Introducing Mangrove Mitigation to the Urban Development in Mumbai.

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ABSTRACT:

Mumbai is the economic capital and the most densely urbanized coastal city of India. Environmental strain caused by rapid development of the city is studied with focus on one aspect of Mumbai's environment, the mangrove ecology, which has been threatened by urbanization ever since the city began to evolve. The development authority of the city proposes a regional plan to guide future growth. An addendum to this regional plan is part of this thesis. The process of developing a mangrove mitigation plan is discussed in this paper. The paper analyzes the potential mangrove stand, which can be restored, and why they need to be restored.

This thesis recommends mangrove conservation and restoration policies for Mumbai, based on the process of data collection, data structuring, comparative analysis and development of implementation strategies.

A study of Mangrove management policies implemented in other countries and coastal cities supports the mangrove management strategies suggested for the city of Mumbai. Future land development proposed by the development authority of Mumbai has been analyzed to identify probable impacts on mangrove ecology and to highlight mangrove mitigation sites. These sites offer a platform for active mangrove management that will provide important environmental services to Mumbai in the future.

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1.0 INTRODUCTION:

Mumbai is an island city located on the western coast of India. The Arabian Sea, Thane creek and the Vasai creek surround the island of Mumbai.

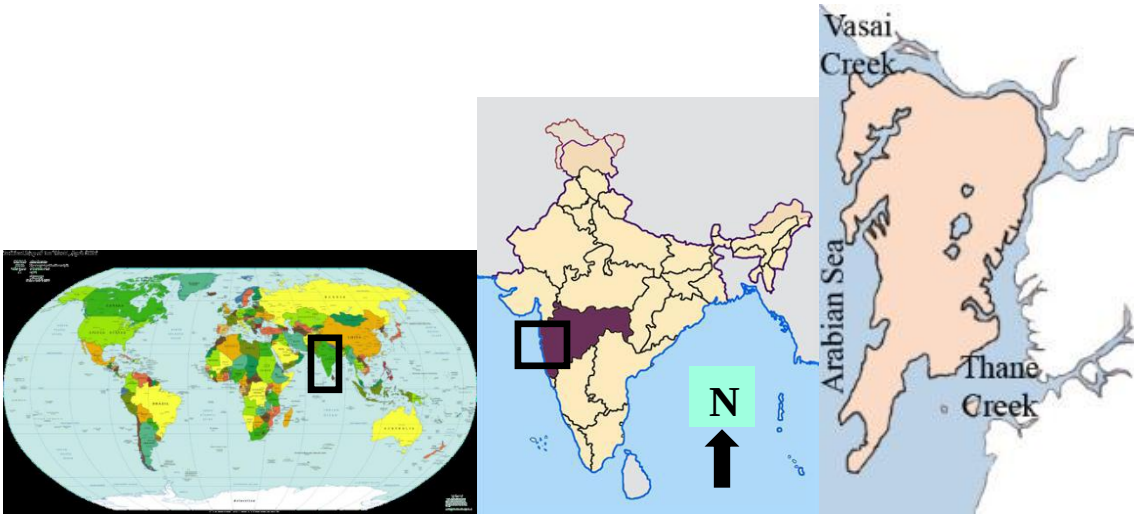


Figure 1 Map showing the location of Mumbai, *Mumbai Metropolitan Region Development Authority*

Mumbai is the commercial capital and the richest city, in India (MMRDA, 2008). The total area of Mumbai is 603.4 square kilometer, with 370 square kilometer coming under the Brihanmumbai Municipal Corporation (BMC) and the rest belonging to the Mumbai Port Trust, Defense, Atomic Energy Commission, and Borivali National Park. With a population of 14 million people, Mumbai is the most populous city in India and the most populous city in the world (Gazetteer, 2009). Due to the deep natural harbor, Mumbai contributes up to 70% of maritime trade in India. The commercial and industrial opportunities provided by the city

attract people from all over the country. The population density is estimated to be about 22,000 persons per square kilometer.

The urban zone of Mumbai developed rapidly to accommodate the sudden rise in population. The land uses in Mumbai changed drastically in a span of seven decades. The agriculture and forestland has been deceased more than 50%, the wetlands reduced more than 25% and the built up land increased more than 300%. The need to accommodate the entire population led to the process of reclaiming land from the sea (Harpreet, 2010).

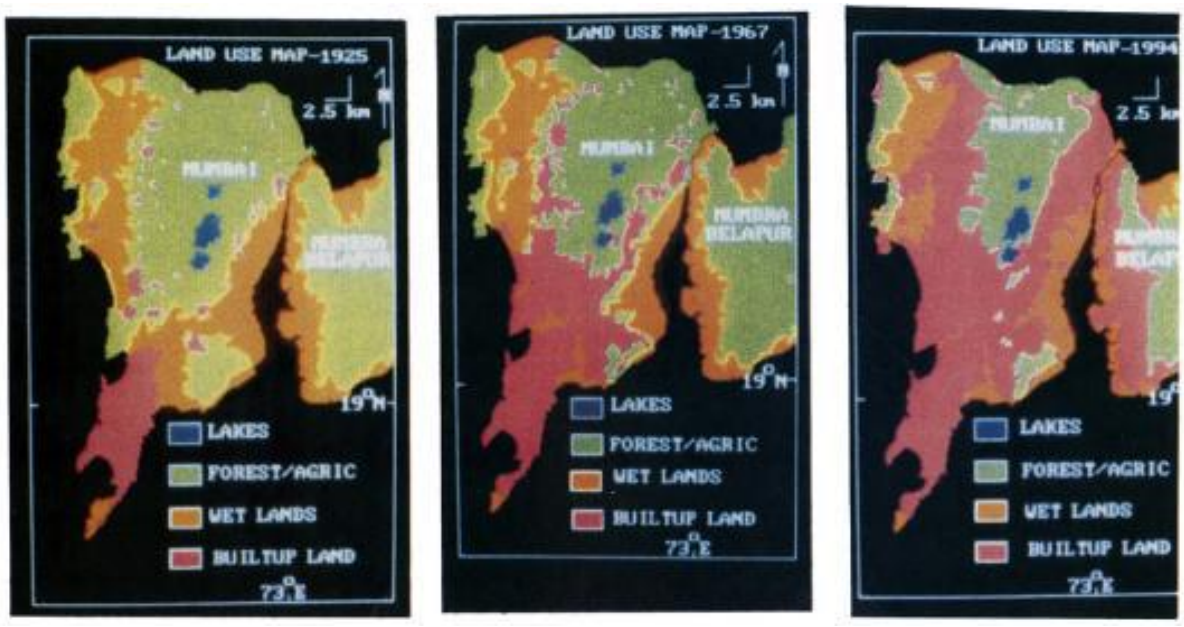


Figure 2 Maps showing the change in urban land use from 1925 to 1994 in Mumbai.

The prospect of joining the prospering commerce hub attracted even more people into the city (general, 1962). The population grew from 13,726 in 1780 to 644,405 in 1872 in less than a hundred years (Dwivedi Sharada, 2001). Mumbai's size, high

growth rate, urban sprawl, and inadequate sanitation are posing serious threats to the quality of life in the city.(Toby Sinclair, 1991).

Mumbai retains, despite rapid growth, an expansive forested area, Sanjay Gandhi National Park. The national park contains two of the six lakes that supply water to the city. The four main freshwater rivers of Mumbai also originate within the park.

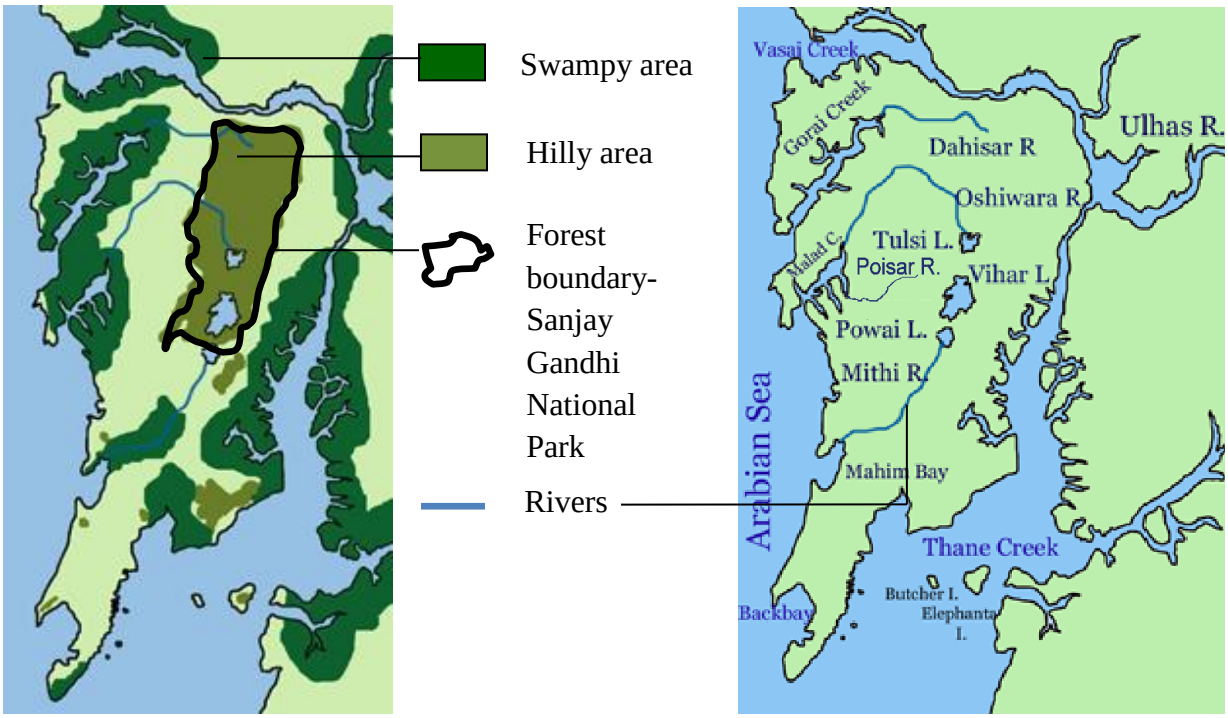


Figure 3 Map illustrating the location of water sources and wetlands in Mumbai.

The coastline of Mumbai has numerous creeks and estuaries. Some rich estuarine pockets still contain mangrove forests and the rest of the coast has sand and rock beaches. Major fresh water streams divide the city into four watersheds. The four major watershed boundaries of Mumbai play an important role in the

flow of the various freshwater streams and major drainage areas. The mangrove forests in each watershed are dependent on these freshwater inflows and sediment load transportation. The urban development in Mumbai has taken place in the absence of watershed planning and the drainage areas were not considered while dividing the city into Administrative Zones. The Mumbai metropolitan region development authority, to propose the urban expansion to take place in the city, uses these Administrative ones.

Figure 4 Map showing the six administrative zones of Mumbai, By Author.

The watersheds containing the Administrative zones play an important role in draining the precipitation and surface flows

from the upland development to the sea. The coastal ecology of each watershed is different due to the difference in the development of each area. The type and level of effluents entering the mangrove forests can be ascertained by studying the characteristics of their related watersheds.

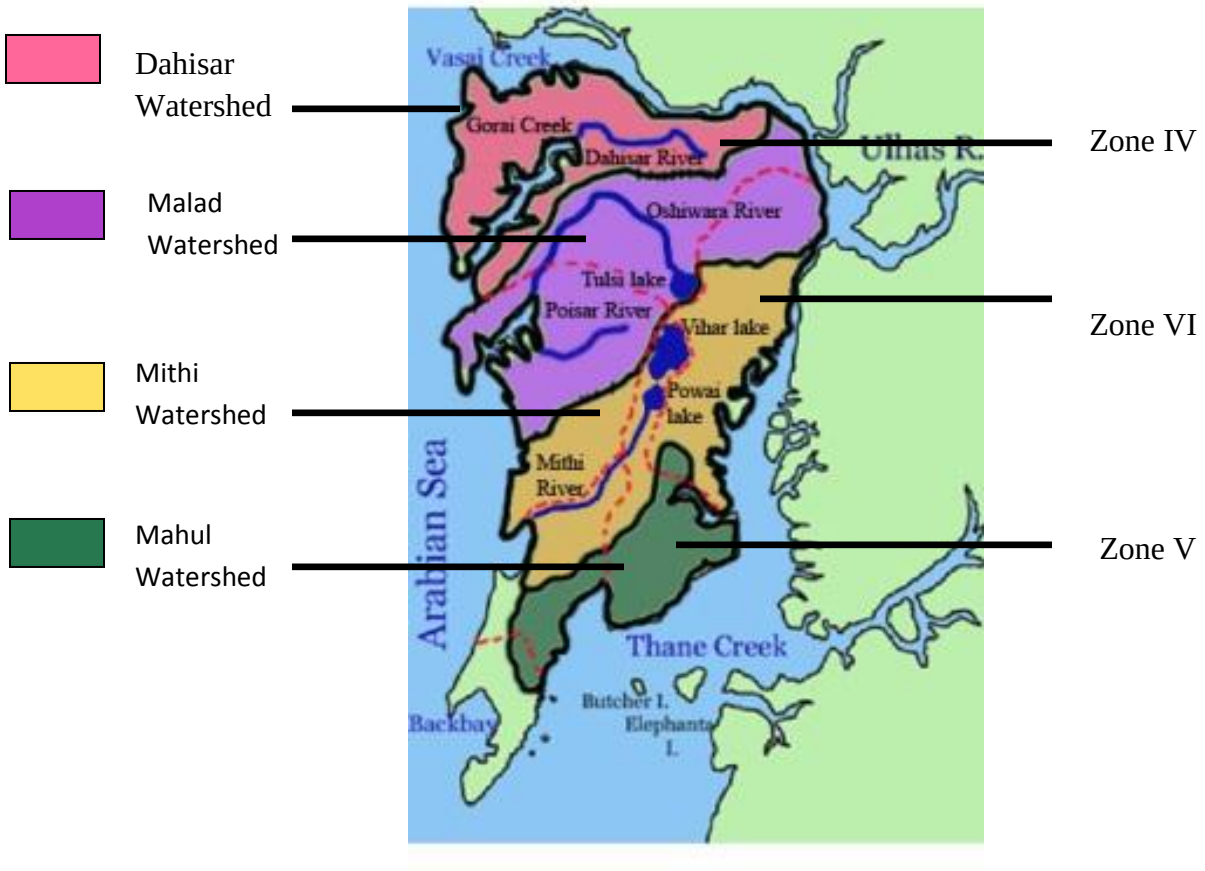


Figure 5 Map showing the four major watersheds of Mumbai, by Author

The estuaries lining the coast of Mumbai provide ideal settings for mangroves to grow. Mumbai, being an island, is subject to heavy tidal changes on all sides. Mumbai experiences four months of monsoon rains, which are in fact heavy thunderstorms. The water level rises too high for the city to tolerate, this is

where the estuaries step in and provide a buffer zone between the sea and land. The mangrove forests dissipate wave force and act as barriers. The high tides and rise in water level does not affect the city due to the protective functions of mangroves. 'The Mumbai Deluge' was a flood event on 26 July 2005, which affected the city badly. Loss of lives and property prompted the city's governing officials to carry out an investigation to explain the reasons of the extensive damage. The fact-finding report states that one of the reasons for flooding was the loss of mangroves. The sea walls were also one of the reasons for heavy property damage caused by water gushing in at high velocity. The walls could not stop or control the force of water, thus not protecting the city as required. The mangrove forests attract more than a hundred species of migratory birds (Bhagat, 2010). The mangrove forests provide habitat for 300 odd species of birds, 35-40 reptiles, 16 crabs, prawns, fish, and several terrestrial mammals (Kaushik, 2009). The fishing industry in Mumbai is largely dependent on mangrove forests. The mangrove stands act as breeding grounds for fishes during the monsoon season. The loss of nursery grounds for young fish will lead to decline in the fish population, thus affecting the fishing industry. This not only affects the anglers, but also affects the rest of the population of Mumbai. Fish is one of the staple diets in Mumbai and the decline in the fish market leads

to food shortage. The importance of mangroves is largely discussed, but the need for mangrove management is not discussed as a major issue in Mumbai. The focus is on protecting mangroves by not interfering into their ecology. This paper talks about why mangrove management and some kind of interference are required to retain the protective and habitat values of mangroves in Mumbai. The mangrove forests in Mumbai have been impacted over the years due to reclamation, conversion of land into salt pans, garbage dumping, chemical pollution, etc. the remaining healthy mangrove stands are under constant threat of being impacted by the urban activities and expansion.

2.0 MANGROVES

Mangroves are defined as woody trees and shrubs that grow in the intertidal region of tropical and subtropical coastlines where river water mixes with seawater, in bays creeks and in estuaries. The nutrient flow from rivers and their sedimentation makes it an extremely productive ecosystem (King, 2002)

Figure 7 Mangrove forest in Mumbai, *by Author*

2.1 Wetlands in Mumbai:

The western coast of Mumbai has cobble, gravel, and sand beaches. These beaches are formed by the sorting of fine to coarse sediments moved by wind and wave energy. These are a type of coastal wetlands, which are usually devoid of vegetation still protecting the shoreline by dissipating wave action across the beach. Concrete structures, tetra pods, break the force of incoming waves onto the sea walls. Mangroves develop along the shoreline and brackish estuaries and deltas inundated with tidal seawater. The eastern coast of Mumbai has creeks and estuaries, which develop dense mangrove forests, open marshes, and mud flats.

Figure 8 the tetrapod protecting the sea wall in the southern coast of Mumbai, Google fair use

2.1.1 Value of mangroves in Mumbai:

The presence of mangroves is beneficial for Mumbai in various ways. Mumbai is susceptible to erosion and large waves. The mangrove stands along the coastline have the ability to control the lashing waves. The buttressing aerial roots of mangrove plants dissipate the high velocity waves and protect the upland developments from the sea. During high tides, the mangrove roots protect the land from flooding. The mesh of aerial roots absorbs the waves and holds the water back, thus avoiding flood events (Baldwin A., 1995). The local fishing communities are the original inhabitants of the island. However, the communities retain their line of work; they have started using modern fishing equipment. The commercial value of fishing in Mumbai is prominent as the local saltwater fish and the dried varieties serve as a staple diet for a large number of locals. The

mangrove forests serve as breeding and nursery grounds for a vast variety of aquatic species (Brewer D.T., 1991). The mangrove forests support the fishing industry by helping the fish grow in the sea. Mangroves trap sediments flowing with the storm water and cycle the organic matter. They absorb chemical elements including certain pollutants. This helps in reducing the leeching of sediment loads into the sea and contains the chemical pollutants. The trapping of sediments helps prevent scouring of coastal lands and protects the shoreline. This also protects the seawater from harmful pollutants and preserves aquatic life.

Apart from the environmental functions and values, mangroves are commercially viable for the local communities in Mumbai. Various parts of the mangrove plant are used for their medicinal properties (W.M., 1998). They provide timber, fuel, food, etc. for the coastal communities in Mumbai (Balaji, 2008).

2.2 Urban development around mangroves:

Habitat destruction because of human encroachment has been one of the primary causes of mangrove loss (Kathiresan, 2003). Mumbai is an example of mangrove destruction due to urbanization as the process of reclaiming land and transforming the archipelago into one land mass has extirpated the mangroves (Stanley, Francis, & Zeigler, 2003). Human activity upland from

mangroves impact the water quality and runoff needed for mangrove growth. The threat to mangroves is not only from reclamation, dredging or draining, but also from faulty design techniques (Trewin, 2001). A flawed design, on a site near a fresh water feed source, can obstruct the flow, and cut off the fresh water coming into the mangroves. Lack of fresh water results in high salinity and reduces the growth of mangroves.

Figure 9 Effects of urbanization and development around mangroves in Mumbai, by Gauri Joshi

Mumbai, a hub for commercial activities has lost 40% of its mangrove forests in last decade (Rita, 2009).The failure in determining the actual source of disturbance leads to misconceptions and eventually destruction of mangroves.

2.3 Commercial activities around mangroves:

Many commercial activities are carried out in coastal regions. Conversion of mangrove areas for agriculture, aquaculture,

saltpans, industrial/residential development, construction of harbors and channels, dams, roads, etc. are some of the activities, which destroy or disrupt mangrove growth (Bird, 1985). Mangroves in Mumbai are affected by urban development and infrastructure built on or around them. The industrial development around the coastline pollutes the mangroves by disposing liquid chemical waste, solid garbage waste into the waterways. Many mangroves are destroyed due to landfill coming in from residential areas.

Figure 10 Wastewater disposals, which empty into the Mithi River, *By Gauri Joshi*.

2.4 Changes in the sea/ocean waters:

Mangrove forests grow around the fringes of seacoasts, estuaries, bays, etc. such regions are highly influenced by the wave action, tides, sea level rise and climate change. Anthropogenic intrusion is leading to certain changes in the environment, which has upset the equilibrium. Coastal wetlands adjust with the slow rise in the sea level and gradually move

upland. This shift in position of the wetland helps synchronize the habitat with the sea level rise. In the event of excessive sea level rise in accelerated time, the mangrove forests fail to move upland and most likely drown. In many regions, this shift is not possible due to obstructions caused by urban infrastructure and developed sites.

2.5 Changes in the upland development:

Clearing out mangroves for land is not the only consequence of urbanization. Over the years, increase in development density has raised the impermeable surfaces. As the impermeable areas spread out, the peak runoff quantity increases too. Due to the reduction of penetrable areas, the storm water flows directly into the storm drains and eventually a huge load of storm water is dumped into the coastal boundaries. Excessive flooding can flush out the mangrove soil. Mangroves suffer from increased water turbidity (results in clogging), prolonged flooding (caused by excessive runoff), and damage by pathogens and boring organisms (entering mangroves forests through sewage). Fresh water flows are greatly altered by urban engineering of the watershed. This results in changes in the nutrient load and salinity entering the mangrove systems.

Figure 11 Site under construction without any erosion and sedimentation monitoring in Mumbai, Google fair use

The various activities carried out to develop a coastal region are taking their toll on the mangrove environments. Most of the activities lead to indirect impacts over coastal environments thus is easily left unnoticed. Urban development and the city's expansion is unavoidable, in fact more development is required in certain areas. The health of the coastal environments is important for Mumbai as the property and infrastructure are currently protected from the sea by the coastal wetland systems. Loss of these protective zones will expose valuable coastal land to the onslaught of the sea and might even risk life.

3.0 DEVELOPMENT MASTER PLAN:

The metropolis of Mumbai along with its satellite towns is called the Mumbai metropolitan region (MMR). A civic body known as the BrihanMumbai Municipal Corporation (BMC) governs the city of Mumbai. The BMC designates administrative zones and wards as means of overseeing the infrastructural needs of Mumbai. The basic services required by the city such as building and maintaining roads, schools, hospitals, garbage disposal, etc. are provided by the BMC.

The infrastructural development of the MMR is planned and managed by the Mumbai Metropolitan Region Development Authority, a body of the government of Maharashtra (MMRDA). The MMRDA manages the development activities pertaining to improvements for housing, transportation, water supply, etc. New development projects are monitored and regulated by the MMRDA.

The MMRDA has proposed a regional plan for the Mumbai Metropolitan Region 1996-2011, which handles the land development strategies.

3.1 Urban development proposed for the city of Mumbai-MMRDA:

The Regional Plan primarily aims at containing Mumbai's growth, reducing congestion and overcrowding, and bringing about balanced regional development through dispersal of population

and economic activity (Chavhan, 2009). The regional plan chalks out the various zones, namely urban, industrial, residential, recreational, green areas, and focuses primarily over areas with potential for high urban development and intensive economic growth in the future (Chavhan, 2009).

A study of the regional plan and the proposed land uses in each administrative zone provides with the essential data required to determine future urban expansion and probable mangrove land conversion.

3.2 Land use distribution:

In the past, the greater Mumbai region was known for industrial development and infrastructure. In the course of time, Mumbai saw the closure of existing industries and decline in industrial employment. In addition the nature of modern industries, suggest that the industrial employment is unlikely to increase in the future (Chavhan, 2009). The closure of industries has led to unused sites, which are proposed to be redeveloped into other land uses. The regional plan proposes to expand the city with residential, commercial, recreational, public spaces. The proposed expansion seeks to redevelop the industrial sites and develop the coastal wetland areas that are impacted by prior urbanization.

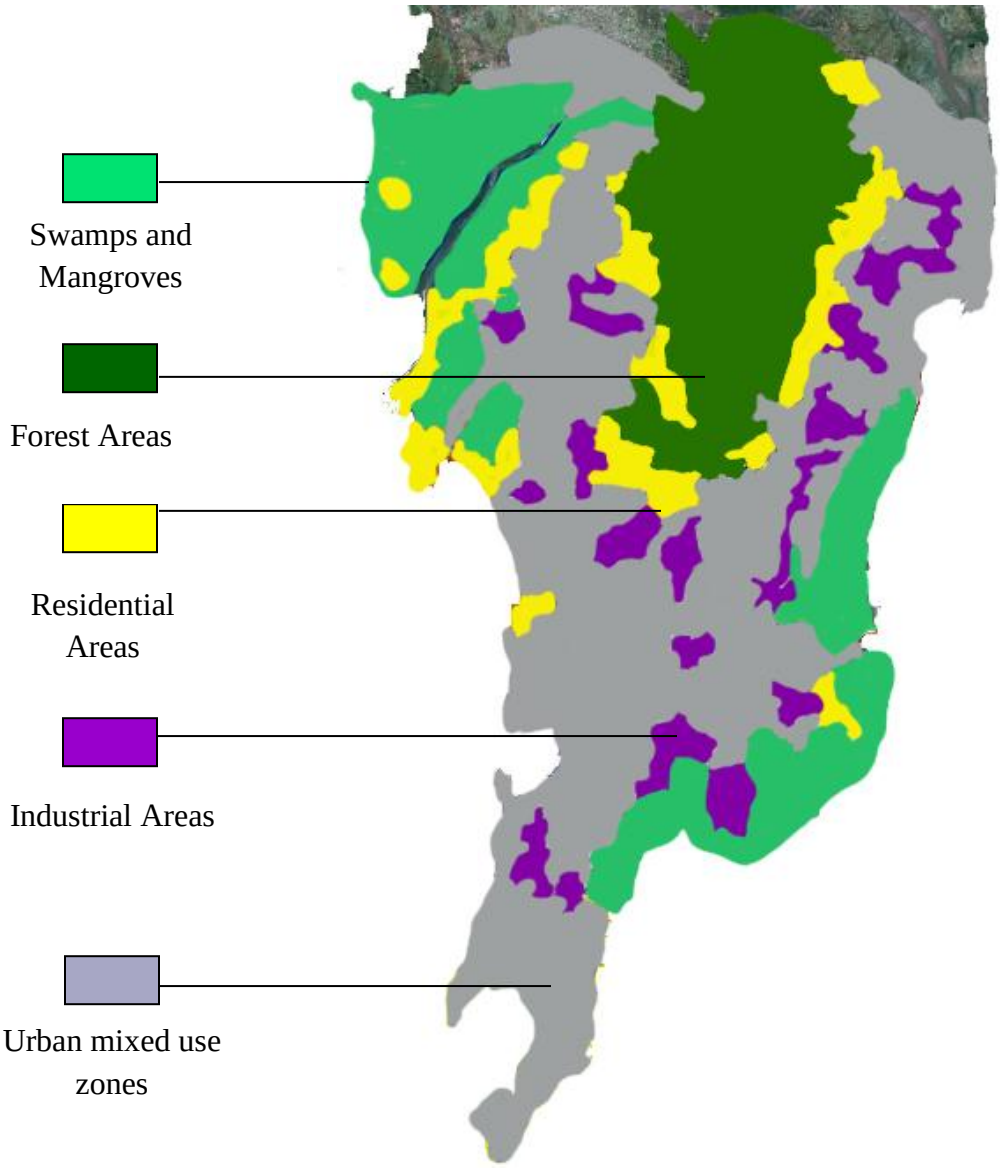


Figure 12 the regional land use plan proposed by MMRDA, by Author

The other zones considered by the regional plan are the green areas, forestland, parkland, open spaces, etc. these land uses play a vital role in balancing the system.

3.3 Mangrove management policies in Mumbai:

The mangroves in Mumbai are protected legally under the following acts: Forest conservation act 1980, Maharashtra tree

act of 1984, Environment protection act 1986, coastal regulatory zone notification of 1991.

The land development in Mumbai has to consider the Coastal regulatory zone notification for the coastal areas. According to the Environment protection rules 1986, the land area from High Tide Line (HTL) to 500 mts on the landward side along the sea front is considered in as the Coastal regulatory zone (Sehgal, 2010). The Coastal regulatory zone is further classified into three parts, namely:

i. **CRZ-I:** The areas that are ecologically sensitive and the geomorphological features which play a role in the maintaining the integrity of the coast.

ii. **CRZ-II:** The areas that have been developed up to or close to the shoreline.

iii. **CRZ-III:** Areas that are relatively undisturbed and those do not belong to either Category-1 or 2, which include coastal zone in the rural areas (developed and undeveloped) and areas within municipal limits or in other legally designated urban areas that are not substantially built up. (FORESTS, 2010)

Mumbai mainly deals with the CRZ-1 and CRZ-2 areas and is required to follow specific norms for regulation activities.

No new construction is permitted in the CRZ-I, which consists of mangroves, biologically active mud flats, salt marshes, nesting

grounds (Correspondent, 2010). A 50 meter buffer area is required be provided around the mangrove forests to protect them from urbanization. (Narayanan, 2009) The CRZ notification permits construction of roads, approach roads and missing link roads approved in the Developmental Plan of Greater Mumbai on stilts ensuring that the free flow of tidal water is not affected. If destruction of mangrove stands is required then, twice the number of mangroves destroyed/cut during the construction process shall be replanted. (FORESTS, 2010)

The existing policies to manage mangroves in Mumbai focus on a passive management technique where the mangrove forests are required to be undisturbed by direct urban impacts.

The direct impacts of urbanization include reclamation, dredging, filling, land conversion, and many similar activities. These urban activities lead to a number of indirect impacts on the environment. The indirect impacts caused by urbanization are scouring or excessive sediment loads, pollution, loss of fresh water inputs, unmanaged storm water flushing into mangrove forests. The direct impacts caused by urbanization are obvious and management techniques such as regulations restricting any development activities around mangroves can be directly applied to stop or control reclamation, dredging, etc. On the contrary, the indirect impacts are caused due to negligence and unmonitored development. The unhealthy environments created up

stream of fresh water streams, excessive sediment pollutants being released, unmanaged land development leading to erosion and sedimentation or flooding and peak runoff rates flushing the mangrove forests are affecting mangrove forests in Mumbai. These impacts can be managed by improving development regulations and enforcements, watershed planning, brown field remediation, etc. most of the impacts need extensive planning and research to identify the source of problems, thus providing more insight on management techniques and modules. This thesis focuses on the mangrove management techniques used to restore and remediate mangrove stands in Mumbai.

3.4 Remediation and restoration:

Management techniques such as remediation of polluted land and restoration of degraded mangroves are some of the various management policies available for mangrove mitigation. A study of the proposed land use patterns and existing land uses around the mangroves of Mumbai highlights the need to incorporate a mangrove mitigation plan into the regional plan of Mumbai. The impacts of pollution caused by industrialization and urban development around mangroves need to be abated. The industrial land use surrounding mangrove forests are a part of the regional plan for Mumbai and the future development scheme proposes conversion and redevelopment of brown field sites like the

industrial sites in Mumbai need to be remediated to improve the environmental settings. The remediation activities include an assessment of contaminants on site and locating the hotspots of concentrated pollutant presence on site. The assessment of contaminant impacts over the surrounding mangrove forests is also required to determine the need for restoration. Remediation process such as phyto-extraction, phyto-stabilization, and phyto-transformation can be applied on the site to remove the pollutants from the free system and contain them into the organic cycle of specific vegetation. Capping of highly polluted areas to hold in certain hazardous chemicals may be required. Restoration of mangrove forests is a complex set of methods to stabilize the mangrove ecosystem and to return the natural environment settings, which aid the growth of mangrove seedlings.

4.0 Case study analysis:

Mangrove forests develop along the tropical and sub-tropical belt, thus spreading across a large number of countries. Mangroves dominate three quarters of tropical coastlines (O.G.Davidson, 1998). Mangrove Eco regions are classified into Afrotropic, Australasian, Indomalayan or Neotropic regions, based on their location on the globe. Each of these Eco regions is riddled with urban spawn and rural expanse. The mangrove

forests in each of the Eco region have to deal with human intrusion. Studying cities from different Eco regions will give more insight in handling the issue of loss of mangroves.

The selected sites are:

1.Chek Lap Kok International Airport, HongKong, China,

2. Olympic Park, Sydney, Australia.

4.1 Chek lap Kok Airport, HongKong, China:

Hong Kong is located on China's south coast and enclosed by the Pearl River Delta and South China Sea (department, 2007) . It is renowned for its expansive skyline and deep natural harbor. With land mass of 1,104 km^2 (426 sq. mi) and a population of seven million people, Hong Kong is one of the most densely populated areas in the world (Ash, 2006). The economic and urban growth of the city has put pressure on the infrastructure and services.

A 1974 planning study by the Hong Kong Civil Aviation and Public Works department identified the small island of Chek Lap Kok, off Lantau Island, as a possible airport replacement site. Away from the congested city Centre, flight paths would be routed over the South China Sea rather than populous urban areas, enabling efficient round-the-clock operation of multiple runways (Yeung, 2008).

The principal reasons of selecting the Chek Lap Kok Island were the location, aeronautical requirements, and the environmental impact during construction and for operations was acceptable (Siu, 1990). An Environmental Impact Assessment was carried out in parallel with the other work-streams and the potential construction and operational environmental impacts from the new airport were described.

The Hong Kong International Airport is built on 1248 ha, of which the 302 ha island of CheK lap Kok and the eight ha island of Lam Chau was excavated to a height of 6 m above sea level, while the remaining 938 ha was reclaimed from the sea. Physical removal of seabed caused immediate injury to the natural communities in the area of the borrow pits, reclamation and dump sites. Much of the coastal habitats around CLK were also destroyed. By far the most visible impact of the airport is the destruction and displacement of almost the entire terrestrial flora and fauna originally found on CLK. The mangroves on CLK, which used to contain many large specimens of the rare *Bruguiera gymnorrhiza*, were also eradicated (world wide fund for nature Hong Kong, 1996).

Figure 14 Aerial view of the Hong Kong International Airport, *Fair use*

The loss of mangrove habitat during the construction of the Hong Kong International airport has been a concern to the environment. Mangrove management and rehabilitation programs have addressed this issue. Mitigation efforts to rehabilitate the mangrove forests have taken place in Tai O Island. Located on the south-west Coast of Lantau Island, Tai O was formerly one of the largest fishing villages in Hong Kong and an historical base for fishing boats in the western approaches of Lantau Island and the Pearl River estuary. The mangrove-habitat creation scheme has significantly benefited the ecology of Tai O. The mangroves planted are likely to develop into a robust ecological habitat, which will be an important intertidal feeding ground for avifauna of local and international importance. In addition, the mangrove is likely to become an important nursery area for juvenile fish and organisms, which

are prey items of fish, thus contributing to the project's benefits to the local fisheries industry. It is also possible that the breakwater to be developed will attract fish through the provision (Wilson, 2000).

Figure 15 Aerial view of the Tai O mangrove mitigation area.

The mangrove rehabilitation efforts have enabled to balance the ecology of the region. The wetland values and functions are lost from the Chek Lap Kok Island, but the habitat and environmental benefits are retained by relocating the mangrove forests. The rehabilitation of mangrove forests is a way of restoring the functions of the mangroves destroyed for urban expansion.

4.2 Sydney Olympic park, Sydney, Australia:

Sydney is the largest city in Australia, and the state capital of New South Wales. Sydney has a metropolitan area

population of approximately 4.5 million (Statistics, 2008) and an area of approximately 12,000 square kilometers (4,633 sq. mi). Sydney has hosted major international sporting events, including the 1938 British Empire Games, 2000 Summer Olympics, the final match of the 2003 Rugby World Cup, as well as the 2008 World Youth Day.

Figure 16. Masterplan of the Sydney Olympic park at the Homebush bay, *by www.blighvollernield.com.au*

Sydney's urban area is in a coastal basin, which is bordered by the Pacific Ocean to the east. Mangrove forests are found along the eastern coast of Australia (C.F., 1986). The Parramatta River is one of the few significant coastal rivers in New South Wales. There are significant stands of mangroves along the river. Sydney Olympic Park is a 640-hectare area in Homebush Bay, which was notable as the site of the Sydney 2000 Olympics.

Since then, there has been much development in the area including office buildings and apartments in the Centre of Sydney Olympic Park. The site for the Sydney Olympic park was selected as an essential component of venue design, construction, and operation representing the magnitude of the Olympic coordination authority's commitment to the environment. Homebush bay area was a former dumping ground for domestic, commercial, and industrial waste. The remediation and restoration of Homebush bay and the integration of ecological sustainable development was officially adopted as the third dimension of the Olympic Charter along with sport and culture. The Homebush Bay site has considerable ecological value, providing ecologically sensitive habitats for a number of migratory birds, a regionally significant remnant eucalypt forest, and series of wetland systems including mangrove forests. However, the site has also been utilized for urban development, government brickworks and abattoir, as well as a naval armaments depot. In addition to those functions, parts of the site were used for domestic and industrial waste disposal for almost 50 years (Campbell, INTEGRATING ESD – THE ENVIRONMENTAL LEGACY OF SYDNEY OLYMPIC PARK, 2001).

Figure 17. Masterplan of the Sydney Olympic Park showing the ecologically sensitive zones, *By Sydney Olympic park visitor center.*

The remediation of past domestic, commercial, and industrial waste at Homebush Bay, including contaminated soil, was the largest project of its kind in Australia and the greatest environmental legacy arising from the Sydney 2000 Games. The contaminated soil from the site was removed from the ecologically sensitive areas and contained in waste mounds with extensive leachate management systems (Campbell, Integrating ESD-The Environmental legacy of Sydney Olympic park, 2001)

The Olympic Parklands recognizes the high ecological values of Badu Mangroves, and its current role in providing for school educational and interpretive programs. The Parklands establishes the importance of the Parklands Program, which must recognize

the “spirit of place” of Badu Mangroves and the Parklands as a whole. The Program is to bring enrichment and enjoyment to the community through a range of structured and unstructured activities such as research, education, eco-touring, recreation, events, and performance, consistent with the characteristics and special features of each Place.

The Plan intends the Badu Mangroves to function as a natural area where wetland habitat values are conserved and enhanced. It has secondary functions for Program education, tour, and research activities, for passive recreation, as a visitor link, for art displays, and for radio transmission.

The innovative and environment sensitive design of the Olympic park has saved the Badu mangroves from destruction. The mangrove wetlands were not only remediated for the years of pollution that they were subject to, but also restored and protected. This management method allows future development of a city with conscious environment rehabilitation. A large-scale project such as the Sydney Olympic park is still functional as a Sports center and an ideal example of sustainable designs. The management methods used in Hong Kong and Sydney has been effective with positive impacts on the current mangrove ecology. The two case studies help us understand the relationship between mangrove wetlands and urban development. They show the possibility of coexistence between the two realms of a

developing city. To understand the applicability of such mangrove management methods we look in to the development trends of the city.

5.0 LAND USE ANALYSIS- comparative analysis of current and proposed land use distribution:

Mumbai is divided into six Administrative Zones. Out of the six administrative zones, only three hold large mangrove stands and the potential for additional mangrove restoration.

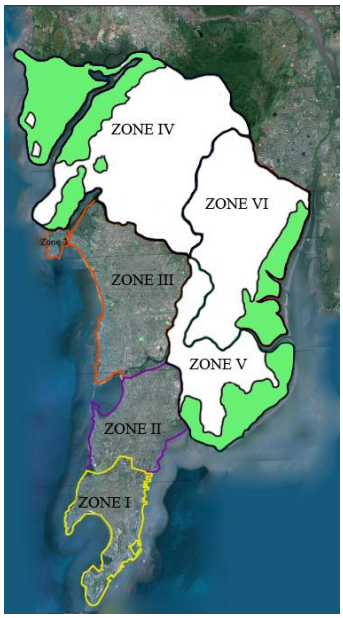


Figure 13 Maps showing the location of the Northern zones and the mangrove forests in the Zones, by Author

The three southern zones (Zone I, II, and III) have lost their mangrove stands and the coastline is presumably protected by a sea wall. The mangroves lost from these zones cannot be restored due to the absence of a natural shoreline and related

development changes that occurred over the years. This study focuses on the remaining three zones (Zone IV, V, VI), which hold mangrove forests with hope of surviving. The following table explains the historic loss of mangroves and the scope of restoration in these zones.

Administrative Zones	Mangroves lost due to development	Mangroves converted into salt pans/landfill	Total area lost	Present mangrove area	Maximum acreage of mangrove restoration
Zone IV	2.21 Sq.km.	4.28 Sq.km.	6.49 Sq.km	14.5 Sq.km.	3.47 Sq.km.
Zone V	2.37 Sq.km.	-	2.37 Sq.km	7.2 Sq.km.	1.2 Sq.km.
Zone VI	1.42 Sq.km.	2.025 Sq.km.	3.445 Sq.km.	6.41 Sq.km.	1.0 Sq.km.
Total	6.00 Sq.km.	6.305 Sq.km.	12.305 Sq.km.	28.11 Sq.km.	5.67 Sq.km.

The mangrove management plan should be able to restore almost 6 square kilometers of mangrove forests in the three zones collectively. The coastline of Mumbai is highly susceptible to environmental threats and the mangrove forests contribute substantially by protecting development from the sea. The protective barrier created by the mangrove forests is an integral part of the city's ecology, culture, and economy.

Mumbai is a reclaimed island with powerful wave action along its entire shoreline. In the last three decades, the wave action has

eroded 500 meters of the 16 Km long coastline. Only mangroves can provide a natural control over the eroding shoreline and increasing tidal amplitude (Tanveeruddin, 2010). The protective values of mangroves also include reducing atmospheric and water pollution; they are natural purifiers (viju, 2010).

The importance of mangroves for Mumbai is well known and the city authorities have initiated mangrove protection plans. The mangrove protection plans concentrate on controlling illegal logging, contamination, and reducing environmental impacts. The existing mangrove forests in Mumbai are constantly threatened by development. The mangroves are exposed to diseases caused by increased soil salinity due to reduced water flow, reduction in periodic inundation, nutrient imbalances, sedimentation, flooding, and pathogens (Mastaller, 1996). The sewage from development around mangroves is dumped directly into the mangrove forests. The biological pests and parasites cause serious impacts on the trees (Kathiresan B. , 2001).Large patches of mangroves forests are currently being subject to pollution and are deteriorating due to the adverse effects. The existing mangrove forests need to be protected from the numerous impacts of development and encroachment.

The regional plan of Mumbai proposes to extend urban development into the wetlands of these Zones. This proposed expansion will

disrupt many mangrove stands, thus making a mangrove management plan necessary. Though it may seem that the regional plan is intruding into the wetland areas, the proposal is in fact an opportunity to change the urban fabric around wetlands. The expansion and redevelopment schemes should be integrated with management plans to develop a balanced and self-sustained land use. The regional plan proposal attracts the possibility of environmental designs, sustainable sites, mangrove management, etc. being implemented on the sites.

To explore the opportunity for desirability of mangrove restoration the three zones have been individually analyzed to assess the extent of threat the mangrove forests face and the scope of restoration possible in the watershed. The description and analysis of the three zones is preliminary, as a more thorough land use analysis is required to develop a workable management plan. The zones are described on the basis of their location in the watershed and their land use development. Each zone is analyzed with respect to its environmental and urban systems and the role these systems play in the development of the city. To be able to develop a mangrove management plan applicable for these complex sites a systematic landscape analysis process is needed. This analysis process includes an extensive study of the storm water drainage and sanitation

infrastructure to understand their role in their respective watersheds and their subsequent contribution to the impacts on mangrove forests. This analysis will aid the restoration process of freshwater streams essential for mangrove forests. The inland development is one of the major causes of indirect impacts on mangrove forests and the analysis of such development projects is required to determine the extent of impacts they have caused or may cause on the coastline of Mumbai. The preliminary analysis of the three zones is introduced in the following sections:

5.1 Administrative Zone IV:

Zone IV is bounded by the scenic hills of the National park on the eastern side and the inlet of manori creek and saltpans on the western side. This zone once had numerous lakes and ponds, which have now been filled over for building construction. The Dahisar River originates from a lake in the National park. The river is protected and stable within the park limits. Once the river reaches the urbanized areas it is extremely polluted with sewage and other wastes generated from the residential buildings (Bank, 2010).

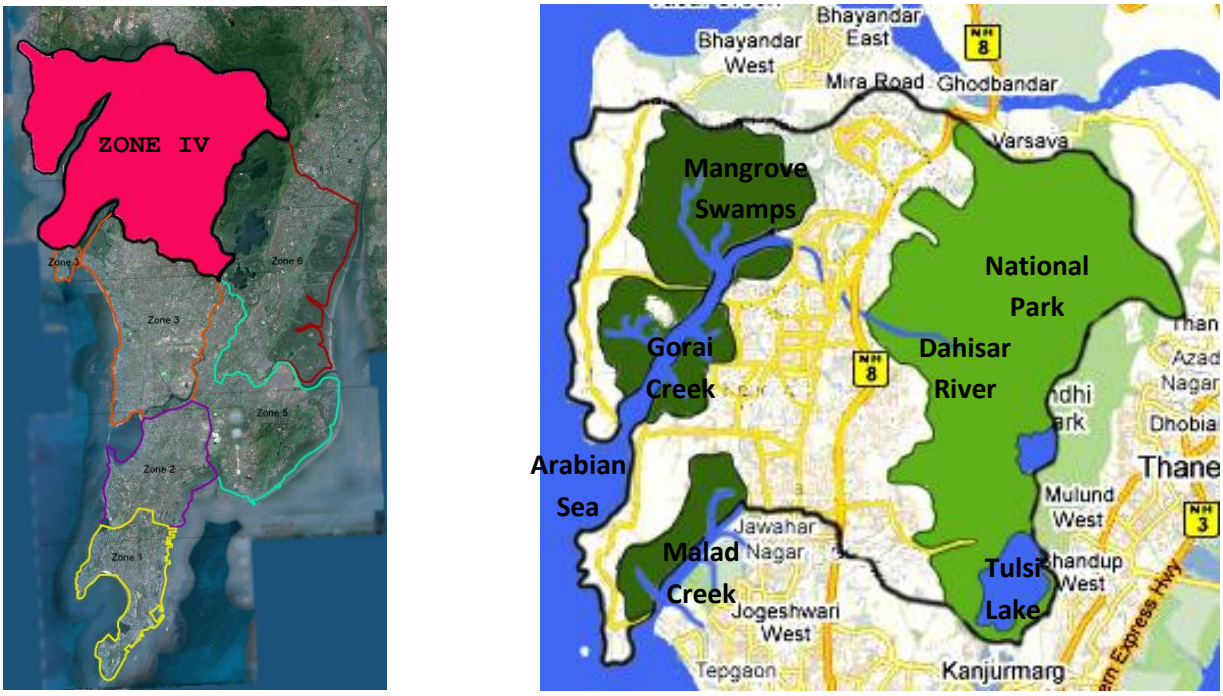


Figure 14 Maps showing the location of Zone IV and Physical features of the zone.

The Gorai creek is surrounded by dense mangroves, which provide the zone its last stretch of wilderness. However, these mangrove forests are under constant threat from pollution and illegal logging. The mangroves are also susceptible to encroachment from the slums and other settlements. Such unauthorized development leads to mangrove destruction. Due to the loss of mangrove forests in the past, the bank of Dahisar River near the sea is prone to cyclone impacts (Maharashtra, 2010). This zone is prone to flooding and water logging due to the presence of low-lying areas and development within close proximity of the sea. In the past, the urban stretch was protected by the mangrove forests,

but now due to the loss of 40% of the mangrove forests the urban areas are exposed to the sea (Swaminathan, 2006).

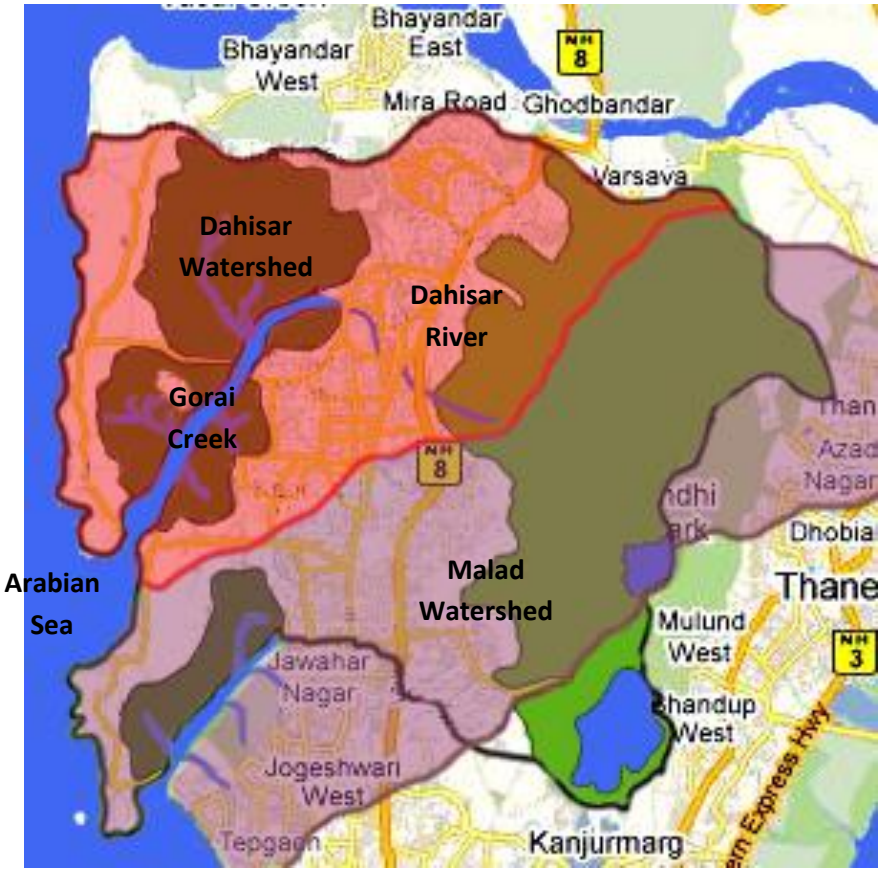


Figure 15 Maps showing the Dahisar watershed and the Malad Watershed in Zone IV.

The zone is divided into two watersheds, the Dahisar river watershed, and the Malad river watershed. The western coast of this zone is contained by the Dahisar river watershed. The western coast has a stretch of dense mangrove forests, which protect the coastline from the sea. This zone is comprised of residential and mixed-use areas. The few industrial buildings present in this zone are located in the Malad watershed, thus

eliminating the threat posed by industrial waste. The storm water inflows are concentrated with sediments and finer debris accumulating from residential sites and playgrounds or open spaces. Even though the mangrove forests are spared from chemical pollution, the sewage and solid waste generated from residential buildings is affecting the coastline. The mangroves are exposed to pathogens, which makes the susceptible to diseases. The mangroves in Zone IV are in need of rehabilitation. The role of watershed planning, wastewater disposal, and storm water management is crucial for the process of urban development with respect to coastline ecology.

The land use of Zone IV has gone through tremendous changes in the last three decades. The need for land and urban expansion has led to the transformation of the zone from a rural scenic land to a highly urbanized residential retreat. This zone was originally known for its numerous lakes and ponds, which have long been filled over for construction. The lakes and ponds used to play the role of natural reservoirs for storm water and used to control the surge of water entering the sea. This containment of water used to reduce the volume of storm water entering the storm water drains too. The storm water drains in Mumbai are outdated as they were designed more than a hundred years ago. The capacity of these drains is much less than the current

requirement. Due to the loss of all the natural reservoirs, the storm water depends solely on the drains to be transported to the sea (Joshi, 2006). This leads to high run off peaks and large volumes of water entering the mangrove forests along the coastline. The land use changes have reduced the permeable surfaces from the developed land, thus adding to the lack of storm water absorption.

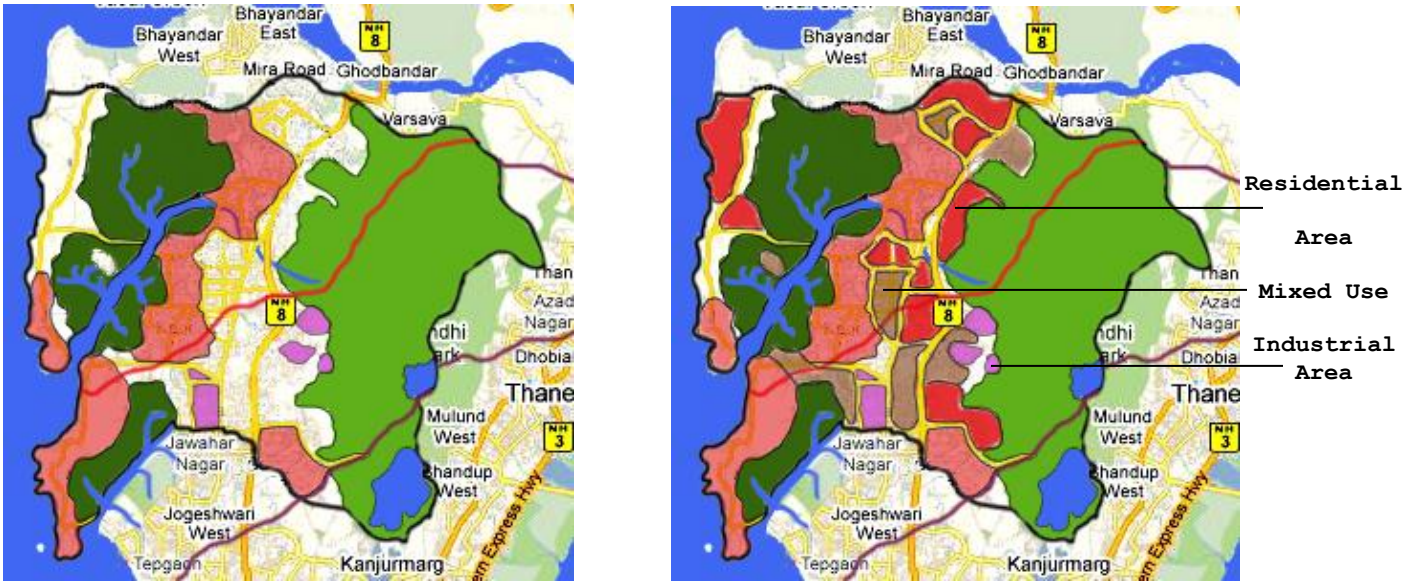


Figure 16 Maps showing the change in land use development in Zone IV.

The land use in this zone has primarily been residential development. The need for space and urban expansion led to the development of the zone. As we can see in the maps above, the residential areas have spread all over the zones. The regional plan of Mumbai 1996-2011 aims to introduce mixed-use zones in the region of administrative zone IV and improve the social

culture of the areas (Chavhan, 2009). The concentration of residential areas makes it important to develop the social environment for better living standards and healthy lifestyles. One of the obstacles faced by the regional plan to develop the zone is lack of space. This space constraint has led to a proposal of expanding the development into the wetland systems.

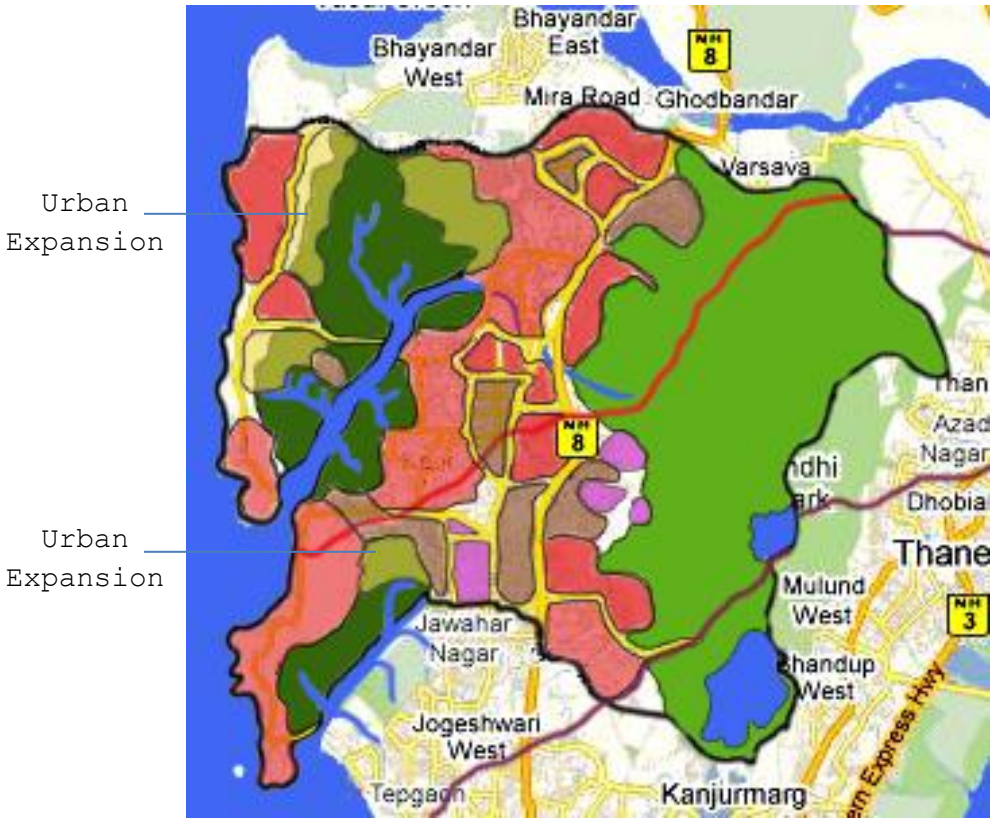


Figure 17 Map showing the urban expansion proposed by the Regional Plan of Mumbai.

As discussed earlier the land use development of the zone has changed its geographical features. The loss of natural reservoirs, increase in impermeable surfaces, and exposure to the sea has made the zone vulnerable to floods and cyclone impacts. The regional plan proposes to expand development into

the last remaining buffer zone provided by the mangroves. The low-lying areas in the zone were protected from flooding in the past. The storm water absorption prior to land development used to control the runoff peaks. However, due to the loss of such natural measures to curb water logging and flooding, the zone is exposed to natural disasters. Further destruction of wetland systems will expose the coastline to erosion and wave action. The mangrove forests are one of the last remaining protective barriers other than the sand and rock beaches. The destruction of such barriers will increase the risk of loss of lives and property. Thus, the regional plan needs to incorporate mangrove management policies into the expansion process to aid the development of the zone along with preserving the coastal ecosystem.

The mangrove forests proposed to be converted into built up land are chosen due to their unhealthy state. The forests are deteriorating due to the intrusion of urban systems. These mangrove forests can be rehabilitated and even included into the development plans. The mangrove stands are evaluated based on a number of criteria to assist the management plan. The main idea of this evaluation is to determine the most essential mangrove stands and the feasibility of preserving them. The urban development has to consider watershed planning, storm water

management and mangrove management to create an environmentally responsive design. The prioritization of mangrove stands will help the urban plans to develop designs with respect to the needs of the mangrove forests.

5.1.1 Evaluation Criteria:

The mangrove forests are evaluated based on the following criteria, proximity to sea and freshwater, minimal interference from built-up sites, manageable levels of chemical pollution, restoration of freshwater streams. The first criteria is the proximity of the site to sea and freshwater. Mangrove stands need freshwater flushing to balance the salinity and seawater flushing to maintain the nutrient levels. The absence of any one of the water sources will lead to degeneration of mangrove soil. Thus, the availability of both water sources ensures healthy environment for mangrove plants. The interference from surrounding built up sites, disturbs habitat and mangrove ecology. The site boundaries and open spaces of built up areas are capable of draining sediments and pollutants into the mangrove forest, suffocating the roots. The priority is given to mangrove sites which are not subject to development impacts, thus helping restore the mangrove stand successfully. Similarly, the storm water inflows need to be studied as the storm water coming in from the upland development can carry heavy sediments

and pollute mangrove soil, the heavy water flows can drain out important nutrient content. The buildings surrounding the mangrove forests cause disturbances for the wild life habitat and may block the required inflow of nutrients into the mangroves. The buildings dump their waste material into the mangrove systems. The interference caused by built up land initiates the process of mangrove deterioration. The consideration of such intrusion is important to evaluate the mangrove stands. The presence of chemical pollutants requires remediation. Excess chemicals do not affect the mangrove plant, but leech into the mangrove soil and possibly enter the sea. This can cause chemical poisoning in aquatic species and plants. Thus, it is important to determine the amount of chemicals entering the mangrove system to understand the remediation requirements. The remediation process involves various scientific fields and a complex study of mangrove sites to establish the most appropriate remediation technique. The initial process involves soil testing to determine the types and levels of chemicals contaminating the soil and locating the sources of these contaminants. Once the initial examination is done, the data collected provides the basis to develop a remediation plan to either cap the contaminants or completely eliminate the chemical content from the mangrove soil. Qualified agencies are available who carry out the remediation process

systematically and are aware of the need to treat each mangrove stand individually. Most of the freshwater streams flowing into the coastline are channelized and polluted. The streams are a source of freshwater for the mangroves. The extent of stream restoration required will help determine the feasibility of mangrove rehabilitation. The possibility of divergence of contaminants from the mangrove forests is important as exceeding amounts of pollutants can deteriorate the mangrove stands. Healthy mangrove forests have the capability of absorbing heavy metals and chemicals; they are natural purifiers (Brewer D.T., 1991). But mangrove stands impacted by urbanization are susceptible to diseases. Excessive chemical input increases the chances of root rot diseases in mangrove trees (Jungblut, 2009). The need to divert chemical pollutants from mangrove sites emerged due to the various industrial and commercial activities developing around mangrove forests. The divergence of chemicals from mangroves is achieved by developing the site design, proper disposal of chemical waste, awareness of the environmental impacts caused by the industrial activities on site, minimizing the impacts on the environment. Such changes can be brought by proper guidance and awareness. The sites affecting mangroves need to be developed into sustainable and environmentally responsive designs.

The mangrove stands are evaluated on the basis of these criteria to determine the feasibility of rehabilitation. The presence or possibility of most number of criteria in a particular mangrove stand makes the mangrove stand an ideal location to rehabilitate, as the chances of it surviving are better. The mangrove stands chosen by the regional plan to convert into built up land is the stands, which are impacted by their surroundings. The regional plan is not wrong in proposing to develop the land, but it fails to see the potential in developing the land and preserving the mangrove stands too. It is true that not all mangrove stands can be rehabilitated, but there are many areas, which can still be saved. The regional plan should focus on introducing projects, which will initiate a well aware environmental design and incorporate mangrove management into the site plan. The evaluation criteria will aid this process by highlighting the mangrove stands most feasible to be rehabilitated and set a benchmark for the development design.

The five criteria used for this process are established on the basis of geographic factors as to how the location of a mangrove stand makes it important for its protective functions and how it is impacted by its surroundings. The criteria are named and placed in an order of hierarchy, but it should be noted that

they are interdependent too. The absence of one criterion will change the rehabilitation method, as the focus will shift to restoring the absent criterion. The absence of more than one criterion does not make the rehabilitation process hard but calls for a more rigorous form of management. The following map highlights the areas proposed to be developed. The mangrove stands in need of rehabilitation are categorized into high and low potential to be rehabilitated. The term low potential to be rehabilitated refers to requirement of rigorous management techniques which involve significant land redevelopment and cleanup of urban runoff. Due to the presence of time and economic constraints the mangrove stands are termed as to have low potential to be rehabilitated and does not suggest conversion into built up land.

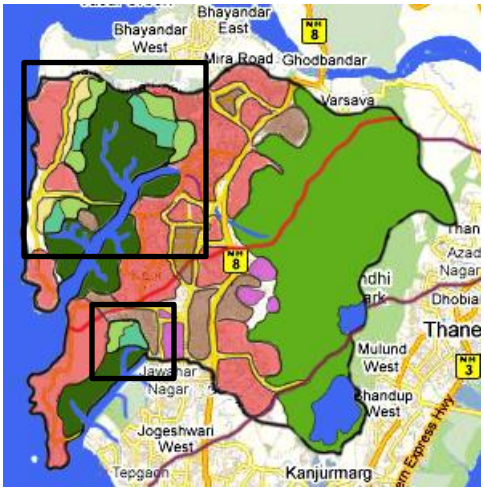


Figure 18 Map showing the mangrove stands proposed to be converted into built up land.

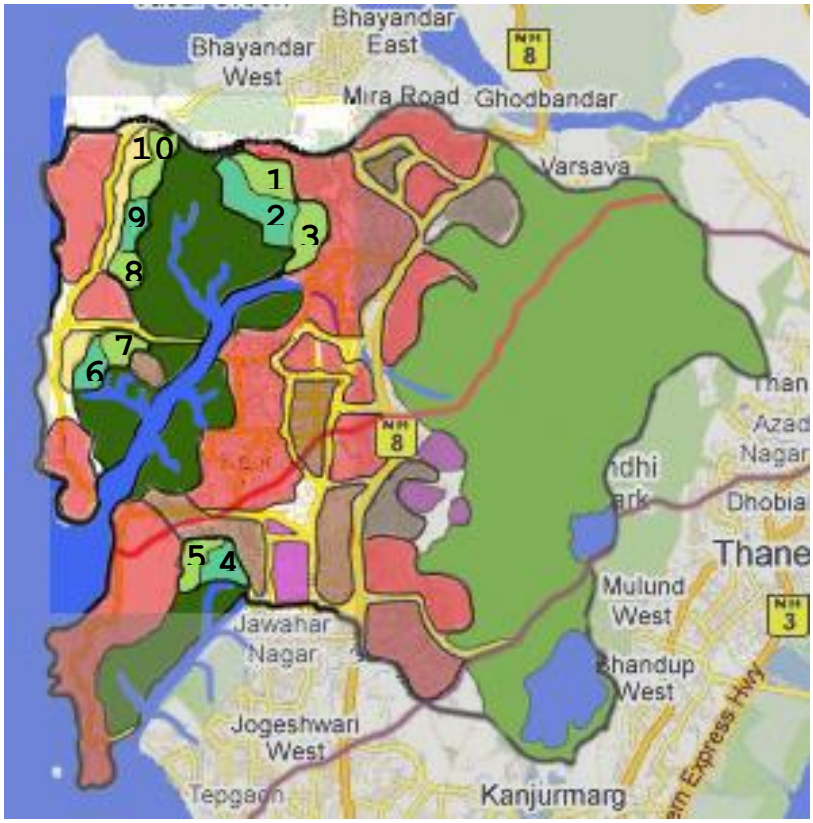


Figure 19Map showing the mangrove stands analyzed using the evaluation criteria.

Sites	Proximity to sea and freshwater	Minimal interference from built-up sites	Manageable Levels of Chemical Pollution	restoration of freshwater streams	Divergence Of contaminants	Points
1	---	---	*	*	*	3
2	*	*	*	*	*	5
3	---	---	*	*	*	3
4	*	---	---	*	*	3
5	---	---	*	*	*	3
6	*	*	*	*	*	5
7	---	*	---	*	*	3
8	---	*	*	*	*	4
9	*	*	*	*	*	5
10	---	*	*	*	*	4

The mangrove stands are marked according to the attributes they possess. A thorough analysis of the land uses surrounding the mangrove sites has aided the process of evaluating the sites. Site number 2, 6 and 9 have high potential to be rehabilitated, as they are located in close proximity of the creeks and are shielded from the built land. Site number 10 also has high potential but does not receive enough seawater flushing. Such issues can be addressed during the planning process of the management policies. The rest of the sites are disturbed by the surrounding areas and need management plans designed to address their individual needs. By studying the sites, separately many factors are revealed which lead to the formation of a set of mangrove management policies.

5.2 Administrative Zone V:

Zone V was originally inhabited by fishing villages. The zone is bounded by the Mithi River on the west, the Powai Lake on the North, the Sion Creek on the south and the Thane Creek on the east. The Zone is known for its vast acres of mangrove forests and the wild life thriving on the wetland systems. The mangrove forests in zone V are known to attract thousands of migratory birds every year. The mangrove forests are also breeding and nursery grounds for a number of aquatic species. The habitat

value provided by these mangrove forests is vast and they are home to many birds, terrestrial animals, and aquatic species.

Figure 20 Maps showing the location of Zone V and Physical features of the zone.

Huge amount of nutritional silt is deposited on the mudflats around mangroves. The mangrove forests thrive on the nutritional silt (India, 2001). Over the years, the zone has under gone an industrial boom, which supported the city's economy, but the industrial development has disturbed the zone's ecosystem. The chemical industries and oil refineries located near the mangrove forests are known to be dumping refuse in the area (Trust, 2006). The debris chokes up freshwater streams and blocks the water flow to the mangroves. Tremendous damage has been caused to the mangroves by slum encroachments. The illegal shacks have

no form of drainage and sewage disposal systems and the waste is directly dumped into the mangrove forests.

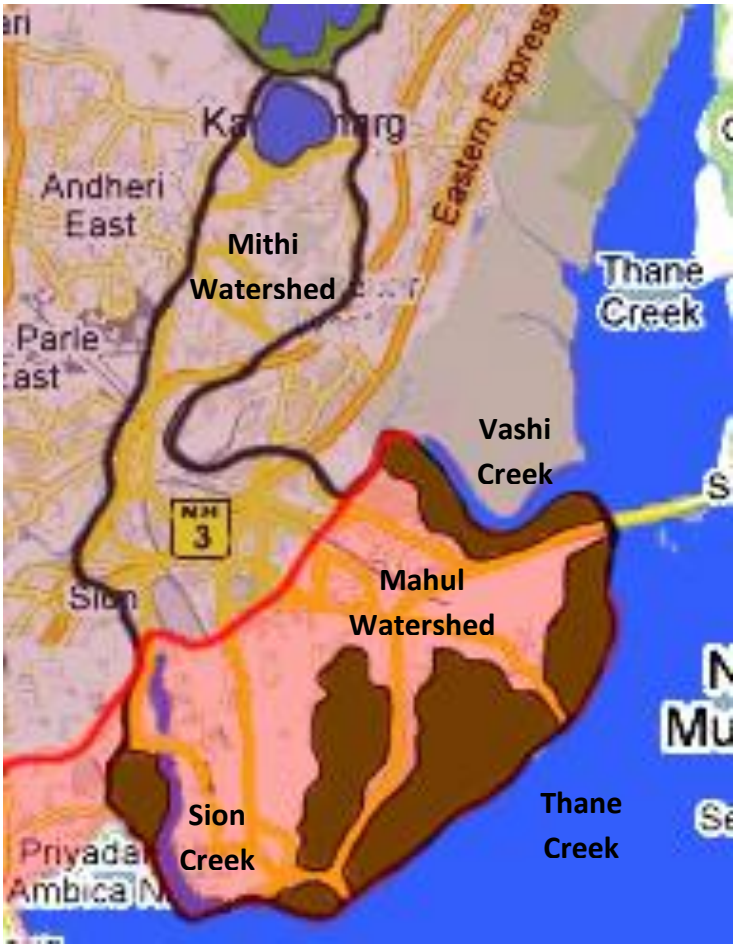
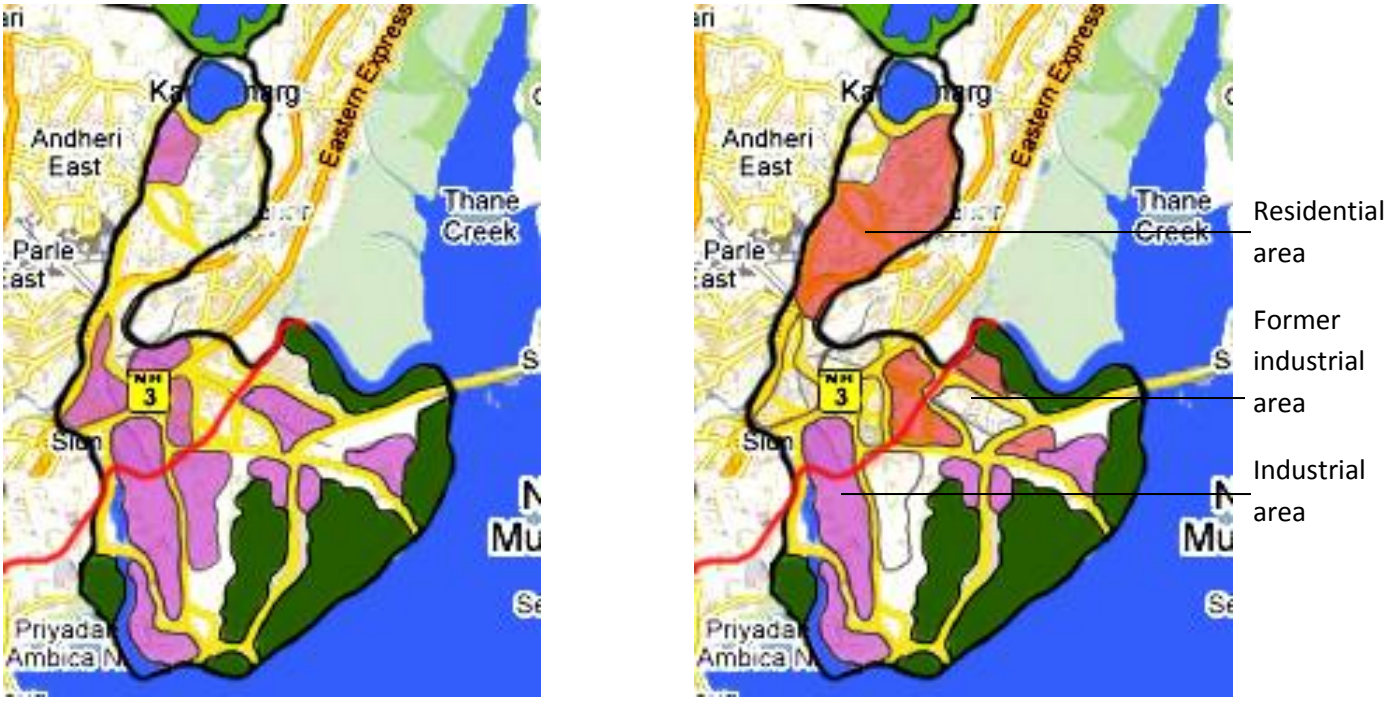


Figure 21 Maps showing the Mahul Watershed and the Mithi Watershed in Zone V.

The Administrative zone V is divided into two watersheds, the Mahul river watershed and the Mithi river watershed. The eastern coast of this zone is contained by the Mahul river watershed. The land use in this watershed is concentrated with industrial and commercial sites. The mangrove forests have been subjected to chemical dumping and storm water flows from the industries.

The land use of zone V has changed drastically. Originally inhabited by fishing villages, Trombay (Zone V) was a scenic place with series of hillocks and creeks. The zone became an attractive place for industrialization due to its proximity to the sea. As the zone boomed with industries, it was not favored for residential development. The large manufacturing cotton and chemical industries changed the scenic place into a vast hard cape. The freshwater streams are subject to industrial waste and large amounts of waste are disposed into the wetlands. The storm water collects the surface pollutants and deposits them onto mangrove soil. The mangroves in zone V inhabit a large number of wild lives. The amount of chemical pollutants discharged into the mangroves pose a threat to valuable wildlife. The mangrove stands act as breeding and nursery grounds for aquatic species. The Thane Creek is a major fishing spot and the fishing activities carried out in these waters contribute to the economy of the city. The Mangrove stands are not only economically viable but also have cultural significance. The fishermen in Mumbai worship the Mangrove forests as they recognize their importance and relevance to their livelihood. The preservation of these mangrove stands is essential for the environment of Mumbai.

In the last couple of years, many industries have been relocated, thus leaving the former industrial sites vacant. The regional plan has classified a major chunk of the industrial zone into redevelopment sites to facilitate the urban expansion. This provides opportunity to remediate industrial sites to be redeveloped and to incorporate environmental site designs, which would mitigate the impact on mangroves. The few industries still in function need to plan impact mitigation strategies to reduce their contribution of pollutants into the mangroves.



Past land use **Present land use**

Figure 22 Maps showing the change in land use development in Zone V.

The change in land use has left the landscape of this zone disturbed as now the zone has large areas of former industrial sites lying vacant and ready to be redeveloped, but the past industrial activities have affected the sites. The brown field sites need remediation before redevelopment to protect the already fragile coastline from further damage. The regional plan of Mumbai 1996-2011 proposes mixed-use development in the zone to enrich the residential areas. The redevelopment sites are proposed to be converted into social and recreational areas. The regional plan provides an opportunity to actively manage the mangrove forests and rehabilitate the mangrove stands impacted by pollution.

Figure 23. Map showing the mangrove stands in close proximity of the redevelopment sites.

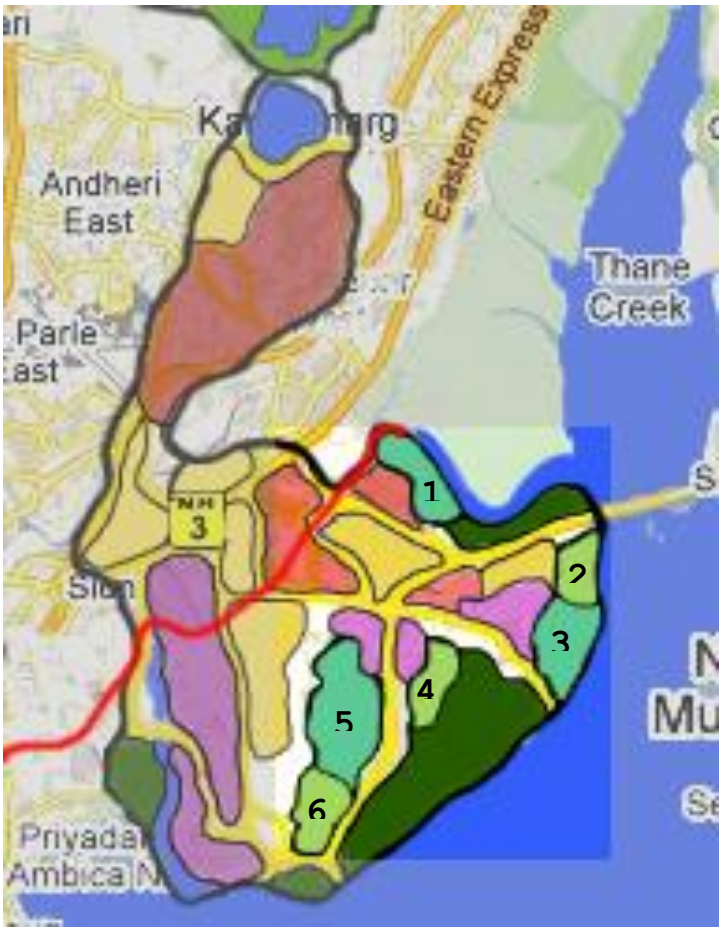


Figure 24. Map showing the mangrove stands analyzed using the evaluation criteria.

Sites	Proximity to sea and freshwater	Minimal interference from built-up sites	Manageable Levels of Chemical pollution	restoration of freshwater streams	Divergence Of contaminants	points
1	*	*	*	*	*	5
2	*	*	*	*	*	5
3	*	---	*	*	---	3
4	---	*	*	*	---	3
5	---	*	*	*	---	3
6	*	*	---	*	*	4

The mangrove forests are evaluated on the basis of the following criteria, proximity to sea and freshwater, minimal interference from built-up sites, manageable levels of chemical pollution, restoration of freshwater streams. (For detailed information about the criteria refer section 5.1.2 Evaluation Criteria.)

The mangrove stands are marked according to the attributes they possess. A thorough analysis of the land uses surrounding the mangrove sites has aided the process of evaluating the sites. Site numbers 1 and 2 have high potential to be rehabilitated, as they are located in close proximity of the creeks and the possibility of cleaning up urban runoff. Site number 6 also has high potential but has high amount of chemical pollution. It is possible to remediate the mangrove stand and bring the chemical levels to a manageable level. Such issues can be addressed during the planning process of the management policies. The rest of the sites are disturbed by the surrounding areas and need management plans designed to address their individual needs.

5.3 Administrative Zone VI:

Zone VI is bounded by the scenic hills of the National Park on the western side and the Thane Creek and saltpans on the eastern side. The zone has a 10 km (6.23 miles) long stretch of dense mangrove forests (Kurian, 2006). Originally Zone VI was a dense forest area, which gradually saw the growth of industrialization

with numerous set ups of industries, and now is becoming a very prominent destination for real estate investors, as it has a lot of opportunity of a further growth (Edwardes, 1902).

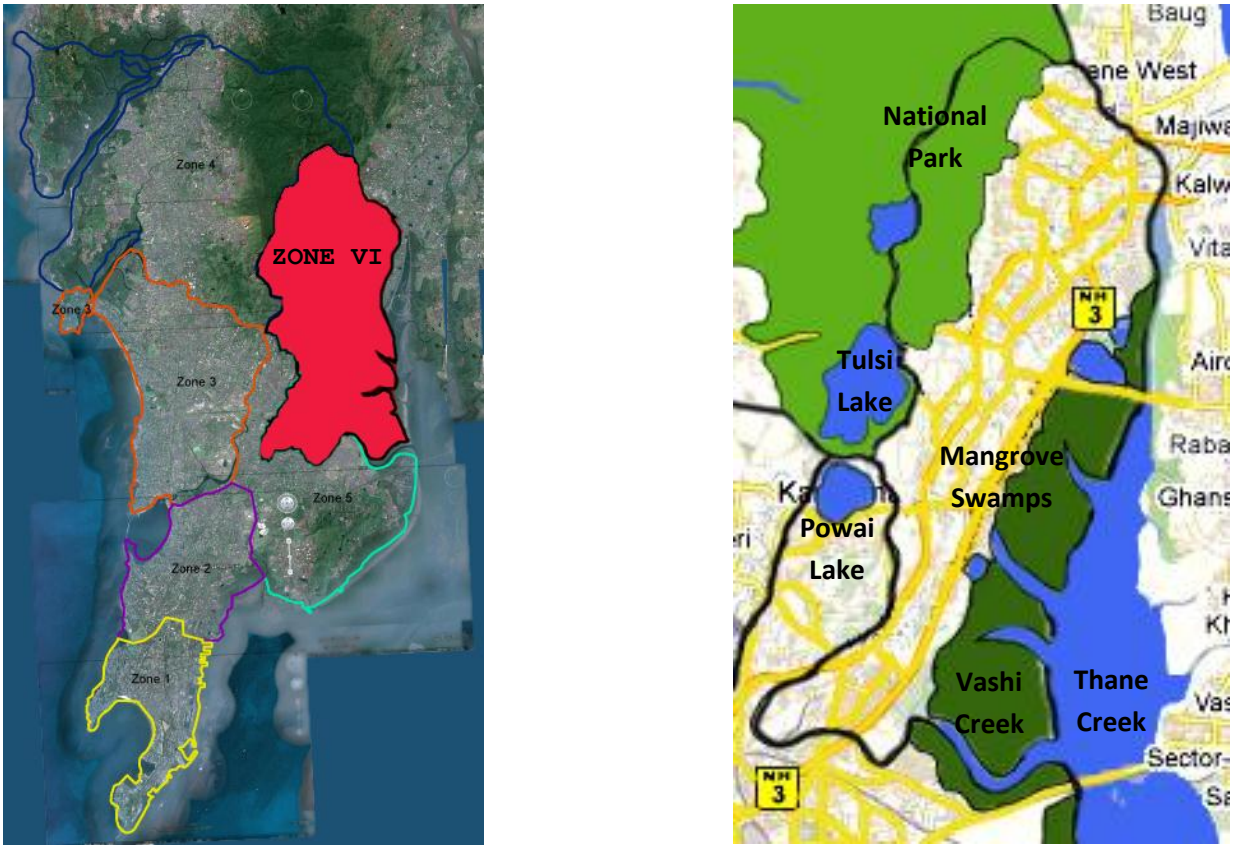


Figure 25. Maps showing the location of Zone V and Physical features of the zone.

The Thane Creek has dense mangrove forests, which provide habitat for numerous wild life species. The habitat value of these mangrove forests is tremendous. The Salt Department of India owns large portions of the wetland area. The land is converted into saltpans to collect sea salt. Saltpans located near mangrove forests leech high amount of salt into the soil

and increase the salinity. The mangrove forests are also subject to dumping of debris from surrounding construction sites (Itcon, 2002). Two large dumping grounds are located near the mangrove forests and collect waste from the city. The dumping of debris around mangrove forests blocks the flow of water to the wetlands and initiates deterioration. Zone VI is one of the oldest zones and prospered as an industrial suburb. Unlike Zone V, which was not considered favorable for residential development, Zone VI was considered ideal for residential areas.

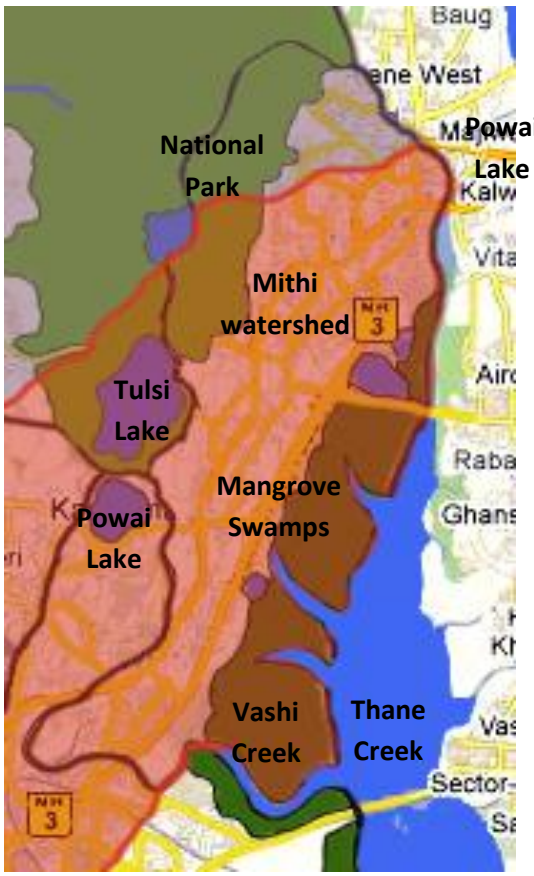
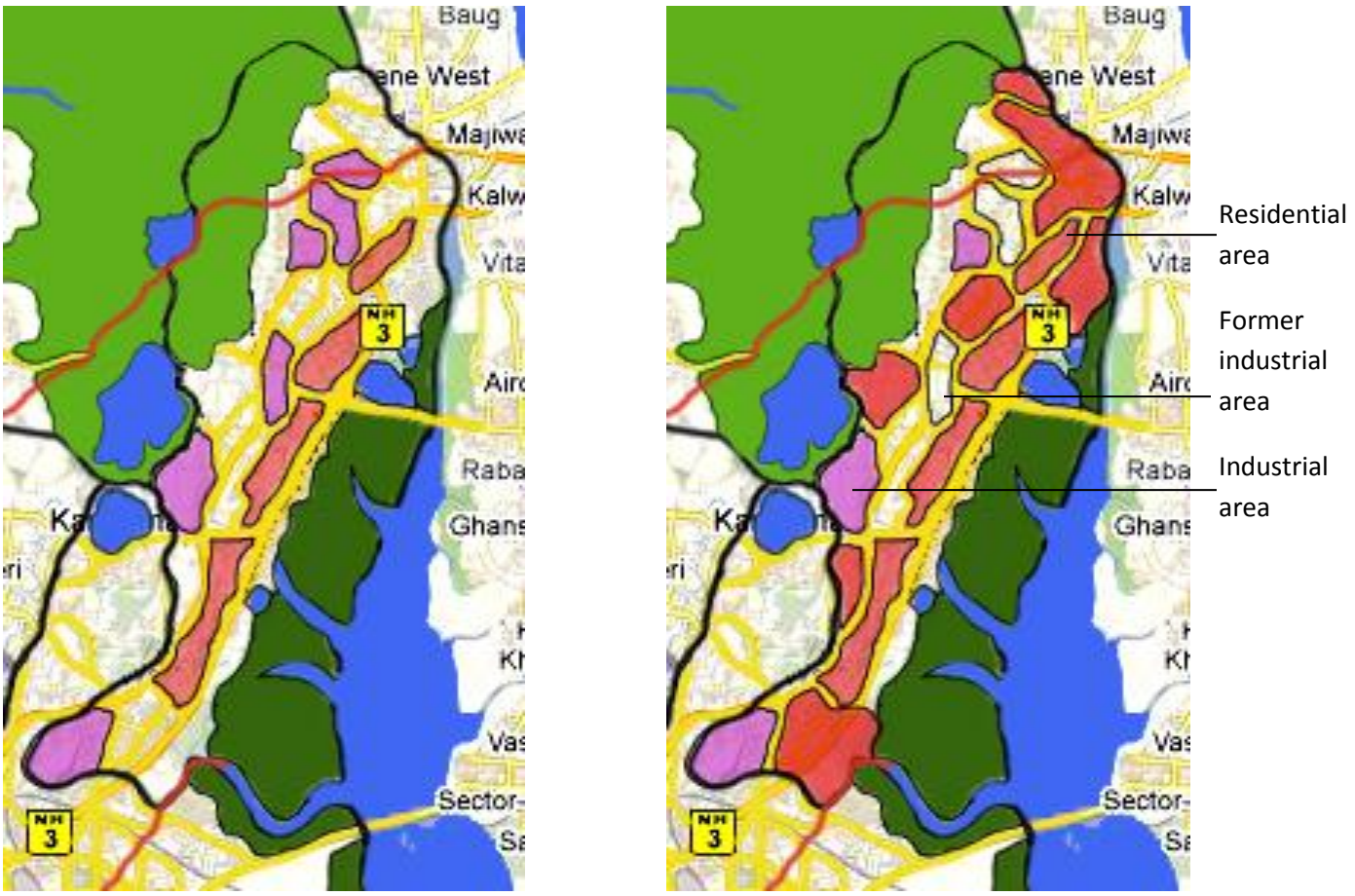


Figure 26. Maps showing the Mithi Watershed and the Mahul Watershed in Zone VI.

The administrative zone VI is divided into two watersheds, the Mithi river watershed, and the Malad river watershed. The eastern coast is contained by the Mithi river watershed. The land use in this watershed is primarily a mix of industrial and residential sites. The southern side of the coastline in this zone has residential colonies built on high tide flood plains. As this area formed the flood plain for high tides, it has a thick deposit of clay. It is one of the reasons for the dilapidated state of almost all buildings in the area. The construction of residential buildings in the wetland systems has led to weak substructures, dilapidated buildings and many demolitions. The mangrove forests are subjected to various direct impacts such as conversion into saltpans, land fill sites, industrial waste dumping, etc. the main freshwater feed for the mangroves is received from the ground water reserves. The mangrove forests in this zone and watershed are the most impacted due to direct interference of human activities. The remediation of mangrove forests around saltpans is a lengthy procedure with low rates of success. The high amount of salinity renders the soil infertile and requires years of freshwater flushing to reduce the salt content. The mangrove patches away from the saltpans have a better chance of surviving. The industrial sites are planned to be redeveloped into residential communities to promote a better lifestyle.



Past land use **Present land use**

Figure 27 Maps showing the change in land use development in Zone VI.

The land use in this zone has changed over the years. The zone has developed into an ideal suburb with generous green spaces. The zone retains its cultural essence, thus making it more favorable for new residents to move in. The green belt along the coast acts as a perfect setting for residential recreation and social activities. The regional plan proposes to develop the former industrial sites into social and recreational spaces. The zone will be introduced with more spaces that are residential.

This urban expansion proposed by the regional plan will affect the mangrove forests tremendously. The mangrove forests are already impacted by high salinity and urban pollution. Further expansion will aggregate the impacts and make the mangrove stands vulnerable to deterioration. The rehabilitation plan of these mangrove forests needs to be included in the development plan for the zone. To aid the process of mangrove management the mangrove stands are evaluated with respect to a number of criteria.

The mangrove forests are evaluated based on the following criteria, proximity to sea and freshwater, minimal interference from built-up sites, manageable levels of chemical pollution, restoration of freshwater streams. (For detailed information about the criteria refer section 5.1.2 Evaluation Criteria.)

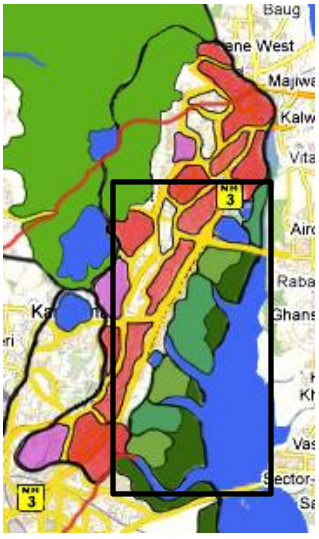


Figure 28. Map showing the mangrove stands in close proximity of the redevelopment sites.

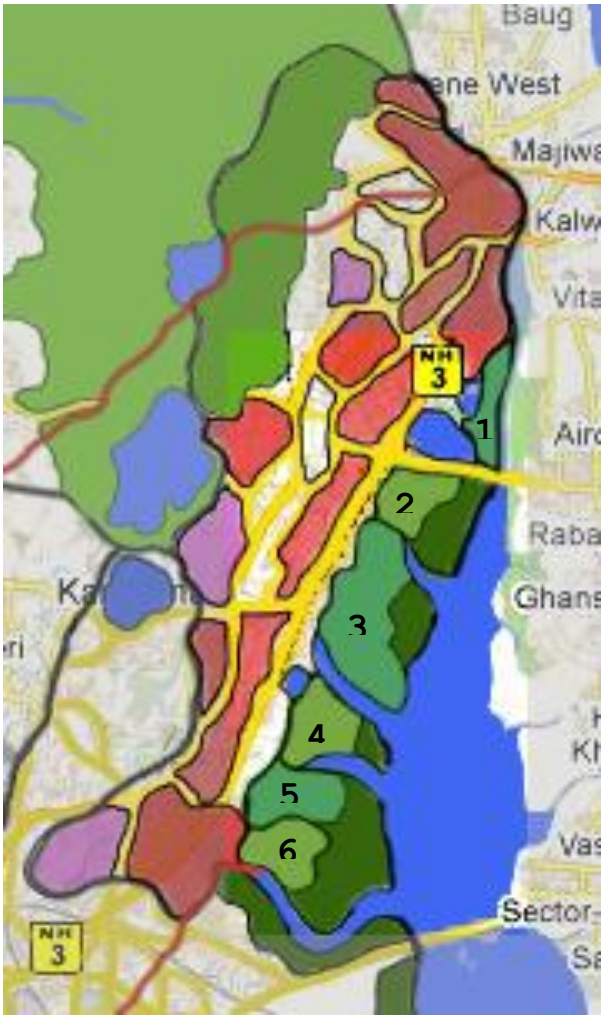


Figure 29 Map showing the mangrove stands analyzed using the evaluation criteria.

Sites	Proximity to sea and freshwater	Minimal interference from built-up sites	Manageable Levels of Chemical pollution	restoration of freshwater streams	Divergence Of contaminants	points
1	*	*	*	*	*	5
2	*	---	*	*	---	3
3	*	---	*	*	---	3
4	*	*	*	*	*	5
5	*	*	*	*	*	5
6	*	---	*	*	*	4

The mangrove stands are marked according to the attributes they possess. A thorough analysis of the land uses surrounding the mangrove sites has aided the process of evaluating the sites. Site numbers 1, 4, and 5 have high potential to be rehabilitated, as they are located in close proximity of the creeks and are shielded from the built up areas. However, Site number 6 has high potential; it is impacted by the adjacent residential area. Site numbers 2 and 3 have low potential to be rehabilitated due to the presence of saltpans. It is possible to remediate the mangrove stand and bring the salinity levels to a manageable level but the process can take years. Such issues can be addressed during the planning process of the management policies. The rest of the sites are disturbed by the surrounding areas and need management plans designed to address their individual needs.

6.0 Strategies for Mangrove Management:

The discussion of existing land use patterns and proposed land developments in the administrative zones helps understand the difference in the development trends and management requirements of each zone. The mangrove forests deal with different issues caused by the effects of urbanization.

6.1 Implementation Strategies:

The city's civic authorities can design and implement policies to guide private development, to protect the coastal environments by reducing impacts generated from private land development.

The mangrove forests are protected by the forest department of Maharashtra but due to lack of monitoring and enforcement regulations, illegal encroachments are destroying mangrove forests. Mangrove management is part of the coastal zone management of India. However, on a regional scale, more focused management tools are needed:

- The National wetland management act should be involved into process as the government, non-government organizations, users, mangrove dwellers, and the scientific communities work together for mangrove management plans to work

effectively. This is currently missing from the city's management policies.

- The information provided to the public should be generated from a collective database with systematic investigations undertaken by the regional and national authorities.
- Public involvement in monitoring and volunteering for management activities promotes a sense of responsibility and ensures local participation. The angler's communities living around mangroves have high regard for the wetlands as the mangroves provide nesting grounds for the fish and are a major part of the anglers' lifestyle. Involving these communities in the management process will ensure public support and certain incentives regarding collection of forest material for these communities can help them more during the low seasons.
- Exemplary Ecological Designs: The planning and development regulations in Mumbai prohibit site development around mangroves. This has led to a series of illegal construction and mangrove destruction. The option of permitting exemplary site designs to be implemented on mangrove sites will allow the urban landscape to merge with the environment of the city.

  A Site design such as the Sydney Olympic Park, Australia, Is a good example of site remediation and successful

mangrove restoration (Campbell, Plan of managemnet for the parkland at Sydney Olympic Park). The mangrove forest within the large sports complex has been restored and is protected from all the impacts possible from its surroundings (Campbell, 2001).

Such designs should be promoted to help restore mangrove forests and allow the city to expand.

- Community based forest management: A Community-Based Forest Management Agreement (CBFMA) is a land tenure instrument for mangrove habitats to be given to qualified and organized coastal communities.

  The residential sites present around mangrove forests should be encouraged to be actively involved in such activities. The residents can in return be allowed to use mangrove forests for passive recreation such as boardwalks, bird watching, walks, social gatherings, etc.

- Tax incentives: the government should provide land tax incentives to site designs, which adopt mangrove mitigation plans to manage the mangroves on or near the site. The government to help the developing agencies with the procedures should support remediation of brown field sites. Such incentives will promote mangrove forest adoption and active involvement from the developers.

The government provides policies for mangrove management and protection but the main implementation and monitoring procedures are carried out on a local and regional scale.

For site scale mangrove-management, the coastal regulatory zone act should be referred and the regional plan proposed by MMRDA should provide basic guidelines to ensure the implementation of mangrove mitigation procedures. If a development site encounters wetland systems on site or if the environment impact assessment of the site plan indicates impacts on nearby mangrove stands, the following strategies should be adopted along with other mangrove mitigation policies:

- Delineate the mangrove forests located on site or assessed to be impacted near site.
- Highlight the impacts from site construction on mangrove forests and develop a mitigation plan to eliminate activities, which are most expected to affect mangroves.
- Consult qualified professionals to guide through the mitigation plan adopted for the mangrove on site.
- Explore options like wetland adoption, environment enhancement methods to be incorporated into the site design concepts.
- Reduce all kinds of direct or indirect impacts on the mangrove environments in the design phase.

- Brown field sites in the industrial zone need to be remediated from chemical and heavy metal pollutants.

The regional plan proposed by the MMRDA should develop guideline policies for brown field remediation to ensure the restoration of mangrove forests during the redevelopment of industrial sites. The policy should ensure the following:

- Proper delineation of mangrove forests on and around brown field sites.
- Brown field assessment carried out by qualified agencies.
- Delineation of contaminated areas and a thorough report on the type and level of contaminants present on site.
- Adopt appropriate phyto-remediation methods with respect to the contamination report.
- Phyto-remediation methods should be implemented and monitored by qualified agencies.
- Depending on the mangrove acreage lost due to contamination, mangrove restoration should be carried out to restore the lost acreage.
- Mangrove restoration can be carried out on site or on another site in the same watershed.
- Regular monitoring of remediation and restoration sites should be reported to ensure the progress of mitigation

7.0 Conclusion:

An overview of the regional plan and mangrove management strategies indicates possibilities of achieving the goal of restoring mangrove forests in Mumbai. The coastline of Mumbai can develop into a thriving urbanized center and still the coastal wetland systems can function to protect the urban sprawl. The population density of Mumbai is expected to keep rising, thus ensuring the need for constant urban development to accommodate the needs of the people.

The Mumbai Metropolitan Region is expanding into the mainland, away from the islands for a better planned environment. But it still requires infrastructure to connect with the Greater Mumbai Region and the demand for land on the islands will never fade due to the presence of the Central Business District. The mangrove environments protect this valuable land and the need to protect them is more required now than ever.

Although the regional plan promises a well-developed future, the absence of a mangrove mitigation plan will lead to major environmental issues. The mangrove mitigation plan, proposed as an addendum to the regional plan helps promote the urban development & balances the environment, and maintains the social landscape of the city.

There is no doubt that the mangrove mitigation plan needs more development and there is scope for more research. In short, the high demand for urbanized land in Mumbai gives rise to high demand for environmental protection. Learning from the mistakes made in the past and current requirements, the city has great potential to establish itself as a vibrant, self-sustained, balanced, and developed coastal city.

APENDIX

Characteristic features of Mangroves:

A distinctive character of mangals is diversity in appearance of vegetation. Some plants have looping stilt roots while some plants have needle- like aerial roots. Some are evergreen with shiny leaves while others have rough and pale leaves. The soil is firm in some places and muddy and slushy in other places, so that walking is walking is difficult if not possible. In the muddy and slushy substrate, a disturbance produces a strong smell of hydrogen sulfide, indicating the completely anaerobic property of waterlogged soils. Canopy height of mangroves depends on climate, topography extent of human disturbance. The mature, undisturbed, mangrove forest develops a high, dense canopy and the trees have tall boles. The canopy looks monotonous because of almost uniform size, shape, and texture of leaves. In a disturbed environment, mangrove plants are stunted and scrubby.

The organisms of mangrove ecosystem can be marine, estuarine, or terrestrial in origin. Floral components include algae, fungi, vascular plants, sea-grasses, phytoplankton, epiphytes etc. Faunal components include benthic dwellers like coelenterates, avifauna, polychaetes, mollusks, annelids, reptiles, & mammals.

Mangroves are a very important part of the ecological system & basically, it helps to stabilize the environment so that there are no extremes of temperature, humidity & wind. They acts as kidneys to the coastal waters - both, sea & fresh water get filtered through mangroves. They are extremely hardy, since they have to survive & grow in the hostile environment of the intertidal zone. Home to a large number of life forms like the fishes, amphibians, reptiles, etc., the mangroves are the stabilising factors of nature. They maintain the balance of the ecosystem within the marine life that is very important to mankind.

MANGROVE FOREST

Types of mangrove forest:

Various types of mangrove forest are as follows:

1. **Over washed mangrove forests**: These are Small Island covered with mangroves frequently formed by tidal washing. The dominant species is Rhizophora or red mangrove.

2. **Fringing mangrove forests:** These strips of mangrove are found along water ways, protected shorelines and island influenced by tidal range. They are sensitive to tides,

prolonged exposure to pure marine conditions and erosion. The dominant species are Rhizophora, Sonneratia and Avicennia.

3. **Riverine mangrove forests:** These are luxuriant patches of mangroves existing along tidal rivers and creeks which get flooded daily by tides. Such forests have taller growing trees because of incursion of large amount of fresh water with alluvial nutrients and these are highly productive. The dominant species constitute Rhizophora, Sonneratia, Bruguiera, Aegiceroas, Avicennia, Excoecaria etc.

4. **Basin mangrove forests:** These are located in drainage depression and along the interior side of swamp with stunted growth of mangroves. They are positioned along the terrestrial run off with a slow velocity of water flow towards the coast. The dominated species is Avicennia.

5. **Hammock mangrove forests:** These are similar to basin mangrove forest with more elevated sites.

6. **Scrub mangrove forests:** These are dwarf mangrove forest along the flat coastal fringes.

According to the physiological and morphological characteristics, mangroves are classified into two types.

True mangroves:

- True mangroves show presence of specialised roots and leaf structure.
- They are highly salt tolerant species.
- True mangroves are taxonomically isolated from their terrestrial relatives.
- Examples: Avicennia marina, Kandelia candel, Bruguiera cylindrical.

Mangrove associate:

- These are the terrestrial plants adapted for the mangrove environment
- Examples: Salvadora persica, Sesuvium portulacastrum

MANGROVES SPECIES IN MUMBAI

1. River Mangrove

Scientific Name : Aegiceroas corniculatum.

Common Name : River mangrove.

Family : Myrsinaceae.

Status (IUCN criteria): EN (Endangered).

Source of honey, tannin, and fish poison

- Prefers less saline area
- Endangered

2. Orange Mangrove

Scientific Name : Bruguiera cylindrica.

Common Name : Orange mangrove.

Family : Rhizophoraceae.

Status (IUCN criteria): EN (Endangered).

- Source of firewood, charcoal
- Leaves for blood pressure and fruits to stop bleeding
- Identified by knee roots
- Endangered

3. Grey Mangrove

Scientific Name : Avicennia marina.

Common Name : Grey mangrove.

Family : Avicenniaceae.

Status (IUCN criteria) : EN (Endangered).

Source of fuel wood, timber, pickle, cattle feed

- Commonest on west coast
- Used as abortive, snakebites and wounds

4. Red Mangrove

Scientific Name : Rhizophora mucronata.

Common Name : Red mangrove

Family : Rhizophoraceae.

Status (IUCN criteria): VU (Vulnerable)

- Source of firewood, mosquito repellant, cure for diabetes, dysentery, hemorrhage
- Identified by prominent stilt roots and pointed apex
- Endangered

5. Scientific Name : Ceriops tagal.

Family : Rhizophoraceae.

Status (IUCN criteria): EN (Endangered)

6. Mangrove Apple

Scientific Name : Sonnertia Alba.

Common Name : Mangrove apple.

Family : Sonneratiaceae.

Status (IUCN criteria): EN (Endangered)

- Source of timber, fruits as food
- Pollinated by bats
- Grows in unstable conditions, preferred for forestation

Mangrove Associates

1 **Sea Holly**

Scientific Name : Acanthus ilicifolius.

Common Name : Sea holly.

Family : Acanthaceae.

Status (IUCNcriteria): EN (Endangered).

- Indicator of mangrove degradation
- Twiny habit and spiny leaves
- Grows on high tide mark, lobster mounds
- Used as desiccant, in rheumatism, neuralgia, kidney stones, cold, skin allergy an as an antiseptic also.

2. Milky Mangrove

Scientific Name : Excoecaria agalocha.

Common Name : Milky mangrove.

Family : Euphorbiaceae.

Status (IUCN criteria): VU (Vulnerable)

- Sap cause skin irritation and blindness
- Sap to treat toothache, ulcers and as fish poison
- Bark for planks, matchboxes, fish poles
- Can grow in dry, saline areas
- Being tested for anti-HIV, cancer, bacterial and viral flowers

3. Meswak

Scientific Name : Salvadora persica.

Common Name : Meswak.

Status (IUCN criteria): EN (Endangered)

- Seeds yield oil for soap industry
- Roots as astringent, toothbrush
- Leaves as food during famine, drought
- Mangrove Associate
- Endangered

4. Scientific Name : Suaeda nudiflora.

Family : Chenopodiaceae.

Status (IUCN criteria): EN (Endangered)

5. Scientific Name : Clerodendrum inerme.

Family : Verbenaceae.

Status (IUCN criteria): EN (Endangered)

6. Scientific Name : Sesuvium portulacastrum.

Common Name : Ghol.

Family : Aizoaceae.

Status (IUCNcriteria): EN (Endangered)

7. Scientific Name : Thespesia populnea

Family : Malvaceae

Status (IUCN criteria)

Associated Fauna:

Terrestrial Fauna:

•Micro-organisms - Bacteria, fungi

•Insects - Ants, Moths, and Butterflies

•Arachnids - Spiders

•Amphibians - Frogs and toads•Reptiles - Lizards, snakes, turtles, crocodiles

•Avifauna- Waders, raptors, egrets, harriers

•Mammals - Bats, mongoose, jackals, cats

Aquatic Fauna:

•Echinoderms - Starfish

•Annelids - Earthworms

•Mollusks – Shells

•Arthropods - Crabs

•Pisces - Mudskipper fish

•Mammals - Otter, sea horse

Mangrove Management- Sustainable management of coastal mangrove forest development and social needs:

The "sustainable" management of "the ecosystem" as a whole or an "integrated management" of the mangrove resources across several tropical countries is an added dimension to the management techniques developed for coastal wetlands . Demonstrated successful adaptation of such management techniques is yet to be recorded though many countries are seriously thinking or starting such practices.

Mangrove users, along with the mangrove dwellers, need to receive due consideration and to be incorporated into such management activities to ensure people's participation at large. It is suggested that the following may be considered in this connection.

- Mangrove management should be a component of the total coastal zone management of the country.
- Mangrove management planning should be a consultative effort between government, nongovernmental agencies, resource users, mangrove dwellers, and the scientific community.
- Public awareness should be raised regarding the value of mangroves with special emphasis on their linkage effects.

- An information database needs to be improved with systematic investigations under national and international sponsorships.
- Political commitments towards the sustainable management of mangrove ecosystems will be required at the national levels.
- Cooperation among international mangrove institutions should be enhanced to exchange ideas and experience in the field of the mangrove ecosystem and its management.

Present mangrove management techniques have often failed to retain the original level of the resource. The dynamic nature of the ecosystem needs to be duly considered and an integrated management approach on a sustained yield basis, under the umbrella of a total coastal zone management plan for the country concerned, needs to be initiated with the creation of true mangrove reserves to conserve biodiversity at large (Junaid K. Choudhury, Forest Department, Bangladesh).

Mangrove Management- Northern Territory coastal management policy, Australia:

Effective mangrove management will be achieved by providing a coordinated framework for future mangrove conservation and utilization around the NT coastline. Around 450 kms i.e., around 12% of the mangroves found throughout the Territory have been protected within National Parks, Conservation Reserves, Nature Reserves, and other Conservation areas.

- Effective management will be achieved by:
- Highlighting mangrove areas which have specific conservation, economic or community values;
- Ongoing monitoring and reporting on the condition of mangroves;
- Research to fill the information gaps;
- Utilizing current legislative mechanisms to conserve these values, and
- Ensuring that future coastal development is progressed in an ecologically sustainable manner.

The Northern Territory Government is committed to conserving and managing the mangroves of the NT in recognition (Mangrove Management in the Northern Territory, Chapter 4, Northern Territory Government, and Australia)

Community-based Forest Management Agreement:

A Community-Based Forest Management Agreement (CBFMA) is a land tenure instrument for mangrove habitats to be given to qualified and organized coastal communities. A CBFMA is a production sharing agreement entered into, between an organized community and the government to develop, and conserve a specific portion of forestland and or allowable portion in protected areas consistent with the principle of sustainable management, and development & pursuant to an approved Community Resource Management Framework (CRMF) Plan. A CRMF Plan defines the terms and procedures for access, use, and protection of natural resources within the CBFMA area. The CBFMA provides a multitude of benefits to the holder ranging from management control over the area and exemption to pay taxes or rent normally levied by the government to natural resource users aside from being bankable (D.M. Melana et al, Coastal Resource Management Project of the Department of Environment and Natural Resources, United States Agency for International Development).

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