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Exploring the Role of Blue - Green Infrastructure to Revitalize Riverfront- A Case of River Musi, Hyderabad

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Abstract - Owing to the background of global warming, blue–green infrastructure (BGI) has become important and to cope with the threat of different aspects of climate change has become an important issue. The study of BGI is a sustainable design solution/approach to redefine the character of the city that uses river and its adjacent land to establish the interconnected passageway between natural habitats and the river belongs to everyone. It benefits everyone in the region with its implementation through nature-based solutions.

The study will analyze how adopting the BGI will benefit for the river re-vitalization and development. It will conclude by adopting strategies for approaching and implementing BGI for the river front development. Secondly, the study will identify the approaches on integrating concept of BGI in current scenario. Finally, the conclusion is based on the benefits of BGI reflected through the approaches showing the importance of BGI.

Key Words: Blue Green infrastructure, BGI, River revitalization, Challenges, Riverfront development.

NEED FOR THE STUDY:

Riverfront development has been invaluable for architecture, settlements, and public spaces. Human interventions have adversely affected riverfront areas, leading to sewage dumping, indiscriminate raw waste, encroachments on these water fronts. To mitigate the above effects, integrating blue-green infrastructure into the present scenario of the cities can offer multiple benefits like planning for water sensitive cities, water purification, water storage, sustainable urban drainage system, urban flood mitigation, enhancing biodiversity, urban heat island mitigation, thermal comfort, carbon sequestration, public health, and well-being. In the last decade, significant efforts have been taken to restore these water fronts and bring them back to life. BGI, blue and green, being the new concept on nature-based solution can become the solution to restore the blue and green cover of the city.

In this context, the Indian Government has taken on a massive urban redevelopment mission known as the National Smart City Mission to elevate the quality of life and wellbeing for the citizens.

1.INTRODUCTION:

Riverfronts in the past have significantly contributed to the evolution of early civilizations and human settlements. The history of riverfronts in India can be divided into four categories: the early stage which focuses on the mythological period; the birth of initial civilizations such as the Indus valley civilization, which led to settlements by various groups, and historical period including the Mughals, Portuguese , Dutch, French and the British; the pre independence stage from the 13th century to 20th century which saw an increase in industries; and finally the post-independence stage from 20th century onwards.

A river is an essential element in everyday life- as a resource, as a means of transport, as a corridor of endless movement and as a hub for recreation.

According to Postel and Richter (2003), water in the city is needed for various key reasons – practical, æsthetic and spiritual.

In the current scenario, most significant riverfronts have been abused and plagued by environmental issues, disturbed habitats and unstable landfills leading to contamination of soil and water. The exponential growth of urban areas has created a strain on urban lands and rivers that has serious implications on the availability of blue green spaces to the city dwellers. This is the primary reason, the continued and rapid pace of urban growth that adds to the demand for existing resources

India is experiencing an extraordinary spike in catastrophic weather events like droughts, cyclones, forest fires, increased temperatures, and severe storms, which are related to climatic change caused by greenhouse gas emissions from the use of fossil fuels and aerosols, as well ae the changes in the land use and land cover.

To mitigate these effects, integrating blue-green infrastructure into the present scenario of the cities can offer multiple benefits like planning for water sensitive cities, water purification, storage of water, sustainable urban drainage system, urban flood mitigation, enhancing biodiversity, urban heat island mitigation, thermal comfort, carbon sequestration, public health, and well-being.

BGI, blue and green, being the new concept on nature-based solution can prove and become the solution to restore the blue and green cover of the city.

2. UNDERSTANDING KEY CONCEPTS

Blue infrastructure usually relates to urban water infrastructure, including ponds, lakes, streams rivers and storm water provision.

Green infrastructure is often described as interconnected networks of multifunctional green space which provides multiple benefits and can accommodate sustainable development. These elements include parks, open space, trees, both street and private, playing fields, woods, private gardens, allotments and green roofs and walls.

"Blue-Green Infrastructure" (BGI), being the interconnected network of natural and semi-natural areas, are vital for building city and landscape resilience in the face of climate threats.

Blue-Green Infrastructure differs from the "grey" infrastructure or traditional engineering due to its natural elements, the network of measures that connect them, and the multiple ecosystem services that they provide. 90% of the world's disasters are related to excess' and shortages of water. These are worsened by climate change; effectuating changes in temperature, precipitation, storm frequency and intensity, as well as sea level rise. Adapting to the impacts of climate change and reducing water-related risk, requires a dynamic and adaptable infrastructure.

If we merge the dynamic and adaptable properties of natural areas (wetlands) with the semi-natural (linear parks with roads), that are interconnected (with drainage systems and green roof corridors), we end up with Blue-Green Infrastructure.

This interconnected network allows the flow of persons, water, and biodiversity. Additionally, the disaster risks related to climate change, such as floods, droughts, and landslides, could be reduced. By utilizing green infrastructure to manage the blue, the flow of rainwater can be attenuated before it enters a watercourse, providing areas where water can be stored and later harvested for re-use.

The works of **Ebenezer Howard** and **Frederick Law** Olmsted laid the foundation of realizing green-space as a continuous space

The European Commission defines green infrastructure as "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities, and enhances biodiversity.

The Australian public sector approach expanded the scope of blue-green infrastructure (in reference to integrating water management and planning with urban landscape and greening outcomes) by recognizing the inherent multifunctionality of the individual blue and green components.

3. BGI IN INDIAN SCENARIO:

First mentioned in an early discussion of environmental policy of the Fourth Five Year Plan (1964-69). Under the response of UNFCC India formulated the National Action Plan on Climate Change (NAPCC – 2008) with 12 missions that deals with agriculture, sustainable water, forestry, and habitat management. In addition, two flagship projects in 2015 Smart Cities Mission, AMRUT also focuses on improving urban living by integrating blue and green components.

In 1980, the Ministry of environment and Forests (MoEF) was setup to be the apex institution for conservation of flora, fauna, forest, and wildlife (Sandhu and Sindhu 2015). Currently India has enacted more than laws for protecting the environment. In addition to this there have been plethora of policies and programs that have been implemented by agencies for conservation of blue – green assets Although a relatively new concept, several Indian cities - such as Delhi, Bhopal, Madurai and Bengaluru- are including blue-green components in their master or action plans, with the aim of enhancing existing natural blue systems in the city and the surrounding public spaces through a planned strategy.

Blue-Green Masterplan, Delhi

- Delhi is one of the first cities in India to include a blue-green policy focus in its 2041 masterplan.According to the DDA's 2041 proposal, 'blue' infrastructure refers to water bodies like rivers, canals, ponds, wetlands and floodplains, and water, while 'green' refers to trees, lawns, hedgerows, parks, fields, and forests. treatment facilities. Subsequently, the 50 big drains (nullahs) that are currently governed by the different agencies will be cleaned up—pollutants.
- Delhi generates about 3,800 million litres of sewage per day, half of which goes directly into water bodies without being treated,64 so the cleaning up of drains will prove beneficial. the cleaned areas alongside the drains will be declared as buffer zones and green corridors that will be backed by creating walking and cycling paths through gardens. Low impact infrastructure like exercise areas, yoga gardens, open air theatres, museums, boating `these agencies on the blue-green policy66 to establish a common rulebook to ensure the integrated development of blue-green infrastructure in Delhi.

Blue-Green Masterplan, Bhopal

- The green and blue masterplan includes initiatives on sustainable water management, making all buildings green, waste management and recycling, and creating a network of parks, cycling paths and green walkways by linking land parcels. The Bhopal Municipal Corporation is in the process of finalising the 2021 masterplan, while the Bhopal Smart City Development Corporation Limited, a special purpose vehicle created under the Smart Cities Mission, will help create a separate 'green and blue masterplan' for the city, the main goals of which are to maintain and grow the green cover, to influence citizens' lifestyle indicators; and to promote an environmentally sustainable city. It also aims to "create conditions for local and international businesses to thrive" in Bhopal and make the city "the place for people centric development and a

cultural hub for arts, architecture, crafts and natural heritage".

Blue-Green Action Plan, Madurai

- In December 2014, the Madurai Municipal Corporation partnered with an international academic institution, a local NGO and citizen groups to create a blue-green action plan, driven by the severe water stress conditions faced by the city and the wider Vaigai Basin. The blue-green plan has been merged with ongoing work under the Smart Cities Mission to "accelerate economic growth via climate compatible development projects" funded by the larger mission.

Bangalore Masterplan 2050 for Water Supply and Sewerage Management

- In 2014, the BWSSB, the Indian Institute of Human Settlements and local stakeholders conceptualised a blue-green action plan to futureproof the city through resource security, climate resilience, a move to a low carbon economy, and ecosystem protection. Consequently, the Masterplan 2050 for Water Supply and Sewerage Management was announced, which had three key drivers - population growth, water demand and climate change. The masterplan, has been divided into a mix of short-term and long-term targets, including the implementation and continuous evaluation of technical aspects of the project, climate adaptation by setting up new approaches and

BGI Urban Ecosystem Service	Housing sector	Water sector	Transport sectors
Water reuse	Reduces impacts of water shortages	Reduces operational costs of abstractions, pressure on the wastewater system and impact on the environment	
Storm water management and water quality	Reduces costs for flood risk management from surface water runoff	Reduces operational costs of the wastewater system and impact on the environment and health	Reduces costs for flood risk management from surface water runoff and offsets impact of road runoff pollution on environment and health
Carbon storage	Offsets impact of energy use in households on CO_2 emissions	Offsets impact of energy use for water processes on CO_2 emissions	Offsets impact of transport use on CO_2 emissions
Heat mitigation	Reduces the energy use for heating/cooling and related costs, and CO_2 emissions		
Air quality			Offsets impact of transport use on air pollution
Recreation and cultural value	Offsets impact of urbanisation on physical activities and mental health and increases the price of the property		Offsets impact of transport on the physical activities and level of noise

network models, and creating systems through academic support and strategic stakeholder engagement. warning systems through academic support and strategic stakeholder engagement.

Table1: Benefits of BGI to different sectors

4. ROLE OF BGI IN SUSTAINABLE DEVELOPMENT GOALS:

For successful BGI planning, interventions need to carry out in different scales of planning and application. Subsequently, green-blue infrastructure planning will be for a complete urban area or catchment but require considering possible interference at various scales and their cumulative impact. The application can be at the global level, macro-level (macro-regions), mezzo level (in the river basin and cross border), and micro-level. Successful green-blue infrastructure planning naturally requires an integration of different scales of planning and application. Accordingly, green-blue infrastructure planning will likely be for a whole urban area or catchment, but will need to consider possible interventions at all scales, and their cumulative impact.

4.1. Need of blue- green Infrastructure arises

The below scenario of blue green infrastructure in different cities and the growing natural disaster like Climate change, heat island, and urbanization lead to many complex urban issues, including rising temperatures and increasing incidences of extreme events like flooding, drought, heat wave, and groundwater stress. The solution to all these urban issues can be found in adapting blue-green infrastructure. The blue-green infrastructure can be defined as natural or artificial elements such as urban forests, parks, gardens, green roofs, vertical green facades', lakes, ponds, canals, wetlands, rain gardens, and rivers, which are used to manage stormwater, temperature control, and other benefits. Still, there are certain barriers while implementing them. This study focuses on identifying such barriers while implementing blue-green infrastructure in Hyderabad to revitalize the riverfront. This study focuses on how the blue-green elements can enable to revitalize the riverfront for sustainable and resilient urban development.

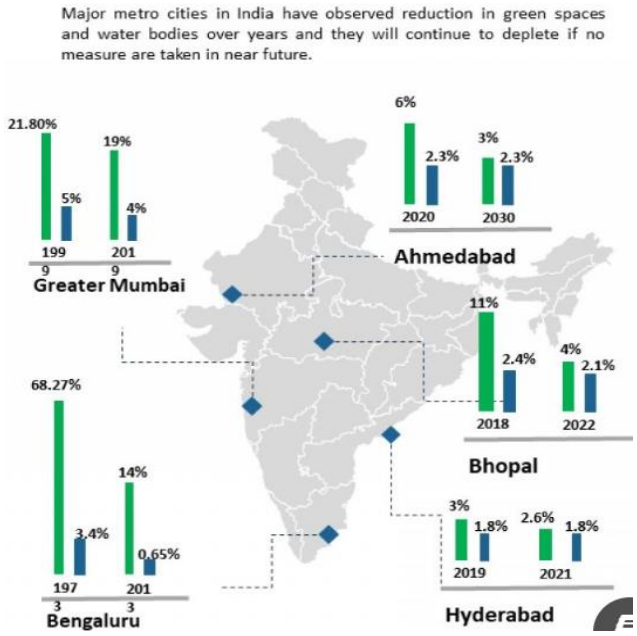


Fig 1: Map showing various parameters for the need of blue green infrastructure (Source: Udas-Mankikar, s, Driver, B. (2021) Blue- Green infrastructure: An opportunity for Indian cities)

Although the concept of Blue-Green Infrastructure is relatively new, it is important that, with infrastructure development at its forefront, adequate policies and plans are put in place to reach the sustainable development goals by putting emphasis on Blue-Green Infrastructure. Especially with India expected to house 6 mega-cities with population above 10 million by 2030,

it is important to recognize that economic and social stability of cities is hinged on the environment with efficient urban planning needed for a sustainable future.

Several Indian cities have seen a decline in green and blue features due to rapid urbanisation, with studies on land-use transitions indicating environmental losses. Bengaluru, for instance, has seen a 925-percent increase in built-up area between 1973 and 2013, with green features decreasing from 68 percent to percent, and blue features from 3 percent to less than 1 percent. Similarly, from 1977 to 2017, Mumbai witnessed a 60-percent loss in vegetation and 65-percent decrease in waterbodies. A technical land-use land cover assessment for Greater Mumbai released in 2020 further indicates up to a 2.5 percent loss in vegetation and a 1.4 percent loss in waterbodies over the 1999-2019 period. And Ahmedabad is projected to see an approximate 50-percent loss in vegetation between 2010 and 2030. An inability to effectively streamline, regulate and monitor urbanisation processes is inadvertently responsible for this vast environmental loss.

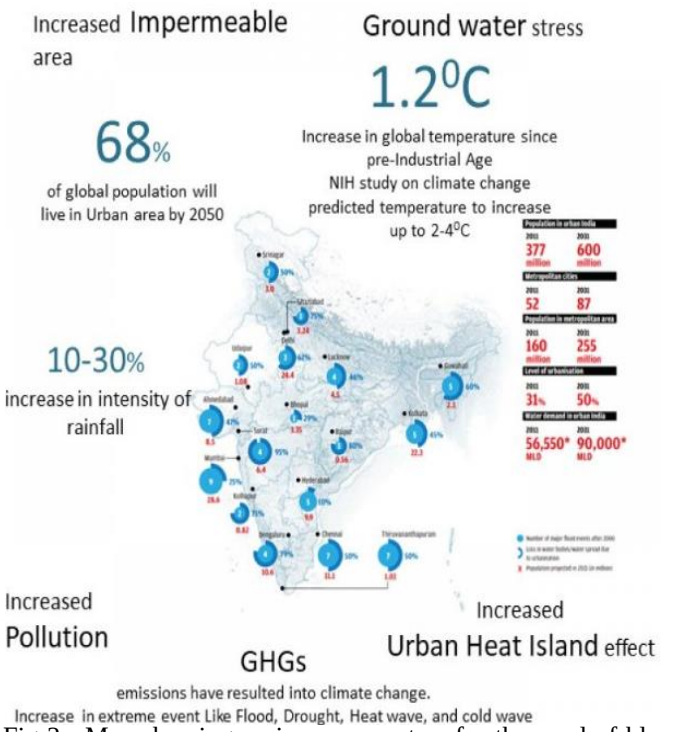


Fig 2: Map showing various parameters for the need of blue green infrastructure (Source: Udas-Mankikar, s, Driver, B. (2021) Blue- Green infrastructure: An opportunity for Indian cities)

5. STUDY AREA: A Case of Musi River, Hyderabad

Taking up the case of Hyderabad, is one such example which is going through several developmental issues along the river Musi. In the last five decades, Hyderabad city has spread in all directions. With the urban development, housing colonies have come up. The narrow lanes and roads, become rivers when heavy rains due to depressions, cyclones and cloud bursts occur. Musi River is a tributary of the Krishna River and therefore acts as an ecological edge between the old and new city. Some part of the city is located at height and some parts that are closer to the Musi River are at a lower level, the overall slope of all the localities in Hyderabad remains the same, almost all the nalas, storm drains, culverts are gone due to either land-filled and built over or simply filled with garbage, detritus and forgotten.

Musi River: Existing Scenario

The existing situation along the edges is summed up by unplanned development, pollution from the untreated sewage water coming from the city, incongruous to its surroundings. Disturbed habitats, depletion of ecological resources, impermeable river edges and no clear policies with respect to conservation of historic buildings along the edges.

The river Musi is pollutedto municipal sewage and industrial wastewater that contains high concentrations of nitrogen, phosphorus, and metals such as lead, zinc, and iron (Mahesh et al., 2018; Ahmed et al., 2019; Surinaidu et al., 2020). Furthermore, the human health is at risk due to presence of potential of non-carcinogenic and carcinogenic health risks of heavy metals for infants, teens, children, and adults (male and female) via different exposure pathways in agricultural soils, water, and crops prescribed by the United States Environmental Protection Agency (USEPA). The study area is part of the Musi River basin situated on the right bank downstream of Hyderabad city in the Indian state of Telangana. The river receives partially treated municipal sewage mixed up with industrial wastewater from the city in and around Hyderabad city (Chigurupati and Manikonda, 2007; Pullaiah, 2013). The river water is then diverted to canals for irrigation from the weirs constructed across river Musi. The farmers in urban and peri-urban areas practice the major crops grown in the area are paddy, para grass, and vegetables for their livelihoods.

The Save Musi Project was launched in the year 2006, to restore the heavily polluted river to its former glory. The project for Musi Revitalization along the entire river corridor of 57.5 kms must be conceived over 3 Scales and time lines:

- The Launch: A six- month project from the time of finalization of designs to revitalize 3km stretch of the Musi riverfront in the historic precinct in the core of the city.
- The Landmark: Concept plan for a two-year transformation for the river corridor of 54.5 kms.
- The Legacy: Strategies that sustain and protects the river, communities, and environment along the entire corridor.

There has been incredible loss of blue and green spaces in Hyderabad. It has seen a decline in Blue Cover by 37% in the 0–50 km Region between 2000 and 2015 (Fig:2). Vegetation Loss Is Distributed Close to Hyderabad's Municipal Boundary and to the North of the Study Area. (Fig 3)

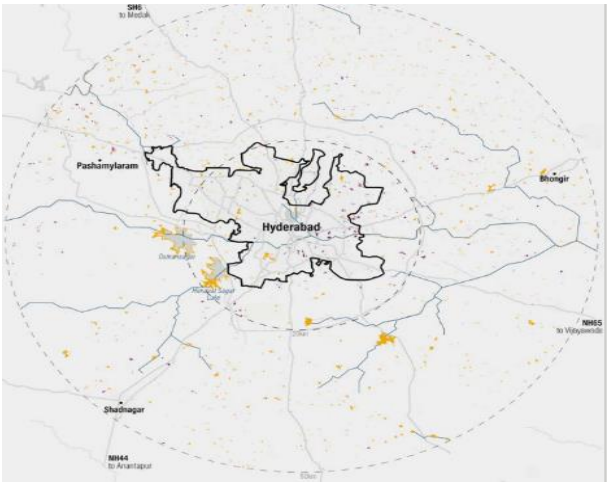


Fig 3: Blue Cover Decreased by 37% in Hyderabad in the 0–50 km Region between 2000 and 2015

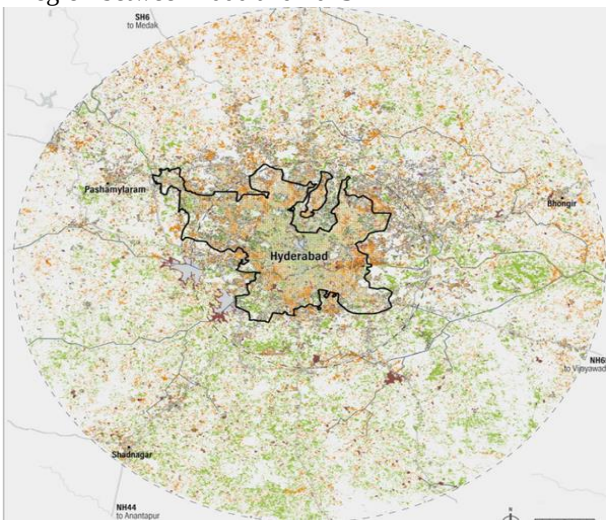


Fig 4: Hyderabad Has a Net Positive Vegetation Trend of 166 sq. km in the 0-50 km Region between 2000 and 2015 Sources: Surface Water Extent – USGS n.d.; River Network – FAO n.d.; Basemap – Esri, DeLorme, HERE, MapmyIndia.

5.1. Identification of problem: Factors contributing to degradation of River Musi

- Industrial and domestic effluent
- Storm Water drainage
- Solid waste dumping
- Idol immersion during festivals

5.2. Existing site condition

In addition to encroachments, pollution of lake waters by untreated domestic sewage and toxic industrial effluents has been going on over the years. Many lakes which provided drinking water earlier no longer serve the same purpose. While there were six very old industrial areas in the Hyderabad city corporation limits (Azamabad, Musheerabad, Sanathnagar, Kavadiguda, New Bhoiguda, and Lalaguda), eleven new industrial estates came up around the city in course of time. 11 Many of the industrial estates are in the foreshore areas of the lakes. Continuous discharge of untreated industrial effluents into the water bodies has turned them into 'toxic ponds' almost devoid of any life. 12 Some of the important rivers/streams polluted by the industrial effluents are Bollaram, Isakavagu, Nakkavagu, and Manjeera (upstream of Nakkavagu confluence). Due to seepage and infiltration from these polluted water bodies/drains and other waste dumps, the groundwater and drinking water sources in the area are highly polluted (Kishan Rao, 2001: 24-26). In a study done for HUDA, it was found that 18 water bodies were identified as the most polluted while 67 were polluted to a lesser extent. Of the 38 lakes identified as potential sources of drinking water, bacteriological and chemical tests revealed that the water of only 6 lakes was in a usable condition.

Fig 4: Snap shot of the view of Musi River from different locations (Source: www.musi.telangana.gov.in)

5.3. Proposed Approach to Riverfront Development:

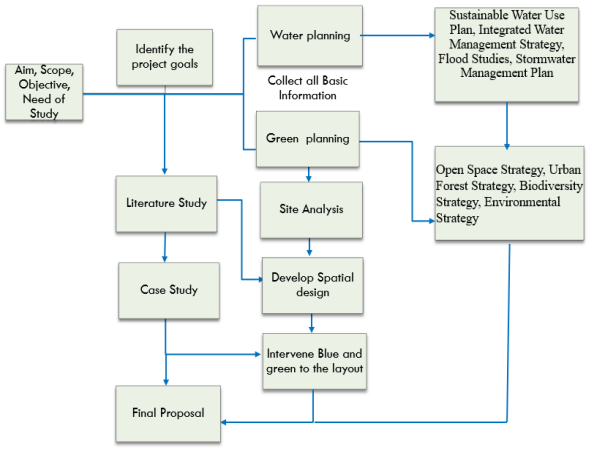


Fig 6: The Methodology process (Source: Author)

5.4. Challenges:

a. Rapid Urbanization and Loss of water bodies: Urbanisation is associated with loss of natural wetlands, forest habitat, farmlands and increase of impervious surface. As the Urbanisation increases catering for drinking water is also becoming complex. Most of the Water bodies which come under water shed area are either dried up or encroached by land developers or very few lakes which exist, bear toxic industrial effluents.

b. Pollution of Water bodies: One of the reasons is Sewage disposal to river and dumping of garbage and debris. Most of the industries are located on the upstream and despite strict laws (Environment Protection Act, 1986, the Water Act, 1974 and the Air Act, 1981) which have been enforced stating that the toxic effluents must be treated first before releasing into the river. Many industries dig up underground pipe lines reaching the river bed and release the waste [7]. This not only impacts the stream quality but also the underground water table of the surrounding area is being polluted. The city Hyderabad produces 850 MLD of sewage waste but whereas only 133 MLD gets treated in the STP n the rest is discharged in its actual form or by diluting it with further waste water.

c. Flooding

In 2000 August there was a rainfall of 24cm in 24hrs which was unpredicted in the aired region of Deccan Plateau and led to severe flooding. It was then which came into notice of everyone that how land encroachment has reduced/narrowed the flood plains and water courses, thus leading to flooding of the river. Some localities of Hyderabad experienced worst flooding where water reached up to the first-floor level and navy boats were used to traverse in the flood water. Thus, Protection of water bodies and watercourses become even more important after experiences of August 2000 in Hyderabad.

d. Slums

Due to lack of land availability and over population encroachment of the flood plains for the slums have been a major concern.

e. Dhobi Ghats

There are Dhobi Ghats situated along the banks of the river. However, with Government law enforcement all the Ghats have been evacuated.

f. Soil erosion and siltation due to encroachment.

g. Degradation of lake inlet and outlet due to continuous supply of waste.

h. Heavy siltation/ Invasive weeds/ Destruction of local hydrology

6. NEED FOR NEW APPROACH TO RIVER FRONT REVITALISATION: BGI

- Making the city accessible for all through active and passive recreation for social life and human well-being.
- Transforming the historic edge into a vibrant and convivial urban space which would create great impact on the surrounding built fabric;
- A rational public space design for both social and ecological benefits, as well as integration of river rejuvenation.
- The spectrum of BGI is very wide in case of ecosystem or habitat cover, BGI can be applied to a riparian land, coastal areas, grasslands, river banks, wetlands etc.
- Successful green-blue infrastructure planning naturally requires an integration of different scales of planning and application.

6.1. Understanding and Implementing Riverfront Re-vitalization, based on BGI for by the following approaches:

i) Strategic Framework for integrated development,

ii) Intervention for creating Sustainable Environment,

iii) Design Intervention by Developing Riverfront Theme Parks.

iv) Spatial planning intervention of BGI intervention of BGI

i) Strategic Framework for integrated development

- Preparation of an exclusive Blue Green Infrastructure plan for the city at Macro Level for integrated development with Urban Local Bodies (ULB's)
- Proposing Nature based solutions based on assessment of the area and identifying the area. This will define a hierarchy of blue green infrastructure in terms of scale, function, location, by analyzing the natural, historic and landscape assets,
- BGI should be the core consideration in preparation of local Area plan. Also propose measurable standards to check the facility provision and performance.
- Increase awareness and understanding of BGI.
- BGI to be non-negotiable in plan and policy frame work.
- Bio diversity management and development of ecological corridors should be fore-grounded.
- Resource management to be encouraged at neighborhood scale.

ii) Interventions for creating Sustainable Environment

Preserving and Restoring Natural River edge:

Riverbanks, shorelines, and riparian buffers are critically important components of riverfront development. The river edges can be developed in various natural ways for integrated regenerative design, storm-water management, habitat restoration, public access, etc., to manage and maintain the natural ecology. The are different elements that can be adopted to preserve and restore the edge. The riverbanks can be developed using natural methods for integrated regenerative design, storm-water management, habitat restoration, and public access to preserve natural ecology.

Creating Riparian Buffer

A permanent naturally vegetated area located adjacent to a stream, river, lake, pond or wetland.

Providing Seawall Treatments

Seawalls are hard engineered structures with a primary function to prevent further erosion of the shoreline. They are built parallel to the shore and aim to hold or prevent sliding of the soil, while providing protection from wave action.

Conserving Natural Hydrology

This advocates the adaptive management of watershed lands to optimize re-hydration. Ensured by implementing and enforcing land use patterns that enhance the receptive capacity of watersheds in times of excess as well as scarcity.

Stabilizing Slope Bank

Slopes can be stabilized by adding a surface cover to the slope, excavating, and changing (or regrading) the slope geometry, adding support structures to reinforce the slope or using drainage to control the groundwater in slope material.

Treating with Local Construction Techniques

This resorts to the procedures and techniques that are used during the building process. Use of local techniques helps in cost effectiveness of construction as well as promotes environmental sustainability.

iii) Design Intervention: Developing Riverfront Theme Parks

Waterfronts have the potential to serve as active as well as passive recreational spaces. While most common along rivers, waterfront theme parks can be developed along other water edges as well. Riverfront theme parks are communal recreational spaces that are intentionally designed to be flooded during storm or flood events. They reduce the impacts of flooding by creating a space that can capture and store floodwaters with minimal damage to the infrastructure

Co-Benefits of Riverfront Theme Parks

• Creates opportunities for community engagement and improved public health & wellbeing, through exercise & community interaction,

• Increased traffic and sales for the surrounding businesses,

• Increase in value of adjacent properties,

• Restoring floodplain and wetland habitat, as breeding ground for local wildlife and the potential for more human-wildlife interactions.

The following **elements in design** can be adopted for sustainability.

Sitting Areas

The theme parks can have sitting areas representing the visual and thematic experience through them.

Perma-Culture Design

It is essentially a multifaceted, integrated and ecologically harmonious method of designing human-centered landscapes.

Permeable Pathways

Permeable pathways are trails with porous surfaces, permitting ground water seepage. These are made by natural techniques or naturally formed after a prolonged time.

Landscape

Unique landscaping features which can reinstate the flora & fauna and add aesthetic value to the space.

Art Installation

Art installations for use or just aesthetics, depicting components related to the theme of the area. These are used to make the spaces vibrant and lively

Construction Techniques

Eco friendly or green construction techniques could be adapted while developing a theme park, which do not affect the natural river habitat and have negligible impact on nature

Recharge Zones

Groundwater is the water stored in the pores of the soil strata by infiltration, i.e., water present below the earth surface. Groundwater recharge denotes the entry of water from the unsaturated zone into the saturated zone below the water table surface. Artificial recharge is the process by which ground water is increased at a rate much higher than that under the natural conditions for percolation.

Bio Retention

Shallow landscaped depressions, which rely on engineered soils with enhanced vegetation for filtration,

Permeable Pavement

Dual usage allows for both water retention and hard surfaces to coexist in the same area.

Detention/ Retention Trench

Stores and holds rainwater. These are dry or wet, depending on their consistency to hold water

Infiltration Pond

Concentrated planted spaces for rapid infiltration of surface water

Blue and Green features are intrinsically connected at different scales and perform varied roles, for instance, a river front can be perfect example to connect both blue and green features and integrate this to form the blue green infrastructure.

iv) Spatial planning intervention of BGI

- Establishing Existing waterway/green network strategies and plans
- Key drivers related to waterways and green corridors (drawn from council objectives and community visioning)
- Existing pathway networks
- Adjoining land uses (current and future)
- Riparian corridor vegetation type and quality
- Current access to waterway for the community
- Water quality and targets for improvement
- Ecosystem health, habitat potential and key species
- Flood studies and mapped flood extents
- Hydrology (and expected future changes in flow)

6.2. Recommendations for Musi Revitalization

Channeling the river to constant width

The shrink river and uneven river banks can have diaphragm walls built into the riverbed at a depth of more than 10 m and retaining walls which can protect low lying areas from flooding. This will prevent flooding and soil erosion as there will be continuous flow of water.

Sewage diversion

Providing Interceptor Sewers: The interceptor lines will run along both banks of river capturing sewage discharge points and routing the sewage with the pumping station.

Functional linkages to be facilitated with Riverfront for easy Accessibility

According to the current scenario, the riverfront is inaccessible from certain locations throughout the stretch. This strategy will help to make riverfront accessible. Easily by analyzing the hierarchy of road network and their uses by which the accessible ways can be sorted. The connection between the riverfront will be main aspect not only physical but also visual.

Heritage promotion

As some of the riverside areas possess high heritage value and because of this historical importance of those areas, they can be developed for heritage promotion to enhance the historical character of the city.

Transportation

To create a network of alternative mobility for the heavy traffic roads by enabling a non-motorized pedestrian friendly network along the river in the form of skywalk.

Open Space

To create one contiguous blue green network integrating the cultural open spaces and opening to the potential open spaces along this network.

Renewable energy

Installing solar panels can be effective to achieve this.

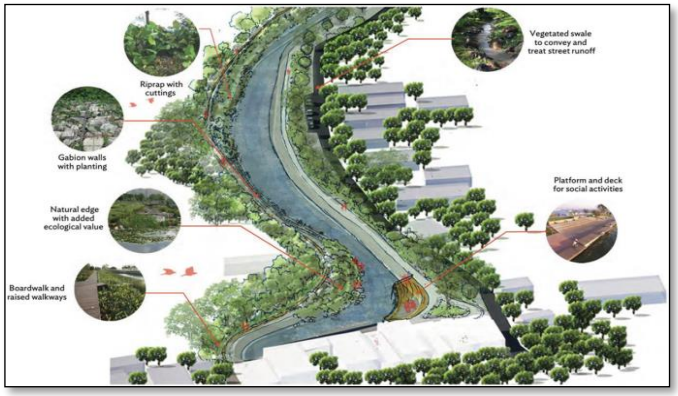
7. CONCLUSION

Riverfront Development Projects should be:

- Environmentally Sustainable
- Economically Viable and
- Socially Responsive

Adopting the following Strategies will create Sustainable Riverfront Development and provide the following benefits-

- Strengthens river access by establishing riverfront walkway, trails, parks
- Help in Expanding leisure and recreational use of the river, by developing culture, art & entertainment,
- Re-establishing the lost citizen-river connect, to attract people and investment to the riverfront,
- Repairing and enhancing the environment,
- The use of high-quality sustainable architectural materials and engineering practices
- Creates visually pleasing river's edge and featuring riverfront as the front yard
- Provides outdoor activities for the people.
- It will showcase the river's history and importance to the city.



- Provide outdoor activities for the people.

Fig 7: Nature based solutions strategy for blue green infrastructure (source: niua.in)

REFERENCES

[1]. Sayli Udas-Mankikar, B. D. (2021). Blue Green Infrastructure: An Opportunity for Indian Cities. Observer Research Foundation.

2]. Nadja Kabisch, H. K. (2017). Nature- based Solutions to Climate Change Adaptation in Urban Areas. Germany: Springer.

3]. Commission, E. (n.d.). The forms and functions of green infrastructure. Retrieved from European Commission: https://ec.europa.eu/environment/nature/ecosystems/benefits/index_en.htm

4]. Tewari, M. G. (n.d.). Better Cities, Better Growth: India's Urban Opportunity: Synthesis Paper for Policy Makers. London, Washington, DC, and New Delhi: New Climate Economy, World Resources Institute, and Indian Council for Research on International Economic Relations 5]. Root-B

5]. ernstein, M. (2020). BIOVEINS. Retrieved from What is green and blue infrastructure? http://bioveins.eu/blog/article2

[6]. Mark A. Benedict, E. T. (2006). Green Infrastructure: Linking Landscapes and Communities. IslandPress.

7]. Kinga Kimic, K. O. (2021). Assessment of Blue and Green Infrastructure Solutions in Shaping Urban Public Spaces—Spatial and Functional, Environmental, and Social Aspects. Poland: sustainability.

[8]. Urban, M. o. (2017). Green Infrastructure A Practitioner's Guide. Centre for Science and

Environnent: Centre for Science and Environnent.

[9]. Department of Environment, L. W. (2017). Planning a green-blue city - A how-to guide for planning urban greening and enhanced stormwater management in Victoria. Victoria: E2Designlab.

[10]. (2021). A new indicator of the effectiveness of urban green infrastructure based on ecosystem services assessment. Spain: Elsevier.

11]. Ranko Bozovic, C. M. (2017). Blue Green Solutions. A Systems Approach to Sustainable, Resilient and Cost-Efficient Urban Development. London: Climate-KIC.

12]. Town and Country Planning Organisation. (2015). URDPFI Guidelines - Volume I. Ministry of Urban Development, Government of India

13]. Central Pollution Control. (2022). Water Quality Criteria. Retrieved from Central Pollution Control: https://cpcb.nic.in/waterquality-criteria/

[14]. Friends of Reservoirs - NGO. (2022). Chapter 8: Riparian Zone. Retrieved from Friends of Reservoirs (FOR) NOG - Science: https://www.friendsofreservoirs.com/science /best-management-practices-manual/chapter8-riparian-zone/

[15]. Minnesota Pollution Control Agency. (2021, June 3). Calculating credits for green roofs. Retrieved from Minnesota stormwater manual: https://stormwater.pca.state.mn.us/index.php /Calculating_credits_for_green_roofs

16]. Miller, B. K. (n.d.). Wetlands and water quality. Retrieved from Water Quality: https://www.extension.purdue.edu/extmedia/ wq/wq-10.html

17]. Eliades, A. (2016, October 25). Understanding Urban Agriculture – Part 3, Calculating the Food Production Potential of a City. Permaculture Research Institute.

18]. International Journal of Advances in Engineering and Management (IJAEM) Volume 4, Issue 7 July 2022, pp: 1193-1198 www.ijaem.net ISSN: 2395-5252.

19]. www.surreycc.gov.uk/community/climate-change/what-are-we-doing/green-and-blue-infrastructure#section-9

20]. https://orda.shef.ac.uk/articles/report/Designing_Blue_Green_Infrastructure_BGI_for_water_management_human_health_and_wellbeing _summary_of_evidence_and_principles_for_design/13049510? file=24971858

21]. https://www.academia.edu/85541945/Planning_of_Urban_Green_Infrastructure_Case_study_Ghaziabad

22]. Why use Green & Blue Infrastructure- Green Blue Urban-Green and Blue.com

23]. The Value of Well-Being: Advancing Urban Blue Infrastructure with Holistic Metrics / https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1131&context=honorstheses

24]. https://theiashub.com/

25]. Building India's Blue-Green Network: A Strategic Framework for Bengaluru by Integrated Design - Issuu

26]. https://issuu.com/janardhan9587/docs/thesis

27]. Guturu, K. (2015). Redeveloping the Musi riverfront in Hyderabad. *Wwwspav*. https://www.academia.edu/13756026/Redeveloping_the_Musi_riverfront_in_Hyderabad

28]. Wang, Y., Bakker, F., De Groot, R., & Wörtche, H. (2014). Effect of ecosystem services provided by urban green infrastructure on indoor environment: A literature review. *Building and Environment*, *77*, 88–100. https://doi.org/10.1016/j.buildenv.2014.03.021

29]. Riverfront Development | PDF | Hydrology | Water (scribd.com)

30]. Kinjawadekar, A. (2023). Assessing the impacts of ecological framework of Indian riverfront revitalization]projects. *Manipal*. https://www.academia.edu/107483170/Assessing_the_impacts_of_ecological_framework_of_Indian_riverfront_revitalization_projects?uc-g-sw=44296839

A Practitioner's Guide. Centre for Science and Environment.

31]. Riverlife & Riverlife. (n.d.). A guide to riverfront development. In *Riverlife* (pp. 1–7). https://riverlifepgh.org/wp-content/uploads/2016/10/A-Guide-to-Riverfront-Development.pdf

32]. https://musi.telangana.gov.in/images/Musi%20River%20Revitalization%20-%20RFP.pdf

33]. Ecofriendly-Interventions-for-Riverfront-Development.pdf (niua.in)

34]. Inspireli.com

35]. *Reinventing urban waterfronts in Indian cities: Five ideas to step-up the way forward*. (2022, October 21). WRI India Ross Center for Sustainable Cities | Helping Cities Make Big Ideas Happen. https://www.wricitiesindia.org/content/reinventing-urban-waterfronts-indian-cities-five-ideas-step-way-forward

36]. Vardhan, H. (2020). Planning of Urban Green Infrastructure: Case study - Ghaziabad. *Iiests*. https://www.academia.edu/85541945/Planning_of_Urban_Green_Infrastructure_Case_study_Ghaziabad

37]. The Blue-Green Cities Research Project, Delivering and Evaluating Multiple Flood Risk Benefits in BlueGreen Cities Key Project Outputs, United Kingdom, Blue-Green Cities Research Project, (2016) http://www.bluegreencities.ac.uk/documents/bluegreen-cities-key-project-outputs.pd

38]. Maksimovic, C; Mijic, A; Suter, I; Van Reeuwijk, M (2017) Blue-green solutions. A systems approach to sustainable, resilient and cost-effective urban development. Imperial College London.

39]. https://greentribunal.gov.in/sites/default/files/news_updates/Part-2%20Affidavit%20in%20Reply%20of%20R-1%20in%20Appeal%20No.%2012-2020%20(page%20nos.%20679-1048).pdf

40]. EESE7961035.pdf (iop.org)

41]. https://webthesis.biblio.polito.it/19830/1/tesi.pdf

42]. Sujatha, M., Chandana, N. R., & Kolli, S. K. (2020). Assessment of Musi River groundwater quality in rural and urban areas of Hyderabad, Telangana-(India). In Research India Publications, *International Journal of Applied Engineering Research* (Vol. 15, Issue 9, pp. 921–929) [Journal-article]. Research India Publications. https://www.ripublication.com/ijaer20/ijaerv15n9_06.pdf

43]. Jainer, S. (2020) Urban flooding around the world: Where is India placed?

44]. Rohilla, S. K., Jainer, S., Matto, M., & Centre for Science and Environment. (2017). *Green Infrastructure:*