# Restoration Strategies for Urban River; A Case of Mithi, Mumbai

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***Abstract*— The river ecosystem exhibits a dynamic relationship of hydrological and geomorphological aspects with its flora and fauna. Urban rivers as an ecological corridor, play a crucial role in sustainability and stability of urban development. Stretches of urban rivers have been reported to increasingly suffer from channel modification, pollution, water abstraction, etc. rendering them to be one of the most threatened ecosystems. The paper presents case of Mithi, an urban river in Mumbai. Increasing urbanisation and development activities along Mithi has drastically altered the natural river channel, caused frequent occurrence of floods, emergence of severe encroachments, water pollution by industrial effluents discharged into the river, etc. CPCB, in 2022 report entitled "Polluted River Stretches for Restoration of Water Quality", has classified Mithi as priority I for restoration. The paper analyses the issues in the floodplains of Mithi and identifies the prospects and possibilities of restoration by comprehensive understanding of existing frameworks in India. Additionally, paper attempts to formulate restoration strategies for Mithi with an integration of urban blue-green infrastructure in the riparian areas. The objectives of Urban River Management Plan, 2020, NIUA, forms the basis of restoration strategies for efficient river management in the context of Mumbai; thereby ensuring stability and sustainability of river corridors by targeting SDG (Sustainable Development Goal) 6, SDG 11 and SDG 15.**



***Keywords*—River Ecosystem, River Restoration, Sustainability, Urban Rivers, Urban River Management, etc.**


## I. INTRODUCTION TO URBAN RIVERS

The river ecosystem exhibits a dynamic relationship between humans, flora and fauna, hydrological and geomorphological aspects (Parihar, 2021). Not only urban rivers are important ecological corridors and physical element of a city, they also contribute in sustainability and stability of urban development (Yue, 2012). In contradiction, urban development is also considered to be the most dramatic alterations of the ecosystem (Everard & Moggridge, 2012). One of the most threatened ecosystems of the world are the urban rivers (Parihar, 2021). Increasing urbanisation has led to immense threat to its ecosystem in terms of flooding and degrading water quality (Miller & Hutchins, 2017). With increasing anthropogenic activities, rivers, urban rivers or their stretches have been reported to increasingly suffer from pollution, water abstraction, damming and channelization. Increase in impervious surfaces, culverting and channel modification, increase in contamination, negligence to rivers and floodplains, etc. are few major factors contributing to the degradation of urban rivers. In Indian context, expanding urban areas have exacted a huge toll on its river. As per the India's CPCB Report 2021, almost 63% of urban sewage that flows into the river is untreated. Riverbanks, wetlands and floodplains have been encroached by slums, industries, etc, resulting in width reduction of natural river channels and flow distortion; this severely impacts the ability of riverscapes to buffer flooding and cease to provide the resources to the settlements.

Urban rivers are an important component of ecosystem as they provide water resources, platform for recreation, fishing, etc. to human settlements (Hua & Chen 2019; Xu et al. 2023). Various authors and researchers have defined urban rivers in different context, as presented in below (Table I).

Table I

Definition of urban rivers

| Definition of urban rivers | Source |
|---|---|
| Urban rivers are one component of catchment systems. | Richardson & Soloviev, 2021 |
| Rivers that have direct connection with human habitat are urban rivers. | May, 2006 |
| Urban rivers are perceived as a platform for interaction between nature and people by acting as public spaces within urbanized areas. | Hermida et al., 2019 |
| Urban rivers not only provide water resource, but also have a role in providing recreational spaces with landscapes. | Mainstreaming urban river management into master plans, NIUA, 2020 |
| The stretch of a river, within a city/town that has a function more than being a source of irrigation and potable water supply is defined as an urban river. | River Centric Urban Planning Guidelines, MoHUA, 2021 |

Comprehensively, urban rivers, can be defined as, component of a catchment system within a city/town that not only has a role of being a source of water supply but also provides interaction between nature and act as a recreational landscape within an urbanised area.

Within the complex and broader urban systems, urban rivers not only play a central ecological role but as well as societal roles. Historically, human settlement has evolved at locations necessary resources like fresh water were found, eventually this took the form of urbanisation (Grimm et al., 2008). Rivers and streams were the foci for most civilizations. Over time, as urbanisation accelerated, the uncontrolled and unchecked development contributed to the widespread degradation of riverine habitat. Water quality and riparian ecotones succumbed to severe degradation (Francis, 2012). Today, the water front in cities, not only offer commercial but also cultural significance.

Globally, creation of embankments and levee structure, is a common practice to form vistas and public spaces is a common practice. However, these structural changes to urban rivers may transform the ecological relationship of a river and a city and give a sense of stability, but further magnify the consequences of floods and disasters (May, 2006). Urban rivers have experienced substantial alterations to their biotic and abiotic systems like pollution of water, privatization of river banks, inaccessibility for citizens, etc. of which over time have rendered them difficult, if not impossible to return to the historic states (Francis, 2014). As urban river ecosystem continues to degrade, there arises a need for developing the restoration strategies for urban rivers (Figure 1).

## II. A CASE OF MITHI RIVER

Mumbai is one of the prime economic regions of India. The city is India's financial hub and fifth largest metropolitan hub (Vaz et al., 2021). As reported by census 2011, it is a home to 12.5 million inhabitants. As coastal cities around the globe remain the regions of economic activities, they face accelerating increase in population (McGranahan et al., 2007). This has threatened the coastal environment. Flooding is a common problem in Mumbai, particularly when heavy rainfall coincides with high tides (Senapati & Gupta, 2017).

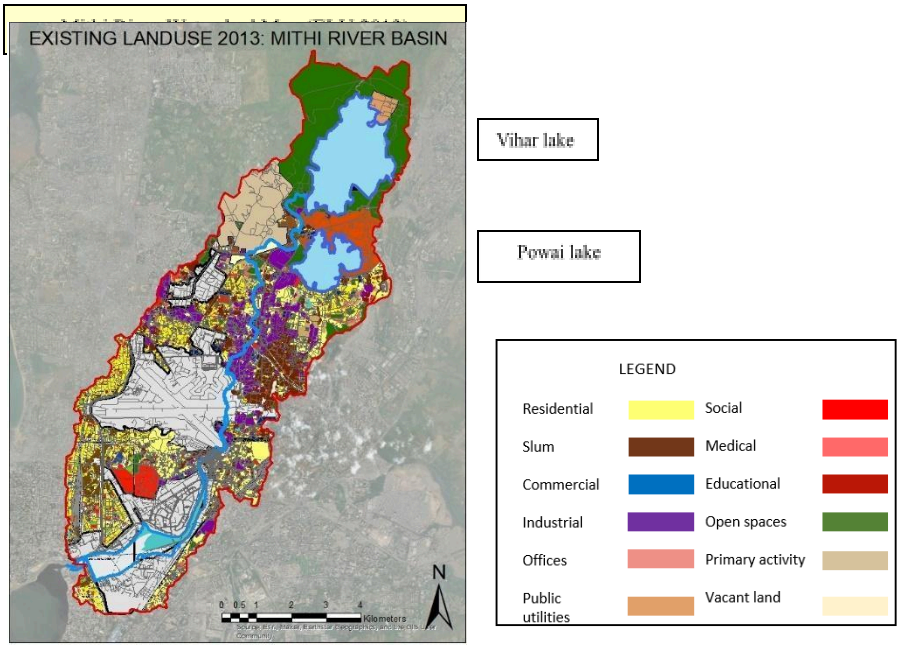
Mithi, one of the major rivers of Mumbai, carries water discharges of Vihar and Powai Lake. As reported by NEERI in 2011, It originates from Vihar Lake and flows to Arabian Sea through Mahim creek approximately 17.80 Km of length, passing amidst residential and industrial premises. The physical attributes of Mithi are presented below (Table II and Figure 2)

Table II

Physical set up of Mithi

| | |
|---|---|
| **Length** | 17.80 Km. |
| **Catchment Area** | 7,298 Ha. |
| **Surrounding Land use** | Residential and Industrial |

Source: NEERI report, 2011




### A. Problem identification

On 26th July 2005, Mumbai received 944 mm of rainfall in a 24-hour period resulting, in one of most devasted floods resulting in damage to Indian economy, city's infrastructure and loss of life and property (The Hindu, 2016). As reported by National Institute of Disaster Management (NIDM, 2009), failure of drainage systems, rapid urbanisation and encroachment of slums over the existing drains, decrease in coastal mangroves, discharge of industrial effluents into Mithi were some of the reasons leading to the disaster. Mithi was one of the way out for the storm water, when Mumbai was built by reclamation of 7 islands. The river acts a natural drain for city's storm water even today. In addition, it serves as a natural boundary between the main city and Mumbai-suburban region. Thus its flooding, has a severe impact on transport corridors viz. railways, western and eastern express highway (Kadave et al., 2016). The path of the river, as seen today, is encroached by unauthorised settlements and industries resulting in issues like solid waste disposal into the river and riparian area, discharge of domestic and industrial waste water, etc.;

Mithi has been subjected to change in its river course and width reduction due to various development activities resulting in its degradation. The impact of these activities is tabulated below (Table III).

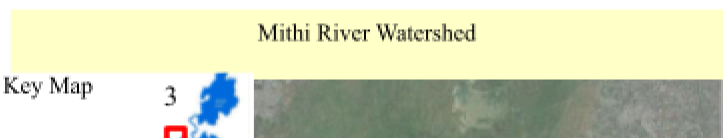
Table III

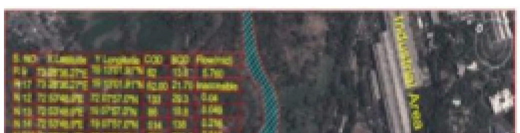
Impact of various development activities on Mithi

Source: Compiled from "Drainage problems of Brihanmumbai, Tiwari,2019"

| Year | Activities | Impact |
|---|---|---|
| 1805 | Construction of the Sion Causeway | Course of the river was changed and it was forcefully turned west |
| 1845 | Construction of Mahim causeway | Exit into the sea was narrowed |
| 1860s | Construction of Tulsi, Vihar and Powai Lake: Mithi dammed at three locations | When the dams get full, following heavy rains, the excess spillover enters the river. |
| Post 1947 | Construction of Bombay airport. | When the airport was con- structed initially with the main runway running east-west, and a subsequent (post- 1970) secondary runway running NW-SE were built, the Mithi was diverted along the eastern wall of the airport adjoining the Kurla hill at Jari-Mari and Bail Bazar into a narrower nala. |
| 1966- 1972 | Settlements began to form on floodplains | Muddy land encroached |
| Early 2000s | The extended run- ways crossed the nala close to the eastern walls over culverts. | The river itself is re- diverted its original course south of the circumscribing southern wall of airport<br>circumscribing southern wall of airport. |
| | Construction of Bandra-Worli sea link | Mithi's mouth near the Mahim creek was narrowed. |
| | Expansion of Bandra-Kurla Complex in Mithi's floodplain | Shrinking of wetlands |
| | Mud flat area fully developed | River course of Mithi and Vakola reduced. |

Increasing urbanisation has drastically affected the floodplains of Mithi over the years. Between 1966- Early 2000s built-up area around Mithi increased from 27.00% to 34.49% leading to increase in impervious surfaces. Approximately 37% of mud flat area was encroached by slums, reducing the width of river and disturbing the smooth river flow. In 2009, 45% of mud flat area was encroached, reducing the width drastically (Zope et al., 2012). Emergence of anthropogenic activities around Mithi has resulted in the degradation of environment and biological life of the river. Studies conducted in past reveals the accumulation of heavy metals in the sediments of Mithi (U. Singare et al., 2012). Maharashtra Pollution Control Board (MPCB), in its report "Comprehensive Profiling of Mithi, 2014, has identified stretch of Mithi with severe degradation, as demarcated below (figure 3).

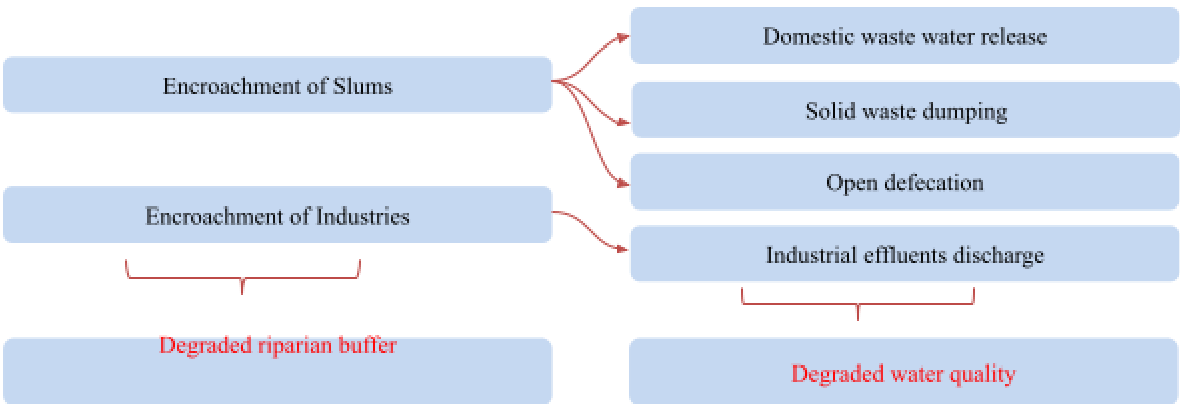


Stretch 3

Stretch 5

As reported by Central Pollution Control Board, Mithi is classified as Priority I for restoration with BOD as high as 50 mg/l (River stretches for restoration of water quality, CPCB, 2022). It is crucial to identify the sources of pollution of Mithi for the formulation of appropriate restoration strategies (Figure 4).




## III. ASSESMENT OF EXISTING SCENARIO

The identified critical stretches of Mithi and its surrounding are assessed quantitatively and qualitatively with respect to its riparian area and green spaces. Issues along these stretches are identified based on the following.

1. Environmental Quality Assessment Index (Quantitative assessment)
2. Citizens' Perception Survey (Qualitative assessment)

### *A. Environmental Quality Assessment Index*

The environmental quality of Mithi watershed is assessed using the Environmental Quality Assessment Index (EQAI), as put forth by Battemarco, 2020. It associates the total number of green areas and their connectivity (figure 5).

The index consists of two components:

1. Land shape index: Assumes that better the shape of land, greater is an ability to resist external disturbances. Regular

landscape patches are relatively stable and resistant to edge effects and external disturbances (Gyenizse et al., 2014).

**LSI = (4√ A)/ P**

Where,

LSI – Landscape Shape index

A- Total Area of patches (m2)

P- Total Perimeter of patches (m)

The ideal value 1 represents the conformation of landscape shape to

2. Connectivity indicator of green spaces: The interlinked network of green patches are defined by continuity of greens, as identified spatially.

**C= Ip/ Tp**

Where,

C- Connectivity indicator

Ip – Number of connected green spaces

Tp- Total number of green spaces

The value should be closer to 1.

*EQAI is the weighted sum of these components, and the weights are distributed equally.*

**EQAI = WLSI X LSI (%Ago / %Ag) + Wc X C**

EQAI - Environmental Quality Assessment Index

WLSI= WC - weights associated both indicators (LSI and C) (Wlsi = Wc = 0.5)

%Ago – Optimal ratio of green spaces to the total area (United Nations 2017, suggests 15%)

%Ag- Existing ratio of green spaces to the total area

C- Connectivity indicator

The index primarily focuses on connecting garmented patches of urban greens in the watershed.

**LSI = (4√ 1033091)/ 33221 = 0.12**

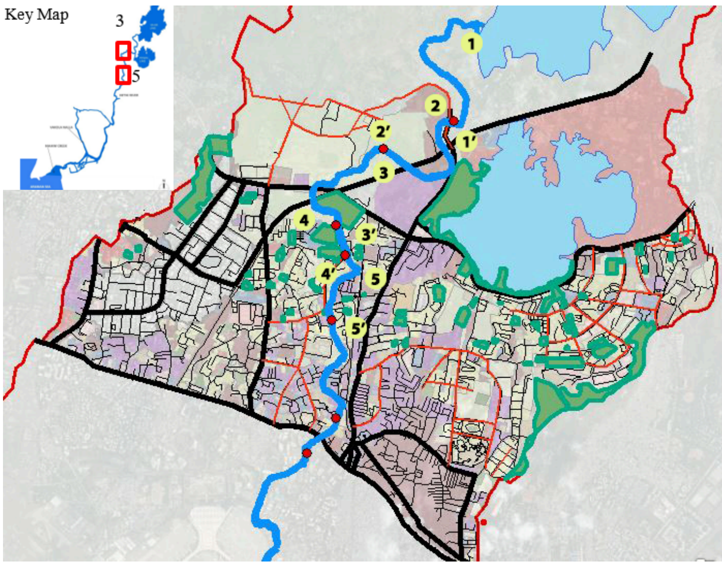
**C= Ip/ Tp= 4/57 = 0.07**

EQAI = WLSI X LSI (%Ago / %Ag) + Wc X

= 0.5x 0.12 ( 15/8.95) + 0.5 x 0.07

= 0.13

**Ideal of EQAI is 1.**




The low value in existing network of green spaces suggests poor environmental quality.

*B. Citizens' Perception Survey*

Perception survey was conducted along the critical stretches of Mithi river, through a survey questionnaire (annexure 1). A total of 100 samples were collected by simple random sampling. The perception of citizens was studied for various parameters viz.characteristics of water quality, characteristics of riparian area, recreational utility of Mithi, desired recreational activities and scope of community participation

Cohort characteristics of surveyed population is presented in the figure 6.

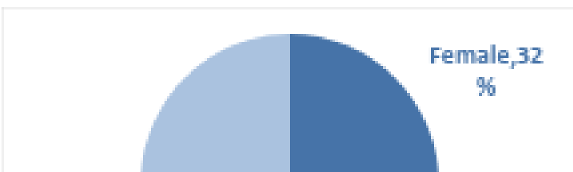



Figure SEQ Figure * ARABIC 6: Cohot characteristics of surveyd population

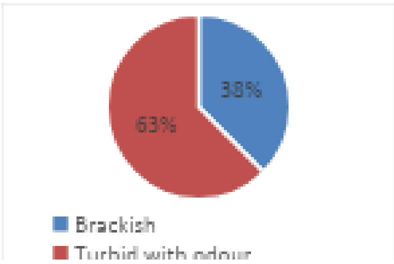
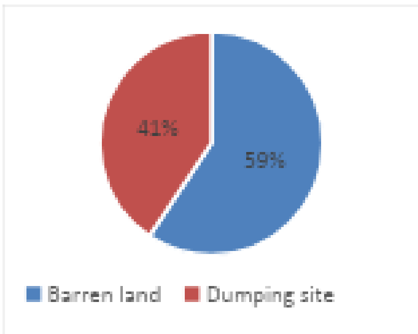
Source: By Author

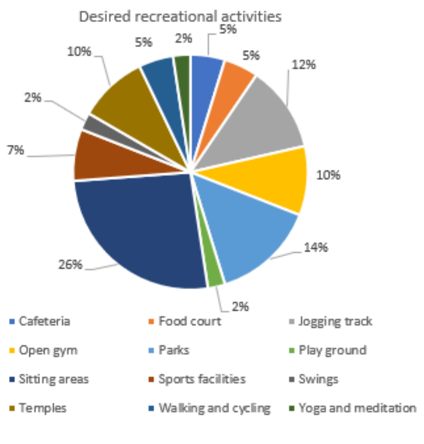
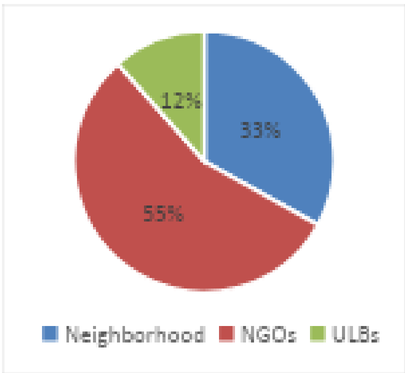
Among the samples, 68% are male and 32% are female. The survey was conducted for all age groups viz. less than 18 (13%), 18-35 (42%), 35-60 (30%), Above 60 (15%).

Citizens' responses on the above-mentioned parameters are presented in table below (Table IV)

Table IV

Citizens' perceptions survey findings

| S. No | Parameters | Survey Response | Remarks |
|---|---|---|---|
| 1 | Characteristics of water quality |   Figure SEQ Figure * ARABIC 7: Perception of water quality | The majority of surveyed population, perceives the water quality as turbid with odor. |
| 2 | Characteristics of riparian area |   Figure SEQ Figure * ARABIC 8: Perception of riparian area | Riparian area is perceived as a dumping site and barren stretch. |
| 3 | Recreational utility of Mithi | No recreational utility observed | 100% of the respondents revealed that they do not visit any place along Mithi for recreational purposes due to degraded surrounding and inaccessibility to river banks . |

| | | | |
|---|---|---|---|
| 4 | Desired recreational activities |  | It was found that citizens desire the listed activities for recreation along the stretch of Mithi. |
| 5 | Scope of community participation |  | Strong willingness for participation is observed. |

Source: By Author

Citizens' perception is crucial for understanding the impact of natural elements on the lives of local residents. In addition, it also aids in the formulation of effective management plan; taking into account, the vision and needs of local communities. Thus, enhancing people's interaction with nature in the long term.

In the context of Mithi, following inferences of the survey, as presented in Table V.

Table V

Inferences from citizens' perception survey

| S. No. | Parameter | Findings | Inference |
|---|---|---|---|
| 1 | Characteristics of water quality | The major portion of surveyed cohort found the water quality turbid with odor. | Interventions to restore water quality is crucial. |
| 2 | Characteristics of riparian area | Riparia area is majorly perceived as barren and dumping site. | Intervention to enhance the quality of riparian area is necessary. |
| 4 | Recreational utility of Mithi | Currently, citizens do not visit Mithi or its surrounding for any form of recreation. | Provision of various recreational activities, as desired by citizens is necessary. |
| 5 | Scope of community participation | No major instances of participation but willing to participate is observed. | Developing community participation framework is necessary. |

Source: By Author

IV. SUMMARY OF IDENTIFIED ISSUES

Mithi, was once a sweet water, that served the residents of Mumbai. However, today, Mumbai's citizens perceive the river as a nallah or a drain that carries sewage, solid, waste and waste water (Kamath & Tiwari, 2022). Various unplanned and unregulated activities along the river stretch have contributed to degradation of river health, thus, leading to its current polluted stretch.

The land use and activities adjoining Mithi have contributed to its pollution. As one walks along the river, most many parts of the river course is lined by a retaining wall leading to visual, spatial and ecological disconnect of the river and the city (Figure 11).

Figure SEQ Figure * ARABIC 11: Polluted state of Mithi

Source: By Author

The issues along the stretch of Mithi are identified from published reports, quantitative assessment through EQAI and qualitative assessment through the citizens' perception survey. The summary of these issues is presented in the table below (Table VI)

Table VI

Summary of issues observed along the stretch of Mithi

| S.No | Issues along the river stretch | Source |
|---|---|---|
| 1 | Release of industrial effluents and domestic waste water | Comprehensive study/ profiling of Mithi river, MPCB, 2014 |
| 2 | Solid waste disposal in river | |
| 3 | Poor connectivity of green spaces | EQA Index |
| 4 | Degraded riparian area | Citizens' perception survey |
| 5 | River- city disconnect | |
| 6 | Lack of recreational utility | |
| 7 | Lack of citizens participation | |

Source: By Author

These issues can be broadly classified into three major parameters viz. Environment, Economic and Social, as depicted in the figure below (Figure 12).

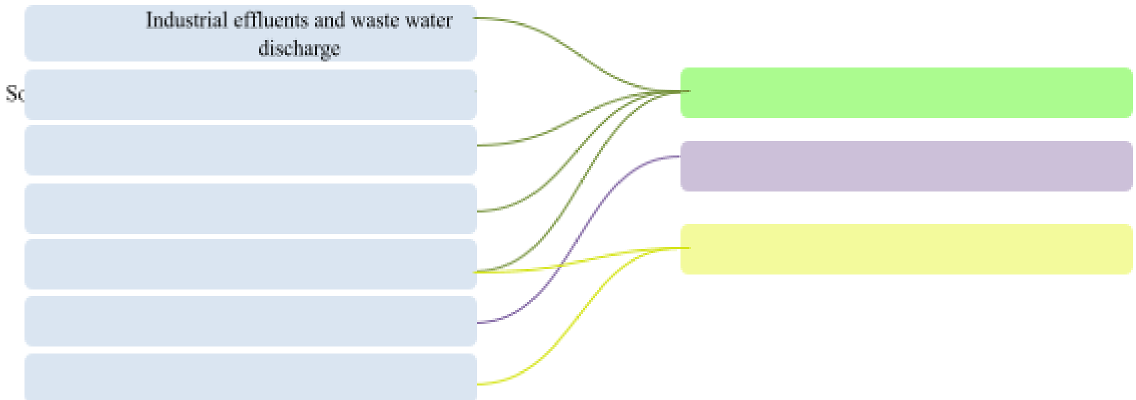



Figure SEQ Figure * ARABIC 12: Classification of issues into major categories

Source: By Author

## V. PROSPECTS OF RIVER RESTORATION

Integration of urban blue-green infrastructure, is an environmental conservation approach primarily focusing on formation of linkages of blue and green spaces of urban areas (Kaur & Gupta, 2022).

In the context of river restoration, it aims at proving alternate approaches to conventional river management strategies. Mitigation of flood, access to clean water, treatment of effluents discharging in urban rivers, etc. are the top priorities of river restoration through integration of blue green infrastructure (Hamel & Tan, 2022). The integrated network of various elements focusing on blue-green infrastructure range from green spaces to riparian vegetation, streetscapes and various engineered systems that increases infiltration and evapotranspiration, reduces urban heat island effect, removes pollutants and increases aesthetic and recreational values (Hack & Schröter, 2021) (Eckart et al., 2017). In addition, conservation of urban rivers is crucial for wellbeing of human civilizations it forms an integral part of habitation; river restoration, thus, becomes a social activity. Thus, community participation becomes crucial. The holistic approach that focuses on the people and dedicated towards the idea that citizen must be involved in a decision-making process, is the objective of community participation. It is an effort that empowers community to improve on certain concerns by utilizing the existing resources (Syahputra et al., 2022) (Sihombing et al., 2018).

Enhancing urban BGI, through integrated participatory approach focuses on connectivity, multifunctionality, social inclusion and enhancing economic functions (Pauleit et al., 2011). Thus, for the formulation of effective strategies; understanding of the effects of alteration in natural areas and elements on the lives of local residents is crucial (Ahern, 2007). In addition, desires of citizens and opportunities of providing recreational utility to urban rivers; thereby enhancing people's experience of living environment is envisioned to form a basis of community participation in river restoration through urban BGI (Daniel et al., 2012). (Figure 13).


Figure SEQ Figure * ARABIC 13: Prospects of river restoration with respect to identified issues

Source: By Author

In an Indian context, The Urban River Management Plan, NIUA, 2020 (URMP) provides a comprehensive and strategic framework to be adopted by river cities for efficient management of urban river stretches. URMP focuses on 10 major objectives catering of urban river management, as shown in the figure below (Figure 14).


The URMP, identified framework for upscaling Blue Green infrastructure and enhancing the role of community participation in river restoration shall form the basis of planning interventions for Mithi.

VI. RESTORATION STRATEGIES FOR MITHI RIVER

Restoration of Mithi is an attempt to reinstate its natural processes and restore biodiversity and improve upon river health. In addition, Mithi is envisioned to form a nexus of human interaction and nature through various measures to enhance its recreational utility and economic value. To combat issues observed along the stretch, strategies are formulated for large-scale intervention and small-scale interventions.

*A. Large Scale Interventions (Urban Blue-Green Infrastructure)*

Integration of blue-green infrastructure (BGI) in existing scenario involves prioritizing sites based on two hydrological models crucial for Mithi river watershed viz. Flood Risk and Topographical index. Along the critical stretches of Mithi, risks with respect to floods and water accumulation and superimposed on vacant lands for identifying the scope of integration of urban BGI.

The maps for floods risks and topographical wetness index are presented in figure 15 and figure 16, respectively.

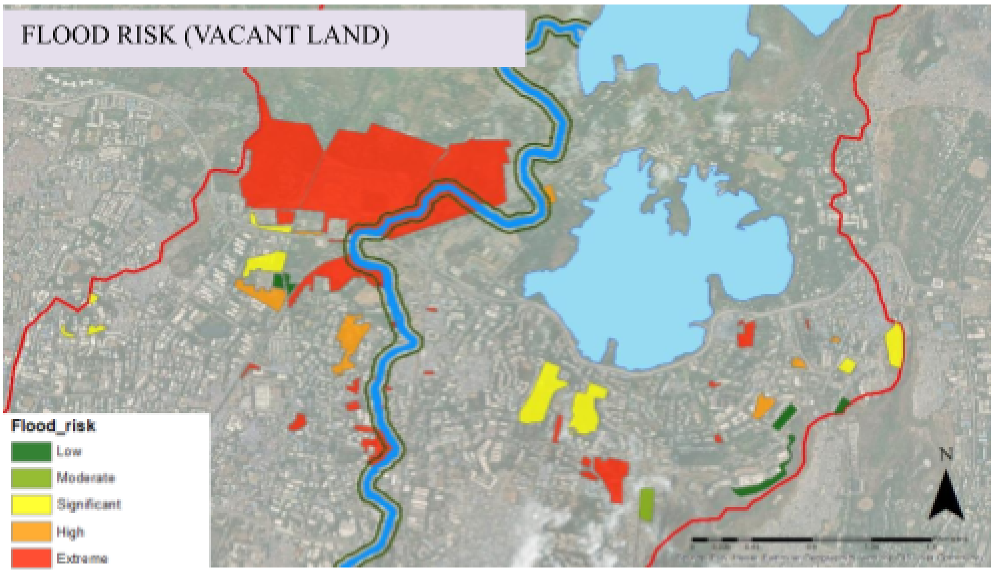
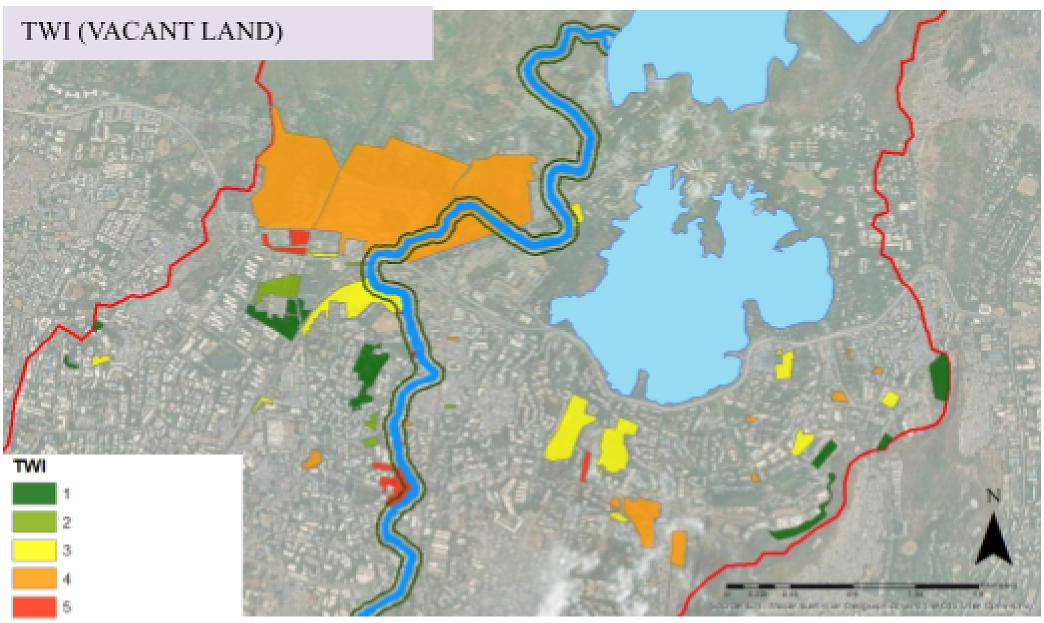



Figure  SEQ Figure * ARABIC 15: Flood risk on identified vacant lands

Source: By Author



The maps are superimposed to identify risks and prioritize sites for integration of Urban BGI with respect to extreme (priority I) and high (priority II) risk. The map of site priority is presented below (Figure 17).

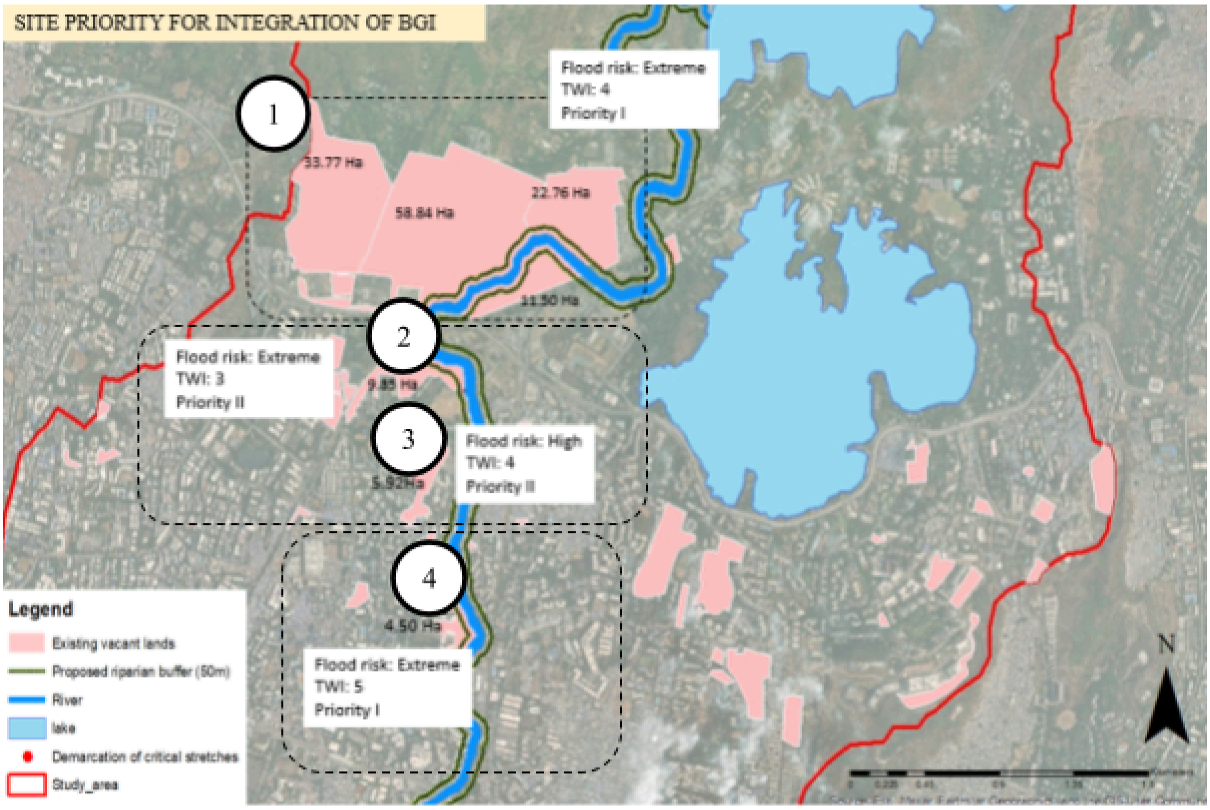



Figure SEQ Figure * ARABIC 17: Site priority for integration of urban BGI

Source: By Author

Extreme and high risks are observed in upstream and middle reach of a river; thus, the interventions of restoration of Mithi by enhancing blue green infrastructure requires the demarcation of zones in accordance with the risks and issues observed along the river stretch. The zones are demarcated as follows

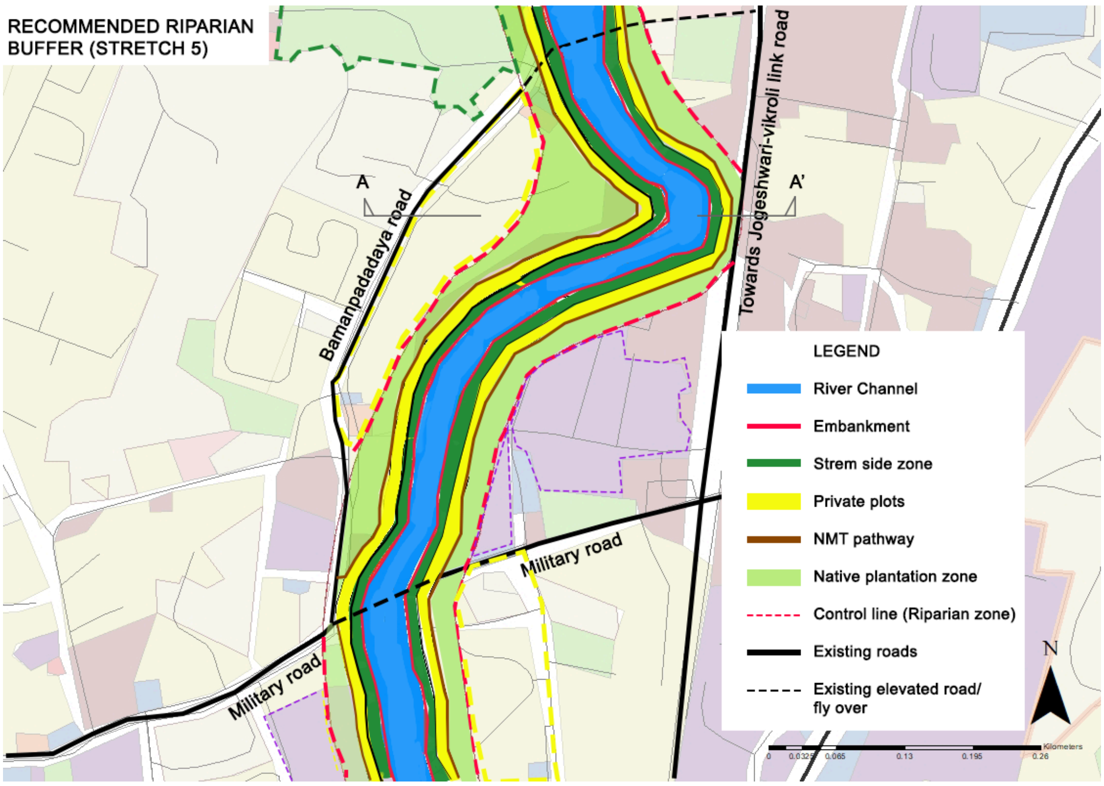
**Zone A (Upper reach):**
The zone has extreme risk of flood and water accumulation, hence is demarcated as environmentally sensitive.
1.Floodplain Forest (Grassland, marshes, wetlands, lakes, etc.): To restore the degraded wetlands and enhance the connectivity of river with floodplains.
2.Bio-diversity Park: To increase accessibility to river stretch and enhance recreational utility.

**Zone B (Middle reach):**
The zone has high risk of flood and water accumulation; the recommendations thus prioritize fluvial parks and river parks in the proximity to Mithi.
3.Fluvial parks/River parks: To mitigate floods and water accumulation and activate river front with desired recreational activities inferred from citizens' perception survey.
Recommendations for recreational activities: Walking and cycling tracks along the edge of Stream side zone , Open gym , Sitting areas/gathering spaces, Gardens, children' play area (swings, slides, etc), Community areas and religious places (temples, etc.) with gathering spaces, Food court/ food street.
(Inferred from citizen' perception survey)

**Zone C (Lower reach):**
Riparian area is highly encroached in this zone.
The stretch shall be developed by incentivizing private developers;
DP 2034 incentivize private developers in following ways:
1.Accomodation Reservation (AR)
2.Transferable Development Rights (TDR)

Lower reach, as demarcated in figure 20, is highly encroached zone. Thus, acquiring land for public purposes becomes of utmost importance. Acquiring land for public purposes becomes crucial for the development of appropriate riparian buffer and regulate the development activities along the river bank. The land can be acquired by Accommodation Reservation and Transfer of Development Rights (DP 2034).

The Riparian buffer can be developed as follows (Figure 20).




Plan of riparian buffer

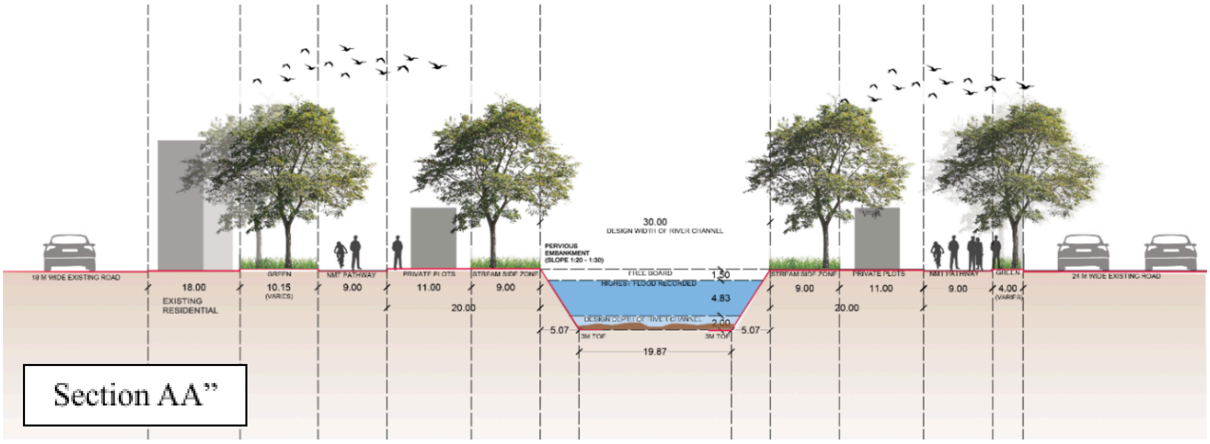



Figure SEQ Figure * ARABIC 20: Development of riparian buffer

Source: By Author

Eyes on the river: To prevent the re-encroachment of the green buffers, it is recommended to allow natural surveillance for the river channel and riparian land. It is recommended, to activate the river edge, through privatization of plot and development of residential uses viz. Bunglow, farm house, etc. with appropriate setbacks and ground coverage.

*B. Small Scale Interventions (Urban Blue-Green Infrastructure)*

Integration of blue-green infrastructure (BGI) in existing scenario involves prioritizing sites based on two hydrological models crucial for Mithi river watershed viz. Flood Risk and Topographical index. Along the critical stretches of Mithi, risks with respect to floods and water accumulation and superimposed on vacant lands for identifying the scope of integration of urban BGI.

Formulation of small scale interventions for upscaling Urban BGI is crucial to address identified critical activities along the river bank viz. ineffective solid waste dumping, ineffective management of domestic waste water and release of raw industrial effluents.

1) *Interventions for Solid Waste Management:*

Excessive Solid Waste Dumping has been observed along the critical stretches of Mithi. The areas with ineffective management are mapped along the stretch, as depicted in the figure 21.


Figure SEQ Figure * ARABIC 21: Areas with ineffective solid waste disposal

Source: By Author

The approximation of total waste disposed in Mithi can be calculated as follows (Table VII)

Table VII

Approximation of total waste disposed in mithi

| S | Stretch | Approx. population on river bank responsible for SW disposal in Mithi<br>(Tenements X HH size as mentioned in DP 2034) | Approximate waste generated (MT)<br>(considering 630 gm per person per day as mentioned in DP 2034) |
|---|---|---|---|
| 1 | III | 350 X 4.58 = 1603 | 1.00 |
| 2 | IV | 126 X 4.58 = 578 | 0.36 |
| 3 | V | 500 X 4.58 = 2290 | 1.4 |
| Total waste disposed in Mithi | | | 2.76 MT/person/day |

Source: Interpreted from Comprehensive profiling of Mithi, 2014, MPCB and Development Plan 2034

For the effective management of solid waste, understanding composition of waste management is crucial; this is approximated by calculating city level data as reported by Development Plan 2034.

Table VIII presents the approximate quantity of solid waste disposed in Mithi

Table VIII

Approximate quantity of solid waste disposed in mithi.

| S | Nature of solid waste | Approximate percentage<br>(As reported in DP 2034) | Approximate quantity (MT) being disposed in Mithi (Total quantity of waste calculated in Table VII) |
|---|---|---|---|
| 1 | Wet organic | 54 | 1.5 |
| 2 | Dry organic | 15 | 0.4 |
| 3 | Recyclables | 19 | 0.52 |
| 4 | Inert material | 13 | 0.35 |

Source: Interpreted from Development Plan 2034

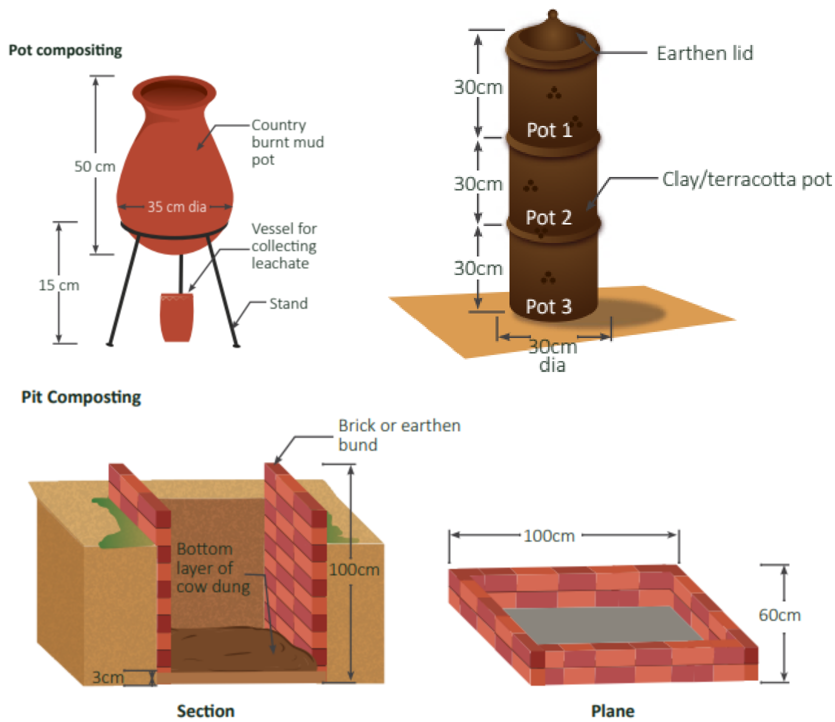
As presented in table above, dry and wet organic waste contributes to be approximately 1.80 MT/ day; thus, its effective management is crucial. Solid Waste Management (SWM) is recommended through various levels of intervention at mentioned in the table below (Table IX)

Table IX

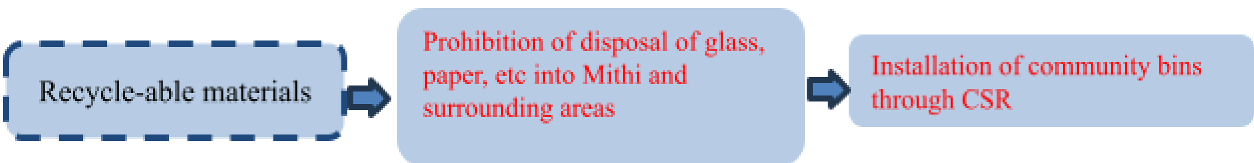
Recommendations for management of organic waste

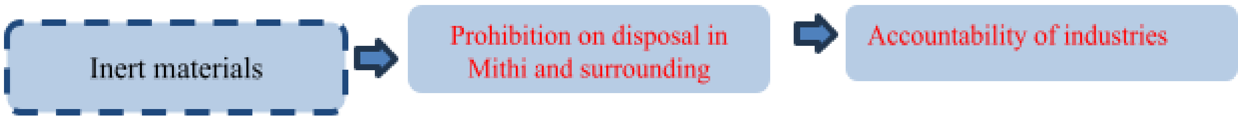
| Level of intervention | Capacity | Recommendations |
|---|---|---|
| Meso level | Household (Small and Large families) | Single pot composting |
| | | Tripot composting |
| Micro level | Neighborhood | Pit composting |
| Macro level | Sector | Vermicomposting |

Source: Modified from Swachh Bharat Mission Manual, 2021




As presented in table VIII, recyable material and inert material constitute to 19% and 13%, respectively. The prohibition of these waste on dumping in river and its surrounding requires interventions to provide alternate solutions. These are presented in the figure in below (Figure 23).

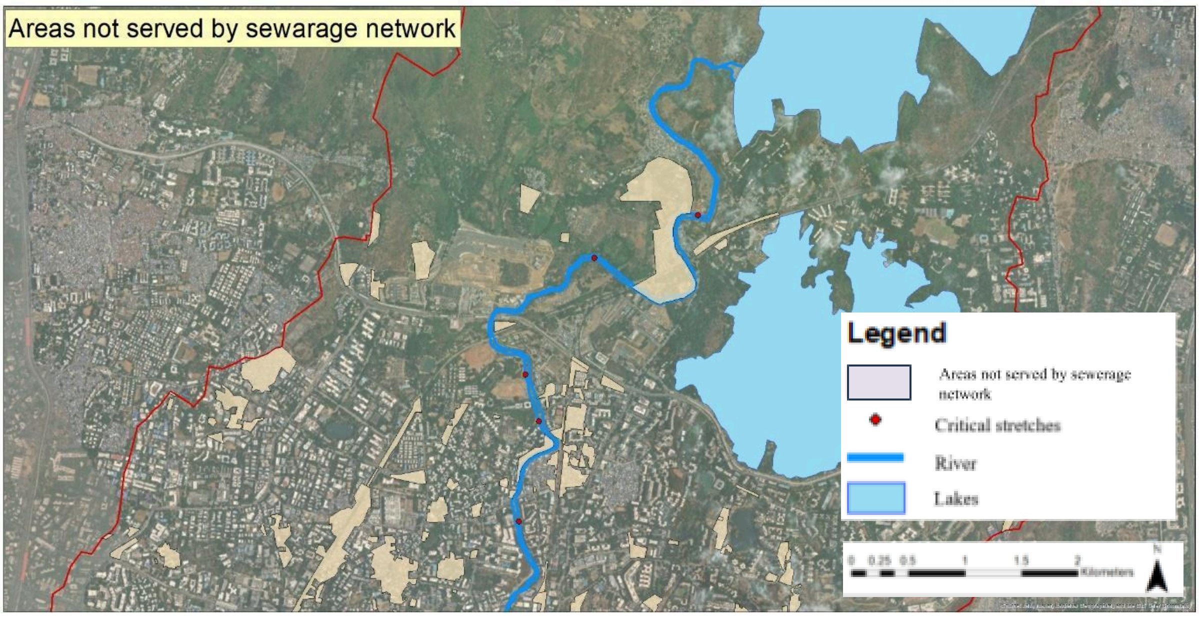





2) *Interventions for mamagement of domestic waste water and industrial effluents*

As reported by Development Plan 2034, 2,680 MLD of sewage is generated in Greater Mumbai whereas only about 1,700 MLD of the total sewage generated is collected accounting for nearly 63% of the total sewage generated. This gap is majorly seen in areas, not served by sewerage network of the city. As a result, the waste water is illegally released into nearby nallah, which in turn, carry the polluted water to water bodies.

In critical stretches, these areas are marked as follows (Figure 24)




In addition, numerous unorganized industrial clusters are developed along the stretch of Mithi, resulting in discharge of industrial effluents; these clusters are identified in the map below (Figure 25).

| Sr No | Type of industries | Remarks |
|---|---|---|
| 1 | RMC plant | Releasing effluents into Mithi |
| 2 | Heavy engineering | Provided with ETP |
| 3 | Jewelers works | Releasing effluents into Mithi |
| 4 | Industrial estate | Provided with ETP |
| 5 | L&T heavy industries | Provided with ETP |
| 6 | Small and medium industries | Releasing effluents into Mithi |
| 7 | LNG, re-gasification | No impact on Mithi documented |

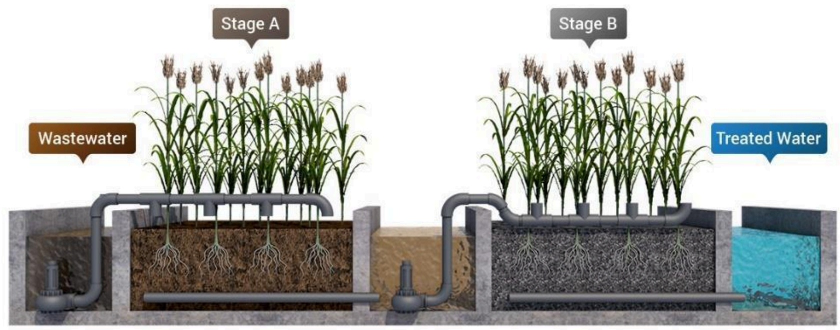
It is crucial for industries to adopt to "zero liquid discharge" policy to prevent the release of raw effluents. However, clusters of these industries are exacerbating environmental concerns for Mithi. These industries are tabulated below (Table X).

Table X

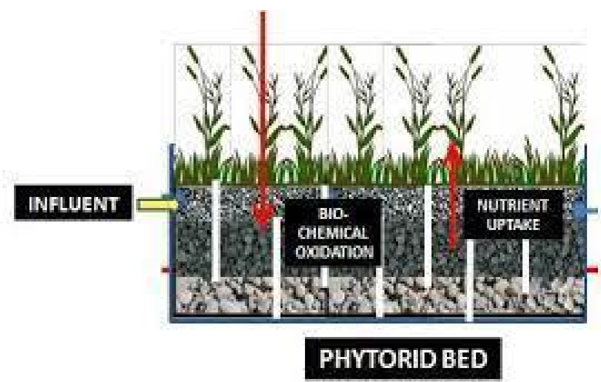
Industries releasing effluents in Mithi

Source: By Author

Heavy discharge of sewage from non-sewered settlements and raw industrial effluents on river banks has affected the ecosystem of Mithi and river health. Studies conducted in the past have produced evidences of decentralised waste water management as green infrastructure solution (Prescott et al., 2021). To ensure, minimal interventions in various, in-situ treatment option are recommended. At Meso level, in a household, for in-situ treatment of domestic waste water, bioremediation techniques can prove to be beneficial. This involves the provision of green beds with dried banana leaves for removal of pathogens (Azzam et al., 2020) from domestic waste water, thereby avoiding the pollutants from entering in Mithi. At macro level, sectoral interventions may include the provision of reed beds with plantation of phytoremediation species of plants. It is envisioned that integration of these beds in riparian belt, will aid in removal of toxic pollutants from waste water, before release into the river. The integration is envisioned to be beneficial where minimal intervention in existing drains is required. The riparian area acts a buffer and absorber of pollutants (Figure 26).




For the removal of toxic metal pollutants, provision of plantation species viz. Durva grass, Halfa grass, Van haldi (Grass species); Mango, neem, sheesham, jamun, moringa, peepal, semal, bael (Tree species) are proven to be effective (URMP for Kanpur city, 2021). These can be provided with Gravel filter in the form of constructed wetlands and phytoroid beds (Figure 27).



*C. Demarcation of River Regulation Zones (RRZs)*

The primary purpose of establishing RRZs is to regulate the activities along the bank of rivers. RRZs are demarcated to prevent encroachment of bank and protect floodplains. As recommended by, River Centric Urban Planning Guidelines, MoHUA, 2021, RRZs are demarcated as follows (Figure 28 and Table XI).

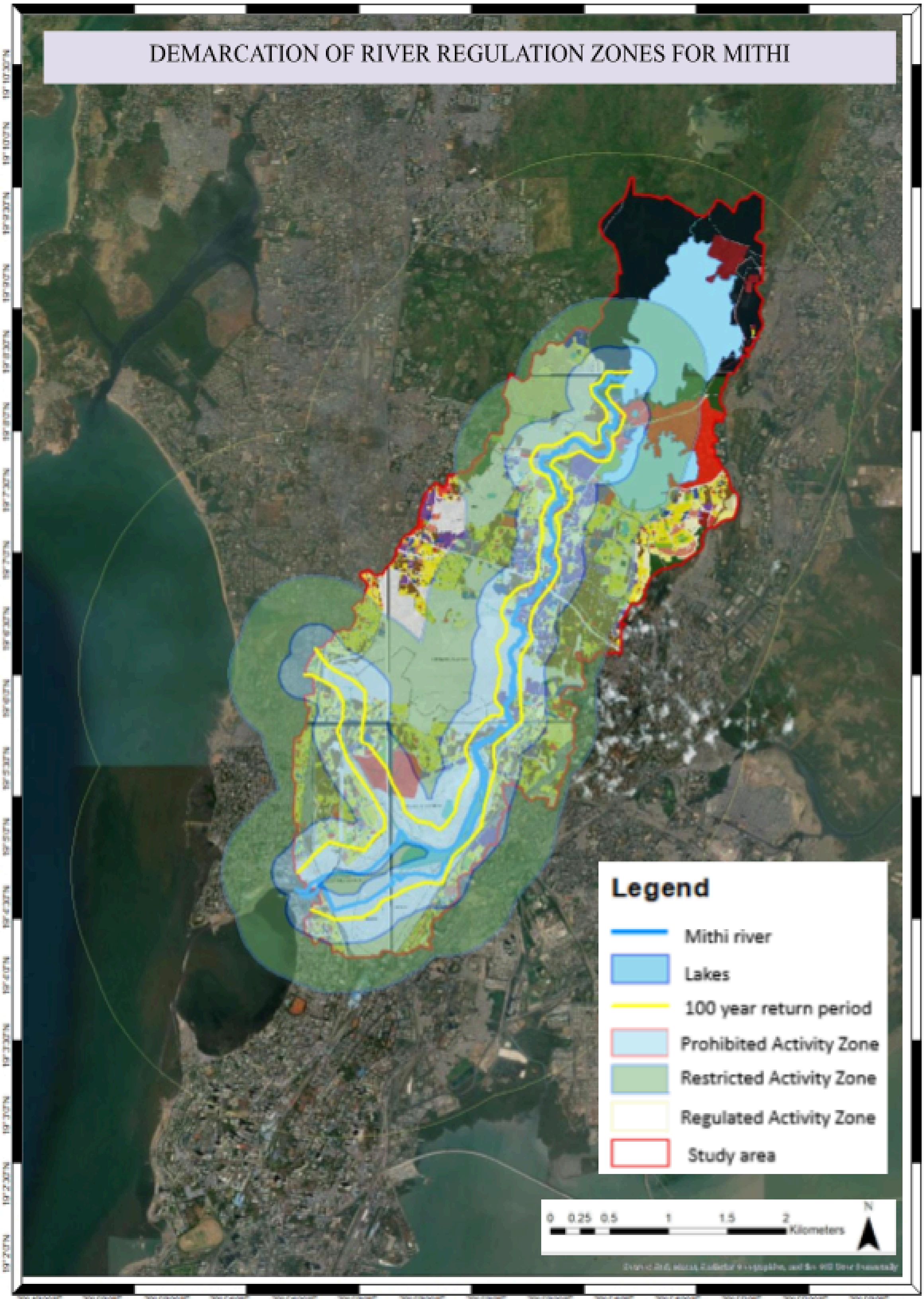


Table XI

| As per RCUP, 2021 guidelines | | Recommendations for Mithi |
|---|---|---|
| Distance from 50 year return period (100 year return period considered as marked in Action Plan for Mithi, 2014) | Zone | Activities |
| 500 m | Prohibited Activity Zone | • Prohibition on SW disposal in Mithi and surrounding area<br>• Prohibition on discharge of raw domestic wastewater and industrial effluents in Mithi<br>• NDZ for new proposals of red industries<br>• ETP/CETP mandatory for existing industries with 60% reuse of treated water<br>• Prohibition on unplanned activities |
| From Prohibited Activity Zone to 1km | Restricted Activity Zone | • Laying of sewers to divert sewage to proposed STP/ ETP/CETP and to reed beds and constructed wetlands. |
| From Restricted Activity Zone to 3km | Regulated Activity Zone | |

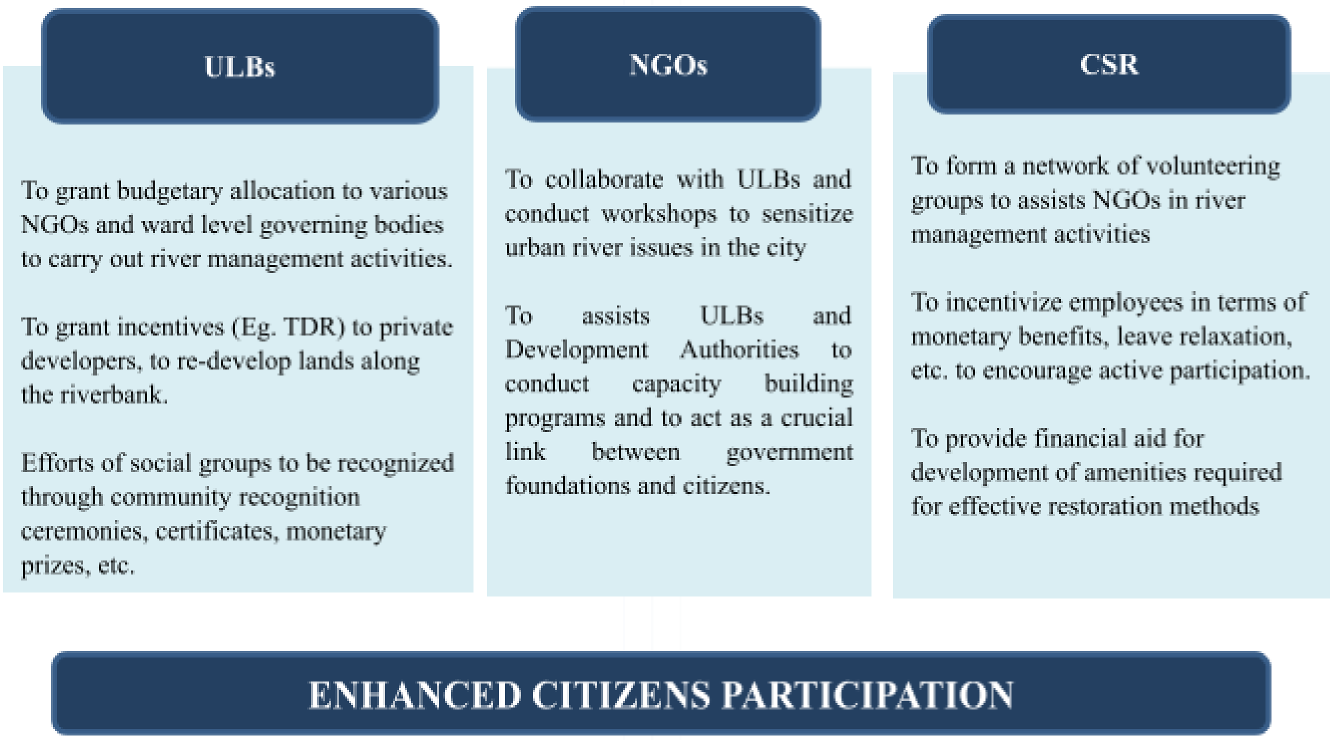
River Regulation Zones for Mithi

Source: By Author

*D. Enhancing community participation*

For the sustainability of urban rivers in the longer run, citizens associated with restoration practices, play a vital role. The participatory approach, not only aids in environmental sustainability, but also proves beneficial for ULBs. This allows all the stakeholder to share the onus of river restoration, thus relieving the stress from development authorities alone. The approach, thus, holistically focuses on citizens to be involved in decision-making process, management activities, etc. In existing scenario, no major modalities of citizen participation are recognized or reported. However, a strong willingness to participate in Mithi river restoration has been observed through primary survey.

Citizen perception survey (revealed) the scope of participation majorly through collaboration with NGOs and ULBs. However, to form an effective model of participation, it necessary to identify the key stakeholders and assign specific roles in accordance with river restoration practices, as depicted in the figure below (Figure 29).




Citizens play a key role in restoration practices, due to the potential of enhanced participation and aid in capacity building for ULBs. Citizens are key beneficiary of any development program in the city, hence, shall be included in all levels of planning process. The conceptual flow chart of citizens' participation is presented in a figure below (Figure 30).

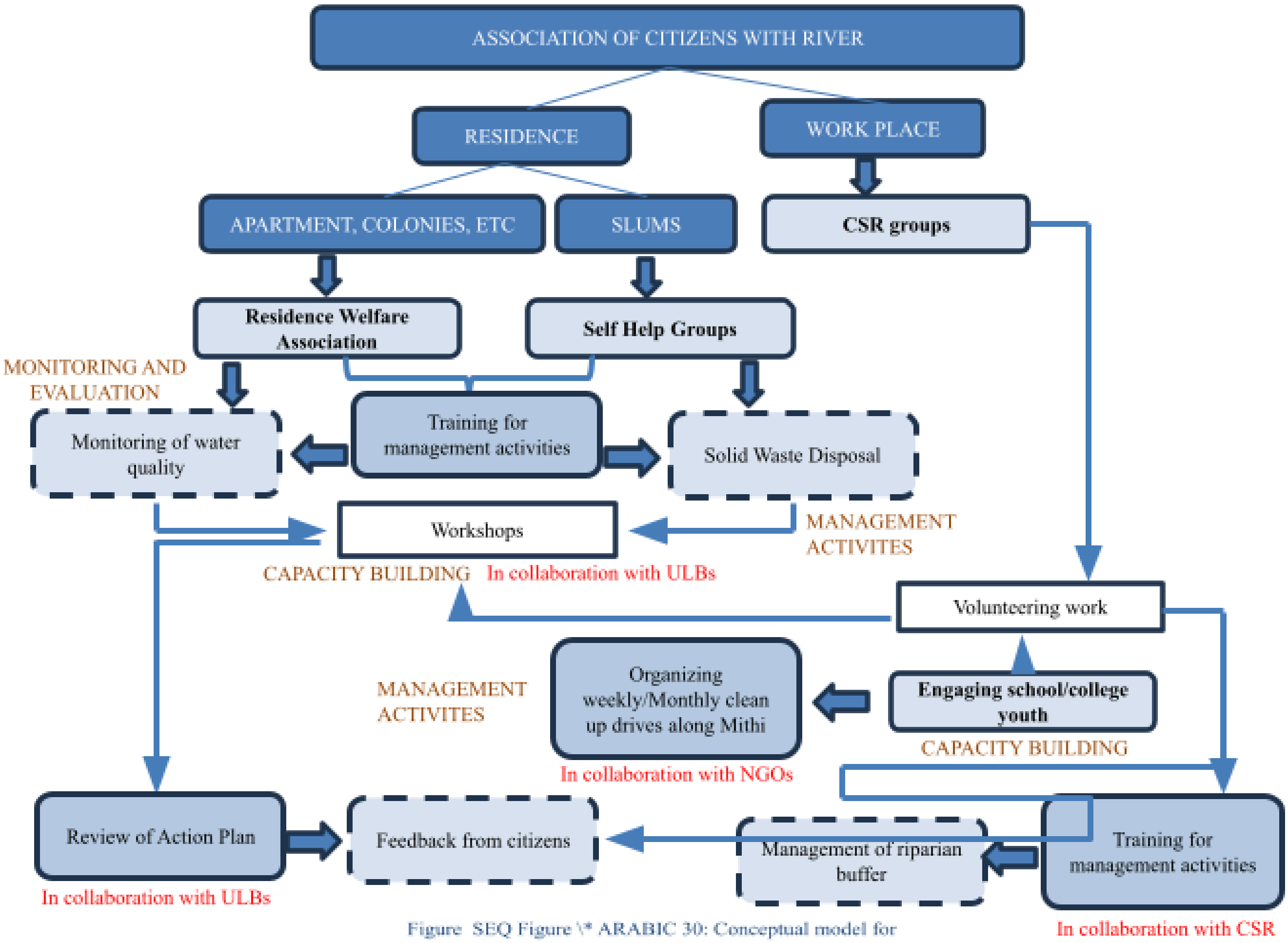



Figure SEQ Figure * ARABIC 30: Conceptual model for participatory approach

Source: By Author

## VII. SUMMARY OF RESTORATION STRATEGIES WITH RESPECT TO URMP OBJECTIVES

The recommended strategies are envisioned to improve on river channel and water quality, that has been degraded due to various invasive activities on the river bank. The regulation of these activities mitigates the multiple causes of degradation of Mithi. Various small-scale interventions, aid larger impact like pollution control, flood mitigation, control over development activities, etc. thereby improving upon river health and allowing the unobstructed flow.

A comprehensive note on strategies is presented in a table below (Table XII):

Table XII

Summary of restoration strategies

| S.No | Issues identified | Key aspect of river restoration | Intervention proposed | URMP objective achieved |
|---|---|---|---|---|
| 1 | Solid waste disposal in river | Environmental | Pot composting, Pit composting and Vermicomposting of organic waste |   |
| 2 | Release of domestic waste water and industrial effluents | Environmental | Reed beds, constructed wetlands and phytoroid beds for treatment of waste water | |
| 3 | Degraded riparian area | Environmental | proposals of bio-diversity parks, river parks |   |
| 4 | Poor connectivity of green spaces | Environmental | Regular riparian buffer of 9m stream side zone | |

| | | | | |
|---|---|---|---|---|
| 5 | Visual, Spatial and Ecological disconnect | Environmental | Appropriate embankment as recommended by IS code | |
| 6 | Lack of recreational utility | Social, Economic | Integrating desired recreational activities within river parks |   |
| 7 | Lack of citizen participation | Social | Models of community participation | |

Source: By Author

## VIII. ENVISIONED IMPACT

The integration of Blue-Green infrastructure is envisioned to improve on river ecology, restoration of wetlands in floodplain of Mithi and providing bio-diversity of flora and fauna.

With the recommended riparian buffer and integration of Urban BGI, EQAI is envisioned to increase to 0.57 from a critical 0.13. An array of green infrastructure along critical stretches, flood risk and topographical wetness index is envisioned to reduce to moderate to low from existing extreme and high risks. Effective river restoration can be achieved by addressing the needs of local residents to provide avenue for recreation and aid in capacity building by enhancing community participation for various river management activities.

Additionally, by developing recreational amenities and upscale residential areas along the riverfront, the economic potential of the Mithi River is anticipated to significantly increase.

Thus, Mithi can be brought at the nexus of human interaction and nature and can be given a fundamental importance with respect to Environment, Economic and Social aspects in the city.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## DECLARATION OF CONFLICTING INTERESTS

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