Enhancing the Urban Water Experience – Rejuvenating Kaliasot River, Bhopal

ALVINA HABIB KHAN
Masters in Recreation Architecture, Jamia Millia Islamia, New Delhi

IMAAD NIZAMI
Assistant Professor, Faculty of Architecture & Ekistics. Jamia Millia Islamia, Delhi

SHIVANI SAXENA
Environment Planner, National Mission for Clean Ganga, Ministry of Jal Shakti, GoI

Abstract

The presence of water bodies in an urban environment is considered to be an important part of the infrastructure as it plays a critical role in enhancing the quality and development of urban spaces. However with increasing urbanisation, the rivers and water bodies in urban areas are subjected to exploitation through several anthropogenic activities thereby resulting in their degradation. The case worsens when the river is non perennial as these are often considered a limited source of water that is renewed unpredictably.

One solution to the conservation of urban rivers lies in rejuvenating the flow of water and developing waterfronts that can connect people to the river. Such initiatives could also aid in rectifying the decades of neglect by adding value to these urban waterbodies. What is lacking is a holistic approach.

This paper attempts to understand, through a review of literature, the value provided by a non-perennial river and its importance. The paper presents the case of the river Kaliasot in Bhopal tributary of the Betwa River, with the aim of exploring reasons for its degradation and arriving at solutions for its rejuvenation. The ultimate objective was to develop strategies and recommendations for transforming the existing, neglected urban river into a centre for social, cultural, and recreational activities in the city, by improving the water quality and developing a riverfront.

Keywords: Urban River, Urban Riverfront, Non-perennial Rivers, Recreation, Ecological, Sustainable Development

Introduction

The presence of waterbodies in an urban environment is considered an important infrastructural element and plays a critical role in enhancing the quality and development of urban spaces. Water bodies can provide social, environmental, and economic benefits but, with the dawn of urbanisation, in urban areas they are subjected to exploitation through several anthropogenic activities resulting in their degradation. The rapid pace of urbanisation has not only exposed water bodies to the stress of degradation, but also led to the loss of many. Frequently, the scale and size of the water body, the volume of water it holds or carries, influences the way it is perceived by the city.

Urban Rivers

When a river flows through an urban landscape it can be defined as an urban river. Unlike a pristine river, an urban river flows through densely populated areas and highly modified landscapes, experiencing some intense interactions between its bio-physical and social realities (Pradhan, 2019). Factors that contribute to the degradation of an urban river include channelisation, artificial banks/bed, dredging, removal of riparian zones, encroachment on riverbeds, pollution from untreated disposal of contaminated water and sewage discharge, solid waste disposal, lack of belonging and awareness, lack of river governance, etc. (NIUA[1], NMCG[2] , n.d.) According to India's Central Pollution Control Board (2015), 63 per cent of the urban sewage flowing into rivers (some 62 billion litres a day) is untreated.

The Plight of Non-Perennial Rivers

The case worsens when the river is non-perennial, seasonal in nature or small in scale. Non-perennial rivers are often considered a limited source of water; one that is renewed unpredictably. In an urban setting these rivers are often misinterpreted as drains. In the eyes of the city dwellers, the lack of volume of water flowing through them makes them generally less valuable and worthy of conservation than their perennial counterparts.

Waterfronts—An Urban Solution

A way to conserve urban rivers is through rejuvenating the flow of water and developing waterfronts that will connect people to the river. The value added by waterfronts can also help reverse decades of neglect urban water bodies have suffered.

With increasing environmental awareness seen in the last decade as a consequence of the pressure to upgrade urban areas, waterfronts are being rediscovered in the city. (Anand & Basak, 2020) The value of the river and other water bodies is being realised and several waterfront development projects have commenced in different cities. But so far, they appear focused more on being a means of generating economic benefit, that is, as real estate projects with the objective of sprucing up the city's image for recreational and commercial value, rather than as river restoration and revitalisation projects (SANDRP, 2014). These projects are being undertaken without due consideration of the social, environmental or ecological aspects. The ecological aspects are lost in the concretisation of the riparian zone, channelisation of river, etc.

[1] *NIUA (National Institute of Urban Affairs)*

[2] *NMCG (National Mission Clean Ganga)*

What is lacking is a holistic approach that considers ecological, recreational, social, aesthetic and economic aspects while keeping in mind the needs of context and people. Each water body has a unique, exclusive relationship with its people irrespective of its scale, and thus, one solution cannot cater to all aspects.

This paper aims at understanding the values provided by non-perennial rivers and rejuvenate the same by using an environmentally sensitive approach to developing eco-friendly riverfronts.

It addresses the following research questions:

- Why is there a need to conserve non-perennial urban rivers, what purpose do they serve? (macroscale)
- How can we develop a nature-based riverfront without compromising on the ecological aspects? (microscale)

Methodology

The study is carried out on two scales. At the macroscale it focuses on understanding the importance of non-perennial rivers and the need to conserve them, the value provided by such rivers and how the scale of a river and the city are interrelated in order to justify that smaller or non-perennial rivers are also worthy of conservation. At the microscale the research focuses on a neglected stretch of Kaliasot River in Bhopal, by attempting to understand the reasons for its neglect and proposing strategies and recommendations to rejuvenate it.

A qualitative approach based on case study analysis, literature reviews, primary surveys, interviews, etc. has been followed here.

Several techniques were incorporated in the data collection process, including secondary data sources from archival data for understanding the role and importance of non-–perennial rivers, as well as the evolution of a river with urbanisation. This was based on the understanding derived from studying literature in the form of relevant papers, journals, articles and guidelines from across the world. Several relevant case studies were analysed to understand, learn and identify best practices being followed in similar contexts.

For the primary data collection (conducted from January to March in the year 2021), field study tools included visual surveys, observations, site documentation through photographs, preparing field notes and activity mapping. The primary survey was based on a questionnaire that was prepared to get an insight on the perception of people about the river and their expectations from the water body. The questionnaire ensured a community-based approach, one that involved primary stakeholders from the initial stages. These were essential aspects in addressing the research questions of the study.

Literature Review

Non-perennial Urban Rivers

Rivers and streams that cease to flow at some point in time or space are referred to as non-perennial. Alternatively, the term non-perennial refers to streams and rivers that do not flow continuously and includes intermittent rivers and ephemeral streams. (Busch, et al., 2020) Such rivers are globally prevalent and hydrologically diverse, providing many ecosystem services such as agricultural and domestic water supply while sustaining the ecological integrity of river networks (Busch, et al., 2020; Stubbington, et al., 2020).

The characteristic of a non-perennial river include a temporary absence of surface flow, resulting in isolated pools or dry channels. (Busch, et al., 2020). By some estimates these rivers constitute 50 per cent of the total global river network length (Zipper, et al., 2021; Datry, et al., 2017).

With a continuous change in climates, anthropogenic activities such as construction of dams, altered land-use patterns and abstraction of water to meet human demands, the occurrence of non-perennial rivers is expected to increase in the future (Steward, Schiller, Tockner, Marshall, & Bunn, 2012).

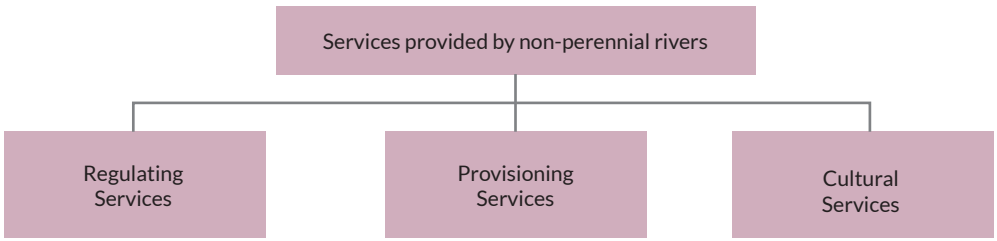
Such rivers usually undergo three phases over the course of a year – ponded, flowing and dry (Stubbington, et al., 2020). These three phases result in different habitats. Thus, ecosystems of non-perennial rivers create a diverse habitat mosaic—the shift in space and time between aquatic and terrestrial phases rendering an aquatic–terrestrial ecosystem.

Despite constituting 50 per cent of the total global river network length, non-perennial rivers are much neglected as a subject. Being undervalued by society threatens their restoration or protection as researchers and government policies are predominantly focused on perennial waters and biased towards larger rivers.

Value and Services Provided by Non-Perennial Rivers

Non-perennial rivers provide regulating, provisioning and cultural ecosystem services (Stubbington, et al., 2020).

Figure 1: Types of Services Provided by Non-perennial Rivers



Source: Adapted from Stubbington et al., 2020

Regulating ecosystem services include:

- Regulating the flow of water by mitigation of floods
- Regulating water quality by storing ground water
- Regulating erosion control
- Regulating the microclimate
- Regulating the water quality

Provisioning ecosystem services include:

- Provision of fresh water that is high quality subsurface water and ponded water
- Provision of livelihood by supporting fisheries, agriculture and livestock
- Provision for extracting sediments during the dry phase

Cultural Ecosystem services include:

- Recreational opportunities such as boating, fishing, walking, tourist hotspot, etc.
- Educational purpose as these ecosystems represent a research gap that creates interdisciplinary opportunities for researchers, stakeholders, and students to develop their knowledge and skills
- Spiritual connect and benefits depending on the region and local traditions

Non-perennial rivers, big or small, have a lot to offer in terms of ecological and socio-cultural value and are thus, worthy of conservation. Several studies (Stubbington, et al., 2020; Acuna, et al., 2014; Datry, et al., 2017) infer that non-perennial streams constitute a higher regional biodiversity compared to their perennial counterparts. It is necessary to understand their ecology as well as their character in order to bridge the huge gap in research regarding the same. Despite the numerous services provided by these rivers they are poorly understood and hardly considered as part of the water management system at all (Acuna, et al., 2014; Zipper, et al., 2021). In order to preserve the many valuable aspects recognised here, the identification, protection and conservation of non-perennial rivers should be incorporated into river management plans. Appropriate indicators should be developed for the continuous monitoring and assessment of the health of these ecotones. The health of the entire river network could be assessed based on the combined wet-dry-ponded phases of the river. Most importantly, non-perennial rivers must be incorporated into policy and legislation.

Background and Context

Kaliasot River

The Kaliasot is a non-perennial urban river in northern India. The river flowing from June to October is dry and ponded from November to May, lies in the Ganga River basin and is a tributary of the river Betwa. It originates in Bhopal, Madhya Pradesh and travels 29 km before joining the Betwa at Bhojpur, Madhya Pradesh. The catchment area of the Kaliasot in Bhopal district is 18.16 sq km covering 8.2 per cent of the total area of Betwa basin in the district (Ministry of Water Resources, 2013). In Bhopal, the Kaliasot flows from Kolar Road till Samardha village near Mandideep, Raisen, covering approximately 16 km. In different parts of its course, the river water is used only for irrigation; there is no water supply from the river in the entire stretch.

Figure 2: Map of Bhopal Locating Kaliasot River

Source: Block Map of Bhopal, District Geoportal – Bhopal (https://bhopal.nic.in/en/map-of-district/)

Historical Importance of Kaliasot River

According to folklore, also quoted by the historian and archaeologist W. Kincaid, when Raja Bhoj (reigned c.1010–1055 CE) of Malwa fell sick, a holy recluse prophesied that the raja's illness would be cured only when he constructed a lake fed by 365 streams or springs and bathed in it (Verma, 2001). A vast triangular valley, now known as Bhojpur, was identified as a feasible location and a cyclopean dam of massive scale was initiated to block the valley from all sides. It was to be fed by the headwaters of the river Betwa and its tributaries. So it was that a lake covering an area of 650 sq km (65000 ha), was constructed in a valley in the Vindhyan range. However, when finished, the lake was fed by only 356 springs and streams.

Kalia, a Gond chief, pointed out a river 32 km to the west of the lake. This river with its eight tributaries made up the requisite number that would cure the raja and consequently, it was turned 90 degrees from its course to feed the Betwa valley lake. The river was appropriately named Kaliasot or Kalia's river, a name that it carries to this day.

From the storage lake thus obtained, the Kaliasot River flowed at a right angle to its former course and became a valuable feeder, carrying its surplus waters into the larger lake for three full months after the rainy season had ended.

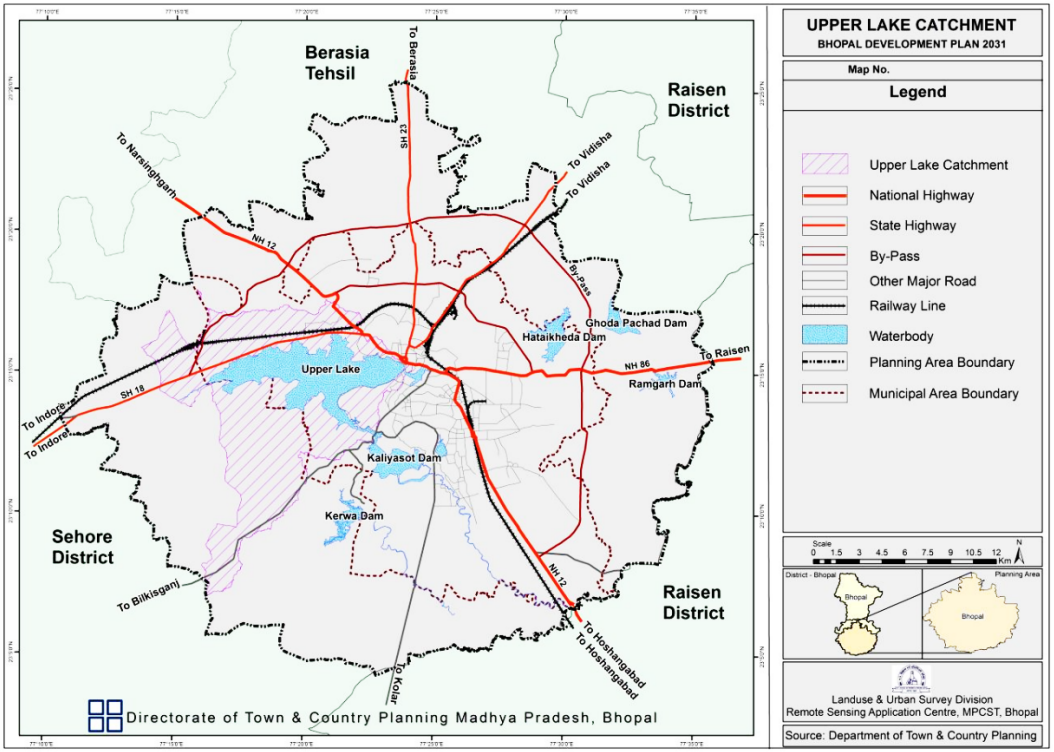
Later, in the early 15th century, the dam across the Betwa was destroyed by the armies of Hoshang Shah. The embankment at Bhopal is still preserved at Kamla Park and so is the lake, known now as Bhoj Tal or Upper Lake, but in a much-constricted size. In 1994, the Kaliasot Dam was constructed on the river for irrigation purposes, about three kilometres from its point of origin. Today, the river originates from Kaliasot Dam at Bhopal as overflow of the dam and flows south-east. The flow in the river from origin up to (river Betwa) Bhojpur is very meagre except for the monsoon season.

Bhopal—City of Lakes

Bhopal, the capital city of Madhya Pradesh, covers an area of 648.24 sq km with a population of 3,454,678 according to the census of 2011. It is also known as the 'city of lakes' because of numerous natural and artificial lakes that abound. The total area of water bodies, which includes lakes, rivers and streams constitutes 54.95 sq km, which is five per cent of the total planning area (Town and Country Planning, Madhya Pradesh, 2021). These water bodies majorly constitute lakes and water impoundments available in and around Bhopal, most of which are maintained and looked after. According to the Bhopal Development Plan – 2031 (draft), there are 18 such water bodies.

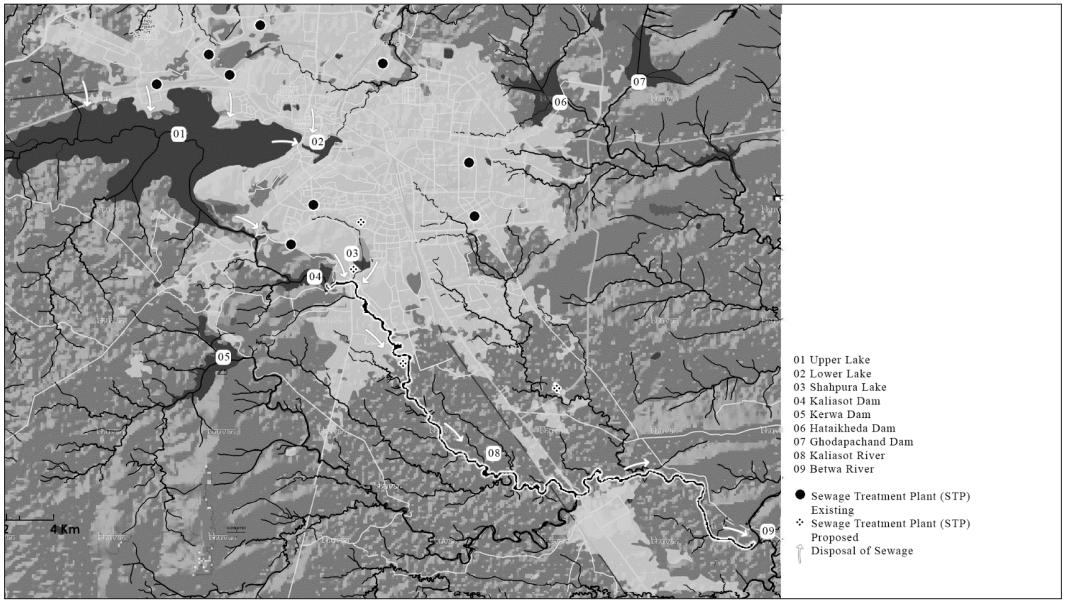
The major important water bodies are mostly lakes and dams—Upper Lake (Bhoj Tal), Lower Lake, Shahpura Lake, Kaliasot Dam, Hataikheda Dam—within the planning area of Bhopal. These water bodies are centres of recreational activity and a few of them also provide drinking water to the city. Kaliasot River and Halali River are tributaries of the Betwa that are non-perennial in nature. Of these, the Halali is outside the planning area.

Figure 3: Map Showing Water Bodies of Bhopal



Source: Bhopal Development Plan – 2031 (Draft), Volume I, Town and Country Planning, Madhya Pradesh, 2021

Figure 4: Map Showing Natural Water System—Rivers and Drains in Bhopal



Source: Bhuvan Image, accessed during March 2021

Natural Water and Drainage Systems

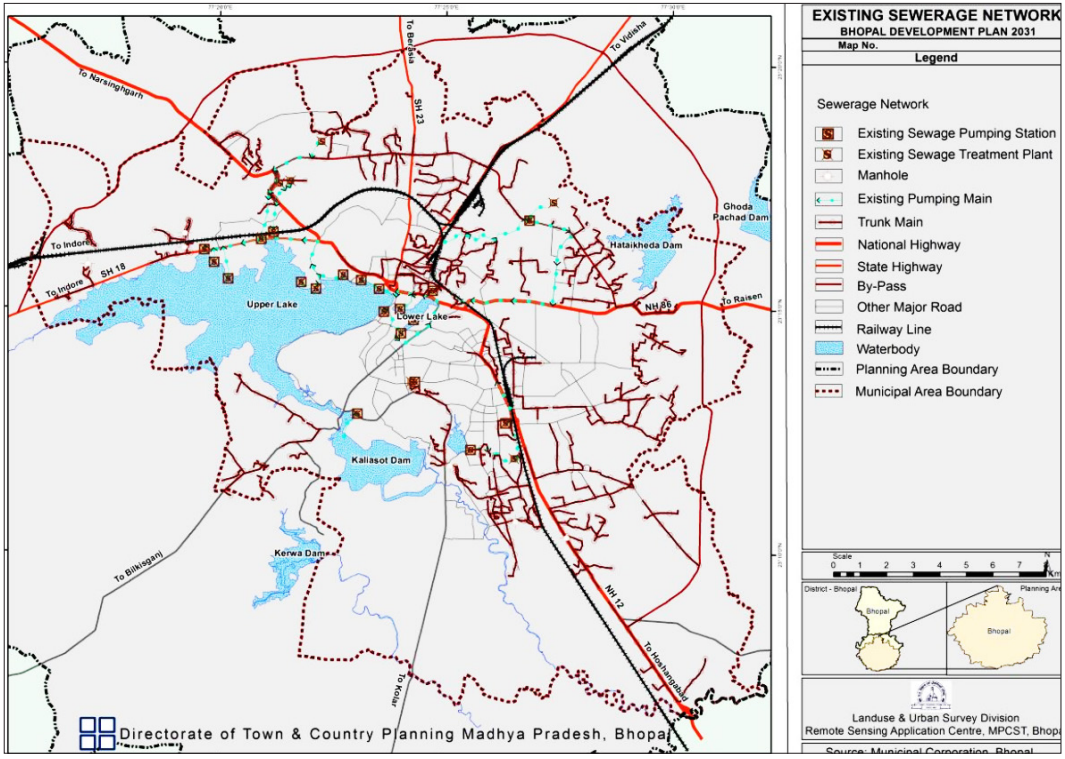
The topography of Bhopal is made up of hilly terrain, with the highest elevation at 640 m to the lowest at 420 m. Three major streams drain storm water from Bhopal. On the north-eastern side the drainage is carried by the river Halali and on the south-eastern side by the Kaliasot. Both these rivers drain into the Betwa River. During the monsoon, the Kaliasot carries surplus water from Kaliasot Dam, which is intercepted by Upper Lake or Bada Talab.

Pollution in Kaliasot River

In 2018 the Central Pollution Control Board (CPCB) identified 357 polluted river stretches in India that did not meet the water quality criteria. Madhya Pradesh ranked third with 22 polluted river stretches of which Kaliasot was one of them (Senapati, 2021).

Bhopal gets around 266 million litres (MLD) of water a day and generates 285 MLD of sewage, of which just 39 MLD is treated. Most of the sewage is discharged into the Upper Lake and drains, from where it eventually finds its way to the Betwa River through its tributaries, i.e. Kaliasot and Halali rivers (Ministry of Water Resources, 2013). A map of the existing sewage network (Town and Country Planning, Madhya Pradesh, 2021) published in the Bhopal Development Plan – 2031 (Draft), Volume I, clearly shows the absence of any treatment plant or sewage pumping station around Kaliasot River.

Figure 5: Map Showing Sewage Treatment Network in Bhopal



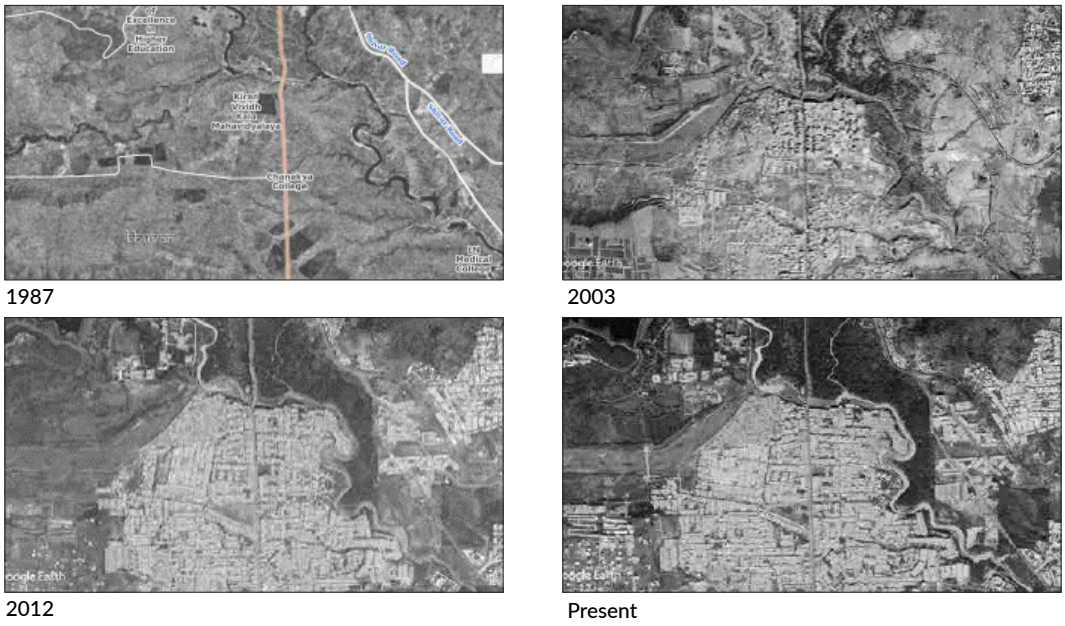
Source: Town and Country Planning, Madhya Pradesh, 2021, Bhopal Development Plan –2031 (Draft), Volume I

Apart from the major drains carrying sewage from Bhopal (Shahpura Lake spillage, Misrod and Mandideep regions) into the river, it is also subjected to domestic pollution as it receives sewage from the unplanned urban development around the river.

Water analysis carried out (M.P. Pollution Control Board, Bhopal, 2019) concludes that water quality that flows into the river falls in 'D' and 'E' categories throughout the year, except for the post-monsoon season when the quality upgrades to 'C' category. This infers that the water cannot be used for drinking or household purposes.

Administrative Boundaries and Kaliasot River

Figure 5: Urban Development Around Kaliasot River



1987 2003

2012 Present

Source: Google Earth Images, accessed during March 2021

Till 2014, the Kaliasot was seen as the natural edge of the new Bhopal development; therefore, initially it was not even in the planning area. Planning around the river was in the hands of governing bodies of gram panchayats with a very myopic vision. The Kolar municipality was included in the Bhopal Municipal Corporation area vide notification of state government on 20 November, 2014. Due to its location outside the planning area, the river was seen as a service water body that became a sink to drain the city's wastewater and sewage as mentioned earlier. As Bhopal expanded beyond its previous boundaries, the Kaliasot had already been subjected to unplanned development and urbanisation, especially along its edge.

According to the Bhopal Development Plan – 2031, Draft, (Town and Country Planning, Madhya Pradesh, 2021), Kaliasot River is identified as a landscape potential area for active recreation and conservation of water bodies and wildlife (birds and animal species). But this does not address the present condition of the river or how to revive it.

Study Area

The area of intervention is an approximate 2.5 km stretch of Kaliasot River, covering an area of 0.17 sq km (42.5 acre) and varies from 5 to 30 m in width across the site. The stretch is surrounded by unplanned urban development (Damkheda slums, Sarvadharam Colony, Sectors A and B till Mandakini Colony), predominantly residential housing on one side and a city forest (Swarna

Jayanti Park) sprawling over 2 sq km, on the other. As mentioned in the previous section, the study area was not inside the boundary of the planning area until 2014, thus, this urban development is accompanied by a lack of infrastructure facilities, proper sewage network, etc. This leads to discharge of solid waste, wastewater and faecal sludge into the existing water body.

Figure 6: Area of Intervention

Source: Google Earth Image, accessed in November 2020

The main purpose of selecting this stretch is to ensure that pollution is curbed right from the origin of the river and to ensure that what flows throughout the river is clean water. In the selected site, the river flows through a very contrasting landscape—on one side it is subjected to urbanisation, and on the other, there is a vast urban forest cover. The river can act as a bridge to connect the two and provide a place to coexist.

Data was collected through a primary survey (conducted from January to March in the year 2021). Field study tools included visual surveys, observation, site documentation through photographs, preparing field notes and activity mapping. A comprehensive questionnaire was prepared to gain an understanding of the perception people have about the Kaliasot River and their expectations from the water body. This questionnaire ensures a community-based approach, involving primary stakeholders from the initial stages. Several layers were documented and studied to understand the present situation, including – land use, open spaces, connectivity, accessibility, building heights, zoning, sewage infrastructure, income groups, activity mapping, etc. The data was analysed to understand the feasibility of developing an eco-friendly riverfront.

The strategic location of the site is an advantage as it provides rich biodiversity to the site throughout the year. Avian life found on the site was documented based on primary surveys and site visits to highlight the rivers ecological importance.

Birds listed included – Little Egret, Cattle Egret, White-browed Wagtail, Common Pigeon, Indian Peafowl, Laughing Dove, Rose-ringed Parakeet, Green Bee-eater, Common Tailorbird, Black-winged Stilt, Great Coucal, Pied Cuckoo, White-throated Kingfisher, Red-vented Bulbul, Jungle Babbler, Indian Silverbill, Purple Sunbird, Red-wattled Lapwing, Common Babbler, Water Hen, Sparrow, Double-crested Cormorant, Black-backed Forktail, Yellow-billed Magpie.

The presence of rich biodiversity on site is proof that non-perennial rivers also house rich biodiversity and need to be conserved to ensure ecological balance.

Factors Degrading the Kaliasot River

Based on primary surveys, site visits and observation, factors leading to the degradation of Kaliasot River were identified. These include:

- Untreated sewage discharge: A significant number of outfalls discharge untreated sewage along with storm water directly into the river, converting it into a polluted 'drain'.
- Solid waste disposal: Households nearby use the adjacent river as their dump yard and throw solid waste into it.
- Lack of accessibility: The river is not easily accessible. Along most of its length, the banks are lined by private properties. There are very few approach points, making the river inaccessible to citizens in general.
- Open defecation, bathing: The river is subject to pollution from anthropogenic activities such as defecation, bathing, washing clothes, etc.
- Lack of value, sense of belonging: Citizens are not sensitised towards the river, giving it the identity of a 'nala'.
- Flash floods: During heavy rains when Kaliasot Dam is filled to the brim, the sluice gates are opened to allow water through. At times, when all the gates are opened simultaneously, it results in flash flooding.
- Lack of governance.

Impact on the Kaliasot River

- Degradation of ecological value: Due to its non-perennial nature, the river acts as a wetland for most part of the year and is home to a variety of plants, birds, fish, etc. But, the insensitivity of residents towards the natural landscape, and the increase of pollutants in the river, make the water that flows through it during non-monsoon seasons incapable of supporting any aquatic life. This impacts the number of migratory birds that visit, etc.
- Erosion and loss of land: Flash floods lead to loss of land and property adjacent to the river.
- Danger to structures: Flash floods have rendered the structures prone to danger of collapsing.
- Unkempt and deserted: The river is underutilised and neglected. Over time, it has been transformed into a polluted drain that remains deserted and encourages illegal recreational activities.

Discussion

In addressing the issues, one solution to conserving Kaliasot River is by rejuvenating it and developing waterfronts that seek to connect people to the water and provide habitat for wildlife species, enabling them to coexist. The waterfronts are also essential to rectify decades of neglect, by adding value to the river through an ecological approach. The goal is to bridge the gap between the urban and ecological fabric through a series of large- and small-scale interventions that balance notions of site, context and ecology and so gain back its value.

Objectives and Strategies

Critical to addressing the issues identified in the previous section, objectives and strategies are formulated keeping in mind the social, economic and, most importantly, the ecological aspects.

Table 1: Objectives and Strategies for Development of an Eco-friendly Riverfront

	Issue	Objective	Strategies and Recommendations
1	Unkempt and deserted	Activate the river edges through multifunctional zones	1. Introduce different activities and programmes to engage the people. 2. Identify sustainable approaches for connecting people and river.
2	Degradation of ecological value	Preserve the ecology of the site	1. Document the existing flora, fauna and avian life present on the site. 2.Ensure sustainable practices are followed on the site. 3. Balance the interventions on site, ensuring ecology is given priority.
3	Untreated sewage discharge, solid waste disposal, open defecation, bathing	Curb the pollution and sewage flowing into the river	1. Increase the capacity of proposed STP and realign existing network. 2. Provide decentralised wastewater treatment plants for existing outfalls. 3. Incorporate treatment wetlands to ensure quality of water.
4	Danger to structures, erosion, loss of land (flash floods)	Minimise risk and impact of seasonal flooding on the neighbourhood	1. Build retaining wall or natural embankments along the residential edge. 2. Stabilise the embankment using soil bio-engineering. 3. Regulate the flow of water released from the dam.
5	Dry riverbed	Retain water in the river throughout the year through means of sustainable drainage systems	1.Retain water permanently by the means of: Engineered landforms Introducing check dams/nala bunds at regular intervals downstream 2. Maintain the flow of water through recycling wastewater.

	Issue	Objective	Strategies and Recommendations
6	Lack of accessibility	Enhance accessibility and connectivity	1. Create access points (entrance zones) to bring high footfall to the site and activate the river edges. 2. Draw up activity based zones that can have connections based on adjoining programme/activity. 3. Create visual nodes – junctions that provide a view of the river or river edge.
7	Lack of value, sense of belonging	Instil a sense of belonging and sensitise citizens about their roles and responsibility towards the river	1. Ensure community participation in the planning process. 2. Engage the locals into riverine ecosystem economic opportunities for their socio-economic upliftment and maintenance of the river. 3. Introduce awareness programmes for educating the locals about the ecological value of the river.
8	Lack of values, sense of belonging, degradation of ecological value, unkempt and deserted	Uplift the value of the river	1. Economic value: Engage slum dwellers with riverine ecosystem economic opportunities for their socio-economic upliftment and maintenance of the river. 2. Social value: Connect the river with the adjacent precincts to socially engage it with local settings as a part of their own space and social responsiveness. 3. Recreational value: Introduce active and passive recreational activities suitable for different age groups. Develop new, sustainable built forms for public recreation such as decks, watchtowers, trails, etc. Integrate the riverfront with existing recreational/ green spaces.

Proposal to Rejuvenate Kaliasot River

Water Treatment Strategy

The first problem that needs to be addressed before the design phase is the issue of water pollution. In order to improve water quality, this proposal suggests three water treatment strategies: wetland treatment, urban treatment, and household treatment.

Wetland Treatment proposed for the site caters to the sewage outfall from residential buildings along the river edge. It was observed during the primary survey that the sewage network proposed by the municipality does not include the Damkheda slums. Thus even after setting up a sewage network, waste from lower income groups will still fall into the river. The proposed wetland treatment plant will ensure that this wastewater and sewage acts as a resource. This

pilot treatment module will cater for 3000 individuals. The treatment involves a 4-step process: Settler (Septic tank); Anaerobic Baffle Reactor (ABR) + Anaerobic Filter (AF); Planted Gravel; and Polishing Pond.

Table 2: Calculations for Expected Wastewater Generation

No. Of Users	Rate Of Water Consumption (lpcd)	Total Water Consumption (L/Day)	Expected Wastewater Generation (L/Day)	Expected Wastewater Generation (Cum)
3000	135	405000	324000	324

Source: Authors' (calculations are based on Green Infrastructure published by the Centre for Science and Environment)

Table 3: Calculations for Area Required for Decentralised Wastewater Treatment Systems Module

DWWTs Module	Standard	Surface Area Required (Sq. m.)
Settler (Septic tank)	0.5 sqm/cum	162
ABR+AF	1.0 sq m/cu m	324
Planted Gravel	4.0 sq m/cu m	1296
Polishing Pond	1.2 sq m/cu m	388.8

Source: Authors' (calculations are based on Green Infrastructure published by the Centre for Science and Environment))

Once constructed, the proposed wetland will treat the effluents from the informal settlements and let the clean, treated water into the river. This water can also be used for landscaping purpose and in bio-toilets.

Urban Water Experience

An important characteristic of Kaliasot River is that it has meagre flow of water and, for most parts of the year, this flow is mainly sewage. In order to improve the water quality and ensure some flow of clean water throughout the year, several sustainable urban design elements can be introduced such as riparian buffers, floating wetlands, aeration fountains, retention basins (holding ponds), check dam (nala bund), swales/filter strips.

Riparian buffer: A 2.5-5 metre buffer on both sides of the water body will help in stabilisation of edges, providing habitat for semi-aquatic and terrestrial ecotone species, filter the run-off and act as buffer, etc.

Floating wetlands: These islands will clean the contaminated water and ensure clean water in the river. They will also build up a natural habitat for native species.

Holding ponds/waste stabilisation ponds/retention basins: Waste Stabilization Ponds (WSPs), often referred to as oxidation ponds, act as holding basins for secondary wastewater treatment where decomposition of organic matter takes place naturally. They also act as wetlands.

Aeration fountains: In several stretches the water is stagnant and is subjected to eutrophication. To avoid algae bloom and ensure sufficient levels of oxygen in the water, aeration fountains will be introduced to induce water currents and get the water circulating, thereby spreading oxygenated water and bringing oxygen starved water from the bottom to the surface.

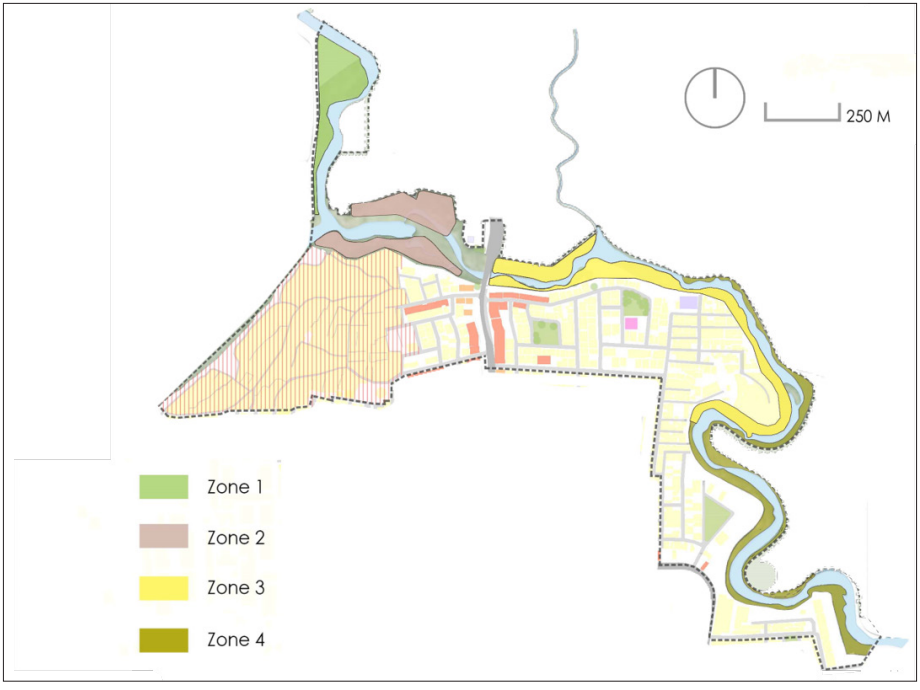
Nala bund/check dam: Small check dams, not more than a metre in height, can help retain water. In addition to providing habitat for aquatic life, this will also help in increasing aesthetic appeal.

Filter strips and swales: These will help in stormwater management, improve the ground water table and remove impurities from the water before it enters the river.

Rejuvenating the River and its Edges through Ecological, Socio-Economic and Recreational Values

The site can be divided predominantly into four zones based on topography, ecological value and strategic location to activate the edges of the river. Different activities and programmes could be introduced in each zone. The proposal will establish the site's identity as a public space and introduce a resilient, multi-layered recreational and social destination that connects its community to nature, the river and each other.

Figure 7: Site Zoning



Source: Authors

Zone 1 is proposed as the Ecologically Sensitive Area. This is the former course of the river, which is surrounded by forest and is home to native and migratory bird species. Passive recreation such as a pedestrian trail (permeable pathways) and resting points can be introduced in this area, while ensuring that the ecology of the place is not hampered. Decks and viewing points that encourage activities such as bird watching, along with awareness programmes can be introduced to educate the public about the river and bird life. This zone will serve as an opportunity to catalyse discussions on the ecological, recreational, and educational dynamics of the riverfront.

Zone 2 is the low lying, flat area, which could be anchored with different activities and functions for socio-economic and recreational values. The multipurpose space would act as an empty canvas that could be used for a series of recreation and socio-economic activities such as a recreational ground for outdoor games, fairs, weekly markets, exhibitions etc. A decentralised wastewater treatment system (constructed wetland system) of grey water for the informal settlement can be introduced across the river, to ensure a flow of clean, treated water into the river. The presence of a natural retention pond would act as a polishing pond for the DWTs. Its closeness to the informal settlement facilitates the introduction of bio-toilets, which will encourage safe sanitation. The treated water can also be used to irrigate the community gardens. This zone will provide valuable open space, protect and enhance the ecological systems and help elevate the socio-economic value of the river. In the social aspect, education and local culture are key tools to change not only communities but also the mentality that generated 'not my problem' responses to the increase in damage and neglect in the questionnaire.

Zone 3 is the recreational zone – spaces that would work as recreational pockets with movement corridors and neighbourhood green edges. This zone could incorporate trails and promenades to cater to recreational purposes—shaded viewing decks, look-out tower, boardwalk, entrance plazas, fishing area etc. are provided. These would ensure accessible and usable open space to all, with a balance of passive and active recreational opportunities within an environmentally enriched riverine setting for diverse ages and interests. This will foster recreational and aesthetic landscape experiences.

Zone 4 comprises the linear green edges that work as surfaces of visual interest to set the background. This zone is too narrow to introduce any anthropogenic activities. Thus, what could be introduced is a promenade along the embankment.

The proposal is low-maintenance, ecologically functional, and active. It will not only provide a recreational place for communities but also rebuild the ecological health of the river, leading to the recovery of biodiversity and native habitat around it. Eventually, it could become an attraction for the whole city of Bhopal.

Recommendations for an Eco-friendly Riverfront

Design and Construction Phase

- Construction
  - Use of natural materials such as stone, mud, mud bricks, lime, local species of timber and bamboo must be encouraged for construction activity. The use of cement should be kept to a minimum.
  - Surrounding natural physical features, habitats and biodiversity should not be disturbed during the construction process.

- Water Quality
  - Regulations must be put in place to ensure that untreated sewage is not allowed into the river.
  - STP network must be adequate and functioning.
  - Alternative sewage management systems should be evaluated and implemented. (Pilot testing must be done before implementation.)
  - All access points from which solid waste dumping into the river takes place must be identified and mapped, and appropriate design/planning solutions have to be suggested to prevent the same.
  - Water quality of the river must be maintained as per international/tropical standards (8PPM DO).

- Channelisation
  - River channelisation by increasing the depth of the riverbed at places will not only help retain water but avoid loss of land.
  - Channelising the river by engineering methods such as straightening and reinforcing the bed and banks must be strictly avoided.

- Retention Basin/Pond
  - Existing natural depressions must be preserved.
  - Soil bio-engineering techniques should be used to stabilise the edges of the basin/pond.
  - A riparian buffer should be maintained along the structure.

- Flood Control
  - A policy to stop further development on the banks of the river must be formulated.
  - All illegal debris dumped within river must be removed.
  - Retention/detention basins must be created along the river wherever sufficient space is available.

- Embankment and Slopes
  - A slope of 1:3 or 1:2 must be maintained to ensure stability of the slope.
  - Use of only sustainable, natural material should be encouraged.
  - Native species of plants should be selected for growing on site.
  - Plant species must be suitable for the intended use and adapted to the site's climate and soil conditions.
  - All installations should be maintained and inspected regularly, and provisions made for prompt repair if needed.
  - Practices that must actively be discouraged include making of rock riprap, rock gabion etc.

Recreational Amenities

- The balance between recreational activities and ecology of the site has to be maintained.
- A balance between active and passive activities should be maintained.
- Recreational activities should respect the ecology of the site.
- No permanent structures should be built on the site that are not sustainable.
- No pollutants of any kind should be released through any recreational activity.
- Fishing
  - Fishing shall be permitted only after water quality and habitats are restored.
  - Fishing on site should be allowed for a limited time (monsoon period).

- Walking/cycling pathways
  - Sustainable infrastructure should be used for enhancing recreational activities such as boardwalks, permeable pathways, viewing decks, etc.

- Nature trails, Birds/Insects/Flora walks
  - Restoration of the river ecosystem will boost the flora and fauna along the river. Thus, trails can be planned for studying plants, birds, insects, fishes etc.
  - Care must be taken to not disturb the hotspots while planning these trails.

- Multipurpose ground
  - Activities on the multipurpose ground such as weekly markets, fairs etc. must not disturb the ecology of the site.
  - A management committee should be set up to ensure that the site is maintained.
  - Cleaning of the site after an event must be the responsibility of the event organising party.

Socio-Economic Benefits

- Introducing awareness programmes to educate locals about the ecological value and local economic benefits from the river.
- Promoting a stewardship programme that encourages the coordinated participation of communities, government, organisations, stakeholders, and the private sector in rejuvenating Kaliasot River and in the riverfront development.
- Educating all involved parties, especially local communities on the sustainable development strategy for the river.

- Encouraging a sense of social responsibility among the locals to take care of the river in return of their economic benefits.
- Creating self-help groups to encourage women to come up with local economic benefits.

Conclusion

The paper attempts to understand through a review of literature the value of a non-perennial river and its importance in urban context. There was limited research on non-perennial rivers that could be found, especially in the Indian context. These rivers should be viewed as a separate type of water body from perennial rivers and lakes, and should be approached keeping in mind their limitations, the ecology they serve and services they provide.

An attempt was also made to study and analyse the different layers of Kaliasot River and to suggest recommendations to develop an eco-friendly riverfront. The proposal aims to be low-maintenance, ecologically functional and active. It aims not only to provide a recreational place for communities but also to rebuild the ecological health of the river leading to the recovery of biodiversity and native habitat around it, making it an attraction for the entire city of Bhopal.

Through an ecologically sensitive approach, the deteriorated urban river Kaliasot can be successfully transformed into a high-performance and low-maintenance front yard, which will retain water, clean contaminated water, provide public access to high quality open space, restore native habitats for biodiversity and attract residents and tourists. This waterfront can act as a catalyst in connecting the community to its context and sensitising them to become aware of the great potential this has for their future development, also stimulating a positive change towards the immediate environment.

Acknowledgements

We would like to sincerely thank all the people that contributed to the completion of this fruitful academic research. We are grateful to National Institute of Urban Affairs and National Mission Clean Ganga for their continuous help and guidance and being a powerhouse of motivation.

Funding

This research is funded and is a part of the sponsorship received under the National Thesis Sponsorship Competition in 2020 by National Institute of Urban Affairs (NIUA) and National Mission for Clean Ganga (NMCG).

Conflict of Interest

The authors declares no conflict of interest.

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