Mumbai Case Study

Product of research on *"Enhancing Blue-Green Environmental and Social Performance in High Density Urban Environments"*

Sponsored by the Ramboll Foundation

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CONTENT

1. PREFACE

This report summarizes the research, findings, and recommendations of the Blue-Green Infrastructure (BGI) case study in Mumbai, India. It is one of seven case studies in the comparative research project funded by the Ramboll Foundation. Blue-green infrastructure extends the well-established concept of green infrastructure (e.g., open space and tree canopy) to encompass hydrologic systems and processes that make enormous contributions to the aesthetic, functional, and cultural values of urban landscapes.

Mumbai was selected as a case study for several reasons. First, it has a suite of blue-green infrastructure systems that include watershed headwaters that are protected as a National Park, stream corridors that radiate from those headwaters through the city, and a variety of urban coastal areas some of which have mangrove tidal flats. Second, these systems face enormous pressures and are not yet integrated in a metropolitan BGI system. Third, this is one of only two case studies in the Ramboll project, which involves a megacity in a rapidly developing country. And finally, notwithstanding these distinctive aspects of Mumbai, it also offers valuable comparisons, for example, with Singapore, Boston, Copenhagen, and Jakarta, all of which have long histories of urban environmental planning and coastal land reclamation. Mumbai is thus a model and problematic case study where much is at stake in BGI protection and integration.

Figure 1. Map of Mumbai water and land resources.

Outline of the Report

This preface is followed by a brief section common to all of the Ramboll case studies that defines blue-green infrastructure along with some brief notes about its relevance for Mumbai. The third section of the report then helps situate and address those challenges with at three levels of analysis -- the local, regional, and comparative international. The Mumbai study differs from

others in the Ramboll project in part by having three BGI components -- the Sanjay Gandhi National Park, Mithi River, and Coastal zone, which are at present not integrated or jointly managed with one another. After briefly noting these three main environmental systems, we describe Mumbai's overall urban density, water supply, and water demand; and we compare these characteristics of Mumbai with a large database of other cities. The fourth section summarizes some of the major planning challenges faced by Mumbai today. The fifth section outlines the historical geography of the city of Mumbai, the evolution of its current geographic landscape, and its unique water heritage. The sixth section discusses different types of blue-green infrastructure and a typology for BGI research and study. The seventh section of the report describes the institutional and governance structures that currently govern the blue green infrastructures of the city of Mumbai and the larger metropolitan area of Mumbai.

With this conceptual framework in place, the eighth and longest section of the report presents the three major BGI case studies in Mumbai -- the Sanjay Gandhi National Park in the headwaters; the urban streams that flow through the city (particularly the Mithi River); and the coastal zone. Each of these cases includes a chronology and a discussion of driving forces, constraints, and values. The attempt will be to present a BGI case from each typology to understand and propose a networked system of BGI that can truly function as a productive natural infrastructure for the city of Mumbai and the greater metropolitan region. The study concludes with recommendations and proposals that highlight the next steps required for the development of an integrated BGI landscape system in Mumbai.

2. DEFINITION OF BLUE-GREEN INFRASTRUCTURE (BGI) IN THE MUMBAI CONTEXT

This section introduces the concept of blue-green infrastructure (BGI), with some initial comments on its relevance for Mumbai. This definition of BGI is shared across all of the Ramboll case studies. A more Mumbai-specific case study of BGI is presented later in the report.

The concept of „green infrastructure" and its benefits for ecology and social life are increasingly well established in urban environmental planning, policy, research, and design. However, much green infrastructure is closely linked with and even defined by „blue" water processes. Some cities such as Mumbai continue to describe these values and systems as „parks" and „open space." Unfortunately, other water bodies and sites are treated as waste spaces for pollutant discharge. Open space in this context may seem somewhat negative in meaning.

At the same time, an increasing number of cities are creating or restoring urban water bodies and systems to enhance urban livability and quality of life. Blue-green infrastructure projects are proliferating in exciting ways. Research is now needed to identify, analyze, and enhance the

benefits and added values stemming from this combination of blue-green infrastructure, especially its impact on improving social life and human-environmental experience.

Mumbai has a fascinating history of BGI development associated initially with land reclamation, and subsequently with early attempts at environmental protection.

What do we mean by Blue-Green Infrastructure (BGI)?

Blue-green infrastructure (BGI) is a dynamic system in urban contexts that connect vegetation with water bodies. BGI integrates hydrological and biological water treatment systems where green features are integrated and seamlessly overlapping with blue features. Together they strengthen urban ecosystems by evoking natural processes in man-made environments. The hypothesis is that such systems have a positive impact on the experience and behavior of people using these infrastructures that have societal benefits.

The term green infrastructure often refers to areas with plants including their rhizomes and natural substrates like parks, green roofs, greenbelts, allees, vertical gardens on buildings, etc. The reclamation of the Back Bay, Mumbai Esplanade, Maidan, and Queens Necklace were early examples of this concept, arising with the modern origin of the city itself to provide common space in the 19th century. Interestingly, these are some of the same place-names used in Boston (e.g., Back Bay and Esplanade). "But BGI often involves non-vegetative, constructed surfaces and substrates, such as porous hardscape, loose stone infiltration basins, gravel wetlands and specialized soils for root growth in narrow spaces."

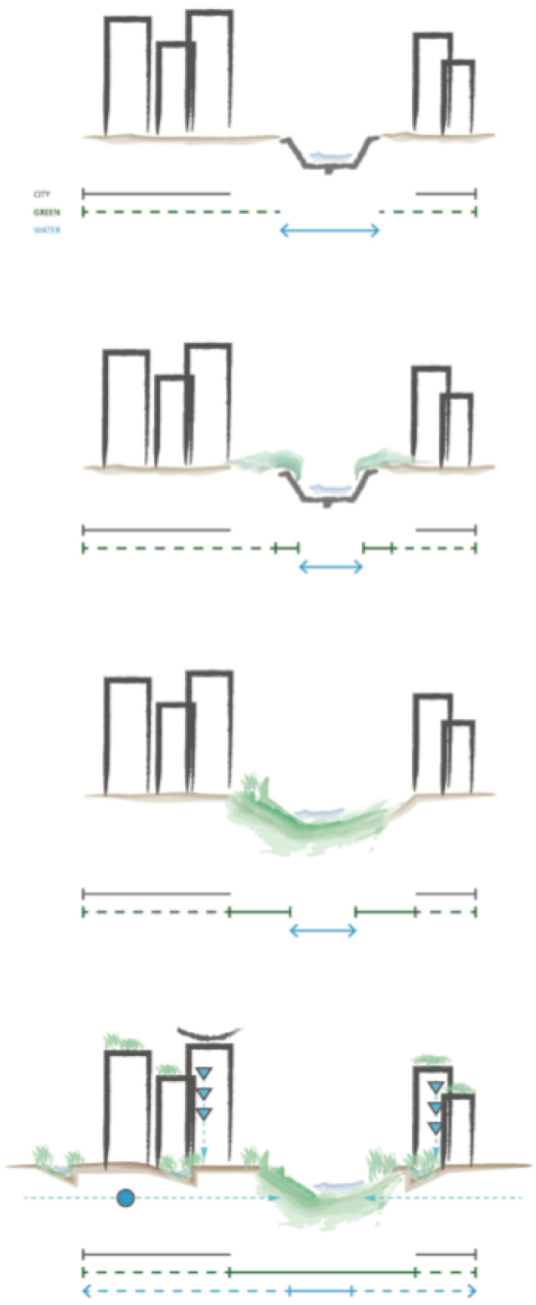
Blue infrastructure is related to hydrological functions including urban storm water systems as well as surface and groundwater bodies. This water infrastructure may be natural, adapted or man-made and provide the functions of retention, storm water treatment, reuse, groundwater infiltration, sewer treatment, freshwater supply, etc. Coastal cities like Mumbai originate around the blue infrastructure of freshwater supplies adjacent to tidal rivers and harbors for trade.

Blue-green infrastructure brings these two systems and values together in ways that are greater than the sum of their individual benefits. The benefits of this more integrated approach can range from a stronger sense of place to the health, happiness, and aesthetics of urban environmental experience. Mumbai's early blue-green infrastructure concentrated around the reclamation of coastal wetlands and shorelines.

In BGI research we especially look at cases where these benefits can be documented, and where blue-green infrastructure can be actively used by people, thus being relevant for social life in areas for recreation, improvement of walkability or bikeability, and beauty.

What are the objectives of BGI?

- Blue-green infrastructure combines the demands of sustainable water and stormwater management with the demands of urban planning and urban life, and thus it:
- Brings the urban water cycle closer to natural hydrologic processes to provide more efficient water treatment, use, supply, as well as mitigation of droughts and floods)
- Contributes to the visual and recreational amenity of the city's ecological and built environment.
- Helps manage conflicts between urban settlements and negative impact on natural systems in innovative ways (e.g., by protecting ecosystems, caring for public open spaces, and adapting to for climate change,)
- Improves urban sustainability and livability.



Blue-green infrastructure: gradient from separated to integrated systems (Herbert Dreiseitl)

This graphic illustrates the gradient from grey infrastructure at the top to blue and green infrastructure being adjacent but functionally separated from each other (second) to overlapping blue and green infrastructure in a riverbed with green banks (third) to full integration of blue-green stormwater management from on roof tops and vertical gardens to naturalistic drainage systems (bottom).

The most defining quality of BGI is this overlapping of blue and green features and processes that provide relevant functions and services. Its services are (1) water related, (2) ecosystems related, (3) have benefits on the social life and by doing so are (4) financially relevant.

This intersection of blue, green and social benefits can:

- Balance water flows (Reduce stormwater runoff and peak flows through local detention and retention measures in soil interstices, minimization impervious areas, etc.)
- Improve water quality (reduce organic pollution through mechanical filtration, biological cleaning, accumulation of oxygen in the soil, etc.)
- Enhance ecosystem services (micro climate improvement like balanced temperatures and evaporative cooling, buffer wet and dry conditions, increase of biodiversity, reduce fine dust and improve air quality, metabolism and photosynthesis, etc.)
- Broaden societal benefits (recreational spots for mental and physical health, attractive meeting places, promotion of creativity, aesthetical values, etc.)
- Increase financial benefits (reduce drainage infrastructure and the related development and maintenance costs, etc.)

What is needed to create Blue-Green Infrastructure?

To implement BGI projects or citywide systems, an interdisciplinary cooperation of water management and urban environmental planning and design is needed. BGI considers all parts of the hydrological cycle and strives for its integration with the design of green spaces. Integrative strategies care jointly about ecological, economic, social, and cultural sustainability. The Mumbai case study shows that institutional coordination is ideal, and that integrative approaches to BGI design and implementation can occur within single or multi-agency contexts.

As demonstrated by the principles for Water Sensitive Urban Planning, methods and technologies that were once solely a civil engineering issue, are expanding to include a much broader array of disciplines. This adds a level of complexity never-before seen in stormwater management discourse, for example, particularly with regard to aesthetics and open space planning. The main challenges for sustainable stormwater management are not technological, but increasing awareness of the benefits and supportive skills needed for BGI implementation. To move forward, communication must improve, and ecologic, economic and social arguments proven by data-driven analysis.

3. SITUATING MUMBAI'S BLUE-GREEN INFRASTRUCTURE IN A LOCAL, REGIONAL, AND COMPARATIVE INTERNATIONAL CONTEXT

This section introduces the Mumbai case study in greater detail. It describes the case at three geographical scales. First, it briefly describes the three types of Mumbai's Blue-Green Infrastructure analyzed in this report. We then proceed to a broader regional perspective on regional water and environmental systems. Finally, we scale out to consider how Mumbai's urban water system compares with that of other cities around the world including the seven other Ramboll case study cities. This sets the stage for an analysis of the planning challenges that cities like Mumbai face in section 4.

a. Mumbai as a set of places, landscape types, and institutions

Although Mumbai does not have one particular focal blue-green infrastructure project in this study, the City has a rich variety of places that function implicitly, explicitly, or potentially as such. As will be shown, the Sanjay Gandhi National Park is a consciously protected blue and green infrastructure project. The coastal zone is an implicit form of BGI. And the many streams and nallahs are rapidly degraded but could still potentially function as such. As these water and environmental systems are described in detail in the sections that follow, here we proceed to set the Mumbai urban water system in context.

b. Profile of Mumbai and its Water Resources

In this section we introduce the broader context of Mumbai as a city defined in part by its population size and density, in part by its hydroclimatic water supply, and in part by its per capita water demand.

i. Population Size and Density

Mumbai, India is the capital city of the state of Maharashtra. With a municipal population of 12,655,220 and a metropolitan population of 20,748,395 in 2011, it is the world's eighth largest city and eleventh largest metropolitan area. Mumbai is the second largest metropolitan area in India (after Delhi). It has been an urban center and important trade node in the region for hundreds if not thousands of years. Mumbai's city area is 603.4 km^2 and its population density is 20,973 people/km^2. It's population density is higher than that of Tokyo and other cities that are generally considered quite dense, including Jakarta and Seoul.

As a city of India, Mumbai has a medium Human Development Index (HDI) of 0.586. Its HDI has increased in recent years. The Brookings Institute estimate for Mumbai's 2014 GDP was $150.9 billion[1]. Dividing by the population of Mumbai city and metropolitan area gives a GDP per capita

of $11,924 and $7,273, respectively (as reported in Wikipedia. URL: //en.wikipedia.org/wiki/List_of_cities_by_GDP#cite_note-Brookings-2, Last Accessed: 11 July 2015).

ii. Hydroclimatologic Water Supply

This section describes the natural water supply locally available to Mumbai. The city's gross water supply comes in the form of monsoon rainfall, and it is partially consumed by evapotranspiration, particularly in the hot dry pre-monsoon months. Mumbai is located at a latitude of 18°58'N and a longitude of 72°50'E on the west coast of India, which receives generous monsoon winds and rain off the Arabian Sea coast. Under the Köppen climate classification system, Mumbai has a tropical climate---specifically, tropical wet and dry (*Aw*).

This climate can be visualized using a water budget approach (Figure 11). The data for average net monthly water balance were obtained from the online interface WebWIMP (climate.geog.udel.edu/~wimp/). A water budget diagram plots Precipitation (P) and Evapotranspiration (ET). From those two variables and some initial assumptions about soil conditions, one can estimate changes in Storage (DST), and the net Surplus (SURP). The data for average net monthly water balance were obtained from the online interface WebWIMP (climate.geog.udel.edu/~wimp/) and displayed below.

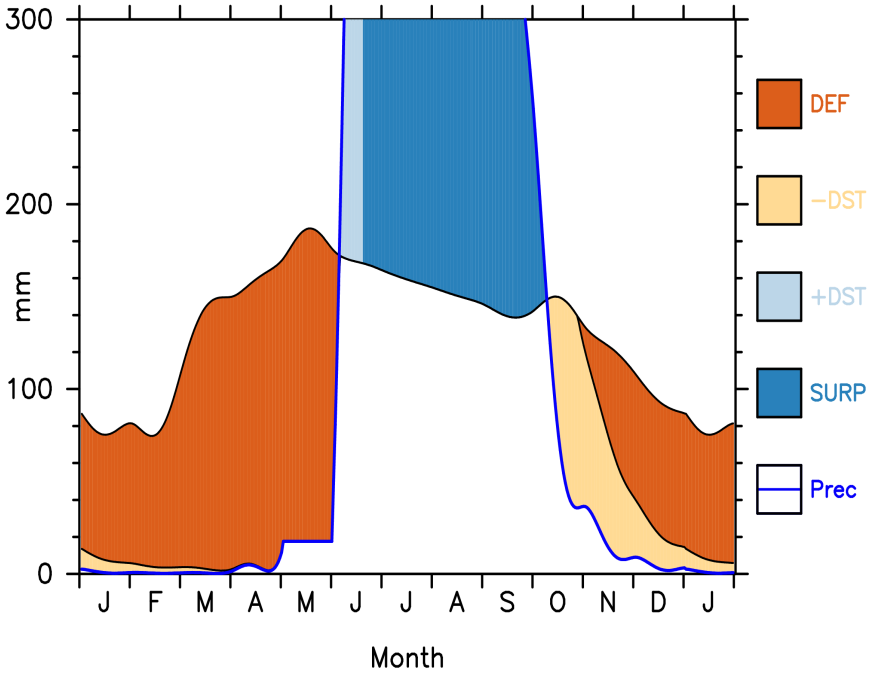


Figure 3. The components of the average net monthly water balance for Mumbai. From WebWIMP.

As seen in this figure, Mumbai has approximately 7 months when it receives almost no rainfall – this occurs during the 'winter' months, from November through May. During the five months that Mumbai does receive significant rainfall – the monsoon seaso – it receives an annual average of 2.2m/year, which is over twice the global average for annual precipitation. In terms of precipitation, the climate oscillates between periods of extreme wet and dry. However, while the precipitation patterns are quite extreme, the temperatures are quite constant. As seen in Fig. 5, the temperature rarely dips below 18.9°C, and rarely exceeds 32.7°C.

Since the temperature of Mumbai never drops below freezing, the evapotranspiration remains high throughout the year. Thus, for most of the year Mumbai has a net deficit in its average monthly water balance, as seen in Fig. 3. Natural storage is an issue for the region---because most of the rainfall is received over a short duration, the local storage quickly becomes saturated and most of the precipitation leaves the area as stormwater runoff. For the four months during the period of highest rainfall the net monthly water balance for Mumbai is positive. The water stored in local natural storage from the monsoon is only able to fully meet the vegetative demand for the following month (October). The rest of the year is characterized by significant water deficit; storage accounts for only a fraction of vegetative demand.

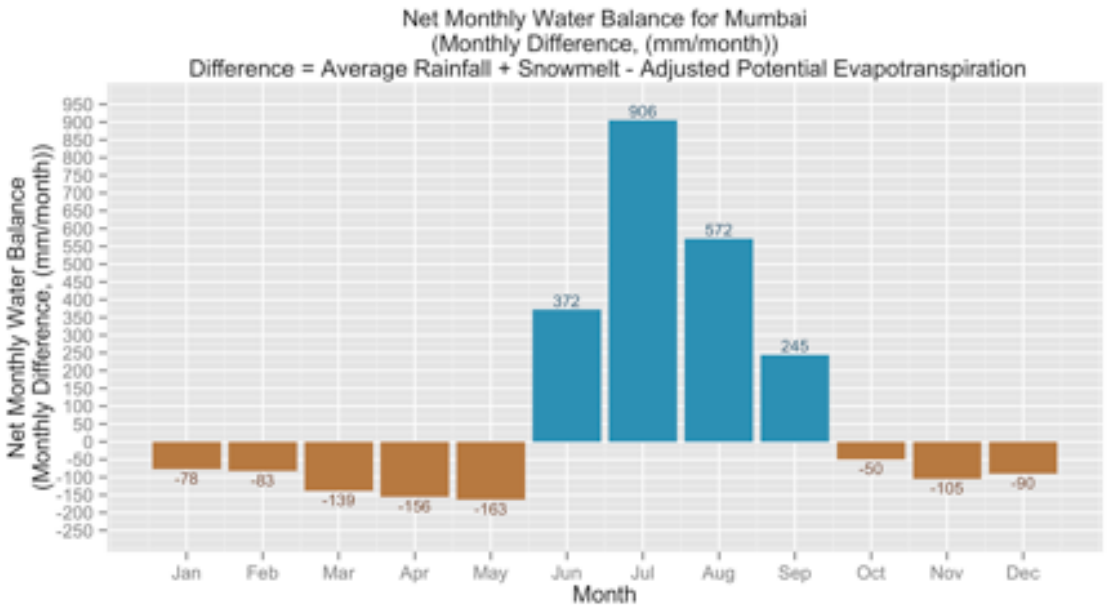


Figure 2. Average net monthly water balance for Mumbai, India. Data from WebWIMP.

The Figure above shows a bar chart of the net monthly water balance for Mumbai, India. The net monthly water balance is also known as a water budget, or difference.
Thus, water resource management in Mumbai is characterized by dealing with the large volumes of excess rainfall during a few months of a year – i.e. flooding – as well as a need to collect and

store as much rainfall as possible for use during the drier months of the year. The figure below indicates the increasing number of Confirmed Flood Events (CFE) per year by decade, which indicates both better recording but also increasing watershed urbanization, and increasing vulnerability (Lomazzi, et al., 2014).

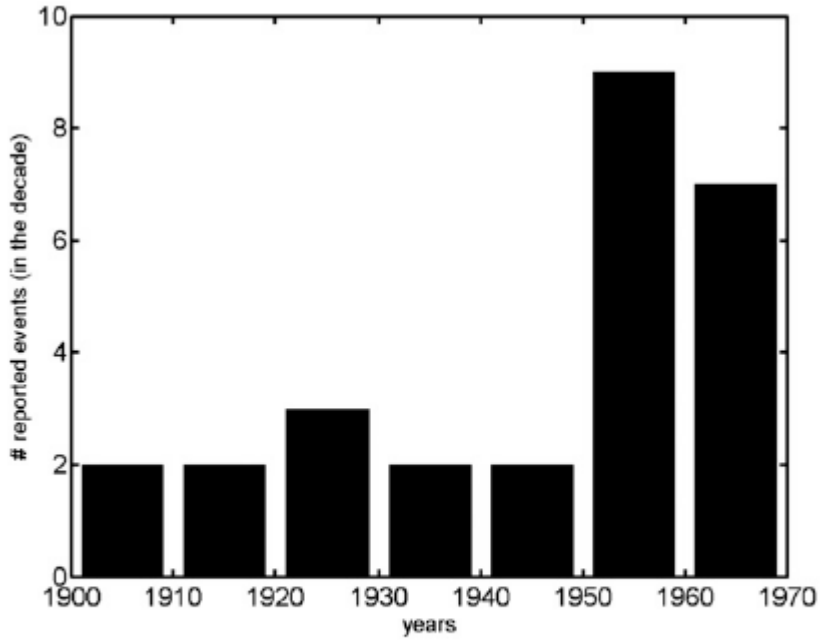


FIG. 2. Number of CFEs in the Mumbai area reported in the flood catalog.

c. How Mumbai Fits Within a Larger International Sample of Urban Water Systems

In our research we also looked at how Mumbai compared to the other case study cities as well as a larger database of 142 cities. This section describes how Mumbai compared with these other cities on four criteria relevant to the implementation of blue-green infrastructure in cities: net climatic water budget; annual per capita water use; and urban population density (Fig. 6, below).

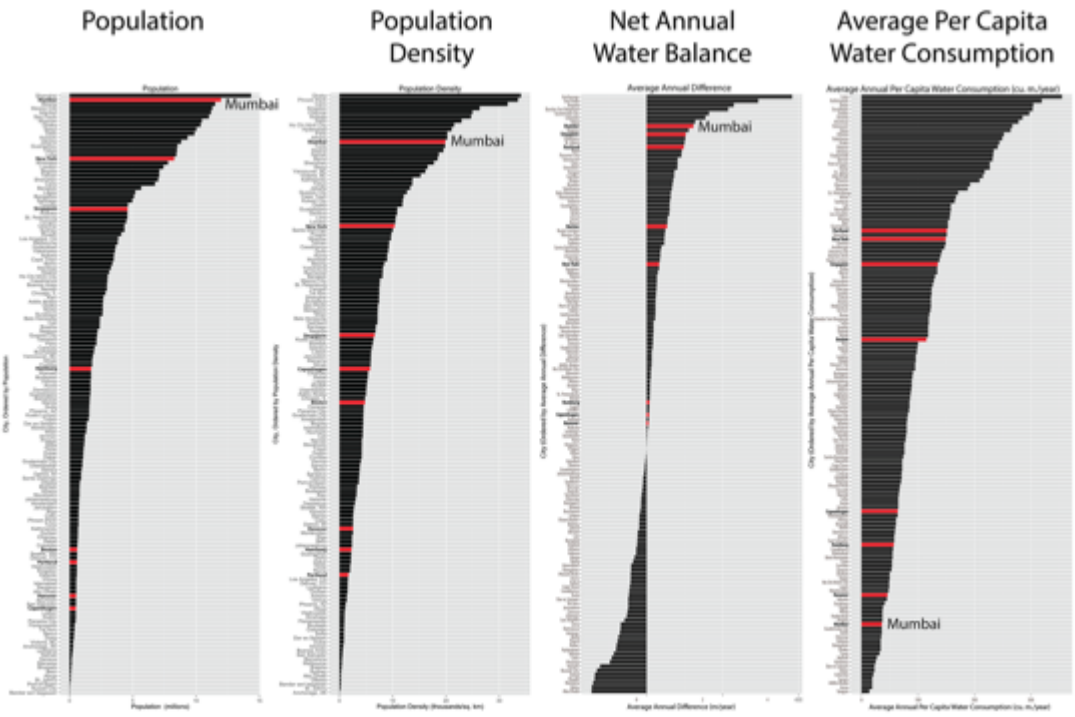


Figure. Rank order plots for population, population density, net annual water balance, and average per capita water consumption.

In the Figure above we see that Mumbai is the largest city in the Ramboll study and one of the largest in the database of 142 cities. It also has the highest population density of the cases, and one of the highest population densities in the larger dataset. OF the other Ramboll cases, New York is closest to Mumbai in terms of population and population density, followed by Singapore.

Mumbai has the highest net annual water balance of all of the cases, and it has one of the higher water balances of the 142 cities as well. Singapore was another Ramboll case study with an annual net water balance greater than 1m/year. However, recall the previous discussion about the seasonality of water availability during the year. In contrast, Singapore has a similar net annual water balance to Mumbai but receives a relatively constant net *monthly* water balance throughout the year. This metric therefore does not adequately take into account the seasonal disparity of water resources, but it does provide a measure of total potential availability of water resources.

Mumbai has the lowest average annual per capita water consumption of all of the cases, and one of the lowest per capita water consumptions of all of the cities in the database. The average annual per capita water consumption in Mumbai is 36 m^3/capita/year, which converts to 99 L/capita/day using standard unit conversions. The recommended minimum water requirement for basic health, sanitation, and quality of life is between 50-100 L/capita/day[1] (Gleick, 1996). As

Mumbai's *average* per capita water consumption falls within this range, it is highly likely that a significant fraction of the population do not have access to a sufficient quantity (and likely quality) of water to meet basic human needs. While BGI might seem like a luxury when such a condition exists, BGI has been shown to have substantial health and community benefits. While a BGI intervention alone would likely be insufficient to ameliorate this situation, existing access to parks and nature might be a key consideration in placement of BGI. Priority for BGI projects might be given to less privileged neighborhoods, although they would likely have to be combined with additional infrastructure interventions. There is an opportunity to consider the pros and cons of BGI in situations of water poverty. Including Mumbai in the Ramboll cases starts to get at this issue. However, even within relatively wealthier cities there is likely to be differences in water availability.

d. Cluster Analysis of Urban and Water Variables

In addition to comparing the position of Mumbai relative to other cities on the basis of each of the four attributes shown in Fig. 6, we also performed a hierarchical clustering analysis on three of these variables: per capita water consumption, population density, and net annual water balance. The results of this clustering are shown below; a description of the clustering methodology is provided elsewhere. The results of the hierarchical clustering are shown as a dendrogram in Fig. 7.

While Mumbai is in many ways an outlier in terms of individual attributes, when considered in terms of the three attributes it was clustered with Hanover and Hamburg.

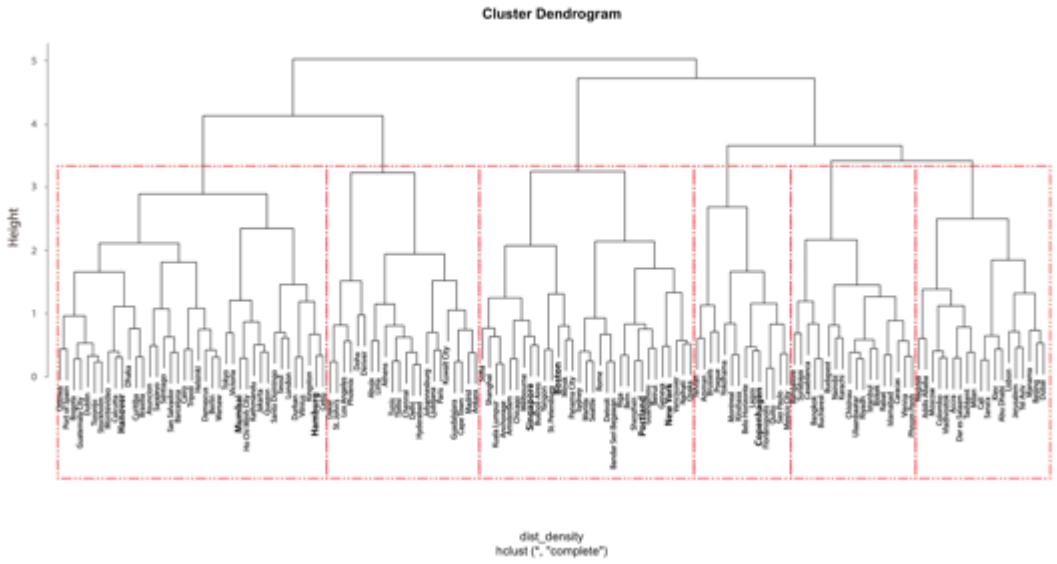


Figure 7. Dendrogram of the hierarchical clustering results of 142 cities based on population density, average per capita water consumption, and net annual water balance.

Within this larger cluster, Mumbai was most closely paired with Ho Chi Minh City. This pair was then grouped with a small cluster of Kathmandu, Jakarta, and Quezon City. Tokyo and Victoria were also grouped together with Mumbai at the next level. This subcluster is seen in Fig. 8a.

Hamburg was paired with the city of Cebu and then grouped together with Kingston (as seen in Fig. 8c). This triad was then grouped together with the pair of Durban and Vilnius. Hanover was paired with Calcutta, and then grouped together with Montevideo. This was grouped at a higher level with Dhaka, Curitiba, and Brasilia (seen in Fig. 8b).

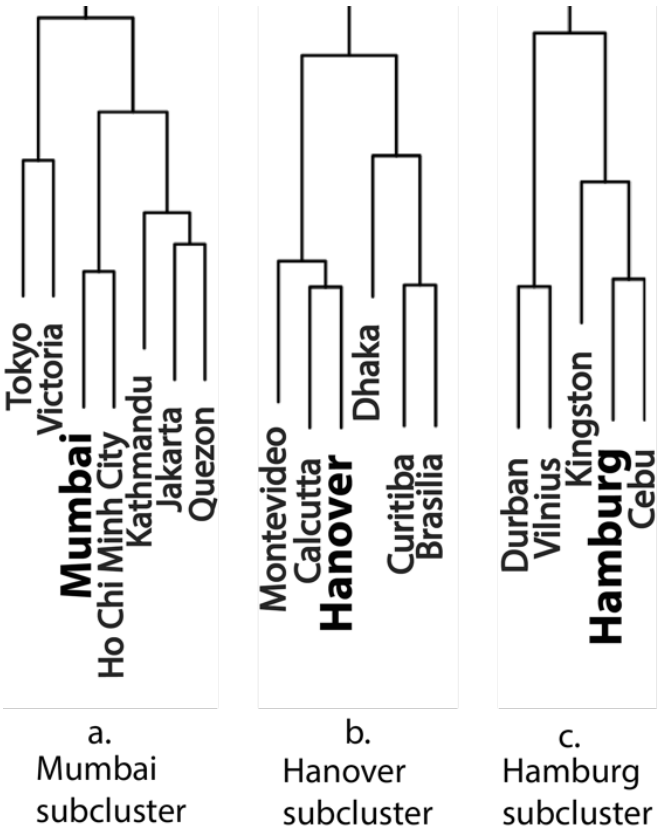


Figure 8. Close-ups of the Mumbai, Hanover, and Hamburg subclusters within the larger dendrogram.

It is interesting to see that the hierarchical clustering groups the Ramboll cases Hamburg and Hanover together with Mumbai (e.g. before grouping them with Boston, Singapore, or Copenhagen). However, the larger clusters themselves are only so useful in assessing the comparability of cities for use in identifying opportunities for transfer of knowledge about BGI. More important, perhaps, is examining the relative positions and linkages of cities within the dendrogram at various levels.

4. CHALLENGES MUMBAI IS FACING TODAY

Mumbai is an important case study in the MIT-Ramboll research because its development trajectory has to contend with both the pressures of growth and heightened local, regional, and global environmental challenges. Studies show that the impact of sea level rise and escalating storms will affect many coastal Indian cities like Mumbai, Kolkata, Surat & Chennai equally and or perhaps more devastatingly than many cities in the west ((Nicholls et al. 2007), (Hallegatte et al. 2013)). A World Bank report indicates that 27% of the world's poor living in coastal cities are in India, and that Mumbai city will bear $6.4 billion US dollars in flood costs annually by 2050, second only to Guanzhou in China. This is an enormous strain on its economy and life. The OECD data indicates that 2.787 million people in Mumbai alone are exposed to climate change risks (Nicholls et al. 2007).However, a historical study of flood damages in Mumbai has identified specific regional storm tracks and tidal conditions that cause the most damage (Lomazzi et al., 2014). What is needed by way of follow up is a blue-green infrastructure strategy for locally addressing these regional and global risks. This is an example of the logic that we pursue in this case study.

Mumbai is also an important case study for the challenges that it faces, it has one of the lowest per capita water uses (135 ltrs/day/person as per MCGM) and a substantial but heavily degraded natural capital (P K Das & Associates and Mumbai Waterfronts Centre 2012), that includes its somewhat protected headwaters to polluted urban stream corridors and reclaimed coastal zones. Thus while the potential for forming an explicit BGI systems are high in Mumbai the internal and external threats and demand on its incredibly diverse ecological infrastructure are also relatively high. If Mumbai is able to revitalize and sustain its natural resources as a productive landscape infrastructure that also serves to mitigate some of the global and regional climate risks through this phase of development, it will benefit from better public health and environment. This will present an important model as a change maker in its regional context by possibly offering an alternative to the prevalent "pro-environment anti-development" narrative that has created a north south divide in the global environmental debate(Martínez-Alier 1995).

Figure 2. Percentage of poor living in coastal areas- Ecosystem Services for Poverty Alleviation, Tim Mc Donnell, World Bank, 2007

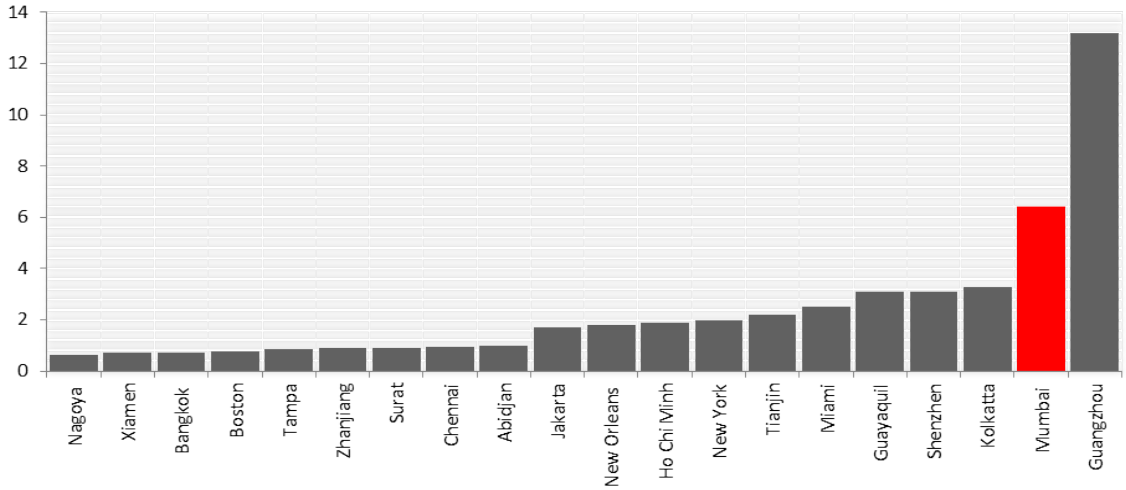


Figure 3. Cities with the highest annual flood costs by 2050, Tim Mc Donnell, World Bank, 2007

a. Need to understand the Institutional landscape

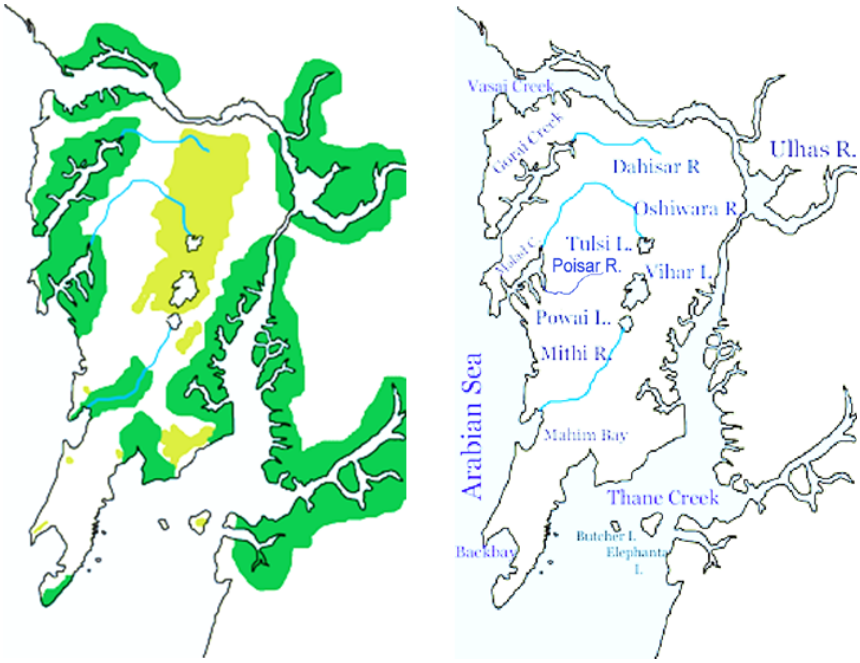
As an estuarine city, Mumbai is naturally endowed with an extraordinary diversity of “blue green” ecosystems- its coastal watershed & wetlands (mangroves, mudflats, salt pans, beaches etc), its forested headwaters (the SGNP, the Aarey, the Mandala & Gilbert hills, the Juhu Irla forest and the Vihar, Powai, Tulsi , Tansa lakes), and extensive network of rivers, nullahs, ponds, lakes and wells. However, Mumbai city has been losing its existing “blue green” infrastructure to pressures of development and growth and lacks adequate regulatory measures and institutional structures

for protection and planning (Kirtane 2011). Conservation of wetlands and mangroves is declining in Thane creek and Ulhas River (Nikam et al. 2009). What Mumbai does or does not do to protect this infrastructure will impact the water and environmental security of the population of not just Mumbai city but also the entire Mumbai Metropolitan Region.

The Mumbai Metropolitan Region (MMR) water management system includes 4 districts, 8 municipal corporations, 9 municipal councils and 1000 villages with a population of 22.2 million (2011, MMR) on a land area of 4355 sq km. In this context it would be important to understand the BGI governance framework operational today and how instances of implicit and explicit BGI formation have been enabled in the Mumbai context in the past and present.

b. Importance of studying the historical geography

The geographic, economic, and cultural history of Mumbai situates it as a place where the people have had a very close association with water (*Mumbai: Liquid City* by Mathew Gandy, 2007) (Matthew Gandy 2008). Its development from the seven islands of Koli communities (fisher folks) dependent on the sea for subsistence, to the great rivers, sacred tanks and estuarine networks of navigation (during the early Hindu & Muslim kingdoms) to the landfills and reclamation defining the island city as a great industrial trading port (British period), its urban network of fountains, tanks, wells (the great Parsi charities) all reflect this close association with water. A large part of these rich networks of association however have been abandoned or submerged as the city continues to grow into its modern mega-city form (Belanger 2009). Today six great reservoirs located more than 150 plus km north of the city are secured to serve the region's water needs while the city's river system, nullahs, tanks and coastal waters suffer compromised flows and reduced capacity due to heavy pollution and encroachment posing severe risks of flooding. Resurfacing these lost water geographies, securing them through green infrastructures (mangroves, mudflats, forests, parks, promenades and green corridors), and connecting them to natural flows offers an approach to improving environmental sustainability while reclaiming Mumbai's rich natural heritage and great environmental traditions. This approach of water heritage conservation combined with innovative productive landscape design could offer an opportunity for Mumbai to reclaim its lost association with water while simultaneously responding to the needs of development and risks of climate change. A study of Mumbai's unique historic geography and water heritage could help ground conservation and restoration approach to BGI creation in its unique history.



Geography of Mumbai, Creative Commons, source: w:en:Image:Geographybombay.png, author:w:en:User:Nichalp

c. Important turning points and opportunities

Important historic moments that highlight key challenges and bring dormant issues to the fore of political and popular consciousness often serve as turning points that ensue policy change. Although a long-distance water transfer, supply-driven, consumptive approach to water and related land “resources” has dominated the development path of Mumbai in the modern times. And while this subsurface hidden infrastructure has kept the discussion on water security out of mainstream discussion, today in the aftermath of the devastating floods of 2005, the voices that support the development of productive “blue green” landscapes that improve environmental security while adding value to development are slowly gaining momentum and have brought back the public discourse on water and the environment. The city today has seen a rise in the number of NGO’s, environmental groups, state and national institutions and think tanks promoting research and understanding of Mumbai’s unique ecological landscape and strategies for its long term sustenance. These include agencies like - the Mumbai Waterfront Center, The Maharashtra Nature Park Society, Soonabhai Phirojsha Godrej Marine Ecology Centre, India Environment Portal, Bombay Environmental Action Group, NEERI, ORF, The Mithi Nadi Sansad, The Mithi Yatra and many others.

d. Need to emphasize values and build on marginal successes

However in spite of the new environmental consciousness the contest between environmental concerns and development pressures continues. Restoring the natural ecology of the urban environment in this context is often seen as an anti-growth paradigm. Caught in this contest the environmental responses are often limited to piecemeal conservation measures, strategic hard infrastructure solutions, risk management studies leaving the space open for a vision for long term sustenance that looks at all the pieces as part of a larger system/a network of natural infrastructures that perform important urban functions. The great advantage for Mumbai unlike Boston is that the possibilities for this reinvisioning are still alive. The interconnected inland freshwater landscape and coastal landscape in Mumbai today though highly compromised still perform important tidal, inter-tidal functions as natural infrastructures. The aim of this analysis would be to both identify potential BGI typologies in Mumbai and highlight the real social, economic and ecological values these potential BGI networks can perform if sustained, protected and enhanced.

e. Importance of comparative analysis

Today Mumbai has the lowest aggregate rate of per capita water use, which is a comparative advantage as well as a problem. Mumbai also has substantial protected areas that bear comparison with those of other island environments in the MIT Ramboll study, such as Singapore. However Mumbai's history of land reclamation also bears comparison with that of Boston and other cities subject to tidal flows (Haglund, *Inventing the Charles River;* Seasholes, 2003, *Gaining Ground*). This research will aim to recommend alternate development and planning approach to urban environmental planning and management for Mumbai by linking insights from innovative "blue green" infrastructure cases in other cities to specific values and opportunities that emerge from the Mumbai research. The next section helps set these initial comparative ideas within the longer-term context of the historical geography of Mumbai and its blue-green infrastructure.

5. HISTORICAL GEOGRAPHY OF MUMBAI

The aim of the historic research is to understand Mumbai's unique cultural, social, political and economic relationship with its natural environment and water systems. This study will start from the pre 1650 era of Mumbai as an agrarian landscape of seven islands, to its transformation to a land filled mercantile town under colonial rule from 1650-1853 and then the period of rapid industrialization from 1853-1947 followed by urban expansion in the post-independence era and the shift to a service economy, to the Floods of 2005 which changed Mumbai's environmental consciousness. The emphasis would be to understand who and what are the motivators for

innovations in Mumbai's Blue Green Infrastructure. How has this altered and changed people's perception and relationship to water and the natural environment in which they live? How these natural environments' have coped with the pressures of development over a period of time and what are the challenges that the city faces today in sustaining these resources. How is the city today reacting to the awareness of impending risks faced by coastal cities due to global climate change and regional climate impacts? Post 2005 how has the institutional environment changed to respond to environmental challenges and how is civil society engaged in this debate? What are people's perceptions of safety and security in this climate risk scenario and how has that played out in considering solutions (Sharada et al. 1995).

400BC-1200: The early settlement patterns (400 BC to 1200) in Mumbai included predominantly agrarian communities settled on the mainland and coastal fishing communities settled on the 7 islands that formed the southern peninsula. The settlers survived on a decentralized system of water supply and rainwater harvesting was a prevalent practice, evidence of this can be seen at the Kaneri rock cut caves at the Sanjay Gandhi National Park. At this stage of existence there was no shortage of potable water and surface water sources (such as ponds, lakes and rivers) were sufficient to supply the needs of the communities.

1200-1800: As the communities consolidated and larger settlement patterns developed (1200 to 1680) agrarian life continued along the rivers and shallow groundwater was tapped to fulfill the potable water needs of the population. A system of wells, tanks are built for both public and private use. Many masonry-lined tanks were built to harvest rainwater; some of them survive to this day. Paddy farming and fishing communities continued to co-exist, though many ruling dynasties changed. The political rule transitioned from the Hindu rule to the Muslim rulers to the Portuguese.

1680-1819: In 1680's the British arrived in Mumbai and the British companies focused on consolidating and developing the southern peninsula and the trading ports. As the land was reclaimed to develop bays, coasts and settle a steady stream of workers, trade activity increased and the southern town grew and became dependent on the northern provinces for its water needs. The first reported water scarcity issue in Mumbai is reported in the Company records from this time (1680- 1819). To resolve this issue the East India Company incentivized the building of tanks by Indian philanthropists. The many Parsi tanks and water fountains built during this period in Mumbai are evidence of the earliest tradition of charitable public water provision on Mumbai.

Source: Landscape+ Urbanism, the time series maps above shows the landfill history of Mumbai and the graph indicates how the land area has been increasing while the mangrove perimeter has been shrinking in Mumbai from the 1780s to the 2008.

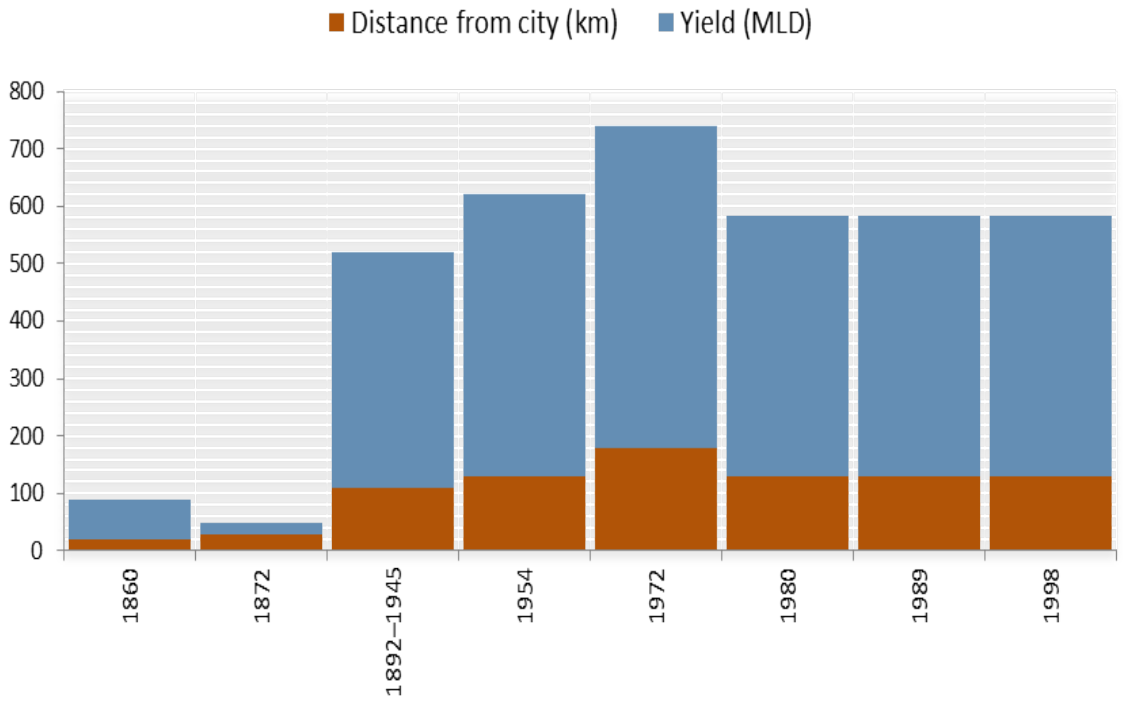
1819-1853- Industrialization in Mumbai from 1819-1853 catapulted this growth further. Cotton mills setup in the island city expanded the water needs of the southern peninsula enormously. In this period the first drought caused due to extreme water shortage is reported in 1824. At this stage the first public works system is setup to manage water supply in the city. Cleaning and deepening of wells and tanks is undertaken to tap deeper groundwater sources to meet the industrial and domestic needs.

1856-1873- During the following decades 1856-1873 with high population density and growth sanitation issues became a big concern. With increased contamination due to industrial effluents and unmanaged mix of water use, water potability became a big problem. In 1845 a committee was appointed to look for opportunities for surface water catchments to meet the needs of Mumbai's population. By 1855 a Water Supply Committee was formed and cattle were shifted out of the city to avoid cross contamination of water. Rainwater harvesting measures and cleaning and deepening of wells and tanks were undertaken. By 1860's the Backbay reclamation company was formed and land underwent further consolidation, marshlands were filled, hills quarried, ground raised and roads built. 1860 saw the building of the Vihar & Tulsi lakes to supply piped water to Mumbai city and the banning of the wells and tanks as a form of water supply. The Bombay Port Trust Company was formed during this period as port activity flourished.

1873-1950- With increased urbanization high stormwater runoff and sewer discharge coupled with the compromised natural drainage due to landfills the following decades (1873 to 1950s) saw the first floods in Mumbai. Flooding was prominent in low-lying areas of the city. This period also saw continued building of large water works and piped water supply to serve the needs of the industrial city and its growing population. Pokran and Bhwandi water works were established in addition to Tulsi and Vihar lakes. The data and chart below indicate the growth of the centralized water infrastructure in Mumbai during this decade.

Year	Source	Yield (MLD)	Dist. (km)
1860	Vihar	70	20
1872	Tulsi	18	30
1892–1945	Tansa	410	110
1954	Vaitarana	490	130
1972	Upper Vaitarana	560	180
1980	Bhatsa - I	455	130
1989	Bhatsa - II	455	130
1998	Bhatsa - III	455	130

Data Source- Municipal Corporation of Greater Mumbai- 2003

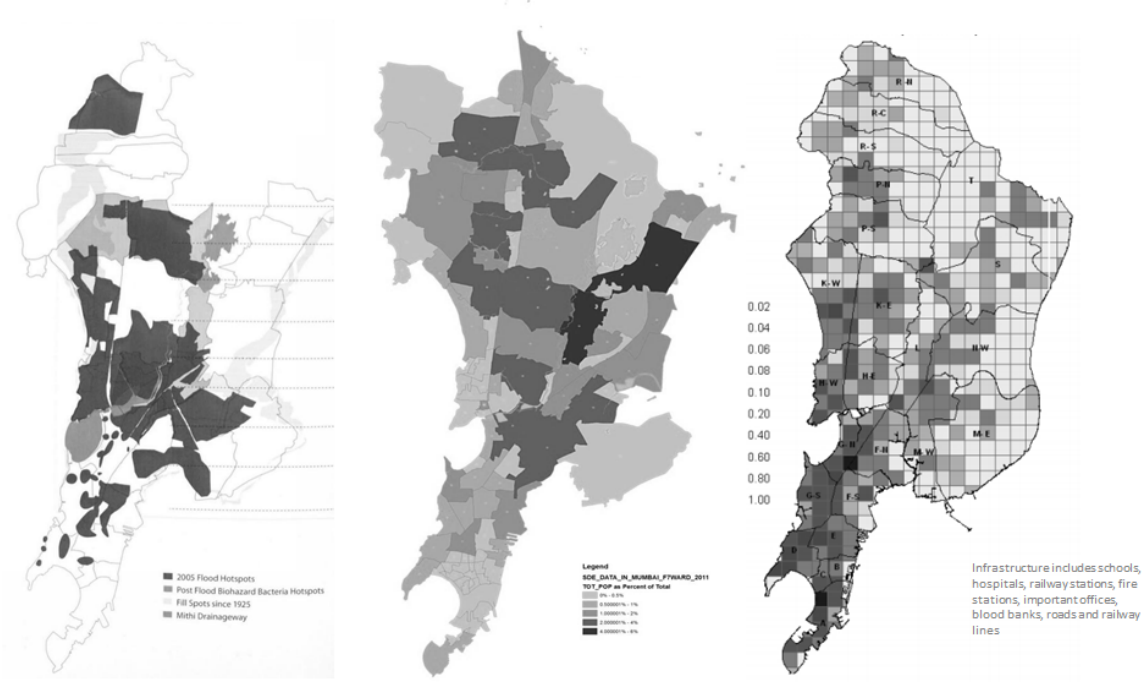


Data Source- Municipal Corporation of Greater Mumbai- 2003

1950-2000- The decades from 1950's to 2000 saw continued reclamations in the island city, this included the Backbay reclamation and the Bandra Kurla Reclamation and the development of the expansion plan for New Mumbai. The city continued to experience exacerbated flooding first in 1974 and then again in 1985. The city also entered into its first phase of transformation to a post-industrial landscape, industries were moved out of the city and the economy slowly shifted to a service industry based economy. During this phase many storm and drainage issues were

studied to improve the city's storm and sewer management; these will be discussed in detail later through the study of the Mithi River case.

2000-2011: The most critical event during the 2000- 2011-decade that changed Mumbai's consciousness to the environmental hazards it faces was the 2005 flood. The citywide flooding caused loss of human lives and disruption of services like never before. Reports indicate that the floods damaged 40,000 commercial establishments, 30,000 vehicles, electric supply was disrupted for 24 hrs and most arterial roads and highways were impacted, the railway services were closed and 500 people lost their lives. in suburban Mumbai 175,885 houses were partially damaged and 2000 were fully damaged (Hallegatte et al. 2010). Most filled areas in Mumbai are only just above the sea level and below high tide level, during high tide this can prevent drainage through the river channel and lead to salt water deluge. Studies establish that 90% of Mumbai's storm drainage is through storm drains and only 10% is through open lands and this leads to additional challenges and load on an outdated and under capacity storm infrastructure which is more than a 100 years old. Some studies estimate that the flood costs the city 2 billion USD in 2005 (Hallegatte et al. 2010). And this is not only important for Mumbai but for the whole country as Mumbai contributes 5% to the country's GDP and is an important commercial and financial center.



Source: Left to right. Flood Hotspots by Landscape + Urbansim, Mumbai Population density based on Census Data, Infrastructure Exposure Map, OECD (Hallegatte et al. 2010)

Various committees since have prepared flood mitigation reports in response to the 2005 floods. Many environmental improvement plan and ecozone protection plans were also recommended; the focus was on the areas of high impact mainly the Mithi River and Vakola Nala flood zone. The solutions implemented focused on engineered grey infrastructure solutions. The impact of this approach will be discussed through the Mithi river case study.

Image source: Mumbai an Estuary to a coastal city- SOAK, A Mathur and Da Cunha,2009, The maps above show the time series of the evolution of Mumbai's land mass as we know it today. It shows the continuous process of land reclamation and consolidation of water catchments further upstream from the 1700 to 2000.

6. TYPOLOGIES OF BLUE-GREEN INFRASTRUCTURE IN MUMBAI

Developing a typology is an attempt to describe the homogeneous landscape units that occur in cities by recognizing their common ecological functions and physical characteristics. It could serve as a tool for planning the city, by urban planners, landscape architects, city parks management agencies, environmentalist and other city service providers and utilities and used as an educational tool for its citizens. It also helps facilitate research on ecological processes of urban areas and allows cities and sectors to be compared to each other. It is an important way of incorporating the urban ecosystem typology into the larger framework that allows urban areas to be integrated into the surrounding hinterland as a landscape continuum (Brady et al. 1979). Many green and blue typologies have been used commonly in scholarly work from India. These include descriptive terms like - forests, parks, gardens, lawns, shrub lands, marshes, beaches, lakes, ponds, tanks, sanctuaries and others. In Mumbai recently an attempt has been made to classify and document Mumbai's landscape elements in an open spaces study by Mr P K Das through the

"Mumbai Open" project. While the plans main effort is to classify all open spaces, the classification indicates a very divided blue green perspective, which does not necessarily recognize the symbiotic nature of the existence of blue-green systems and the ecological values of the network as a natural functional infrastructure that exists embedded in Mumbai's urban fabric. (P K Das & Associates and Mumbai Waterfronts Centre 2012)

Existing Open Space Classification - a divided Blue-Green perspective (P K Das)

Proposed Blue-Green Infrastructure Classification

We propose that the Mumbai's natural infrastructure be reclassified as a blue-green landscape in recognition of its true natural characteristics. The forests and national parks serve as the catchment area for the great lakes that provide the city's water needs and thus cannot be separated from the lakes. Hence we recognize these elements as a singular unit the "forested headwaters" of Mumbai where the green and blue co-exist. These large vegetated areas are also important green lungs for the city that help sequester carbon and are great biodiversity hotspots serving as habitats for a great number of flora and fauna species.

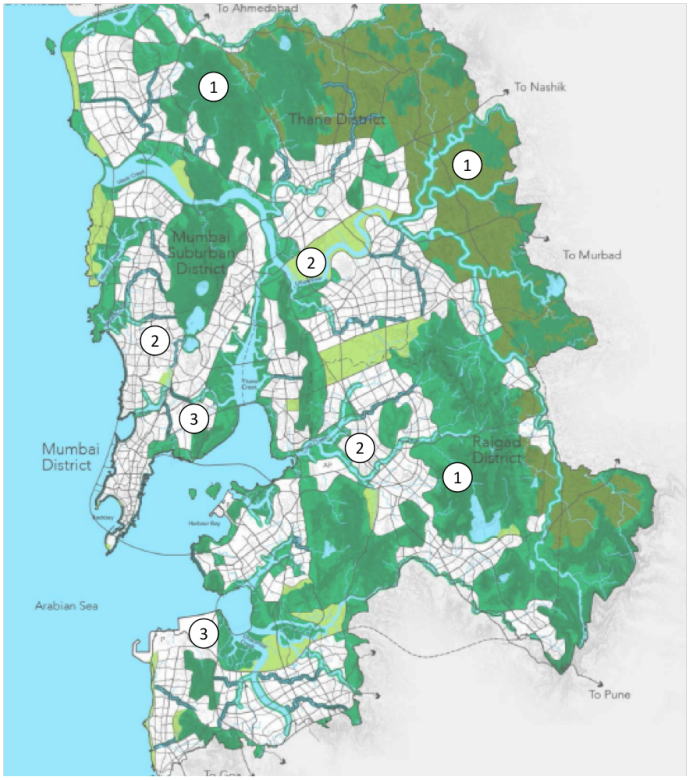
Similarly the rivers in Mumbai form a continuum that connects the inland freshwater system to the coastal ecosystem through its unique inter-tidal landscape with brackish water environments. The river, its vegetated banks and mangrove landscape therefore cannot be separated from each other and must be categorized as one unit. Mumbai has 4 rivers (the mithi, oshiwara, dahisar **and poisar) over 81.4 km (P K Das & Associates and Mumbai Waterfronts Centre 2012) in length, that have been currently encroached and their capacity compromised, they need to be restored to their natural value and ecological functions to carry storm water runoff and form a flushing mechanism through tidal flows from the ocean. These tidal mechanisms support anadromous and catadromous species of fish, which are likely to perish if the capacity of tidal action is compromised by pollution**

(Singare, Mishra, and Trivedi 2011). Mumbai also has 16 planned nullahs covering a length of 48km designed to be storm water drains, but the capacity of these channels have been compromised by the dumping of untreated sewage and garbage. These need to be cleaned and restored to enable efficient stormwater discharge.

Mumbai also has a large number of built landscape elements, which include the somewhat segregated green, and blue landscapes of the parks, gardens, promenades and the shallow built water bodies such as tanks, wells and ponds. These serve as important locations for groundwater recharge, enable rainwater harvesting and provide important spaces for recreation thus serving important public health and environmental functions. Mumbai's rich coastal environment includes the mud flats, the creeks, the saltpans, natural beaches and mangroves. Mumbai is one of the few cities in the world with over 70 sq km of creeks and mangroves. These act as natural barriers against high tides, cyclonic winds, storm surges and coastal erosion. These brackish waters are also breeding grounds for various fish and nesting sites for numerous bird species (Unnikrishnan, Singh, and Kharat 2012).

This study will focus on the three regional scale blue-green landscapes of Mumbai Metropolitan Region to understand their values, their interrelation, their current status, the opportunities to restore them and the constraints they face. These three typologies and their broad geographic distribution is illustrated in the map below. These are:

1) Typology 1: Forested headwaters, Sub case- Sanjay Gandhi National Park
2) Typology 2: Rivers, streams, floodplains, Sub case- Mithi River and its flood plain
3) Typology 3: Coastal environments, Sub case- The Coastal Regulation Zone



① Typology-1-Forested headwaters

② Typology-2-Rivers, streams and floodplains

③ Typology-3-Coastal environments

Map showing the geographic extend of the BGI network in the MMR region. Base Map Source: Concept Plan for Mumbai Metropolitan Region, by Surbana

7. INSTITUTIONS AND GOVERNANCE

In Mumbai's context it is interesting to see that both the Coastal Regulatory Zone policy advocating a strong environmental preservation path and the Industrial relocation policy passed in 1980's have largely supported repurposing of city's underused industrial infrastructure to support environmental causes. And yet a large part of Mumbai's Eastern waterfront continues to be dominated by largely unregulated industrial/commercial uses on land owned by a central government agency. This institutional analysis will focus on understanding which ideas get implemented and what gets left out and why. What are the governance and institutional politics and capacity issues and how those impact implementation of environmental regulations that effect each of the typology selected for the case study. Are national and state governance agencies in concert over environmental policies? Why are local government agencies like Municipal Corporation of Greater Mumbai (MCGM) and Mumbai Metropolitan Regional Development Authority (MMRDA)being held in contempt by court for breaking national environmental regulation which

stipulates environmentally sensitive coastal development (CRZ regulation, MOE)? What is the regulatory environment, who formulates and who implements it, what are the pressures on local agencies and do they have the capacity to enforce and implement policies. What would be a more enabling environment? Who are the non-state players- civilian actors, environmental groups who can act as watchdogs and what are their motivations. How will they influence public debate and policy on environmental issues? Will there be public pressure to consider more environmentally sensitive land policies.

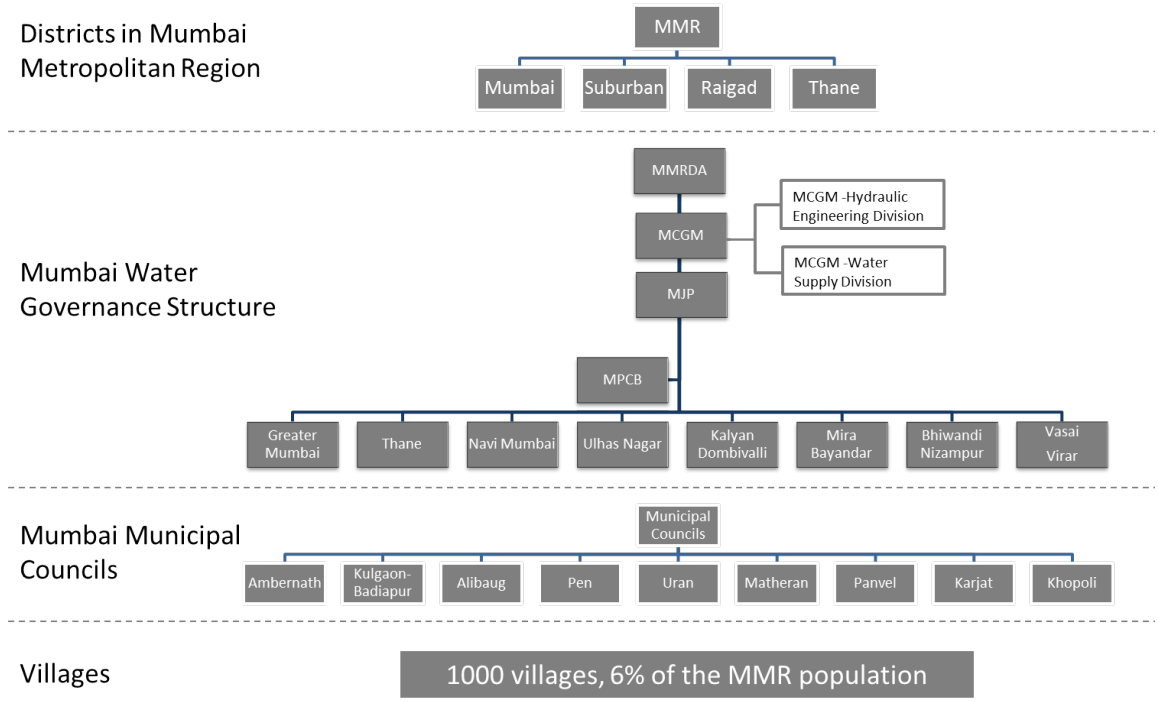
The OUP handbook on urbanization describes these conflicting and contrasting pressures that are shaping a polarizing environment versus development perspective in India today (Kumar and Martinez-alier 2011). The pro development intellectuals claim that “development that meets the needs of the present without compromising the ability of future generations, is too intellectually neat and politically convenient an idea” (Lele, 1991, Lohmann, 1990). It suggests that a distinction needs to be made between “survival” and “Luxury” in the context of developing countries. The pro-environment groups contends that this stance as merely “ hiding behind the poor” or “protecting growth” and “avoiding climate change” (Martínez-Alier 1995). Scholars have also raised concern over the trend of “executive and or judiciary setting the environment policy to the exclusion of the parliament”, perhaps indicating to their lack of legitimacy and lackadaisical enforcement by local legislators. In 2009 the National Action Plan on Climate Change (GOI, Prime minister's council on climate change) developed a co-benefit agenda. This was an important milestone and provides a political opportunity and institutional vehicle to re-frame the existing development debate. It established that the climate agenda in India is the governance of multiple objectives, rather than singular objectives.

While at the macro scale environmental policies in India face a legitimacy and enforcement challenge, at the local scale there are also many administrative challenges. The city of Mumbai consists of 2 administrative districts: the island city and the suburban district. The Mumbai Metropolitan Region (MMR) includes 2 more districts: the Thane district and the Raigad district. The total area of the entire metropolitan region is 4355 sq km. The administration of the region incorporates 8 planning corporations and 9 municipal councils and a1000 villages. 94% of regional population is urban and 6% is rural. Mumbai city extends between 18° and 19.20° N and between 72° and 73° E. The city extends from East to west by about 12 km, where it is broadest, and from North to South extends about 40 km (Hallegatte et al. 2010). Geographically, Greater Mumbai is an island separated from the mainland by the narrow Thane Creek and the relatively wider Harbour Bay. Thus, the area of Greater Mumbai is surrounded on three sides by the seas: by the Arabian Sea to the West and the South, the Harbour Bay and the Thane Creek in the East. The entire Mumbai city is divides into 6 zones and 24 wards. The island city has 9 wards and the

suburban district had 15 wards. A total of 37% of the population is employed in the formal sector and 63% in the informal sector. The city receives on an average 2400mm of rainfall annually. The rain falls primarily in a short period of 3-4 months during the monsoon season stretching from June-August. Continuous rainfall during the monsoon season often results in flashfloods in many low lying areas of the city, disrupting traffic, commerce and destroying property and causing many hardships to its citizens.

Area	4355 sq.km.
Population	About 22.2 million (2011)
Districts in MMR	1. Mumbai 2. Suburban 3. Thane 4. Raigad
Corporations in MMR	1. Greater Mumbai 2. Thane 3. Navi Mumbai 4. Ulhas Nagar 5. Kalyan-Dombivali 6. Mira Bhayandar 7. Bhiwandi- Nizampur 8. Vasai-Virar
Municipal Councils in MMR	1. Ambernath 2. Kulgaon-Badlapur 3. Alibaug 4. Pen 5. Uran 6. Matheran Hill Station 7. Panvel 8. Karjat 9. Khopoli
Villages	1000
Urbanisation	94% Urban Population 6% Rural Population

Mumbai Metropolitan Region Map- source- MMRDA website



MMR water management- Institutional Structure, source MCGM website

The institutional map above illustrates the hierarchical structure of the agencies responsible for managing water supply for the greater metropolitan region, their roles are described below. The Municipal Corporation of Greater Mumbai (MCGM) is responsible for the overall water management within the jurisdiction of Mumbai, as a water resource developer and manager. The City and Industrial Development Corporation (CIDCO) is responsible for water management in Navi Mumbai. The local municipalities in Mumbai metropolitan Region purchase water from MCGM or use ground water. The Maharashtra Jeevan Pradhikaran is a state agency that facilitates water procurement. The MCGM has two departments responsible for water management. The Hydraulic Engineering Division is responsible for construction, operation and maintenance of reservoirs and treatment plants. The Water Supply Division is responsible for service delivery, maintenance, water works, meter reading, billing and procuring municipal appurtenances. The Mumbai metropolitan region development authority (MMRDA) prepares the strategic regional plans for ensuring water supply during the plan time and horizon. The Maharashtra Pollution Control Board (MPCB) sets up the regulatory framework and standards to meet the water quality requirements for the state.

The Gardens department of MCGM develops, maintains public open spaces like gardens and recreational grounds and playgrounds in the city of Mumbai. The department engages its own

workforce for the purpose and also has outsourced these activities to private sponsors in lieu of advertisement and publicity rights. MCGM maintains about 753 such open spaces admeasuring a total of 4.4 sq km spread across the city. Though the city has regulations in place for development of open spaces in the development plan, the regulations for acquisition of these public spaces is not included and is cost prohibitive due to land costs.

8. MAJOR BGI CASE STUDIES IN MUMBAI

Having an overview of Mumbai's historic geography with specific focus on the development of its water infrastructure and its overall administrative structure and challenges. We now return to the main BGI case studies for a detailed examination of how they developed, using the Expanded Process Model, and what values they embody today. In contrast with urban case studies that have only one main BGI case, here we have three: the Sanjay Gandhi National Park in the headwaters of Mumbai's watershed; followed by the Mithi River; and then the Coastal ecosystem. In this section, we examine each of these in sequence from the headwaters to the ocean.

a. CASE-1- FORESTED HEADWATERS-SANJAY GANDHI NATIONAL PARK

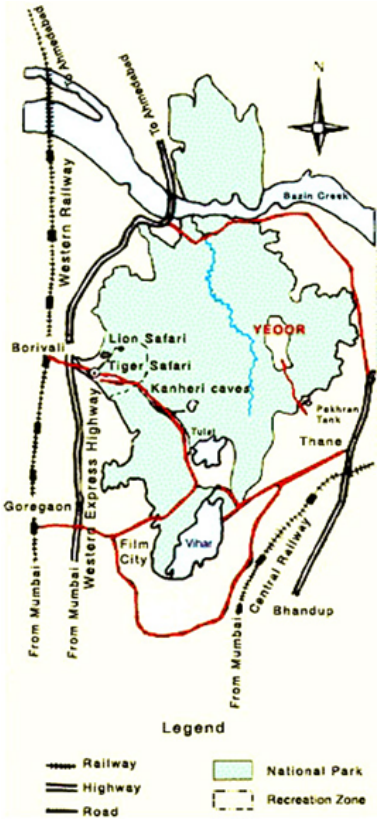
To understand the antecedent conditions for the development of the Sanjay Gandhi National Park as an implicit BGI we developed a historic chronology of the case. This might have relevance to other case studies in helping inform them of the necessary political, social, environmental and economic conditions that enabled formation of this BGI and perhaps project what could lead it to become an explicit BGI.

i. Chronology. The chronology of the case is:

- 1845-1855- A water committee was established to protect surface water sources from pollution and look at other sources of water north of the island city to meet the growing water needs of the island city.
- 1865- The Indian Forest service was established under the Government Forest Act and given the charge to manage forests across the country.
- 1868- In Mumbai the Tulsi lake was commissioned
- 1883- The Bombay Municipal Corporation acquired the forest catchment areas of the Tulsi Lake. (10 sqkm of forest area)
- 1927- A notification was issued to designate the forest area as a protected forest under the Indian Forest Act. This act restricted timber production and cattle grazing thus enabling a protection and conservation mandate.

- 1939- The Maharashtra State Forest Department Act, acquired the Sanjay Gandhi National Park forest. This was an important step in decentralizing forest management.
- 1947- All private forests in India were nationalized and came under the respective state forest departments. The municipal government added 21 sqkm of green space around Vihar and Tulsi. The lakes within SGNP are still governed by the BMC.
- 1950- SGNP was declared as a national park mainly to protect the catchment area for the two lakes that served Mumbai's water needs. And an additional 20.26 sq km of privately owned land was pieced together to create a green space for the people of Mumbai and this area was called the "Krishnagiri National Park".
- 1960- A committee under the chairmanship of the then chief minister recommended extending Krishnagiri National Park areas to 68.27 sqkm. The park was also renamed to Borivali National park and a forest subdivision was created.
- 1970- Union cabinet minister decided to restrict the core area to visitors and expand the park further, in order to protect it from growing encroachments from slum settlements. This also reflected the push for environmental conservation at the national level under the leadership of Prime Minister Indira Gandhi (1966-77; 1980-84).
- 1972- the forest subdivision was upgraded to forest division at SGNP. And at the National level the National Wildlife Protection Act was enacted. The act banned hunting and harvesting of the ecosystem and established protection of certain species.
- 1974 - under the acquisition of revenue land, the Maharashtra Private Forest Acquisition Act 1975 and the Maharashtra Urban Areas Preservation of Trees Act 1975 the park was extended. Though a number of legal battles ensued which are not yet resolved, the Forest Department acquired 10+15 sq km of land through this act.
- 1975- Government of Maharashtra decided to build a highway through the park but Humayun Abdulali through a PIL he filed against the Government of Maharashtra stopped this.
- 1976- The Government of Maharashtra constituted an area of 68.977 sqkm from Borivali and Thane to be declared as a national park.
- 1977- the management of the park was transferred to the Forest development corporation of Maharashtra
- 1980- The forest conservation act of India protects all forest lands and restricts the de-reservation of forest land for non-forest purpose. In 1981 the Borivali National Park was renamed the Sanjay Gandhi National Park
- 1983- Taking advantage of the rights granted by the conservation act the Government of Maharashtra declared that an areas of 86.865 sqkm should constitute SGNP and include the previous 68.977 sqkm
- 1988- The Management of SGNP was transferred back to the State Forest Department.

- 1996- The final notification was passed to declare approximately 103.09 sqkm as SGNP a protected national forest.
- 1997- BEAG filed PIL in the Maharashtra High Court requesting action against illegal encroachers at SGNP. The high court ordered eviction and rehabilitation of encroachers.
- 2000-The national park is divided into 3 thematic areas. Krishnagiri Upavan, SGNP and Yeur. Upavan is a recreational area approx.5.88 sqkm, SGNP is 38.57 sqkm, Yeur is 58.64 sqkm. Tulsi & Vihar cover 8.5 sqkm. Borivali is 44.45 sqkm and Thane 58.64 sqkm
- 2006- 772. 82 hectares of the national park still contains encroachments in spite of some action at policing and relocation of existing settlers by the local government.

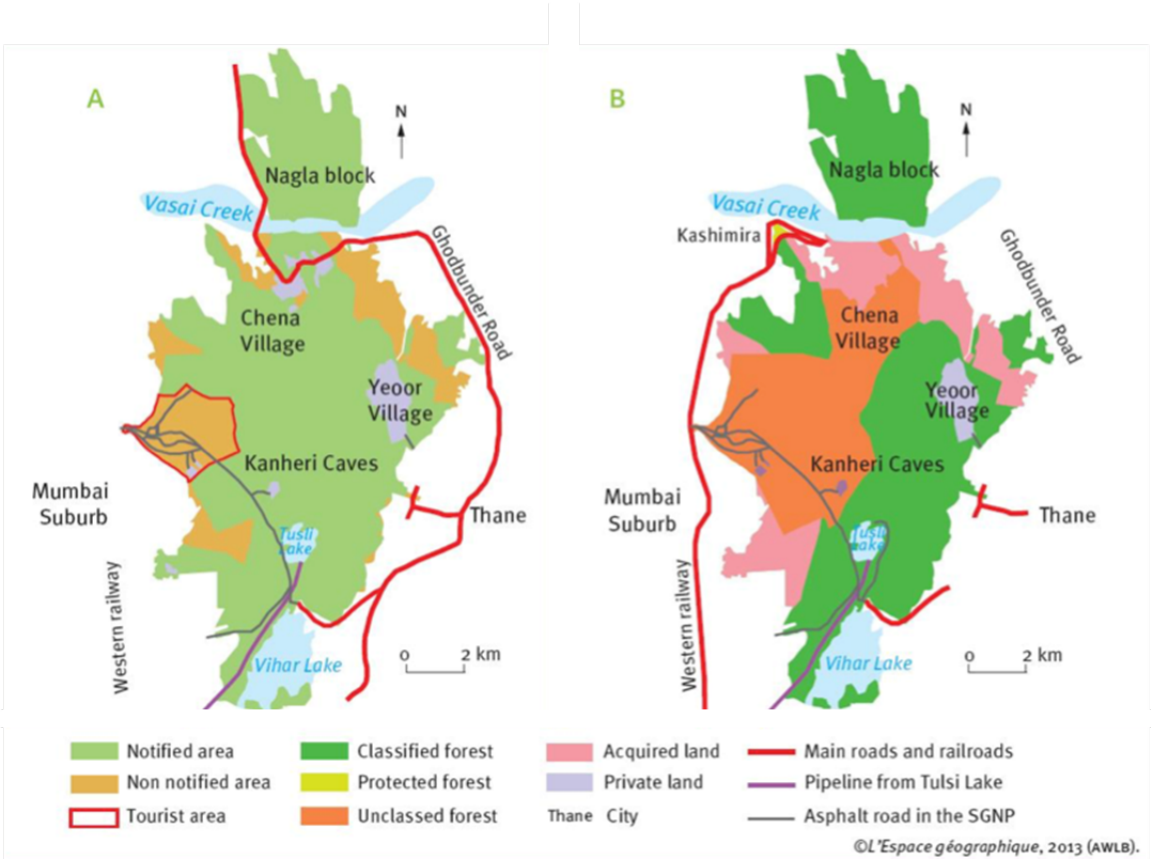


Map source: Maharashtra Forest Department, SGNP-Bombay. Licensed under CC by - SA 3.0 via Wikimedia Commons

ii. Institutional Framework

The Sanjay Gandhi National Park division is a composite of Sanjay Gandhi National Park and the adjoining forest areas. The park division has been formed by piecing together forests of different ownership and now comprise of Reserved Forests (RF), Protected Forests (PF) and Unclassed Forests (UCF). The reserved forests consist of the old reserved forest of Thane, Municipal forests of the catchment of Tulsi and Vihar lakes; and the private areas acquired under the land acquisition act. The other category of reserve forests consists of private forests acquired under the Maharashtra Private Forest Acquisition Act, 1975. Studies indicate that 485.271 hectares of land in SGNP is disputed (Krichewsky et al. 2011). Many legal disputes against the acquisition of

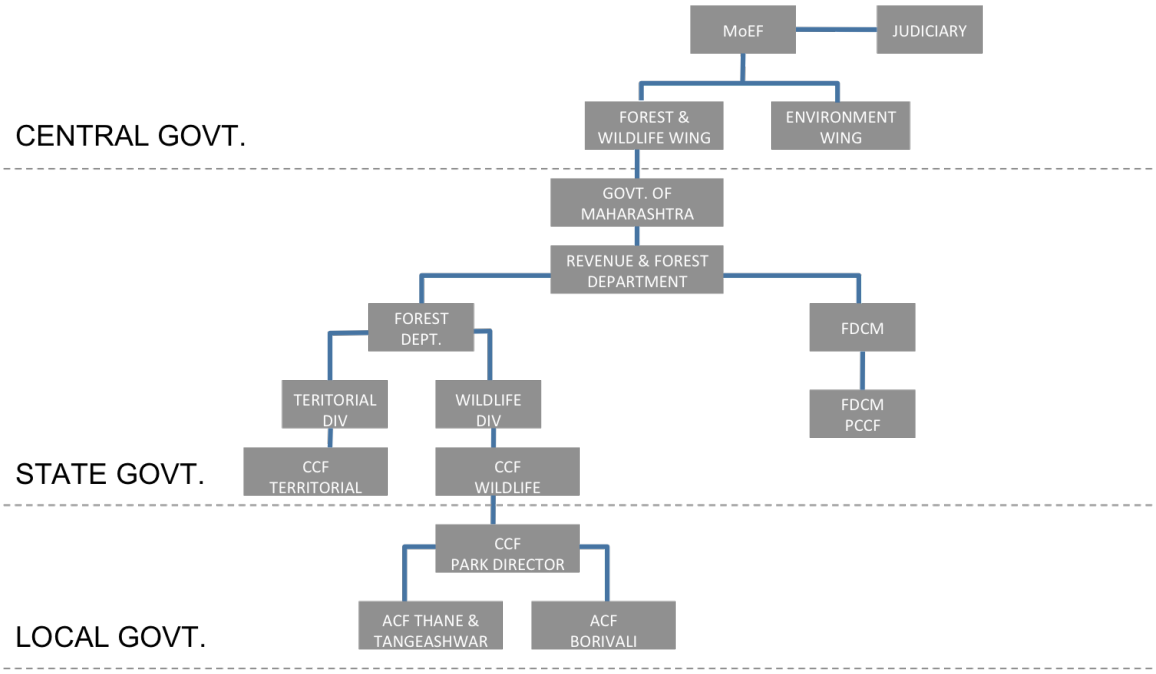
private forestland filed by the original owners are pending final resolution. In addition 2076.095 hectares of land in the division is unclassed forest. The disputed areas and the unclassed forest areas within SGNP enjoy little legal protection and are highly vulnerable to abuse and encroachment and need to be protected. SGNP's fragmented land ownership structure is complicated by its multi-agency administrative structure (forest department, archeology services, BMC etc). The administrative divisions within the park (core, recreational and buffer etc) further complicate the management.



Map Showing Classified and Unclassified forest areas in SGNP, Source: L' Espace geographique, 2013

As a national park the SGNP is considered a public service and its administration is shared between the state and the central government. Though the state retains managerial control, all projects for park development have to be approved by the central government. The state level forest department in divided into three departments: the territorial, the wildlife division and the Forest development corporation of Maharashtra (FCDM), each headed by a principal chief conservator of forests (PCCF) and supported by an additional chief conservator of forest (ACCF). The wildlife division is responsible for the park itself and mandated with management and protection of the national parks and sanctuaries and the territorial division concerned with the surrounding areas and charged with sustainable use of forest resources. These two divisions are substantially standalone with separate funds, staffing and roles and responsibilities. However the

Territorial division controls recruitment and transfers, thus often wildlife matters receive second priority. The SGNP is one of 13 national parks included in the Borivali wildlife circle. Though there is a robust national legal framework that allows the Park management to defend against external pressure, this does not overrule threats of state legislation that impact forest conservation. The park is dependent on the state government budget allocation and uses its Public Leisure Account (PLA) for funding. PLA account is all the revenue generated from recreation and tourism activities and can be reused only for that purpose; allocation of the same to cover other forest management activities is dependent on forest department and central government approval (for land use change). The park management plan acts as a guiding document for all conservation and operational activities.



Institutional structure for SGNP Management, Recreated from Capstone Report on SGNP, Mumbai (Krichewsky et al. 2011)

iii. Driving forces:

High water demand due to industrial and population growth- Initial conditions that led to the establishment of SGNP point to Mumbai's turning into an industrial economy as the main precursors to the formation of this implicit BGI infrastructure. In the 1850's the growing textile industry in the south Mumbai commanded high water consumption for both its industrial needs and the growing worker population. This led to severe water shortage in Mumbai. In 1845 a committee was appointed to look for opportunities for surface water catchment to meet the water needs of Mumbai's population.

*Centralized water system to ensure water security- I*n 1850 Captain Crawford submitted the report to establish the Vihar lake. In 1860's piped water from Vihar and Tulsi lake was inaugurated and local wells and tanks we banned to avoid unregulated water extraction from a decentralized system. The same year the Mumbai Municipal Corporation acquired the forest catchment area in order to ensure impounded water quality can be maintained without much treatment.

Institutional mandates and regulations safeguarding BGI interests- The establishment of the Water Supply Committee and the Indian Forest Service was key to setting institutional ownership of this blue & green infrastructure. Central government leadership through the tenure of Prime Minister Indira Gandhi enabled environmental conservation in India. At the state level several phases of the consolidation of land with the support of the various national acts was key to building up of the SGNP. The 1980 forest conservation act was a key turning point that ensured preservation of the forest areas.

Continued centralization of water infrastructure- Today Mumbai has added many more reservoirs (4 more) to serve its water need. However many of the catchment areas for these new reservoirs remain unprotected and SGNP offers an important precedent to advocate for protection of these catchments and linking them through wildlife corridors to serve the dual purpose of protecting catchments and safeguarding wildlife.

Joint forest management potential- tribal population protection under the forest rights act supports a joint forest management strategy. There are 14 tribal Padas in SGNP (Krichewsky et al. 2011). The Koli, Chena, Yeour, Varli are all tribes who have lived in the area and have depended on the forest resources for their survival before their land was acquired to form the SGNP. Yet today Maharashtra has not adopted joint forest management at SGNP. This is an important opportunity that will help tide over some man power constraints the forest department faces.

*Volunteer activity potential***-** Environmental groups provide approximately 150 volunteers to the park each year in conservation activities. The work of volunteers could be expanded and further utilized to spread knowledge about the park and help in other park management work. However SGNP administrative procedures for such engagement are extremely bureaucratic and this discourages leveraging outside resources.

iv. Constraints:

Budget constraints- The main constraining condition to SGNP's full realization as an explicit BGI infrastructure is the low budget allocation by State govt., reduced grants by the central government and the low productivity of the Public Leisure Account funds generated by the activities at the park, which has led to low staffing, poor maintenance and increased encroachments, which has compromised the potential of the park.

Lower contributing yield- Today the Tulsi and Vihar lakes only yield 5% of Mumbai's water needs and the rest comes from the Tansa, Vaitarna, Upper Vaitarna, Bhatsa-1, Bhatsa-2 and Bhatsa-3. Today this reduced dependency on Tulsi and Vihar and increased pressure on surrounding land for development is posing new threats to the maintenance of this implicit BGI.

Encroachment removal versus rehabilitation- the 1999 verdict by High court both enabled clearance of slum settlements as well as debilitated it. The forest department has reported the practical difficulties of attempting to rehabilitate 600,000 individuals as a complex task involving dependence on other state actors like SRA and BMC and civil society organizations like NHSS. While 65% of the park staff time continues to be spent on policing ongoing violations and encroachments as per the Capstone report (Krichewsky et al. 2011).

Human- wildlife conflict- specifically the leopard attacks have been sensationalized by the mainstream media and have resulted in much public anxiety and negative image for the park. Long-term solutions about restoring wildlife habitats have become secondary to the agenda of providing immediate human security (eg. the boundary wall project at SGNP). This diverts resources away from crucial forest maintenance and regeneration efforts.

Park Access policy- the park management currently follows a differential access treatment policy towards its different users based on its own assessment of optimal and desired use rather than building awareness of best use practices for all users.

Lack of cooperation between actors - many reports indicate that the parks administrative structure and permitting process is complex and not encouraging of external pro-environment agencies implementing forest development initiatives in SGNP.

Organizational Fragmentation- High degree of organizational fragmentation with many organizations, many individuals, many zonal classifications and many legal conditions make the parks administration and management a difficult task.

However increased environmental awareness and understanding of other social, economic, human and environmental values of this important natural infrastructure element is key to its sustenance. Presented below is a short assessment of SGNP's values to Mumbai categorized under 3 heads- environmental, social and economic capital.

v. Values

a. Environmental capital & constraints

- Hydrological values- the SGNP forest cover plays an important role as a catchment area in water harvesting, groundwater recharge, reducing soil erosion, runoff and siltation of the lakes. Other than the lakes there are many forest streams and rivers like Dahisar which contribute to water of the park. The Tungareshwar forest is a catchment area important to recharge of thousands of freshwater wells in Vasai taluka and it is also connected to Tansa, through the Tansa wildlife sanctuary, which acts as a catchment for the Tansa lake.
- The SGNP has a rich variety of flora and fauna and has been recognized as a biodiversity hotspots. It sustains 286 species of birds, 150 butterfly species and 4 times as many moth species. Among the macro-fauna SGNP has 6 -species- the sambar, deer, the leopard, the tiger, the wild boar and Chital population. At the Bassien creek and the lake SGNP contains marine and fresh water fish, a total of 25 types of marine fish, 25 types of fresh water fish thrive in these environs.
- There are 1000 species of plants at SGNP and various fungi and orchids. The park also has a variety of bamboo. A good floral example is stobilanthes or karvi flowers, which cover the forest in purple once every seven years. There are 134 tree species, which represent 4 major types of forests, the southern moist teak bearing, southern moist mixed deciduous, the mangrove scrub, the western sub-tropical hill forest.
- The SGNP is the green lung for the city of Mumbai it helps sequester carbon and offers micro-climate benefits such as reduced heat island effects. The temperature at the park averages 38C in March and 12 C in January. The monsoons commence at the end of May and continue until August with a mean average rainfall of 2600mm.
- The SGNP has great geographic diversity; it incorporates 3 distinct geographic regions- the Malabar Coast situated at the creek, the Western coast which forms 95% of the park and the Western Ghat mountains that form 3.5% of the park.
- Flora and Fauna constraints- Most replanted tree species at SGNP were exotic and their colonizing effect was probably not considered while planting. Also the lack of wildlife buffer zones creates human animal conflict at SGNP. Many leopard attacks have been cited at SGNP. There is a need for corridors to connect to other forests, like Tungareshwar to the north. Being an island ecosystem surrounded by Mumbai and

Thane, there is inbreeding among species and loss of genetic diversity. Corridors will allow animal movement from one environment to another, enlarging animal range. The Tungareshwar is in turn connected to the Tansa wildlife sanctuary.

b. Social capital & constraints

- Cultural capital- The SGNP has one of the oldest Buddhist caves, the Kaneri Caves. There are 109 rock cut caves that are 2000 years old and are a great cultural asset at the park. The Kaneri caves are visited by 8000 to 10,000 visitors per day. (Mayes, Bhale, and Bhatti 2004).
- Symbolic capital- The SGNP is one of the largest national parks in the midst of an urban area, a unique symbolic capital for Mumbai city to be proud of.
- Human capital- The SGNP offers many health benefits to its citizens in the form of recreation activities. There is an area of 5.88 km2 that has been reserved in the park for recreation use called Krishnagiri Upavan. It includes playgrounds for children, pedal boats in Dahisar river, the lion and tiger safari and a nature interpretation center, bird watching, trekking, animal safaris. Others could be developed such as biking trails, jogging trails, flora trails.
- Educational capital- Education tours, nature trails and environmental research are some of the key contributions of SGNP to the Education capital of the region.
- Bequest capital- Interestingly one study on the SGNP park also mentions “existence and bequest value” which relates to the pleasure individuals get from knowing about it and the contentment of making the park available to future generations (Krichewsky et al. 2011).
- Constraints- human intrusion has impacted the SGNP in many ways. Many forest fires have resulted from illicit activities and tourist negligence, many encroachments and illegal settlements have destroyed patches of the forest and caused pollution. Today 772.82 hectares of the national park contains encroachments.

c. Economic capital & constraints

- Revenue generation from tourism at the SGNP is a potential source of income for the city and could be used effectively for self-sustenance of the park. SGNP gets 3 million visitors per annum and is the largest and most visited park in India. However due to low pricing of tickets the park does not generate sufficient revenue for its maintenance and is dependent on state support. There have been a number of proposals to improve tourist facilities, provide buffer zones from tourist activities, protect forestland from encroachers but these have all lain dormant due to lack of funds.
- Increased property taxes in the surrounding areas because of the revitalized park, as a great public asset is an additional source of income for the city.

- The ecological services the park provides as a natural infrastructure element are many and need to be quantified to understand the full potential of this threatened infrastructure.
- Today the national budgets for forests rarely exceed 1% for nearly a quarter of India's forestland.

d. Value versus Valuation

In 1995 a survey was commissioned by the Indira Gandhi Foundation to assess both the valuation and the value of the park. 500 residents of Mumbai were surveyed for this study a brief summary of the survey results is provided below. It is important to note that 22% of the sample had not visited the park and of those who had visited- 52.8% had visited once or twice and 24.7% were frequent visitors (Hadker et al. 1997: 110---111,(Krichewsky et al. 2011)) and yet only 10% declared that they were not concerned with the degradation of the park.

Surveyed households expressed a willingness to pay Rs 7.5 per month for the upkeep of the park, the report calculated a contingent value of the park at Rs 1.04 billion or USD 31 billion based on this survey information. On the question regarding the motivations to pay- 21.6% wanted to pay for present use, 19% to help the cause of the environment, 7% to preserve the park for use of future generations. 68% wanted to pay now to invest in the environment for future generations.

Values attributed to the park by surveyed citizens is shown below:

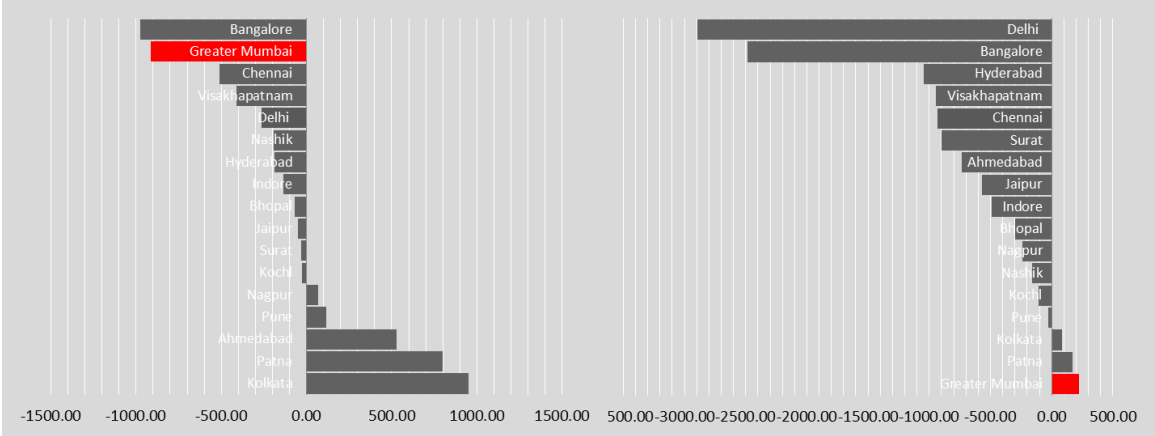
86%	quietude and aesthetic beauty
24.9%	protects water bodies that supply drinking water to Mumbai
42.1%	natural flora and fauna
13.8%	uniqueness
22.5%	getaway from the city for future generations
20.9%	historic and educational importance
7.5%	frequently visited nature reserve for other visitors

The report recommends that the high intangible value that SGNP displays in peoples views offers a great opportunity for preservation and conservation as it indicates high non-use satisfaction from the population.

However, to realize the importance of ecosystem services provided by natural infrastructures it is important to quantify the ecosystem services, forecast returns on investment, convert their values into effective policy and finance mechanics. One such study developed by S Singh and A Mishra documents the impacts of deforestation at the Sanjay Gandhi National Park and its induced cost

on drinking water supply in Mumbai. Mumbai forests are the catchment area for a number of reservoirs and Mumbai mainly relies on this locally stored rainfall for its water supply(Singh and Mishra 2014). These forests play an important part in stream stabilization, reducing runoff, reducing water loss, improving water quality and reducing siltation. Till the 70s the water from these sources was mainly cholrinated water, but as pollution increased new treatment plants at Bhandup and Panjrapur were built to treat water. This study documented the rate of deforestation in the past decades through the study of ortho rectified landstat images from landstat.org and digitized land use maps from the National Remote Sensing Centre. It also analyzed information on water quality through the MCGM records and state hydrological project that maintains data on water quality and turbidity levels and controlled for rainfall through the time series. The study estimates that every one percent decrease in the forest cover will increase turbidity by 8.41% and treatment cost of drinking water by 1.58%. The analysis also illustrates that with annual rate of change of forest cover at -0.0088% (1994-2007) the deforestation induced costs translates to 3.73 million Indian rupees /year according to the 2010-11 prices for the Panjrapur treatment plant.

At present the Forest Department in Mumbai works independently of the Municipal Corporation, even though forest management decisions like plantation, trenching felling and deforestation directly impact the sedimentation and water quality from the watershed and affect the treatment costs borne by the municipal corporation. The study lays out clear economic incentives for an integrated forest management and water resource planning approach implying the value of the development of the Sanjay Gandhi National Park as a valuable explicit Blue Green Infrastructure.



Projected deficit /surplus water demand/supply across major India cities- per available supply 2001 and projected demand 2021. Data source: Ministry of Water Resources, GOI-2001, Data in MLD

The other challenges to Mumbai's water supply are high environmental cost of a long distance supply network that has submerged many forests to build reservoirs(M Gandy 2004). As per Bombay Municipal Corporation (BMC) the estimate per capita water use in Mumbai is 135 ltrs/day/person. The actual average water use for formally supplied water is 245 ltrs/day /per

person (for middle income to high income households), the slum dwellers (constituting 60% of Mumbai's population) use 25-60 ltrs/day/person of water(Anand 2011). This is well below the recognized standards for maintenance of human hygiene and sanitary conditions; the public health dangers of this condition are quite significant. While Mumbai can meet some of this largely unmet demand it will need to look at other means of achieving water sufficiency. Improving the efficiency of its supply chain by reducing leaks in the system is an approach often mentioned in research papers, but perhaps it could gain from other alternates like: encouraging recycling of water, rain water harvesting, waste water reuse and perhaps restoring traditional water sources such as wells, tanks, lakes, start water metering to prevent misuse and regulate use, use alternate technology like desalination and improve catchment forests to lower costs of treatment and improve environmental quality of the city.

e. Summary findings

Legal defensive action has proved an important strategy to support conservation efforts and prevent deforestation. And this has been a resource effective tool as it allows the park management to rely on key relationships with green NGOs and support from progressive state judiciary.

But legislation or judicial action cannot be a long-term solution; the park management needs to enlarge its supportive stakeholder base. The park has many use and non-use values and the management should focus on delivering these values through products and services to enlarge it supportive stakeholder base. And also promoting these values through communication tools (websites, campaigns) for building awareness.

The protection of public goods depends on balancing public interaction in a manner that is supportive of building a relationship but not destructive to the public good itself. The management today follows a very restrictive protectionist stance while it could use, use value products like eco-tourism, education, recreation, and ecosystem services to continue to highlight the non-use values of the park.

A value and valuation based analysis that creates awareness of social, economic and environmental values of BGI infrastructures could also help create a balance between the protective benefits and productive benefits. Research recording and evaluating long term quantitative data to establish productive ecosystem benefits of BGI's is still lacking and need to be supported and developed.

The park does not engage in fundraising for development of other products and services and most resources are currently spent on protection and some on conservation. It could facilitate NGO and private agency proposals of park improvements and conservation thus leveraging external expertise and financial support. For active supporters the park should create friends of the park association. Singapore National Park and Boston Esplanade Association are some good examples of such associations.

B. CASE-2-STREAMS, CHANNELS & FLOODPLAINS- THE MITHI RIVER

After the 2005 flood the Mithi River was singled out as the primary cause of the flood. It was considered to have failed to perform its dual function as a drain to carry monsoon waters out and accommodate the high tide of the Arabian sea. Today engineers are working to master plan the Mithi River and train it with walls. The Brimstowad report studied 121 catchments for stormwater management in Mumbai city and identified deficiencies in cleaning, maintenance, reviewed design criteria and prepared a master plan for augmentation of the storm water drainage (SWD) system in Mumbai. The Chitale committee (appointed by GOM) prepared a report that recommended reducing future risks, through desiltation, widening, deepening of the cities drainage system and evacuation of encroachers. Many measures were taken to reduce effluent discharge in the rivers including cancelling licenses of polluting industries and construction of public toilets etc. Measures for deepening and widening of riverbeds and lengthening bridges at crossing are also part of the initiatives to retain and restore the rivers carrying capacity. The report also recommended establishing an urban hydrology authority and installation of automatic rain gauges for early warning and a Doppler radar system for coast of Mumbai. To understand the context of this discussion about Mithi River we will trace the timeline of different proposals made for Mithi River improvements and understand how they place themselves in the integrated Blue Green framework.

i. Chronology

1974- The Natu Committee an independent committee appointed by the Government of Maharashtra studied the Mahim Causeway, Cleveland Bunder and the Love Grove area for flooding issues. Their recommendations included installing pumping stations and electrically operated sluice gates and desilting and upgradation of drains across the city.

1978- The Central Water and Power Research Station in Pune undertook model studies on the effects of the proposed reclamation in Mahim creek. The scope area included the study of the entire BKC reclamation zone and the Mahim creek reclamation. The proposal included widening and deepening of the Mithi River and adding sluice gates at Mahim causeway and pumping of flood waters into the creek.

1988- Shah Technical consultants were appointed to study the Dharavi storm water drainage, the scope area included the Dadar-Dharavi catchment area. Their recommendations included dividing the catchment into 4 zones and installing pumping station and raising drainage capacity between Dadar and Dharavi.

1993- Watson Hawksley International ltd. and Associated Industrial Consultants India Pvt. Ltd. were appointed to study flooding issues along the Mithi River. The BRIMSTOWARD report that was formulated recommended widening, deepening, modifying the existing drainage for higher capacity. Installing pumping stations at Cleveland Bunder, Love Grove and Milan subway. Recommended clearing encroachments along the Mithi River and the Vakola Nallah. Only 15% of the recommendations have been implemented by MCGM.

1996- Neeri developed a report to study the Impact of the removal of mangroves at BKC due to reclamation work. The report concluded that mangrove removal at BKC is the main cause of flooding in the Mithi River and recommended that an environmental assessment of the area needs to be carried out to assess ecological damage.

2004- The Maharashtra Pollution Control Board (MPCB) developed a report to assess the water pollution at the Mithi River and make recommendations for its control. The report recommended a reduction of pollutant discharge from domestic sewage, industrial waste, animal waste, garbage dumping and industrial sludge at Kalina and CST road into the river. It suggested an immediate closure of all industrial effluents, sludge, oil and chemical discharge. Other recommendations included provision of garbage collection system, sewage treatment plants and dredging the entire length of the river.

2004- Neeri developed a report to study and assess flood prone areas along the Mithi River. The report identified 8-9 high flood areas along the length of the river. It identified encroachment, siltation, unauthorized activities such as waste dumping and discharge as the main reasons for flooding at the Mithi.

2005- IIT Mumbai developed a study of flooding issues at Milan Subway and Slater Road/Nana Chowk. The recommendations to reduce flooding at these areas included installing pumping stations at Slater Road, diverting flow from Milan subway and through a new pipeline.

2006- CWPRS developed a mathematical model and desk studies for flood mitigation. The study analyzed upstream and downstream discharge capacity analysis. It recommended providing a

dredged channel from the sea to Mahim causeway, widening from Mahim causeway to Dharavi bridge, and from Dharavi to CST and deepening from the Mahim causeway to CST bridge, removal of temporary bridges across Mithi and Vakola nala. The work was divided between MMRDA for the downstream stretch and MCGM for the upstream stretch.

2006- Chitale committee developed a fact-finding report for the July 2005 flood. They recommended developing contour maps for all watersheds, demarcating flood risk zones, mandating a 15m buffer strip along the Mithi River with 12m carriageway on either side for access. It also recommended widening the waterways under airport taxibay and assessing the role of lakes and ponds in flood protection.

2006- IIT Bombay developed an action plan for environmental improvement of the Mithi River. Their key recommendations included stopping waste discharge into the river, establishing STP's, desilting the river bed and developing water quality assessment and pollution tests and creating properly engineered storm drains. It also recommended declaring a 200m stretch on either side of the river as an ecozone, requiring removal of all debris and proper plantation along the entire banks.

2006- Mithi River Development and Protection Authority (MRDPA) formulated a development and protection plan for Mithi River and Vakola Nala and its surroundings. Most recommendations from this study were similar to the IIT Mumbai study, it recommended desilting the riverbed and developing treatment facilities. It also recommended declaring the banks of Mithi and Vakola and its tributaries, including the areas around Vihar and Powai lake as ecozones.

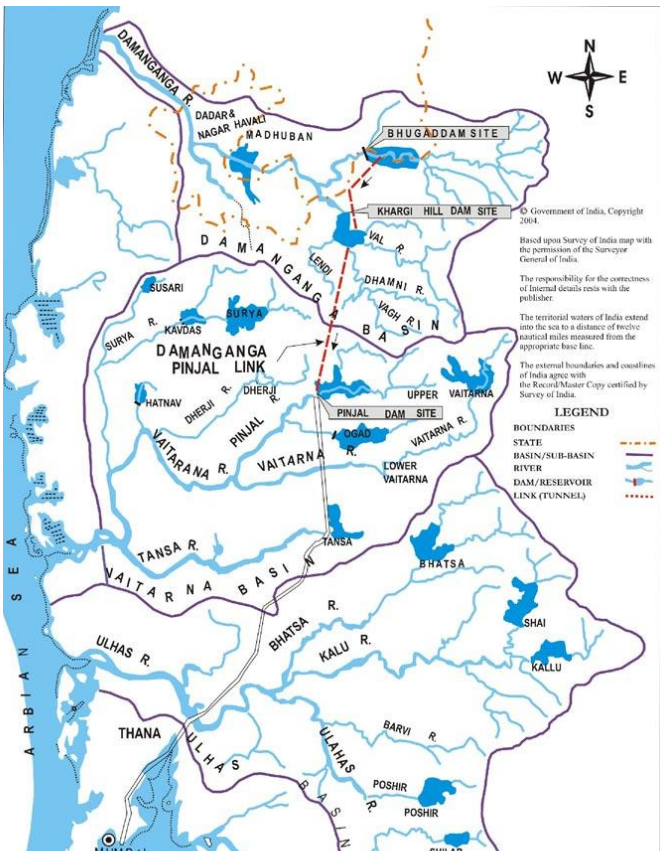
2009- Mumbai Metropolitan Region Development Authority (MMRDA) commissioned a project to improve water quality in the Mithi River and prevent noxious odors, this included a process of oxygenation in the entire stretch between BKC to CST area.

2011- National Environmental Engineering and Research Institute (NEERI) presented a report, which recommended stopping all untreated sewage, industrial waste, garbage from residential areas being dumped into the river. It also proposed riverbanks upto 50m on either side be cleared and various shrubs and grasses planted to optimize drainage and percolation, this will help reduce erosion, remove oils, fuels accumulated over many years. It also recommended a cohesive Mithi River rejuvenation plan be established and all plans be discussed with local areas committees to raise awareness about water quality and flooding issues.

Date	Blue Blue	Grey	Blue Green
1974			
1978			
1988			
1993			
1996			
2004			
2004			
2005			
2006			
2006			
2006			
2006			
2009			
2011			

The chart indicates a trend towards a BGI approach in Mithi River revitalization proposals since the 2005 floods.

Many scholars (A Mathur et al. 2009) contend that this hard infrastructure approach encourages a design that channels water out rather than hold it and suggest that a more resilient approach should allow the river to hold water rather than flush it out. The other contention against the grey infrastructure approach is that such interventions destroy natural ecosystems and thus impact livelihood of coastal communities employed through small-scale fisheries. Manmade structures like seawalls loose value over time while natural systems appreciate in value with time. Countries like Netherland have gone back and reinforced their grey infrastructure (dykes) by planting sea grasses and other vegetation in front of the dykes to reduce wave height by 80% after the 1993 floods. The Skjern River restoration work in Denmark has restored the natural ecosystem of a river that was channelized in the 60s(Pedersen et al. 2007). The idea was to restore the physical and hydrological dynamics of the river and its flood plain. The project was completed in 2002 and today the biological communities and vegetation have re-colonized the terrestrial and aquatic habitat and the link between the two.



Map indicating streams, rivers and reservoirs in the MMR region, Map source: The Ministry of Water Resources and the National Water Development Agency.

The map above shows the extraordinary network of headwaters, rivers, streams and nallas that serve as the natural drainage system of Greater Mumbai. This unique network that connects the coast to the mainland is an extraordinary natural infrastructure that if restored and respected can not only enhance the environment, provide important means of water transport, recreation but also serve as infrastructure that safe guards the city from storm surges, sea level rise and other extreme climatic conditions. The Mithi River has 11 other nallas draining into it. There are a number of ponds and lakes in the Mithi river catchment together forming an area of 1106 hectares, but half the ponds and two thirds of the streams have already been filled up and reclaimed for development work.

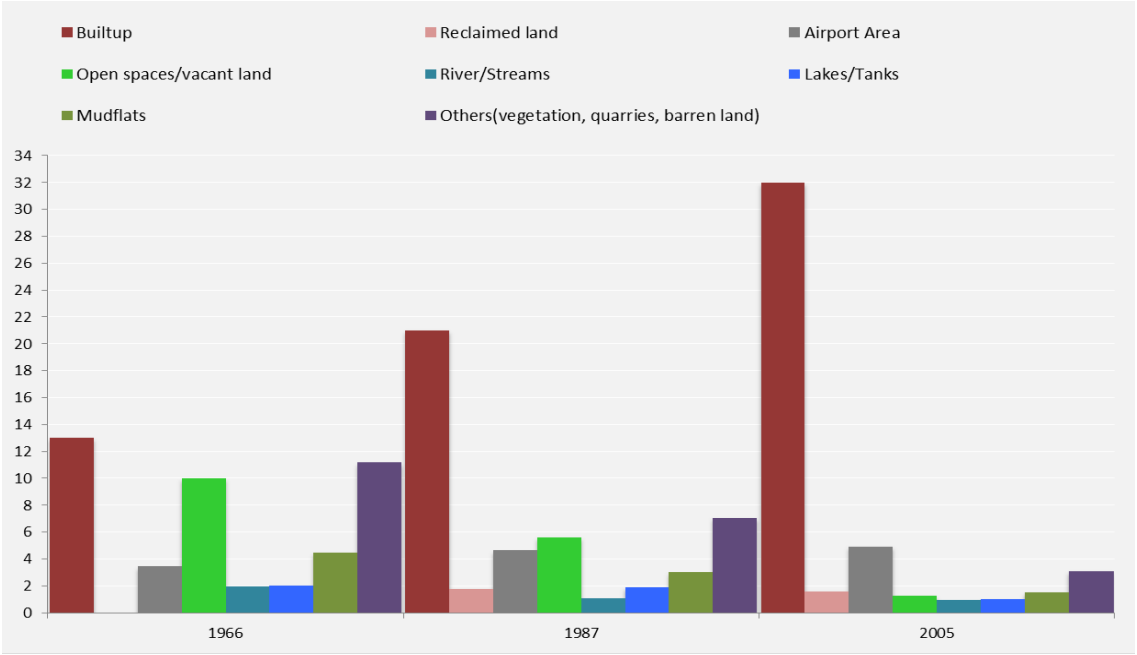
ii. Driving forces

The 2005 flood stands out at the most significant recent driving force for river channelization, and potentially for multi-purpose multi-means BGI floodplain design and management.

iii. Constraints

The chief constraints on river channel protection and improvement are threefold:

a. *Spatial constraints and pressures.* Pressures for floodplain development are enormous, both from the formal real estate market, and from informal settlement processes.
b. *Pollutant loading.* The volume of sanitary wastewater drainage is very heavy, and can comprise the bulk of the stream flow in the hot dry pre-monsoon season. Solid waste disposal in nallah channels is also enormous, so much so that pre-monsoon dredging to reduce flood risks is becoming an annual activity and expense.
c. *Engineering hydrology models.* Lead the channel to be regarded as a conduit for the most rapid discharge possible from areas of upstream runoff into the channel, and culminating in downstream discharge into the Arabian Sea on the westward side and the Bay on the eastern side.
d. These three constraints reinforce one another, as the inability to limit floodplain development and waste disposal then requires an engineering approach, which creates greater space for land development immediately adjacent to the flood channel.
e. *Catchment conditions*: No only is the river capacity itself eroded but the catchment area of the river has been impacted by increased urbanization. A spatio-temporal analysis of the Mithi river catchment done using landsat, cartosat and radarsat data from the years1966, 1987 and 2005 suggest significant land use and land profile changes in the catchment area (Kamini, Jayanthi, and Raghavswamy 2006). There has been 50% reduction in the river width due to encroachments and landfills. The study indicates that the width of the river has been reduced from 58 to 20m near Vihar lake and 90 to 50m at the Mahim creek. There has been 70% decrease in the mudflats and open spaces in the river catchment. The amount of built up area has increased from 29% to 70%, thus increasing the impervious areas leading to increased run-off during heavy rainfalls. The lower Mahim basin shows an increase in reclaimed area from 0% in 1966 to 13% in 1986. Further the study of the river course indicates that the reclamation and encroachment has reduced the length of the river from 18.8 km to 15.16 km. These changes have severely affected the natural drainage of the Mithi catchment, reduced surface porosity (impervious surface has increased from 46% to 85%), caused heavy runoff, reduced carrying capacity of the river and increased water pollution. (Kamini, Jayanthi, and Raghavswamy 2006)



Graph illustrating land use/ land cover changes in the Mithi River Catchment, Mumbai during 1966, 1987, 2005. Data source: (Kamini, Jayanthi, and Raghavswamy 2006)

iv. Values -- [more to be added in this section]

In first impressions it is difficult to emphasize the values associated with the Mithi River and other urban creeks in Mumbai. They have been so altered by pollutant loading, along with channelization and floodplain development, as to border on "dead" rivers (cite CSE *Sewage Canal* and *Excreta Matters* reports). The nallahs of Mumbai are in some ways typical in the cities of northern India (Wescoat, 2015a, "A Tale of Two Nallahs," ISOLA proceedings; and idem., 2015b, "Nallah to Nadi, Sewer to Stream," forthcoming Routledge, India). But that would be a mistake, as even "ganda nallahs" perform important functions of flood and sewage conveyance, and can in some circumstances be transformed. One of the best examples is the Osho Ashram nallah restoration project in Pune, a city east of Mumbai.

a. **Environmental Capital and issues.** There is little positive that can be said about the natural capital of the Mithi River. Its headwaters have and serve some natural watershed processes. However, by the time it reaches critical reaches above the international airport it is channelized and obviously degraded in visual and olfactory, as well as ecological terms. Other creeks are not as radically transformed, but face other risks, e.g., industrial discharge into drainages into the eastern mangroves, and fisheries management in the northwestern drainages. India has many examples of Nallas being rejuvenated into beautiful streams and even though Mithi River has been reduced to a Nalla there is no reseaon it cannot be restored to its natural environmental state, where it can once again fulfill these important environmental functions:

- as a dynamic ecosystem, that responds to hydrological and biological processes and human intervention, they have regenerative powers unlike manmade built interventions like flood walls, dykes.
- recharge groundwater and improve its quality by a tidal flushing mechanism
- that promotes bio-diversity- as habitats for a variety of fish, reptiles and amphibia. Provides livelihood for small fishing communities that have lived in the area for generations
- that carries storm water runoffs from urban areas
- acts as a green lung that sequesters carbon
- with its restored vegetated banks serves as natural barriers against floods and storm surge
- serves as a restored public open space, creates a temperate microclimate that provides relief to citizens from the heat island effect of the heavily built surroundings.

Taking cues from the Coastal Regulatory Zone policy development, there has been a push at the central government level for a similar national “River Regulation Zone” policy. This would certainly be a viable approach for advocacy groups to push for, as this will help delineate a protection zone around urban rivers. This will also force local and state officials to enforce regulations that prevent further encroachments and pollution that cause degradation of the rivers. As can be seen from the case of CRZ, vigilance and legal activism from environmental groups supported by progressive judiciary has forced state and local governments to enforce important mandates for environmental protection in many coastal regions. This could be an important starting point for saving urban rivers in India.

b. Built Capital. The built capital of the urban creeks is more substantial investment was made in floodwalls, canal engineering, bridge construction, and regular drainage. However, it is not all positive built capital, in part because it displaces other built environmental capital, such as floodplain corridors, and in part because some structures are poorly designed and constructed, notably levees on the right bank of the lower Mithi River.

c. Human capital. Again, this is a very mixed category, as on the one hand the river channel provides a location for informal settlement and thereby favorable urban location for economic opportunities. On the other hand, it is unhealthy for sanitation and disease vectors as well as flood risks.

d. Social Capital and issues. Social lives along the nallahs are an underappreciated form of value. Sanitary hazards and real estate land development pressures have led to

widespread displacement of informal settlements along many of the urban nallahs of India. At the same time they are vibrant places of work, interaction, small-scale capital accumulation in housing and personal possessions, and place attachment. While displacement has been criticized, social capital accumulation along sewer-streams has not been well documented.

e. **Economic Capital and issues.** This topic follows closely from the one above. Informal economic activity (a.k.a. "penny capitalism" of anthropologist Sol Tax), is underestimated or altogether ignored, while real estate development potential is closely watched and advanced. However, these land values are so speculative and contingent on various forms of uncertain permits and structural protection as to defy quantification at present.

f. **Symbolic capital.** The symbolic capital of most nallahs is largely negative, as places of risk and pollution. However, the Mithi River has environmental advocacy groups that bestow it with a new and rising form of symbolic capital. The question of whether that symbolic capital can be transformed into new forms of natural, built and social capital will be pivotal in determining whether the Mithi River and others streams. The floods of 2005 have certainly brought the discussion on the degraded condition of the Mithi River to public notice. Advocacy groups like Mithi Nadi Sansad, The Mithi Yatra, Tarun Bharat Sangh, BEAG and other groups like NEERI, ORF have seized this opportunity to project more restorative approaches to rejuvenating the river and its ecosystem.

g. **Valuation versus Values.** The Mithi River and other urban creeks raise the most complex challenges of valuation. The upstream Sanjay Gandhi National Park is a classic case of protected area valuation, to which the "people and parks" literature has helped balance social and environmental values. The downstream coastal zone protected area involves larger scale common property resources in the beach, estuarine, and near shore environments, though again these have been the subject of methodological refinement in wetland and coastal economic research. However, intensively developed urban streams are valuation anomalies. The highest land value has historically been to bury them in large sewerage pipes -- until they are so choked up or unstable as to collapse and contribute to urban disasters. Stream and river day lighting is expanding but usually in areas that have gained control of waste flows, and that are prosperous enough to create civic open space amenities in place of degraded corridors. But in areas of intensive land development this has usually come at a high cost in social values. Again, the Singapore River case has relevance for the Mithi River in Mumbai, while the Boston Muddy River may have relevance for estuarine rivers in northeast Mumbai.

v. Recommendations

Recommendations take three main forms in the case of degraded urban nallahs in Mumbai.

- First, there is the sanitary upgrade and protection of local populations along their banks. This is feasible in many if not most sites, and where it is not progressive relocation in better housing nearby -- as learned from the Singapore case study when relocating houseboats from the Singapore River attests (Dobbs, 2003).
- Crucial to this is effective and sustainable interception of sanitary waste flows, and conveyance to functioning wastewater treatment plants. Innovative in-channel and side channel wastewater treatment processes may also be considered.
- Third, there are small seeds of valuable protected areas along Mumbai's urban creeks, for example, the Mahim Nature Park on the left bank of that river, which can serve as a model for replication in other reaches, and connectivity among such places.

Finally, it is worth noting, by way of analogy to other larger scale water dispute resolution and restoration that several precedents (positive and negative) have developed in India. They include the following two examples (which will be edited in the coming weeks):

- River disputes have become common in India. The Punjab-Haryana dispute over river Sutlej, the Tamil Nadu - Karnataka dispute over the river Cauvery are known to have dragged on for many years now. Though most of these disputes are inter-state disputes and conflicts over state rights versus central government mandates/ water treaties. They are an indication of regional water stress issues. MMR has the advantage of being blessed with 4 rivers that are first order rivers with origins within the metropolitan boundary. This gives an enormous advantage to the state to secure it water infrastructure and better its environment.
- A draft National River Regulation Zone notification (National River Conservation Directorate 2002)has been prepared and portends a good direction for protecting a freshwater and non-tidal water bodies, which have been compromised by urbanization and pollution. The Pen-Alibag region in MMR has a 500m protection on both sides of the floodplain of the riverine system of the Amba and Patalganga Rivers. Mumbai's has 4-rivers that can and should be protected to reduce flood risk, provide adequate channels of drainage and water security.
- Thane is often referred to as a "city of lakes", lakes are important surface water bodies that allow rainwater harvesting, groundwater recharge, act as lung spaces and provide a recreational amenity. However the number of lakes in Thane today has dwindled from 100 in 1915 to 40 (Quadros et al. 2009). The number of ponds and lakes in the Mithi catchment has reduced to half since 1966. This has significantly increased the storm water runoff load on the Mithi it would be important to restore these other sources of

rainwater harvesting and storm water detention in its catchment to reduce the load on the river. There are already a few precedents for lake conservation in India, it would be important for Mumbai to follow suit to preserve these symbols of its water heritage. On 4th of May 200 Hyderabad Urban Development authority issued a notification entitled " save the lakes for a better future". The notification calls out 169 lakes in Hyderabad covering an area of 25 acres for protection. It allows protection for the entire area falling within the full tank level of the lake and also 30m width on all sides.

C. CASE-3- COASTAL ENVIRONMENTS- MANGROVES--AN EXPLICIT BGI LANDSCAPE

There are 13 maritime provinces in India and they hold 49% of the country's population (Panigrahi and Mohanty 2012). Coastal zones have been the forefront of human civilization and also have been the most exploited geographic unit of the earth. The coastal regulatory zone protects not only the seacoast but also the lands close to the coast and this includes thousands of km of estuaries, rivers, creeks and backwaters that are subject to tidal action. The 3-main objectives of the 2011 CRZ notification are (Panigrahi and Mohanty 2012):

1. Ensure livelihood security of fisher communities and other coastal communities
2. Conserve and protect coastal stretches and its unique environment and marine areas
3. Promote sustainable development using scientific principles with due consideration of natural coastal hazards.

i. Chronology

1917- Goa in 1917 during the Portuguese times had a coastal regulation that prohibited construction within 90m of the high tide line on Sandy beaches and restricted the height of such buildings to that of a coconut tree (Chainani, 2007, Heritage & Environment). The National Coastal Regulations approved by the Ministry of Environment, Government of India was finally gazetted in *1991* (by recommendation of the then minister of environment Ms Maneka Gandhi). Thereafter a long period of negotiations and modifications ensued and the notification was re-gazetted in 2011 after many amendments. Passing of the Integrated Coastal Management Plans through the CRZ represents an important achievement in India's environmental history and a study of its evolution makes for an important BGI case(Murthy, Rao, and Inamdar 2001). The timeline of this process and the key parties involved in providing advice and feedback to the government is described below.

1981- Prime Minister Indira Gandhi issued a directive to the state chief ministers, which recommended that to prevent degradation of the coastal environment all beaches have to be kept clear of all activity for at least up to 500m from the water at the maximum high tide. These areas

should be planted if vulnerable to erosion and be kept free from pollution from industrial and town wastes.

1982- Government of India's department environment constituted a 7-member working group which included members from the pollution control board, town and county planner, representative from the environment ministry, tourism ministry, institute of oceanography, dept of ocean development, department of zoology and noted scientist. The committee was given the charge to prepare guidelines for the environmental management of the beaches and for the development near beaches. The working group listed activities that affect ecological, aesthetic and cultural values. It was interesting that the group focused on aesthetic values and sites of historical significance and discussed recreation values not just for the existing population but for projected future populations.

1983- The environmental guidelines for development of beaches was published by the environment ministry based on the findings of the working group. This defined the beach as the shore especially of the sea between the high tide line and the low tide line. This has now been enlarged to include rivers and lake systems subject to tidal action. This definition of the beach includes all coastlines- Sandy, rocky, marshy.

1985- The environment ministry brought out guidelines for siting of industry that stipulated a distance of at least 1/2km from the high tide line. A similar distance was stipulated from the floodplain for riverine systems.

1987- Environmental guidelines for thermal power plants stipulated that to protect coastal areas a 500m buffer from the high tide line or a buffer zone of 5km should be kept free of any Thermal Power Stations. These regulations impacted all public sector projects, projects referred for environmental clearance, private sector projects belonging to polluting industries and thermal power projects.

The guidelines emphasized protection of aesthetic values- scenic beauty, allowed small hamlets that blended with the surrounding architecture. Recognized the recreational values of the place. However this was just a directive from the PMO it was not gazetted or notified under the environment act to be legally binding. Political alignment was key, states like Maharashtra ruled by the Congress government paid more heed to the Prime Minister’s Directive while other state governments paid no heed. Many environmental groups like Bombay Environmental Action Group (BEAG) under the leadership of key figures like Shyam Chainani filed many court cases

against state government and private agencies seen to be condoning or purporting violation of the directive.

1984- Pressure from the Ministry of Environment forced the Maharashtra Government to issue a directive to the Bombay Municipal Corporation to amend the Development Control Regulations (DCR) for Greater Mumbai so that construction would be restricted to landward side of existing structures or roads along the coast of Mumbai.

1988- Under pressure from development agencies the Maharashtra Govt. tried to Change the restrictions to only Sandy beach zones. However on May 1989- a writ petition filed by BEAG led to Bombay high court passing an order staying the Maharashtra Government from finalizing these Development Control Regulations. However in Dec1989 only 6 months after the high court stay order the Government of Maharashtra (GOM) published a DCR where only Sandy beach zone were protected.

20th Feb 1991- The beach definition was extended to include coastal areas (including rocky, marshy, Sandy, craggy, foreshore). However these beach zones and coastal areas were still small. No development was allowed in this zone except for greening and signs for display. There were category-1 and 2 types of restriction in this zone.

1988- The PM's directive was coming under pressure and there were many encroachments. In an effort to give the directive statutory backing BEAG suggested that the GOI should consider imposing restrictions under the Environmental Protection Act by using section 3(2)(v). And consider extending the regulations to rivers, lakes, creeks, estuaries and other water bodies in non-tidal zones. Also many foundations and NGO realized that many violations were also because many DCR's and regional master plans themselves contradicted the directive. In Oct 1989 the Ministry framed guidelines for this Act. However the government changed in Nov 1989. And Maneka Gandhi under V P Singh was appointed the environment minister.

1990-In 1990 a meeting was held with Debi Goenka, Chainani and Maneka Gandhi to discuss the coastal regulations. This meeting resulted in the final EPA act being drafted as the Coastal Regulation Zone notification. This notification identified the zone of restriction in 4 categories. In 1990 in spite of a change of political power and infighting in the ministry the modified notification was finally gazetted for public objections.
Other NGO groups that played an important role in helping give feedback and suggest improvements included the Goa foundation, Sanctuary magazine, Centre for Science and Environment, Kerala Shashtra Sahitya Parishad and Lokayan.

There were many objectors to the regulations and they included defense and industry personal who were concerned with the implication of the regulations to their activities. From the Government the BMC, CIDCO were the main objectors and the main objection of the GOM was the requirement to seek environment ministry approval.

1990- with Chandrashekar becoming the PM there was again reshuffle in the ministries. Though Menaka Gandhi retained the Ministry of Environment, there was pressure from the GOM not to ratify or gazette the CRZ notification without the approval of the then Chief Minister Sharad Pawar.

Dec 1990- In 1990 after reshuffling her ministry Ms Menaka Gandhi ratified the notification and invited public objections. Many reasonable accommodations were made like the issue of land wastage was addressed by allowing agriculture and horticulture in some CRZ-3 zones that fell in the municipal jurisdictions.

15th February 1991- Is a red letter day in India's environmental history. Menaka Gandhi signed the file on this day after allowing a 60=day period for public objections and responses. The final notification removed any relaxation clause for development in Zone-3. In this notification however non-tidal water bodies remain unprotected. This includes Rivers, creeks, lakes and the land surrounding them.

20th February 1991- was also the day of gazetting the first set of heritage regulations for Bombay. The requirements for approval by the environmental ministry were reinstated. However the challenges to the coastal regulations did not stop here. There were many subsequent review committees setup by the state governments in Maharashtra to review the coastal regulations and often with the intent of diluting the 1991 regulations.

1992- environment ministry set up a task force to examine the Coastal Zone management Plans for all coastal states and UT's . The Bombay CZMP review saw the GOM taking a stance to try and declare the entire greater Mumbai and its suburbs and extended suburbs as substantially built up and hence classified as CRZ-2. Attempts were also made to remove No Development Zones, SEZ's, Defence areas, Ports and harbors, national parks, sand dunes and other green areas demarcated in the DCR taken out of the CRZ zoning restrictions or classified as CRZ-2. Some of these attempts were fought in the court with writ petitions filed by BEAG against the GOM. Finally in 1996 the Maharashtra CZMP was sanctioned after many discussions and negotiations between the GOM and the task force.

26th Nov 1998- The National Coastal Zone Management Authority was constituted along with 13 other coastal zone authorities. However these authorities had little or no funding and few dedicated staff. In most states, the secretary of the Pollution Control Board doubles up as the member secretary of the coastal zone management authority. They also have no representation of any environmental groups; far from being proactive they are nonfunctional.

1998-2009- Several committees were set up by environment ministry to review the CRZ regulations based on contestations against and violations of the CRZ by the state and union territory governments. This included the Sukthankar Committee, the Swaminathan Committee and B. B. Vohra Committee. There have been 25 amendments to the 1991 notification between 1991-2009. The final amended notification was passed as the Coastal Regulation Zone Notification of 2011.

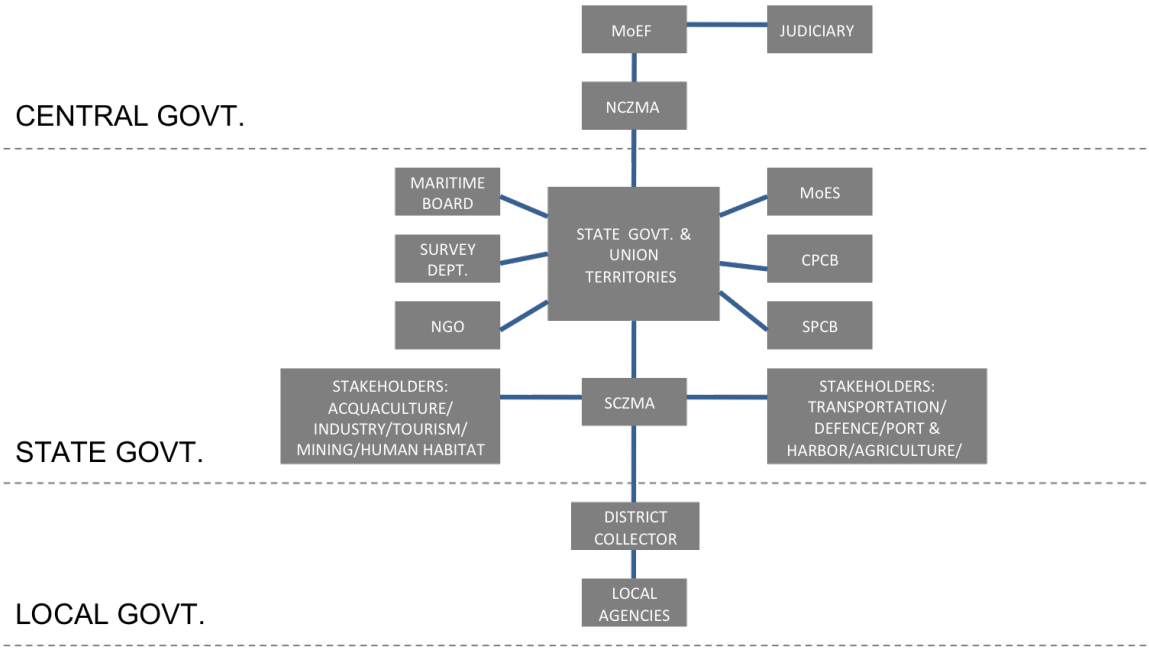
2011 CRZ Notification- The 2011 notification made several important contributions in defining and clarifying the previous notification and fillings gaps. It required the mapping of the hazard line in addition to the HTL and LTL lines to incorporate vulnerability along the coastal zone in the management plans. It also expanded the CRZ to include territorial waters upto 12 nautical mile on the seaward side as the 4th category in the CRZ zoning to allow for protection and monitoring of seawater conditions and marine life. It also stipulated the inclusion of geomorphological structure and structures of archaeological and heritage significance to be included in the coastal zone plan. The notification also made clearances for projects time bound thus reducing red tape and for the first time required post clearance monitoring of projects and inclusion of public participation in the preparation of the CZMP's.

ii. Institutional framework

Institutional framework for the coastal zone management can be segmented in 3 distinct responsibilities, the statutory responsibility, the administrative responsibility and the procedural responsibility. They are described as below:

The statutory framework at the central government level consists of the Ministry of Environment and Forest (MoEF) that establishes the statutory guidelines for the Coastal Regulation Zone (CRZ). The National Coastal Zone Management Authority (NCZMA) is established under the MoEF to provide advisory service and coordinate with the state management agencies (SCZMA). The state and union territory governments are to implement the provisions of the Coastal Regulation Zone Notification, 2011. They do so by establishing the State Coastal Management Authority (SCZMA) these authorities prepare the Coastal Zone Management Plans (CZMP) for

each state, the same have to be approved by the MoEF. The Monitoring and enforcement of the CRZ and the CZMP is the responsibility of the SCZMA and the NCZMA. SCZMA holds important and extensive mandate that includes - monitoring coastal activities, advising changes, inquiring into violations, taking action against violators and recommending project changes (Panigrahi and Mohanty 2012).



Institutional structure for Enforcement of the CRZ notification, Recreated from source: (Panigrahi and Mohanty 2012)

The administrative process for adapting the CRZ guidelines at the local level involves all 3 tiers of the government with the NCZMA at the central level, the SCZMA at the state level and the district collectors at the local level. A high power committee is setup by MoEF at the central government for inspection of violations of norms and guidelines. The Supreme Court and the High Court have legal authority to take effective steps for enforcement of the CRZ and have known to have a progressive stance in protecting CRZ regulations in the past. The Ministry of Earth Sciences is responsible for scientific decision-making. The state government take assistance of maritime boards, survey departments, NGOs, pollution control boards both state and central level in developing the Coastal Management Plans.

Approval and review of all development proposals in the coastal zones are handled by the SCZMA's. The SCZMA establish guidelines and formats for this approval, which mandate disaster and risk management plans, EIA reports, and pollution control board certification. Once the SCZMA completes its review it recommends the proposal for approval to the MoEF or the

State Environmental Impact Assessment Authority (SEIAA). A broader list of coastal stakeholders engaged in the institutional process is shown in the table below(Murthy, Rao, and Inamdar 2001).

TABLE: Stakeholders with interests in coastal zone development:

- Ocean development department
- Ministry of environment and forest (MoEF)
- Municipal corporations with coastal land ownership (Bombay Municipal Corporation, BMC, CIDCO)
- NGO's, environmental activists, minority rights activists (fisherfolks, adivasi), livelihood support groups
- Scientists from various universities (IIT-Mumbai)
- Center for taxonomic studies
- Pollution control boards
- Forest department
- Community building organizations (fishing communities, agricultural community, urban settlers)
- Tourism industry
- Defense department
- Shipping industry
- Mining industry
- Construction industry
- Centre for earth sciences studies

iii. Driving forces for Coastal Zone Protection

- Political leadership - Prime Minister Indira Gandhi's directive for coastal zone protection was an important keystone in getting this process started.
- Civil society leadership- well networked organizations like BEAG, the Goa foundation in Maharashtra led the charge in making recommendation to the GOI for formulating the CRZ regulation.
- Importance of dialogue and discussion with key government officials through active participation in committees and task force formed an effective advocacy strategy by key green NGOs and activists.
- Astute administrative maneuvering by key progressive environmental ministry officials noteworthy among them being Ms Maneka Gandhi helped avoid the influence of negative political and development pressure on the CRZ notification
- Vigilance and legal confrontation by NGOs where required to stop violations with help and support from a progressive state and national judiciary was to ensuring enforcement

- Use of PIL to demand compliance and RTI to obtain information from the state agencies on regulations and amendments has led to effective environmental activism.
- The CRZ notification has a well-defined legal structure supported by other progressive environmental regulations like Indian Fisheries Act, Wildlife Protection Act, Maritime Zones Act, Marine Fishing Regulation Act, Merchant Shipping Act, Forest Conservation Act, the National Environmental Tribunal Act, Biological diversity act and others.
- India is also a signatory to many International conventions and treaties on environmental protection; these have offered important forums for exchange, learning and debate.

iv. Constraints

- Development pressure and a growing population has increased the need for land for habitation and resource extraction, this continues to create pressure from interest groups to accommodate their interest in coastal resources extraction and or land development
- Political interests in collusion with landed elites have often tried to dilute the CRZ notification and its goals to capture land for development. Corruption and red tape have resulted in misuse of public resources and inefficient implementation processes.
- With a booming construction industry and need for urban infrastructure development extraction of resources like sand, ore and rocks from the beaches and other coastal areas is increasing
- With economic growth there is higher demand for power generation and with this thermal power plants are increasingly demanding access to coastal waters for industrial activity.
- With expanded import and export economy there is pressure to increase access to coastal waters for expanded port and harbor infrastructure.
- Revenue gains to be made by tourism infrastructure along the sea shores has often led to interagency tussle in implementing CRZ regulations.
- Lack of baseline information on valuation and documentation of all coastal resources and assets has allowed obfuscation and abuse by violators.
- Weak social basis- lack of participatory processes in formulation has led to low public awareness and a lack of public vigilance of violations.
- Ineffective implementation and enforcement- lack of funding and human resource allocation has been one of the key problems for the enforcement of the CRZ regulations at the state and UT level, today many states still do not have CZMP's approved by MoEF.
- Inadequate scientific basis- lack of human resource capacity with adequate knowledge of coastal and marine systems has led to inadequate scientific basis for determining some of the regulatory requirements. Issues like measuring of carrying capacities for polluting activities and monitoring of degradation due to discharge of pollutants have not been

taken up on a regular basis. Often leading to multiple interpretations and confusion over implementation.

- Inadequate measurements standards- The notification does not have defined standards in determining High Tide Lines (HTL) and Low Tide Lines (LTL) that take into account vulnerability to define the scope of land to be considered for CRZ demarcation.
- Lack of transparency- Most HTL and LTL maps are not available for public view due to proffered confidentiality issues, thus local communities and industry lack adequate information for planning development projects.
- Multi-agency structure and gaps- many different ministries and agencies are mandated to protect different aspects of the coastal environment like heritage infrastructure, ports, harbors, pollution issues and forest resources. Many gaps exist in this multi-agency responsibility structure and there is a lack of interagency coordination that exacerbates effective implementation.

v. Values

a. Environmental capital

- On environmental grounds the CRZ preserves the habitats of a variety of plants, birds, marine animals and fishes thus maintaining the biodiversity of the marine ecosystem
- Enhancing plantation and maintaining the vegetation cover along the coast also reduces erosion, prevents pollution of ocean waters and provides a habitat for number of bird and animal species.
- On safety grounds the CRZ helps maintain the geomorphological forms such as cliffs, rocky outcrops etc and plantations like mangroves that act as natural barriers to coastal storms, sea level rise and other issues

b. Economic capital

- CRZ protection ensures sustenance of coastal livelihood by protecting fisheries and coastal agriculture
- Coastal landscapes like mangroves and sand dunes reduced hazard or risk due to storm surges and sea level rise and thus offer an economic benefit in reduced costs of damage to life and property due to natural disasters.
- By maintaining the scenic and natural beauty and balancing development with ecosystem conservation CRZ increases the ecotourism potential of the coastal zones.
- By stipulating and mandating the use of low polluting technologies the CRZ promotes sustainable industrial activity in the region
- By restricting and managing extractive activities the CRZ ensures progressive thinking on sustainable management of our coastal resources

c. Social capital

- CRZ aims to maintain the coastal zone as a public commons that gives access to all people to commune and develop civic values.
- CRZ protection enhances the possibility of providing open public amenity space for active recreation and relaxation that benefits public health.
- Protection of the coastal ecosystem offers a great opportunity for education and learning initiatives that create public awareness of our incredibly diverse marine environment
- Preservation of heritage and archeological sites of importance within the coastal zone protects the cultural heritage of coastal communities.

d. Valuation versus Value

- Mahim bay and Thane creek once bestowed with good fisheries, flourishing oyster beds and a number of migratory birds, today has lost most of these coastal biodiversity assets due to high industrial and domestic activities and pollution of the waters. The Mumbai Metropolitan Region generates 7500 tons of solid waste daily and this is dumped at 4 dumping sites along the creeks. There is a need for valuation of this impact by documenting these ecosystem changes.
- Marine pollution comprising of industrial and domestic loads as well as hydrocarbons and tar deposits has rendered most beaches and beach water around Mumbai unfit for bathing; this has rendered this great coastal asset unsuitable for recreation and tourism. The quantification of this economic loss would be essential to understand the impact of coastal pollution on Mumbai's economy.
- Mangroves and wetlands aid in flood control, stabilization of the shoreline by preventing soil erosion. They also serve as habitat for several marine species including birds, shrimps and fishes. Loss of mangroves and wetlands has added to the problem of siltation of Mumbai harbor further adding to the cost of dredging at ports. Quantification of the value of mangroves in flood protection and prevention of soil erosion would help present an economic case for valuing this coastal landscape.

vi. BGI Opportunities

- Increased prosperity is leading to higher levels of education and greater awareness and demand for more civic amenities and eco-friendly environments for recreation and relaxation
- NGOs are promoting self-help and cooperative movements for restoration of degraded coastal landscapes. Projects like the Arvari, Ruparel river restoration projects are great examples of same.

- Capacity building and training of scientists, managers, policy makers required for coastal management and marine environment studies is an opportunity for the education industry to explore and expand to and would facilitate new job opportunities for Indian youth.
- Mapping information on marine ecosystems and coastal resources can be brought to the public domain enhancing environmental awareness and engendering a new wave of ecotourism for the Indian and international tourists.

D. Integrating the three BGI case studies in Mumbai.

The main conclusion from these three case studies is how logical -- and time sensitive -- it is to integrate them as part of an urban and regional BGI system. The Sanjay Gandhi National Park provides invaluable protection of the urban watershed, as well as a place of *biophilia* for citizens of the Mumbai metropolitan region and the country. Although it faces many pressures and problems, it is arguably the best-protected component of Mumbai's blue-green infrastructure. It has the strongest institutional protection, but that is not well linked or coordinated with other BGI components downstream.

The urban streams, by contrast, are the least protected environmental systems in the city. The Mithi River and its tributaries are in terrible, and declining condition, in ecological, and increasingly in socio-economic terms as well. Institutionally, responsibility for them is split between the BMC, MMRD, and myriad riparian land settlements. It may be that other urban stream, e.g., Mahim and Malad Creeks have greater potential at this point, in which case, the Mithi River could become an engineered sacrifice stream….

The coastal zone has gone from one of the least protected to a much more strongly protected system, but it is an uphill battle with so many commercial, residential, and industrial pressures on the coastal and nearshore marine ecosystem.

Even so, the vision is to link these three systems in a metropolitan coastal BGI system -- of the sort that is emerging in coastal cities like Copenhagen and Singapore, and that could still be developed in Boston and New York.

9. FINDINGS AND RECOMMENDATIONS FOR IMPLEMENTING BGI IN MUMBAI

One of the key challenges to environmental policy legitimacy in India is the executive and judiciary setting in which policy has been made in the past, often to the complete exclusion of a parliamentary and public engagement process. Many local administrators have scant regard for such top down policy making that has no grounding in reality and that does not take into account local political, social & economic needs. This lack of legitimacy has posed many challenges to policy implementation while environment challenges continue to be compounded by development pressures.

Development, governance and politics are key themes in all debates on the environment in India. Responding to these pressures debates on environment in India tend to delve in binaries on both sides of the debate (Müller et al. 2013). The “pro-development environmentalists” pose environmental protection as an issue of “survival versus luxury” in the developing country context. The need for “Environmental leeway” and “development space” is a common demand on this side of the debate. The “scientific environmentalists” call this as the “environmentalism of the poor” or “hiding behind the poor”, they contend that this is simply about “protecting growth” and “avoiding climate change”.

The National Action Plan on Climate Change (2009, GOI, prime minister's council on climate change) has developed a co-benefit agenda that is an important milestone that provides an opportunity to reframe this existing environment/ development debate. It contends that the climate agenda in India is the governance of “multiple objectives”. In this contention also lies true value of the concept of Blue Green Infrastructure. Where nature is understood as a regenerative living landscape that performs “multiple productive functions” in the urban environment. It offers multiple values and these values are not only aesthetic, social, symbolic or environmental but are functional as infrastructure improvements that help carry and flush urban waste, prevent pollution from storm runoff, prevent flooding, recharge groundwater, provide food and livelihood support, sequester carbon and cleanse our air and provide important means of outdoor recreation to support public health and open space for civic engagement.

Recommendations

- *Regulations and legal defensive action*- Legal defensive action has proved an important strategy to support conservation efforts for the SGNP and to some extent for the Coastal Zones. And this has been a resource effective tool as it allows the Public agencies like the Park Management to rely on key relationships with Green NGOs and support of the

Judiciary to enforce unpopular decisions (like removal of encroachments etc). The CRZ zones and the River zones lack an agency with a mandate for proactive management of these areas, thus they are unable to act on the legal defensive victories of the NGOs. River improvement advocacy groups need to push for the notification of the "River Regulation Zone", as this will provide a protective legal framework for activists to build on this strategy to save urban rivers in India.

- *Participatory planning and conservation*- Legislation or judicial action alone cannot be a long-term solution; the public agencies responsible for managing these natural assets need to enlarge its supportive stakeholder base. The headwaters, the rivers, the coastal landscape have many use and non-use values and the agencies should focus on delivering these values through products and services to enlarge it supportive stakeholder base. And also promoting these values through communication tools (websites, campaigns) for building public awareness of these assets. There are many successful examples of Joint Forest Management in India where local governments have engaged tribal communities to partner in forest restoration projects(Bhattacharya Prodyut, Pradhan, and Yadav 2010). There is no reason why such grass roots and public partnership movements supported by civil society agencies and local governments cannot support urban rivers and coastal zones protection and regeneration projects in India.

- *Balancing use and non-use for conservation*- The protection of public goods depends on balancing public interaction in a manner that is supportive of building a relationship but not destructive to the public good itself. Emphasizing and developing productive value whether it takes the form of water sports or water transport at the river or open space along the river banks that provides a restorative environment to experience riparian flora and fauna these uses will need to be balanced. Such that environmental benefits are not damaged by excessive use. Today public agencies responsible for managing these natural assets in India tend to oscillate between two extreme approaches either a very restrictive protectionist stance or an unprotected stance lacking enforcement. While they could use, use value products like eco-tourism, education, recreation, ecosystem services to continue to highlight the non-use values of these systems. Such a strategy will allow both increasing public access and knowledge of resources and at the same time building them.

- *Need for valuation*- The valuation based analysis for ecosystem services offered by these natural assets in India are not well documented. Important studies for the SGNP already indicate to the important cost savings from headwater catchment protection by proper forest management to water treatment. Similarly studies of mangrove systems already

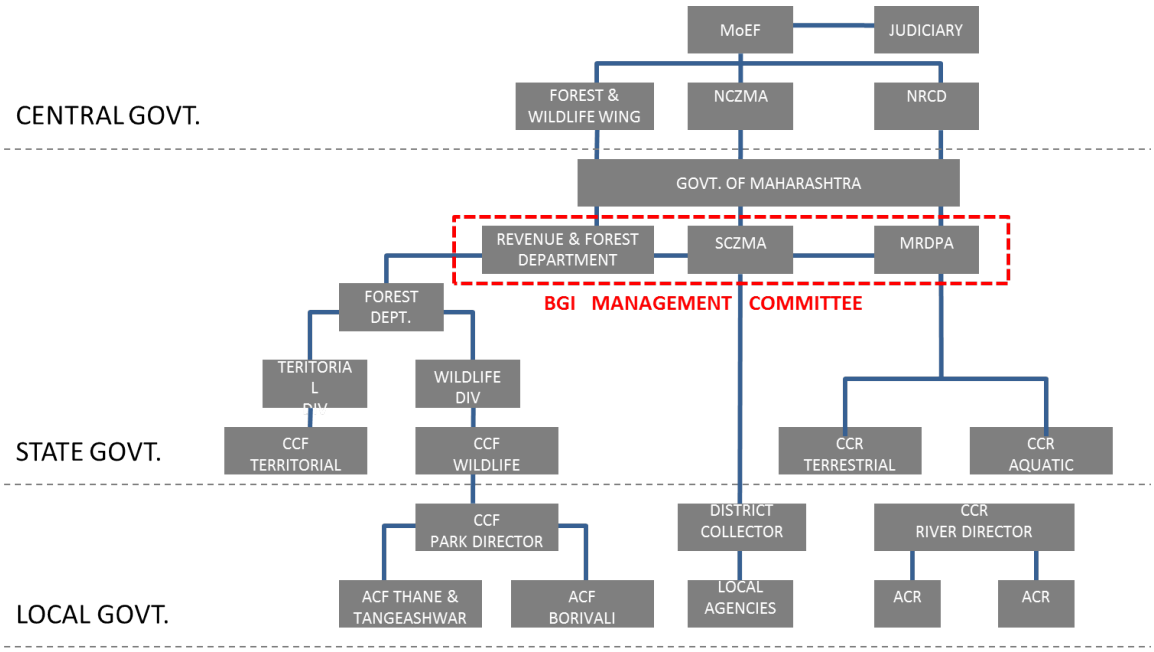
indicate that they act as effective barriers for flood risk reduction and thus reduce flood damage costs. However there is still need for more scientific studies, which show impact of ocean water and river water pollution on the aquatic and terrestrial flora and fauna, which are also sources of livelihood for many coastal communities and important bio-diversity hotspots.

- *Active stakeholder participation* -None of the agencies engage in active fundraising for development of products and services in these zones and most public resources are currently spent on protection and some on conservation. Public agencies could facilitate NGO and private party proposals for improvements and conservation thus leveraging external expertise and financial support. For such active supporters the park should create a Friend of the Park , River or Mangrove association. Singapore National Park and Boston Esplanade Association are some good examples of such associations. Many NGOs in India are promoting self-help and cooperative movements for restoration of degraded coastal landscapes. Projects like the Arvari, Ruparel river restoration projects are great examples of same.

- *Human resource requirements*- Capacity building and training of scientists, managers, planners and policy makers is required for ecosystem planning, documentation, analysis, management and research. This is an opportunity for the education industry to explore and expand on and would facilitate new job opportunities for Indian youth. Data collection, documentation including using visual tools like Mapping to display information on marine ecosystems, coastal resources, river systems are essential to bring information to the public domain enhancing environmental awareness and engendering a new wave of ecotourism for the Indian and international tourists and public at large.

- *Institutional integration*- Today the key issue for BGI system management in Mumbai is that all three BGI components in Mumbai are managed by separate agencies. The SGNP is managed by the State Forest Department, whereas the CRZ is managed by the State Coastal Zone Management Authority (SCZMA) and the Mithi River singled out for management among the other rivers, streams and Nallas is currently managed by the Mithi River Development & Protection Agency (MRDPA) a special division under MMRDA. Though the National River Conservation Directorate (NRCD under MoEF) has been given the mandate to manage river conservation across the country, it is currently focusing on only 18 major rivers across the country. To enable integrated planning of all rivers, nallas, streams in MMR perhaps MRDPA's mandate can be expanded and the acronym can be effectively reused to refer to MMR River Development & Protection

Agency (MRPDA). Further MRPDA can be brought under the direct purview of the National River Conservation Directorate (MoEF) to ensure better alignment with national environmental policies. This would mimic the state- center institutional structure for forest management and coastal management. Further to ensure that its interconnected network of blue green natural assets is sustained in an integrated manner a state level Integrated BGI Management Committee needs to be formed for the MMR. This BGI Management Committee should include key representatives from the State Department of Forest, SCZMA and MRDPA and should be given the mandate for coordinated management and conservation of these assets in the Mumbai Metropolitan Region.



Proposed Institutional structure for BGI management for the Mumbai Metropolitan Region for integrated management of Blue Green Resources

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