1970). First record of a soft-shelled turtle, Trionyx gangeticus Cuvier, 1825, in Afghanistan. Bonn. Zool. Beitr. , 21 , 269–273.
- Shaikh, P. A., Mendis, A., Luis, J., Das, D. K., & Surve, S. (2018). Status and distribution of Indian Skimmer Rynchops albicollis in the National Chambal Sanctuary, India. Final Report submitted to BirdLife International, 46.
- Shaikh, P.A. & Mendis, A. (2019). Status and distribution of Indian Skimmer Rynchops albicollis breeding population in the National Chambal Sanctuary, India. Progress Report submitted toBirdLife International.
- Shaikh, P.A. (2020). Status and distribution of Indian Skimmer Rynchops albicollis in India, with focus on breeding population in the National Chambal Sanctuary, India. Final Report submitted to BirdLife International.
- Sharma, A., & Mathur, A. K., (2022, October). Chambal River Water Quality Assessment at Kota Metropolis Through the Irrigation Water Quality Indices from 2017-2021. In IOP Conference Series: Earth and Environmental Science (Vol. 1084, No. 1, p. 012051). IOP Publishing.
- Sharma, D., & Kansal, A. (2011). Current condition of the Yamuna River-an overview of flow, pollution load and human use.
- Sharma, R. K. (1999). Survey of gharial in National Chambal Sanctuary: 1993–97. Indian Crocodilians, ENVIS (Wildlife and Protected Areas), 2(1), 84-86.
- Sharma, R. K., & Dasgupta, N. (2013). Status and population trends of gharial in the Chambal River, National Chambal Sanctuary. In Proceedings of the 22nd Working Meeting of the Crocodile Specialist Group (pp. 74–77).
- Sharma, R. K., & Singh, L. A. K. (2014). Status of Gangetic Dolphin (Platanista gangetica) in National Chambal Sanctuary after thirty years. Zoos' Print Magazine, 29(7), 22-27.
- Sharma, R. K., & Singh, L. A. K. (2015). Status of mugger crocodile (Crocodylus palustris) in National Chambal Sanctuary after thirty years and its implications on conservation of Gharial (Gavialis gangeticus). Zoo's Print, 30(5), 9–16.
- Sharma, R., & Basu, D. (2004). Recent reversals in the population trends in the population of Gharial in the National Chambal Sanctuary in North India; implications and a suggested strategy for the conservation of one of the world's most endangered crocodilians. In Crocodiles. Proceedings of the 17th Working Meeting of the Crocodile Specialist Group, IUCN–The World Conservation Union (pp. 180–186).
- Sharma, R.K. (1993). Annual gharial census in National Chambal Sanctuary. Journal of Tropical Forestry. Vol. 9(1), Jan-March 1993:90-93.
- Sharma, R.K., Mathur, R. and Sharma, S. 1995. Status and distribution of fauna in National Chambal Sanctuary, Madhya Pradesh. The Indian Forester 121:912–916.
- Sharma, S. P., Ghazi, M. G., Katdare, S., Badola, R., & Hussain, S. A. (2024). Population status and genetic assessment of mugger (Crocodylus palustris) in a tropical regulated river system in North India. Scientific Reports, 14(1), 7438.
- Siddiqui, A.I., J. Pandey & R. Mandal (2007). House-crow: threat to Indian Skimmer. Mistnet 8(2): 4–6.
- Singh VB. (1978). The status of the gharial (Gavialis gangeticus) in UP and its rehabilitation. Journal of the Bombay Natural History Society. 75(3): 668–683.
- Singh, A., Antil, E., Dehiya, B. S., & Chaudhary, S. (2024). Assessment of Water Quality Characteristics along the Course of the Yamuna River (India). Current World Environment, 19(3), 1204–1222. https://doi.org/10.12944/CWE.19.3.13
- Singh, C. P., Chauhan, R. R. S., & Mishra, S. B. (2014). Status, Habitat and distribution pattern of the Gangetic dolphin (Platanista gangetica) in National Chambal sanctuary, Uttar Pradesh. India. Journal of Entomology and Zoology Studies, 2(3), 179-181.
- Singh, H. (2010). Habitat characteristics population dynamics and conservation of aquatic mammals (Dolphin and otter) in National Chambal Sanctuary, Madhya Pradesh, India (Doctoral dissertation, Ph. D. thesis submitted to Jiwaji University. Gwalior, Madhya Pradesh, India).
- Singh, H., & Rao, R. J. (2012). Sighting frequency and group composition of the Ganges River Dolphin (Platanista gangetica gangetica) in the National Chambal Sanctuary, India. Zoo's Print, 27(8), 18-23.
- Singh, H., & Rao, R. J. (2017). Status, threats and conservation challenges to key aquatic fauna (crocodile and dolphin) in National Chambal Sanctuary, India. Aquatic Ecosystem Health & Management, 20(1-2), 59-70.
- Sinha, R. K. (2000). Status of the Ganges river dolphin (Platanista gangetica) in the vicinity of Farakka barrage, India.

In R. R. Reeves, B. D.Smith, & T. Kasuya (Eds.), Biology and conservation of freshwater cetaceans in Asia (23rd ed., pp. 42–48). Gland, Switzerland and Cambridge, UK: IUCN.

- Sinha, R. K., & Kannan, K. (2014). Ganges River dolphin: an overview of biology, ecology, and conservation status in India. Ambio, 43, 1029-1046.
- Sivasankar, T., Borah, S. B., Das, R., & Raju, P. L. N. (2020). An Investigation on Sudden Change in Water Quality of Brahmaputra River Using Remote Sensing and GIS. National Academy Science Letters, 43(7), 619–623. https://doi.org/10.1007/S40009-020-00938-8/FIGURES/3
- Smith, B.D., B. Ahmed, M.E. Ali, & G. Braulik. (2001). Status ofthe Ganges River dolphin orshushuk Platanista gangetica inKaptai Lake and the southern rivers of Bangladesh. Oryx 35:61–72.
- Song, S., Schmalz, B., Zhang, J. X., Li, G., & Fohrer, N. (2016). Application of modified Manning formula in the determination of vertical profile velocity in natural rivers. Hydrology Research, 48(1), 133-146.
- Stappert, H. M., Blanke, P., Hering, D., & Kail, J. (2025). Mitigating the effects of extreme low-flow on stream macroinvertebrates: the role of woody riparian vegetation and groundwater. Hydrobiologia, 1-18.
- Sundar, K. S. G. (2004). Observations on breeding Indian Skimmers Rynchops albicollis in the National Chambal Sanctuary, Uttar Pradesh, India. Forktail 20: 89–90.
- Swift, R. J., Anteau, M. J., Ring, M. M., Toy, D. L., & Sherfy, M. H. (2020). Low renesting propensity and reproductive success make renesting unproductive for the threatened Piping Plover (Charadrius melodus). The Condor, 122(2), duz066.
- Taigor, S. R., & Rao, R. J. (2008). Sand mining practices on the Chambal river banks and their impact on the aquatic animal biodiversity. J. Environ. Res. Dev, 2, 644–650.
- Taigor, S.R. & R.J. Rao (2010). Anthropogenic threats in the National Chambal Sanctuary,Madhya Pradesh, India. Tigerpaper 37(1): 23–27.
- Tharme, R. E. (2003). A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River research and applications, 19(5-6), 397-441.
- Thomson, J. R., Taylor, M. P., Fryirs, K. A., & Brierley, G. J. (2001). A geomorphological framework for river characterisation and habitat assessment. Aquatic Conservation: Marine and Freshwater Ecosystems, 11(5), 373-389.
- Torres, A., Brandt, J., Lear, K., Liu, J., (2017). A looming tragedy of the sand commons Science, 357 (6355) pp. 970-971, 10.1126/science.aao0503.
- Tripathi, A., & Lang, J. W. (2017). Spatial ecology and seasonal activities of Indian narrow headed softshell turtle (Chitra indica) in NCS, India. In NCS, India. https://ruffordorg.s3.amazonaws.com/media/project_reports/Presentation%20%20RSG%20India%2C%20Goa%202018.pdf
- Tripathi, A., & Upadhyay, S. K. (2015). Demography of fresh water turtles in confluence area of five rivers (panchnada) off northern india.
- Vaidya, S. D., Kelkar, P. S., & Mhaisalkar, V. A. (2008). Minimum flow requirement for fish population affected by dam construction in temperate areas. International Journal of Sustainable Development and Planning, 3(3), 293-306.
- Vyas, R., & Singh, H. (2004). Biodiversity survey of Gandhi Sagar Reservoir, Madhya Pradesh. Zoos print journal, 19(7), 1525-1529.
- Wakid, A. (2009). Status and distribution of the endangered Gangetic dolphin (Platanista gangetica gangetica) in the Brahmaputra River within India in 2005. Current Science, 1143-1151.
- Wesche, T.A. and Rechard, P.A., 1985. A summary of Instream flow methodologies for fisheries and related research needs. Eisenhower Consorium Bulletin, USDA Forest Service.
- Wetzel, R. G. (2001). Limnology: Lake and River Ecosystems. Gulf Professional Publishing. https://www.sciencedirect.com/book/9780127447605/limnology
- Whatmore, S. J., & Landström, C. (2010). Manning's N: Putting roughness to work. How well do facts travel, 111-135.
- Whitaker, R., & Daniels, J. C. (1980). The status of Indian crocodilians. https://biostor.org/reference/281849.
- WII (2018): Assessment of Wildlife Values of the Ganga River from Bijnor to Ballia Including Turtle Wildlife Sanctuary, Uttar Pradesh. Technical Report. Wildlife Institute of India, Dehra Dun. Pp. 66.
- WII-GACMC(2018).Ganga river-State of Biodiversity at a glance. Ganga Aqualife Conservation Monitoring Centre, Wildlife Institute of India. www.indiawris.gov.in
- WQA. (2013). Established Drinking Water Standards.
- Zusi, R. L. (1996). Family Rynchopidae. Pp. 670–677 in J. del Hoyo, A. Elliott and J. Sargatal, eds. Handbook of the birds of the world. Vol. 3. Barcelona: Lynx Edicions.


© Anuradha Marwah

APPENDICES

Appendix 1:

Checklist of Birds recorded during the Boat-based Associated Biodiversity survey along the entire study stretch of Chambal River from Rajghat to Pachnada, June 2024.

S.No.	Species	Scientific Name	Count	Relative Abundance	Family	IUCN Status
1	Ashy-crowned sparrow-lark	*Eremepterix griseus*	5	0.045	Alaudidae	LC
2	Asian green bee-eater	*Merops orientalis*	266	2.386	Meropidae	LC
3	Asian openbill	*Anastomus oscitans*	197	1.767	Ciconiidae	LC
4	Asian wool-ly-necked stork	*Ciconia episcopus*	67	0.601	Ciconiidae	NT
5	Bank Myna	*Acridotheres ginginianus*	158	1.417	Sturnidae	LC
6	Barn swallow	*Hirundo rustica*	23	0.206	Hirundinidae	LC
7	Black Bellied Tern	*Sterna acuticauda*	128	1.148	Laridae	ED
8	Black drongo	*Dicrurus macrocercus*	94	0.843	Dicruridae	LC
9	Black francolin	*Francolinus francolinus*	5	0.045	Phasianidae	LC
10	Black kite	*Milvus migrans*	5	0.045	Accipitridae	LC
11	Black-headed ibis	*Threskiornis melanocep-jalus*	8	0.072	Threskiorni-thidae	NT
12	Black-necked stork	*Ephippiorhyn-chus asiaticus*	23	0.206	Ciconiidae	NT
13	Black-shoul-dered kite	*Elanus axillaris*	9	0.081	Accipitridae	LC
14	Black-winged stilt	*Himantopus himantopus*	120	1.077	Recurvirost-ridae	LC

15	Blue-tailed bee-eater	*Merops phillippinus*	158	1.417	Meropidae	LC
16	Bonelli's eagle	*Aquila fasciata*	16	0.144	Accipitridae	LC
17	Bronze-winged jacana	*Metopidius indicus*	2	0.018	Jacanidae	LC
18	Brown crake	*Zapornia akool*	3	0.027	Rallidae	LC
19	Cattle Egret	*Bubulcus*	158	1.417	Ardeidae	LC
20	Common babbler	*Argya caudata*	5	0.045	Leiothrichi-dae	LC
21	Common buzzard	*Buteo buteo*	3	0.027	Accipitridae	LC
22	Common greenshank	*Tringa nebularia*	15	0.135	Scolopacidae	LC
23	Common kingfisher	*Alcedo atthis*	1	0.009	Alcedinidae	LC
24	Common myna	*Acridotheres tristis*	19	0.170	Sturnidae	LC
25	Crested lark	*Galerida cristata*	5	0.045	Alaudidae	LC
26	Egyptian vulture	*Neophron percnopterus*	110	0.987	Accipitridae	ED
27	Eurasian collared dove	*Streptopelia decaocto*	40	0.359	Columbidae	LC
28	Eurasian spoonbill	*Platalea leucorodia*	86	0.772	Threskiorni-thidae	LC
29	Greater Flamingo	*Phoenicopterus roseus*	1	0.009	Phoenicopte-ridae	LC
30	Great cormorant	*Phalacrocorax carbo*	4	0.036	Phalacro-coracidae	LC
31	Great egret	*Ardea alba*	34	0.305	Ardeidae	LC
32	Great thick-knee	*Esacus recurvirostis*	135	1.211	Burhinidae	NT
33	Greater coucal	*Centropus sinensis*	7	0.063	Cuculidae	LC

34	Grey francolin	*Ortygornis pondicerianus*	5	0.045	Phasianidae	LC
35	Grey Heron	*Ardea cinerea*	149	1.337	Ardeidae	LC
36	Grey-throated martin	*Riparia chinensis*	132	1.184	Hirundinidae	LC
37	House crow	*Crorvus splendens*	39	0.350	Corvidae	LC
38	Indian cormorant	*Phalacrocorax fuscicollis*	4	0.036	Phalacro-coracidae	LC
39	Indian ea-gle-owl	*Bubo bengalensis*	1	0.009	Strigidae	LC
40	Indian pea-fowl	*Pavo cristatus*	58	0.520	Phasianidae	LC
41	Indian pied starling	*Gracupica conta*	3	0.027	Sturnidae	LC
42	Indian robin	*Copsychus fulicatus*	3	0.027	Muscicapidae	LC
43	Indian skimmer	*Rynchops albicollis*	888	7.966	Laridae	ED
44	Indian spot-billed duck	*Anas poecilorhyncha*	15	0.135	Anatidae	LC
45	Indian thick-knee	*Burhinuds indicus*	3	0.027	Burhinidae	LC
46	Intermediate egret	*Ardea intermedia*	104	0.933	Ardeidae	LC
47	Knob-billed duck	*Sarkidiornis melanotos*	329	2.951	Anatidae	LC
48	Large grey babbler	*Argya malcolmi*	1	0.009	Leiothrichi-dae	LC
49	Laughing dove	*Spilopelia senegalensis*	17	0.153	Columbidae	LC
50	Lesser Whis-tling Duck	*Dendrocygna javanica*	1854	16.632	Anatidae	LC
51	Little Cormorant	*Microcarbo niger*	79	0.709	Phalacro-coracidae	LC
52	Little egret	*Egretta garzette*	205	1.839	Ardeidae	LC
53	Little ringed plover	*Charadrius dubius*	125	1.121	Charadriidae	LC

54	Little stint	*Calidris minuta*	2	0.018	Scolopacidae	LC
55	Little tern	*Sternula albifrons*	546	4.898	Laridae	LC
56	Black-crowned Night heron	*Nycticorax nycticorax*	14	0.126	Ardeidae	LC
57	Oriental darter	*Anhinga mela-nogaster*	1	0.009	Anhingidae	LC
58	Osprey	*Pandion haliaetus*	7	0.063	Pandionidae	LC
59	Paddyfield pipit	*Anthus rufulus*	1	0.009	Motacillidae	LC
60	Painted Snipe	*Rostratula benghalensis*	3	0.027	Rostratulidae	LC
61	Painted Stork	*Mycteria leucocephala*	613	5.499	Ciconiidae	LC
62	Pied bush chat	*Saxicola capra-ta*	25	0.224	Muscicapidae	LC
63	Pied Kingfisher	*Ceryle rudis*	150	1.346	Alcedinidae	LC
64	Pond heron	*Ardeola grayii*	80	0.718	Ardeidae	LC
65	Purple heron	*Ardea purpurea*	3	0.027	Ardeidae	LC
66	Red-naped ibis	*Pseudibis papillosa*	165	1.480	Threskiorni-thidae	LC
67	Red-wattled lapwing	*Vanellus indicus*	974	8.738	Charadriidae	LC
68	River Lapwing	*Vanellus duvaucelii*	912	8.182	Charadriidae	NT
69	River tern	*Sterna aurantia*	27	0.242	Laridae	VU
70	Rock Pigeon	*Columba livia*	709	6.360	Columbidae	LC
71	Ruddy shelduck	*Tadorna ferruginea*	1	0.009	Anatidae	LC
72	Rufous treepie	*Dendrocitta vagabunda*	1	0.009	Corvidae	LC
73	Sand lark	*Alaudala raytal*	1	0.009	Alaudidae	LC
74	Sarus crane	*Antigone antigone*	31	0.278	Gruidae	VU

75	Small pratincole	*Glareola lactea*	771	6.917	Glareolidae	LC
76	Spotted owlet	*Athene brama*	4	0.036	Strigidae	LC
77	Striated heron	*Butorides striata*	9	0.081	Ardeidae	LC
78	White-breasted waterhen	*Amaurornis phoenicurus*	5	0.045	Rallidae	LC
79	White-browed wagtail	*Motacilla man-deraspatensis*	141	1.265	Motacillidae	LC
80	White-tailed swallow	*Hirundo megaensis*	1	0.009	Hirundinidae	VU
81	White-throated kingfisher	*Halcyon smyrnensis*	25	0.224	Alcedinidae	LC
82	Yellow-footed green	*Treron phoenicopterus*	1	0.009	Columbidae	LC

IUCN Status: LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered

Appendix 2:

Checklist of mammals and reptiles recorded during the boat-based Associated Biodiversity survey along the entire study stretch of Chambal River from Rajghat to Pachnada, June 2024.

S.No.	Species	*Scientific Name*	Count	Class	Family	IUCN Status
1	Golden Jackal	*Canis aureus*	8	Mammal	Canidae	LC
2	Nilgai	*Boselaphus tragocamelus*	6	Mammal	Bovidae	LC
3	Spotted deer	*Cervus axis*	3	Mammal	Cervidae	LC
4	Wild boar	*Sus scrofa*	11	Mammal	Suidae	LC
5	Batagur Sp.		43	Reptile		
6	Gharial	*Gavialis gangeticus*	1360	Reptile	Gavialidae	CR
7	Indian softshell turtle	*Nilssonia gangetica*	48	Reptile	Trionychi-dae	ED
8	Monitor lizard sp.		2	Reptile		
9	Mugger	*Crocodylus palustris*	164	Reptile	Crocodyl-idae	VU

IUCN Status: LC: Least Concern, VU: Vulnerable, EN: Endangered, CR: Critically Endangered

ANNEXURE 1:

Year-wise count of Ganges river dolphin in NCS from 1985 to 2014 (Sharma & Singh, 2014).

Year	Length of river surveyed (in Km.)	No. of dolphins (Density= no. of Dolphin per km)	Data source
1983-85	570 Chambal in NCS.	45 (0.14)	Singh & Sharma 1985
1988	320 Batesura-Pachhnada	59 (0.18)	Rao, Hussain and Sharma, 1989
1989	265 Batesura-Chakarnagar	43 (0.16)	Rao, Hussain and Sharma, 1989
1990	305	55 (0.18)	MPFD (RKS)
1992	305	56 (0.18)	MPFD (RKS)
1993	425	72 (0.17)	MPFD (RKS)
1994	415	75 (0.18)	MPFD (RKS)
1995-96	415	84 (0.20)	MPFD (RKS)
1996-97	415	89 (0.21)	MPCST, Bhopal (RKS, R.Mathur)
1998	230	83 (0.36)	S.K. Behera and R.K. Sharma (WWF-India and MPFD)
2001	230	88 (0.38)	S.K. Behera and R.K. Sharma (WWF-India and MPFD)
2002	315	93 (0.30)	S.K. Behera and R.K. Sharma (WWF-India and MPFD)
2003	395	66 (0.17)	MPFD (RKS)
2004	395	65 (0.16)	MPFD (RKS)
2005	425	65 (0.16)	MPFD (RKS)
2006	425	69 (0.17)	MPFD (RKS)
2007	425	91 (0.21)	MPFD (RKS)

2008	425	84 (0.20)	MPFD (RKS)
2009	425	86 (0.20)	MPFD (RKS)
2010	425	69 (0.16)	MPFD (RKS)
2011	425	65 (0.15)	MPFD (RKS)
2012*	222 (from Batesura to Chakarnagar)	56 (0.25)	MPFD (RKS)
2013*	222	59 (0.27)	MPFD (RKS)
2014*	222	66 (0.30)	MPFD (RKS)

Key:
MPFD = Madhya Pradesh Forest Department, MPCST = Madhya Pradesh Council of Science and Technology,
RKS = R. K. Sharma. *Area surveyed during 2012 onwards is limited to Sarsaini to Chakarnagar

ANNEXURE 2:

Table showing Population trend of Gharials from 1979 to 2004 in National Chambal Sanctuary (Source: Sharma & Basu, 2004).

Population of Gharial in the Chambal River differentiated into 3 size classes. (To facilitate comparison of populations between years, crude population densities per river km are shown, since river stretches surveyed in different years were not identical). SA+J = sub-adults and juveniles; H+Y = hatchlings and yearlings. References: 1 = Singh (1978); 2 = Singh (1985); 3 = Rao (1988); 4 = Hussain and Choudhury (1991); 5 = R.K. Sharma (unpublished information).

Year	Section of River Surveyed	Length of River Surveyed (km)	Details of Enumerated Gharials								Ref.
			Total Adults	Adult Density (gh/km)	Total SA+J	SA-J Density (gh/km)	Total H+Y	H+Y Density (gh/km)	Total Popula-tion	Total Population Density (gh/km)	
Pre-1979	Sections near major breed-ing sites	~250	30	0.12	43	-	34	-	107		1
1983-84	Rahuka Gaon to Pachna-da**	315	37	0.117	369	1.171	45	0.143	451	1.432	2
1984-85	Pali*** to Pachnada	425	49	0.115	491	1.155	65	0.153	605	1.424	2
1985-86	Pali to Gyanpura/ Jagtauli	385	66	0.171	391	1.016	170	0.442	627	1.629	3
1988	Pali to Pachnada	425	114	0.268	536	1.261	170	0.4	820	1.929	4
1990	Pali to Pachnada	425	113	0.266	727	1.711	142	0.334	982	2.311	4
1993	Pali to Pachnada	425	186	0.438	305	0.718	407	0.958	898	2.113	5
1994	Pali to Bhare	415	202	0.487	418	1.007	488	1.176	1108 (*1026)	2.67	5
1995-96	Pali to Bhare	415	212	0.511	445	1.072	557	1.342	1214 (*1042)	2.925	5
1996-97	Pali to Bhare	415	226	0.545	459	1.106	554	1.335	1241 (*1078)	2.993	5
1997-98	Pali to Bhare	415	0	0	0	0	0	0	1289 (*1121)	3.106	5
2003	Pali to Chakarnagar	395	150	0.38	265	0.671	99	0.251	514	1.301	5
2004	Pali to Chakarnagar	395	158	0.4	276	0.699	118	0.299	552	1.397	5

*** Pali is the upstream-most point of National Chambal Sanctuary
** Pachnada is the downstream-most point of National Chambal Sanctuary
* Total population corrected for the river section from Pali to Chakarnagar


© Gitanjali Kanwar

ANNEXURE 3:
REPORT BY CENTRAL WATER COMMISSION

Introduction to Environmental Flows Assessment Methodologies

The major criteria for determining environmental flows (EF) generally include the maintenance of both spatial and temporal patterns of natural river flows. Depending upon the purpose and the input required, the assessment of EF can be classified into two major tiers namely:

- Desktop or rapid assessment, primarily using ecologically relevant hydrological data, and
- Detailed assessment, using primarily holistic methods or habitat modeling.

A large number of methodologies are being used worldwide to determine environmental flows. Majority of environmental flow methodologies (EFMs) can be grouped into following distinct categories:

i. Hydrological Method

Hydrological methods can be termed as simplest of assessment procedures. Methods in this category are based on the assumption that maintaining some percentage of the natural river flow will address the environmental issues. These methods primarily use hydrological data to estimate e-flows for maintaining river health. The methods do not account for the specific needs of the flora and fauna in the river explicitly and are more suited where the recommendations are to be made in the absence of detailed data required for other methods of assessment.

ii. Hydraulic Rating Method

These methods assess the hydraulic requirements (flow depth, velocity, wetted perimeter etc) of the biological habitat limiting to target biota and same is converted into environmental flows requirement using the cross section(s) of river reach.

iii. Habitat Simulation (or rating) Method

This method combines the hydraulic rating with characterisation of habitat preferences of large target species under different flow regimes (integrated hydrological, hydraulic and biological response simulation).

iv. Holistic Method

These are comprehensive methods for assessing E-flows that identify all major components of river ecology, model relationships between flow and ecology, geo-morphological and social responses, and use interdisciplinary team approach to establish E-Flow regime.

Suggested Approach for Assessment And Implementation of E-Flows

On perusal of the recommendations of various research studies that are available in India on E-flows, hydrological characteristics of river and dependence of the society on river water, the suggested approach for assessment and implementation of E-flows is as follows.

- We need to identify critical reaches in our river basins which are likely to be impacted due to diversion or impoundment of water in the reservoirs.
- In case of hydropower project, such critical reach shall be from point of diversion or dam to outfall of tailrace or joining of a tributary as shown in Figure 1. After the outfall of tailrace, all the water diverted to power house comes back to the river system.
- In case of diversion for consumptive uses like irrigation, the critical reach shall be from the point of diversion or dam till the location where the flow is augmented by a tributary contributing significantly to the river as shown in Figure 1.

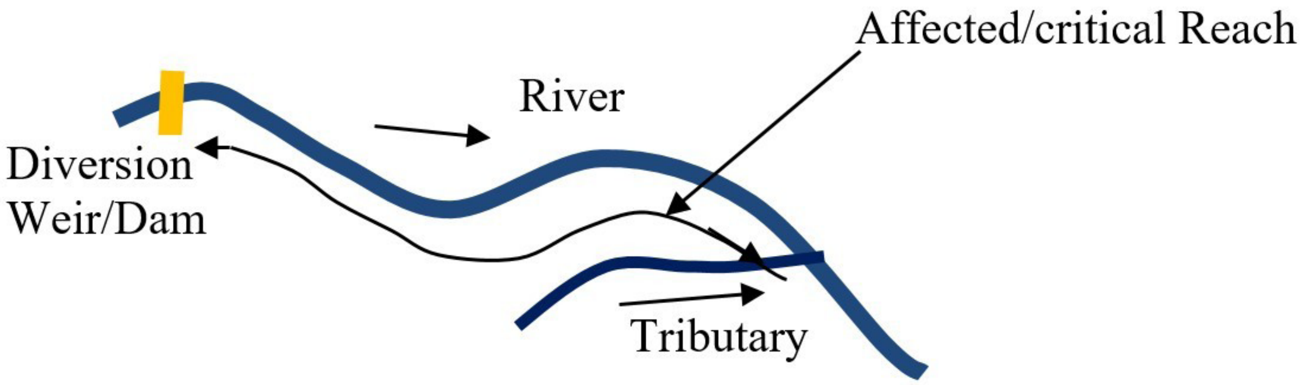


Figure 1: *Critical reach in a river from E-flows view point*

Implementation of E-flows should be taken up in adaptive mode. As shown in Fig. 2, this consists of assessment, implementation, monitoring and then modification based on feedback.

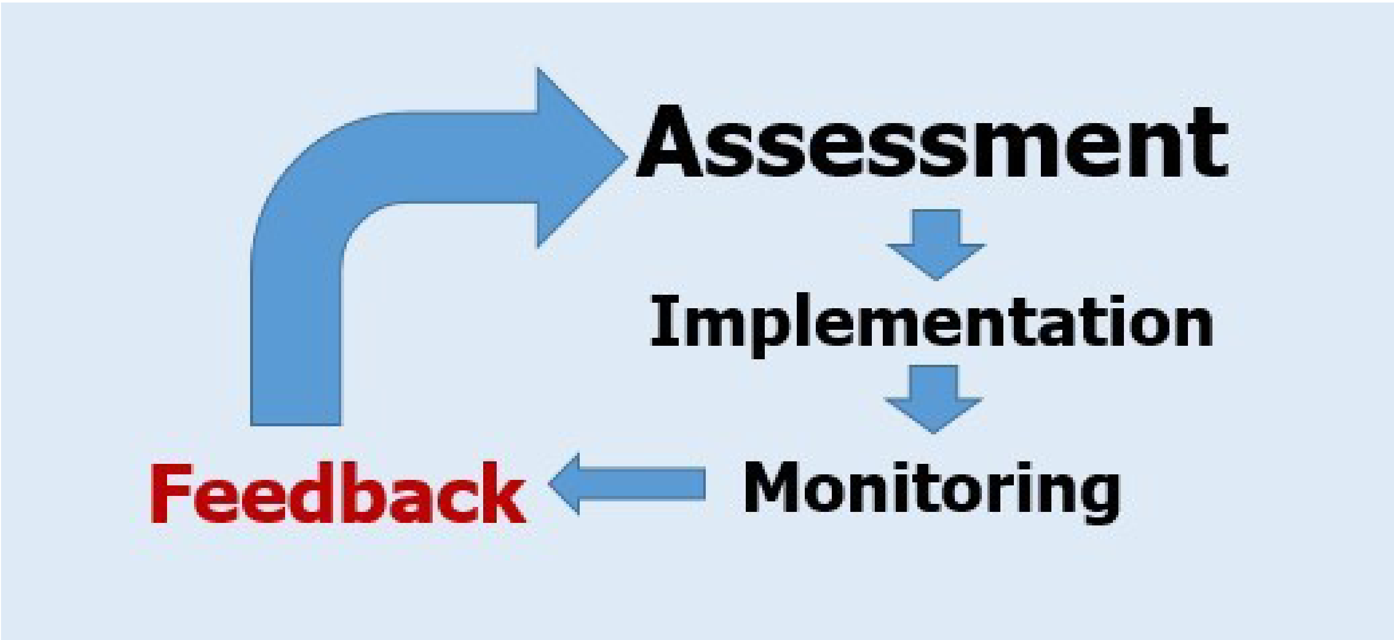


Figure 2: *Adaptive mode of E-flows assessment and Implementation*

Accordingly, the following methodology/framework for assessing the E-flows is proposed:

a. Assess the aquatic habitat characteristics and ecological status of the identified reaches: This assessment may be carried out by expert agencies such as the Wildlife Institute of India (WII) or the Central Inland Fishery Research Institute (CIFRI) etc. A biodiversity survey would document the baseline ecological status of these reaches and will be of immense value.
b. Identify the critical reach that is likely to be impacted due to any diversion or impoundment of water in the river. In case of hydropower project, such critical reach shall be from point of diversion or dam to outfall of tailrace or joining of a tributary. In case of diversion for consumptive uses like irrigation, the critical reach shall be from the point of diversion or dam till the location where the flow is augmented by a tributary contributing significantly to the river.
c. Take river cross-sections at regular interval say 200 m to 1000 m depending upon variability in river geomorphology.
d. Carry out hydraulic simulation using a hydrodynamic model such HEC-RAS for various inflow discharges.

e. Assess the requisite discharges corresponding to hydraulic parameters fulfilling the ecological requirements in different seasons.
f. The requisite discharges in different seasons may be expressed as percentage of average flows or 90 percent dependable flows in that season for ease of implementation.

For time being, the above method for assessing the E-flows requirement may be adopted.

Case Study of Chambal River

In the 70th meeting of the Standing Committee of the National Board for Wild Life held on 13.10.2022 under the chairmanship of Hon'ble MEFCC, the proposal for use of 0.95 ha of forest land from National Chambal Wildlife Sanctuary for construction of Intake Well, Approach Bridge and water pipeline by Water Resources Dept, Bhind, Madhya Pradesh was considered. After discussion, Standing Committee decided that a committee shall be constituted by the Ministry to prescribe the minimum flow in the Chambal River that should be maintained for conservation of Dolphins and associated species in river Chambal.

In view of above, representative from Central Water Commission was nominated to be Member of this committee.
In the telephonic meeting with WII, it was decided that in the preliminary study stretch from Kota Barrage to confluence with Yamuna can be considered for the study.

This stretch is approximately 548 km long. Central Water Commission as 5 Gauging and Discharge sites namely, Mandwara, Pali, Manderial, Dholpur & Udi sites. A GIS map at figure-3 is shown below containing the location of sites.

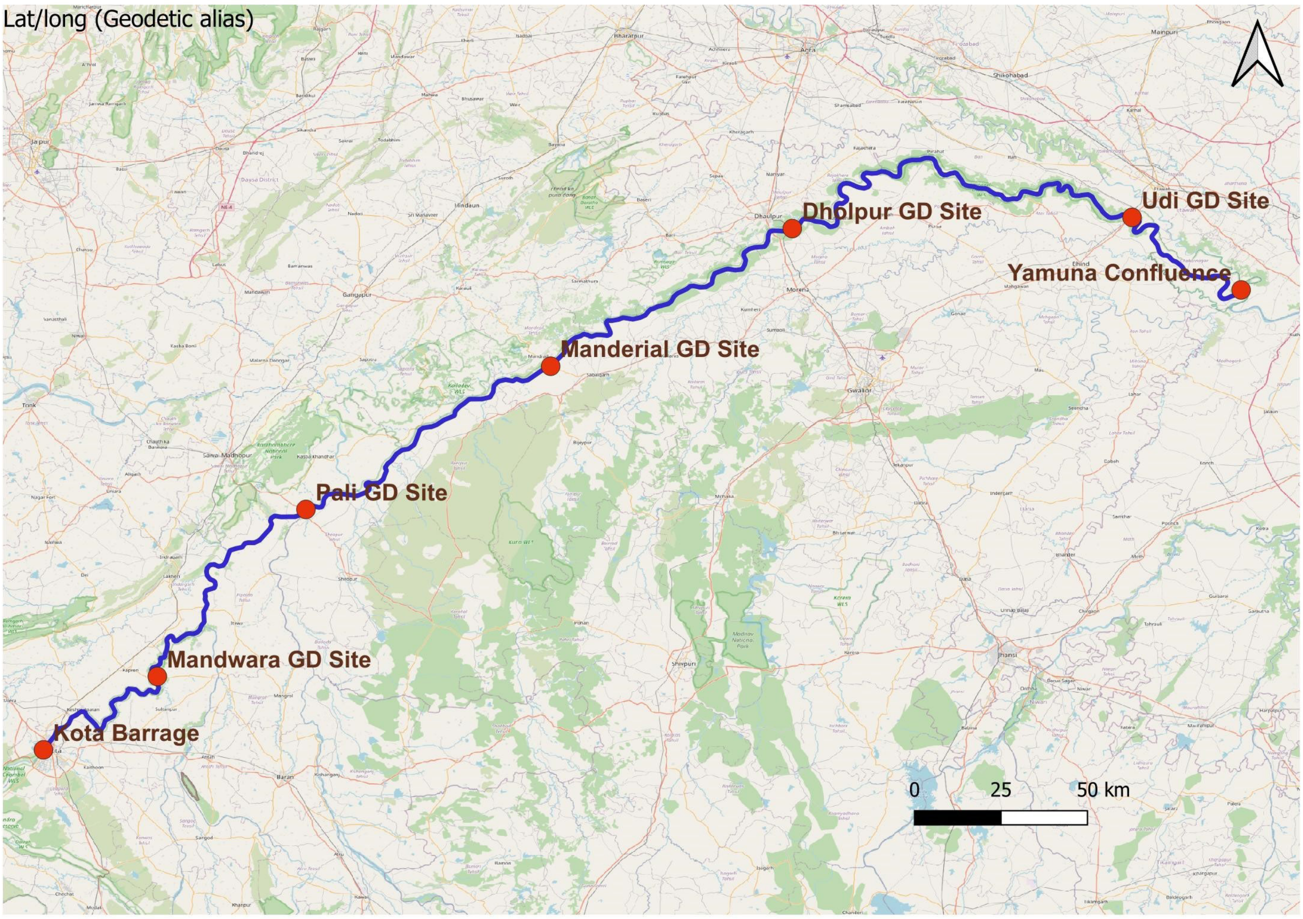


Figure 3: *Map containing G&D site locations*

Tables – 1 to 5 and figures 4-8 contains the Average 10-daily flow values at 5 G&D sites from period 1990-2021 and Cross-Sections of river at these sites.

Mandwara GD Site

Table 1: *10-daily Average flow data at Mandwara HO Site*

		June	July	August	Septem-ber	October	No-vember	Dece, mber	January	febru-ary	March	April	May
1990-1991	I	10.0	179.2	436.6	293.7	52.1	15.5	23.7	27.1	68.0	106.8	90.4	33.1
	II	10.5	73.5	71.0	169.5	10.0	19.1	22.7	36.4	90.0	102.2	76.4	16.3
	III	40.2	20.5	127.2	86.8	14.5	25.6	19.6	47.1	105.1	111.4	53.7	29.2
1991-1992	I	113.4	38.0	338.3	750.1	14.5	9.3	4.3	17.6	12.4	17.4	24.3	20.9
	II	24.2	51.5	139.7	210.0	15.1	8.1	9.5	16.8	11.9	34.8	7.6	24.3
	III	19.7	467.5	2204.9	15.8	13.7	5.4	14.6	22.4	18.0	26.5	22.5	9.5
1992-1993	I	99.6	94.8	42.5	102.5	12.4	9.7	18.9	34.9	43.9	66.5	69.1	12.4
	II	169. 0	38.3	206.5	22.5	86.3	17.1	29.7	39.7	46.4	62.9	53.7	5.4
	III	24.1	141.7	102.7	12.6	9.4	19.3	25.7	39.9	56.6	88.1	30.2	5.3
1993-1994	I	10.4	122.9	644.4	17.7	15.7	6.8	12.7	23.9	48.5	55.2	84.2	8.3
	II	18.2	232.5	88.3	226.8	10.9	9.3	21.0	40.2	48.5	68.5	34.4	6.4
	III	108.4	37.1	110.8	82.5	6.1	11.1	25.7	34.8	55.9	74.6	8.7	3.9
1994-1995	I	4.9	1190. 1	1495.1	843.0	29.5	29.9	48.2	60.2	50.7	71.9	18.2	72.2
	II	5.8	89.8	1085.8	286.0	47.9	22.2	58.9	81.8	23.5	122.6	17.5	40.3
	III	48.5	287.1	447.7	238.6	43.1	26.2	45.8	47.6	41.6	40.4	36.6	33.8
1995-1996	I	37.8	123.0	421.8	816.0	48.4	32.2	27.0	77.3	49.2	18.1	15.1	133.3
	II	94.3	76.6	40.8	249.2	49.9	39.9	47.8	72.2	25.4	20.6	55.8	92.6
	III	81.0	315.6	605.1	130.1	34.7	26.6	51.5	108.1	21.0	25.5	157.1	42.9
1996-1997	I	84.5	78.8	378.8	3086.1	20.7	7.2	11.1	23.8	41.5	20.3	17.6	106.7
	II	64.1	129.9	524.6	2763.2	17.6	7.5	5.4	7.9	33.3	21.2	40.4	104.4
	III	45.6	815.2	5259.5	164.5	11.3	8.5	5.7	13.4	35.7	34.8	105.1	66.1
1997-1998	I	118.7	361.3	942.7	86.7	21.4	11.8	104.5	189.5	34.8	13.7	23.8	145.4
	II	192.2	204.0	77.1	61.5	21.1	16.5	57.0	98.6	19.1	15.1	58.8	254.2
	III	136.2	134.4	225.5	26.6	13.4	23.6	113.9	27.2	14.1	14.5	108.1	246.1

1998-1999	I	230.8	17.4	88.0	16.1	20.6	33.0	34.9	36.0	28.4	51.3	81.9	102.9
	II	101.4	485.0	34.0	38.3	19.1	21.2	33.6	39.4	31.0	72.6	98.5	62.5
	III	169.2	97.7	48.1	209.0	16.6	27.3	34.5	43.2	52.4	58.0	87.1	55.8
1999-2000	I	54.0	161.4	231.8	197.5	16.6	26.2	95.4	23.1	20.5	21.1	43.9	12.0
	II	77.5	182.0	158.6	57.0	24.5	33.6	215.2	25.7	23.7	22.1	24.6	7.5
	III	88.2	1947. 8	140.5	28.2	24.3	24.7	36.4	26.8	19.7	24.9	23.3	28.6
2000-2001	I	32.2	35.3	13.7	13.4	5.5	24.6	27.5	17.5	5.3	1.3	1.9	1.1
	II	36.1	120.8	41.5	8.7	12.5	25.8	19.8	13.1	2.5	1.5	1.9	1.0
	III	19.1	1330. 4	24.3	5.1	16.2	31.0	21.3	8.5	1.7	1.8	1.8	1.6
2001-2002	I	1.5	1078. 2	22.2	17.1	9.9	19.5	35.7	11.1	7.1	5.3	3.9	2.0
	II	77.7	329.3	469.9	3.8	9.8	23.6	28.7	12.3	7.2	4.8	3.1	2.6
	III	43.8	44.5	96.9	6.7	11.4	26.0	10.4	12.6	5.6	4.7	2.7	2.6
2002-2003	I	15.5	33.4	116.6	48.9	4.3	2.7	2.2	3.1	2.2	2.3	0.1	0.0
	II	18.3	4.7	68.9	23.8	3.9	2.6	2.1	3.1	2.1	1.0	0.1	0.0
	III	47.4	11.4	27.7	16.2	3.3	2.4	2.3	2.7	2.3	0.2	0.0	0.0
2003-2004	I	0.0	33.3	25.6	64.5	29.1	12.5	23.1	79.4	63.4	25.7	2.2	0.7
	II	0.0	58.0	107.6	88.2	9.1	16.2	28.5	46.4	60.3	19.0	1.3	0.8
	III	69.8	93.0	59.6	104.6	2.8	19.4	30.6	60.6	41.2	4.2	0.9	0.7
2004-2005	I	0.7	29.4	161.3	42.5	47.3	6.0	18.7	47.7	98.0	40.9	26.1	4.1
	II	0.8	77.4	1474.8	7.9	18.9	11.6	26.3	59.8	106.8	31.4	21.0	3.3
	III	1.1	36.3	2061.3	10.1	7.5	21.0	40.0	79.0	71.2	26.0	6.8	2.2
2005-2006	I	0.2	435.9	63.4	9.8	28.3	31.2	29.1	8.5	0.0	0.0	0.0	2.5
	II	0.2	74.0	25.7	67.5	27.3	22.3	46.2	2.4	0.0	0.0	2.9	2.9
	III	0.4	69.1	5.0	39.9	34.3	51.0	8.8	0.0	0.0	0.0	3.4	2.9
2006-2007	I	3.5	4.0	448.6	9579.9	11.5	9.6	7.5	7.3	8.5	11.8	15.4	104.9
	II	4.6	4.3	7186.9	331.8	10.6	11.6	7.4	15.2	13.4	10.1	206.5	74.8
	III	2.5	274.7	2360.2	15.4	9.6	25.4	7.2	15.9	9.7	8.8	144.0	182.3
2007-2008	I	216.8	1448. 1	129.9	9.8	13.3	4.5	25.7	14.7	17.2	20.5	16.3	3.5
	II	243.4	308.5	81.5	9.5	8.6	10.8	13.4	16.4	17.5	16.3	9.4	1.1
	III	545.2	175.8	21.2	10.0	7.5	13.0	13.8	17.0	17.6	19.1	8.0	1.0

2008-2009	I	22.1	127.4	103.4	22.9	11.4	5.7	12.5	20.9	19.4	5.8	2.4	2.0
	II	111.7	88.5	50.1	47.3	5.5	10.0	16.3	17.9	14.3	3.3	2.6	2.3
	III	145.5	67.3	28.2	29.7	3.1	14.0	19.1	15.6	5.0	2.6	2.5	1.5
2009-2010	I	1.1	12.7	6.0	24.8	5.6	5.2	6.8	12.4	4.3	1.4	1.0	1.3
	II	1.1	79.7	5.3	4.4	3.1	10.5	7.0	13.1	2.7	0.9	0.9	0.7
	III	1.1	104.9	8.5	1.6	2.5	7.5	10.6	5.6	2.4	0.8	1.2	0.5
2011-2012	I	0.2	24.7	70.4	63.8	2.7	2.9	4.7	9.6	11.8	7.2	1.8	0.8
	II	0.0	11.3	66.5	35.6	2.2	9.2	5.4	11.4	9.0	4.3	1.2	0.8
	III	0.1	9.3	72.1	5.2	2.4	5.0	7.0	11.9	9.1	2.9	0.7	0.6
2012-2013	I	0.2	22.1	1382.4	311.7	13.4	5.1	6.7	16.2	19.1	15.4	7.4	3.7
	II	0.7	15.6	105.4	295.2	3.6	7.8	7.5	16.4	16.6	13.7	4.9	3.6
	III	421.1	93.5	72.5	38.7	4.2	12.0	11.3	18.3	14.6	13.3	4.2	2.5
2013-2014	I	1.6	8.0	31.5	91.7	13.7	7.2	15.9	7.0	7.8	8.0	2.3	2.4
	II	2.7	7.1	175.8	76.2	3.8	10.4	14.8	7.8	7.6	6.6	2.3	2.5
	III	2.7	44.7	70.1	41.7	4.6	14.3	6.1	10.4	6.9	5.4	2.9	1.8
2014-2015	I	2.9	17.1	887.5	91.4	200.9	13.3	9.9	14.5	10.4	16.2	4.8	2.5
	II	4.6	38.8	721.2	10.2	268.2	14.4	12.7	10.6	14.8	14.1	3.6	2.3
	III	6.4	491.1	8207.9	193.6	36.3	15.1	15.2	13.4	16.3	9.5	3.1	2.1
2015-2016	I	2.4	2.4	527.5	29.5	6.2	13.7	14.2	21.9	20.6	23.8	4.3	2.9
	II	2.6	3.9	263.4	74.0	8.6	14.3	18.0	22.9	23.5	23.6	4.1	2.8
	III	2.9	62.6	28.9	19.0	10.5	13.7	20.3	21.2	24.0	11.0	3.9	2.7
2015-2016	I	2.6	10.7	988.0	9.4	3.4	8.6	11.6	20.6	13.0	18.4	4.0	2.5
	II	16.2	98.4	800.4	8.2	2.9	11.9	11.3	18.0	15.3	15.1	3.4	2.3
	III	4.5	1582. 0	177.8	6.8	7.4	12.8	18.4	17.4	17.5	8.1	2.6	2.2
2016-2017	I	2.2	14.3	1512.4	1124.2	16.5	9.3	10.0	16.0	14.8	15.0	5.7	3.4
	II	2.2	85.0	222.2	21.1	16.2	11.1	10.1	15.7	14.5	13.9	3.8	3.8
	III	3.1	44.0	1734.1	29.8	7.2	12.4	14.8	15.5	14.1	7.7	3.3	5.2
2017-2018	I	3.6	13.5	143.9	4.5	2.6	6.7	11.3	16.7	17.8	14.1	6.0	3.6
	II	4.1	19.0	59.2	6.4	3.3	8.0	13.0	20.1	20.2	11.5	4.7	4.1
	III	14.5	80.0	12.9	4.9	6.6	10.8	16.7	23.1	20.0	7.7	3.8	3.2

2018-2019	I	4.9	25.7	12.9	237.8	17.7	7.8	14.3	19.5	21.1	19.2	5.9	3.3
	II	3.0	56.3	38.8	82.4	7.5	9.8	15.5	18.1	21.5	12.6	4.6	2.8
	III	29.3	118.6	117.6	32.7	5.4	15.4	19.3	19.8	22.2	7.4	4.7	3.4
2019-2020	I	2.7	86.8	297.0	2245.4	726.2	10.2	11.0	24.2	18.9	18.1	8.2	5.3
	II	2.7	13.1	2307.5	17351.1	246.5	43.6	12.0	18.7	18.0	17.3	5.9	4.5
	III	5.5	117.9	1134.5	1799.1	15.2	17.4	19.6	18.3	18.0	13.8	5.5	3.7
2020-2021	I	3.3	4.4	7.5	241.4	4.9	6.8	9.8	24.4	16.1	16.8	5.2	3.9
	II	4.1	2.5	36.8	11.6	3.6	10.5	17.3	12.3	19.9	16.1	4.4	4.3
	III	5.2	3.5	631.6	9.2	5.4	13.3	17.6	10.7	14.6	8.1	3.9	4.2
2021-2022	I	3.3	3.4	1774.2	43.6	59.3	7.6	9.6	14.1	22.2	22.2	6.8	57.6
	II	4.2	8.1	77.5	164.5	76.2	14.3	17.3	14.0	22.2	22.4	5.7	43.1
	III	4.3	35.6	59.9	108.4	104.2	21.8	25.1	21.4	22.1	13.9	5.1	101.5

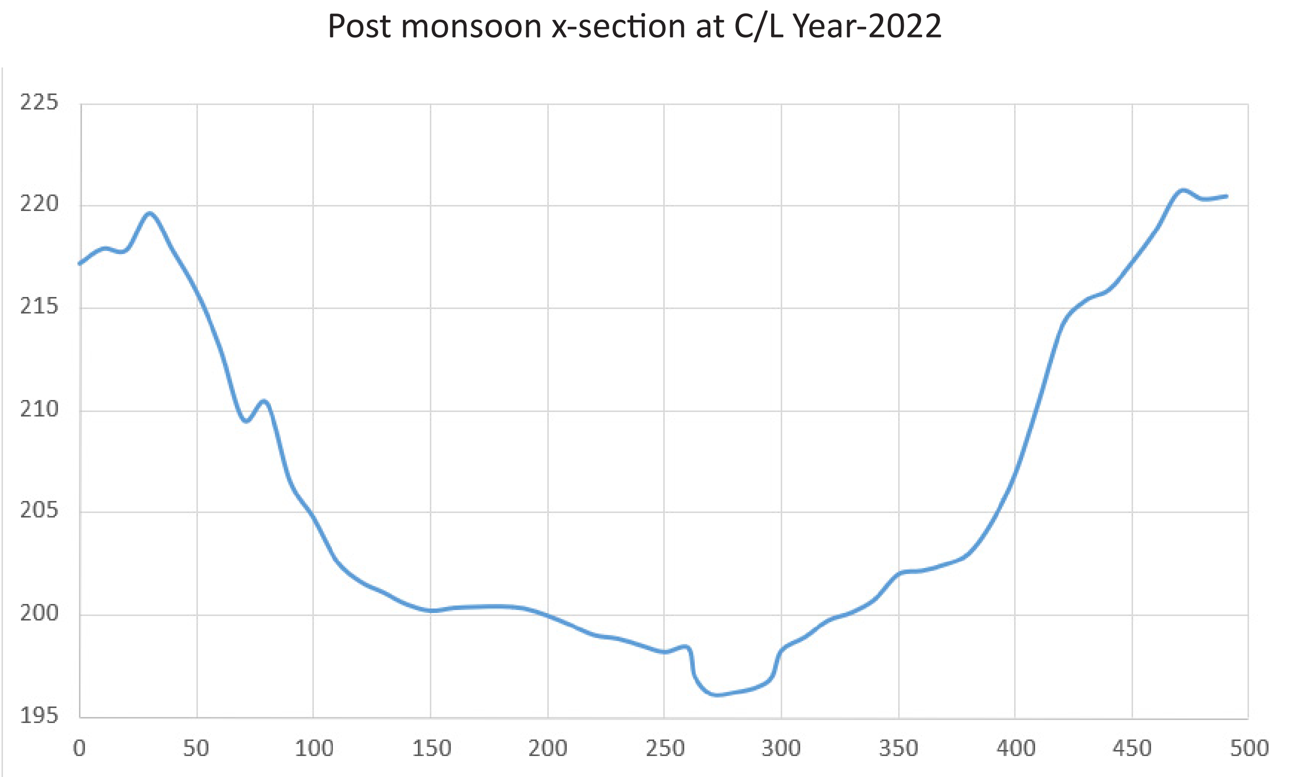


***Figure 4:** Cross-Section of River at Mandwara G&D Site*

Pali GD Site

Table 2: *10-daily Average flow data at Pali HO Site*

Average values in cumec

		June	July	August	September	October	November	December	January	february	March	April	May
	I	13.9	2059.7	1821.5	3246.8	610.2	99.2	92.2	101.1	84.3	108.1	60.7	14.3
1990-1991	II	8.8	733.7	859.9	2672.4	201.7	88.2	94.3	93.6	84.2	58.7	33.1	11.7
	III	515.0	560.5	2136.9	1989.4	139.7	96.0	99.5	86.7	92.0	54.0	19.0	10.8
	I	44.7	10.9	2388.8	2359.1	109.3	85.3	85.2	76.3	75.0	42.8	31.9	16.6
1991-1992	II	16.8	38.3	1453.8	500.7	86.6	88.1	85.3	71.0	55.3	43.5	17.3	15.2
	III	13.2	3536.1	7332.7	188.6	83.9	89.9	92.1	66.7	49.7	42.6	13.6	13.4
	I	14.3	31.2	1026.2	1316.2	152.9	108.3	76.2	75.2	71.9	85.4	60.3	17.8
1992-1993	II	43.1	182.2	2758.4	541.3	821.6	87.1	77.1	68.8	76.4	79.7	44.7	13.0
	III	45.6	1119.2	1273.1	188.4	142.2	82.8	83.3	64.4	68.1	72.8	30.5	9.2
	I	14.6	335.9	3396.5	549.0	746.6	167.0	81.1	61.0	62.9	50.8	49.2	20.1
1993-1994	II	21.2	1789.3	507.6	2454.7	226.8	135.4	72.3	67.3	60.0	51.8	40.4	14.7
	III	391.5	401.4	496.4	1840.9	180.2	122.3	69.5	67.1	51.8	46.8	28.2	10.8
	I	9.5	2626.1	4810.4	6065.9	127.9	82.0	62.2	62.6	61.6	84.5	82.7	23.4
1994-1995	II	24.6	1035.5	2696.1	1059.3	87.8	60.1	74.1	126.2	34.5	119.0	44.2	31.2
	III	253.9	2010.7	3440.0	547.3	84.1	53.3	78.6	85.8	60.6	123.5	28.6	22.1
	I	27.8	109.0	2025.6	5448.9	165.5	98.7	91.8	109.7	107.9	91.1	49.0	86.4
1995-1996	II	57.5	253.7	484.0	577.6	136.6	99.9	91.5	112.4	105.9	66.9	29.8	83.3
	III	43.3	1255.0	3075.0	276.3	126.7	91.8	93.0	112.7	97.2	65.8	43.8	62.9
	I	74.5	65.9	2054.8	5655.7	242.6	110.7	70.2	67.3	61.2	51.8	45.3	81.4
1996-1997	II	77.7	159.1	1418.5	2757.0	169.3	87.0	77.2	56.7	60.7	51.6	43.3	76.8
	III	44.0	3841.3	19099.0	747.5	133.5	68.2	69.2	59.3	65.0	57.8	113.5	58.7
	I	105.9	327.6	2093.1	907.6	205.0	103.0	848.0	202.9	87.9	51.7	48.1	81.0
1997-1998	II	146.2	262.3	432.1	759.7	159.5	63.4	613.9	125.1	73.7	49.4	33.7	96.0
	III	132.1	641.0	1489.9	403.6	93.8	86.0	241.6	89.3	66.9	50.2	70.6	99.6
	I	90.2	127.7	548.1	195.9	334.5	96.6	40.0	45.3	45.9	42.0	34.4	56.9
1998-1999	II	43.8	1827.5	904.6	521.0	232.9	52.7	37.0	51.7	54.4	58.4	58.8	23.8
	III	74.4	267.4	391.1	1491.0	196.2	43.5	43.3	55.4	42.2	41.8	65.9	11.4

1999-2000	I	58.0	77.7	2053.7	1577.8	676.4	112.0	75.1	39.8	33.0	29.1	58.1	14.5
	II	83.9	155.3	1382.7	1554.0	554.2	66.5	105.9	35.4	31.2	22.3	40.2	16.0
	III	122.0	5120. 4	555.1	895.8	183.5	42.4	38.2	33.1	30.1	15.2	27.2	19.2
2000-2001	I	58.9	55.7	298.4	379.3	13.5	21.9	27.9	10.3	2.6	0.8	0.1	0.1
	II	29.2	821.7	399.2	116.4	15.6	24.8	13.2	8.5	1.7	0.5	0.1	0.2
	III	18.4	5643. 5	587.1	33.3	18.8	27.0	8.8	4.5	1.1	0.3	0.1	2.0
2001-2002	I	0.6	5661. 2	333.5	154.2	18.3	11.5	23.3	32.6	17.4	6.1	3.0	0.1
	II	226.3	2375. 3	4598.0	42.3	24.6	10.5	27.4	42.9	24.6	3.9	1.5	0.0
	III	373.9	1682. 4	656.0	13.7	7.9	13.9	27.8	31.7	9.6	3.4	0.6	0.0
2002-2003	I	0.0	35.9	289.1	1134.8	1.7	1.6	0.7	0.8	1.0	1.1	0.1	0.0
	II	0.0	3.6	407.9	157.7	2.5	0.9	0.6	0.8	1.1	0.9	0.0	0.0
	III	16.3	3.7	134.5	20.9	1.9	0.7	0.7	0.8	1.2	0.4	0.0	0.0
2003-2004	I	0.0	86.1	279.3	1095.8	662.2	14.1	25.2	32.0	31.8	3.6	2.4	0.4
	II	0.0	240.7	1159.9	439.3	101.0	9.2	29.1	24.5	22.9	2.5	2.0	0.7
	III	13.4	677.1	345.7	1108.3	21.7	14.3	31.2	32.5	7.3	1.4	0.6	0.5
2004-2005	I	0.1	71.4	1046.1	351.7	98.5	20.1	31.3	36.5	37.5	32.7	11.6	5.1
	II	8.3	32.7	4532.5	148.0	119.1	20.9	32.6	34.5	28.1	26.4	10.8	3.2
	III	42.3	29.2	5617.1	61.3	58.6	26.5	30.8	40.8	26.3	13.2	7.8	1.9
2005-2006	I	1.3	1430. 0	788.5	50.8	108.1	45.7	55.4	18.3	59.8	35.8	4.9	2.6
	II	1.3	1645. 2	190.8	459.0	55.1	43.3	58.9	59.1	70.4	13.1	3.7	1.2
	III	7.7	469.1	91.6	261.2	47.7	50.0	42.2	68.2	57.7	8.1	3.6	4.0
2006-2007	I	15.9	28.3	2460.0	11126.7	222.6	135.0	119.2	122.9	122.2	57.9	33.2	71.9
	II	14.5	17.6	8247.7	703.6	163.6	128.4	120.2	125.4	124.5	51.4	160.5	46.2
	III	12.4	726.2	3204.2	368.6	151.1	123.9	118.1	122.8	73.0	44.9	66.2	99.1
2007-2008	I	106.1	1465. 8	877.5	501.3	196.6	60.3	76.1	74.4	82.0	64.1	43.0	8.8
	II	138.1	1187. 3	434.0	274.5	93.9	53.3	71.4	74.4	73.2	71.4	18.3	8.5
	III	478.9	398.2	307.3	177.0	75.2	58.4	64.3	73.0	66.7	70.1	10.4	6.2
2008-2009	I	14.5	619.9	1142.2	194.3	106.6	32.1	86.3	99.7	89.3	22.5	8.1	6.3
	II	269.4	853.6	873.9	536.0	52.8	50.4	87.8	94.0	85.1	11.6	7.7	6.3
	III	677.0	421.8	286.8	370.2	33.6	82.1	93.2	89.5	48.0	9.2	7.0	6.2

2009-2010	I	80.0	38.0	123.0	202.0	87.7	25.2	108.0	90.0	16.8	4.5	1.9	0.9
	II	95.0	169.0	143.6	234.0	154.9	30.7	39.8	136.8	9.4	3.4	1.3	0.7
	III	90.0	383.6	130.0	128.4	31.7	99.5	83.7	62.0	7.9	2.7	1.0	0.6
2010-2011	I	0.2	4.6	284.7	432.7	51.4	0.4	32.2	60.5	93.1	8.4	0.0	0.0
	II	0.0	33.3	337.2	379.0	15.0	28.3	16.1	88.0	52.9	7.1	0.0	0.0
	III	0.0	101.1	479.6	140.3	5.1	102.9	23.8	87.8	22.9	2.5	0.0	0.0
2011-2012	I	59.0	1200. 5	6059.2	3774.0	307.2	218.9	226.4	236.6	229.4	216.0	183.7	105.4
	II	57.2	1025. 4	1830.2	2163.9	252.6	212.6	229.5	235.0	231.1	218.3	134.3	105.9
	III	4421. 4	1873. 5	1536.4	464.0	217.1	217.5	234.3	220.5	222.6	214.3	122.1	80.1
2012-2013	I	65.5	94.1	1127.2	1218.6	290.6	209.4	215.6	231.9	215.3	216.2	194.0	4.2
	II	63.7	330.8	1256.8	969.9	230.9	207.7	226.4	230.1	221.1	226.3	122.5	4.3
	III	64.1	896.4	1943.7	377.2	211.2	213.6	219.7	217.8	227.7	230.6	6.6	3.1
2013-2014	I	2.3	637.3	8413.5	625.3	427.5	149.8	149.5	222.1	372.8	205.6	14.6	10.6
	II	29.6	1623. 2	9726.9	309.6	569.0	115.7	155.0	187.5	473.0	111.2	12.9	7.7
	III	263.7	6763. 5	10018.4	644.0	250.9	152.4	166.3	240.8	184.5	57.0	16.2	5.1
2014-2015	I	4.6	4.3	738.0	1074.8	347.6	270.2	62.1	67.2	45.9	50.2	18.0	2.5
	II	3.2	7.3	587.7	1911.9	283.0	217.9	61.1	61.6	53.1	138.5	6.9	2.4
	III	3.9	288.6	470.8	475.8	294.4	109.6	61.5	60.5	50.4	45.2	2.7	2.1
2015-2016	I	2.1	180.9	3947.0	1130.2	86.3	74.8	80.1	80.5	93.5	72.5	14.8	9.3
	II	4.5	1605. 4	5616.2	423.0	78.9	73.8	80.7	86.7	90.0	61.9	10.5	9.1
	III	54.6	9415. 8	1448.3	181.8	74.6	73.5	79.5	102.3	82.0	42.3	9.9	8.5
2016-2017	I	6.8	259.2	5470.7	2456.5	314.9	160.0	97.8	78.0	88.5	55.7	32.0	12.9
	II	3.4	2404. 1	3329.0	444.8	342.1	112.1	88.3	100.2	85.1	59.4	26.2	11.4
	III	5.3	582.7	7893.1	376.5	221.9	102.6	65.5	90.5	60.9	46.9	24.2	6.9
2017-2018	I	6.3	121.1	574.3	203.1	137.1	17.6	49.4	60.7	64.6	60.5	21.2	6.9
	II	5.9	80.8	475.7	184.2	87.8	12.7	63.2	60.8	68.5	63.2	11.9	6.3
	III	21.7	714.4	193.0	398.2	57.5	23.0	57.4	60.9	61.7	31.7	7.5	6.0
2018-2019	I	4.0	90.8	241.2	2279.9	223.8	43.4	77.5	71.5	78.6	63.2	28.2	6.1
	II	5.9	289.9	306.8	965.2	97.0	59.0	64.8	70.8	82.9	61.6	10.8	4.4
	III	5.3	2096. 0	1092.5	390.3	41.0	66.1	72.7	75.6	68.3	50.2	11.7	4.1

2019-2020	I	4.4	120.9	2324.8	4336.5	2306.7	228.5	103.7	109.1	94.3	73.3	38.4	9.1
	II	4.6	98.6	10333.5	22258.9	628.2	219.6	92.2	103.1	91.5	135.2	14.0	10.5
	III	9.5	1230. 0	4173.8	4985.7	286.1	137.9	102.1	93.2	81.7	58.0	13.8	7.7
2020-2021	I	7.7	207.5	101.9	2313.1	241.4	43.8	57.0	115.3	56.2	50.5	13.1	9.0
	II	8.0	193.7	365.8	515.6	73.3	45.3	71.9	47.7	65.7	57.2	10.4	7.6
	III	19.0	119.3	3977.3	713.6	61.9	61.6	71.0	38.3	62.7	25.3	7.9	8.7
2021-2022	I	5.5	6.2	19765.0	781.0	670.9	140.5	76.0	93.3	100.8	73.3	20.5	39.1
	II	4.4	93.5	1547.1	1972.4	430.5	106.3	89.0	81.0	91.4	76.6	14.0	46.3
	III	8.3	1452. 1	924.6	1750.0	473.2	138.5	112.3	106.5	79.6	51.1	11.7	75.5

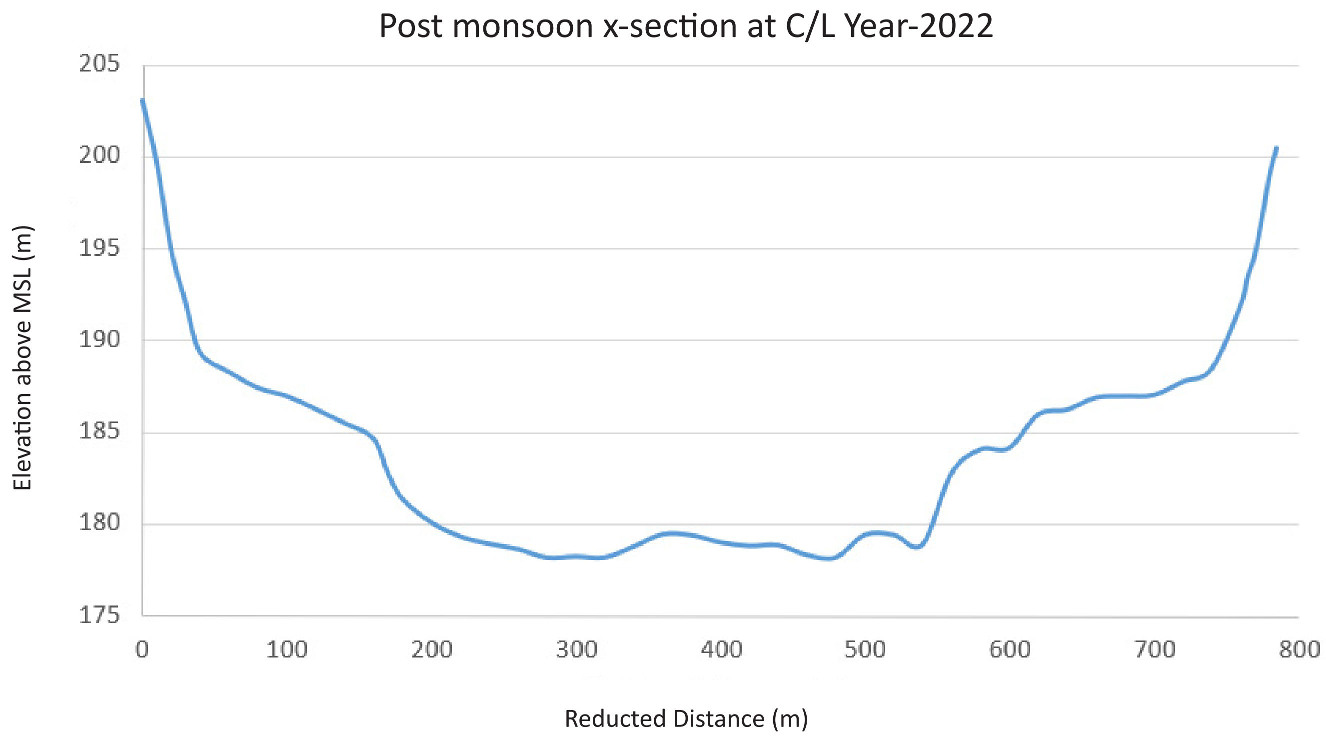


Figure 5: *Cross-Section of River at Pali G&D Site*

Manderial GD Site

Table 3: *10-daily Average flow data at Manderial G&D Site*

Average values in cumec

		June	July	August	Septem-ber	October	No-vember	Dece, mber	January	febru-ary	March	April	May
1990-1991	I	22.1	2672.2	2499.3	3377.7	568.9	139.6	103.9	112.5	93.9	89.3	51.6	34.2
	II	29.2	928.9	1419.8	2547.4	402.2	111.9	103.2	97.8	90.1	78.6	42.6	31.9
	III	42.5	588.6	1984.7	1668.3	142.1	97.3	107.6	94.1	82.3	63.4	38.8	29.3
1991-1992	I	36.8	37.9	2759.9	3001.9	115.2	81.4	71.7	87.4	88.6	66.8	65.3	57.4
	II	54.4	75.4	1132.8	682.2	82.9	75.6	72.3	71.8	77.8	67.0	64.6	44.6
	III	30.7	2794.9	5801.9	232.0	86.9	73.9	85.8	69.9	68.0	68.4	64.3	30.4
1992-1993	I	18.3	66.2	1674.4	1119.1	124.3	246.0	121.3	119.9	114.3	129.0	96.2	60.4
	II	137.0	340.7	3139.3	705.8	744.1	118.1	121.3	120.0	113.5	111.5	76.9	41.1
	III	109.3	1860.2	1594.0	300.6	193.8	119.8	121.0	111.6	112.0	108.6	65.2	34.0
1993-1994	I	36.2	407.1	4794.9	586.0	478.2	175.0	89.1	125.2	129.7	126.5	88.1	45.8
	II	63.8	1605.9	701.6	2601.0	251.7	131.7	122.4	162.0	130.9	117.1	92.7	34.9
	III	429.1	589.2	663.3	2010.1	203.9	109.4	124.0	133.0	128.6	95.5	78.1	33.4
1994-1995	I	32.0	3597.8	5577.7	3660.9	202.5	188.6	89.1	148.0	160.0	89.0	153.6	52.5
	II	42.8	879.5	2925.6	1050.4	199.5	159.9	147.7	98.9	101.3	177.3	123.2	45.9
	III	218.8	2541.2	3083.4	477.6	197.9	123.8	197.7	106.4	91.7	168.8	79.5	40.3
1995-1996	I	50.5	159.0	3155.0	6530.7	220.5	166.4	155.3	204.1	178.5	156.3	122.1	152.5
	II	180.2	229.6	631.0	707.8	180.4	158.9	172.7	208.1	165.5	144.2	109.0	152.4
	III	95.1	1009.0	3882.1	392.4	181.1	149.8	178.7	206.7	155.0	137.0	147.5	139.4
1996-1997	I	174.0	160.4	2961.5	8463.0	317.2	216.8	164.0	170.8	156.2	142.0	140.9	149.9
	II	162.6	285.6	1536.4	2888.0	260.2	195.0	172.0	157.1	160.5	132.5	110.9	108.9
	III	129.6	5748.2	23577.3	652.2	234.4	170.6	172.7	158.7	159.4	141.9	152.5	119.0
1997-1998	I	86.1	490.1	2701.1	1711.2	378.0	238.0	971.8	387.2	198.2	148.0	138.6	147.3
	II	131.6	499.5	869.7	1296.6	335.7	170.6	1113.1	294.4	179.5	135.8	117.2	169.4
	III	255.5	1104.3	1967.0	694.6	242.7	189.9	499.6	211.0	155.3	140.5	159.4	187.0
1998-1999	I	198.5	390.0	616.9	395.4	457.4	258.7	103.4	112.8	106.1	109.1	105.5	115.5
	II	162.8	2943.0	1493.5	519.4	409.5	288.7	101.2	116.9	118.7	122.1	122.1	92.2
	III	219.7	529.6	685.6	1596.7	659.5	213.5	109.1	124.2	105.6	108.4	122.9	71.0

1999-2000	I	57.5	47.2	2111.1	1136.9	382.5	63.9	37.4	58.5	58.9	57.4	46.6	18.9
	II	126.8	83.8	908.1	1049.4	319.4	40.7	57.5	59.2	58.4	54.6	37.3	18.1
	III	134.6	2066.9	1057.3	556.7	101.2	25.1	61.5	58.8	57.9	53.1	29.7	18.6
2000-2001	I	41.2	59.8	236.4	255.4	47.5	51.1	41.2	23.6	16.0	11.2	8.8	7.0
	II	34.9	217.5	256.8	154.5	39.4	51.0	25.0	25.3	14.8	9.6	8.8	7.2
	III	39.6	3432.6	342.3	86.6	45.0	39.9	14.6	19.3	13.4	9.8	9.5	10.8
2001-2002	I	9.6	4860.9	257.2	84.4	50.2	33.7	41.2	54.1	43.9	32.4	28.7	19.0
	II	87.7	1640.6	3628.5	36.8	50.8	30.1	46.4	64.2	48.9	28.6	25.0	14.8
	III	343.0	1061.4	484.5	38.1	39.5	33.8	47.0	57.1	39.1	34.0	23.1	12.6
2002-2003	I	13.5	85.2	160.5	1476.6	44.1	53.6	28.7	12.1	10.3	8.9	10.8	19.5
	II	10.4	43.6	835.6	408.8	49.2	50.2	20.6	10.9	9.7	8.3	12.5	24.2
	III	29.2	33.0	185.0	68.3	53.9	40.9	14.9	10.5	10.3	9.4	16.7	22.4
2003-2004	I	26.1	299.9	542.5	1818.1	1000.8	19.7	24.9	48.3	81.6	23.0	8.9	3.0
	II	28.9	633.3	1595.5	440.5	110.8	12.1	35.3	37.1	40.8	13.1	6.5	2.6
	III	91.4	1081.9	736.7	813.3	45.2	12.2	42.5	49.1	37.3	11.3	4.7	2.0
2004-2005	I	1.8	17.5	1068.6	289.3	131.5	94.4	74.8	84.5	90.0	91.6	33.2	14.0
	II	1.8	27.6	7775.7	167.6	144.3	54.6	80.7	78.8	80.1	90.6	22.0	6.8
	III	38.5	19.4	11047.3	129.9	123.0	61.4	79.9	90.9	57.0	47.1	18.1	4.4
2005-2006	I	7.3	2377.2	1203.0	63.3	125.5	65.4	68.1	36.4	78.6	53.7	14.4	9.6
	II	7.1	4005.0	218.8	577.6	64.1	46.5	69.5	68.9	84.9	25.9	13.7	6.4
	III	17.7	1013.6	126.8	297.6	55.0	61.4	64.1	83.8	75.3	18.6	11.2	6.8
2006-2007	I	14.2	68.8	3710.0	21048.9	248.7	154.1	148.9	150.7	152.3	151.7	111.0	134.0
	II	17.0	31.0	17432.3	634.0	190.9	142.1	149.5	162.6	167.0	142.1	166.5	110.7
	III	20.6	439.0	7386.2	355.4	171.1	147.2	145.8	153.2	138.5	127.0	142.1	140.7
2007-2008	I	173.1	1410.5	1348.5	505.6	163.3	36.8	47.0	45.5	46.6	36.0	28.6	13.3
	II	200.6	1522.7	607.9	289.5	71.6	29.2	47.7	44.1	43.1	40.7	23.2	9.9
	III	380.3	444.2	381.3	163.1	51.6	32.8	41.0	45.7	39.2	40.6	15.9	7.7
2008-2009	I	11.3	733.4	1406.7	207.4	171.8	74.4	98.7	116.6	101.0	45.3	20.1	14.5
	II	508.4	1203.2	824.0	514.2	102.5	66.0	99.0	112.9	103.3	30.6	16.3	14.0
	III	824.0	486.9	281.6	395.3	76.7	88.9	110.1	104.4	64.0	23.9	11.2	16.2

2009-2010	I	13.9	16.7	122.1	256.7	116.7	22.4	28.7	35.2	22.9	16.2	10.3	7.0
	II	15.5	290.1	159.4	295.4	100.5	28.1	18.8	37.3	21.3	13.4	9.3	6.9
	III	32.4	1207.3	112.1	70.7	28.5	30.7	22.3	31.7	19.1	11.6	7.8	6.4
2010-2011	I	5.9	13.8	0.0	0.0	0.0	0.0	218.5	101.5	127.4	39.5	15.5	8.0
	II	5.9	1.9	0.0	0.0	0.0	0.0	114.7	168.3	113.4	28.9	15.0	6.7
	III	6.0	0.0	0.0	0.0	0.0	0.0	88.2	225.5	77.0	17.6	13.4	6.1
2011-2012	I	10.5	929.2	4588.0	3075.0	51.5	37.1	39.9	47.9	13.0	11.7	11.5	11.3
	II	10.7	1063.0	1280.0	2109.0	46.2	32.4	39.9	42.1	13.6	11.7	11.4	11.3
	III	3518. 3	1302.7	1172.7	237.9	43.6	40.3	43.9	37.1	13.5	11.7	11.4	11.3
2012-2013	I	11.0	121.1	1514.5	1348.1	339.0	146.0	166.0	82.2	81.6	9.8	9.6	10.7
	II	11.0	452.0	1725.7	1222.0	222.5	141.0	182.0	81.5	80.2	9.7	9.4	10.8
	III	11.0	360.0	2668.5	495.0	182.7	157.0	162.7	80.0	89.3	9.8	9.1	10.3
2013-2014	I	47.6	654.6	8506.2	672.4	255.9	105.9	83.8	98.4	90.7	94.2	71.1	56.6
	II	59.2	1721.4	11965.7	121.3	495.7	83.4	86.2	89.8	85.5	89.7	59.8	55.0
	III	239.4	12509.1	14294.2	254.4	149.1	81.6	90.7	103.0	88.5	87.6	58.0	52.9
2014-2015	I	48.3	53.2	8148.2	370.3	111.9	84.8	82.0	100.1	85.6	91.3	40.6	20.8
	II	52.7	60.2	3801.5	969.5	80.2	83.1	88.5	98.0	81.4	111.3	25.0	18.8
	III	53.6	719.8	278.5	184.4	89.0	83.8	93.7	101.7	81.0	85.0	22.6	17.1
2015-2016	I	15.9	77.3	2344.4	490.1	119.4	54.2	55.8	62.5	68.6	61.1	52.6	44.4
	II	13.5	107.3	3210.3	365.5	66.7	52.6	68.1	69.4	68.0	62.5	48.4	40.0
	III	54.4	4809.1	874.4	254.2	57.2	52.0	60.8	65.4	65.4	61.8	48.0	36.1
2016-2017	I	35.1	293.9	2687.5	1518.5	263.0	61.1	87.4	83.8	93.5	76.0	77.5	69.3
	II	36.0	1682.6	2457.0	398.7	239.4	58.4	86.9	93.2	89.6	87.8	74.2	69.5
	III	36.9	560.9	3988.2	321.7	89.9	71.2	84.0	93.1	89.0	83.0	72.3	69.5
2017-2018	I	40.9	159.2	687.9	350.1	216.9	49.1	58.2	68.8	75.1	66.0	38.0	22.9
	II	46.0	86.9	716.8	130.3	153.0	32.5	69.4	76.1	74.1	66.6	32.4	21.8
	III	47.0	707.8	277.5	346.4	100.1	29.3	68.8	83.2	71.3	55.6	25.6	18.7
2018-2019	I	14.1	73.7	219.0	1803.0	192.3	71.7	65.5	92.2	93.2	68.0	34.3	19.7
	II	24.4	244.3	184.5	926.0	211.8	56.2	69.5	79.2	95.8	68.3	23.1	13.8
	III	23.5	1265.0	863.6	300.5	85.4	60.4	85.8	82.5	83.2	60.4	22.4	9.4

2019-2020	I	6.2	113.0	2025.5	4306.4	2845.1	296.2	150.4	132.8	111.1	90.6	77.4	18.2
	II	6.5	162.5	12114.2	29305.5	561.5	302.7	147.1	137.9	110.3	87.2	23.7	17.4
	III	10.5	1133.3	4630.5	6160.0	368.1	231.0	148.2	128.5	95.8	92.5	20.0	14.0
2020-2021	I	13.9	212.9	185.5	3711.4	276.1	62.6	94.1	129.6	63.7	57.6	27.4	13.3
	II	12.8	244.3	583.8	503.7	95.3	73.4	81.0	115.5	71.5	64.6	17.9	16.3
	III	35.4	221.9	3919.0	796.3	98.2	92.6	79.5	43.8	71.3	51.8	15.4	14.6
2021-2022	I	10.9	10.3	28153.1	922.4	850.1	194.1	107.0	149.9	124.8	87.3	40.6	26.2
	II	12.1	119.1	2632.5	2202.6	635.4	140.0	109.3	126.0	110.7	91.0	29.2	72.9
	III	12.9	2611.9	1171.1	2112.7	707.6	180.0	137.7	132.5	98.0	87.0	23.9	79.6

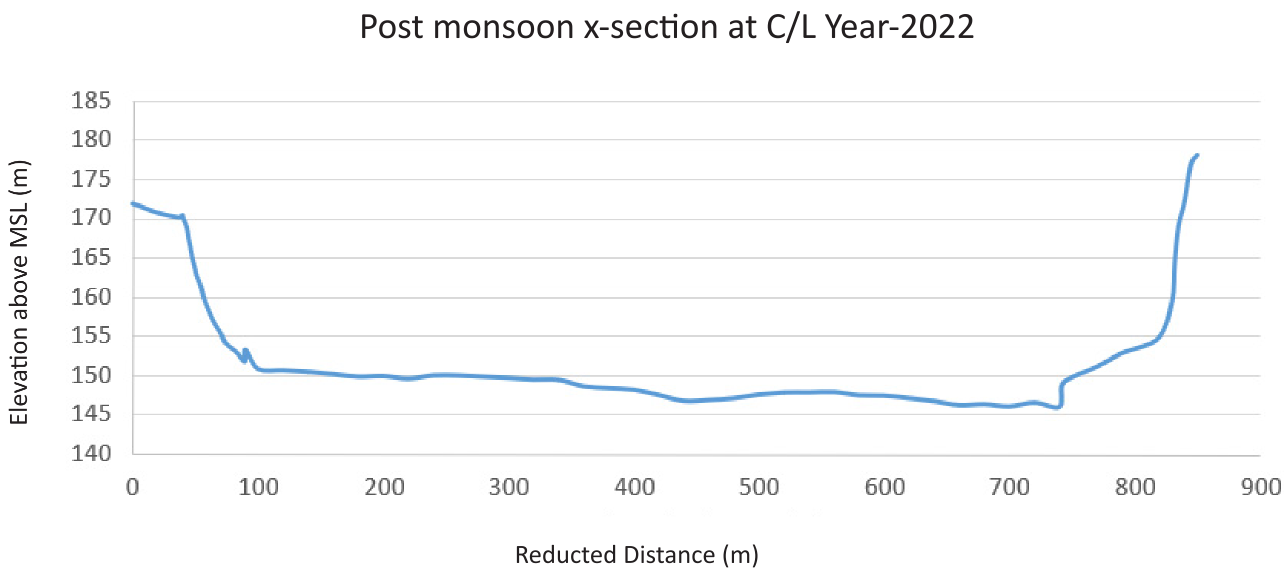


Figure 6: *Cross-Section of River at Manderial G&D Site*

Dholpur GD Site

Table 4: *10-daily Average flow data at Dholpur G&D Site*

Average values in cumec

		June	July	August	September	October	November	Dece, mber	January	february	March	April	May
1990-1991	I	51.9	4738.2	3211.4	4418.2	1854.9	423.5	297.6	248.7	162.4	157.4	116.8	67.6
	II	67.8	1339.5	2378.3	5391.6	900.7	345.3	290.0	222.7	133.6	116.0	98.1	64.7
	III	90.2	1439.9	3050.8	4697.6	577.7	282.6	246.5	184.4	126.6	110.1	76.1	61.1
1991-1992	I	58.7	60.5	3390.5	4048.4	222.8	133.0	73.4	66.8	111.5	90.8	94.0	73.1
	II	149.2	74.5	855.1	686.5	182.4	100.9	70.5	66.5	108.3	92.1	81.3	73.1
	III	101.5	4389.0	8846.1	312.4	153.2	79.8	71.7	63.9	95.7	111.1	74.3	72.5
1992-1993	I	56.4	83.4	1980.1	2009.1	266.3	182.5	151.1	126.4	120.2	134.5	109.9	40.5
	II	122.4	369.7	3725.1	1621.5	1215.3	134.1	151.3	122.0	118.5	121.3	105.6	28.2
	III	111.3	2236.8	2772.4	507.8	281.7	152.6	128.8	119.7	117.1	111.6	83.4	22.6
1993-1994	I	21.3	534.2	3619.3	837.7	1175.2	212.3	77.5	87.5	80.0	52.8	68.7	63.1
	II	24.3	2947.2	1237.2	2692.8	394.1	132.4	88.0	218.1	62.4	75.5	67.9	62.9
	III	569.7	990.4	1003.7	3833.6	254.3	105.7	98.6	91.5	60.9	73.6	66.4	61.7
1994-1995	I	61.7	3305.0	6262.0	5866.5	511.7	238.7	126.7	136.2	133.0	99.2	131.2	43.0
	II	57.8	1955.8	5736.2	2674.3	349.0	181.1	116.0	160.2	140.5	136.5	108.9	37.8
	III	505.0	4929.1	5407.2	1287.3	287.3	143.4	139.2	224.3	109.8	163.3	62.6	35.1
1995-1996	I	44.9	136.2	3963.3	6131.2	312.6	209.5	131.8	214.7	180.6	154.5	119.1	203.9
	II	146.0	519.5	1459.8	1118.8	235.8	155.3	161.2	245.3	167.5	135.2	86.1	163.0
	III	105.3	1922.6	4193.5	524.1	228.4	143.2	211.8	231.0	148.7	124.3	102.6	126.5
1996-1997	I	130.5	115.1	3751.4	10858.7	579.8	253.8	223.2	231.5	200.2	191.7	186.6	187.0
	II	149.9	253.2	2220.5	4338.8	495.0	194.3	205.2	197.5	268.5	183.0	104.7	102.7
	III	149.9	253.2	2220.5	4338.8	495.0	194.3	205.2	197.5	268.5	183.0	104.7	102.7
1997-1998	I	104.4	402.5	3068.6	1858.0	350.6	239.6	523.4	284.3	164.8	125.2	125.9	149.0
	II	208.6	620.8	1217.0	1613.0	305.8	183.8	1653.5	230.8	146.3	121.6	103.7	188.5
	III	231.6	1076.2	1944.9	832.9	252.4	182.5	421.6	183.1	132.8	125.2	157.6	218.9
1998-1999	I	212.6	331.0	656.3	438.3	664.1	262.5	143.0	153.3	158.2	164.1	140.2	179.4
	II	196.4	3026.0	1738.6	677.6	384.1	207.4	121.4	177.2	179.2	179.9	190.1	146.0
	III	179.8	585.0	735.2	2453.0	442.8	162.0	152.2	193.1	160.1	164.6	203.8	95.8

1999-2000	I	74.2	200.5	3696.6	2307.7	1285.0	321.7	139.6	106.1	109.7	106.3	94.9	88.7
	II	158.0	253.7	2038.9	2541.3	1012.1	222.6	302.2	109.2	107.3	105.0	92.3	54.9
	III	277.9	3692.8	1075.4	1516.0	494.7	146.7	146.4	106.3	105.0	98.2	92.7	46.6
2000-2001	I	62.2	107.2	747.0	790.1	110.7	71.4	82.6	55.5	50.4	43.9	37.4	34.0
	II	70.5	914.7	721.5	358.1	67.3	75.1	100.3	55.6	47.0	42.3	34.2	29.0
	III	53.7	7660.2	1093.9	182.8	62.3	80.7	74.2	54.5	44.5	39.6	35.9	41.9
2001-2002	I	43.8	5644.5	510.1	312.5	113.9	82.2	81.5	95.1	91.6	68.9	48.8	39.8
	II	156.1	2740.0	4892.9	180.2	109.7	71.4	91.5	94.8	87.0	57.4	45.7	37.3
	III	625.8	2211.4	1259.4	110.7	97.8	69.3	95.8	101.3	80.6	51.8	43.1	35.0
2002-2003	I	38.2	117.3	187.6	1307.4	50.5	21.2	8.2	9.9	9.4	10.3	8.5	4.5
	II	38.7	90.3	958.1	479.5	25.2	20.7	7.7	9.9	11.1	10.1	7.9	4.5
	III	38.3	70.1	361.9	144.0	18.8	9.3	8.8	8.7	11.3	9.5	5.9	5.2
2003-2004	I	5.4	271.5	586.6	2343.0	969.0	127.1	86.2	162.6	118.0	54.2	12.6	7.7
	II	5.5	886.7	2020.4	673.6	226.7	102.9	102.3	133.3	81.7	31.9	10.1	7.1
	III	18.8	1428.8	546.4	1702.7	166.3	70.2	157.0	118.6	69.7	13.6	7.9	7.2
2004-2005	I	7.2	14.2	1286.7	802.3	178.7	146.6	84.7	149.3	151.3	88.6	77.4	18.3
	II	7.1	81.6	5480.9	437.7	284.6	103.4	88.6	141.5	134.5	101.6	65.1	15.8
	III	11.2	84.1	7074.8	208.1	218.2	82.6	100.3	146.2	95.6	94.5	43.7	13.3
2005-2006	I	12.1	1618.5	962.4	228.9	435.8	218.6	83.5	78.7	58.2	97.8	52.2	30.7
	II	12.1	2704.5	371.5	411.9	362.5	175.3	87.4	59.6	65.0	90.4	45.4	26.7
	III	13.6	759.3	326.7	557.0	236.4	98.5	85.3	51.6	97.2	63.9	34.3	24.9
2006-2007	I	33.8	73.5	2092.5	13324.4	504.9	166.1	103.3	106.9	108.1	93.6	54.2	80.4
	II	37.4	64.0	11817.1	1268.3	440.8	99.2	107.7	114.7	106.2	84.3	125.7	84.8
	III	49.5	550.4	6246.5	657.5	260.5	97.2	102.6	113.7	87.4	71.8	160.7	107.9
2007-2008	I	217.6	2066.7	1197.7	945.9	349.3	104.8	114.2	112.9	125.5	105.6	79.8	31.1
	II	242.0	2335.3	1201.7	643.6	199.8	81.1	118.9	121.3	121.9	106.6	45.6	16.8
	III	507.9	812.7	694.9	310.3	146.8	83.7	105.3	124.1	111.1	114.4	34.5	10.2
2008-2009	I	13.9	1219.3	2453.6	389.7	199.7	36.0	92.2	122.4	120.0	28.8	16.6	10.9
	II	646.5	2134.5	1753.1	705.4	79.3	45.8	94.2	126.3	112.8	22.6	12.7	10.2
	III	1182. 8	642.1	491.3	878.9	41.6	68.9	112.1	117.9	63.1	19.2	10.6	10.1

2009-2010	I	8.9	16.2	208.5	524.9	135.1	35.1	72.8	65.9	34.7	16.4	7.8	6.7
	II	8.2	339.9	270.2	690.9	201.6	43.5	41.4	72.3	25.9	12.0	6.9	5.8
	III	8.2	1659.0	205.4	128.9	61.0	75.3	41.0	65.9	20.7	9.1	5.5	5.3
2010-2011	I	3.6	24.5	369.8	596.1	81.7	29.7	105.9	75.9	72.0	23.9	16.0	8.6
	II	6.1	96.2	452.3	557.5	38.0	58.5	88.7	50.0	63.5	20.2	14.5	7.7
	III	7.3	165.8	723.0	139.4	29.1	151.0	75.3	64.9	29.8	17.9	10.7	7.8
2011-2012	I	7.0	2561.8	5816.1	4641.2	207.3	77.3	64.2	90.9	42.2	66.7	56.1	27.3
	II	6.4	1585.7	3203.2	2896.2	114.2	56.4	71.6	53.1	49.5	63.7	37.3	22.5
	III	4915. 4	3245.3	2441.7	617.0	70.0	50.5	74.0	44.7	75.0	65.5	30.7	19.1
2012-2013	I	17.3	69.9	2011.6	1854.4	181.1	49.0	65.4	69.2	73.9	77.5	62.4	26.9
	II	17.6	538.1	1915.0	1810.1	104.7	42.7	55.9	73.2	73.8	65.9	45.4	23.7
	III	15.8	371.4	2572.7	638.4	68.7	54.1	57.9	81.2	77.9	59.0	28.7	18.3
2013-2014	I	16.1	962.4	9304.5	1256.8	469.4	142.1	123.1	127.9	108.3	163.4	77.0	49.7
	II	31.7	2202.6	10308.8	387.3	621.5	115.4	114.2	123.6	109.9	119.7	47.9	38.5
	III	131.8	7954.9	13097.1	495.8	248.2	119.1	119.3	167.9	118.5	112.4	52.5	34.5
2014-2015	I	31.0	22.4	6019.7	874.3	193.4	148.5	146.7	168.9	146.0	157.6	82.6	43.0
	II	23.8	31.4	4741.1	1750.7	145.6	141.2	160.2	162.5	145.6	169.2	59.8	41.6
	III	22.4	1264.1	608.4	432.6	146.9	141.6	160.2	181.3	144.1	175.3	50.0	31.7
2015-2016	I	21.6	204.1	4910.1	967.1	199.9	148.9	155.2	156.3	151.0	104.8	57.2	34.9
	II	25.1	399.1	8272.0	342.4	164.4	147.9	151.8	156.9	123.9	112.3	45.8	21.9
	III	122.5	11983.5	1832.3	255.5	150.8	152.4	148.6	154.0	112.1	102.6	39.1	11.3
2016-2017	I	11.0	654.7	4926.3	2949.2	636.1	228.1	221.5	213.8	191.3	178.8	121.6	18.9
	II	12.8	2672.6	4959.2	879.7	640.4	216.9	221.6	215.5	171.9	169.9	86.9	19.1
	III	28.5	1028.1	7944.2	782.6	307.7	198.8	221.5	199.1	163.7	168.0	59.9	18.7
2017-2018	I	19.2	177.0	611.6	248.7	238.7	86.4	50.6	69.6	87.6	95.5	47.7	19.6
	II	19.2	133.5	968.5	200.7	182.8	47.7	61.3	87.7	87.9	99.7	41.1	18.6
	III	19.8	576.5	229.7	521.1	135.7	47.6	67.0	88.7	83.5	97.2	25.4	15.4
2018-2019	I	12.3	125.0	357.6	3439.3	304.2	83.1	89.8	102.1	97.5	82.3	49.1	25.7
	II	17.5	302.9	409.0	1690.9	166.4	88.4	89.2	94.8	103.8	71.7	29.3	24.3
	III	14.1	2438.5	1497.4	633.7	110.3	89.8	91.0	94.7	95.3	66.0	27.2	21.1

2019-2020	I	14.1	2438.5	1497.4	633.7	110.3	89.8	91.0	94.7	95.3	66.0	27.2	21.1
	II	13.0	216.1	6830.0	28827.5	910.5	249.3	140.7	138.3	147.8	104.7	55.5	37.4
	III	12.1	993.3	4133.9	5231.0	426.5	184.8	133.5	149.4	140.7	98.7	49.7	29.0
2020-2021	I	24.5	226.7	239.4	3167.1	460.0	88.2	118.6	103.4	62.6	61.6	46.5	14.7
	II	25.6	320.1	783.5	738.3	196.9	86.0	99.8	143.3	67.8	80.6	22.7	21.9
	III	51.6	307.8	3035.9	945.6	129.8	89.3	103.9	47.8	75.6	76.1	16.3	17.8
2021-2022	I	13.4	15.0	19840.4	1097.5	1080.2	277.7	147.7	146.3	91.7	58.6	31.9	14.8
	II	16.8	34.0	2817.8	2414.8	659.0	202.1	130.0	93.8	76.6	54.9	18.9	38.0
	III	14.5	2219.4	1377.6	2651.9	970.4	229.4	166.4	103.7	69.7	56.0	16.7	40.2

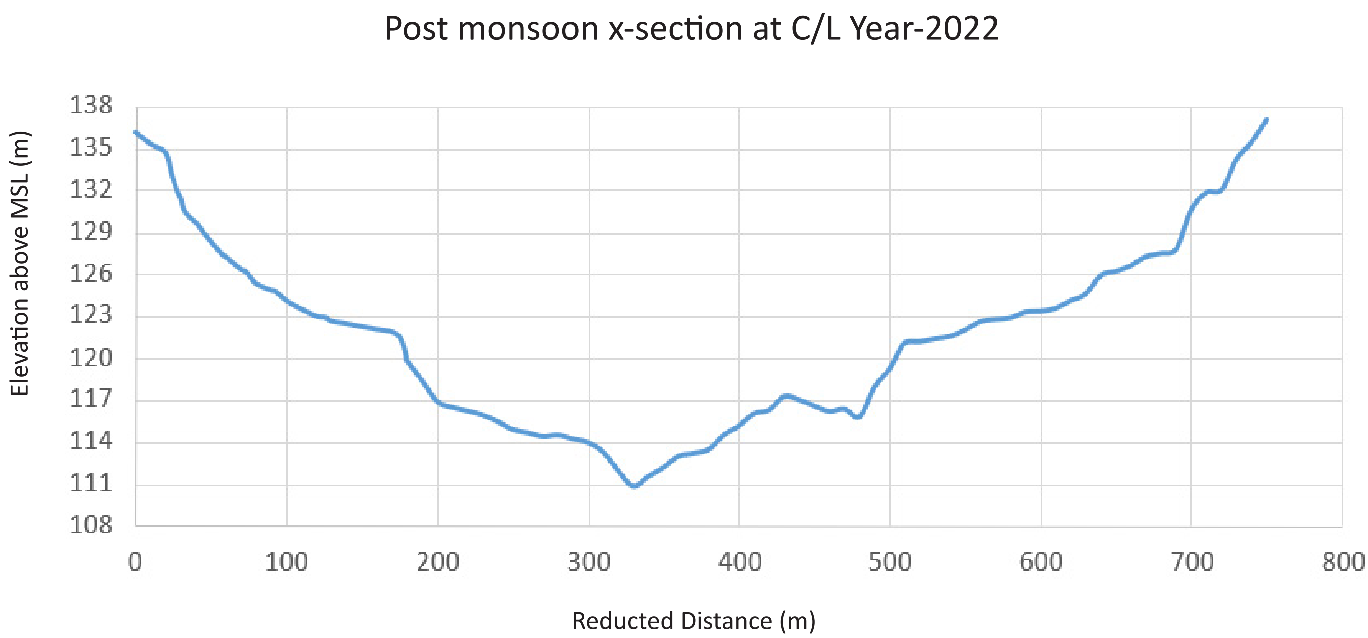


Figure 7: *Cross-Section of River at Dholpur G&D Site*

Udi GD Site

***Table 5:** 10-daily Average flow data at Udi G&D Site*

		June	July	August	Septem-ber	October	No-vember	Dece, mber	January	febru-ary	March	April	May
1990-1991	I	15.5	3369.1	2576.7	3922.3	1249.8	184.8	122.9	113.2	91.6	117.3	81.2	37.5
	II	17.8	841.6	2626.7	3668.8	501.7	149.6	121.3	106.5	101.0	100.6	77.3	29.1
	III	30.6	1659.8	2802.5	3002.5	271.3	118.3	113.5	99.9	100.1	84.2	50.3	26.1
1991-1992	I	23.6	35.6	4306.6	3635.4	295.0	99.7	76.4	103.0	115.6	70.4	65.9	34.2
	II	59.4	51.7	880.3	1060.7	169.7	89.2	88.6	103.6	105.0	64.2	50.7	37.2
	III	26.8	4952.8	11707.8	569.0	126.9	83.3	106.2	102.5	84.9	84.6	35.8	28.2
1992-1993	I	24.8	87.3	2045.3	1939.7	246.6	159.1	109.0	97.5	94.6	113.3	91.4	41.0
	II	75.6	249.9	3868.5	1656.8	1219.0	121.8	104.7	100.2	97.9	102.2	70.3	33.9
	III	148.7	2094.2	2860.9	466.3	269.1	112.5	99.0	93.9	89.7	92.3	54.7	27.6
1993-1994	I	25.3	410.9	4215.9	847.2	1230.5	187.1	108.0	102.5	106.2	79.1	57.7	35.0
	II	29.8	2167.8	1410.8	2566.6	341.9	146.7	125.5	126.6	99.3	70.3	55.9	30.6
	III	311.9	1434.0	1184.8	5335.1	229.3	123.0	111.9	138.8	87.0	64.0	42.8	28.1
1994-1995	I	23.0	3087.2	5249.8	4803.2	698.8	206.0	130.9	133.7	130.7	88.1	106.9	51.5
	II	23.8	1332.5	4792.1	3074.9	251.2	177.2	146.6	178.3	116.5	138.0	87.1	73.7
	III	324.7	4204.7	4684.5	1445.2	236.0	125.7	171.4	157.3	107.4	151.7	62.5	52.9
1995-1996	I	45.4	94.7	3231.8	6571.3	437.7	220.1	132.8	226.0	198.3	130.4	122.5	144.3
	II	149.0	372.6	2058.3	1515.7	296.7	177.2	166.4	230.7	157.8	122.3	91.3	185.6
	III	105.0	1683.0	3507.2	628.2	230.2	140.9	207.6	229.8	140.5	124.8	88.1	131.3
1996-1997	I	106.0	101.2	4418.0	10523.7	650.6	327.9	176.2	143.0	121.7	84.0	93.3	123.5
	II	161.1	192.1	2502.5	6002.8	480.0	285.6	168.6	129.3	120.9	66.9	78.2	68.2
	III	169.1	4583.2	19613.6	2263.1	361.7	209.5	163.8	133.8	84.3	63.3	77.9	98.6
1997-1998	I	69.4	217.6	2386.5	2072.1	390.2	182.6	259.1	315.6	141.6	139.9	144.9	145.6
	II	102.0	523.6	1787.2	1634.7	279.4	160.0	1901.0	234.9	132.8	146.4	139.6	156.6
	III	153.1	843.9	1885.5	762.8	189.6	140.6	526.6	144.0	125.5	149.0	138.3	178.3
1998-1999	I	184.9	440.6	609.1	637.6	841.7	250.3	121.9	118.1	112.0	106.5	108.7	99.6
	II	177.0	3834.7	1937.5	529.5	368.5	175.2	109.7	118.4	122.1	113.5	120.7	99.4
	III	138.9	842.3	859.7	2684.4	631.8	138.7	122.7	122.3	121.5	112.4	133.6	70.2

1999-2000	I	62.3	175.2	4746.2	2276.6	1256.8	306.3	109.9	99.1	102.7	75.7	71.6	58.9
	II	88.0	187.2	2427.6	2594.0	1001.7	226.3	246.4	106.6	101.5	84.8	67.4	46.2
	III	178.9	4570.8	1015.9	1448.6	542.7	138.9	158.0	97.8	85.3	73.1	60.9	36.2
2000-2001	I	79.8	60.8	1318.5	795.0	146.8	98.6	100.4	55.3	41.1	21.3	17.3	17.0
	II	65.4	1009.2	700.0	510.5	104.5	98.4	95.3	56.8	26.8	21.7	17.2	14.9
	III	43.7	12394.3	1412.8	230.3	96.0	97.6	61.7	52.8	23.6	19.4	19.3	16.7
2001-2002	I	25.4	5996.9	982.2	364.3	74.8	52.8	47.6	56.5	68.9	54.6	23.0	19.6
	II	26.3	2983.6	4496.3	200.1	77.3	45.6	57.2	75.9	64.2	49.8	20.5	17.6
	III	723.4	2165.1	1837.1	98.1	70.7	40.8	57.9	88.4	58.1	28.0	20.4	15.5
2002-2003	I	17.9	55.5	29.8	1021.7	58.6	19.5	11.3	11.6	8.5	8.4	4.3	6.7
	II	15.3	53.1	598.7	649.0	33.6	14.8	9.3	10.1	8.2	6.6	6.9	6.5
	III	15.6	23.5	307.0	172.7	23.7	11.9	8.8	9.5	8.1	5.6	7.2	6.1
2003-2004	I	5.8	156.5	665.5	2112.1	1016.0	78.6	35.4	62.3	57.4	24.0	13.8	19.4
	II	4.0	582.5	1341.6	980.8	254.8	50.3	56.3	55.5	47.1	16.0	14.7	13.0
	III	9.5	956.0	503.6	1312.8	136.1	38.2	56.0	52.9	39.3	12.6	13.0	10.9
2004-2005	I	10.9	156.1	895.3	812.5	137.8	72.2	67.0	88.9	97.0	54.6	35.5	21.6
	II	8.4	74.5	4186.2	392.9	204.2	44.9	97.9	68.9	74.1	88.3	27.7	21.0
	III	32.7	78.1	5769.5	176.6	132.6	46.2	97.8	94.7	57.6	53.0	23.3	14.9
2005-2006	I	13.2	1418.5	1067.9	109.2	212.8	60.8	59.5	46.1	57.4	59.5	52.2	13.9
	II	11.8	2746.1	323.3	237.9	106.4	54.0	60.6	42.8	67.4	53.2	22.0	11.4
	III	12.8	735.0	256.8	390.8	85.5	48.4	67.1	57.9	62.0	41.8	17.1	11.7
2006-2007	I	11.8	46.2	2138.9	10288.4	417.0	141.0	85.1	81.2	78.3	71.2	43.6	52.3
	II	18.1	64.2	6753.3	1840.8	261.3	90.8	82.7	84.7	91.0	66.0	33.4	72.0
	III	31.3	335.2	5456.7	735.3	180.8	84.4	76.4	82.2	76.5	54.2	84.3	38.2
2007-2008	I	119.0	925.3	649.7	524.5	202.4	48.5	34.9	28.6	68.0	48.3	44.1	23.4
	II	82.3	2416.6	907.3	507.2	100.0	37.8	40.4	38.2	63.5	44.7	38.9	17.2
	III	235.2	536.2	351.9	172.4	65.6	29.1	32.0	58.4	52.1	48.6	28.8	16.2
2008-2009	I	16.3	1056.3	1522.8	153.4	121.6	59.5	72.5	74.8	67.6	49.0	15.2	13.7
	II	138.3	1685.3	973.1	280.0	37.4	52.0	74.6	75.5	61.6	33.1	14.2	11.6
	III	893.3	215.5	259.2	549.4	69.1	52.6	74.9	72.6	63.6	17.5	12.9	10.3

2009-2010	I	9.3	12.4	133.5	247.1	97.2	45.5	50.0	22.4	21.5	10.5	6.5	7.3
	II	7.1	26.1	105.8	398.4	144.5	31.2	36.6	37.7	13.7	12.0	8.5	7.1
	III	6.8	1074.3	198.8	134.3	65.7	52.0	16.6	37.8	10.8	14.1	8.0	6.5
2010-2011	I	5.3	11.3	295.0	732.0	382.9	22.3	40.7	27.5	36.7	16.8	12.7	9.9
	II	4.8	35.7	373.4	973.2	71.2	19.7	33.5	29.1	36.7	14.8	11.4	9.7
	III	4.7	107.8	748.9	832.9	38.2	43.6	33.5	29.6	33.0	13.8	10.5	9.6
2011-2012	I	8.5	3135.5	4043.6	3985.8	219.4	54.3	122.2	128.1	77.9	61.0	46.2	35.6
	II	8.6	675.8	4094.7	1335.4	161.1	121.5	114.4	109.4	73.5	52.5	43.2	19.6
	III	2559. 1	2919.3	2454.9	578.9	86.1	103.4	110.6	99.2	61.7	42.6	41.3	17.2
2012-2013	I	13.9	7.6	1719.5	694.4	149.1	34.9	30.9	23.6	19.5	41.0	32.4	13.4
	II	9.5	204.4	1628.7	1900.8	98.1	34.4	28.0	21.6	18.8	39.3	29.8	11.8
	III	8.1	158.2	2149.6	374.7	48.4	33.8	26.5	19.8	29.4	33.6	21.6	9.8
2013-2014	I	8.9	705.8	7793.0	2034.5	918.4	203.7	97.2	104.7	90.7	113.1	65.4	39.2
	II	8.8	1830.9	7195.7	869.6	878.9	98.2	86.1	81.7	69.9	98.5	48.9	39.5
	III	59.2	5231.6	10155.7	643.7	463.0	88.9	75.6	120.4	95.8	88.2	42.6	35.5
2014-2015	I	32.4	33.6	4693.1	1008.3	284.1	81.7	78.1	101.5	94.7	98.7	61.8	37.9
	II	29.1	33.7	6236.3	2322.5	91.5	68.8	96.8	113.2	80.0	130.9	46.7	28.2
	III	31.5	950.2	1067.5	789.8	82.2	72.0	126.0	129.1	86.9	171.3	39.0	23.2
2015-2016	I	18.2	172.8	4687.0	1192.8	184.8	76.5	72.0	66.2	69.9	59.7	36.1	19.8
	II	16.9	487.4	6390.7	459.3	111.1	67.4	75.9	75.5	63.6	58.4	25.9	16.2
	III	55.5	7875.4	2688.4	245.5	74.2	61.5	70.1	72.1	61.0	56.8	23.3	14.5
2016-2017	I	13.6	308.7	5000.7	4003.3	389.2	144.0	119.6	119.5	122.3	76.0	46.5	24.4
	II	12.1	4339.4	7294.5	935.2	380.6	114.6	124.3	122.4	103.4	72.8	32.1	25.7
	III	26.3	1011.3	7916.3	606.1	199.3	109.2	118.8	121.3	82.4	72.3	27.0	21.0
2017-2018	I	17.4	76.4	990.3	361.2	343.1	72.0	60.7	68.0	63.8	57.1	38.5	22.0
	II	15.2	74.5	953.8	212.9	181.4	49.7	70.9	67.3	63.6	58.2	31.1	16.8
	III	19.4	367.8	258.1	534.8	113.8	38.4	64.6	69.0	60.9	56.8	24.7	12.8
2018-2019	I	8.9	49.3	456.9	2349.6	349.1	68.4	76.5	84.3	82.5	71.3	53.9	24.2
	II	25.8	137.7	376.0	2394.4	165.5	65.3	76.5	77.9	83.0	65.5	42.3	19.0
	III	14.8	2602.5	1661.2	533.4	105.8	63.7	77.7	79.1	79.3	64.5	31.1	15.4

2019-2020	I	13.6	52.5	3424.2	5247.1	5758.7	381.7	200.1	150.2	121.5	100.6	72.4	34.1
	II	11.8	289.7	8673.4	23581.9	1655.7	366.5	164.5	151.4	118.7	87.3	50.1	31.7
	III	19.0	977.9	6089.5	7583.5	699.7	299.9	151.1	150.7	105.1	79.8	40.7	25.0
2020-2021	I	20.5	115.1	175.9	4376.3	482.0	81.2	87.1	90.5	51.9	59.4	36.3	22.6
	II	19.6	263.9	509.2	653.1	171.4	73.1	79.3	159.5	59.3	52.2	25.9	22.0
	III	34.5	244.7	3173.3	817.8	110.8	84.0	83.2	67.3	66.5	56.6	23.5	41.9
2021-2022	I	20.9	18.7	19907.1	821.7	1011.8	240.5	130.6	131.6	107.5	74.4	55.1	26.6
	II	19.8	18.5	4374.0	1433.5	472.0	161.3	101.1	111.0	100.5	68.6	35.2	34.5
	III	19.8	1769.4	1132.0	2683.6	788.3	156.6	110.7	107.4	90.6	71.9	33.4	44.6

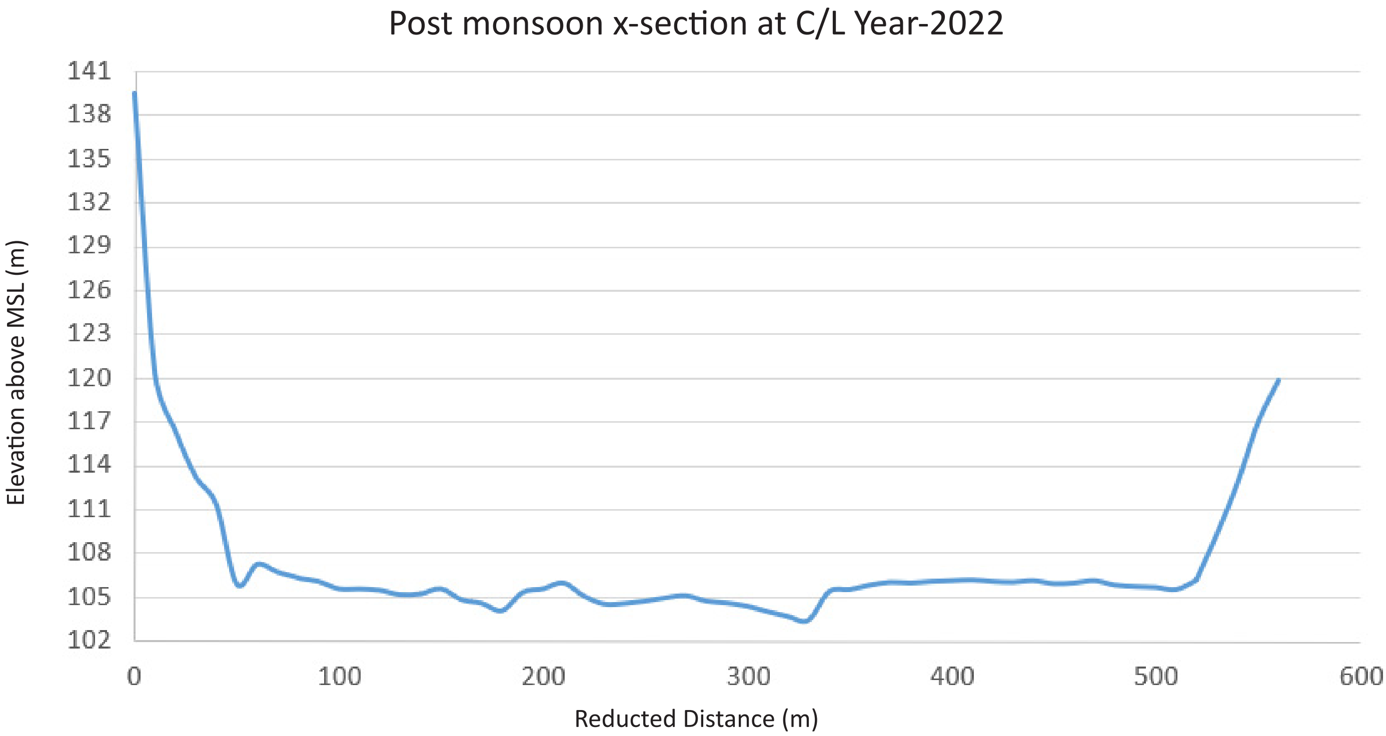


Figure 8: *Cross-Section of River at Udi G&D Site*

Computations for Environmental Flow Assessment

a. As elaborated at point no. 2, suggested methodology requires following data
Assess the aquatic habitat characteristics and ecological status of the identified reaches: This assessment may be carried out by expert agencies such as the Wildlife Institute of India (WII) or the Central Inland Fishery Research Institute (CIFRI) etc. A biodiversity survey would document the baseline ecological status of these reaches and will be of immense value.

b. Identify the critical reach that is likely to be impacted due to any diversion or impoundment of water in the river. In case of hydropower project, such critical reach shall be from point of diversion or dam to outfall of tailrace or joining of a tributary. In case of diversion for consumptive uses like irrigation, the critical reach shall be from the point of diversion or dam till the location where the flow is augmented by a tributary contributing significantly to the river.

c. Take river cross-sections at regular interval say 200 m to 1000 m depending upon variability in river geomorphology.

Therefore, computations will be done when the above data is collected.

REFERENCES

- Acreman, M. C., & Dunbar, M. J., 2004. Defining environmental river flow requirements–a review. Hydrology and Earth System Sciences, 8(5), 861-876.
- Acreman, M.C. and King, J., 2003. Defining water requirements. In: Flow: the essentials of environmental flows, M. Dyson, G. Bergkamp and J. Scalon (Eds), IUCN, Gland Switzerland and Cambridge, UK.
- Ali, S., Ripley, S. D., & Dick, J. H. (1987). Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. 2nd ed. Delhi:Oxford University Press. Pp. i–xlii, 1 l., 1–737, 52 ll.
- Andreadis, K. A., G. J.-P. Schumann, and T. Pavelsky (2013), A simple global river bankfull width and depth database,WaterResour. Res.,49, 7164–7168, doi:10.1002/wrcr.20440.
- Banyal, H. S., & Kumar, S. (2015). Fish diversity of Chambal River, Rajasthan State. Aquatic Ecosystem: Biodiversity, Ecology and Conservation, 271-281.
- Bevilacqua, M.S., Vitório, A., Felix, R.W. et al. Small is better: comparing the efficiency of two Surber samplers' sizes for biomonitoring programs in tropical headwater streams in the Amazon region. Environ Monit Assess 192, 708 (2020). https://doi.org/10.1007/s10661-020-08676-6
- BirdLife International (2023) Species factsheet: Rynchopsalbicollis.http://www.birdlife.org/
- Correa-Araneda, F.; Nunez, D.; Diaz, M.E.; Gomez-Capponi, F.; Figueroa, R.;Acuna, J.; Boyero, L.; Esse, C., (2021). Comparison of sampling methods for benthic macroinvertebrates in forested wetlands. Ecol. Indic., 125(107551): 1-11
- Döll, P., Kaspar, F., Lehner, B. (2003). A global hydrological model for deriving water availability indicators:model tuning and validation. Journal of Hydrology, 270, 105-134.
- Dunbar, M.J., Acreman, M.C., Gustard, A., and Elliot, C.R.N., 1998. Overseas Approaches to setting river flow oblectives. Phase 1 Report to the environment agency. Environment Agency R&D Technical Rport W6-161. 82pp.
- Dyson, M., Bergkamp, G., & Scanlon, J., 2003. Flow: the essentials of environmental flows. IUCN, Gland, Switzerland and Cambridge, UK, 20.
- Grimmett, R., Inskipp, C., &Inskipp, T. (1998). Birds of the Indian Subcontinent. 1stEditio. A&C Black, 548, 549.
- Hails, J.R. (1982). Grab samplers. In: Beaches and Coastal Geology. Encyclopedia of Earth Sciences Series. Springer, New York, NY. https://doi.org/10.1007/0-387-30843-1_212
- Hill, M.T. and Baschta, R.L., 1991. Ecological and geomorphological concepts for instream and out – of- channel flow requirements. Rivers 2, 198-210.
- Wildlife Institute of India, 2011. Assessment of minimum water flow requirements of Chambal River in the context of Gharial (Gavialis gangeticus) and Gangetic Dolphin (Platanista gangetica) conservation.
- Hussain, S.A., 2009. Basking site and water depth selection by gharial GavialisgangeticusGmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary, India and its implication for river conservation. AquatConserv Mar FreshwEcosyst 19:127–133
- Hussain, S. A. (1996). Group size, group structure and breeding in smooth-coated otter LutraperspicillataGeoffroy (Carnivora, Mustelidae) in National Chambal Sanctuary, India.
- Hussain, S. A. (2009). Basking site and water depth selection by gharial GavialisgangeticusGmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary, India and its implication for river conservation. Aquatic Conservation: Marine and Freshwater Ecosystems, 19(2), 127.
- Hussain, S. A. (2013). Activity pattern, behavioural activity and interspecific interaction of smoothcoated otter (Lutrogaleperspicillata) in National Chambal Sanctuary, India. IUCN Otter Specialist Group Bulletin, 30(1), 5-17.
- Hussain, S. A., & Choudhury, B. C. (1997). Distribution and status of the smooth-coated otter Lutraperspicillata in National Chambal Sanctuary, India. Biological Conservation, 80(2), 199-206.
- Hussain, S. A., & Choudhury, B. C., 1992, August. The Gangetic river Dolphin and the status of its habitat in National Chambal Sanctuary. In Proceedings of the Seminar on conservation of river Dolphins of the Indian subcontinent (pp. 18-19).
- Hussain, S. A., Badola, R., Sharma, R., & Rao, R. J., 2013. Planning conservation for Chambal River basin taking gharial Gavialis gangeticus and Ganges River dolphin Platanista gangetica as umbrella species. Faunal Heritage of Rajasthan, India: Conservation and Management of Vertebrates, 135-156.
- Jain, R. K., Goyal, R., &Goldar, D., 2022, March. Study of Sustainability Aspects of Chambal River Linking System Using Reservoir Simulation Techniques. In Environmental Restoration: Proceedings of F-EIR Conference 2021 (pp. 209-229). Cham: Springer International Publishing.

- Johnson, J. A., George, A., Sharma, M., Kavin, D., Sreelekha Suresh, P. C., Gopi, G.V., & Hussain, S. A. (2021). Status of wildlife between Kota Barrage and JawaharSagarDam, Rajasthan, Wildlife Institute of India, Dehradun 59p. Rapid Assessment Report, 4.
- Junk, W.J., Bayley, P.B., and Sparks, R.E., 1989. Theflood pulse concept in river- floodplain systems. Can. J. Fisheries Aquat. Sci., 106, 110-127.
- Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. doi: https://doi.org/10.1038/s41597-019-0300-6
- Mackie, Andrew & Coggan, Roger &Heteren, Sytze. (2007). Grab sampling.
- MESHRAM, P. K. (2010). Diversity of some fauna in National Chambal Sanctuary in Madhya Pradesh, India. Biodiversitas Journal of Biological Diversity, 11(4).
- Nair, A. K. (2009). The status and distribution of major aquatic fauna in the National Chambal Gharial Sanctuary in Rajasthan with special reference to the Gangetic Dolphin Platanistagangeticagangetica (Cetartiodactyla: Platanistidae). Journal of Threatened Taxa, 141-146.
- Nair, T., & Krishna, Y. C. (2013). Vertebrate fauna of the Chambal River basin, with emphasis on the National Chambal Sanctuary, India. Journal of Threatened Taxa, 5(2), 3620-3641.
- Nair, T., 2010. Ecological and anthropogenic covariates influencing gharial Gavialisgangeticus distribution and habitat use in Chambal River, India. Unpublished Master's Thesis.
- Nair, T., 2010. Ecological and anthropogenic covariates influencing gharial Gavialisgangeticus distribution and habitat use in Chambal River, India. Unpublished master's thesis, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore.
- Nair, T., 2017. Of Government, God and Gharial: The Ecological Pogrom in Chambal's Badlands. The Wire.
- Narain, S., Tripathi, A., & Mishra, S. B. (2006). Population ecology of a freshwater turtle Kachuga tentoria near Panchnada(Etawah: U. P.) and its role as water purifier. Journal of Environmental Biology, 27(3), 589-596.
- Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005. Fragmentation and fl ow regulation of the world's large river systems. Science 308:405–408
- Poff, N. L., Allan, J.D., Bain, M.B., Karr, J.R., Pretegaard, K.L., Richter, B.D., et al 1997. The natural flow regime. Bioscience 47, 769-784.
- Rao, K. S., Kartha, K. N., Gupta, D. R., Pandya, S. S., &Iyer, H. K. (1988). Studies on morphometry and hydrology of Gandhisagar reservoir with special reference to its fisheries.
- Rasmussen, P. C., &Anderton, J. C. (2005). Birds of south Asia: the Ripley guide (Vol. 2, pp. 1-378).
- Reiser, D.W., Wesche, T.A., and Estes, C., 1989. Status of Instream flow legislation and Practices in North America, Fisheries, 14, 22-29.
- S.A. Hussain (1993) Aspects of the ecology of smooth coated indian otter Lutraperspicillata, in national Chambal sanctuary.
- PhD thesis, Centre of wildlife and ornithology Aligarh muslim University, Aligarh, India
- Sahu, Nosad& GANESH, Thiruchitrambalam&Lakra, Raj. 2021. Efficiency of sampling gears (Quadrate and Core) and Taxonomic Resolution on the Soft Bottom Intertidal Macrobenthic community of Port Blair coast. RESEARCH JOURNAL OF CHEMISTRY AND ENVIRONMENT. Vol. 25(11). 10.25303/2511rjce93103.
- Saksena, D., Garg, R. K., & Rao, R. J., 2008. Water quality and pollution status of Chambal river in National Chambal sanctuary, Madhya Pradesh. Journal of Environmental Biology, 29(5), 701–71.
- Sharma, A., &Mathur, A. K., 2022, October. Chambal River Water Quality Assessment at Kota Metropolis Through the Irrigation Water Quality Indices from 2017-2021. In IOP Conference Series: Earth and Environmental Science (Vol. 1084, No. 1, p. 012051). IOP Publishing.
- Sharma, R. K., & Singh, L. A. K. (2014). Status of Gangetic Dolphin (Platanistagangetica) in National Chambal Sanctuary after thirty years. Zoos' Print Magazine, 29(7), 22-27.
- Singh, C. P., Chauhan, R. R. S., & Mishra, S. B. (2014). Status, Habitat and distribution pattern of the Gangetic dolphin
- (Platanistagangetica) in National Chambal sanctuary, Uttar Pradesh. India. Journal of Entomology and Zoology Studies, 2(3), 179-181.

- Singh, H. (2010). Habitat characteristics population dynamics and conservation of aquatic mammals (Dolphin and otter) in National Chambal Sanctuary, Madhya Pradesh, India (Doctoral dissertation, Ph. D. thesis submitted to Jiwaji University. Gwalior, Madhya Pradesh, India).
- Singh, H., & Rao, R. J. (2017). Status, threats and conservation challenges to key aquatic fauna (crocodile and dolphin) in National Chambal Sanctuary, India. Aquatic Ecosystem Health & Management, 20(1-2), 59-70.
- Sinha, R. K., & Kannan, K. (2014). Ganges River dolphin: an overview of biology, ecology, and conservation status in India. Ambio, 43, 1029-1046.
- Sundar, K. G. (2004). Observations on breeding Indian Skimmers Rynchopsalbicollis in the National Chambal Sanctuary, Uttar Pradesh, India. Forktail, 20, 89â.
- Tharne, R.E., 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. Rivers Res. Appl., 19,397-441.
- Torres, A., Brandt, J., Lear, K., Liu, J., 2017. A looming tragedy of the sand commons Science, 357 (6355) pp. 970-971, 10.1126/science.aao0503.
- Tripathi, A., &Upadhyay, S. K. (2015). DEMOGRAPHY OF FRESH WATER TURTLES IN CONFLUENCE AREA OF FIVE RIVERS (PANCHNADA) OFF NORTHERN INDIA.
- Vashistha, G., Mungia, N., Lang, J. W., Ranjan, V., 2021. Gharial nesting in a reservoir is limited by reduced river flow and by increased bank vegetation. Scientific Reports. DOI:10.1038/s41598-021-84143-7.
- Vyas, R., & Singh, H. (2004). Biodiversity survey of Gandhi Sagar Reservoir, Madhya Pradesh. Zoos print journal, 19(7), 15251529.
- Wesche, T.A. and Rechard, P.A., 1985. A summary of Instream flow methodologies for fisheries and related research needs. Eisenhower Consorium Bulletin, USDA Forest Service.
- WII-GACMC(2018).Ganga river-State of Biodiversity at a glance. Ganga Aqualife Conservation Monitoring Centre, Wildlife Institute of India. www.indiawris.gov.in
- Zusi, R. L., 1996. Family Rynchopidae. Pp. 670–677 in J. del Hoyo, A. Elliott and J. Sargatal, eds. Handbook of the birds of the world. Vol. 3. Barcelona: Lynx Edicions.