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Editorial Note

Flood is the most common and recurrent natural disaster in our country. Every year, on an average, we are losing well over thousand five hundred people, hundred thousand animals, hundred and fifty thousand houses besides standing crops over eight million hectres of land. It is estimated that goods and assets worth more than thousand crores are lost every year due to the furies of floods.

Over the years the country has invested hundreds of thousand crores on flood protection and mitigation measures. Many of these measures have protected lands and assets in many places, but the overall impact of such investments are not seen in reducing the risks of flood. In fact, the risks of flood seem to be increasing every year.

A number of factors are responsible for these developments. First, carrying capacity of our rivers are getting reduced due to increasing silt loads. Even normal to heavy rains are swelling rivers to flood the banks. Secondly, increasing demand of water have reduced the capacity of reservoirs to store excess water and spill off even during normal rains, thereby creating manmade floods in many places. Thirdly, the rainfall pattern itself is changing breaking past trends and records, as demonstrated during the unprecedented rainfall in Mumbai in July 2005 when a single day rain exceeded the annual average. Last, but not the least, pressures of population, particularly in the urban areas, have resulted in unplanned and even planned settlements in flood panes that have exposed more people to the risks of flood.

In fact, urban flood has emerged as an important issue of disaster management in our country. As we are passing through the peak process of urbanization, when about 300 million people are expected to be added to our cities during the course next two decades, we have the challenging task to ensure that the risks of flood in our cities are reduced.

The National Institute of Disaster Management had conducted a series of coordinated studies on urban flood. The last issue of our journal had published four such study reports. We are happy to publish the remaining four reports in the current issue.

(P. G. Dhar Chakarbarti)

Urban Floods: Case Study of Bangalore

T. V. Ramachandra and Pradeep P. Mujumdar

Profile of the City

Bangalore is one of the fastest growing cities in India and is branded as 'Silicon Valley of India' for heralding and spearheading the growth of Information Technology (IT) based industries in the country. With the advent and growth of IT industry, as well as numerous industries in other sectors and the onset of economic liberalisation since the early 1990s, Bangalore has taken lead in service-based industries fuelling substantial growth of the city both economically and spatially. Bangalore has become a cosmopolitan city attracting people and business alike, within and across nations. This profile notes the urban setting and provides an overview of the urban fabric, while discussing various prospects related to infrastructure and governance (Sudhira, et al. 2007).

Bangalore

Bangalore[1] is the principal administrative, cultural, commercial, industrial, and knowledge capital of the state of Karnataka. Greater Bangalore[2], an area of 741 square kilometres agglomerating the city, neighbouring municipal councils and outgrowths, was 'notified' (established) in December 2006 (Figure 1.1 and Figure 1.2). A tiny village in the 12th century, it grew to become one of the fastest growing cities in the world by the 21st century and to figure among the million-plus cities in India[3]. Bangalore has grown spatially more than ten times since 1949 (Table 1.1).The city enjoys a pleasant and salubrious climate throughout the year. Its tree-lined streets, numerous parks and abundant greenery have led to it being called the '*Garden City*' of India. It has also been identified as the country's *'Silicon Valley'* and it is one of the technological innovation hubs with a technological achievement index (TAI) of 13[4]

* Contributed as Bangalore city team under National Coordination Project of NIDM (Anil K Gupta and P.G. Dhar Chakraborti, Disaster & Development, 3 (1): 1-14,2009).

* Data compilation Analysis: Uttam Kumar, Sudhira H.S., Chitra S. Raju and Ranjini V.

1 *The name, Bangalore has been proposed for renaming to 'Bengalooru' by the State government following suit of Bombay to Mumbai, Madras to Chennai and Calcutta to Kolkota. However, we use Bangalore all through.*

2 *The Urban Development Department, Government of Karnataka has issued gazette notification vide No. UDD/92/MNY/2006, dated 2.11.2006 for constituting the Bruhat Bangalore Mahanagara Palike (Greater Bangalore City Corporation) merging the existing area of Bangalore City Corporation, 8 Urban Local Bodies (ULBs) and 111 Villages of Bangalore Urban District.*

3 *PTBangalore is the fifth largest metropolis in India currently with a population of about 7 million.*

4 *Almost on par with San Francisco, USA, while Silicon Valley, USA is number 1 with TAI of 16.*

according to the Human Development Report (United Nations Development Programme, 2001). However, with all the hype about growth in IT and IT based industries, Bangalore also houses numerous other leading commercial and educational institutions, and industries like textiles, aviation, space, biotechnology, etc. As an immediate consequence of this growth in the last decade, apart from creating a ripple effect in the local economy, there has also been great pressure on infrastructure and resources like water supply, energy, public transportation, land, etc. The local body and other parastatal agencies responsible for delivery of basic services are facing stiff challenges in catering to this demand.

Table 1.1: Bangalore City Corporation limits over the years

Year	Area (sq. km)
1949	69
1963-64	112
1969	134
1979	161
1995	226
2007	716

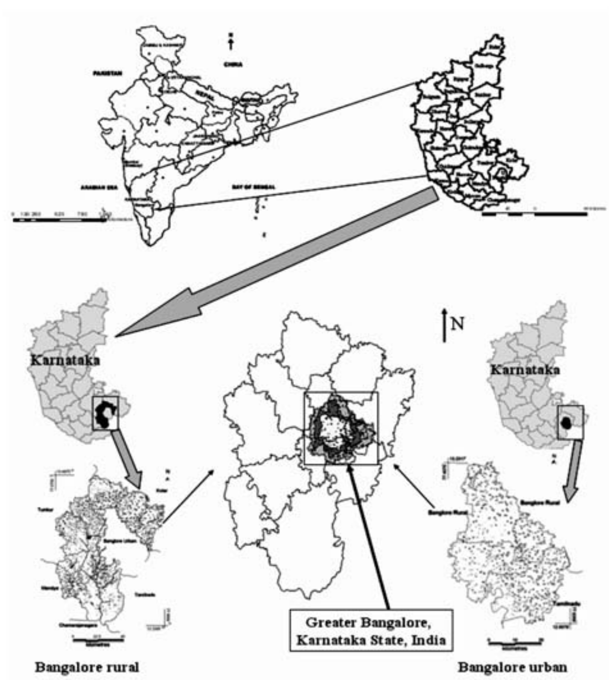

Figure 1.1. Location of Creator Bangalore

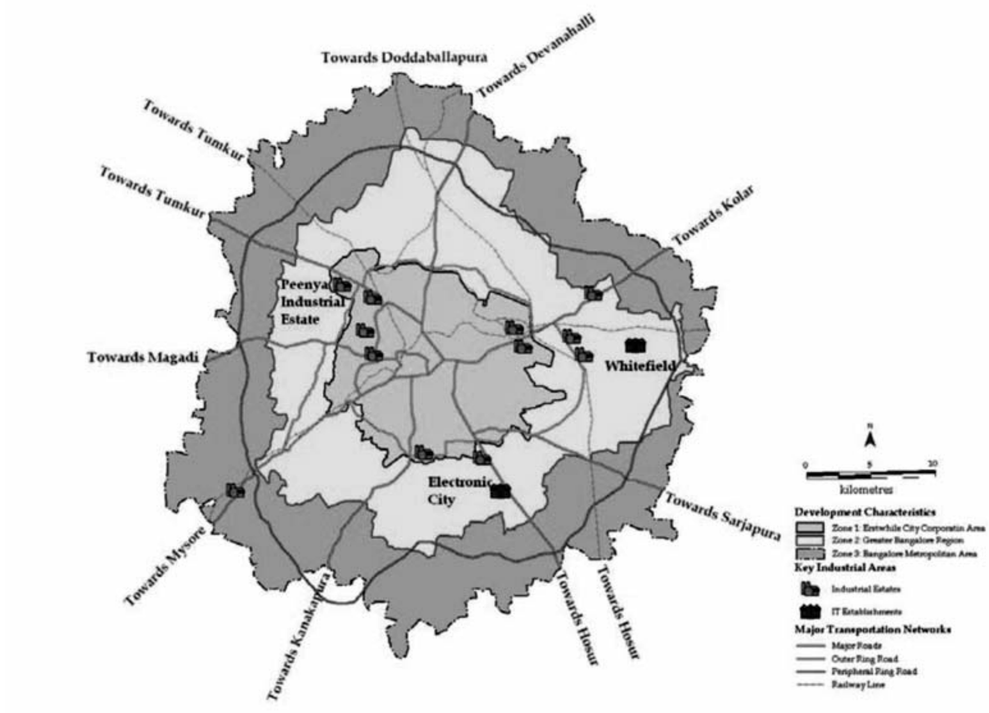

Figure 1.2: Map depicts Development Characteristic over Bangalore with the erstwhile City Corporation limits, Greater Bangalore region and Bangalore Metropolitan area and noting some of the prominent industrial areas.

Quite recently there have been serious attempts by sociologists and urban planners to characterise the city. Heitzman (2004) has analysed the nature of growth that the city experienced with the emergence of the information society, while bringing out the ingredients that led to the transformation of planning methodologies and spatial planning tools for the city. Nair (2005) has exemplified Bangalore as 'the promise of the metropolis' while illustrating the urban fabric of Bangalore over the last century. In this profile, an attempt is made to bring out the status of current infrastructure and various facets of planning and governance.

The next section deals with the origin and history of the city followed by a description of climate, geography and environment. The subsequent section considers culture, demography and economics. Lastly, the urban agenda addressing governance and infrastructure discussing the stakeholders involved, challenges in managing urban infrastructure and issues in planning and development are elaborated.

History and Culture

The earliest reference to the name, in the form '*Bengalooru*', is seen in a ninth century Ganga inscription (hero-stone) from Begur , referring to a battle that was fought in that place. The present name of the city, Bangalore is an anglicised form of *Bengalooru* which according to the popular belief is derived from *Bengaalu* - synonymous of *Benda kaalu* or boiled beans and *ooru* meaning a town. Tradition associates Hoysala King Vira Ballala (12th Century) with the origin of this name. Vira Ballala, during one of his hunting expeditions in this region, lost his way and after hours of wandering reached the hut of an old woman. This woman is believed to have offered cooked beans to the king. Pleased with her hospitality, the king named the place as '*benda kaala ooru*' (town of boiled beans). But it is interesting to note that there was already evidence for name of the place much before Hoysalas. Kamath (1990) notes that Bangalore is said to have got its name from *benga,* the local Kannada language term for *Pterocarpus marsupium*, a species of dry and moist deciduous tree, and *ooru*, meaning town. However, the founding of modern Bangalore is attributed to Kempe Gowda, a scion of the Yelahanka line of chiefs, in 1537 (Kamath, 1990). Kempe Gowda is also credited with construction of four towers along four directions from *Petta*, the central part of the city, to demarcate the extent of city growth (Figure 2). By the 1960's the city had sprawled beyond these boundaries (Asian Development Bank, 2001).

Figure 2: The Kempe Gowda Tower at Lalbagh – one of the four towers Kempe Gowda built to demarcate the extent of city growth in four directions [**Photo: H. S. Sudhira**]

Later on, the city was administered by the Wodeyars, rulers of Mysore, until it was given as *Jagir* (with rights for general administration and collection of taxes) to Hyder Ali during late 18th Century. Hyder Ali and later, his son, Tippu Sultan, were responsible for growth and development of Bangalore in a significant way with the construction of summer palace and Lalbagh. Indeed, Bangalore was already the commercial capital during Tippu's time and the second important city after Srirangapatna, Tippu's capital. During the early nineteenth century, the city was known to have almost all coins in circulation from different places and kingdoms, thus evidencing a flourishing trade and commerce (Buchanan, 1870). The fall of Bangalore in the Second Mysore War of 1792, may also have led to the fall of Tippu Sultan in Third Mysore War of 1799, after which Bangalore became a base for the British troops and saw the establishment of the Cantonment in 1802. British control over Bangalore was initially established indirectly through the Maharaja of Mysore. By 1831 the administration of the city was taken over by the British, and in 1862 two independent municipal boards were established: Bangalore City Municipality (in the older areas), and Bangalore Civil and Military Station Municipality. At Independence, Bangalore was notified as the capital of Mysore (now Karnataka) State. In 1949, the two municipalities were merged and the Bangalore City Corporation was formed. Subsequently, to keep up with the pace of growth and development, there have been reorganizations with respect to the zones and wards within the corporation, rising from 50 divisions in 1949 to 95 wards in 1980s, 100 wards in 1995 and now about 150 wards. With the 2006 notification, the Bangalore City Corporation is now reorganized as Greater Bangalore City Corporation (Note 2).

Bangalore, in spite of the buzz around IT-based and related commercial activities, has retained much of its unique cultural ties keeping its date with its history, culture and tradition. The city is known for historical temples such as the Someshwara temple in Halasuru (neighbourhood of Bangalore) built during 12th – 13th century by Cholas, Basavanagudi (Bull Temple) built by Kempe Gowda during 16th century, Kaadu Malleshwara temple built during 17th century in Dravidian architecture, and Gavi Gangadhareshwara temple, all nestle in the middle of the city. Apart from the numerous temples that have mushroomed around the city, Bangalore also has one of the six basilicas in the country, built during the 17th century, St. Marks Cathedral built during 1808, the oldest mosque, Sangeen Jamia Masjid built by the Moghuls during the 17th century, and the popular Jamia Masjid near the City Market built during the 1940s. The 'Bengalooru Karaga' is a major annual fair associated with the Dharamaraya temple, is considered to be the actual fair of the erstwhile city, and is still persistent in the older central parts of the city. Karaga, a five-day festival of Tigalas, a community who migrated from Tamil Nadu, has many unique features such as intense religious fervour, strict rituals, unchanged traditions over centuries, a fixed route and stops for the procession, welcome and respect shown at all the temples on route. The annual groundnut fair, '*Kadalekai Parishe*' takes place in a part of old city, Basavanagudi during November-December. More recently, an annual cultural fest called '*Bengalooru Habba*' ('*habba*' in kannada means festival) is held during the first week of December hosting various cultural programmes like music, dance and drama. The involvement of all sections of people and the unique communal harmony displayed by the special prayer at Tawakkal Mastan Darga (mosque) are also remarkable (Chandramouli, 2002).

Geography and Environment

Bangalore is located at 12.591/4 north latitude and 77.571/4 east longitude, almost equidistant from both eastern and western coast of the South Indian peninsula, and is situated at an altitude of 920 metres above mean sea level. The mean annual total rainfall is about 880 mm with about 60 rainy days a year over the last ten years.. The summer temperature ranges from 18^{o} C – 38^{o} C, while the winter temperature ranges from 12^{o} C – 25^{o} C. Thus, Bangalore enjoys a salubrious climate all round the year. Bangalore is located over ridges delineating four watersheds, viz. Hebbal, Koramangala, Challaghatta and Vrishabhavathi watersheds (Figure 3). The undulating terrain in the region has facilitated creation of a large number of tanks providing for the traditional uses of irrigation, drinking, fishing and washing. Their creation is mainly attributed to the vision of Kempe Gowda and of the Wodeyar dynasty. This led to Bangalore having hundreds of such water bodies through the centuries. Even in early second half of 20th century, in 1961, the number of lakes and tanks in the city stood at 262. These, and open spaces generally, were seriously affected however with the enhanced demand for real estate and infrastructure` consequent to urbanisation. Temporal analysis of waterbodies indicate sharp decline of 58% in Greater Bangalore attributing to intense urbanisation process, evident from 466% increase in builtup area from 1973 to 2007. Figure 4.1 provides the distribution of wetlands in 1973, 1992, 2002 and 2007 based on the respective years' remote sensing data. The analysis revealed that there were 51 wetlands (321 ha) in 1973, 38 (207 ha) in 1992, 25 (135 ha) in 2002 and dropped down to 17 with an extent of 87 ha in 2007 in the Bangalore city limits. The corresponding number of waterbodies and their areas were computed and are listed in table 1.2 (Ramachandra and Kumar, 2008). There were 159 waterbodies spread in an area of 2003 ha in 1973, that reduced to 147 (1582 ha) in 1992, which further declined to 107 (1083 ha) in 2002 and finally there are only 93 waterbodies (both small and medium size) with an area of 918 ha in the Greater

Bangalore region. Waterbodies in northern part of greater Bangalore are in a considerably poor state compared to the waterbodies in southern greater Bangalore. With the city's unprecedented growth, the large number of public open spaces diminished over the years. Much of the loss in green cover is due to the rapid change in land use. As the city grew over space and time, inner areas got more crowded and congested. Initiatives to ease congestion on road networks have led to axing numerous road-side trees. Many lakes have been converted into residential layouts, bus stands, play grounds and stadiums, etc (Figure 4.2).The built-up area in the metropolitan area was 16 % of total in 2000 and is currently estimated to be around 23-24 %. The rest of the area is occupied by either agriculture lands, quarries or other vacant land.

In the aspect of nurturing flora and fauna, the situation in Bangalore is quite complex, with prominent green spaces like Lalbagh and Cubbon Park almost at the city centre and a few water bodies, such as Ulsoor, Sankey, Lalbagh, Yediyur and Madiwala, scattered across city's landscape, the remaining green spaces in the

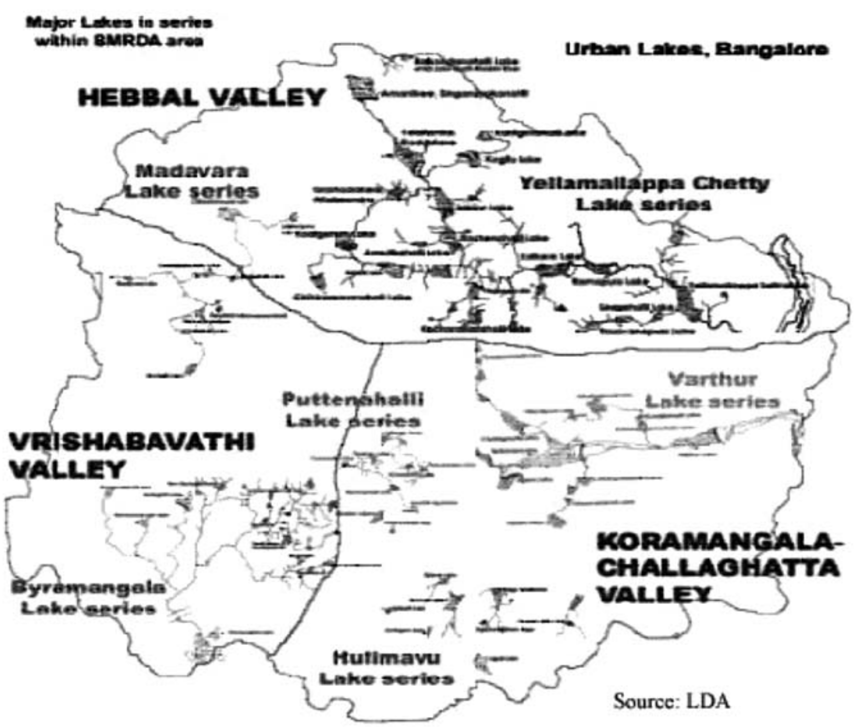

Figure 3: Cascading Lake series of Bangalore (Source: Lake Development Authority)

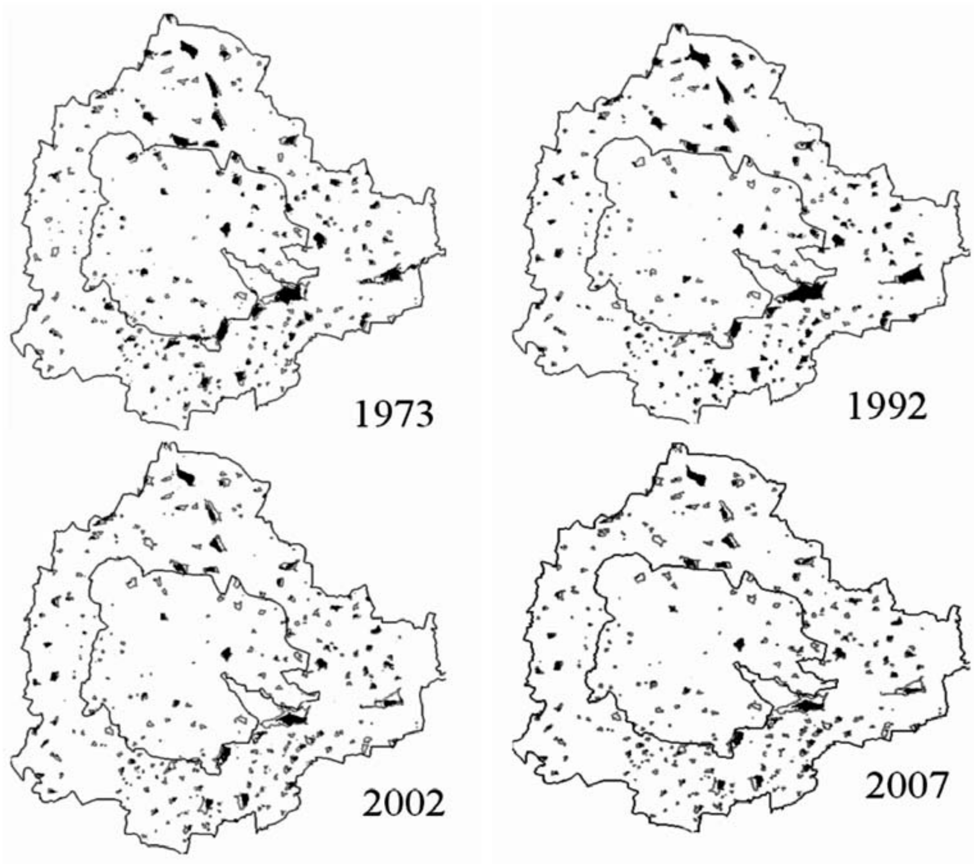

Figure 4.1: Temporal (1973-2007) changes in number of waterbodies in Greater Bangalore

periphery harbour a great number of species. In a compilation of fauna present in and around Bangalore within a radius of 40 km from city centre (Karthikeyan 1999), about 40 species of mammals, more than 340 species of birds, 38 species of reptiles, 16 species of amphibians, 41 species of fishes and 160 species of butterflies have been recorded. A new 'ant' species, *Dilobocondyla bangalorica*, was discovered in Bangalore recently (Varghese, 2006). In another study, Sudha and Ravidranath (2000) have investigated the floral assemblage in different land-use categories and the changes in vegetation over Bangalore City. About 164 species were identified in different residential areas, of which 149 were recorded within compounds and 87

Figure 4.2: Bangalore, once boasted of 81 lakes in the city limits, while now about 34 show some signs of existence. High-rise buildings sprouting across Bellandur lake.

Table 1.2: Changes in number of waterbodies during 1973 to 2007

	Bangalore City		Greater Bangalore	
	Number of Water bodies	Area in (ha)	Number of Water bodies	Area in (ha)
SOI	58	406	207	2342
1973	51	321	159	2003
1992	38	207	147	1582
2002	25	135	107	1083
2007	17	87	93	918

were avenue trees. The rich diversity speaks for the volume of life still persisting in spite of rapid urban growth.

In recent times, the increase in vehicular traffic (see section on Urban Agenda Addressing Infrastructure) has increased suspended particulate matter and other oxides of carbon, nitrogen and sulphur in the environment. Air pollution and the reduction in tree cover have induced the urban heat island effect resulting in variations in local temperature and sudden unanticipated showers during late afternoon.

Demography and Economy

The state of Karnataka was carved out in 1956 based on linguistic boundaries, with regions dominated by Kannada speaking people. Bangalore was retained as the capital of the state, with Kannada as the official language while accommodating other languages like Tamil, Telugu, Malayalam, English and Hindi, true to its cosmopolitan status,. The census of population in Bangalore has been recorded every decade since 1871, during the colonial times, the most recent census being carried out in 2001. Figure 5.1 shows the growth of population in Bangalore from 1871 to 2001 (5.7 million), along with an estimate for 2007 (7 million). Now, Bangalore is the fifth largest metropolis in India currently with a population of about 7 million. Population growth and population density changes during 1871 to 2007 is given in Figure 5.2. It is notable that since the first census, Bangalore was already the most populous city in Karnataka. This urban primacy has been retained consistently for more than a century now. After Independence, Bangalore, now a State capital, saw an influx of population migrating to the city, although it should be noted that the steep population rise in the decade 1941-1951, while due in part to this migration, also reflects the amalgamation of Bangalore Civil and Military Station Municipality with the Bangalore City Corporation. Population growth during the 1970s could be ascribed to numerous public sector industries and other defence establishments that came up during the period and fuelled significant immigration. By this time, incidentally, Bangalore had lost its tag of 'Pensioners Paradise', gained before Independence. Although the advent of IT is attributed to the late 1980s, major growth and expansion of this industry happened only during the late 1990s. Still, population growth in Bangalore in the last census decade, 1991-2001 (38%), was substantially less than in 1971-1981 (76%). Nevertheless, the physical growth of the city has been phenomenal over the last few years, and the glaring evidence of this is increased travel-times and the escalating real-estate prices.

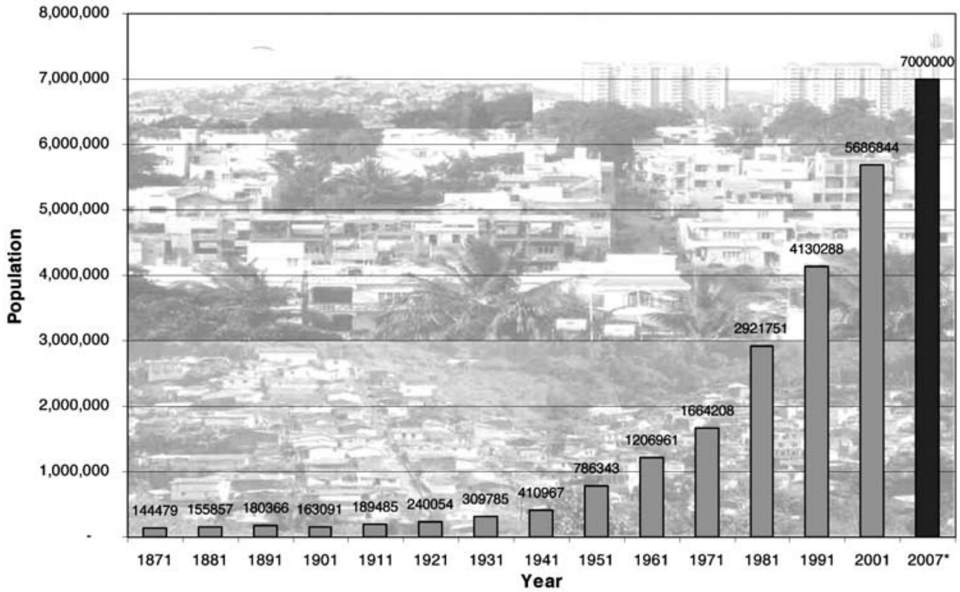

Figure 5.1: Population Growth of Bangalore City 1871 – 2007* (* The population for 2007 is an estimate) Source: Census of India (2001b)

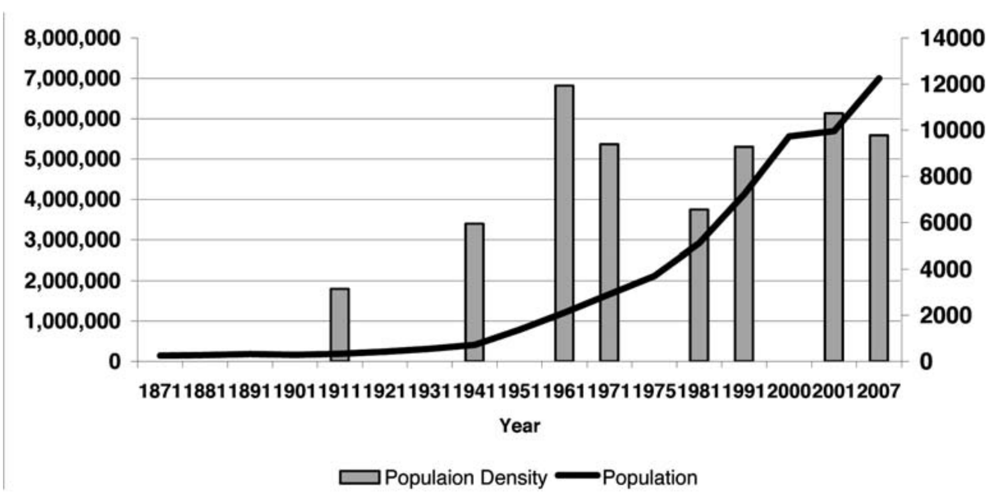

Figure 5.2: Population growth and population density

According to the latest census (Census of India, 2001a), the urban agglomeration had an overall population in 2001 of 5.7 million, including a workforce of 2.2 million, within an area of 560 sq. km, and a literacy rate of 75.1 %. The hype over the IT industry is underlain by Bangalore having about 30 % of all IT workforce in the country and a personal disposable income greater than the Indian city average. This has also resulted in a trickle down effect within the urban economy. Further, investments in industries (not only IT), infrastructure and other services, have significantly increased purchasing power among the people and have nurtured real estate with consequent land market dynamics, apart from creating numerous secondary employment in services. Interestingly enough, of the 5.7 million population in the urban agglomeration in 2001, about 2 million were migrants (Census of India, 2001b). About 1.2 million of these were from Karnataka state, mainly from the rural parts, while the remaining 0.8 million were from outside the state, the majority of these from urban areas. It is further noted that people have migrated chiefly for employment or moved with household or for education. The large number of migrant population from other parts of India explains the multitude of languages spoken and understood in Bangalore.

Bangalore is home to numerous high-tech knowledge hubs evident from the establishment of premier centres like Indian Institute of Science (IISc), National Institute of Advanced Studies (NIAS), Tata Institute for Fundamental Research (TIFR), Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Indian Space Research Organisation (ISRO), National Aerospace Laboratories (NAL), Defence Research and Development Organisation (DRDO), Indian Institute of Management (IIM), Institute for Social and Economic Change (ISEC), Indian Institute of Information Technology (IIIT) and several professional engineering and medical colleges at undergraduate and graduate levels. In tune with recent trends, Bangalore now has numerous malls and multiplexes that are swarmed during weekends. With an active night life and Bangaloreans penchant for fast-food, a large number of restaurants, pubs and ‘eat-outs’ throng the city.

The economic fabric of the city, although at times masked by the IT-based industries is varied, being also characterised by textile, automobile, machine tool, aviation, space, defence, and biotechnology based industries. In addition, numerous services, trade and banking activities mark the city’s economic landscape. An important feature of the economic activities of Bangalore is the huge concentration of Small & Medium Enterprises (SMEs) in diversified sectors across the city. Bangalore has more than 20 industrial estates/areas comprising large, medium and small enterprises. Of these, Peenya Industrial Estate located in the northern part of the city comprises about 4000 SMEs and is considered the largest industrial estate in South and South East Asia (PIA, 2003). A majority of the SMEs function as ancillaries/subcontractors to large enterprises in the field of engineering and electronics industries, among others. The industrial estates sprung up mostly in the periphery of the erstwhile city and gradually as the city grew became part of its sprawl. Notable among these are the Peenya Industrial Estate just mentioned, Electronic City and Whitefield (Figure 1.2). The proliferation of SMEs in residential and commercial areas, in addition to the industrial areas, has added to the chaos and congestion in the city. Thus, the thriving economy of the city has resulted with a net district[5] income of Rs. 262,592 million (approx. US $ 5.8 billion) and a per capita income of Rs. 39,420, a little more than twice the State's average per capita income of Rs. 18,360 (Government of Karnataka, 2005). Despite higher per capita income within the urban district than in the rest of the State, and with significant migrant population, the number of urban poor has been on the rise and the slum settlements in the city have not been contained. The escalating costs of land prices coupled with rise in cost of living has pushed the urban poor to reside in squatter settlements with inadequate amenities and services (Figure 6). Some of these settlements have speckled the city's landscape garnering immediate action from civic authorities. According to BMP (2006), the number of households in the urban agglomeration defined as poor was 0.22 million, housing approximately 1.1 million people out of 5.7 million population (Table 2). Noting the importance of the matter, the State Government has set up a special agency, Karnataka Slum Clearance Board (KSCB)[6] specifically to address the redevelopment of slums in partnership with various stakeholders like the Housing Board, Local Bodies, Water Supply Boards, etc. The initiatives taken up by the local body addressing redevelopment of slums are noted in the section on Issues in Planning and Development.

Table 2: Distribution of Slums across Greater Bangalore (BMP, 2006)

Agency / Authority	No of slums	No of Households	Remarks
Karnataka Slum Clearance Board (KSCB)	218	106,266	Declared
Greater Bangalore City Corporation	324	110,991	310 Undeclared & 14 Declared
Grand Total	542	217,257	

Note: Estimates are based on 2001 Census

5 *In the Indian federal system, each state is divided into districts (which are further divided into taluks) for administrative purposes, including decentralised implementation of developmental programmes. The State of Karnataka has 27 districts, of which Bangalore Urban is one, comprising Bangalore East, Bangalore South and Anekal Taluks. Taluk boundaries dissect the city and extend beyond the Bangalore Metropolitan Area. Thus the 'net district income' refers to the entire district and not to the city alone.*

6 *Karnataka Slum Clearance Board is responsible for slum improvement, clearance and rehabilitation of the slum dwellers.*

Figure 6: The plight of urban poor in Jayanagar 9th Block [Photo: BMP]

Urban Agenda: Governance and Infrastructure

An important aspect of a city is how well it is planned, managed and administered, activities which form the core part of an urban agenda – governance. However, appropriate state mechanisms through organisational structures, procedures and policies are needed to enable these. Also, apart from the formal administrative structures, the presence and involvement of civil society significantly drive the urban agenda.

Organisations and Stakeholders

Greater Bangalore City Corporation (Bruhat Bengalooru Mahanagara Palike) is now the key 'Urban Local Body' (ULB), that is, the local governmental structure representing and responsible to the citizens) for the city and outlying areas. Notified in December 2006, the new Corporation replaced the erstwhile local bodies, Bangalore City Corporation (Bangalore Mahanagara Palike), 8 neighbouring councils (7 City

Municipal Councils and one Town Municipal Council) and 111 outlying villages. Independently of the Corporation[7], which is governed by locally elected representatives, parastatal bodies controlled by the State government are responsible for many essential services (see Table 3).

Planning in the form of land use zoning and regulation are vested with Bangalore Development Authority (BDA), a parastatal agency, in spite of the he 74th Constitutional Amendment Act, passed by the national parliament in 1993. This Act requires that the planning function be vested with the (elected) urban local body and not with any parastatal agency. But, in the case of Bangalore, the Corporation have not been granted adequate powers by the State to plan, decide and administer their city! Furthermore, the State has created numerous other organisations of its own to manage various services such as water supply, law and order, energy, etc. The result is the existence of many parastatal organisations, each acting in its own geographic area, leading to complication and confusion in coordinating different activities. Apart from the issue of a common geographical unit and the lack of coordinated effort, even basic information related to different sectors is extremely difficult to collect, collate and to correlate. For effective planning it is imperative that all the basic information is gathered across a common geographical unit with the effect of creating a robust city information system. In addition to the official bodies, civil society of Bangalore is known for its vibrant community participation. The spectrum of their activities ranges from literacy and green brigades to urban governance, ensuring continuous interactions with the local administration. Notable spheres of activity of these Non-Governmental Organisations (NGOs) include: improving urban governance by Citizens Voluntary Initiative for the City (CIVIC) and *Janaagraha*; improving living conditions in slums by *AWAS*, *APSA*, *Paraspara*, etc.; addressing child literacy by *Prerana* and the India Literacy Project; taking on environmental issues by the Environment Support Group, *Hasiru Usiru*, etc. Apart from the NGOs, there are numerous resident welfare associations, trade and commercial organisations, and professional organisations that have played a major role in some of the important activities of local bodies and influencing their decision-making. Civil society has contributed considerably in shaping the policies and governance structures and has always intervened whenever there has been any apathy on the part of the administration towards activities of interest to society at large. An experiment to promote public private partnership and bring together citizens, NGOs, industry representatives and the erstwhile local bodies resulted in

7 *'Corporation' refers to the recently notified Greater Bangalore City Corporation unless otherwise stated.*

"Bangalore Agenda Task Force (BATF)". This experiment was about to be benchmarked as one of the 'best practices' in urban local governance, when it faced strong criticisms from several civil society groups for setting aside priorities favouring the urban poor and was accused of making a back door entry towards policy making (Ghosh, 2005). In the event, the activities of BATF came to a standstill with the change of guard at the State government two years ago and it is currently dormant. Another instance of strong action by civil society groups, was seen when the local government started tree felling and pruning for road widening. Members of the green brigade, *Hasiru Usiru,* staged protests, held an all night vigil, stormed the Commissioner's office and also moved to High Court and finally got the actions stayed. The High Court also ruled later that *Hasiru Usiru* members should inspect the trees along with the designated Tree Officer from the Forest Department (TOFD) before any tree felling and pruning of branches was begun.

Challenges in Managing Urban Infrastructure

Urban activities require the support of infrastructure. Broadly, urban infrastructure can be divided into social and economic infrastructure. Social infrastructure encompasses facilities like health care, education, housing, commercial (shops, markets and hotels), sports, recreation and entertainment. With mixed land use being practiced in most parts of Bangalore, shops and markets are the most commonly found amenities (approximately 1 shop per 100 persons) in the urban agglomeration[8] (Karnataka Urban Infrastructure Development & Finance Corporation, 2006). The provision and maintenance of primary health care, elementary education, sports, recreation and entertainment are administered mostly by the Corporation, while BDA also facilitates some of the social infrastructure like shopping complexes, with provisions for private participation. Economic infrastructure encompasses water supply, wastewater treatment, storm water drainage system, solid waste management, telecommunication network, and transportation network.

Bangalore Water Supply and Sewerage Board (BWSSB) is the parastatal agency responsible for drinking water supply, and wastewater collection and treatment in the city. Bangalore is on a ridge and does not have its own year-round sources of water. Drinking water is pumped from the river Cauvery, a distance of about 100 km over an elevation of 500 m with an energy expenditure of 75 MW for approximately 900 million litres per day (MLD). Apart from the river Cauvery supply, ground water and water from the river Arkavathy are also tapped. However, while water supply distribution is 100 percent in the

8 *The urban agglomeration refers to the area formally administered by Bangalore City Corporation and the 8 councils.*

Table 3: Organisations Concerned with Bangalore

Organisations	Functional Areas (Scope of Work)
Greater Bangalore City Corporation [Bruhat Bangalore Mahanagara Palike (BBMP)]	Urban local body responsible for overall delivery of services - Roads and road maintenance including asphalting, pavements and street lighting; solid waste management, education and health in all wards, storm water drains, construction of few Ring roads, flyovers and grade separators
Bangalore Development Authority (BDA)	Land use zoning, planning and regulation within Bangalore Metropolitan Area; Construction of few Ring roads, flyovers and grade separators
Bangalore Metropolitan Region Development Authority (BMRDA)	Planning, co-ordinating and supervising the proper and orderly development of the areas within the Bangalore Metropolitan Region, which comprises Bangalore urban district and parts of Bangalore rural district. BDA's boundary is a subset of BMRDA's boundary
Bangalore Water Supply and Sewerage Board (BWSSB)	Drinking water – pumping and distribution, sewerage collection, water and waste water treatment and disposal
Bangalore City Police	Enforcement of overall law and order; Traffic Police: Manning of traffic islands; Enforcement of traffic laws; Regulation on Right of Ways (One-ways)
Bangalore Metropolitan Transport Corporation (BMTC)	Public transport system – Bus-based
Bangalore Metro Rail Corporation Ltd (BMRC)	Public transport system – Rail-based (Proposed)
Regional Transport Office (RTO)	Motor vehicle tax; Issue of licenses to vehicles
Bangalore Electricity Supply Company (BESCOM)	Responsible for power distribution
Lake Development Authority (LDA)	Regeneration and conservation of lakes in Bangalore urban district

former Bangalore City Corporation limits, only about 20 % of the Municipal Council households are serviced. In view of the rapid growth of the city, and recent notification of Greater Bangalore, it remains a challenge to service the remaining areas.

Regarding collection and treatment of wastewater, the sewerage system is based on the city's four natural river valleys already noted and BWSSB is the nodal agency. There are three major treatment plants with a total capacity of about 450 MLD (the outlets of Koramangala and Challaghatta valleys are combined to form the K&C Valley Treatment Plant at Bellandur). Wastewater stress on natural water bodies is evident from the fact that the present wastewater treatment capacity in the city is around 450 MLD as against an estimated generation of domestic wastewater of 700 MLD. Although more secondary wastewater treatment plants are in progress, they are yet to be completed. Another problem is the frequent clogging of storm water drains, resulting in pollution of natural water bodies. Hence it is now proposed to rehabilitate and remodel all the major trunk sewers to prevent any discharge into the storm water drains.

Addressing mobility in Bangalore city, an overview of transportation and traffic reveals the following facts. Bangalore city is estimated to have vehicle population of about 2.6 million while the current city population is about 7 million. The vehicle to person ratio is far higher than any other city in India. This has led to increased congestion in road networks across the city and frequent traffic jams. Manning signalling at traffic islands have also become unmanageable with the amount of traffic plying across junctions. Again, in this sector different components related to mobility are vested with different parastatal bodies.

Public transportation forms one of the key functionalities for mobility in any urban area. In Bangalore where the working population is around 2 million, the Bangalore Metropolitan Transport Corporation (BMTC) operates on any given day with 4,144 schedules, 4,262 buses, 60,475 trips, and carries 3.5 million passengers. It earns Rs. 20.5 million per day and pay Rs. 0.955 million to the government as taxes (Bangalore Metropolitan Transport Corporation, 2006). Further, according to recent estimates, there are about 1.6 million two-wheelers, 0.32 million motor-cars, 80,000 auto-rickshaws, and 0.17 million other vehicles totalling to around 2.2 million vehicles on road (Regional Transport Office, 2006).

The onus of maintaining and improving road networks lies with the Corporation. Although a study for the City by consultants iDeCK and Rites (2005) identified 52 high and medium traffic intensity corridors requiring various interventions by different organisations, the former City Corporation proposed only to widen some of these roads. A key aspect ignored while addressing mobility is the role of land use in generating traffic demand. Failure by the city to acknowledge this, and in particular the implications of changes in land use from residential to commercial or industrial, has led to stereotypical approaches in addressing mobility such as road widening, creation of new flyovers and underpasses, or conversion into 'one-ways'. In general Bangalore has over a period promoted mixed land use which at some level has led to inefficient usage of land. With the City's compartmentalised approaches to widening of roads or construction of flyovers and grade separators, the problem of mobility is far from being solved.

Issues in Planning and Development

To understand the development characteristics of the Bangalore metropolitan area, it may help to distinguish three concentric zones – zones which correspond closely with previous current local authority areas. The first zone would comprise the erstwhile city corporation area of 226 sq. km. The second zone would include the areas of the former 8 neighbouring municipal councils and 111 villages, which together form the peri-urban areas and are now incorporated into the Greater Bangalore City Corporation. The third zone would include other villages extending up to the Bangalore Metropolitan Area limits as proposed by Bangalore Development Authority. The development characteristics and agencies across these zones are summarised in Table 4 and depicted in Figure 1.1.

Traditionally, planning has been restricted to land use planning, being vested with BDA for the region under Bangalore urban agglomeration, and with Bangalore Metropolitan Region Development Authority (BMRDA) for the larger peripheral area comprising the rest of Bangalore Urban DistrictP8P. BDA obtains the land, develops it as residential layouts which eventually are handed over to the city corporation, often involving the extension of city limits. Land use plans are formalised through the Comprehensive Development Plans (CDP) prepared every 10 years. Accordingly, the last CDP, prepared in 1995 for the period up to 2011, was revised in 2005-06 for the period up to 2015 (BDA, 2006) and is currently awaiting approval. A key aspect of these CDPs are that they indicate the amount and location of land use allocated for various uses (like residential, commercial, industrial, etc.) as well as restricting development in specific areas demarcated as Green Belt and Valley Zones. However, another organisation similar to BDA, the Karnataka Industrial Area Development Board (KIADB), is responsible for development of industrial areas. These industrial estates are situated for the most part in the outskirts of the city and KIADB has powers under the law to take over agricultural lands for the purpose.

Generally, however, the regulation and enforcement of land use zoning regulations are dismal, leading to a large number of illegal developments and encroachments on public land – problems which have led Karnataka State to constitute a legislative committee to look into irregularities in and around the city. In the particular case of growth occurring around outer industrial areas, the urban local bodies are generally unable to provide basic infrastructure and services, thus further aggravating inefficient utilisation of land and other natural resources. With such instances prevailing especially in the areas of the former Municipal Councils, the new Corporation faces a great challenge to deliver basic infrastructure and services.

On 3rd December 2005, the Ministry of Urban Development, Government of India, launched the Jawaharlal Nehru National Urban Renewal Mission (JNNURM). This countrywide programme addresses renewal of urban areas for 63 cities encompassing nearly 70% of total urban population, its primary aim being to link the revitalisation of urban infrastructure with a specific agenda of institutional reforms. Bangalore is one of the beneficiaries under this programme with an estimated outlay of US $ 1.7 billion over the next six years. The key mission of this programme is to support reforms-driven, fast track, planned development with focus on improving efficiency in urban infrastructure and service delivery mechanisms, through community participation and ensuring accountability of urban local bodies and parastatals towards citizens. JNNURM is made operational with two sub-missions:

- Urban Infrastructure and Governance (UIG)
- Basic Services to Urban Poor (BSUP)

The sub-mission on UIG focuses on major infrastructure projects for water supply, sanitation, sewerage, solid waste management, road network, urban transport and redevelopment of inner (old) city areas with a view to upgrading infrastructure therein, shifting industrial and commercial establishments to conforming areas, etc. The sub-mission on BSUP focuses on integrated redevelopment of slums combining housing, water supply, drainage, storm water drains, solid waste management, street lighting, and community halls.

In accordance with the JNNURM guidelines, the erstwhile Bangalore City Corporation prepared the City Development Strategy Plan (CDSP) for both UIG and BSUP (Bangalore Mahanagara Palike, 2006). The CDSP outlines only an investment plan and financial strategy for taking up various initiatives envisaged in the mission. Under BSUP, 218 declared slums in the former City Corporation limits would be taken up by KSCB for redevelopment. Further, there are 169 slums under the erstwhile City

Table 4: Development Characteristics across Bangalore

Characteristics	Development Zones		
	Zone 1	**Zone 2**	**Zone 3**
Authority	Greater Bangalore City Corporation (formerly Bangalore City Corporation)	Greater Bangalore City Corporation (formerly 8 municipal councils) and 111 Villages)	Development Authorities and other Town and Village Municipal Councils
Urban Status	Core city	Outgrowth	Potential areas for future outgrowth
Infrastructure Services	Present, but nearly choked, needs augmenting of existing infrastructure	Not fully present, with new growth, requires planning and augmentation of infrastructure	Farmlands and scattered settlements with minimal no infrastructure
Impact of growth	No scope for new growth but calls for urban renewal to ease congestion, etc	High potential for growth since already peri-urban area and emergence of new residential layouts and other developments	Mostly rural, with minimal growth currently, but potential for future growth
Planning, Development and Regulation Controls	Corporation operates building controls. Planning vested with BDA.	Corporation operates minimal building controls. Planning vested with BDA.	Planning vested with parastatal agencies: BDA and BMRDA and not other local bodies. No regulation on building/ construction

Corporation jurisdiction that remain undeclared, which would be redeveloped by the new Corporation. There are, in addition, 155 slums in the neighbouring former municipal council areas that would be redeveloped by the new Corporation and KSCB. However a draft community participation law has not been enacted and in Karnataka State most of the infrastructure projects and redevelopment plans have been administered by ULBs and parastatal agencies and not through community participation as envisioned by the mission. The result is a continuation of top-down rather than bottom-up modes of planning and delivering infrastructure and services. This calls for introspection on the implementation and achievement of the mission objectives. However, with various initiatives under JNNURM underway, it does offer hope, and perhaps promise, and in improving the essential urban infrastructure and services in city.

Conclusion

Bangalore, with all due respect to its status as 'Silicon Valley' and 'Garden City', faces real challenges in terms of addressing and delivery of basic infrastructure and services to all its stakeholders. In spite of numerous initiatives and activities envisaged by the urban local bodies, past and present, and by parastatal bodies, the rationalisation of geographical units for these activities could mark the beginning of a coordinated effort in addressing the needs of the city. In the wake of recent notification of Greater Bangalore City Corporation and initiatives under JNNURM, Bangalore is currently experiencing a strange transformation. Bangalore also stands out as a beacon of globalising world and to sustain this, it needs to systematically address the key challenges facing the city in terms of governance and infrastructure.

City Infrastructure with special reference to Drainage

Bangalore Roads

Bangalore population has been growing at a rate of 2.8 to 3.20% per year during the last two decades. There has been a phenomenal growth in the population of vehicles as well especially the two and four wheelers in this period due to rising household incomes consequent to IT sector boom in the region. The number of motor vehicles registered has already crossed three millions. The issues relating to traffic and transportation in a large and growing city like Bangalore need to be viewed in the larger perspective of urban planning and development. Issues relating to land use planning and development control, public-private transportation policy, industrial locations and IT corridors would need to be integrated at the perspective planning level.

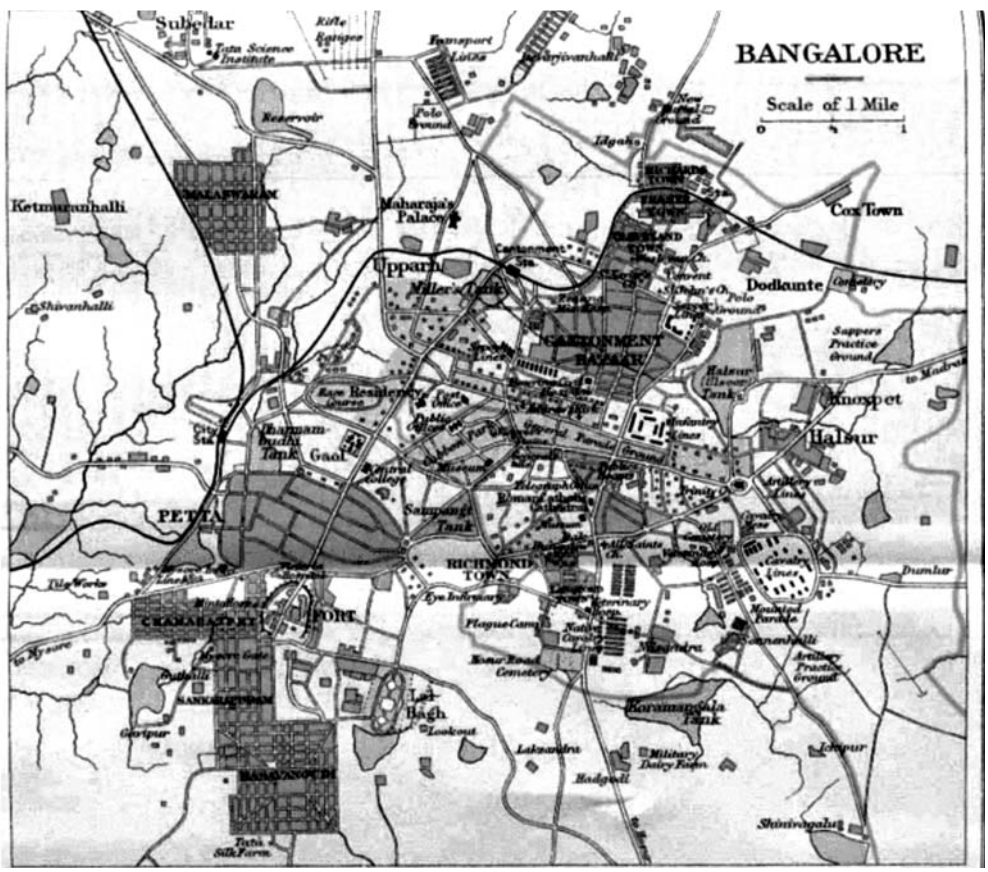

Figure 7.1: Road network in erstwhile Bangalore (Source: Murray's 1924 Handbook)

Bangalore's road network exceeds 3,000 km and consists of ring roads, arterial roads, sub-arterial roads and residential streets. The city road network is mainly radial, converging in the centre. The main roads of Bangalore coming into the city include Bellary Road in the north, Tumkur Road and Mysore Road in the west, Kanakpura Road and Hosur Road in the south and Airport Road and Old Madras Road in the east (Figure 7.2, and 7.1) . Many of Bangalore's erstwhile colonial and town streets were developed into commercial and entertainment areas after independence. The B.V.K Iyengar Road became the retail hub of Bangalore, while MG Road, Commercial Street and Brigade Road became important shopping, recreation and corporate areas . Consequently, traffic increased exponentially, especially on MG Road, which forms the main artery for the city's east-west traffic. But for MG Road, other roads in and around the erstwhile Parade Ground remain narrow, winding roads. Road network capacity is inadequate. Most of the major roads are with four lane or less with limited scope of their widening. This indicates the need for judicious use of available road space.

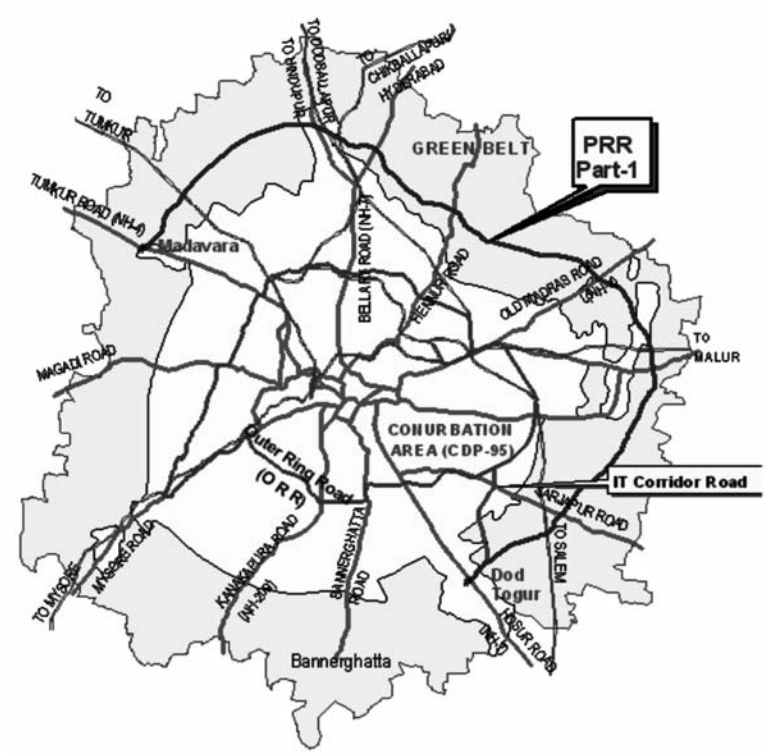

Figure 7.2: Road network as on 2007 (source: www.bdabangalore.org)

The maintenance and construction of roads to address the growing traffic in the city has been a challenge to the BDA and the BBMP. Development of the city road infrastructure has revolved around imposing one-way traffic in certain areas, improving traffic flow in junctions, constructing ring roads, bridges, flyovers and other grade separators. Six high volume junctions were identified for improvements, through a private public partnership involving corporate sponsors and various state government agencies, such as the Siddapur Road and Hosur Road junction, sponsored by Infosys and the Airport Road and Intermediate Ring Road junction. Flyovers were constructed in the city to ease traffic congestion. Newer flyovers were planned for the city for 2006 and beyond (HTUhttp://en.wikipedia.org/wiki/Infrastructure_in_BangaloreUTH). Area of the BMP has been increased as per Revised Master Plan-2015. This plan has provided for densification of existing areas, Mutation corridors, hitech areas etc in various parts of the city. This is likely to have a major impact on traffic demand. The transport network including mass transport system needs to be planned taking the proposed development in to consideration.

Solid Waste Management

The city is facing acute problems related to solid wastes. This is despite the fact that the largest part of the municipal expenditure is allotted to management of municipal solid wastes. The current waste generation in Bangalore is 3613 tonnes per day and the number is likely to grow in the next few years due to the increasing population and will present a formidable challenge to authorities unless an integrated approach is taken. The objective of this paper is to present an overview of the current waste management practices in Bangalore and to discuss suitable methods to overcome the constraints. This paper was built up on various interviews conducted with the authorities and of experiences and observations (Ramachandra, 2006; Ramachandra and Saira Varghese, 2003).

An overview of the current waste management practices in Bangalore

Bangalore City is divided into 100 administrative wards, which have been further divided into 273 health wards for functional convenience (Ramachandra and Saira Varghese, 2003). Of these, 147 health wards are under private contract system and the remaining 126 health wards are managed through Pourakarmikas (municipal sweepers) of the Corporation. Except for few wards in Bangalore there is no door-to-door collection service in Bangalore. The areas not served are mostly unincorporated or illegal settlements and slum areas with small and inaccessible streets. By contrast more prosperous areas are better served, kept clean and swept on a regular basis.

Waste generation: The waste generation in Bangalore is given in Table 4.1:

Table 4.1: Waste generation in Bangalore

Stakeholders	Quantity of Waste (tonnes/day)	%
Households	650	18
Commercial Establishments	1436	39
- Markets	369	1067
- Hotels		
Institutes	128	4
- Hospitals	20	
- Offices	16	
- Educational institutions	92	
Industries	1399	39
Total	3613	100

Source: Beukering, et al., 1999

As evident from the table, wastes from commercial establishment make up for the bulk of the total wastes. Although industries also generate a significant amount, it was analysed that most of this is recovered for recycling and reuse and only a small percentage find it's way into the city waste stream.

A typical waste composition for major Indian cities is given in Table 4.2

Table 4.2. Composition of urban solid waste in Indian cities (percentage by weight)

City	Paper	Metals	Glass	Textiles	Plastic[1]	Ash, dust	Organics	Others[2]
Chennai	5.90	0.70	-	7.07	-	16.35	56.24	13.74
Delhi	5.88	0.59	0.31	3.56	1.46	22.95	57.71	7.52
Kolkota	0.14	0.66	0.24	0.28	1.54	33.58	46.58	16.98
Bangalore	1.50	0.10	0.20	3.10	0.90	12.00	75.00	7.20
Ahmedabad	5.15	0.80	0.93	4.08	0.69	29.01	48.95	10.39
Mumbai	3.20	0.13	0.52	3.26	-	15.45	59.37	18.07

Source: Planning Commission on "Urban Solid Waste Management in India', GOI (1995), The expert Committee,2000

1 Includes rubber and leather

2 Includes bones, stones and wooden matter

As evident from the Table above, the composition of organic waste is high in all the cities and Bangalore ranks the highest. Waste densities and moisture contents are high, which require different technology and management system. High organic content and low biodegradable waste are typical of Indian cities and hence incineration is a less appropriate option.

Waste storage: Waste is stored in 14,000 bottomless and lidless cement bins having 0.9 meters diameter and 0.6 cubic meter storage capacity and large masonry bins for depositing waste placed at a distance of 100-200 meters. Recently 55 metal containers have been placed at different parts of the city. However not all parts of the city are provided with storage systems. In some places, the wastes are just deposited on roadsides.

Waste collection and transport: Collection of waste is either done by Bangalore Mahanagara Palike (BMP) or by private contract system. In December, 2001 BMP and Bangalore Agenda Task Force (government appointed body) through a joint initiative established a public private partnership, by launching a sustainable cleanliness program called 'Swachha Bangalore'. Twenty five percent of the city is served under this scheme. Swachha Bangalore is mainly door to door collection of wastes using pushcarts (Plate 2.1). There are totally 2105 pushcarts in operation in Bangalore, which consists of 4 buckets that are used to store dry wastes and wet wastes separately. Swachha Bangalore scheme also covers selected slum areas and auto tippers have been deployed for collection of wastes (Plate 2.3). There are 6500 pourakarmikas in charge of door to door collection, sweeping, emptying dustbins and clearing black spots. They arrive at a designated spot to transfer the waste to the truck. Trucks have a capacity of 4-5 tonnes capacity and are either openbodied or covered with a mesh (Plate 2.2). The ratio of truck to ward is 4:20. Other collection systems consist of bullock carts, tricycles etc. Collection is sometimes difficult due to narrow roads and due to this waste is not picked on time causing unsanitary conditions. There are no transfer stations in Bangalore.

Plate 2.1. Pushcart Plate 2.2. Waste transfer Plate 2.3. Auto tipper

Transportation of wastes to disposal site is done in two ways through the same trucks.

- by engaging 82 trucks of the corporation;
- through contractors by engaging 129 vehicles for layouts and markets and 72 vehicles on contract for transportation of waste.

The corporation also has 13 dumper placers for transporting metallic containers of 2.5 to 3 tonnes capacity and 6 minicompactors for transportation of wastes.

Waste processing and recovery: The method adopted to process waste is composting. Karnataka Compost Development Corporation handles 120 metric tonnes of raw garbage/day in the yard. Out of 100 tonnes of raw garbage, 55 tonnes of compost is obtained. Due to constraints of land, finance and demand, the facility can handle only 120 tonnes of wastes. As such out of the 369 markets in and around the city, only 2 have been accepted for composting. Vermicomposting is also practised to handle a portion of the waste. Dry wastes such as plastic, rubber, glass and other contraries are later disposed off.

Waste disposal: Disposal is the final stage of waste management system. About 90% of the municipal wastes collected by the civic authorities in Indian cities are dumped in low-lying areas outside the city/town limits. The waste disposal trends in major Indian cities are as given in Table 4.3.

Table 4.3 Waste disposal trends in India

Waste disposal methods	1971 – (40 cities)	1991 and 1999 (23cities)
Land dumping	Almost all	89.8%
Composting	-	8.6 %
Others (pelletisation, vermi-composting)	-	1.6 %

In Bangalore, the waste collected from roads and bins is directly transported to the final disposal site, usually an open dump. There is the likelihood of soil and groundwater contamination due to this practice. Birds (scavengers), vermin, insects and animals are attracted to the open dump for feeding and breeding. Since many of these may act as disease vectors, their presence may constitute a potential health problem. Sometimes plastic and other contraries are burnt, which may be hazardous to human health. Landfilling of wastes is not practiced in Bangalore. Figure 7.3 provides information on the various SWM options in Bangalore. Recycling takes up 43% and is an area to be further exploited. Thirty one percent of the waste is disposed, which is mainly burnt or simply dumped in open spaces.

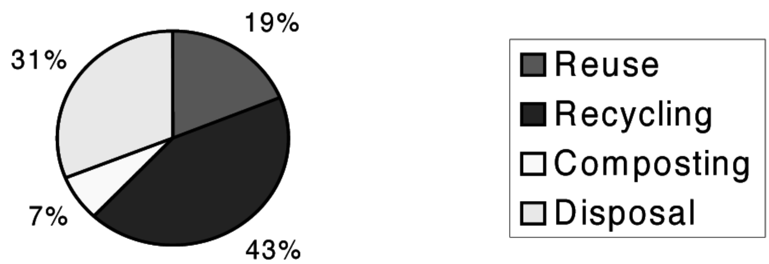

Figure 7.3: SWM Options in Bangalore

Under the Central Government Municipal Solid Wastes (Management and Handling) Rules, 2000, gazetted in India on 25th September 2000, all municipal authorities must:

1. Provide a waste collection service to all domestic dwellings, including slums and squatter areas, and commercial premises (note that no distinction is drawn between urban and rural areas).
2 Provide waste storage facilities which do not create unhygienic and unsanitary conditions;
3. Remove waste stored in the above facilities on a daily basis and in a manner such that manual handling by sanitary workers is avoided; and
4. By no later than the end of 2003, establish waste processing facilities and landfills at which:
   - the biodegradable fraction of municipal solid waste is only processed by biological conversion technologies; and
   - landfilling is restricted to non-biodegradable, inert waste and other waste that is not suitable either for recycling or for biological processing.

It is apparent that none of these, are presently being met in a satisfactory way in Bangalore. In this regard, recommended waste storage, segregation and collection, treatment and disposal (Ramachandra and Shruthi, 2007) are:

1. Adoption of door-to-door collection service daily, in all urban areas, including slums, where practical and affordable to do so. The household waste storage bins are collected, emptied and returned by the sanitary worker from the front of the residential premises at a predetermined period of the day (i.e. morning or afternoon) and day of the week. Community waste storage system in all markets, commercial and industrial premises, and domestic premises where it is either not practical or affordable to provide a door-to-door collection service. This will probably include multi-storey dwellings and rural areas where population densities are low. These containers are positioned to ensure convenience to users, particularly women who are the primary users, and hence minimise illegal littering and dumping practices. Segregation of waste at source in domestic, markets, restaurants and hotels and other commercial and industrial premises where biodegradables constitute a major component of the waste stream into wet and dry fractions.
2. A network of local and regional waste modular transfer stations is established throughout the region and municipal solid waste is hauled in bulk from these transfer facilities to the closest regional waste processing facility.
3. Decentralised biological treatment facilities are established and operated by the community based organizations at local levels (with the technical and financial support) where it complements the formal systems. Further expansion of the Karnataka Composting Development Corporation (KCDC) biological processing facilities are undertaken and similar units be initiated in other parts (Figure 7.4). Landfills are established close to biological processing facilities for disposal of waste processing rejects and other wastes not suitable for recycling.

Sewage System

Bangalore is located over ridges and the city's topography is characterized by a series of well defined valleys which radiate from a ridge (Figure 3) of high ground to the north of the city and fall gradually towards a wide belt of flat cultivated land extending beyond the limits of the BMP boundary to the south. Four major watersheds are Hebbal, Koramangala, Challaghatta and Vrishabhavathi. Three of the valleys, Vrishabhavathi (V-Valley), Koramangala (K) and Challaghatta (C), run generally in a north to south direction and divide the greater part of the metropolitan area which lies to the south of the ridge into three separate and distinct drainage zones. A fourth major valley, referred to as the Hebbal series, forms the drainage zone to the north of the ridge and runs in a north-easterly direction. Five minor valleys, the Kathriguppe and the Tavarakere to the south, the

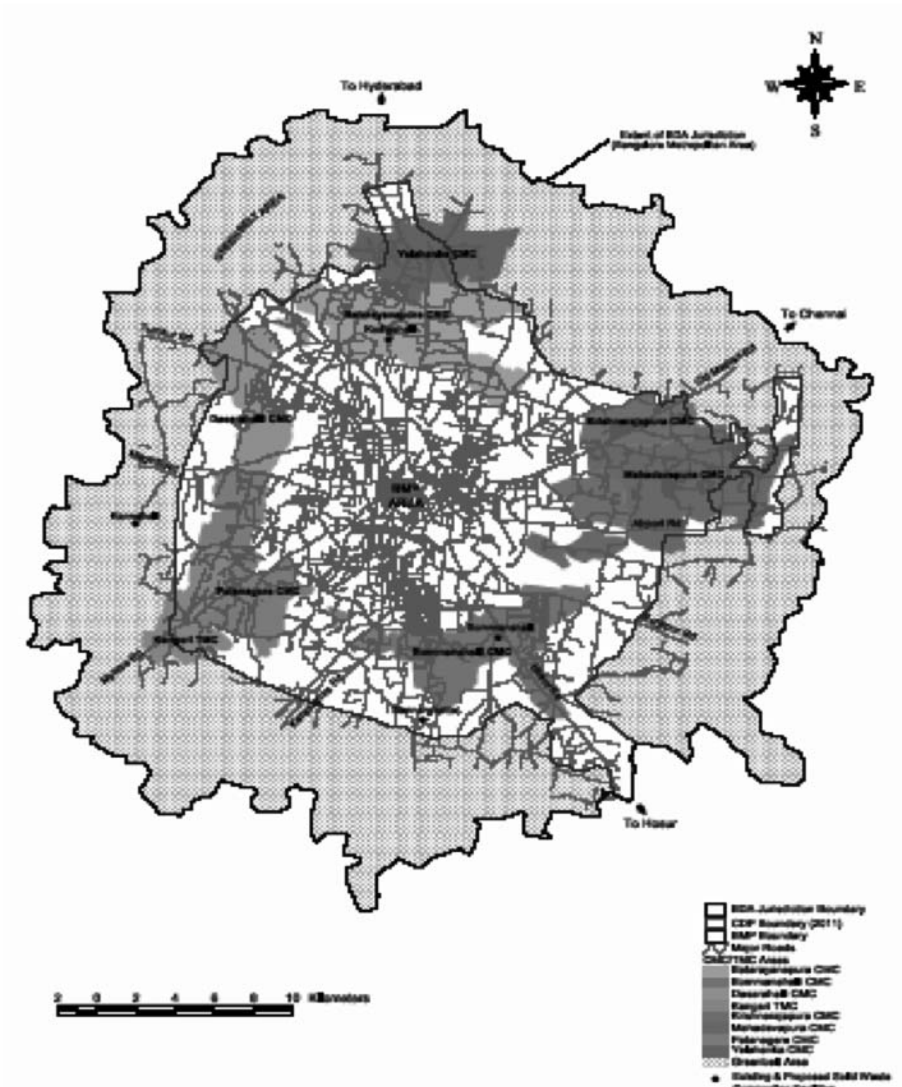

Figure 7.4: Road network in core area and CMC's with SW treatment facilities

Arkavathi and Kethamaranahalli to the north-west, and the Marthahalli to the east, lie outside the tributary areas of the major valleys and these drain independently the fringe areas which form the remainder of the metropolitan area. Table 5 lists the major and minor valley with the respective catchment area (BWSSB, 2003).

Table 5: Major and Minor Valleys in the core area of the city

Sewerage Zone	Major Valley(s)	Area (km^2)	Minor Valley(s)	Area (km^2)
Vrishbavathi (V – Valley)	Vrishbavathi	38	Katrhiguppe	16
			Kethmaranehalli & Arkavathi	35
Koramangala and Challagatta (K&C Valley)	Koramangala Challagatta	71	Tavarekere	19
Hebbal	Hebbal	32	Hebbal I	11

History of sewage systems in Bangalore: Plague outbreak in 1889 forced the town administration authorities to provide wider roads, open drains and sewage carrier lines. Localities such as Basavanagudi and Malleswaram were provided with conservancy roads and a good network of drains. The system for the conveyance of domestic and industrial waste was established in Bangalore in early thirties, which was initially confined to the densely populated old parts of the city. Following completion of the Thippagondanahalli reservoir in 1940's, the extension accelerated. The old city and 60% of the former Civil and Military area had been sewered by 1960's, and about 60,000 connections had been made to the sewers. Then followed the major sewerage development under the first three phases of the Cauvery project (CWSS), extending from the mid-1970's to late 1990's.

Coverage of Sewerage in Bangalore: The sewerage system in Bangalore has been guided by the nature of the topography formed by natural ridges and valleys and sewers were laid along natural channels to save on pumping costs. The sewerage system covers about 229 kmP2P and is made up of four principal drainage areas (major valleys) which drain to three wastewater treatment plants. Sewage flows from three of five minor valleys are intended to be treated at two of these treatment plants. The existing sewage system is given in Figure 8.1 and Figure 8.2 shows the drainage zones together with the major sewer system (sewers of 450mm diameter and above).

Sewerage and sewage treatment provided under CWSS Stages I, II & III since the 1970's in four major valleys (Vrishabhavathi, Challaghatta, Koramangala and Hebbal) and five minor valleys (BWSSB, 2003). Wastewater from the two major valley zones of Koramangala and Challaghatta is collected and treated at K&C Valley STP at the southern extremity of the same zone on the northern edge of Bellandur Tank. The Taverekere Minor Valley is also a part of the contributory area of this treatment plant.

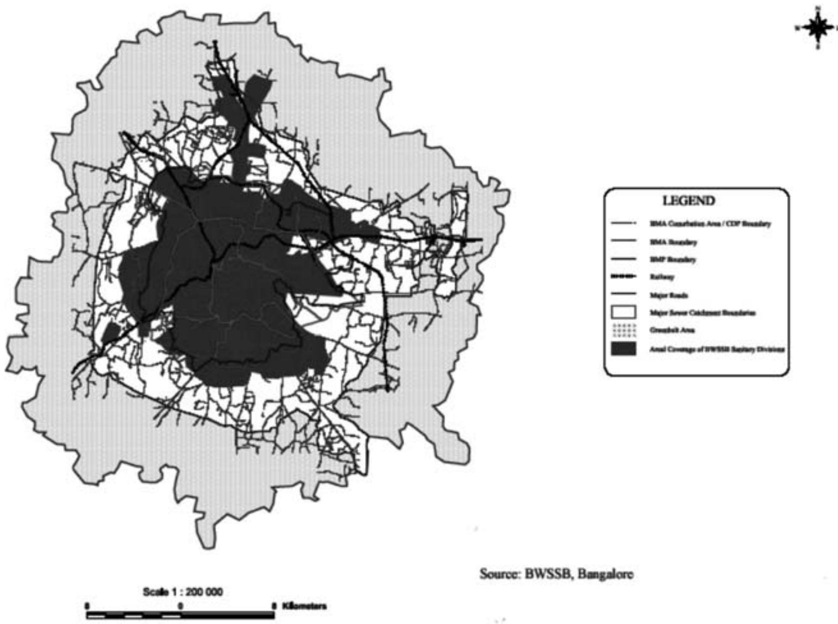

Figure 8.1: Major sewer system in Bangalore core area

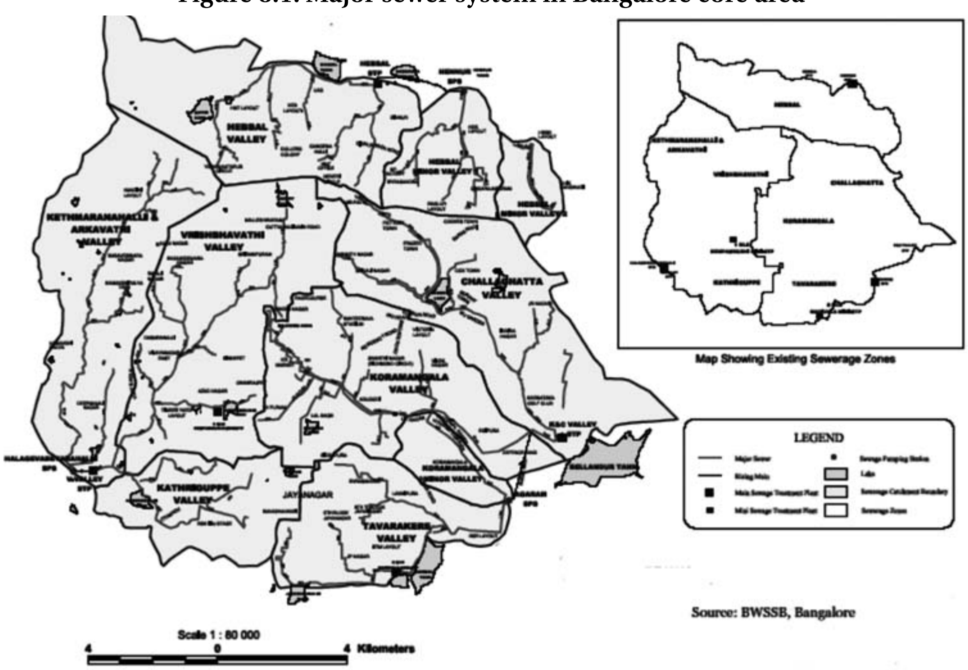

Figure 8.2: Drainage zones with major sewers

The Vrishabhavati Valley zone is part of a contributory area to the V-Valley STP in the south-west of the city which includes the minor valleys of Arkavathy and Ketmaranahalli (A&K) and Kathriguppe. The Hebbal zone to the north is served by a sewage treatment plant near the Nagavara tank; it has an associated minor valley to its east.

- Main and sub-main sewers were laid along the major valleys (V-Valley, K-Valley and C-Valley); and sewage treatment plants providing primary treatment only were constructed for the V-Valley (123 MLD) and K&C valley (163 MLD) catchments under CWSS Stage I.
- Main and sub-main sewers were constructed in the minor valleys from 1981 to 1984 (K&A, Kathriguppe and Tavarakere); main and sub-main sewers were laid in Hebbal (1982 – 1984); a 60 MLD sewage treatment plant was constructed at Hebbal (1989 - 1999); the V-Valley STP was expanded from 123 MLD to 180 MLD (1990 to 1999) and secondary treatment added; and secondary treatment was added at the K&C STP (1989 – 1999) (without increasing overall capacity but with screens and detritors sized for 218 MLD) under CWSS Stages II & III,.
- Under Cauvery IV Phase I, trunk sewers, pumping stations and seven sewage treatment plants in eight zones, will serve the peripheral area of the city, the zone between the outer boundary of the existing sewerage catchments and the BMA conurbation boundary.

Most part of the sewerage system operates under gravity in the drainage zones, while three pumping stations have been deployed to pump flows from the minor valleys to the main valleys: Halagevadeyarahalli SPS in the south-west of the city serving the A&K Minor Valley; Hennur SPS in the north-east (Hebbal); and Agaram SPS in the south which serves Tavarekere Minor Valley and part of the Koramangala Valley.

Bangalore is currently served by three major sewage treatment plants, all providing secondary treatment, with a combined capacity of 403 MLD. Two recently constructed much smaller plants (total capacity 9 MLD) also exist, these having been provided by BWSSB to rejuvenate lakes (BWSSB, 2003). The STP's are:

- V-Valley STP, a plant first commissioned with primary treatment in 1974 (123 MLD), then upgraded in the 1990's (commissioning in 1999) to 180 MLD with secondary treatment by trickling filters. This plant serves V-Valley and the Kathriguppe and K&A minor valleys;
- K&C STP, a plant also constructed with primary treatment only in the 1970's (163 MLD), then upgraded to secondary treatment by activated sludge in the late 1980's (commissioning 1990). This plant serves the Koramangala and Chalaghatta

valleys and Tavarakere minor valley;
- Hebbal STP, a 60 MLD plant with secondary treatment provided by activated sludge, commissioned in early 1999. This plant serves the Hebbal Valley catchment as well as a minor catchment served by Hennur SPS;
- Madivala STP, an 8 MLD ultimate capacity plant in the Tavarakere Minor Valley which provides treatment by UASB and oxidation ponds, the treated effluent providing rejuvenation to Madivala Tank. The plant has been operating for nine months; and
- Kempambudhi STP, a 1 MLD plant in V-Valley which treats sewage to secondary standard using the extended aeration process ; the treated effluent will rejuvenate Kampambudhi Tank.

Major problems in these sewer systems are:
- encroachment of sewers by buildings preventing access for maintenance;
- siltation of sewers, unrepaired broken pipe bridges – with sewage discharging to the drains;
- sewer crown corrosion leading to sewer collapses;
- poor design and construction standards- lack of conformance to Indian Standards (CPHEEO) on the current sewer laying contracts in the primary drain of V-Valley
- sewage diversions by farmers for irrigation purposes in the V-Valley and Kathriguppe valleys.

Stormwater System

Four major storm water catchment systems (Vrishabhavathi Valley; Challaghatta Valley; Hebbal Valley; and Koramangala Valley) pass from the city's ridge in the north to an enclosed lake system at the perimeter of Bangalore (Figure 3). Waterbodies are part of these four major waterways "valley" systems, which drain the majority of the city's storm water to large tanks or lakes, which were traditionally used for recreation and water supply for irrigation. These waterways with interconnected lakes in addition to their primary function as flood carriers, have provided the city with reasonable ecological and recreational values. The urban growth in recent times, not guided by strong strategic planning or development control measures to minimise the impacts on existing infrastructure, on the surrounding environment, and in particular on the storm water system, had severe impacts on waterways. This has lead to the depletion of waterways in addition to pollution and wastewater discharge to the storm water system.

One of the main problems that characterises the storm water system in Bangalore is that the larger sewer pipes are frequently located in the drainage channels (Plate 2.4). This has lead to the significant reduction in the storm water system with obstruction from sewers and also from the sewer manholes. These sewer manholes and other structures cause significant turbulence and redirection of the storm water flows, during high storm water flows, resulting in erosion of the bed and bank instability (Plate 2.5). This also restrict drainage rehabilitation and maintenance works, including stabilisation, widening and de-silting activities. Manholes in drainage channels trap significant amounts of solid waste as well as localised sediment deposit due to the reduction in velocity of flows. In addition to this, sewer maintenance and construction in the drainage channel contributes major quantity of sediment. During periods of high storm water flows, floodwater sometimes back-up into houses through the sewer connections.

Road drains typically consist of a box shaped trench on either side of the road, covered by slabs in the core areas of the city. The inlet pits consist of an open pipe or hole in the side of the road, with no grating covers. These inlets are generally not located in the lowest point in the road and are slightly above the road gutters, which results in ponding in low lying areas before storm water flows into the drains. These roadside drains connect to secondary drains and finally to the main open channel drains. Main drains consist mainly of open channels lined with concrete retaining walls, especially in the built up area. The levels of service provided by drains has diminished in most areas due to increasing degrees of imperviousness and encroachment on drainage waterways by building, roads, culverts and other infrastructure, such as sewers (BWSSB, 2003).

Flooding is a wide-spread problem through-out the drainage system due to lack of drainage upgradation consequent to the increase in impervious area due to land use changes in the catchment from open space to high-density urban developments. This is compounded by the encroachment of drains and filling in the floodplain on the waterways, obstruction by the sewer pipes and manholes and relevant structures, deposits of building materials and solid wastes with subsequent blockage of the system and flow restrictions from under capacity road crossings (bridge and culverts).

Plate 2.4: Manhole and a sewer connection – obstruction as well as pollution (Source: BWSSB)

Plate 2.5: Sewer manhole and dumping of solid waste – reducing channel section (Source: BWSSB)

Drainage System

Lakes and wetlands are an essential part of human civilization meeting many crucial needs for life on earth such as drinking water, protein production, energy, fodder, biodiversity, flood storage, transport, recreation, climate stabilisers and also they aid in improving water quality by filtering sediments and nutrients from surface water. Wetlands play a major role in removing dissolved nutrients such as nitrogen and to some extent heavy metals (Ramachandra, 2002). They are getting extinct due to manifold reasons, including anthropogenic and natural processes. Burgeoning population, intensified human activity, unplanned development, absence of management structure, lack of proper legislation and lack of awareness about the vital role played by these ecosystems are the important causes that have contributed to their decline and loss. Identifying, delineating and mapping of wetlands on temporal scale provide an opportunity to monitor the changes, which is important for natural resource management and planning activities (Ramachandra *et al.*, 2002). Bangalore is situated on the divide between the Cauvery Basin and the Ponnaiyar, with approximately 50% of the existing population concentrated within the Cauvery Basin. There are three major drainage outfalls and five small outfalls from the Conurbation Area as shown in Figure 9 and listed in Table 6. The unsanitary conditions created by large volumes of raw, or partially treated, sewage and dumping of large volumes of solid wastes including building debris have seriously impacted the drainage system.

Table 6: Drainage Catchments with valley gradients

Catchment names	Municipalities in Catchment	Typical Valley Gradients		
		Upper	Middle	Lower
Arkavathi & Vrushabhavathi (V) Valley	BMP, Kengeri TMC, Patnagere CMC	1 in 60	1 in 200	1 in 120
Koramangala, (K) Tavarakere (K& C) Valley	BMP, Bommanahalli CMC, Mahadevpura CMC,	1 in 270	1 in 980	1 in 710
Challagatta (C) Valley	Krishnarajpura CMC	1 in 210	1 in 640	1 in 430
Hebbal	BMP, Krishnarajpura CMC, Batarayanpura CMC, Yelahanka CMC	1 in 230	1 in 700	1 in 450
Minor (to TG Halli Reservoir)	BMP, Dasarahalli CMC, Batarayanpura CMC			

Note: Drainage catchments do not coincide with sewerage valleys of the same name

Lakes constructed for agricultural and water supply have suffered in the transition to an urban environment. These lakes provided flood prevention by storing excess flows, slowing down the passage of flood waters and protecting the downstream waterways from erosion and flooding caused by the urbanisation of the catchments. They allowed

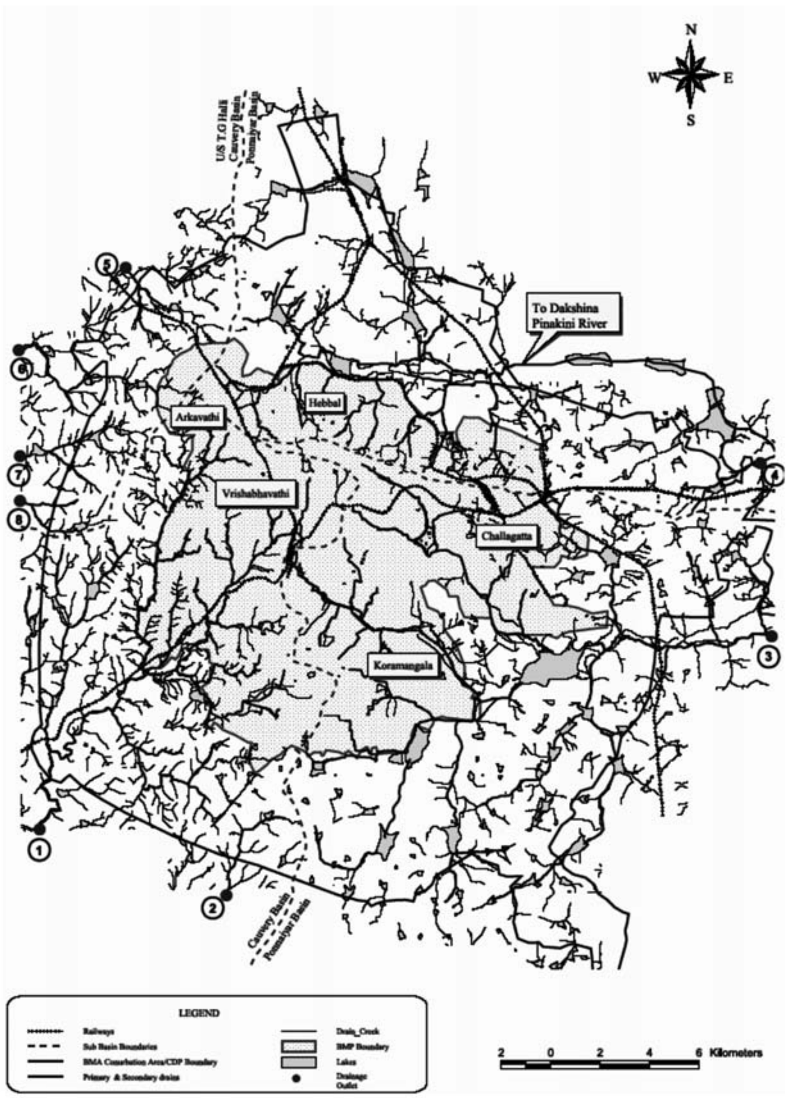

Figure 9: Drainage system in Bangalore (Source: BWSSB)

an opportunity for storm water to percolate to aquifers to supplement groundwater resources (Ramachandra and Uttam Kumar 2008). Now, lakes original function of water supply have been impaired due to dwindling number and size, depleting functions of remaining waterways due to reduced widths, conversion to hard lined drains and to pollution from wastewater discharges, solid wastes and a generally high silt load. Increasing development pressures within the core area have been accompanied by a general neglect by private and public institutions of even the basic flood protection function of drainage system (Ramachandra, 2006 and 2007).

An important function of drainage is to minimise flood damage and as per the estimates by BWSSB for Koramangala Valley the extent of flooding as 8.8 sq. km/year on average (Ashwathnarayana, 1999), would amount to 20 sq. km/year for the core area. Principal factors contributing to the flooding problem in Bangalore are unplanned urbanisation with mushrooming layouts (land development) and buildings with respect to easement provisions and floor level controls (Plate 2.6 and 2.7). Other related contributing factors are inadequate culverting at major and minor roads (Plate 2.8), obstructions by sewerage works in channels, restrictions caused by cross services (including water supply, power and telecom utilities), encroachment of buildings into waterways, dumping of solid wastes and accumulation of sediments in the drains and low design standards (Plate 2.9), combined with use of inappropriate data and analysis techniques. Low-lying and flood-prone lands are listed in Table 6.

Plate 2.6: Flood plain encroachment (Source: BWSSB)

Plate 2.7: Bank erosion and instability due to modification in the floodplain

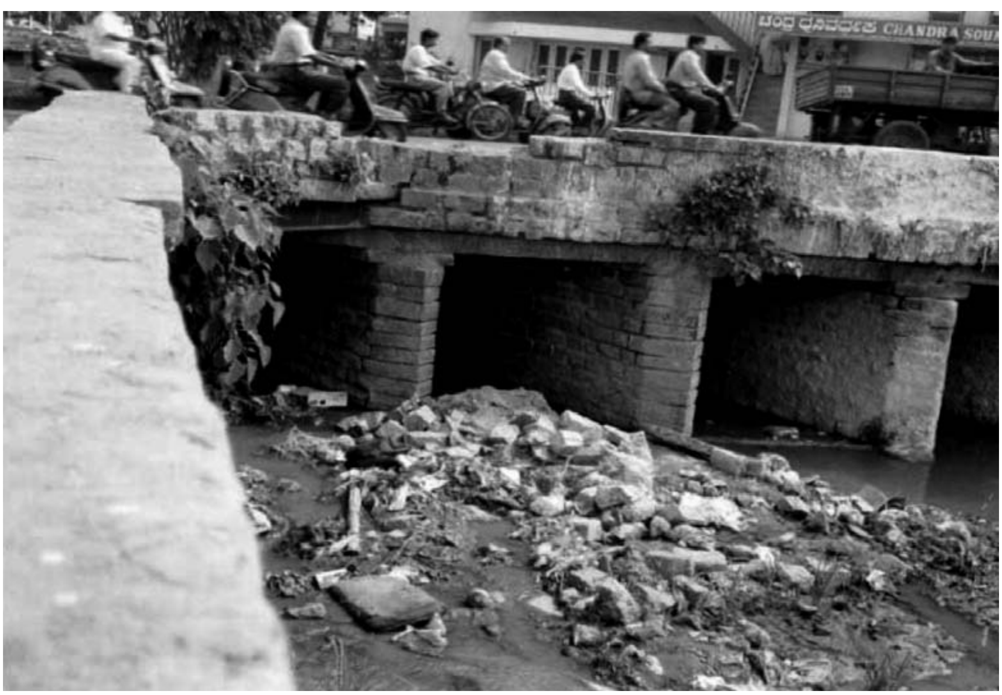

Plate 2.8: Reduced culvert capacity - dumping of solid waste and supports (Source: BWSSB)

Plate 2.8: Reduced culvert capacity - dumping of solid waste and supports (Source: BWSSB)

Plate 2.8: Stormwater flow hindrance from water pipes, solid waste, reduced culvert capacity

Plate 2.9: Sewer manhole, solid waste and under capacity road crossing

Table 6: Low-lying and flood-prone regions

Flood prone regions	Ward No.
Koramangala Valley	
City Market Area	30
Sulthan Palya Main Road	28
Jayanagar 3rd Block LIC Colony	
Krishnappa Garden behind Byrasandra Tank D/s	
Wilson Garden Area up to Bannerghatta Road	63
Arekempannahalli Area	61
Jurist Colony	47
Marehahalli Tank	58
Bismillanagar - Agencies	67
Pillappa Gard en - Agencies	63
Ejipura	69
Koramangala Slum	
Sampangiram Nagar	77
Wipro Junction	

Table 6: Low-lying and flood-prone regions	
Hebbal Valley	
Brindavananagar below Matthikere Tank Market	2
KEB Compound Maththikere	4
Tannerana Halli	2
Anandanagara	96
Ring Road	96
New - Bangalore Layout	94 & 95
Challaghatta Valley	
Miller Tank, Chinnappa Garden	
Shivajinagar, Munireddy Palya	
Saraswath ipuram - Jogu Palya	
K R Garden	
Vrushabhavathi	
Gubbanna Layout	22
Shankarappa Garden Gopalapura	25
Cholurpalya	32 & 33
Bapujinagar	42
Minerva Mill	33
Dhovi Colony, near Sane Guruvanahalli Tank	19
Kamakshipalya Tank Slum Area	18
Binny Mill Tank Area	30
Markandayyanagar (n ear Binny Mill)	31
Sanjaya Gandhi Slum Area	41
Rudrappa Garden	45

Land-Use Changes

Land use is the use of land by humans, usually with emphasis on the functional role of land such as land under buildings, plantation, pastures, etc. Flows in the catchment were indirectly estimated by the land use area, runoff coefficient and precipitation. Land use pattern in the catchment has direct implications on hydrological yield. The yield of a catchment area is the net quantity of water available for storage, after all losses, for the purpose of water resource utilization and planning. Runoff is the balance of rainwater, which flows or runs over the natural ground surface after losses by evaporation, interception and infiltration [Ramachan dra and Uttam Kumar 2008]. The runoff from rainfall was estimated by rational method that is used to obtain the yield of a catchment area by assuming a suitable runoff coefficient.

Land use analysis was done using temporal remote sensing data - Landsat data of 1973 (of 79 m spatial resolution), 1992 and 2000 (30 m), IRS LISS-3 data of 1999 and 2006 (23.5 m) and MOD IS data of 2002 and 2007 (with 250 m to 500 m spatial resolution).

The analysis was done with supervised pattern classifiers based on maximum likelihood (ML) estimation followed by a Bayesian statistical approach. This technique quantifies the tradeoffs between various classification decisions using probability and costs that accompany such decisions. It makes assumptions that the decision problem is posed in probabilistic terms, and that all of the relevant probability values are known with a number of design samples or training data collected from field that are particular representatives of the patterns to be classified. The mean and covariance are computed using maximum likelihood estimation with the best estimates that maximizes the probability of the pixels falling into one of the classes.

Data: Survey of India (SOI) toposheets of 1:50000 and 1:250000 scales were used to generate base layers of taluk boundaries, city boundary, drainage networks, and water bodies. Field data were collected with a handheld GPS. Remote sensing data (spatial and spectral resolutions are listed in table 1) used for the study are:

- Landsat MSS of 1973 [downloaded from http://glcf.umiacs.umd.edu/data/]
- Landsat TM of 1992 [downloaded from http://glcf.umiacs.umd.edu/data/]
- Landsat ETM+ of 2000 [downloaded from http://glcf.umiacs.umd.edu/data/]
- IRS (Indian Remote Sensing) LISS (Linear Imaging Self Scanner)-III of 1999 and 2006
- MODIS (Moderate Resolution Imaging Spectroradiometer) Surface Reflectance 7 bands product [downloaded from http://edcdaac.usgs.gov/main.asp] of 2002 and 2007
- MODIS Land Surface Temperature/Emissivity 8-Day L3 Global and Daily L3 Global (V004 and V005 products)
  [downloaded from http://lpdaac.usgs.gov/modis/dataproducts.asp#mod11]
- SRTM (Shuttle Radar Topography Mission) elevation data of 90 m resolution
  [downloaded from http://glcf.umiacs.umd.edu/data/] and
- Google Earth image (http://earth.google.com) served in pre and post classification process and validation of the results.

Supervised classification was performed using Bayesian classifier and was verified with field knowledge, visual interpretation and Google Earth image. The supervised classified images of 1973, 1992, 1999, 2000, 2002, 2006 and 2007 with an overall accuracy of 72%, 75%, 71%, 77%, 60%, 73% and 55% were obtained by using the open source programs (i.gensig, i.class and i.maxlik) of Geographic Resources Analysis Support System (http://wgbis.ces.iisc.ernet.in/ grass) as displayed in Figure 11.1. The class statistics is given in table 6.1. The implementation of the classifier on Landsat, IRS and MODIS image helped in the digital data exploratory analysis as were also verified from field visits in July, 2007 and Google Earth image.

Table 6.1: Land use in Greater Bangalore

Class → / Year ↓		Built up	Vegetation	Water Bodies	Others
1973	**Ha**	5448	46639	2324	13903
	%	**7.97**	**68.27**	**3.40**	**20.35**
1992	**Ha**	18650	31579	1790	16303
	%	**27.30**	**46.22**	**2.60**	**23.86**
1999	**Ha**	23532	31421	1574	11794
	%	**34.44**	**45.99**	**2.30**	**17.26**
2000	**Ha**	24163	31272	1542	11346
	%	**35.37**	**45.77**	**2.26**	**16.61**
2002	**Ha**	26992	28959	1218	11153
	%	**39.51**	**42.39**	**1.80**	**16.32**
2006	**Ha**	29535	19696	1073	18017
	%	**43.23**	**28.83**	**1.57**	**26.37**
2007	**Ha**	30876	17298	1005	19143
	%	**45.19**	**25.32**	**1.47**	**28.01**

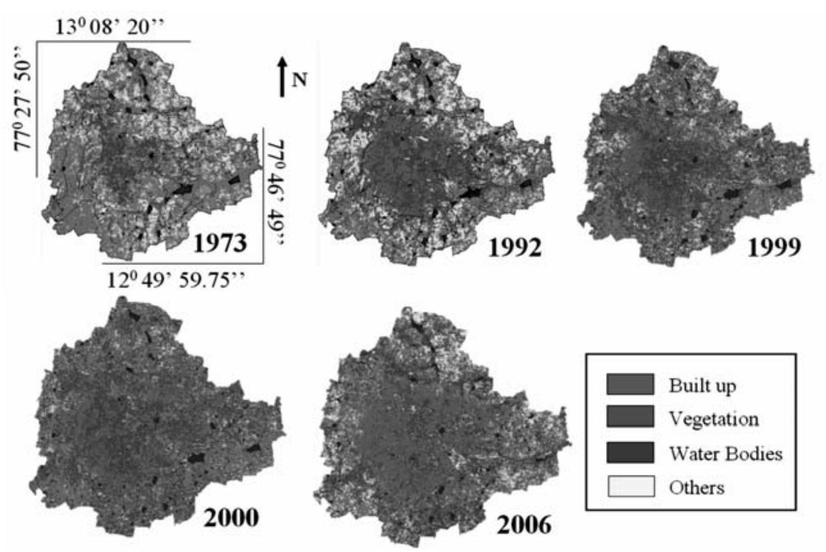

Figure 11.1: Temporal land use changes in Greater Bangalore

From the classified raster data, urban class was extracted and converted to vector representation for computation of precise area in hectares. There has been a 466% increase in built up area from 1973 to 2007 as evident from temporal analysis leading to a sharp decline of 61% area in water bodies in Greater Bangalore mostly attributing to intense urbanisation process. Figure 11.2 shows Greater Bangalore with 265 water bodies (in 1972). The rapid development of urban sprawl has many potentially detrimental effects including the loss of valuable agricultural and eco-sensitive (e.g. wetlands, forests) lands, enhanced energy consumption and greenhouse gas emissions from increasing private vehicle use. Vegetation has decreased by 32% from 1973 to 1992, by 38% from 1992 to 2002 and by 63% from 2002 to 2007. Disappearance of water bodies or sharp decline in the number of waterbodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes were unauthorised encroached for illegal buildings (54%). Field survey (during July-August 2007) shows that nearly 66% of lakes are sewage fed, 14% surrounded by slums and 72% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The surrounding of these lakes have illegal constructions of buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervene the natural catchment flow leading to sharp decline and deteriorating quality of waterbodies.

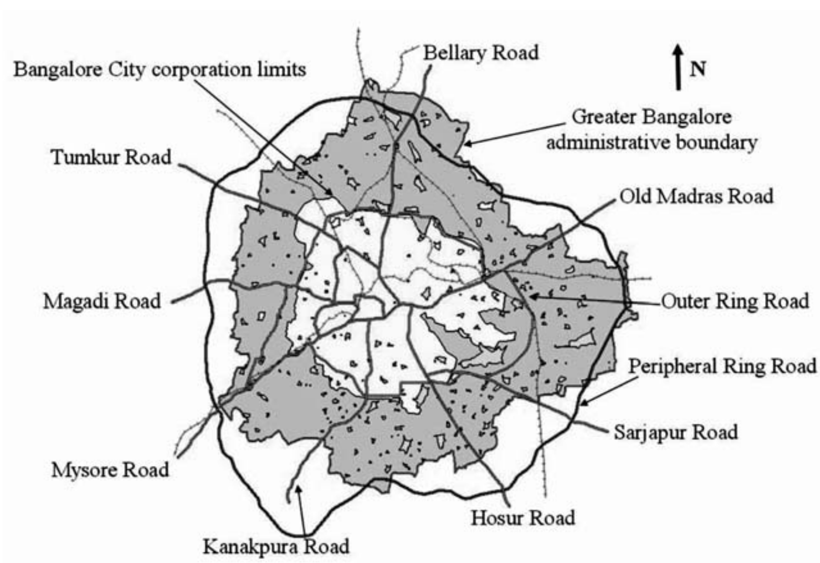

Figure 11.2: Greater Bangalore with 265 water bodies.

Figure 11.3 provides the distribution of wetlands in 1973, 1992, 2002 and 2007 based on the respective years' remote sensing data. The analysis revealed that there were 51 wetlands (321 ha) in 1973, 38 (207 ha) in 1992, 25 (135 ha) in 2002 and dropped down to 17 with an extent of 87 ha in 2007 in the Bangalore city limits.

There were 159 waterbodies spread in an area of 2003 ha in 1973, that reduced to 147 (1582 ha) in 1992, which further declined to 107 (1083 ha) in 2002 and finally there are only 93 waterbodies (both small and medium size) with an area of 918 ha in the Greater Bangalore region. Waterbodies in northern part of greater Bangalore are in a considerably poor state compared to the wetlands in southern greater Bangalore. Validation of the classified data was done through field visits during July 2007, which indicate the accuracy of 91%. The error of omission was mainly due to cover of water hyacinth (aquatic macrophytes) in the waterbodies due to which the energy was reflected in IR bands than getting absorbed. 54 waterbodies were sampled through field visits while the remaining waterbodies were verified using online Google Earth (http://earth.google.com).

Temporal analyses indicate the decline of 34.48% during 1973 to 1992, 56.90% during 1973-2002 and 70.69% of waterbodies during 1973-2007 in the erstwhile Bangalore city limits. Similar analyses done for Greater Bangalore (i.e Bangalore city with surrounding 8 municipalities) indicate the decline of 32.47% during 1973 to 1992, 53.76% during 1973-2002 and 60.83% during 1973-2007 (Table 4). This is correlated with the increase in built up area from the concentrated growth model focusing on Bangalore, adopted by the state machinery, affecting severely open spaces and in particular waterbodies. Some of the lakes have been rested by the city corporation and the concerned authorities in recent times [13].

Urbanisation and the consequent loss of lakes has led to decrease in catchment yield, water storage capacity, wetland area, number of migratory birds, flora and fauna diversity and ground water table. Studies in selected lake catchments in Bangalore reveal the decrease in depth of the ground water table from 10-12 m to 100-200 m in 20 years due to the disappearance of wetlands.

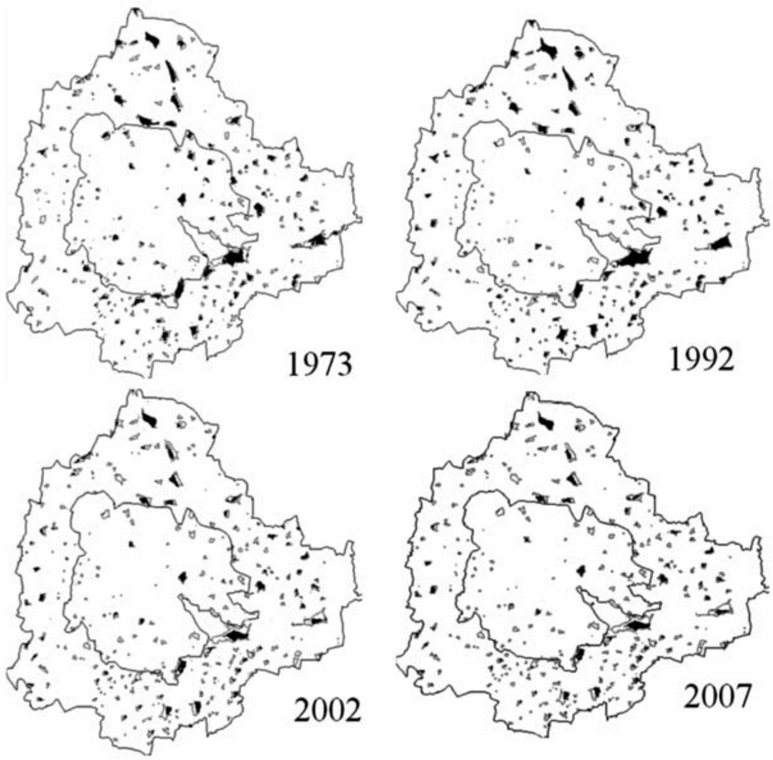

Figure 11.3: Unsupervised learning to extract waterbodies from NIR bands. Waterbodies are represented in blue and the vector layer of waterbodies generated from SOI Toposheet is overlaid (in red colour) that exactly fits on the exiting waterbodies. The inner boundary (in black) is the Bangalore city limit and the outer boundary represents the spatial extent of Greater Bangalore.

The dramatic increase in builtup area could be attributed to the urban sprawl in the peri urban areas of the city. The Shannon's entropy was computed to detect the urban sprawl phenomenon. Shannon's entropy computed for Bangalore city, Peri-urban and outskirts (hence n = 3), together comprising Greater Bangalore for 1973, 1992, 2000 and 2006 are listed in Table 6.2. The entropy values obtained for 2000 and 2006, (1.0325 and 1.0782) are closer to the upper limit of log n, i.e. 1.0986, showing the higher degree of dispersion of built-up in the city. The urbanisation process increased in 2000 and 2006, indicating higher entropy value as the distribution of built-up during 2006 was more dispersed than in 1973 or 1992.

Table 6.2: Shannon's entropy for Greater Bangalore				
Year	**1973**	**1992**	**2000**	**2006**
Entropy	0.9007	0.9023	1.0325	1.0782
ln(n)	1.0986			

Consequences of urbanisation and urban sprawl: Urbanisation and urban sprawl have posed serious challenges to the decision makers in the city planning and management process involving plethora of issues like infrastructure development, traffic congestion, and basic amenities (electricity, water, and sanitation), etc. [Ramachandra and Uttam Kumar 2004, 2007]. Apart from this, major implications of urbanisation are:

- **Floods:** Common consequences of urban development are increased peak discharge and frequency of floods as land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Conversion of water bodies to residential layouts has compounded the problem by removing the interconnectivities in an undulating terrain.
- **Heat island:** Surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, and the associated decreases in vegetation and water pervious surfaces, which reduce surface temperature through evapotranspiration.

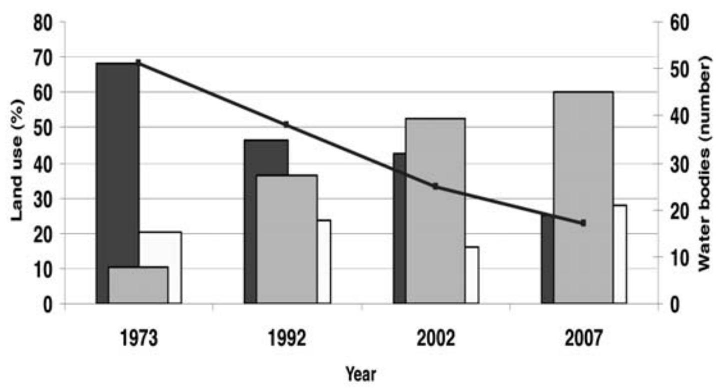

Figure 11.4: Temporal changes in built up and its impact on vegetation and water bodies

- **Loss of aquatic ecosystems:** Urbanisation has telling influences on the natural resources evident from the sharp decline in number of water bodies and also from depleting groundwater table. Figure 11.4 illustrates the loss of aquatic ecosystems (70% decline during 1973-2007 in the Bangalore city limits) and vegetation with the increase in built up area (466% during 1973-2007).

Floods in the City

Purpose of Assessment

Burgeoning human population coupled with the increased urban concentration has escalated both the frequency and severity of disasters like floods, etc. With the tropical climate and unstable land forms, coupled with land use changes, unplanned growth proliferation non-engineered constructions make the disaster-prone areas mere vulnerable. In this regard basic policy statements as part of comprehensive development plan of a region need to address:

- Protect life and health
- Minimising property losses
- Enhance floodplain use
- Ensure a functional drainage systems
- Encourage aesthetics
- Curb large scale land use changes in the immediate vicinity of waterbody catchment
- Guide development

This entails appropriate strategies for natural resources planning, development and management by adopting an integrated approach for a hydrological unit such as lake catchment, incorporating quantity, quality and environmental considerations (Ramachandra, 2007). Development projects and investment proposal has to be formulated and considered within the framework of lake catchment, river or sub-basin plan so that the best possible combination of options can be obtained for poverty alleviation, increasing incomes and productivity, equity, reduced vulnerability to natural and economic risks and costs (Ramachandra, *et al.*, 2007). Solutions to water allocation and planning issues will be found adopting a demand management approach.

Techniques adopted for assessment include data collection (primary and secondary data), analysis (remote sensing and collateral data) and interpretation.

Incidence Description

Unplanned urbanisation has drastically altered the drainage characteristics of natural catchments, or drainage areas, by increasing the volume and rate of surface runoff. Drainage systems are unable to cope with the increased volume of water and are often encountered with the blockage due to indiscriminate disposal of solid wastes. Encroachment of wetlands, floodplains, etc. Obstructs floodways causing loss of natural flood storage. Damages from urban flooding can be grouped into two categories:

- Direct damage—typically material damage caused by water or flowing water.
- Indirect damage—social consequences that are negative long term effects of a more psychological character, like decrease of property values in frequently flooded areas and delayed economical development, for e.g. traffic disruptions, administrative and labour costs, production losses, spreading of diseases, etc.

Table 7: Rainfall during 1995-2005, Bangalore

Wettest day		Rainfall in May	
Year	Day	mm	mm
2005	28-May	61.2	150.1
2004	4-May	42.9	207.9
2003	14-May	0.8	1.3
2002	26-May	95	183.5
2001	4-May	31.6	60.2
2000	6-May	19.2	56.6
1999	15-May	46.9	200.6
1998	12-May	52.2	110.3
1997	3-May	28.1	77
1996	30-May	33.6	117.6
1995	21-May	39.4	147.7

Source: IMD

Rainfall pattern in Bangalore: Monthly and Yearly rainfall record

Month	Days	Mm
Jan	0.2	2.70
Feb	0.5	7.20
Mar	0.4	4.40
Apr	3.0	46.30
May	7.0	119.60
Jun	6.4	80.80
Jul	8.3	110.20
Aug	10.0	137.00
Sep	9.3	194.80
Oct	9.0	180.40
Nov	4.0	64.50
Dec	1.7	22.10
Total	59.8	970.00

Year	Rainy days	Rainfall (mm)	liters/ 100sq.m
1990	42	509.40	40,752
1991	65	1338.50	1,07,080
1992	56	844.60	67,568
1993	65	1059.70	84,776
1994	45	587.10	46,968
1995	61	1072.20	85,776
1996	64	1173.30	93,864
1997	52	717.40	57,392
1998	68	1431.80	1,14,544
1999	52	1009.40	80,720
Average	57	974.34 mm	77,947

Urban flooding creates considerable infrastructure problems and huge economic losses in terms of production, as well as significant damage to property and goods. Flooding in urban areas causes large damage at buildings and other public and private infrastructure. Besides, street flooding can limit or completely hinder the functioning of traffic systems and has indirect consequences such as loss of business and opportunity. The expected total damage; direct and indirect monetary damage costs as well as possible social consequences is related to the physical properties of the flood, i.e. the water level above ground level, the extend of flooding in terms of water volume escaping from or not being entering the drainage system, and the duration of flooding. With sloped surfaces even the flow velocity on the surface might have an impact on potential flood damage. Precipitation, intensity and the duration of time are the key elements that decide flooding. Sometimes even 8 cm to 10 cm of rainfall in a short span of time have resulted in flooding, and if it occurred in a matter of one or two days, the water seeps into the soil, in the case of mixed land use (urban, vegetation). Even a 30 mm rainfall in a matter of 30 minutes could cause flooding, especially in the low-lying areas, due to

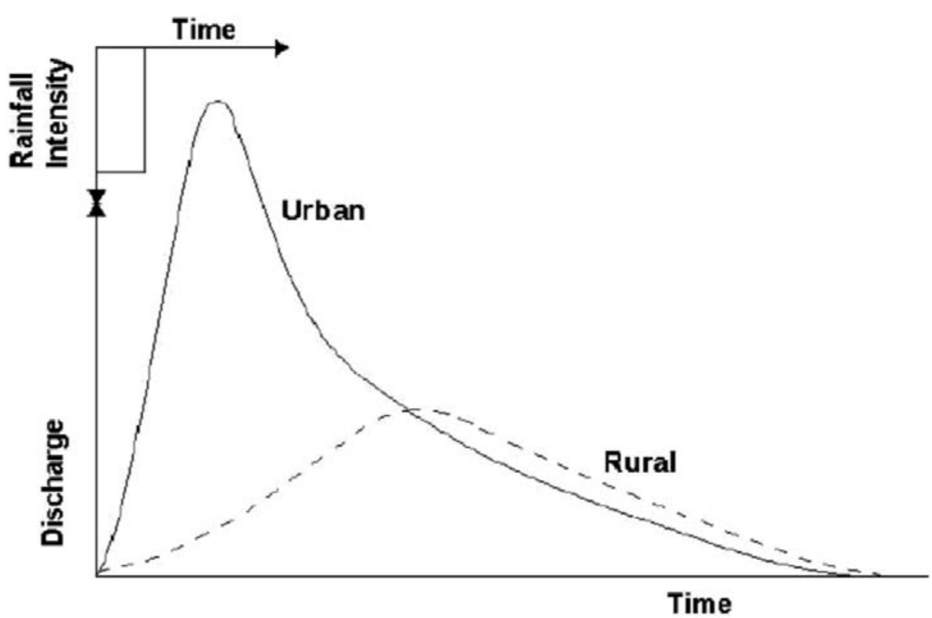

Figure 12.1: Flood Hydrographs for Urbanized and Natural Drainage Basins

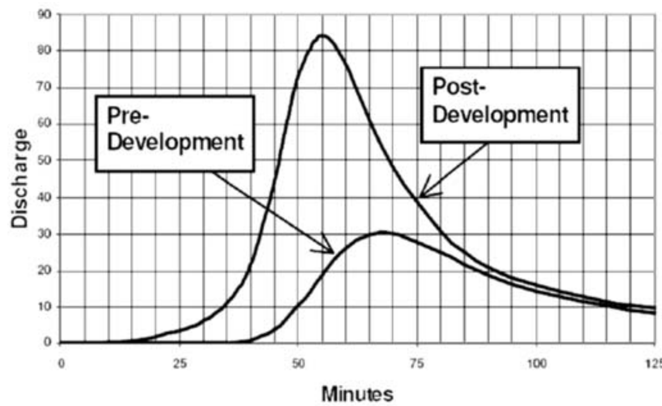

Figure 12.2: Runoff Hydrograph under Pre-and Post-Development conditions

intense urbanisation. Frequent thunder showers accompanied by squall and hail being the characteristic of the month of May, resulting in the uprooting of trees.

The highest rainfall recorded on a single day has been 10 cm during the month of May in 2002 (Table 7.1). The closest in record to this was 9 cm recorded in 1991 on a single day. Earlier, 1999 witnessed 200.6 mm rainfall and the lowest rainfall recorded has been 1.3 mm in 2003. The heaviest rainfall in 24 hours has been 153.9 on May 6 1909. As the development of land use in urban areas, less water can be absorbed by the soil and the volume of urban stormwater is increasing. This escalating volume of urban runoff not only increases pollution, it elevates the risk of flooding. The amount of urban runoff is largely a factor of rainfall and the amount of paved area. As paved area increases – for

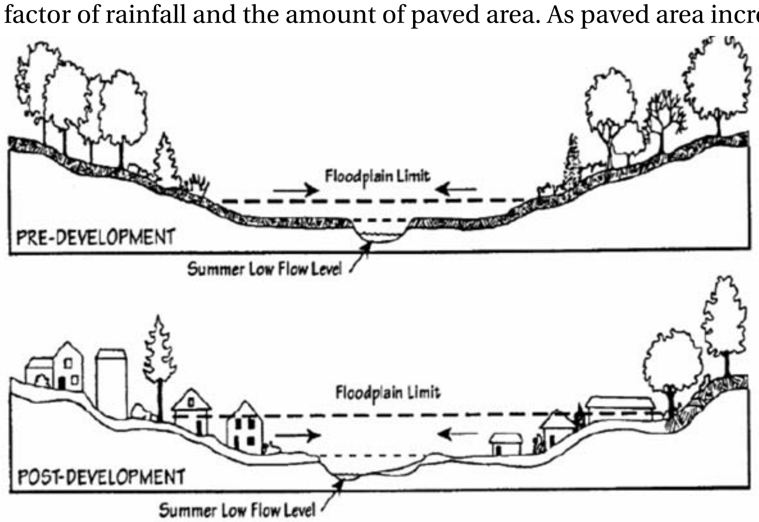

Figure 12.3: Change in Floodplain Elevations

example, due to vegetation clearing, new housing or industrial developments, urban infill, paving driveways, patios, new roads etc., so does the amount of runoff.

Increasing urbanization has led to significant changes in the natural systems. These changes include alterations in the hydrologic flow regime as well as shifts in the chemical and biological makeup of stormwater runoff from these developing areas. As an area is developed, the natural ability of the catchment to withstand natural hydrologic variability is removed. Infiltration capacity is decreased due to the increase in impervious surface and disrupted native soils and vegetation. Natural retention and detention capabilities of a catchment are removed through channelization of natural waterways and the installation of formal drainage systems such as pipes and gutters (Vijay Kulkarni and Ramachandra, 2006). Anthropogenic activity also introduces chemical and biological constituents to the catchment.

Increased peak discharges for a developed watershed can be two to five times higher than those for a watershed prior to development (Figure 12.1). The changes in the rates and amounts of runoff from developed watersheds directly affect the morphology, or physical shape and character, of creeks and streams (Figure 12.2). Some of the impacts due to urban development include: Stream widening and bank erosion, stream down cutting, changes in the channel bed due to sedimentation, increase in the floodplain elevation. Urban floods differ from those in natural basins in the shape of flood hydrographs (Figure 12.1), peak magnitudes relative to the contributing area, and times of occurrence during the year. The imperviousness of urban areas along with the greater hydraulic efficiency of urban conveyance elements cause increased peak stream flows but also more rapid stream response. Summer floods resulting from high intensity thunderstorms are more common in urban areas. Infiltration and evapotranspiration are much reduced at this time of the year under developed conditions (Prasad, et al., 2002, Ramachandra, 2002, WHGM, 2003).

Some of the impacts due to urban development include: reclamation of lakes (Plate 4.1), stream widening and bank erosion, stream down cutting, changes in the channel bed due to sedimentation, increase in the floodplain elevation (Figure 12.3). Urban floods differ from those in natural basins in the shape of flood hydrographs (Figure 12.1), peak magnitudes relative to the contributing area, and times of occurrence during the year. The imperviousness of urban areas along with the greater hydraulic efficiency of urban conveyance elements cause increased peak stream flows but also more rapid stream response (WHGM, 2003). Summer floods resulting from high intensity thunderstorms are more common in urban areas. Infiltration and evapotranspiration are much reduced at this time of the year under developed conditions.

Thus, flooding is a consequence of the increase in impervious area due to land use changes in the catchment from open space to impervious surfaces with the high-density urban developments. This is coupled with lack of drainage upgrade works with the changes in enhanced run-offs, the encroachment and filling in the floodplain on the waterways, obstruction by the sewer pipes and manholes and relevant structures, deposits of building materials and solid wastes with subsequent blockage of the system and also flow restrictions from under capacity road crossings (bridge and culverts).

The lack of planning and enforcement has resulted in significant narrowing of the waterways and filling in of the floodplain by illegal developments. This has subsequently caused flooding to other properties that have not previously been flooded, new properties in the flood plain built below the high flood marks (designated flood levels), these being frequently flooded and restrictions of options for future flood mitigation including widening of waterways.

Pre-Incidence Scenario

Table 7.2: Rainfall during May-November for forested and urban area (40% impervious)

Distribution of May to November Rainfall for Forested and Urbanized Areas Item	**Forested Areas**		**Urban Areas with 40% Impervious Cover**	
	Depth (mm)	% of Total Depth	Depth (mm)	% of Total Depth
May to November Rainfall	515	100.0	515	100
Interception Storage and Depression Storage on Impervious Areas	342	66.5	235	45
Infiltration	155	30.0	100	20
Runoff	18	3.5	180	35

Urban floods are linked to the total lack of attention to the nature of region's hydrological system. Despite the knowledge of occurrence of heavy downpours and its frequency, the natural drainage channels are not maintained, catchment area of lakes and lakes have been allowed to be encroached by land mafia in connivance with the government machinery. This is something our ancestors knew but our current urban planners and politicians don't worry about such mundane things (http://www.rainwaterharvesting.org/

catchwater/oct2000/newslet9_1.htm,http://www.downtoearth.org.in/editor.asp?foldername=20000930&filename=Editor&sec_id=2&sid=1).

Urban flooding is not a new phenomenon. Increasingly, more and more cities and towns face waterlogged streets. Post 2000 have witnessed, even relatively small downpours are enough to clog up drains, fill up streets and disrupt life and the study proved that unchecked construction of big buildings, loss of open spaces, and clogged drains were the cause.. Meanwhile, cities continue to face water scarcity and the water tanker business continues to grow. Bangalore is just one example of bad water management practices. Years of siltation of tanks have reduced their water storage capacity. Encroachments of nalas, lakes and other waterbodies, choking of streams and stormwater drains have taken their toll. There is a need for urban areas to improve water management. Urban water harvesting offers a solution to deal with meeting water demand as well as reducing the intensity of urban flooding. Thus, the urbanization process and the hydraulic insufficiency of drainage systems are two of the most common causes of urban flooding.

Development and redevelopment of the district, by nature increases the amount of imperviousness in the surrounding environment. This increased imperviousness translates into loss of natural areas, more sources for pollution in runoff, and heightened flooding risks. In recent decades, stormwater runoff has emerged as an issue of major concern. Stormwater affects local waterways both in terms of the volume of runoff that is generated, and the nature of the pollutants that may be conveyed. Allowing stormwater to infiltrate in urban residential areas is one of the major ways for urban floods.

A major consequence of the increase in impervious area which accompanies urbanization is an increase in direct runoff and a corresponding decrease in infiltration. Table 7.2 illustrates the changes in hydrological components that result from developing a forested area. Urbanization also results in decreased evapotranspiration. The net effect of conventional development practices on an urban stream is a dramatic change in the hydrologic regime of the stream.

The downstream urban flooding problem has become acute during the past thirty years as communities have grown and as curbed roadways (paved channels) have been installed in both new suburban areas and throughout older areas that formerly provided runoff-retarding storage in roadside swales or ditches. Amelioration of the unfortunate results of past urbanization requires very large investments to construct additional flood control works. Where flood control is infeasible, the flooding hazard reduces property values and may lead to abandonment, which is unacceptable.

Response & Loss Summary

The survey carried out by BWSSB in Bangalore reveals that few households from the peri-urban and the Green Belt areas reported that their houses had been flooded in the recent past, suggesting that high density of houses and unplanned urbanisation have contributed to the problem of improper drainage in the Corporation Area. Major highlights of the survey are:

- 7% of households reported that they faced instances of flooding;
- 10% of households of lower socio-economic status reported that they had faced flooding in the past decade – instances of flooding had been more common in the central part of the city;
- Of the households that had experienced flooding, 72% reported such occurrences in the last one year, 15% had experienced flooding in the year 1999, 7% during the period 1995 to 1998, while 2% reported that they had experienced flooding prior to 1995;
- Of the households that had experienced flooding, a majority said that the effects had lasted for one to three days, while 3% said they had extended beyond a week;

BANGALORE CITY BUS STAND, ONCE DHARMAMBUDHI TANK

THE KGA GOLF COURSE STANDS ON WHAT WAS ONCE THE CHALLAGHATTA TANK

THE KARAMANGALA TANK IS TODAY A SPORTS COMPLEX

A SPORTS STADIUM TODAY..,
THIS WAS THE SAMPANGI TANK EARLIER

Plates 4.1: Conversion of lakes in Bangalore Similar past incidences

[Source: http://www.thisismyindia.com/pictures_of_india/bangalore-pictures.html]

GARVIBAVI PALYA NEAR HOSUR RADO

HOSUR ROAD FLOODED IN BANGALORE

HOUSE IN JP NAGAR BANGALORE

TRAFFIC JAM TO HEAVY RAINS

SUBWAY BETWEEN MAGESTIC AND RAILWAY STATION

RISING WATER LEVEL AND VEHICLES

Plate 4.2: Rain havoc in Bangalore during 2005 and 2007

- Two thirds of the households ascribed the reasons for flooding to blockages in the sewerage system, 12% to ingress of rainwater into the house, while 11% said that it had been caused by a blocked drain or gutter;
- Lower income households and those living in the slums were more vulnerable to flooding caused by blocked drains; and

All households reported damage to assets and loss of workdays on account of such flooding. Majority of these affected communities are engaged in daily wage labour or small-scale retail activities. Flooding and the resultant disruption of mobility have a direct impact on the incomes of the households. Their ability to cope with such disturbances is much lower than that of other socio-economic groups who have larger social and economic security nets to fall back upon. Women, children and the elderly are most vulnerable to hazards of poor environmental sanitation, as they spend more time in the house and its vicinity than adult men who have greater mobility and often spend little time within the house or the neighbourhood.

In addition to this, newspaper reports in response to rain havoc (one such example on May 28, 2005, Plate 4.2)

- A woman and a man were killed (HTUhttp://www.thisismyindia.com/UTH pictures_of_india/bangalore-pictures.html)
- Heavy water logging was reported from 35 areas in southern and eastern parts of the city
- The Fire and Emergency Services had to press in 20 vehicles to clear uprooted trees and pump out water in flooded areas
- 434 electric poles were uprooted. BESCOM suffered a loss of Rs. 4.8 crore
- A number of trees were uprooted, damaging a BMTC bus, a car and three other vehicles

Litter, building debris, sediments and solid waste are the main causes of blockages of the drainage system and subsequent floodinge. Therefore, minimising flooding and the establishment of clean healthy waterways are some of the many benefits which can be achieved through appropriate solid waste and catchment management practices by reducing pollution from the sources. BWSSB's Sewer Division has, over the last two years, carried out de-silting of the 2000 mm diameter outfall sewer including sewer section through Ejipura – where much of the silting up was caused by local residents breaking into the sewer to release flood water.

Various Factors Responsible for the Floods

Reclamation of lakes for various developmental activities (Plate 4.1) has resulted in the loss of interconnectivity in Bangalore district leading to higher instances of floods even during the normal rainfall. Analyses of Bellandur and Ulsoor drainage network (Figure 13.1)

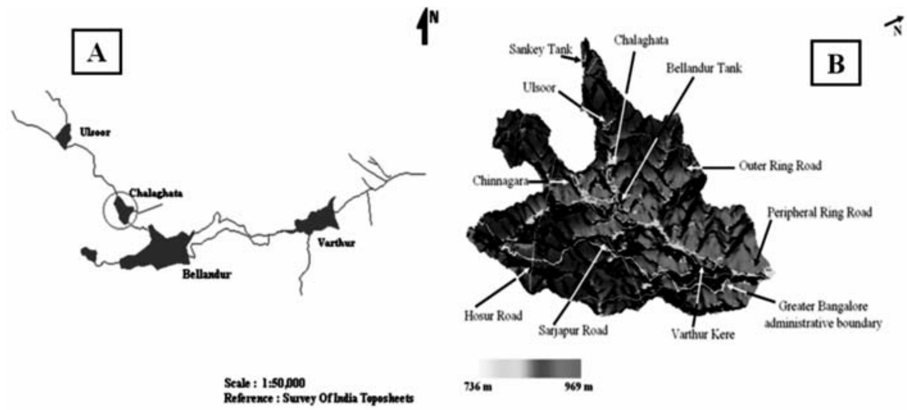

Figure 13.1: Ulsoor-Bellandur-Varthur (a) drainage network (b) lakes overlaid on 10 m DEM showing their missing interconnectivity

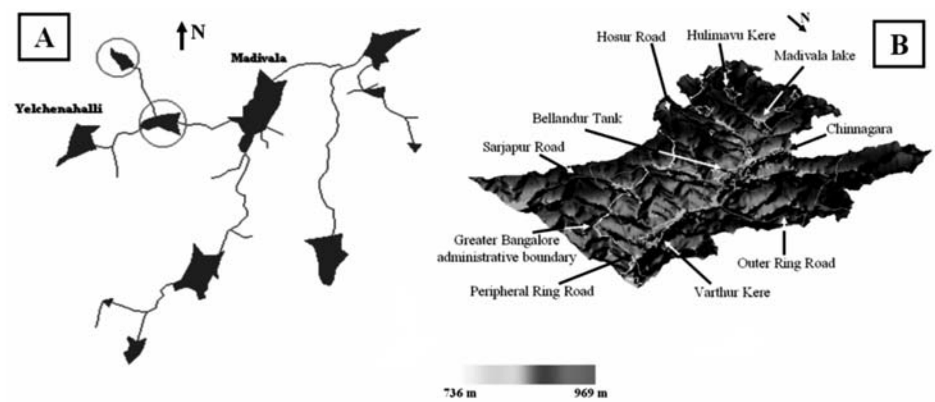

Figure 13.2: Madivala-Bellandur-Varthur (a) drainage network (b) lakes overlaid on 10 m DEM showing their missing interconnectivity

showed that the network is lost due to conversion of Chelgatta tank into a golf course. Similarly the drainage network between Madivala and Bellandur revealed of encroachment and conversion that has resulted in the loss of connectivity between Yelchenhalli kere and Madivala (Figure 13.2). Figure 14.1, 14.2 and 14.3 provides the line diagrams of drainage systems of three valleys namely Challaghatta , Ulsoor Valley and Hebbal Valley

Increased peak discharge and higher frequency of floods are the consequences of urbanisation. As land is converted from fields to built up, it loses its ability to absorb rainfall. Urbanisation has increased runoff 2 to 6 times over what would occur on natural terrain in some pockets of Bangalore. During periods of urban flooding, streets become swift moving rivers, while low lying residential areas and basements become death traps as they fill with water. Conversion of water bodies to residential layouts has further exaggerated the problem.

Flooding in urban areas causes large damage at buildings and other public and private infrastructure (evident during 1997, 2002 and 2007). Besides, street flooding can limit or completely hinder the functioning of traffic systems and has indirect consequences such as loss of business and opportunity. The expected total damage; direct and indirect monetary damage costs as well as possible social consequences is related to the physical properties of the flood, i.e. the water level above ground level, the extent of flooding in terms of water volume escaping from or not being entering the drainage system, and the duration of flooding.

Ulsoor–Belandur catchment: This catchment has 6 lakes – Sankey, Ulsoor, Chalghata, Chinnagara and Varthur and was classified into three major land use types – built up, vegetation and others (comprising open land, waste land etc). The total rainfall yield in this catchment is 240 MmP3P, percolated water is 90 MmP3P and water overflow is 150 MmP3P. The SRTM DEM data were resampled to 10 m resolution and the volume of each lake was computed assuming the depth to be 1 m and the mean annual rainfall to be 850 mm. The total volume of all the 6 lakes in this catchment is 73 MmP3P. Hence there is surplus overland flow of 77 MmP3P, which cannot flow to downstream due to disruption of natural drainage (removal of lakes and blockage of storm water drains) resulting in flooding (even during normal rainfall).

Madivala–Varthur catchment: Similar analysis was done for Madivala catchment which has 14 lakes – Venkatapura, Yellakunte, Bandepalya, Begur Doddakere, Madivala, Hulimavu, Marenahalli, Govindanaikana kere, Tank north of Doresanipalya, Gittigere and Vaddarpalya. The total rainfall yield is 247 MmP3P, percolated water is 97 MmP3P and the remaining 150 MmP3P water flows as overland flow and storage in lakes. The total volumes of all the lakes considering 1 m depth is 110 MmP3 Presulting in the excess of 40 MmP3P from the catchment leading to artificial floods. In addition to rainfall, Belandur-Varthur watershed receives untreated municipal sewage to the order of 500MLD.

Disappearance of waterbodies or sharp decline in the number of waterbodies in Bangalore is mainly due to intense urbanisation and urban sprawl. Many lakes were encroached for illegal buildings (54%). Field survey (during July-August 2007) shows that nearly 66 % of lakes are sewage fed, 14 % surrounded by slums and 72% showed loss of catchment area. Also, lake catchments were used as dumping yards for either municipal solid waste or building debris. The surrounding of these lakes have illegal constructions of

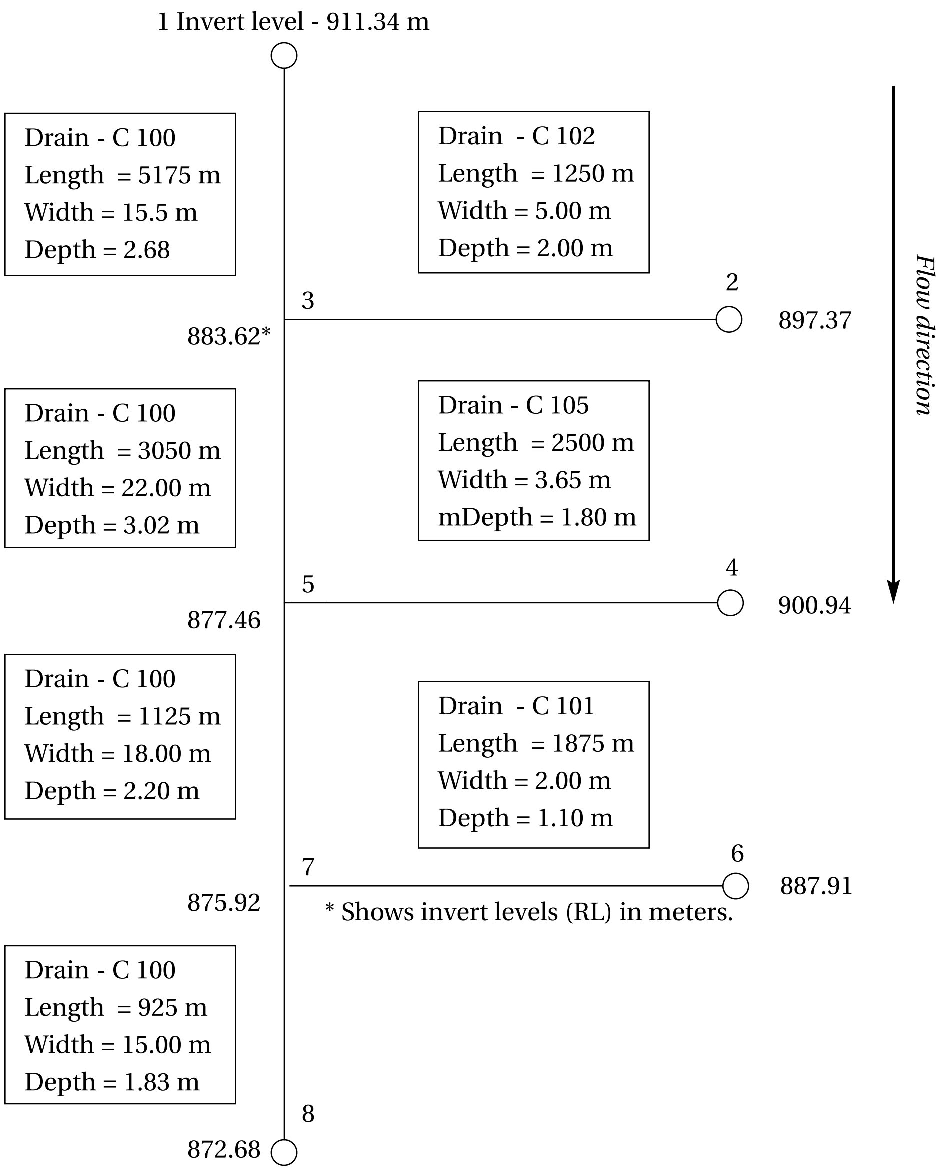

Figure 14.1.Line-diagram showing the Drainage System of Challaghatta Valley

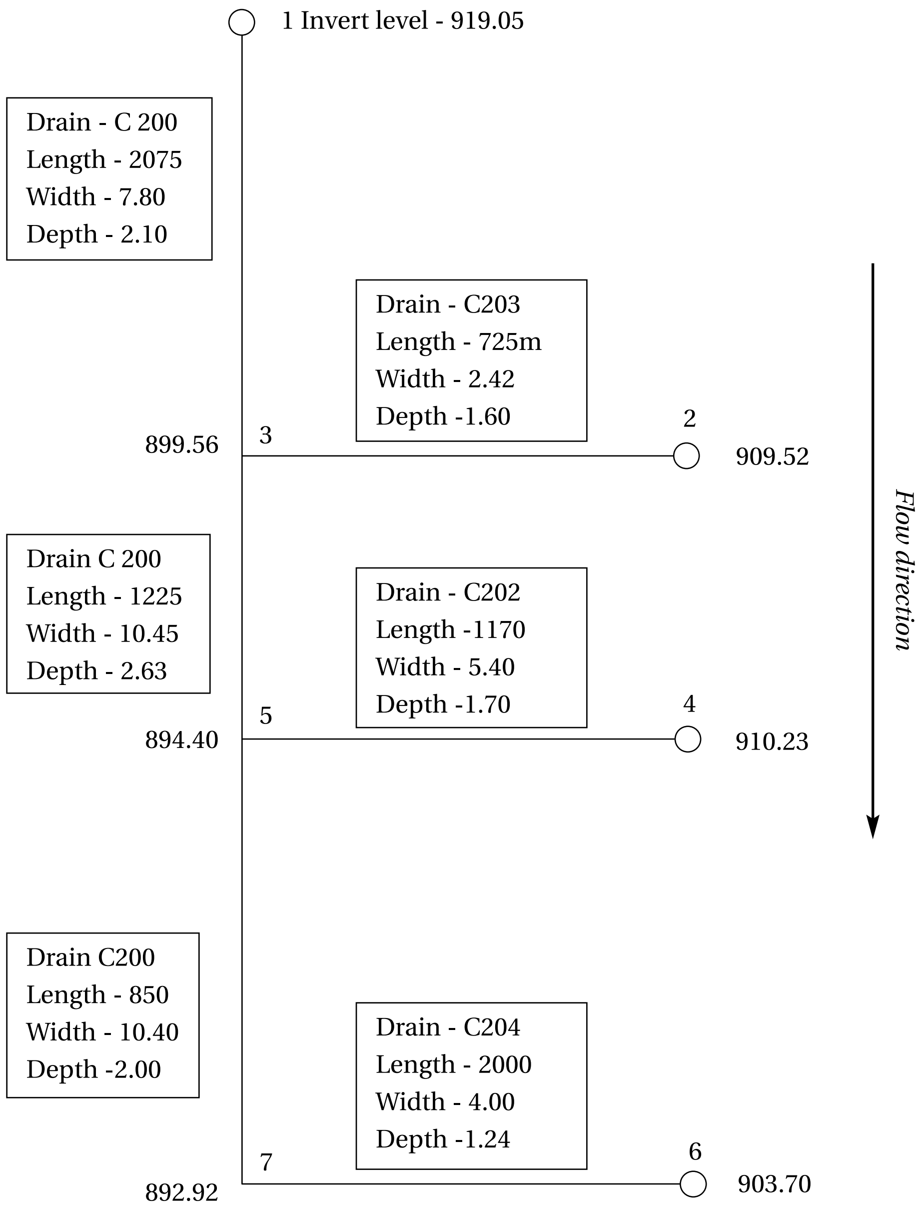

Figure 14.2: Line diagram showing the drainage system of Ulsoor Valley

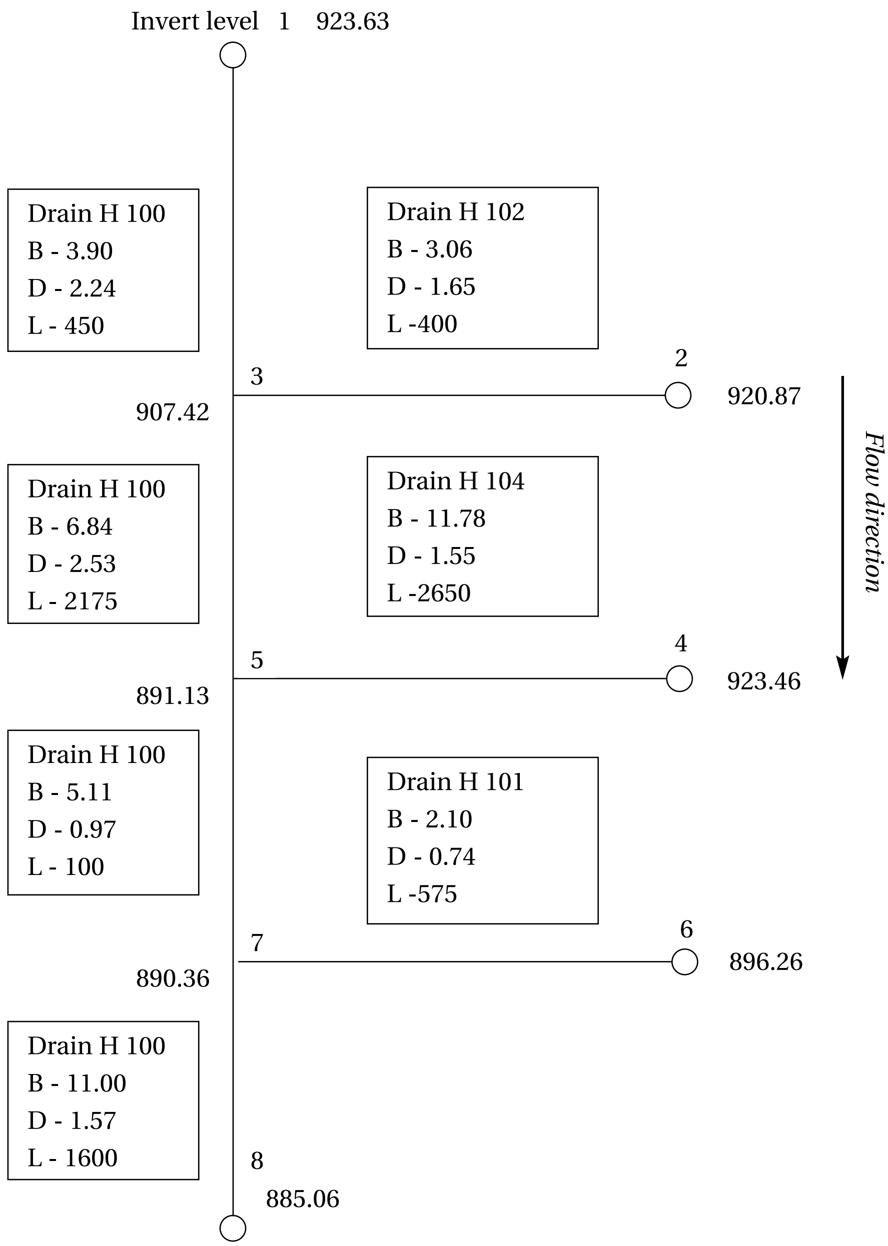

Figure 14.3: Line diagram showing the drainage system of Hebbal Valley

Table 8.1: Causal factors and key impacts

Causal factors	Key Impacts and remedial actions
Unplanned urbanisation	
Increase of impervious surfaces and non-upgradation of drains to handle enhanced runoff Encroachment of drain	Causes increased volume and rate of surface run-off from developed lands, which leads to more flash flooding and increased extent, height and frequency of flooding. ✓ Prevention of alteration of topography in the catchment. Upgradation of drains from top of catchment to catchment outlet for handling increases in run-off
Sediment and erosion from median strips and verges, spills from construction vehicles (e.g. concreting, earthmoving)	Reduced capacity, ✓ Improved catchment management practices
Development in flood-prone areas	
Encroachment and alteration of floodplain	Restricts flow and increases flooding on unfilled lands ✓ Control filling to overall valley Reduces flood storage capacity, increasing downstream flooding ✓ Undertake whole of catchment planning for drainage
Inadequate provision for main drains in development plans	Causes gradual reduction in waterway capacity due to encroachments ✓ enforce compliance ✓ Incorporate drainage reserves
Development below flood level	Creates high flood damage, lowers standard of housing and reduces property values ✓ Prepare flood level plans to a datum and use them to control building floors and other development
Cross drainage (and services in drains)	
Lack of capacity of cross drainage works	Causes localised and widespread flooding ✓ Reconstruct to a standard equal to the future drain requirements
Construction of services (water, telecommunication, power etc.) above invert and below flood level	Obstructs flow and aggravates flooding ✓ Relocate services, coordinate works and agree on service locations
Sewerage system in drains	
Reduction in stormwater system capacity	Increases flooding significantly ✓ Lower manholes and reconstruct sewers below drain invert
Obstruction and redistribution of stormwater flow, generally poorly constructed sections	Causes bank and bed erosion; flooding in the waterways ✓ Reconstruct and improve future designs
Solid waste disposal	
Dumping of solid waste and building site waste in the drainage channel	Causes blockage and pollution in the drainage system ✓ Implement solid waste strategy plan
Unstable and degraded waterways	
Weed infestation, encroachment, vegetation loss, and eroded and unstable riparian zones	Causes siltation of downstream waterways ✓ Treat erosion sites and develop guidelines for silt control during construction

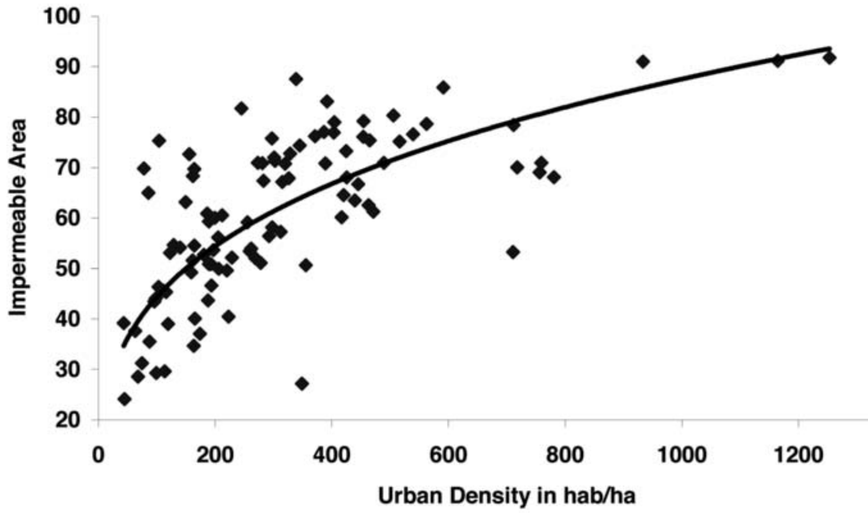

Figure 15: Impermeable area and urban density for Bangalore

buildings and most of the times, slum dwellers occupy the adjoining areas. At many sites, water is used for washing and household activities and even fishing was observed at one of these sites. Multi-storied buildings have come up on some lake beds that have totally intervened the natural catchment flow leading to sharp decline in the catchment yield and also deteriorating quality of waterbodies. Table 8.1 summarises the causal factors for poor drainage system and remedial measures to be undertaken to improve the condition.

Plate 4.3: Flooding In Banashanakari (Photo: Ranjini)

Landsat ETM+ data of 15 m spatial resolution (on fusing with Landsat ETM+ PAN) have been used to estimate impermeable areas that does not distinguish between types of urban land use (industrial, commercial and residential) but consist of a sample from a mixture of residential and commercial areas. Figure 15 shows the relation found between impermeable area to urban population density. Consequence of increase in built up pixels (evident from the increase in paved surface or impermeable area) is the increase of population density in a region.

There is a general lack of appreciation of the potential values and importance of waterways in the urban environment and also fragmented management approaches have contributed to decline in waterways in the catchment. Although sewerage system is provided in many drainage basins in the core area by BWSSB, there are still large quantities of raw and partially treated sewage flowing in the urban drains and ultimately polluting the lakes. This is due to combination of wastes discharged from un-sewered premises, branch sewers not connected to the trunk sewers, and effluent from trunk sewers that are under capacity due to siltation or higher than planned development densities. Another significant factor contributing to frequent flooding of low-lying areas and to unsanitary conditions in drains and lakes is the large and rapid accumulation of sediments in the drains, dumping of solid wastes, building debris and casual litter disposal on drains. Similarly, erosion control practices in construction sites, public parklands, private gardens and on the medians and verges of roads are not sufficient to prevent large silt loads

Plate 4.4: Encroachment of a drain by slums and disposal of solid and liquid waste

reaching the main drains. These factors, combined with infrequent clearance of drains, have lead to the unsanitary conditions in drains and to drains with much reduced capacity.

Also, due to increased paved surface and concentrated human activities the magnitude of the difference in observed ambient air temperature between urban pockets (artificial land surface) and the regions covered with vegetation (natural area), which is ascribed as urban heat island effect. The urban heat-island effect results in increased local atmospheric and surface temperatures in urban pockets compared to the surrounding open spaces, etc. Specifically, surface and atmospheric temperatures are increased by anthropogenic heat discharge due to energy consumption, increased land surface coverage by artificial materials having high heat capacities and conductivities, increased vehicular and industrial emissions and the associated decreases in vegetation and water pervious surfaces, which reduce surface temperature through evapotranspiration. An attempt is made here to understand the implications of land cover changes on local climate.

Inadequate drainage causes inconvenience and loss to the property and human life depending on the intensity (Plate 4.3). It leads to flooding of houses and establishments in the floodplains. In its least severe form, poor drainage causes water stagnation that provides a breeding ground for disease vectors.

Vulnerability of Communities with Poor Drainage

Socio-economic condition, age and gender decide the vulnerability. This is aggravated by type of dwelling as well as inadequate drainage in and around living areas. Many of the slums and informal settlements of poor communities are either located along the drainage lines or in low-lying areas (Plate 4.4). They build their houses using semi-permanent materials (such as earth, thatch and plastic sheets) that afford little protection from floods. These communities suffer extensive damage to their property in the event of even minor localised flooding and are also are vulnerable water logging from slow drainage of rainwater. Many of these settlements are illegal encroachments, the losses suffered by residents are never formally recognised or compensated. Vulnerability arising from the specific location of poor households is one of the key factors contributing to the inadequate living conditions of the poor in urban areas. Often plinths of houses in slums and informal settlements are lower than the road heights, which are raised over the years due to road development activities. Such areas require very good drainage, as even small quantities of stagnant water can flood the houses. Out of the 360 officially recognised slums in Bangalore only 30 percent have underground sewerage services. Hence, in the majority of slums wastewater must be discharged via the stormwater system, where one exists.

Efforts made to mitigate and manage the floods

Sustainable urban development is possible only with the effective good governance at local levels. These are more effective than statutory authorities in mobilising community resources and undertaking local action to improve or protect the local environment. There is a need to integrate the functioning of all parastatal agencies. Transferring lakes to local government ownership provide an incentive for collective community action against polluters. In 1988 the Government transferred responsibility for 114 tanks within the conurbation area from the Minor Irrigation Department to the Karnataka Forest Department (KFD). The total area of the tanks is 1584 ha, of which 220 ha are under unauthorised occupation. Between 1988 and 2000, the KFD fenced 37 tanks and posted watchmen, and undertook minor improvement works at 10 tanks. In Calcutta, for example, the major drainage is the responsibility of the Irrigation Department and the minor drainage is the responsibility of local governments. In Bangalore, local governments have to coordinate with the KFD, the Minor Irrigation Department, and the BDA.

Name of the village	Survey nos.	Proposed CDP Land use	Existing development
Bommanahalli CMC			
Puttenahalli	31 - 41, 55 - 60	Park	Residential
	29,30 (part)	Residential	Forest nursery
	51,61 (part)	Public & Semi Public	Mango garden
Sarakki kere	24,25	Park	Residential
Billekally DoresanypaIya)	151 (part), 154	Residential	Industry
Jaraganahalli	24,25 (Part)	Traffic & Transportation	Residential
Arekere	26, 30	Industry	Residential
Hongasandra	33, (part)	Residential	Industry
Bommanahalli	61	Park	Residential, industrial
Kodichikkanahalli	3, 4, 5, 6 (parts)	Commercial	Residential
	34, 35 (part)	Public & Semi Public	Residential
Devarachikkanahalli	20, 21 (part), 19 (part)	Public & Semi Public	Residential
Hulimavu	77 (part)	Park	Industry
	86	Park	Residential
	76, 78 (part), 79 (part) 80	Industrial	Predominantly residential

Krishnarajapura CMC.			
Kowdenahalli	82-84, 86, 87, 88P P(part)	Industrial	Residential
	89	Public & Semi Public	Residential
	90, 91, 92	Traffic & Transportation	Residential
Virjnapura	121 (part), 118-119P P(part)	Park	Residential
	23P P(part), 24P Ppart), 103P P(part) 104 (part)	Traffic & Transportation	Residential
	34 (part), 35 (part), 42 (part)	Park	Residential
Krishnarajapuram	115 (part), 123 (part), 112 (part)	Public & Semi Public	Residential
G M Palya	123, 124	Industry	Residential
Devasandra	4 (part), 5, 6 (part), 7 (part)	Residential	Industry
Vibhuthipura	104 (part), 105 (part), 106 (part) 170 (part), 205 (part)	Railway	Residential
	108P P(part), 110P P(part), 184P P(part)	Park	Residential
Bhattarahalli	50, 51, 53, 54 (all part)	Green Belt	Industrial and residential
Medahalli	All survey nos.	Green Belt	Industry

Three statutes define the responsibilities and powers of local governments in Karnataka:

- *The Karnataka Municipalities Act 1964*, which applies to the CMCs and the TMC;
- *The Karnataka Municipal Corporations Act 1976*, which applies to the BMP;
- *The Karnataka Panchayat Raj Act 1993*,which applies to the panchayats.

Each statute sets out obligatory and discretionary functions and specific powers. The functions are in partial alignment with the functions that the Twelfth Schedule to *The Consitution) Seventy-fourth Amendment Act 1992*.

The 73rd and the 74rd amendments to the Indian Constitution in 1994 have been regarded as landmarks in the evolution of local governments in India. The Constitution (73PrdP Amendment) Act, 1992 (commonly referred to as Panchayat Raj Act) came into effect on April 24th, 1993 and the Constitution (74th Amendment) Act, 1992 (the Nagarpalika Act) came into effect on June 1st, 1993. While the 73rd amendment provides for constitution of Panchayats in rural areas, the 74th amendment provides for constitution of Municipalities in urban areas. Since local government is a State subject in Schedule VII to the Constitution, legislation with respect to local government can only be done at the State level. Therefore, upon the coming into force of the 73PrdP and the 74PthP amendments, it was the task of the respective States to pass laws in conformity with the amendments.

The Comprehensive Development Plan (CDP)

In 1984, the Government of Karnataka approved the first CDP for BMA. The Government approved a revised plan in 1995 (GO Bi. HUD 139 MNJ, 5 Jan 1995). The CDP covers the entire 1279 kmP2P of the BMA, comprising a 565 km^2 "Conurbation Area" and a 714 km^2 Green Belt. The CDP permits only a few types of development in the zone. BDA can demolish any construction in the Green Belt without its approval. However, extensive construction has taken place within the Green Belt. .

Under *The Karnataka Town and Country Planning Act 1961*, any new layout in the region requires the approval of the BDA. The widespread practice of forming sites for sale out of agricultural land contravenes the Karnataka Land Reforms Act, the Karnataka *Land Revenue Act, and the Bangalore Development Authority Act*. Verification of development in the region, reveals numerous discrepancies from the CDP (Table 9.1 and Table 9.2).

Table 9.1 Deviations from CDP

City Development Plan (CDP, 2006. City Development Plan for Bangalore, BMP, Bangalore), prepared for the city of Bangalore by BMP, is a 6- year policy and investment

Table 9.2: Land use Pattern in BDA Area

Category	Area (Hectares)	Area (%)
Residential	16,042	14.95
Commercial	1,708	1.59
Industrial	5,746	5.36
Park and open spaces	1,635	1.52
Public, semi-public	4,641	4.33
Transportation	9,014	8.40
Public utility	192	0.18
Water sheet	4,066	3.79
Agricultural	64,243	59.88

Souce: CDP, 2006

plan (2007-12) designed to articulate a vision of how Bangalore will grow in ways that sustain its citizens' values. Bangalore city has developed spatially in a concentric manner. However, the economic development has occurred in a different manner in different sectors of the City. The current urban structure results from the interlocking of these two developments. Five major zones can be distinguished in the existing land occupation:

- **1st Zone - The core area** consists of the traditional business areas, the administrative centre, and the Central Business District. Basic infrastructure (acceptable road system and water conveyance), in the core areas is reasonably good - particularly in the south and west part of the city, from the industrial zone of Peenya to Koramangala. This space also has a large distribution of mixed housing/commercial activities.
- **2nd Zone - The Peri-central area** has older, planned residential areas, surrounding the core area. This area also has reasonably good infrastructure, though its development is more uneven than the core area.
- **3rd Zone - The Recent extensions** of the City (past 3-5 years) flanking both sides of the Outer Ring Road, portions of which are lacking infrastructure facilities, and is termed as a shadow area.
- **4th Zone -** The New layouts that have developed in the peripheries of the City, with some vacant lots and agricultural lands. During the past few years of rapid growth, legal and illegal layouts have come up in the periphery of the city, particularly developed in the south and west. These areas are not systematically developed, though there are some opulent and up-market enclaves that have come up along Hosur Road, Whitefield, and Yelahanka. The rural world that surrounds these agglomerations is in a state of transition and speculation. This is also revealed by the "extensive building of houses/layouts" in the green belt. Both BDA and BMRDA are planning to release large lots of systematically developed land, with appropriate infrastructure, to address the need for developed urban spaces.
- **5th Zone - The Green belt and agricultural area** in the City's outskirts including small villages. This area is also seeing creeping urbanization. While the core area has been the seat of traditional business and economy (markets and trading), the peri-central area has been the area of the PSU. The new technology industry is concentrated in the east & southeast. These patterns are obviously not rigid - especially with reference to the new technology industry and services that are light and mobile, and interspersed through the City, including the residential areas. Table 9.2 provides the current land use pattern in BDA area

While infrastructure in the City is reasonably good in some aspects (water and sewerage, for instance), it is under stress in other aspects, particularly urban transport. Qualitatively, the urban infrastructure situation is profiled in the following:

- **Water supply:** The availability of raw water at about 140 lpcd is adequate, though the draw distances are increasing progressively. UFW is high, and distribution is uneven - being better in the BMP areas and poor in the peripheral areas.
- **Storm water Drainage:** Drainage is an area of concern, with the natural drainage system (Valleys) being built upon. With the growth of the City, the number of lakes has dwindled, and small lakes and tank beds have vanished because of encroachment and construction activities. This has resulted in storm-water drains reducing to gutters of insufficient capacity, leading to flooding during monsoon. Dumping of MSW in the drains compounds the problems, leading to blockages. To control floods, it is important to remove silt and widen these storm water drains to maintain the chain flow and avoid water from stagnating at one point.
- **Transport:** Rising traffic congestion is one of the key issues in the City. Though the length of roads available is good, the problem lies with the restricted widths. BMTC is one of the best bus transport corporations in the country, but the absence of a rail-based commuter system compounds the problem.
- **SWM:** Collection and transportation coverage is very good, but proper and adequate treatment/ disposal facilities are lacking.
- **Green Areas & Water bodies:** The City has a tradition of being a "Garden City" with plenty of green spaces and water bodies. However, the very high growth rate in the past two decades is having an adverse impact on these.

Key Issues of Urban Drainage Systems

Urban drainage has a direct impact on the City's image, citizens' life, and health. If the system does not work properly, it leads to environmental hazards (CDP, 2006). Improving the urban drainage system requires not only capital infusion, but also recurring expenditures for operation and maintenance. A single point obstruction in a storm-water drain would have a cascading overall impact. Citizen awareness is therefore a critical issue, and citizens and non-governmental organizations can play a key part in monitoring development in the region to ensure that drainage is not obstructed, and dumping of debris and MSW in drains does not occur.

Adherence to best practice guidelines as pre conditions to issuing a permit for development will help to ensure that all development within the city contributes positively to the maintenance of water quality, structural stability, hydraulic capacity and environmental and ecological values of the City's waterbodies. This includes:

- the protection and enhancement of the good water quality of the waterbodies and the improvement of areas of degraded water quality;
- the maintenance of the structural stability and hydraulic and flood carrying capability of the cities waterbodies;
- the protection of the water supply function (i.e. for irrigation) of the City's existing catchments, waterways and lakes;
- the inclusion of appropriate storm water quality and quantity management in the planning and design of developments; and
- the provision of adequate space for stormwater quantity and quality management infrastructure and the utilisation of existing features of the site such as drainage lines and waterbodies, in the design of the development and stormwater layout.

Suitable measures to assist in maintaining the pre-development storm water discharges include; retention/detention basins as part of a storm water treatment, increase in pervious areas on the site, the use of porous materials in those areas normally surfaced (such as footpaths); and the inclusion of on-site detention storage tanks with the design of multi-unit/building developments. The objectives of an urban drainage system should include:

- No encroachment of the designated waterway area or reduce the waterway area or obstruct the flows by filling in the floodplain
- nsuring habitable buildings are not flooded in major storms (i.e. 5, 10 or 25 year Average Recurrence Interval (ARI) or as appropriate).
- Flood waters do not present an unacceptable risk to personal safety in major storms (i.e. 5, 10 or 25 year ARI or as appropriate).
- Underground drains with sufficient capacity to ensure that flooding is not a regular nuisance in minor storms.
- The risk of pollution of drains and waterways minimised by preventing sewage discharge to storm water, by managing the storage and discharge of hazardous materials, by controlling land use and by reducing the major sources of pollutants.
- Drainage and waterways must be considered in the development of a strategic plan for future development including:
  - ✓ protection of waterways by incorporating open space as a designated waterway corridor in the City Plan. This will reduce future building encroachment and subsequent flooding; and

✓ any developments in the stormwater catchment will increase flooding and potential pollution of downstream. These issues should be considered in the planning stage, especially in cases where flood mitigation options are limited in the downstream system.

Drainage lines can contribute substantially to the landscape and open space amenity of development. A decision needs to be made as to the appropriate land take for drainage areas and the style of waterways to be adopted. Key actions required are:

Core Area Drain Rehabilitation: A broad approach towards correcting the more severe problems would involve work on cross drainage, cross services and sewers in manholes, together with new drains and wall replacement. Such works would be followed by the correction of severe - but more problematic - drain deficiencies. That may involve land resumption and major construction of walls. Approximately 81 km of main sewers are laid in drains. At least 20 km of these sewers are in need of replacement for capacity reasons. Additional lengths may have to be replaced for condition or other reasons. Similarly, drain improvements will require modification of these sewers. Total relocation of sewers out of drains is not essential and it is proposed that wherever a sewer needs to be replaced, consideration be given to relocation into adjacent roads or reserves. Of those sewers that will remain in drains, the vast majority should have their manholes modified to avoid flow obstructions. Sewer leakage and direct discharge to drains is to be addressed under the sewerage rehabilitation program.

Scheduled Drain Clearance: Until such time as drain inverts are redesigned for self-cleansing velocities and solid waste programs are implemented, ongoing regular clearance of drains is necessary to minimise flooding risks.

Even when drain upgrading as well as improvements in solid waste collection are completed, there will remain a need to remove silt and litter from the drains and inlets to tanks. In the longer term, catchment management practices which control silt loads from erosion sources will also need to be implemented.

Water Quality Improvements: At present, the principal causes of poor water quality are the sewage flows and large solid waste content in the drains. The sewer rehabilitation program would involve sewerage of unsewered premises (including those directly connected to drains); repair of sewer leaks; and upgrade of sewer capacity.

Capacity building: Training of drainage practitioners, operating within private and government organisations, is needed in a range of main drainage activities, including rainfall trends analysis, run-off estimation for small catchments, run-off estimation for larger catchments, using hydrograph techniques, hydraulic analysis of channels, culvert and pipes, using basic and backwater techniques, planning and design for major and minor drainage systems; and powers and duties relating to drainage and planning legislation.

Land Use and Development Controls: Review of regional planning, including the Bangalore Metropolitan Region Development Authority (BMRDA) structure plans and the Comprehensive Development Plan (CDP) to include drainage policy, provision for identification of flood-prone lands and control of its subsequent development, creation of wide reserves and easements for primary and secondary drains and control of development in the floor of primary and secondary valleys with respect, at least, to building floor levels and set-backs from reserves. In implementing land use and development controls and in enforcing legislation, consideration needs to be given to the special needs of the urban poor who are likely to bear the disproportionate burden of such measures.

Legislation and Institutional Reforms: A comprehensive review of the institutional arrangements for management of primary and secondary drainage within the BMA is desirable, with a view to creating one single drainage authority with the responsibility for identification of flood-prone lands and flood levels, approval of development plans for layouts with respect to flooding and drainage, planning of all waterways and drainage, integration of waterways and drainage with urban land use planning, including identification of easements, setting of levels of service for all secondary and primary drains and lands adjacent to tanks, in conjunction with all stakeholders, preparation of integrated drainage plans for each main catchment; and Monitoring of development and advising planning authorities on non-complying urban development.

The roles of implementation and operation could be undertaken within existing and strengthened municipalities and/or an expanded BMP.

Education and Consultation: Environment education programs through schools, colleges, NGO's and mass media to raise community awareness and understanding of the risk of flooding, the importance of clean waterways and their role in supporting community well being, health and the overall life style in the city of Bangalore.

Best management practices (sediment fences, re-vegetation, sediment barriers, graved channels, dimension channels, etc.) for erosion and sediment control to manage development activities in a catchment, and involves:

- Erosion Control - the process of minimising the potential of soils to be eroded and transported in the first instance through the effects from wind, water or physical action through surface stabilisation, revegetation, erosion control mats, mulching, surface roughening, etc. These techniques represent a source control in preventing erosion of the soil material in the first instance.
- Sediment Control - the process of minimising the transport of eroded material

Plate 5.1: Removal of storm water drain encroachments in Nayandahalli, Bangalore *(Source: BMP)*

Plate 5.2: Removal of solid waste from the drain in KH Road, R.R. Nagar *(Source: BMP)*

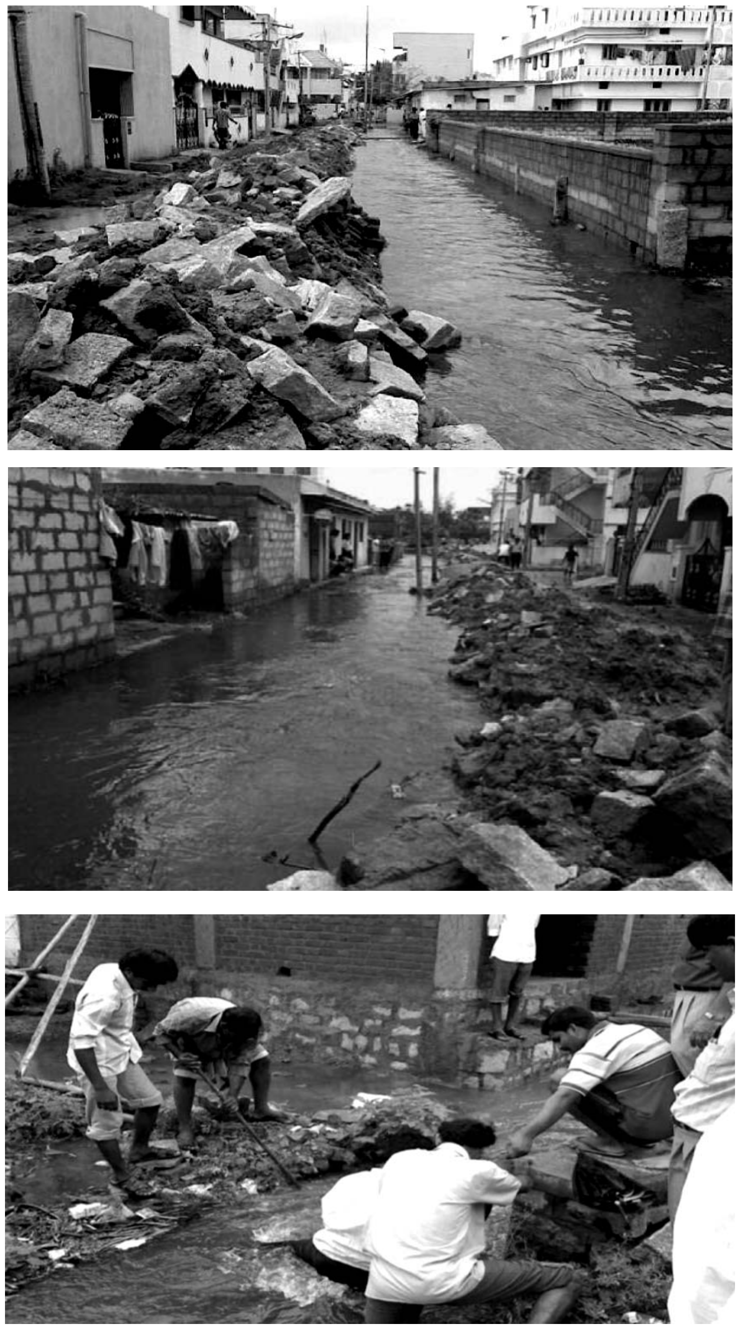

Plate 5.3: Removal of blockage in Kalappa layout *(Source: BMP)*

Plate 5.4: Desilting in Koramangala main valley, KH Road and Chalgatta valley

(source: BMP)

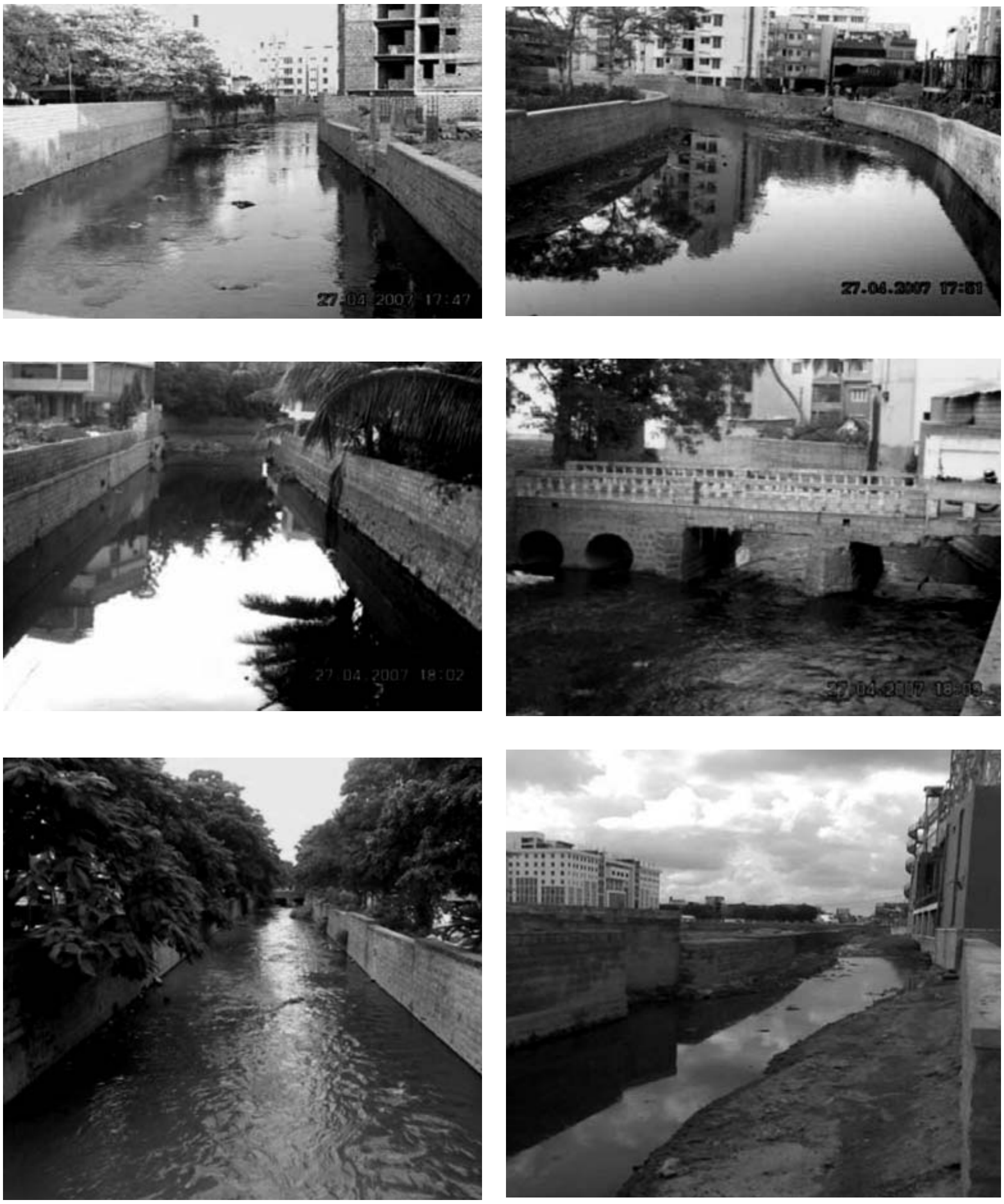

Plate 5.5: After desilting - Koramangala Valley, Vajapayee nagar

Plate 5.6: Construction of RCC box drain in Puttenahalli *(Source: BMP)*

Plate 5.7: Remodelled storm water drain

Plate 5.8: Storm water drain retaining wall construction *(Source: BMP)*

Plate 5.9: Chain link fencing to prevent solid waste dumping *(Source: BMP)*

Plate 5.10: Providing screen in storm water drain

Plate 5.11: Restoration of Ulsoor lake with STP *(Source: BMP)*

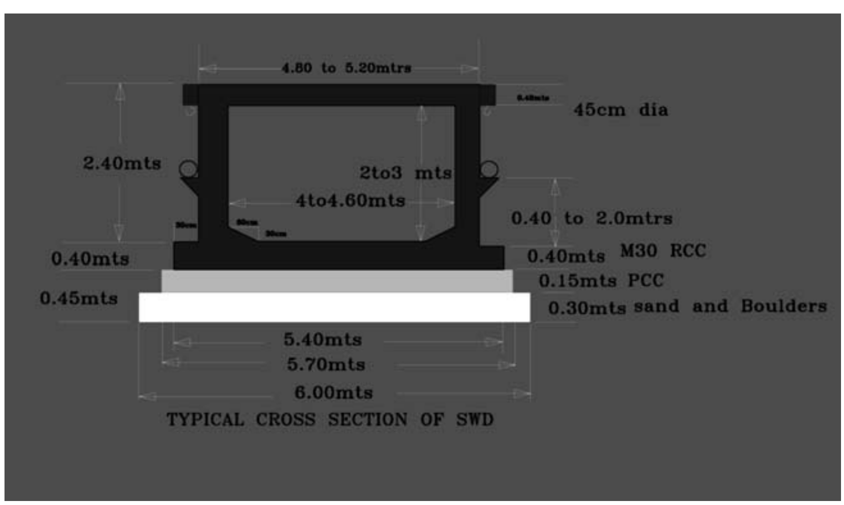

Plate 5.12: Redesign of storm water drain *(Source: BMP)*

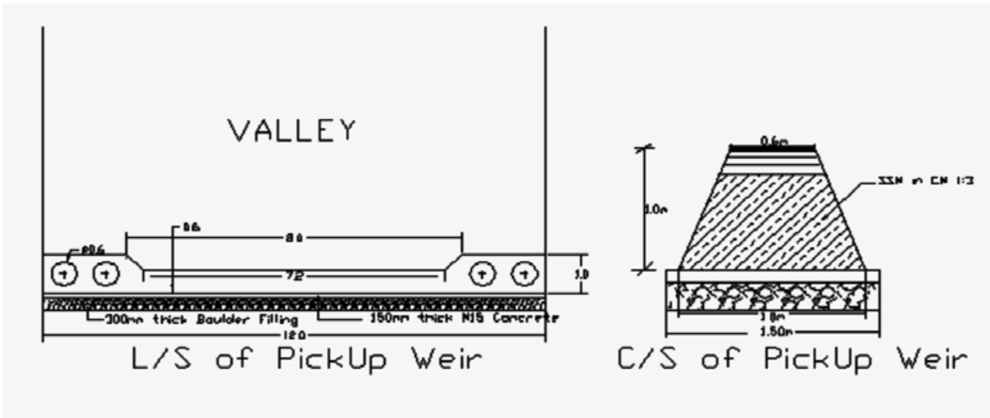

Plate 5.13: Design of pickup weir *(Source: BMP)*

(sediment) suspended in water or wind through catch drains, check dams, lined channels, grassed channels, and diversion channels, drop pipes, chutes and flumes.

In Bangalore, the sources of sediment supply to the drains include wash-off and erosion of unvegetated median strips, walkways and parklands, litter from trees and other vegetation, wash-off from roadways and impervious areas, wash-off and erosion from unmade roads and partially developed layouts, erosion of steeper unlined drains, construction site erosion or drainage water, drainage channel erosion and solid wastes dumped directly into drains or washed from pavements.

Key activities implemented for improvement of SWD

The key activities for improving storm water drains in the city included construction and rehabilitation of roadside drains, remodeling and strengthening, clearing silt, constructing of walls, laying of beds, provision of enabling and awareness information architecture and green area development. The action plan included:

- Clearing all encroachments that come in the way of the storm water drain network in the city (Plate 5.1);
- Aligning the drain network and checking blockage and overflowing of drains; Removing silt (Plate 5.2, 5.3, 5.4 and 5.5);
- Construction/remodeling/rehabilitation of road side drains (Plate 5.6 and 5.7) - Constructing 1,500 km of roadside drains (cost of construction assumed at Rs. 30 lakh per km for a 5-metre drain);

- Decreasing the load on Koramangala storm water drain (originating from Majestic and flowing into the Bellandur Lake) by building a bypass box canal from this drain via Agaram to the Bellandur Lake;
- Constructing a similar bypass canal via the Karnataka Golf Association; Reviewing existing storm water drains, ensuring connectivity of primary, secondary and tertiary drains;
- Constructing retaining walls (Plate 5.8);
- Redesigning for current load conditions along with building barriers between roads and open drains at crossings (Plate 5.9 and 5.10).
- Restoration and conservation of waterbodies (Plate 5.11)
- Laying of beds (plate 5.7);
- Remodelling of storm water drains (Plate 5.12 and 5.13);
- Provision of enabling and awareness information architecture; and
- Green area development.

The City is proposing to have a coordinated action plan to address the issue of urban drainage. At present BMP is coordinating the "valley projects," and is carrying out the works in coordination with other agencies, facilitated by the GoK.

Compounding the flooding problems are the unsanitary conditions created by large volumes of raw, or partially treated, sewage and large volumes of solid wastes entering the drainage system (Plate 5.2 and 5.3). Strategic options for rehabilitating and extending the Bangalore Water Supply and Sewerage Board (BWSSB) sewerage system and for expanding the BMP (Bangalore Mahanagara Palike) solid waste management system have been prepared. Following filing of writ petitions in 1999, and subsequent issuance of High Court Orders against the Government of Karnataka (GOK) and several authorities in Bangalore responsible for provision of environmental sanitation services, an Environmental Action Plan was devised to address the worst of the existing problems and remedial actions, including desilting of drains, have been completed in some localities (Plate 5.3 and 5.4).

The potential values and importance of waterways in the urban environment have been undermined consequent to fragmented management arrangements. Similar fate might befall the waterways in the rapidly developing lands within the Bangalore Metropolitan Area (BMA), but outside of, and downstream of, the BMP catchments. The critical issues that is to be addressed relates to the fact that inadequate drainage in a particular ULB jurisdiction may not have the impact in that ULB but elsewhere. Coordination and continuity of action between the ULBs is of critical importance.

Objective	Action Areas	Summary of Measures
Manage the Flood Risk		
Minimisation of the impacts of flood events and potential damage costs	Existing development (core area and outer area)	Introduce flood mitigation structural measures, (restriction removal, widening/deepening) Remove illegal encroachments Develop and implement awareness programs
	Proposed development (core area and outer area)	Control land use, development Develop and implement awareness programs
To collect and provide best available data for managing the flood risk	Develop spatila information system with an up to date Topographic, land use, hydrologic, flood impact data, etc.	Identify flood-prone areas, flood levels Collect flood impact information Conduct topographic surveys
Control Land Use Planning and Development		
Integrating urban storm water drainage functions in CDP	Land use planning	Amend planning legislation and regulations if necessary Incorporate drainage policy into structure and consolidated development plans (CDP) Provide drainage reservations in planning schemes
	Development controls	Impose development controls (filling levels, floor levels, reserves, set backs) for each drainage authority/municipality
	Monitoring and enforcement	Monitor encroachments and floor levels Enforce policy and regulations
Implement Effective Asset Operation and Maintenance		
To manage the urban storm water drainage assets economically and to protect public health and safety	Drain siltation and litter	Schedule and perform regular drain clearance Support solid waste strategy (at source collection) Trap gross sediment on tank inlets
	Asset condition monitoring and maintenance	Schedule inspections and audits of drain assets Conduct safety audits of tank embankments and spillways Prioritise maintenance activities Coordinate other infrastructure assets
	Construction standards	Develop design, construction and maintenance standards to reflect economic life cycle asset costing Apply construction standards through appropriate supervision and QA systems
	Drain safety	Erect warning signs, fencing, etc., where appropriate Minimise safety risks in design

Objective	Action Areas	Summary of Measures
Enhance the Environment and Social Conditions		
To expand and protect the social and environmental amenity of open urban waterways, where possible	Social equity	Promote community based representative decision making Set basin wide drainage levels of service Target improvement works according to agreed priorities
	Cultural and heritage	Restore water quality in tanks (drainage system) Desilt tanks Develop and implement education programs within an overall communications strategy Restore tanks
	Recreation/landscape	Landscape riparian lands Provide access and linkages along drainage corridors Provide in-stream features (water falls, swales, wetlands)
	Aquatic environment	Introduce water quality improvement actions Use alternative waterway design
Improve Water Quality		
To improve the quality of water in the drains and tanks	Sewage entering stormwater system	Extend sewerage system Repair sewer leaks Upgrade sewer capacities
	Litter & solid wastes	Collect solid wastes Develop and implement education and awareness programs
	Stormwater quality improvement	Enforce appropriate stormwater and catchment management practices (erosion control, litter and silt traps, street sweeping)
Provide Supporting Drainage Legislation and Regulations		
To provide effective drainage regulations and management arrangements	Drainage authority	Review roles and responsibilities of authorities involved in drainage and provide effective mechanisms for drainage planning, implementation, monitoring, enforcement and funding
	Land use planning	Amend structure plan, CDP to reflect drainage policy
	Building and development controls	Amend municipal and planning legislation to provide adequate controls over land filling, floor levels etc.
Prioritise Resources & Actions		
To provide adequate funding and resources for capital and recurrent activities according to agreed priorities	Priorities and funding	Collect supporting flood damage data Prepare integrated drainage management plans Consult with stakeholders on priorities Introduce general drainage tariffs Introduce development contributions to main drainage Allocate appropriately government grants and loans Use lending agency loans
	Training	Train practitioners in drainage management methodologies and techniques

Strategies for improved service delivery include:

- The importance of inter-ULB and Agency coordination:
- Inadequate drainage in a peripheral ULB may impact drainage in BMP areas;
- Improper drainage of BWSSB's system may pollute the valley system and impact quality of life across the City; and
- Improper roadside drainage and cross-connectivity may similarly impair system performance;
- Citizens to be involved to monitor contractor's activity on clearing of drain systems in their area:
- Citizens who dump debris into storm water drains could be penalized; and
- Removing silt to be a regular activity before the monsoons starting with the main (primary) drain.

Drainage management plans (DMPs) for each catchment are required to enable all deficiencies identified, an affordable level of service developed, all upgrades designed to a consistent standard and priorities set for implementation. Action plan suggested in this regard are listed in Table 9.3

Progress during 2008-09

The torrential rain of May 2006 crippled almost the entire city. Posh residential layouts, poor low-lying slums and even the busy streets such as Mahatma Gandhi Road and Vidhana Veedhi were affected. While parts of Jayanagar went without power for three days as the junction boxes were damaged following the rain, Church Street, Shantinagar, Rest House Road were inundated in knee-deep water. The impact of the rain in areas such as Ejipura, Jogupalya, Jeevanabimanagar, Murgeshpalya, parts of Sampangiramnagar and surrounding areas was devastating. During 2006 monsoon, people used boats to cross the road in this locality because of flooding of water. The water logging happens when the intensity of rain is high and whenever the flow of water into the drains is more than the discharge capacity. Several areas in the surrounding suburbs such as Puttenahalli, Pai Layout, HSR Layout and Bommanahalli were the worst-affected last year. That was because these areas did not have a stormwater drain network and, moreover, they had encroached upon lake-beds.

TTraditional storm water management techniques simply collect the rain water and funnel it across the city downstream. Newer methods combine traditional approaches with new ones such as Sustainable Drainage Systems (SUDS). It employs a range of natural processes to purify urban runoff. Removal of sediment, bio-filtration, biodegradation and water uptake by plants all help to remove pollutants. The city needs many such recharge wells in the catchment area of critical flood zones to detain flood waters and top up the aquifers instead of surface flow floodingT. TAt the broader scale, tanks and lakes need to be networked and managed as retention and detention structures. With rainfall prediction accuracy being developed, tanks have to be linked to catchments and kept ready to hold the maximum water to dampen peak storm eventsT. A deslited tank in Bengaluru can recharge up to 11 mm of water every day while an undesilted one can recharge hardly 1 mm. Desilted tanks can recharge aquifers quickly, lower the surface water levels and be in a position to function as flood mitigators. Full tanks are not good at dampening floods.

The Bruhat Bangalore Mahanagara Palike (BBMP) during 2008-09, focused on providing permanent solution to overflowing of storm water drains, water logging, and other related problems during rains. BBMP built a new storm water drain to prevent flooding in Bandeppa Colony. Similarly, a storm water drain was widened besides raising the height of retaining walls. BBMP was successful partially in evicting the encroachers of storm water drains as owners of buildings, built on the raja kaluve, had obtained stay orders from courts. The BBMP demolished 10 structures covering 600 sq.m. of drain area in Bhadrappa Layout in Hebbal. These structures had come up on the storm water drain leading to the Hebbal Lake. Work on increasing the height of retaining walls of storm water drain and providing gradient to shoulder drains at Bhadrappa Layout were in progress and the situation was likely to improve once the works were completed. BBMP established control rooms, including the zonal control rooms. The control rooms were fully equipped with men and material. Of the 280 identified vulnerable areas, 48 had been marked under "A" category and four of these are under "A+" category (the region highly vulnerable). The Central Silk Board area, Puttenahalli, Arakere, Nayandanahalli, Katriguppe, Illyas Nagar, Bhadrappa Layout, S.T. Bed Layout, Kamakhya Layout, Hennur, Ejipura and Bandappa Colony are these vulnerable spots.

Strategies for the future

Strategy to incorporate Integrated Storm Water Management (ISWM) approach to flood management integrating land and water resources development in a lake catchment or river basin, within the context of integrated water resources management, and aims to maximize the net benefit from floodplains and to minimize loss to life from flooding.

This is based on

- A participatory approach involving users, planners and policy-makers at all levels and should be open, transparent, inclusive and communicative.

Table 10 - Strategic Actions

Proposed Actions	How	Possible Implementation Mechanisms
Integrated catchment based management and planning to improve catchment landuse and drainage conditions	Developing Catchment and Stormwater Management Plans (CSMP) to integrate all stormwater issues on catchment levels including: Water quality, flooding, waterways, assets management and funding, planning and development control, and other environmental and social issues. More details on typical CSMP's contents, objectives, and outcomes are presented in section 8.2 of this report.	Catchment and Stormwater Management Plans should be developed for each major catchment. Significant coordination between all stakeholders is required. This study would require multi-disciplinary team, with expertise in hydrology, environmental, planning and socials issue.
Enforce best practice guidelines as conditions to issuing permits for new or reconfiguration of developments	This should include guidelines for: This should include guidelines for: • Erosion and sediment controls • Setting Floor levels above designated floods) • Restrictions on filling in the floodplain and obstruction to flow • Legal point of discharge and connection to storm water and sewerage systems. • Storm water quality objectives and treatments prior to discharge. • Preferred subdivision layout in relation to storm water assets.	Accountability of the agency to ensure implementation of best practice information
Stormwater management solutions to the overall urban water cycle and water conservation strategy	• Encourage and promote "water sensitive urban design" for maximising infiltration, treatment of stormwater runoff by grass strips, reduction in paved areas in new developments. • Rehabilitate and maximise the use the remaining waterbodies to reduce flooding through retardations and to maximise infiltration to groundwater by retaining floodwaters in these basins. • Maintain (where possible) the natural conditions (i.e.; unlined) of the channels and waterways to maximise infiltrations to groundwater and also to treat water quality.	The BMP should develop and promote best practice design manual for urban developments and implement these options in the development of the flood mitigation strategy.
Regular water quality monitoring in major waterbodies through a network of educational institutions	This helps to establish base line data, assess the impacts of land use changes and management practices on water quality, and provide instructions for water usage and human health purposes. • Review the conditions and the importance of waterbodies • Identify priority areas	The key objective is to monitor improvements rather than to confirm existing conditions are poor.

Proposed Actions	How	Possible Implementation Mechanisms
	• Determine the type and frequency of monitoring required (this should include average values and events monitoring) • Develop and undertake program for storm water quality monitoring	
Minimise flooding	Identify educational institutions to undertake at regular interval drainage and flood studies for the city to: Identify existing drainage system and flood prone areas. • Develop overall flood mitigation strategy for the city. • Prioritise and undertake the mitigation works based on flood risks. • Control new developments, which may impact on flooding.	Develop centralised infrastructure database with a network of instituions. BMP currently embarking on major flood study, Flood mitigation options and strategy will need to be coordinated and endorsed by a number of other authorities to cover issues such as land resumption, planning, changes in sewerage system.
Establish designated flood levels along the main waterway, to provide guidance for new developments or reconfiguration of existing developments.	• Determine flood profile for the high flood levels (say 10, 20 or 50 years ARI) from the t drainage study • Use new survey and contour maps to plot the extent of the flood levels along the waterways. • Use GIS based technology to develop a spatial database with web based information systems.	BMP to develop and maintain spatial information systems
Protect the remaining waterways corridor from encroachments of new developments	• Identify preferred waterway corridor width based on the above high flood levels and other planning and environmental factors. • Incorporate the corridor in the Comprehensive City Plan as designated areas for new or reconfiguration of developments.	As part of the review of the City Plan, the BMRDA, BDA in conjunction with the BMP should incorporate the designated corridor area into the plan.
Minimise sewage inflow to storm water	• Separation/ relocation of the sewerage system from stormwater system • Implement the Sewerage Master Plan including treatment plant upgrade. • Enforce/develop planning laws on illegal connections. • Develop and upgrade guidelines on sewer construction and maintenance	Establish coordinating committee/taskforce between BWSSB and BMP to coordinate these issues and to undertake an option study (risk, cost, constraints) to identify the preferred option to separate the two systems.

Proposed Actions	How	Possible Implementation Mechanisms
		It is may be cost effective to incorporate this option investigation study into the BMP current drainage study. The BWSSB may provide additional funding to this component of the study.
Integrated Municipal Solid Waste Management	Adoption of an appropriate strategy is essential for any improvement in the storm water quality and quantity in Bangalore.	Implementation to conform MSW Rule, 2000.
Community education programs to improve understanding of the important of clean drainage and waterways	Raising community awareness and understanding of the risk of flooding, the importance of clean waterways and its role of supporting the community well being, health and the overall life style in the City of Bangalore. with numerous successes around the world. This can be undertaken in various forms: • Environmental education at schools and colleges • Education through mass media • Encouraging the community to be involved in catchment care groups • CBD and NGO's to devlop and implement catchment management plan.	• Schools and colleges • NGO's and CBO's • BMP

- Decentralization of decision-making is necessary, with full public consultation and involvement of stakeholders in planning and implementation.
- Coordination at the highest level to promote coordination and cooperation across functional and administrative boundaries needs to be ensured.
- Land use planning and water management are combined in one synthesized plan, through coordination of land and water management authorities to achieve consistency in planning.
  - Clearing all encroachments that come in the way of the storm water drain network in the city.
  - Restoring all lakes. Removal of all encroachments in lake catchments
  - Declaring 500 m around the lake as no activity zone
  - Aligning the drain network and checking blockage and overflowing of drains.
  - Reviewing existing storm water drains, ensuring connectivity of primary, secondary and tertiary drains.

Redesigning for current load conditions along with building barriers between roads and open drains at crossings.

Thus, an integrated approach to stormwater management maintains the traditional function of minimising flooding, in addition to integration of water quantity and quality management policies and practices with the coordinated, total catchment approach to the issues of stormwater management. In addition to flood management, a primary goal is to protect downstream water bodies from contamination and erosion, while maintaining, or in some cases re-establishing, natural waterways and wetland features as part of the drainage network. The location and design of significant stormwater management infrastructure (e.g. drainage corridors, culverts, etc.) is to be based on a firm understanding of the local needs/values, legislative requirements and practical constraints considering the hydraulic, hydrologic, environmental, economic, social, legal and practical aspects. For example, maintaining or improving the natural conditions of a waterway in Bangalore (i.e., widening and grading the banks) instead of channelising and concreting, could bring multiple benefits including flood mitigation, water quality improvement by vegetation and recreational benefits. Suggested strategic actions are outlined in Table 10.

The storm water system consists of many natural water-bodies and a high-density waterway system. Sewage contamination leading to eutrophication of waterbodies would result in a major health and socio-economic disaster for the city. Some receiving waterbodies have no major outlets and pollutants are accumulated in the sediment deposits. Litter, discarded building materials, sediments and other solid waste items are the main causes of blockages of the drainage system resulting in flooding in some pockets of Bangalore.

The objective of Catchment and Storm water Management Plan is to integrate all water quality, quantity and waterways issues from a catchment perspective to enhance and stabilise degraded waterways, minimise flood risk, maximise amenity and property values and improve water quality in the stormwater system with the following objectives:

- Prevention of raw sewage from entering the stormwater system;
- Promotion of best management practices to improve stormwater quality;
- Management of storm water drainage ensuring the protection of waterways, water quality and minimising floods;
- Integration of water quality management with flooding and waterway corridor management issues;
- Design and implementation of flood mitigation schemes (where necessary) to

minimise the impacts of large flood events and potential damage costs;

- Mapping and monitoring of flood prone areas and flood levels along the waterways under appropriate Average Recurrent Interval storms through drainage and flood studies. Based on the designated flood levels along the main waterway system, waterway corridors are to be determined and to be incorporated as "no development" areas into the City Comprehensive Development Plan to prevent development within these corridors.
- Alteration in topography in the catchment area to be banned through an appropriate legislative measures;
- To provide and coordinate an information and education program for the community and schools to improve understanding of the risk of flooding, the importance of clean waterways and their role in supporting the community well being, health and the overall lifestyle in the City. The objective should be to achieve increased community involvement in waterway care.

List of Abbreviations

ARI	Average Recurrence Interval (years)
BDA	Bangalore Development Authority
BMA	Bangalore Metropolitan Area
BMP	Bangalore Mahanagara Palike (or Bangalore City Corporation)
BMRDA	Bangalore Metropolitan Region Development Authority
BWSSB	Bangalore Water Supply and Sewerage Board
CBO	Community Based Organisation
CDP	Comprehensive Development Plan
CMC	City Municipal Council
CPHEEO	Central Public Health and Environmental Engineering Organisation
DMP	Drainage Management Plan
GIS	Geographic Information System
GOK	Government of Karnataka
KSCST	Karnataka State Council for Science and Technology
KSPCB	Karnataka State Pollution Control Board
LDA	Lake Development Authority
NGO	Non-government Organisation
TMC	Town Municipal Council
UGD	Underground Drain for Sewerage

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Urban Floods: Case Study of Mumbai

Kapil Gupta

Abstract

Mumbai city having an area of 437 sq km with a population of 12 million came to a complete halt due to the unprecedented rainfall of 944 mm during the 24 hours starting 0830 on 26 July 2005. More than 419 people (and 16,000 cattle) were killed due to the ensuing flash floods and landslides in Mumbai municipal area, and about 216 people died due to flood related illnesses. Over 100,000 residential and commercial establishments and 30,000 vehicles were damaged. The paper describes Mumbai's drainage system, the details of the flooding, and the measures being taken by the city to mitigate such floods in the future. The Mumbai experience would be helpful for the other metropolitan cities to make panned response strategies to cope-up with similar disasters in the future.

Keywords: *Extreme rainfall, Urban flooding, Mumbai drainage system, Flood resilience*

Introduction and City Profile

Mumbai, formerly called Bombay, (lat 18 N to 19.20 N, long. 72 E to 73 E) is the capital of Maharashtra state of India and the commercial and financial centre of India. It generates about 5% of India's GDP and contributes to over 25 % of the country's tax revenues. During the past 5 years, Mumbai has also become a centre for BPOs (Business Process Outsourcing) for major international organizations. Thus, any disaster in Mumbai has roll-on effects affecting the global economy. Mumbai is located on the windward side of the Western Ghats of India and receives high rainfall due to orographic effect from strong westerly/southwesterly flows over the Arabian Sea. The average annual rainfall of Mumbai City is 2050 mm as recorded by the Colaba meteorological station of IMD located at the southernmost tip of the city while that for the suburbs is 2300 mm as recorded at Santa Cruz, located 27 km away to the north. Monsoon rainfall occurs primarily during June to October and about 70 % of the

* Contributed as Mumbai city team under National Coordination Project of NIDM (Anil K Gupta and P.G. Dhar Chakraborti, Disaster & Development, 3 (1): 1-14,2009).

average annual rainfall occurs in July and August and 50 % of this occurs in just 2 or 3 events. During these 2-3 events, it usually rains uniformly over the city and severe flooding occurs in many parts of the city. Mumbai is administered by the Municipal Corporation of Greater Mumbai and is divided into two revenue districts, viz. Mumbai city district (which has been formed due to the merging of seven islands by massive reclamation from the sea during 1784-1845) (Figure 1). Historically, these 7 islands were ceded to King Charles II of England as dowry in 1661 by the Portuguese. In 1668, the islands were leased to the East India Company for a sum of £10. In 1877, the control passed to the British crown. The land reclamations have continued and in 1961 the Mumbai suburban district was formed which comprise the erstwhile island of Salsette and the former Trombay Island. A small part in the north Salsette Island, however, lies with the Thane Municipal Corporation. The Salsette-Mumbai creek and the Thane creek together separate Mumbai from mainland India. Thus, Mumbai is surrounded by the Thane creek and the Arabian Sea.

There has been a rapid and uncontrolled all round growth of the city - the influx of migrant workers have seen the population rise from 9.9 million in 1981 to 13.0 million in 1991 and to 17.7 million in 2001. However, the area under the Greater Mumbai Municipal Corporation covers an area of 437.71 sq km (excluding 200 sq km green belt) and is divided into 24 municipal wards (Figure 2). The average population density is 27,209 persons per sq km while some areas, for example Ward 'A' has a daytime (floating) population density as much as 394,390 persons per sq km and the night-time population is 200,000 persons with a density of 17,528 persons per sq km.

There are a large number of vulnerable informal settlements, many of them located on the flood plains of the Mithi River and the open storm water drains. About 65% of the Mumbaites live in informal settlements and over 2,768,910 structures - residential, commercial and industrial are listed with the Municipal Corporation of Greater Mumbai (MCGM). The Mumbai population is projected to reach 25 million before 2025.

The municipal area is highly susceptible to frequent flooding and witnesses severe disruptions annually. In addition, this area falls in an active seismological zone. The city is strongly oriented in a north-south direction. A majority of the population resides in the suburbs in the north and commutes to the City located in the south. The rail network constitutes the lifeline of the city and over 6 million people are transported daily by Mumbai's suburban railway system alone- this is almost 50% of the total number of passengers travelling daily by train in India. Thus, any disruption due to flooding results economic and social disruption - loss of livelihood to the individuals and loss of business to commerce and industry.

A new authority called the Mumbai Metropolitan Regional Development authority was set up in 1975 as an apex body for planning and co-ordination of development activities in the Region. The jurisdiction covers Mumbai and the neighbouring municipalities of Thane, Kalyan, Navi Mumbai, Bhiwandi, Virar and other municipal councils in the geographical area (Figure 3).

City Infrastrucutre with Reference to Drainage

The drainage system of Mumbai is a mix of simple drains and complicated network of rivers, creeks, drains and ponds. A network of closed drains below the roads has evolved in the city - the roads have evolved by covering the old drains in the city whilst there are open drains in the suburbs (Figure 4). The southern city area has long complex networks which drains relatively large low-lying areas, while short drains from small areas drain directly to the sea. During 1870 to 1930 many royal commissions of enquiry were set up and they found that due to lack of knowledge of the monsoon rainfall and expertise during the 1870s, sanitation designs were based on empirical considerations and a system of "trial and error" was used. The history of drainage of the south city area is exceptional due to its unique history of reclamation of the area in between the original seven separate islands (James, 1917). In 1672, Mumbai consisted of seven separate islands. During 1672-1845, the municipal interests of the city were looked after by the Board of Conservancy and intensive reclamation of the spaces between the islands was undertaken with the reclaimed ground being below high-water level. This is one of the main reasons why many parts of Mumbai still experience severe flooding during intense rainfall, particularly at times of high tide. Water usually recedes during low tide, but if the rainfall persists for 7-10 hours and the next tidal cycle starts, then it becomes difficult for the water to recede and compounds the flooding. Most detention ponds have been lost to development and it is estimated that urbanisation has contributed to increased runoff by 2-3 times.

However, an open ditch was left for drainage purposes - known as the old main drain- from the town centre to the Flats where it emptied itself into a tidal estuary. In 1824, arching over this drain was started and completed in phases by 1856. The arching and the walls of the drains consisted mostly of roughly dressed stone; there was no foundation in many parts, but where it existed it was of rubble. The width of the old drain varied from 2 ft to 20 ft 3 in while the height varied from 2 ft to 9ft 10 in and the gradients were from 1 in 450 to 1 in 5000. This drain carried all the surface water in the monsoon, and all the year round sewage which was discharged into it by gravity or by hand. Due to the inadequate slopes, it functioned as a vast elongated cess-pool during the non-monsoon months.

In 1866, Mr Rusell Aitkin, then Municipal Engineer proposed that the sewage should be discharged into a reservoir at Colaba (southernmost point of Mumbai) near the lighthouse and pumped into the sea at ebb-tide. He proposed a main sewer from Null Bazaar to Colaba with large branch sewers from different districts. The main sewer was designed to carry only two inches of rainfall per day and Mr Aitkin proposed to retain the existing open main drain to receive the surplus when more than two inches of rainfall fell in a day.

In 1890, it was shown by Mr Baldwin Latham that the arrows indicating the directions of the floats were wrongly shown in the plan - they pointed to the north instead of the south and thus erroneously led to the conclusion that the current during the low tide set into the harbour instead of flowing to the open sea (These observations were again confirmed by another set of float observations by Mr Santo Crimp in 1899). This extraordinary mistake has no doubt been the principal cause of Bombay having its outfall on its western foreshore with all the consequent nuisances.

Hence, Mr Russell's scheme therefore remained in abeyance; however, Mr Aitkin constructed a low-level sewer system from the city which intercepted all the sewage from the old main drain and conveyed it to a pumping station at Love Grove, where it was lifted by two centrifugal pumps into the sea. In subsequent years, in most areas of Mumbai, brick-sewers and pipe-sewers were substituted for open drains.

By 1877, the nuisances due to lack of drainage increased, and the report of Hunter Commission marked the commencement of an entirely new era regarding the drainage history of Bombay. The Commission recommended the adoption of a scheme of pumping of sewage into the sea at Love Grove outfall. This scheme consisted of laying a main ovoid sewer from the east city passing through the city centre and the Flats to Love Grove on the west coast. A pumping station was to be set up at Love Grove to pump the sewage into the sea. The commission strongly recommended free ventilation of all sewers and the separation of storm water from drainage. The work commenced in December 1878 and was completed in May 1881. During 1881-1917, several other areas of Mumbai were also sewered. The drainage of Bombay, as laid out in the Island City at the beginning of the 20th century has mainly followed these recommendations.

The last major study was taken up in 1993, called the BRIMSTOWAD project (Brihanmumbai Storm water Drainage Project) and it recommended the augmentation of the drainage network. However, on grounds of economy, it recommended the augmentation of the drainage network for a rainfall intensity of 50 mm/hr which allowed two flooding per year. This scheme was implemented only partially due to limited funds. However, recent data analysis for the years 1999 to 2004 show that the peak rainfall intensity for the time of concentration of 15 minutes exceeded 72 mm/h over 80 % of the times (Table 1).

Major Floods in the City – 26th July 2005 Extreme Rainfall of 944 mm in 24 hours

Flooding has been a regular feature during the monsoon and several earlier committees have identified the main causes of the flooding and these are summarised in Table 2.

The 26th July 2005 event has been classified as "very heavy" (> 200mm/day as per the rainfall classification of IMD). The Santa Cruz observatory at Mumbai airport recorded 944 mm during the 24 hours ending 0830 am on 27th July 2006 while the Colaba observatory recorded only 74 mm of rain (Jenamani, et al., 2006). The event has been attributed to a highly localized "offshore vortex". The rainfall hyetograph for the 26th July 2005 event is shown in Figure 6. From the figure it can be seen that at Santa Cruz, heavy rainfall started at 1430 with 481.2 mm falling in just 4 hours between1430 to 1830 and hourly rainfall exceeding 190 mm/h during 1430 to 1530. This has exceeded the rainfall record of Cherrapunji, which has been considered the world's wettest place. The already inadequate drainage system was unable to drain out because of the highest high tide level of the month of 4.48m at 1550.

Extent of Flooding and it's Effects

Over 60 % of Mumbai was inundated to various degrees on 26th July 2005 as shown in Figures 7 and 8 (FFC, 2006). 107 low lying areas were severely flooded and the northern suburbs were severely affected.

The Indian Meteorological Department was unable to issue advance warnings of this event. Even when there was heavy rainfall in the northern suburbs, the IMD was unable to monitor the rainfall and issue warnings in real time. This has been attributed to the lack of state-of-the-art equipment like tipping bucket rain gauges with the IMD. IMD has only two rain gauges in Mumbai and both are of the syphonic type which record data on graph paper attached to clockwork driven drums. These are read only at 0830 daily.

The immediate impact of the heavy rainfall was that there was a total collapse of the transport and communication system. Both the main Mumbai Santa Cruz airport and Juhu airport used mainly for helicopter operations had to be closed down for two days on 26-27 July, 2006. The runways were waterlogged, the terminal buildings were flooded and crucial navigation and landing aids damaged, thus forcing over 750 flights to be either diverted or cancelled. Both the major roads linking the northern suburbs to the city, namely the western expressway and the eastern expressway were submerged. Most arterial roads and highways in the suburbs were severely affected due to waterlogging and traffic jams resulting in breakdown of vehicles in deep waters. Intercity train services had to be cancelled for over a week, while suburban trains, which are the lifeline of the city, could not operate from 1630 onwards for the next 36 hours. Many people were stranded in their offices while students had to spend the night at their respective colleges and schools. Others spent the night in the trains and buses and some even on top of the buses. The mobile phone network also collapsed- the transmitters had diesel generators to last only two hours and the fuel could not be replenished due to failure of transport; over 2 million landline phones were also affected. Electricity was cut off in most parts of Mumbai- this resulted in the failure of sewage pumps and further led to backflow of sewage into the stormwater. Excessive rainfall resulted in waterlogging in several areas of the suburbs with water entering even the first floor flats in some areas. Almost 419 people lost their lives including 65 killed in the several landslides. 216 people died due to the various deluge-related epidemics. Animals too were not spared; around 6307 animal carcasses were disposed off.

A substantial number of buildings were damaged- 2000 residential buildings were fully damaged while 50,000 were partially damaged and 40,000 commercial establishments suffered heavy losses. 30,000 vehicles were damaged and 850 buses of the Mumbai Transport were damaged. Some vehicle occupants lost their lives because they could not open their power windows as their car engines went dead after being submerged in flood waters.

Post-Flood Measures

As thousands of people had to wade through sewage waters on 26-27 July, 2005, the risk of epidemics of water-borne diseases such as gastroenteritis, hepatitis, leptospirosis, malaria and possible cholera was high. To prevent an outbreak of epidemics, 6307 carcasses were disposed of on a priority basis by the staff of the Mumbai Corporation of Greater Mumbai (MCGM) - these included 1307 buffaloes and 5000 sheep and goats. The removal of the carcasses was facilitated by employing 27 cranes, 87 dumpers and 24 bulldozers during 27-30 July 2005. In addition, extensive spraying of disinfectants and insecticides to control pests and minimize flies and mosquitoes was undertaken. MCGM also provided comprehensive healthcare services through 130 specially constituted medical teams and over 300,000 patients were treated virtually at their doorstep through health camps and outreach camps. 253,612 metric tones of solid waste which had accumulated in various parts of the city was removed by employing 107 bulldozers, 438 dumpers and 511 compactors during 29th July to 21st August 2005.

Chitale Committee (2006)

A fact finding committee was also set up by the Government of Maharashtra to identify the cause of floods and to suggest measures for the future. Earlier reports by the Natu committee (1974), CWPRS - Central Water Power Research station (1978), BRIMSTOWAD (1993) and IIT Bombay (Gupta, 2005) were also placed before the Chitale committee. The Chitale committee reiterated the causes of the flooding as mainly the inadequate drainage system, rapid developments and loss of holding ponds, encroachment by the slums on and over the existing drains and decrease in the coastal mangrove areas. The Mithi River in the north has been reduced to an open drain due to severe encroachments and discharge of industrial effluents into the river. Nearly 54 percent of the original river flow has been lost to slums, roads and new developments. The new sea-link has also reclaimed the mouth of the river by about 27 hectares of landfill. Other rivers in the northern suburbs which overflowed are the River Dahisar and the River Poisar.

The committee recommended detailed contour maps of all watersheds, stream gauging, installation of automatic rain gauges by the IMD, regular maintenance and desilting of the existing drains, removal of obstructions and provision of additional gated outfalls/ pumping stations and holding ponds. Further, it recommended that the BRIMSTOWAD report be revised to take into account 100 mm/hr rainfall for the major roads and critical structures in the city.

Enhancement of the Flood Response Mechanism During 2006–09

Institutional mechanisms

Several institutional mechanisms have been strengthened - the Mumbai Disaster Management Committee headed by a very senior bureaucrat, the MCGM Disaster Management Committee headed by the Municipal commissioner and the Ward Disaster Management Plan headed by the Assistant Commissioner of the ward. A new Mithi River Development Authority has been set up to look exclusively into the restoration of the Mithi River to pre-development conditions. In addition, all construction works in the city which are carried out by central government organizations would require clearance from the MCGM. Rainwater harvesting has been made compulsory for development on areas greater than 1000 sq. m. - this would ensure that no additional runoff reaches the drains from new developments.

Emergency Control Centre

The emergency control centre of the MCGM has been upgraded at an estimated cost of Rupees 5 crore and now has been made self-sufficient to withstand and handle most disaster situations. It has an array of communications systems, television sets tuned to major news channels, networked computer systems with disaster management related software, video conferencing setup, conference and press rooms, emergency water supplies and rations, uninterruptible power supply with standby generators.

Automatic Weather Stations

Independent of the recommendations of the Chitale committee, the MCGM had already initiated the procurement and completed the installation of 30 automatic weather stations by June 2006. The weather station included tipping bucket rain gauges capable of giving rainfall data every minute. The weather station also has a console capable of giving an audible alarm at preset rainfall intensity values (in this case when the rainfall exceeded 40 mm/hr). The weather stations have been spread out on a more or less uniform basis in the city so as to provide representative rainfall data over most of the catchments in Mumbai. Considering the safety of the instrument (protection from vandals) and the fact that the fire and rescue services are the first respondents, the weather stations have been sited on the top of the fire stations in each area. The other weather stations have been located at the MCGM headquarters where the emergency control centre is located, and one each in the catchments of Powai Lake (at IIT Bombay), Vihar Lake (MCGM water intake) and Tulsi Lake (MCGM water intake). The data for the monsoon of 2006 is presently under compilation and work is under progress to study the spatial and temporal pattern of rainfall in Mumbai.

During monsoon 2006 and 2007, it has been possible for the duty officer at each location to monitor the rainfall every 15 minutes and issue alert too the central control room. As compared to earlier years when real time data for rainfall was not available, this has resulted in a substantially enhanced response mechanism and judicious deployment of resources to the waterlogged areas. It has also enabled the MCGM to issue warnings to the public through mass media. The schematic for the early warning system is shown in Figure 9.

The procurement of flow gauges and identification of suitable sites is currently in process and is targeted to be implemented before monsoon 2008.

Removal of Solid Waste from Stormwater Drains

To prevent clogging of the stormwater inlets, a ban on plastic bags less than 50 microns has been enforced. Enhanced desilting of drains, clearing og blocked inlets and deployment of manpower at critical locations on 24 hour basis has also been carried out. A significant achievement has been the restoration of the width of the Mithi River to between 7 m to 35 meters at various locations through removal of encroachments from the river banks.

Response Mechanisms

For enhancing the search and rescue operations, six fire brigade control rooms have been upgraded to command centres with state-of-the-art equipment and manpower of 30 personnel. MCGM has also constituted three search and rescue) "ask Force One" comprising of 26 members each from various disciplines. They have undergone training in collapsed structure search and rescue, confined space search and rescue, rope rescue and medical first response. Their training has been based on INSARAG and ADPC guidelines. These teams have also been equipped with 6 inflatable boats, 12 kayaks. In addition, there has been an agreement with the navy to deploy boats in seven low-lying areas.

The hospitals form the backbone of any emergency response and measures like shifting of medical equipment and wards to higher floors, deployment of additional medical and paramedical staff and establishment of additional trauma care centres at various hospitals in the city have been implemented.

The following additional measures have also been implemented:

- To prevent a recurrence of stranded vehicles which was seen during July 2005, 84 parking spots have been demarcated for people to park their cars in the event of severe rainfall.
- 120 temporary shelters for stranded people have been identified as temporary shelters for stranded people - these comprise of 5 schools in each of the 24 wards.
- Additional pumps have been installed in 40 high risk flood prone areas with manpower on 24 hour standby.
- Involvement of home guards, various voluntary organizations has been enhanced.

Strategies for the Future

The extreme rainfall event of 944 mm on 26th July 2005 has been a lesson for Mumbai and has resulted in Mumbai setting up a much better response mechanism based on real-time monitoring of rainfall at 27 locations in the city during 2006. During 2007-

2008, the number of rain gauges has been increased to 32 and an ultrasonic flow gauge has also been installed to better monitor the rainfall and flow level in the Mithi River. In 2008-2009, the rainfall density is further being intensified and 30 more additional weather stations are proposed to be installed. In addition, 4 more flow gauges are being installed at major locations to monitor the flow levels and improve the response mechanism.

During 2009-2010, the budget provisions of Rs. 2058.43 crore has been made for improving storm water drainage and sewerage as shown in Table 3. It has focused on the improvement of storm water drains to minimize water logging. Construction of storm water pumping stations has been proposed at various locations including Britannia Outfall, Gazdarband, Mogra Nalla and Mahul Creek. Under the JNNURM, the BMC has also been working on the replacement and rehabilitation of city's ancient sewerage system to increase the life and capacity of the pipelines.

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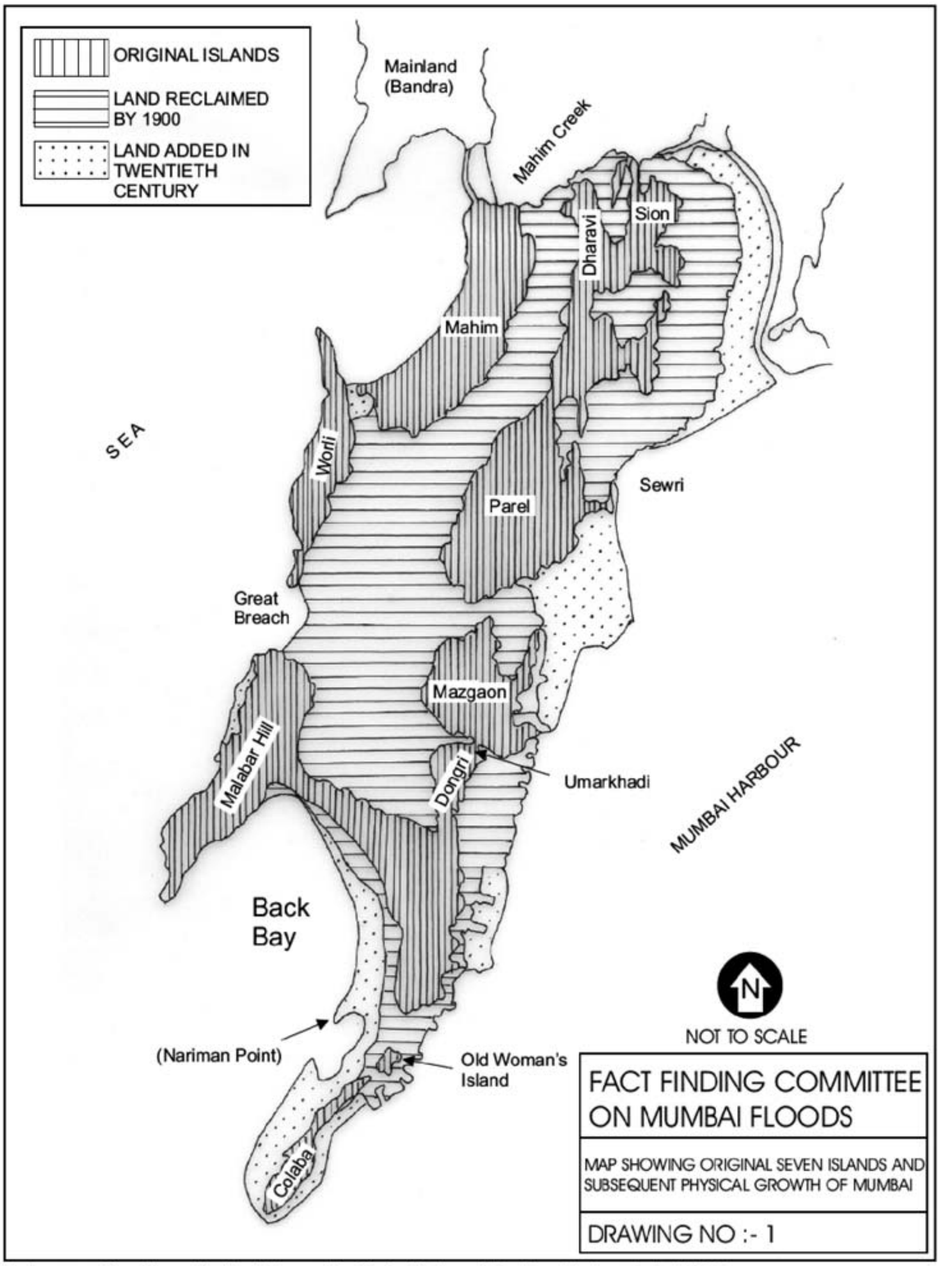

Reference - Gazetteer of India, Maharashtra State, History of Bombay, Modern Period 1987

Figure 1. The Mumbai city district showing the original seven islands and subsequent physical growth of Mumbai (Gazetteer of India, 1987)

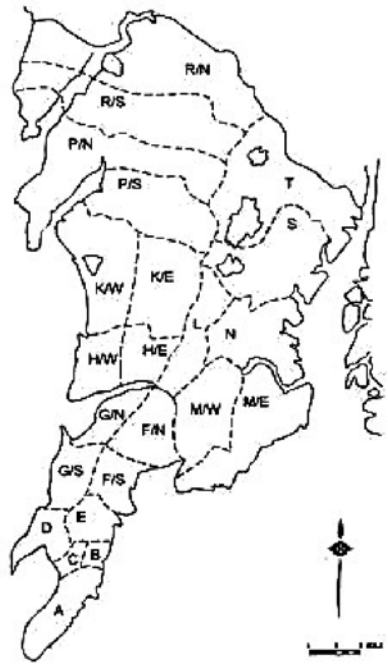

Figure 2: 24 municipal wards of Mumbai

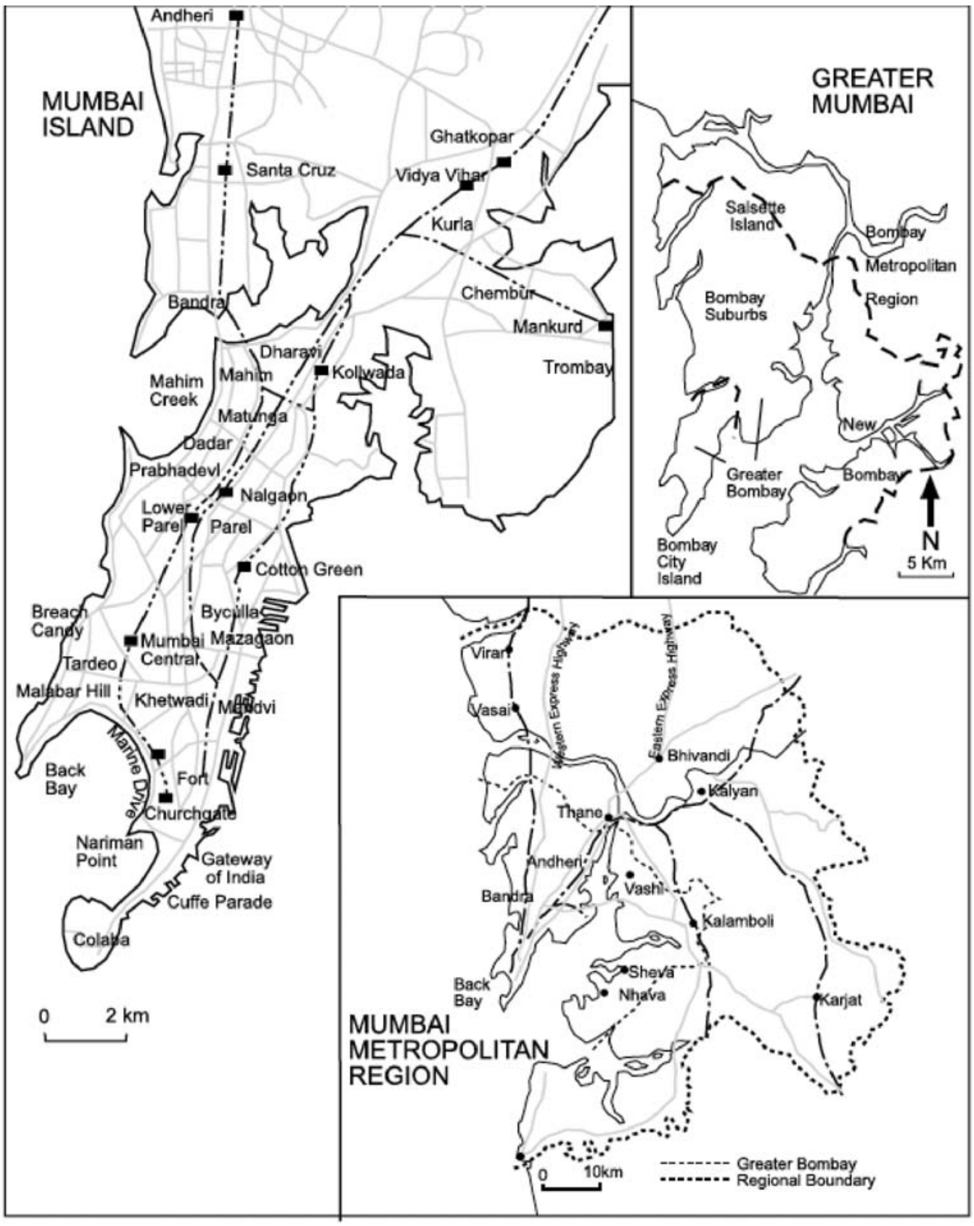

Figure 3: Area under MMRDA

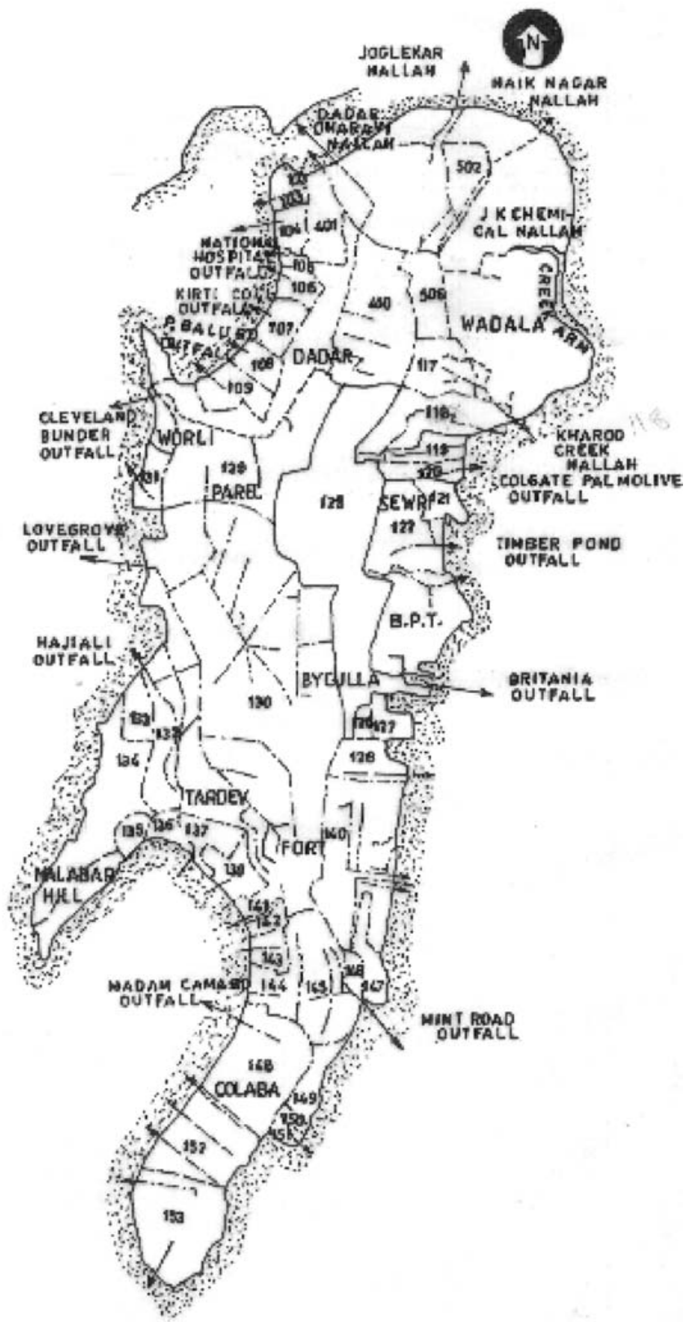

Figure 4. Drainage of Mumbai City area (MCGM, 1993)

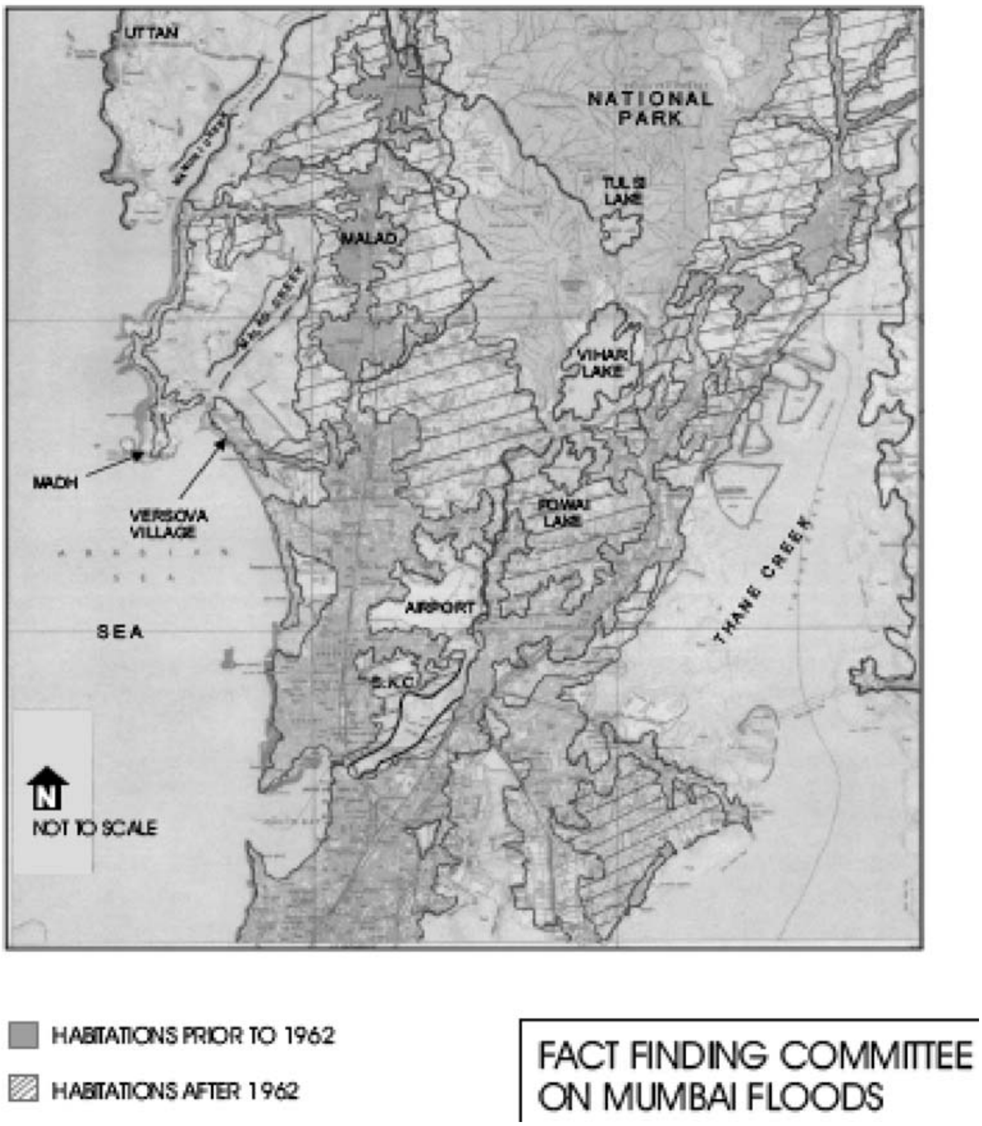

Figure 5. Drainage of northern suburbs (FFC, 2006)

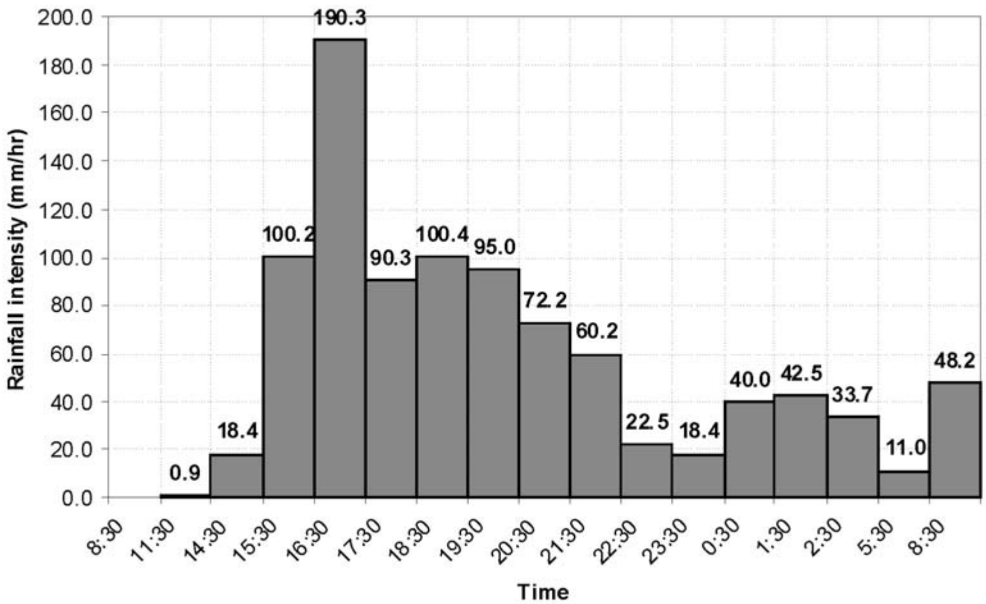

Figure 6. Hyetograph of 26th July 2005 rainfall- 24 hours ending 0830 on 27th July 2005 (source: IMD, 2005)

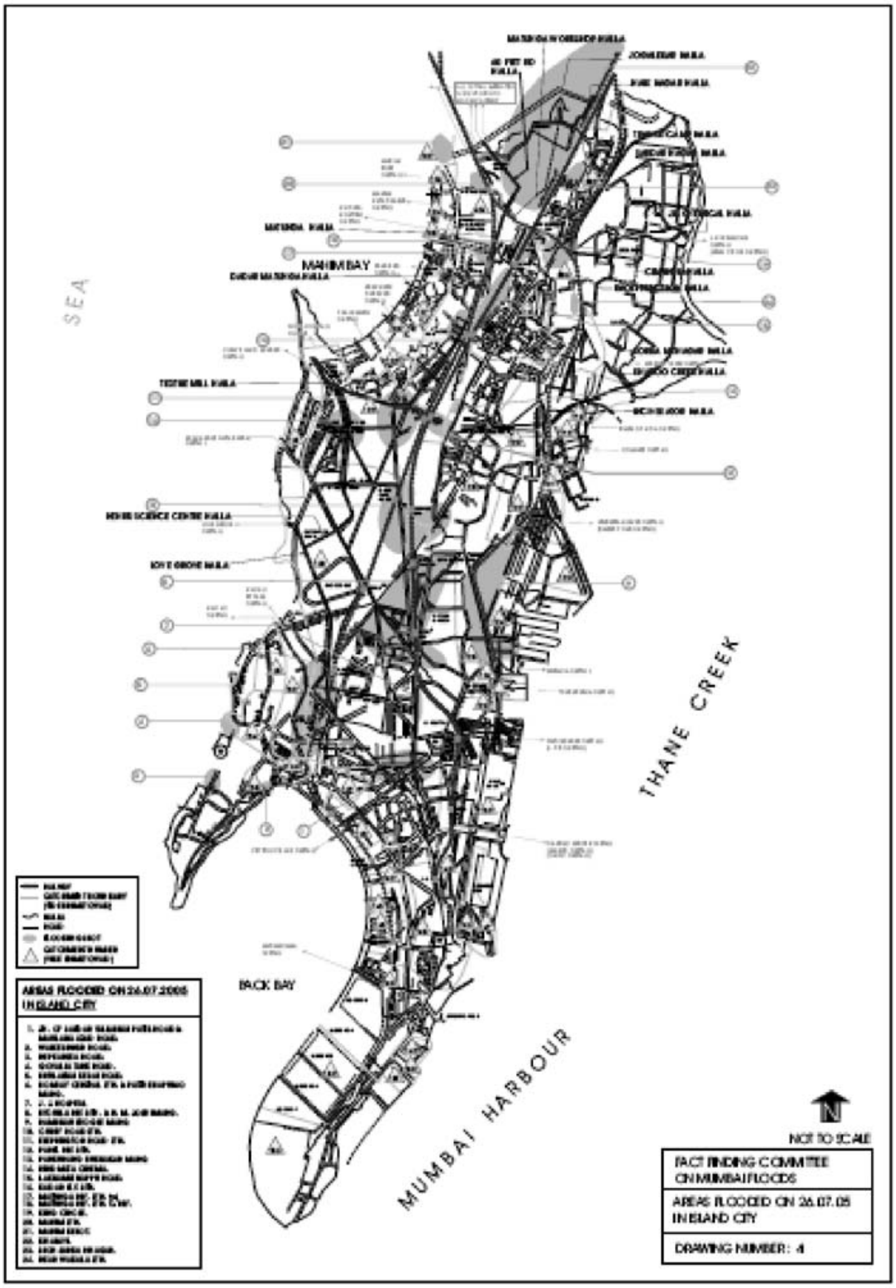

Figure 7. Inundated areas in City area (Fact Finding Committee, 2006)

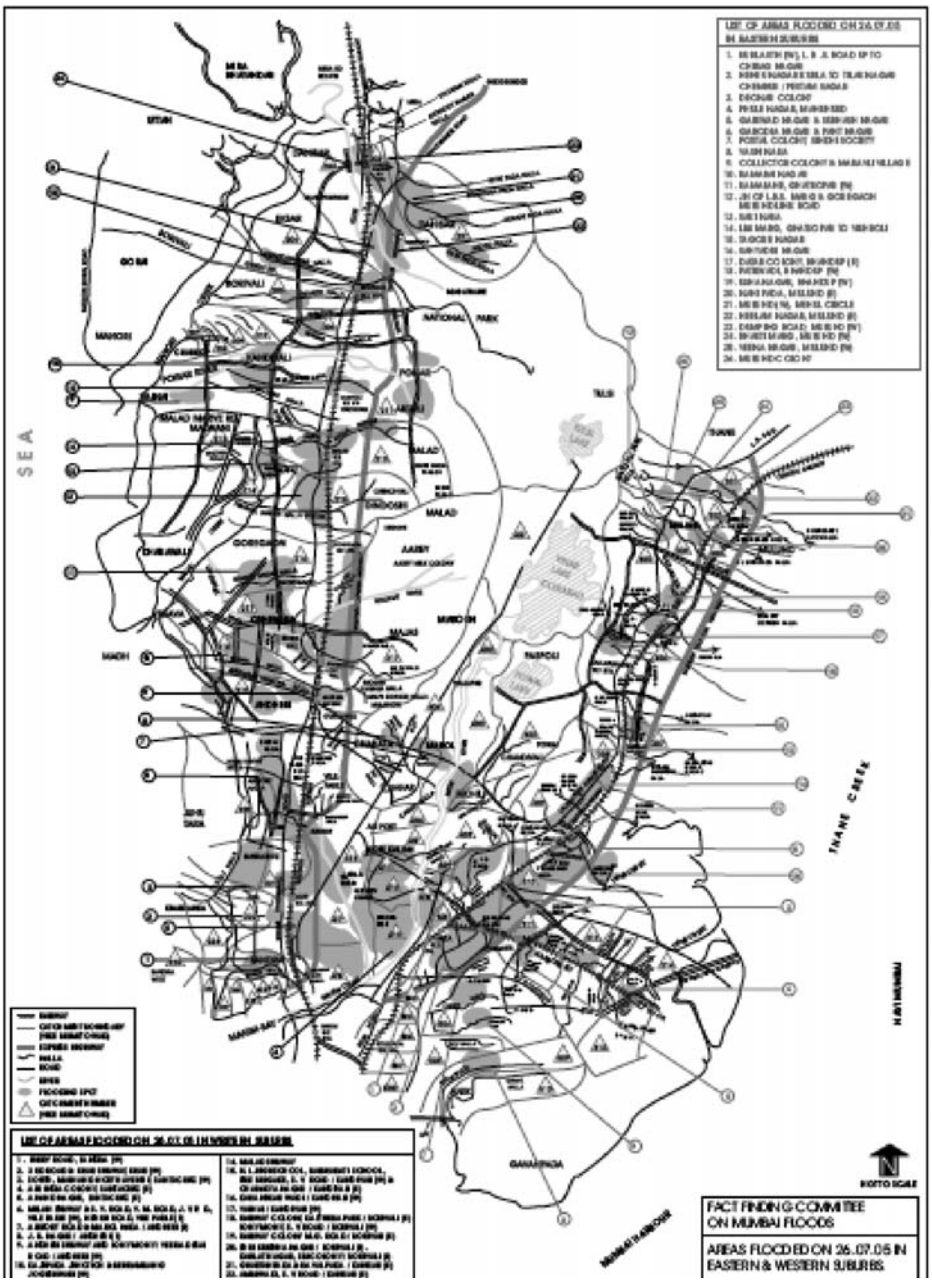

Figure 8. Inundated areas in the northern suburbs of Mumbai (FFC, 2006)

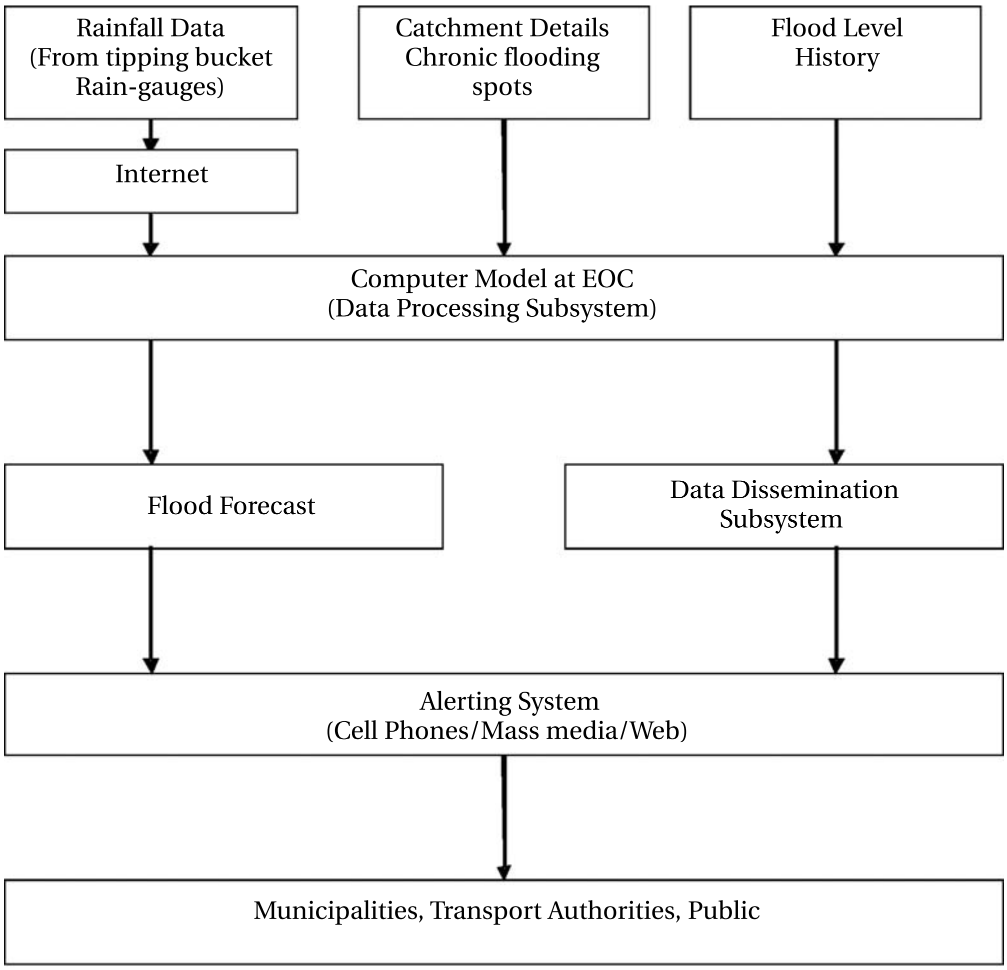

Figure 9. A flood warning system for mitigating urban flooding in Mumbai

Table 1: Peak 15-min rainfall intensities on flooding days (compiled from BMC/IMD)

		15-min	rainfall	intensity	Yearly	maximum	(15 min
		(mm/h)			intensity) mm/h		rainfall
Year	Flooding date		Santa Cruz	Colaba		Santa Cruz	Colaba
1999	23.05.1999	-	48		116	76	
	16.06.1999	72	-				
	23.06.1999	-	76				
	07.07.1999	-	56				
	16.07.1999	70	-				
	10.09.1999	72	-				
	12.09.1999	-	48				
	07.10.1999	116					
2000	18.05.2000	116	60		116	88	
	08.06.2000	100	68				
	03.07.2000	-	76				
	12.07.2000	104	-				
	24.08.2000	-	88				
	22.09.2000	50	-				
2001	08.06.2001	68	-		80	96	
	17.06.2001	-	80				
	08.07.2001	80	96				
	08.08.2001	-	43.2				
	16.08.2001	69.2	-				
	27.09.2001	40	-				
2002	14.06.2002	60	-		64	80	
	26.06.2002	-	56				
	06.08.2002	64	-				
	09.08.2002	-	52				
	23.09.2002	-	48				
2003	18.06.2003	-	80		64	80	
	19.06.2003	64	-				
	07.07.2003	64	-				
	14.07.2003	-	88				
	23.08.2003	64	-				
	30.08.2003	-	53.6				
	10.09.2003	-	72				

	26.09.2003	56	-			
2004	18.05.2004	88	-	120	75.2	
	17.06.2004	48	-			
	18.06.2004	-	62			
	04.07.2004	74	-			
	29.07.2004	-	60			
	01.08.2004	-	75.2			
	04.08.2004	120	-			
	05.08.2004	80	-			
	20.09.2004	70.8	-			
	30.09.2004	-	40.4			
	Maximum 15 -min peak intensity (mm/h) during 1999-2004				**120**	**96**

Table 2. Main causes of flooding in Mumbai (FFC, 2006)

S No	City area	Suburban areas
1	Low ground levels	Low ground levels
2	Siltation of drains/ nallas	Siltation of drains/ nallas
3	Obstructions of utilities	Obstructions of utilities
4	Low Level of outfalls	Encroachment along nallas
5	Dilapidated drains	Slums along outfalls
6	Urbanisation and loss of holding ponds	Garbage dumping in SWDs/Nallas mainly in slums
7	Increased runoff coefficients	No access for desilting

Table 3: Funds allocated for improving stormwater in Mumbai during 2008-09

S.No.	Particulars	Rs. (crore)
1	Maintenance of storm water drains (SWD)	248.10
2	Infrastructure projects under Brimstowad	1,576.82
3	Widening and cleaning or Mithi River	40.00
4	Laying of 5.95 km sewage lines with the help of micro-tunnelling	25.00
5	Construction of sewage treatment plants at Colaba, Worli and Malad and a recycling plant at Versova	55.00
6	Rehabilitating old sewer lines across city	70.51
7	ISO 9001-2000 certification for sewage installations	0.90
8	Construction and repair of public toilets under the slum sanitation programme	42.10
	TOTAL	2058.43

Urban Floods: Case Study of Hyderabad

Kalpana Markandeya and G. Suryanarayana

Profile of the City

Hyderabad is located in the heart of the Deccan plateau between 78° 22' 30" East Longitude and 17º 18' 30" and 17º 28' 30" North Longitude. Mohammed Quli Qutub Shah the fifth king of Golconda founded this historic city in the year 1591. Not only does it occupy a central location in the Deccan and by extension South India, but it also occupies a strategic location in the country lying as it does on a major highway of intersection between the northern and the southern part of the country. Established as a city with a single core, it evolved as a bi - nodal entity with Secunderabad as its twin city. It is surrounded by Rangareddy district on all sides, in which the impact of the spatial spread of the city is felt.

Hyderabad is the fifth largest and one of the fastest growing cities in the country. The urban agglomeration has increased enormously in size, from 245 sq. km in 1971 to 1865 sq. km in 2001 and in population from 1.8 million to 6.14 million. It is the second largest city of India with respect to area. The Greater Hyderabad Municipal Corporation (GHMC), which constitutes erstwhile Municipal Corporation of Hyderabad and erstwhile municipalities all around, is spread over 625 sq.km. and has a population of 5.33 million as per the 2001 census. Rapid urbanization and industrialization have brought about unforeseen changes in land use, burgeoning rural-urban migration, increasing pressure on civic infrastructure and environmental degradation.

Demography

The population of the city has grown fast especially after independence in 1947 (Fig. 1), owing to large-scale migration especially from the coastal districts of Andhra Pradesh. However, the primacy of the city in Andhra Pradesh, has come down, as has its position in the hierarchy of large cities of India. During the feudal era, Hyderabad was the only large city in the region; after independence, other cities have also grown at fast pace, due

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* Contributed as Hyderabad city team under National Coordination Project of NIDM (Anil K Gupta and P.G. Dhar Chakraborti, Disaster & Development, 3 (1): 1-14,2009).

to the infusion of secondary and tertiary activities, to make the urban landscape of the state poly nucleated.

Hyderabad was the fourth ranking town in what is now India, from 1901 to 1941. With the rapid increase in the population of Delhi by 106.58 percent during 1941-51, Hyderabad came to occupy the fifth position in the post-independence era. This fifth position was maintained through 1971. During 1971-81, Bangalore and Ahmedabad, the two industrial cities, registered a very rapid increase, (75.56 and 45.31 percent respectively) overtaking Hyderabad in the ranked array. Hyderabad could not keep abreast with the growth rates of these two metropolises, which had stronger industrial base to begin with and hence there was retrogression in its rank to the seventh position in 1981. In 1991, it reclaimed its fifth position by registering a 67.86 percent population growth. But the recovery was more apparent than real. The main reason for this rapid growth was the inclusion of a large number of independent towns like Ramachandrapuram, Patancheru, Shamsabad etc. in Hyderabad Urban Agglomeration (HUA) in 1991 (Gopi, K.N. and Markandey, Kalpana,1994). The fifth position has however been retained by the city even in 2001 (Markandey K, forthcoming).

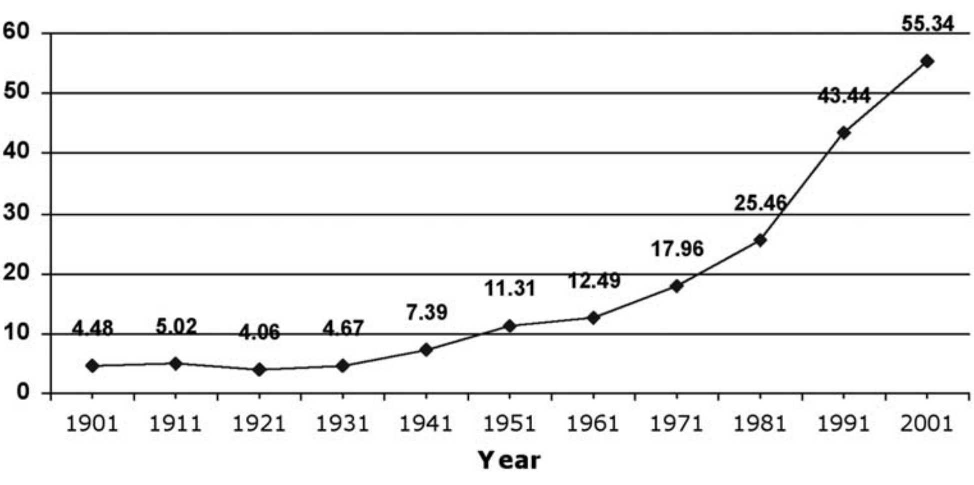

Figure 1: Growth of Population 1901-2001

Source: Census of India 2001

Hyderabad Urban Agglomeration (HUA) consists of the Municipal Corporation of Hyderabad (MCH), 12 peripheral municipalities, Secunderabad Cantonment, Osmania University etc. It has grown faster than Mumbai, Kolkata and Chennai during 1991 -

2001. The population density is also higher than that of Chennai, Kolkata and Bangalore. A perceptible feature of population growth in the surrounding areas has been that most of it is taking place on the periphery. The population growth in the surrounding municipalities during 1981 - 91 was 158% as against that of 42% in the MCH. Between 1991 - 2001 population growth in surrounding municipalities was 72% as against that of 19% in the MCH. Most of the growth has taken place away from the core of the city. It is expected that high rates of population growth will continue into the future as well and the HUA population would reach 77.2 lakhs in 2011 and 108.9 lakhs in2021. It has been found that the contribution of natural growth vis a vis that of migration in the overall population growth of the city had escalated in the year 2001, implying thereby that 'long term and strategic planning' is needed 'to promote equitable growth and service delivery'. (http://www.ghmc.gov.in/cdp/chapters%202.pdf)

Settlement Pattern

The city had a modest beginning. It originated as a trading center at Golconda on the route that linked Aurangabad with Masulipatnam. The most densely built up area was within the fortress - Golconda on the extreme west. With the passage of time the fortress town decayed and before the 19th century began, the nobility had shifted to the southern side of River Musi. Though the main axis of the city remained east-west, a northerly extension along the road north of the Charminar became quite visible. Once the Secunderabad Cantonment came up in northern Hyderabad in 1798, a second nucleus of the city started developing. It was named Secunderabad in 1806 after the then Nizam- Sikandar Jah. The Cantonment initially developed in an east-west direction, but later took on a north-south direction, in response to the stationing of the troops. The Cantonment consisted of the troops and the civilians employed by the British, and the businessmen who sold some of the imported commodities to the rest of the population of Hyderabad. This part of the city was distinct from its southern counterpart in language, culture and economy, yet the two grew together and towards each other (Alam S.M.1965, in Markandey K, forthcoming).

The setting up of the British Residency in the heart of Hyderabad in 1806, lent a new dimension to the growth of the city. Commerce coupled with churches and schools in close vicinity started sprouting up in this part of the city. In due course of time it developed a Central Business District (CBD) of its own. The coming of the railways in 1874 and their further expansion subsequently, brought the twin cities still closer to each other as well as integrating them with the far flung areas that now constitute the hinterland of Hyderabad. The trade links of Hyderabad also shifted from Masulipatnam to Mumbai and Chennai. The axis of the growth of Hyderabad moved from east-west to north-south in response to the expansion of the rail network. South Hyderabad, however, fell into a lull and it took time before the recovery began in the mid-twentieth century.

The growth axis of the city was also influenced by the location of the high-class residential areas of the city. These areas were located close to those of the ruling classes in order to satisfy the snob appeal of the upper echelons of the society and also to provide a physical proximity in the event of any unforeseen contingencies. To begin with, these areas were in and near Golconda. When the center of power shifted from Golconda to Hyderabad, the Charminar area, which was developed on a grid-iron pattern, became the prime attraction. The houses of the nobles were located along the four main roads that diverged from the Charminar.

When the Nizam shifted his residence to the King Kothi area in the eastern part of the city core in 1912, the upper income groups also shifted and started living in the central and western parts of the city, which includes Raj Bhavan, the Governor's Residence, in the post- independence era (Alam, S.M. and Pokshishevsky, V.V.1976). Subsequent developments have been concentrated in the western part of the city including the residences of the 'leaders of the society'- industrialists, politicians, administrators and film personalities.

Apart from this area, the Secunderabad Cantonment, with its colonial ambience has been developing as a high-class area of limited spatial extent. The Banjara and Jubilee Hills areas as well as Secunderabad are ranked high on the scale of preferences by the city residents so far as the choice of residence location is concerned as well as with respect to facilities, amenities, physical and social environment, ease of travel and recreational facilities (Markandey K, forthcoming).

Climate

Hyderabad is not known for its pleasant climate. This is notwithstanding the fact that in the previous century Secunderabad Cantonment was known as a 'non-fan station' by the British. The climate of Hyderabad is generally hot and dry and is characterized by seasonal variations of winter from November to February, summer from March to June and monsoons from July to October.

The annual range of temperature varies from 120 to 420 C. The average maximum temperature varies between 400 and 440, the average minimum temperature varies 70 C and 100 C. Sky clearance factor is 50 to 70 except in rainy season, when it is above 20. The climate is more or less semi arid nature. But its perennial lakes subdue the harshness to a manageable limit. The Southwest monsoon brings about average rainfall of 750 mm around June to September. July to September is the humid period. December and January are the months with the lowest temperature and high pressure (Op. Cit.)

Topography

The ground elevation in Hyderabad varies from 487 m to 610 m above mean sea level. The general gradient of land is from the West to the East. Rugged topography with isolated small hills is a feature of the western part of the city and flat plains mark the eastern part. Granite outcrops are a typical feature of this region and are seen on the outskirts of the city in ample measure. However, the construction activity in the city has taken a toll on the rocks which have been ruthlessly blasted in the recent past (Op.Cit.).

Hydrology and Water Bodies

The city is bisected into two, a northern part and a southern part, by River Musi, which is a tributary of River Krishna (Figure 2). In the event of heavy rains, floods are common; the largest of these occurred in 1908. The river was dammed and a reservoir formed to store drinking water for the city. The Osman Sagar Lake was constructed on the river Musi between 1912 and 1920. Subsequently, Himayat Sagar Lake was constructed between 1920 and 1927 on the stream Musa, a tributary of Musi. Before the construction of these two major reservoirs, Musi had a catchment area of 729.6 sq.km. and Musa had 1295.36 sq.km.

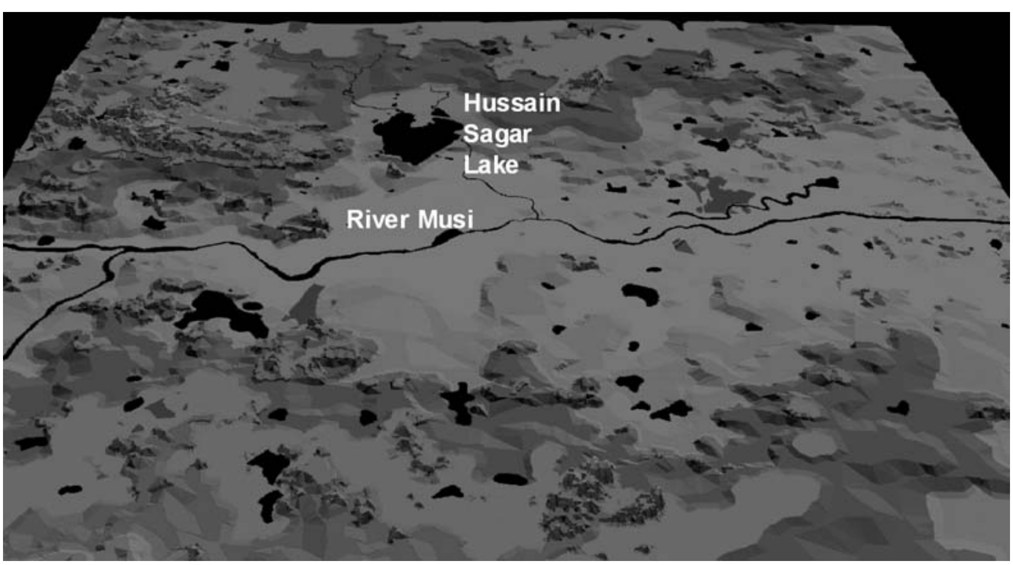

Figure 2 Topographic Profile of Hyderabad region

After these reservoirs were constructed, about 351.63 sq.km. of basin area drains into Musi bringing waste waters from Hyderabad agglomeration into the river. River Musi, which flows through the city takes on a very narrow course and dries up in this stretch, except for the city sewage flow. The water in the river in this stretch is not suitable for drinking or bathing.

There are about 400 big and small lakes in the Hyderabad Development Area of 2200 sq.km. Out of these 169 lakes have more than 10 hectares of water spread and 231 smaller lakes have water spread areas ranging from 1 - 10 hectares (HUDA report on Management of Urban Lakes, 2005). These water bodies make the microclimates of Hyderabad, especially in summer months, more bearable and in winters, highly salubrious. Unfortunately, rapid development and man made structures have gnawed into many of these water bodies depriving the city of a pleasant environment.

City Infrastructure

Even for the erstwhile Municipal Corporation of Hyderabad, which comprises of 9% of HUDA area, the coverage of underground sewerage system is less than 70% of the area. Of the 10 adjoining municipalities, which now form part of GHMC, only parts of Lal Bahadur Nagar, Uppal, Qutbullapur, Gaddiannaram and Kukatpally have underground sewers. All other areas in HUDA depend on septic tanks. The present capacity of STPs in the city is 113 MLD at Ambarpet and 20 MLD at Khairatabad. It is proposed to construct about 14 Sewerage Treatment Plants to facilitate clean flow in River Musi by various agencies. It is estimated that water demand by 2020 is 2050 MLD resulting in sewage load of 80% of that water supply, which is nearly 1640 MLD.

There are about 117 kms of drains in erstwhile Municipal Corporation of Hyderabad. There are about 63 storm water drains in 10 surrounding municipalities, which now form part of GHMC, with a total length of 102.34 km.

The present per capita garbage generation in the city is around 500 grams per day. In the Greater Hyderabad Municipal Corporation area (comprising 625 sq.km.), the garbage generation is 3450 metric tones. This constitutes solid waste generated from 0.14 million households and sweeping of 7158 road lengths and common markets. There are about 4169 garbage collection points. About 400 metric tonnes of garbage per day is used for pelletization and production of power. The remaining garbage is land filled.

Land Use Changes

The land use of parts of what is now the Hyderabad Urban Development Authority Area was first surveyed by the Municipal Corporation of Hyderabad and the Director of Town

Planning in the sixties as part of the process of Development Plan preparation. Those surveys were limited to the MCH area.

After the formation of HUDA, base maps and land use maps were prepared by Hyderabad Urban Development Area (HUDA) between 1975 and 1980 for its entire jurisdiction for preparing the Master plan and zonal development plans. For the first time a Land Use Survey was carried out for the Metro areas. The first statutory Master Plan for Hyderabad Development Area (HDA) was brought in to force in the year 1980.

Since the 1984 base maps had become out dated, in 1999-2000 HUDA launched a joint project with the National Remote Sensing Agency (NRSA), Hyderabad to update not only base maps but also the land use maps for the non MCH area with the help of IRS satellite (LISS III + PAN) as well as ground verification in 2000. In 2002, existing Land Use data was received from the MCH, which was based on work done by consultants engaged by MCH for strategic planning for the MCH area.

Out of the total HUDA area of 18,647 ha., at present water bodies occupy 5%, open areas and parks about 1% and forest blocks and plantations about 6%. However, a study of the two imagery for 2000 and 2001 is presented in figure given below (Figure 3).

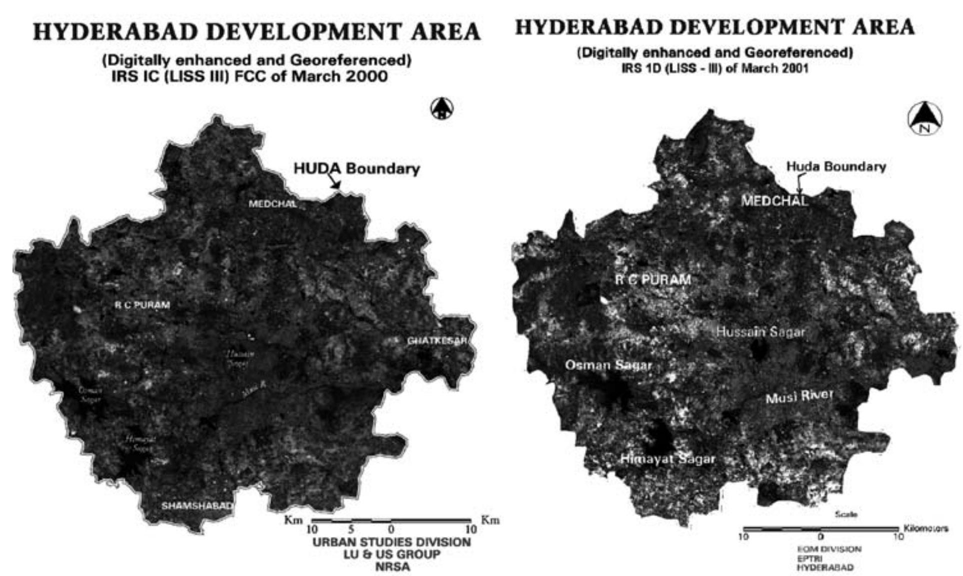

Figure 3

The Municipal Corporation of Hyderabad has witnessed a process of infilling of space leaving small proportion of vacant space in the city. Infilling has been more pronounced in the western, southern and northeastern parts of the city while the first part of the twentieth century witnessed an expansion along the northwestern and northeastern areas of the city. In response to the process of industrialization, the city witnessed growth in the west where Digital Economy finds expression in a large number of IT industries. The HiTech city in close proximity has produced marked infilling in the western part of the city by elite residential colonies. In fact the HiTech city or Cyberabad as the western 'exclusive enclave' is called, also mirrors a process of selective 'Nerdistization of urban spaces', where the people from the Information Technology sector are concentrated. Thus, this area not only has a concentration of the upper class of the city but also the newly upcoming middle class, a critical section of the society for the Digital Economy who look for a clean and healthy environment.

Extension of the built up area to the city limits is also witnessed in the southern of northeastern sides. In fact, the southern part of the city has experienced intense building activity in the past three decades, consequent to the remittances from the Gulf émigrés, members of whose extended families reside in this part of the city. The northeastern part, which is part of the Secunderabad component of the twin cities, has also witnessed a marked growth, which is phenomenally linked to industrial development along the north eastern corridor (Markandey K, forthcoming).

'The land use structure has been worked out *(by GHMC*) based on a survey and the activity centres present and future. The structure would help in limiting the decaying of certain areas through a conscious and judicious development of the core city and the peripheral wards, which have the maximum potential to grow in future. According to the survey, residential area constitutes 44% followed by 12% under open ground and agriculture. The mixed use is around 6.2 %.

There is also an increase in the institutional land uses than envisaged in the Zonal Development Plan (ZDP). The area under roads is also around 7% and considering the road widening initiatives, it would be slightly more than what is observed. It is quite evident from the analysis that there has been a modest increase in the mixed-land use, decreasing changes in industrial land use than that envisaged in the ZDP. This might be due to the successive industrial policies of the Government encouraging shifting of industrial units from the city. An analysis of spatial growth patterns in the past as well as for the future indicate saturation of growth in the core area, high growth and high densities in the surrounding areas along the industrial growth corridors' (http://www.ghmc.gov.in/cdp/chapters%202.pdf) . The same is presented in figure given below (Figure 4).

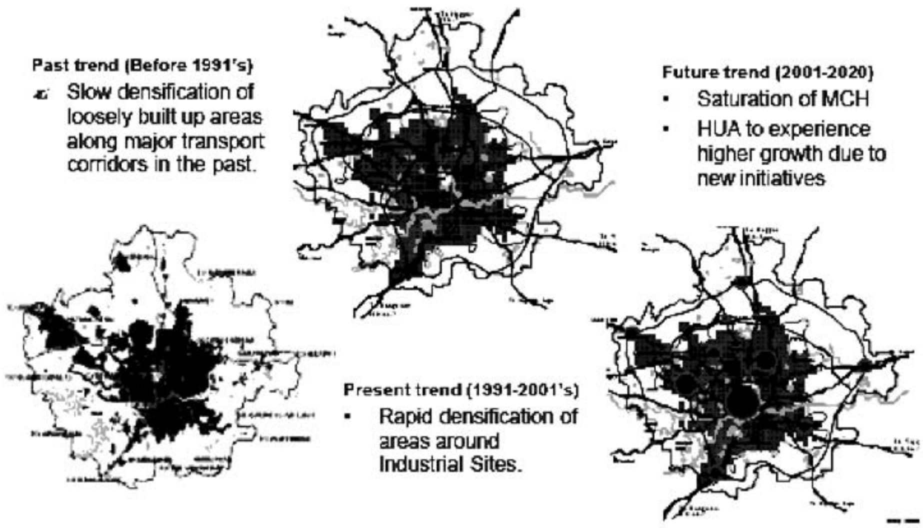

Figure 4

Source: GHMC http://www.ghmc.gov.in/cdp/chapters%202.pdf

Floods in the City

Hyderabad experienced unprecedented floods in the year 2000. The State capital, which experienced a record 263.6 mm and 246.2 mm of rainfall on 23rd and 24th of August 2000 - a 46-year record, wore a battered look with the gushing waters not sparing any area, not even the upmarket Banjara Hills and Jubillee Hills. The worst affected areas were Bowenpally, Safilguda, Maktha, Gandhi Nagar, Ashok Nagar, Bagh Lingampally, Chikkadpally, Rasoolpura, Begumpet, Viman Nagar, Indira Nagar, Hasmathpet, Trimulgherry, Lalaguda and Mettuguda. In Nadeem Colony near Toli Chowki, Army personnel rescued over 100 marooned families in boats. The casualties, mostly victims washed away in the floodwaters, were reported from Jubillee Hills and Chilkalguda (three deaths each), Chikkadpally, Kukatpally, Nallakunta (two each). (Deccan Chronicle, Aug. 24, 2000)

This act of nature, combined with urban geography and social structure, created the worst local disaster in half a century. At the heart of the city there is a large lake, the Hussain Sagar, the overflow from which is channelled via a canal to the nearby river Musi. Poor migrants from villages who came to the city 20 to 30 years ago in search of livelihoods have settled in hutments along these waterways and other waste lands. There are now 1,000 slums in the city. Building and 'beautification' around the lake and encroachment onto the riverbed has diminished the natural flood and rainfall drainage area. This combination of factors has resulted in a human tragedy as massive flooding along the canal resulted in 77 slums being completely washed away. (www.hindustantimes.com/ photogallery/storypage.aspx)

Urban storm water runoff can cause the flooding of local rivers as well as of the urban area itself. Urbanization drastically alters the drainage characteristics of natural catchments, or drainage areas, by increasing the volume and rate of surface runoff. While the impact on major river systems may be minimal, the carrying capacity of small streams may be quickly exceeded, causing flooding and erosion problems. Often, the runoff from intense rainfall exceeds the carrying capacity of the storm water sewer system, creating a backup in the system and hence the flooding of basements and of roads.

Hyderabad is the new hub for software industry. However, these industries made an assessment that there is loss of revenue to the industry since many workers who lived in the flood-hit area could not make it to the office. Hyderabad suffered an estimated damage of Rs 700 crore in the year 2000 due to floods.

GHMC has engaged consultants, M/s.The Kirloskar Consultants Ltd., Pune (KICONS) to prepare detailed designs for modernization of storm water drainage system. After conducting the necessary studies, the consultants have identified the following as some of the key reasons for flooding in Hyderabad:

- Inadequate drainage system, designed for the rainfall of 12 mm/hour.
- Excessive concentration of flood due to breaching of tanks.
- Disappearance of flood absorbing tanks
- Dumping of debris and garbage into the open nallas.
- Illegal encroachment of natural water courses
- Patta lands in the natural water courses
- Springing up of housing colonies in the foreshores of the tanks.
- Sanctioning of layouts without reference to the ground levels.
- Indiscriminate laying of service lines all along and across natural water courses.
- Collection of building materials on the roadsides resulting in excessive silting of drains.
- Diversion of natural water courses to accommodate habitations.
- Increased run off due to increase in impervious areas.

The biggest reason for urban floods is the total lack of attention to the nature of India's hydrological system. It is known fact that heavy precipitation is inevitable every few years or so, it is essential that natural drainage channels are well-maintained and instead of encroaching upon and filling up urban lakes to use the high-value urban land for buildings, these lakes and tanks should be well protected.

Built in 1562, the storage capacity of Hussain Sagar tank, the city's biggest waterbody, is now half. Once the number of water bodies within the city was about 530, it has now come down to 150. Years of siltation of tanks have reduced their water storage capacity. Encroachment of nalas, lakes and other water bodies, choking of streams and stormwater drains have taken their toll. While hunting for scapegoats and blaming the central government and meteorological office, the Government admitted that encroachments were responsible for the floods.

Good Practices and Lessons Learnt

In spite of the suffering caused by floods, the spirit of the people was still strong and their desire to rebuild their lives was impressive as they sought to recover what they could. Local organizations had pitched in to help, including hotels, women's and youth groups who were cooking food in the streets and handing out clothing. More was needed and Oxfam, which has an office in the city, acted and is now working with its local partner NGO's to co-ordinate the relief and rehabilitation programme. These NGO's called everyone together and formed 'The Hyderabad Flood Relief Co-ordination Committee'. 4000 families in the slums had been identified as the most needy for immediate relief in terms of supply of food, utensils clothing and bed sheets.

Oxfam's is also looking at the long term by continuing its work with local partners The Confederation of Voluntary Organisations (COVA) who works on projects to promote communal harmony between cultural traditions in the city and the Campaign for Housing and Tenorial rights (CHATRI, umbrella in Urdu). CHATRI is affiliated to the Indian national campaign for housing rights and seeks to uphold UN conventions on the right to housing. Slum housing is often a contentious issue in Hyderabad where only 60% of tenure is legally held and even then tenants are liable to eviction as development schemes or 'beautification' projects envelope their neighbourhoods. Residents are reluctant to leave their ruined house in case they loose their tenorial rights. CHATRI is working with them to help stop evictions, to protect their legal rights and to ensure their needs for shelter will be addressed. (www.hindustantimes.com/photogallery/storypage.aspx)

Strategies for the Future

Strategies for the future in view of the inherent threat of floods could include:

- Unified Urban Flood management
- Flood Mitigation
- Land use and zoning plans which could be remedial and preventive
- Flood proofing of buildings, infrastructure etc
  - Including tank embankments
  - Prevention of houses in tank and river beds
  - Protection of tanks and lakes
  - Avoiding construction or granting of pattas in natural water courses
- Legal and Institutional measures
- Public Education and Participation
  - Against encroachment on lake beds
  - Against dumping of garbage in open water sources etc
- Encourage horizontal spread of the city rather than vertical as congestion, pollution etc generate a lot of hygroscopic nuclei which lead to heavy rainfall in select locations

Flood Mitigation

Flood Mitigation measures alter the exposure of life and property to flooding. It reflects the holistic nature of those flood management measures that do not have structural nature. Its non-structural nature led some countries to denote mitigation as institutional measures, while other countries preferred to use the name of best management practice (BMP). The latter is in use in urban conditions for many years. In Europe, the term SUD (sustainable urban drainage) is obtaining increased popularity.

Mitigating means planning, programming, setting policies, co-ordinating, facilitating, raising awareness, assisting and strengthening. It also involves education, training, regulating, reporting, forecasting, warning and informing. However, it does not exclude insuring, assessing, financing, relieving and rehabilitation. If structural measures are the bones of a flood management program, then mitigation is its flesh. http://unesdoc.unesco.org/images/0012/001240/124004e.pdf

Effort made to mitigate and manage the floods

Hyderabad has a decentralized system of disaster management in place. As per the short term programme, emergency teams have been set up to scout low lying areas and address necessary relief measures.

The Municipal Corporation has a call centre number 1913 functioning 24x7.

Since long-term planning is about getting things in place and making sure that they fall into place when the need arises, bad town planning is also identified as one reason. The numerous flyovers and mismanaged road widening has also come under flak.

The city planning unit had prepared a master plan in 1975 that was ratified and implemented by the government. The same year, HUDA was constituted and entrusted with the job of urban planning and development. Although they have prepared some general plans from time to time, finally a comprehensive master plan is notified recently.

The Municipal Corporation of Hyderabad (MCH) has begun remodeling and widening major storm water drains in the last few months. It has already completed work on 8 km of the 40 km identified for repairs in the first phase. The balance of 32 km is likely to be completed shortly. Kirloskar Consultants, appointed after the August 2000 floods, submitted a master plan covering major drains and primary, secondary and tertiary nalas for a total length of 170 km, suggesting widening, deepening and retaining of walls along open drains. A separate engineering wing in the name of 'Hyderabad Lakes and Management Circle', was formed after the floods to study hydrology of the water basin and its management. Some works have been taken up across Balkapur, Durgam Cheruvu, Begumpet and Murki nalas covering Langer Houz, Fatehnagar, Falaknuma, etc. As a part of this, necessary retaining walls were constructed with required widths and depths at places where there are less encroachments. It was reported that they had removed 500 encroachments and paid compensation to 60 affected parties.

Drain widths range from 2 to 50 metres while depth can be up to 7 metres. While 3,500 encroachments have been enumerated for the 40-km stretch, officials estimate the total encroachments to be twice for the entire 170 km. The Corporation received support from Government of India which agreed to grant Rs. 147 crores under the National Urban Renewal Mission and Rs. 47 crores under the Mega City Project. Officials estimate that the entire project costing Rs. 598 crores will be completed in three years.

Experiences of 2008 Floods

The fury of floods unleashed itself on Hyderabad yet again in August 2008. Within a span of two days, Hyderabad received over 15 cm rainfall. The city was not prepared to take heavy rains in a short span. The city recorded 12 cm of rainfall in less than 14 hours, the second highest rainfall in four decades. The city had recorded 24 cm of rainfall during the devastating floods in August 2000. Sources say that the city's drainage network cannot take more than 1.2 cm of rain per hour whereas over 4 cm was recorded in less than an hour in August 2008.

Experts said lack of a disaster management plan is leading to such urban flooding. Lack of co-ordination among the GHMC, Hyderabad Metropolitan Water Supply and Sewerage Board, traffic police and other agencies coupled with improper land utilization has made the city more vulnerable to flooding.

Normal life came to a grinding halt in the affected areas. With some roads under water, vehicular traffic between twin cities remained paralysed. Hyderabad bore the brunt of the natural calamity with 14 people losing their lives, mostly in house collapses. As many as 52 residential areas in and around the state capital were inundated as twenty tanks and several major storm water drains overflowed. Boats were pressed into service in the city to rescue people from marooned areas. Even after the rains receded, hundreds of houses remained under water.

The vehicles movement was affected due to rain battered roads of the city. The average speed of vehicles in the twin cities of Hyderabad - Secunderabad came down to just eight km per hour as against the usual 14 km per hour, due to the bad condition of roads. The roads on LB Nagar-Miyapur and Secunderabad-Uppal sections faced the brunt of rains.

To add to the woes of motorists, more than 23,000 potholes appeared on the roads. There are 6,000 km roads in GHMC limits in addition to 250 km of State and National Highways running through the city.

Environmentalists have traced the recent flooding in the city to the irreparable damage caused to natural watersheds through unregulated urbanisation. These watersheds were buried in an overabundance of concrete structures and sought constitution of an independent body to manage "urban watersheds" by involving municipal and urban development authorities, academicians and NGOs.

According to them haphazard urban land use had increased both the magnitude and the frequency of floods in small drainage basins (of a few square kilometres) - a direct offshoot of lopsided water and land management practices. The rate of incidence of floods in urban areas was directly related to the extent of land covered with rough pavements and cement concrete - commonly referred to as impervious cover and shrinkage of open green spaces. The frequency of urban flooding had increased owing to unregulated urban expansion.

Roads inundated with water in September, 2008

Vehicles trapped in the storm waters

Marooned Colony during 2008 Floods

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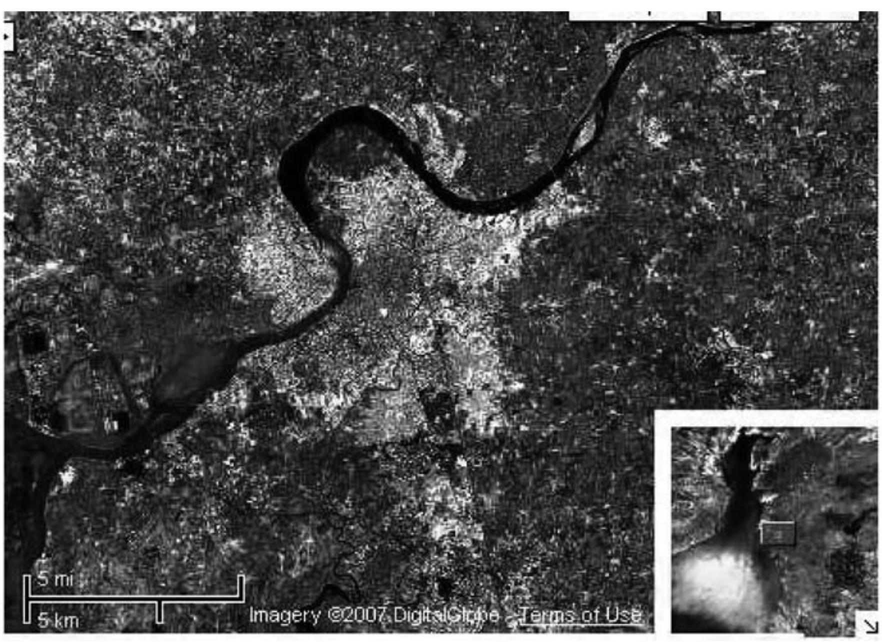
Urban Floods: Case Study of Surat

N. J. Mistry

City Profile

Surat is located midway on the 500 km long Ahmedabad-Mumbai western railway corridor and as many as forty pairs of express, mail and passenger trains pass through it. The state government has also established an airstrip to facilitate smaller aircraft landings but no domestic air service has been started yet.

The city forms the major urban core on the Ahmedabad- Bombay regional corridor, centrally located at a distance of 260 kms North of Bombay and 224 kms South of Ahmedabad.



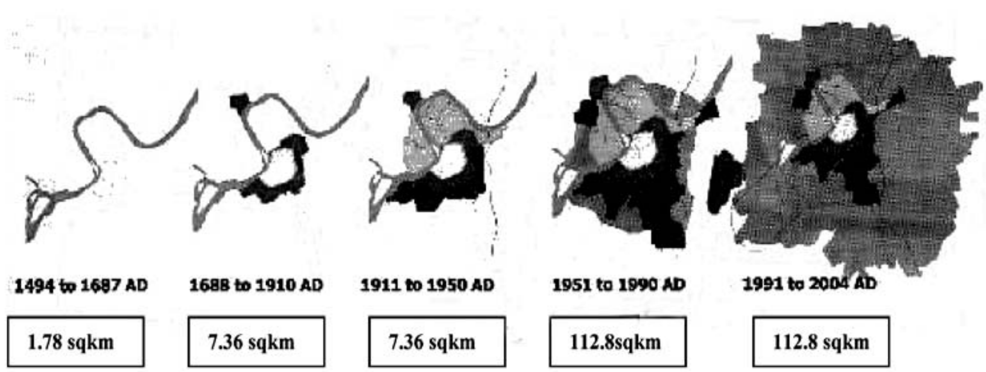
Surat: A Satellite Image Indicating Urban Sprawl (Source: www.google.com)

* Contributed as Surat city team under National Coordination Project of NIDM (Anil K Gupta and P.G. Dhar Chakraborti, Disaster & Development, 3 (1): 1-14,2009).

The area of Surat Urban Development Authority is 722 sq. km. which falls within 2I°-00’ N latitude to 2I°-I5’N latitude & 72°-40f East longitude to 73°-00f East longitude

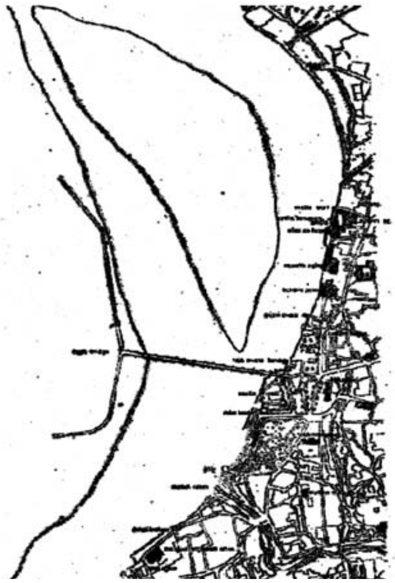
Historical Development of the City

The city of Surat has glorious history that dates back to 300 BC. The origin of the city can be traced to the old Hindu town of Suryapur, during 1500 – 1520 A.D., which was later colonized by the Brigus or the King from Sauvira on the banks of River Tapi. In 1759, the British rulers took its control from the Mughals till the beginning of the 20th century. The city is located on the River Tapi and has about 6 km long coastal belt along the Arabian Sea. Due to these reasons, the city emerged as an important trade centre and enjoyed prosperity through sea trade in the 16th, 17th and 18th centuries. Surat became the most important trade link between India and many other countries and was at the height of prosperity till the rise of Bombay port in the 17th and 18th centuries. Surat was also a flourishing centre for ship -building activities. The whole coast of Tapi from Athwalines to Dumas was specially meant for ship builders who were usually Rassis. After the rise of the port at Bombay, Surat faced a severe blow and its ship building industry also declined. During the post-independence period, Surat has experienced considerable growth in industrial activities (especially textiles) along with trading activities. Concentration of these activities combined with residential developments has resulted in considerable expansion of the city limits.

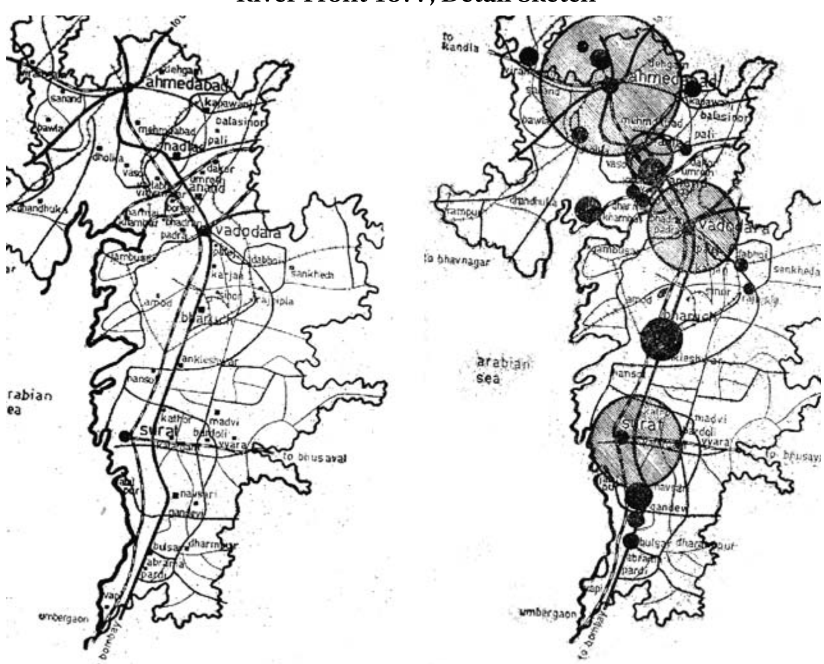


Surat: A City in Transition, Since 1400 AD

Source: Surat Vision 2020 Report



River Front 1877, Detail Sketch

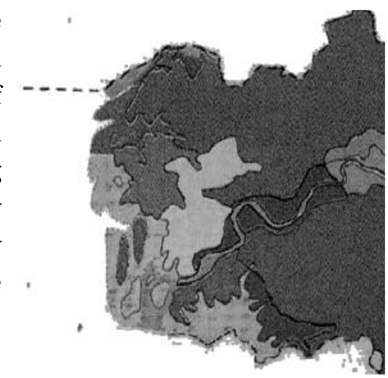


Source: Surat DP 1

Regional Context and Integration

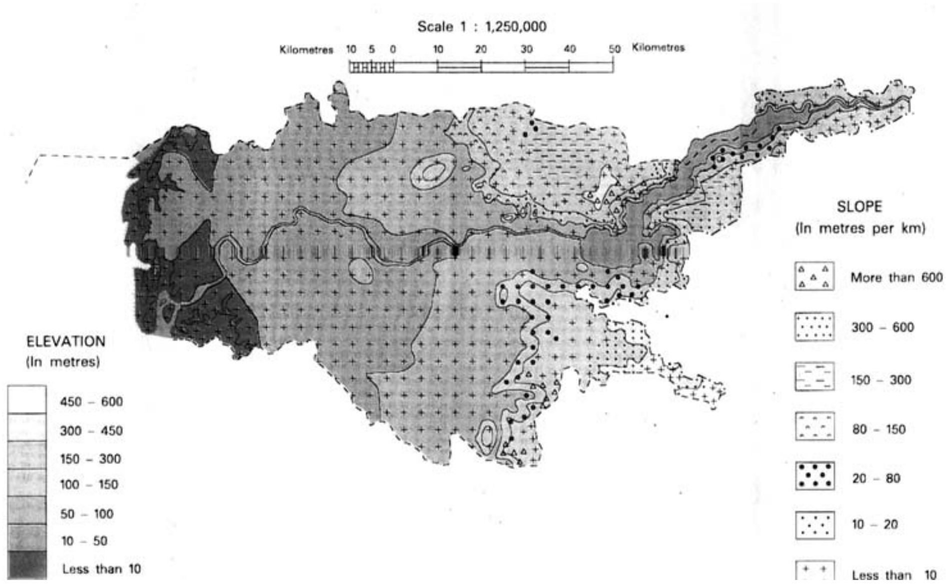
Physical Characteristics: Topography

The city lies at a bend of the River Tapi, where its course swerves suddenly from the north-east to southwest. With the walled city at its centre, the city forms an arc of a circle, the bends enclosed by its walls stretching for about a mile and a quarter along the bank. From the right bank of the river, the ground rises slightly towards the north, but the height above mean sea level is only 13 meters. The topography is controlled by the river and the general slope is from north-east to south-west. The area of Surat Urban Development Authority has a gradual slope towards the western and southern side having natural drainage systems towards Tapi River. The city is 13 m above mean sea level. Certain areas are low lying and during the monsoon season get flooded. The coastal lines along the villages of Hazira, Mora, Damka, Limla, Dumas, Bhimpor, Abhava, Gavier, Sarsana and Vesu and the land between the mouth of the rivers Tapi and Mindhola are very low-lying.



Soil Condition

Source: Survey of India

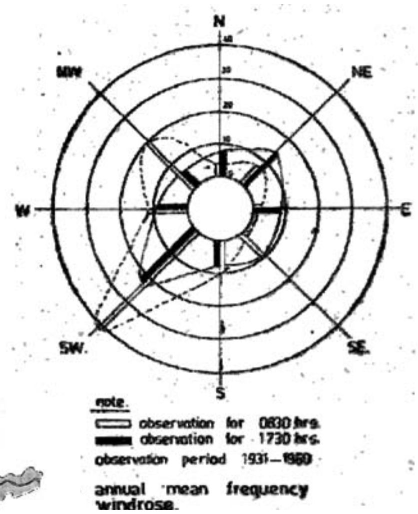


Relief and Slope

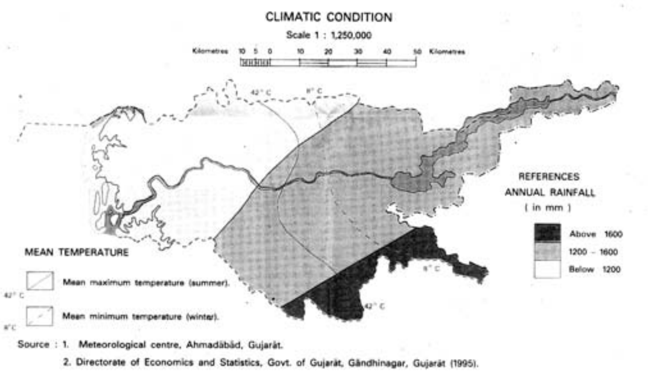
Source: Meteorological Centre, Ahmedabad, Directorate of Economics and Statistics, Govt. of Gujarat, Gandhinagar

Climate and Rainfall

The summers are quite hot with temperatures ranging from 37.78 degree C to 44.44 degree C. The climate is pleasant during the monsoon while autumn is temperate. The winters are not very cold but the temperatures in January range from 100 C to 15.50 C. The average annual rainfall of the city has been 1143 mm. the monsoon onset months are June and July and the monsoon wins recede during late September.



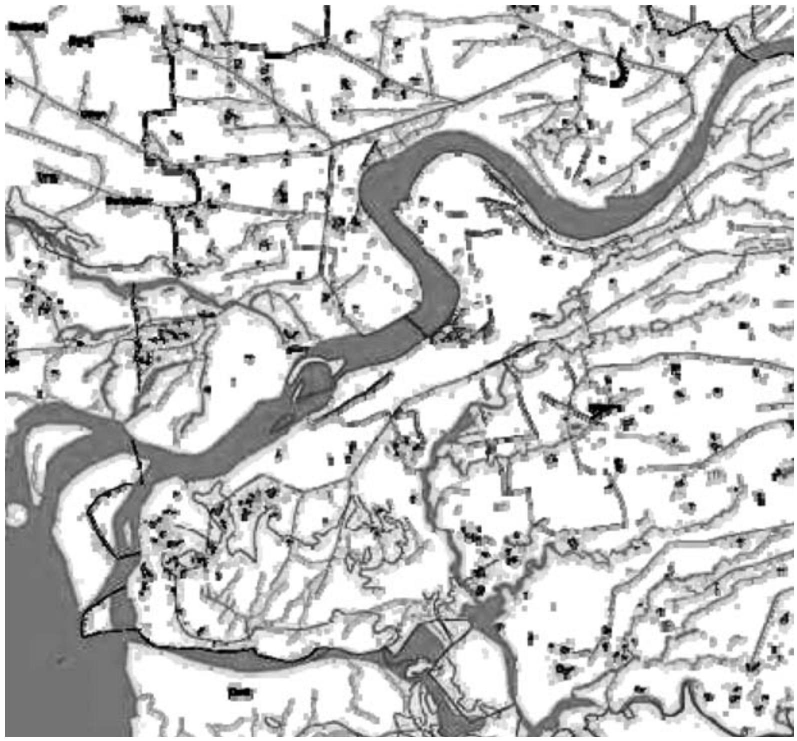
Annual Mean Frequency Wind Rose



Source: Meteorological Centre, Ahmedabad, Directorate of Economics and Statistics, Govt. of Gujarat, Gandhinagar

Ecology

The dominating geographical and ecological feature in the Surat region is the presence of an estuary condition, making the landscape unique in terms of both opportunities and threats. The condition of an estuary combined with a small delta, with changing land cover in the coastal regions over a period of time, have made it difficult to 'map' the region in the past due to technological constraints. Now, with the latest technology in remote sensing and GIS mapping has presented before the authorities a chance to detail surveys done periodically to understand the geographical parameters of the region better. Most of the area falls under water shed of the perennial river Tapi, and is prone to floods. This poses a major challenge to town planners for locating potential area for development.



Map of water bodies

Source: DPVIC Pvt. Ltd. Surat

SUDA area and SMC area Population Trends

DISTRIBUTION	AREA	POPULATION IN LAKHS				REAL GROWTH RATE %		
		1971	1981	1991	2001	1971-81	1981-91	1991-2001
SMC								
Walled city	8.18	3.63	4.4	4.2	-	78.0	-4.0	-
Areas added upto 1975 limit	47.37	1.3	3.3	6.4	-	157.6	91.4	-
Area added thereafter	56.53	0.3	1.6	4.3	-	335.1	168.32	-
Total	112.08	5.3	9.3	14.9	24.3	76.7	59.8	
SUDA								
Area excluding SMC area of 1994	609.72	1.4	2.0	2.9	6.5	36.9	43.1	
Area including SMC area	722.00	6.7	11.4	17.9	30.9	68.0	56.96	72.9

Source: SUDA DP 2004

City Infrastructure

Roads

"The contours of the city landscape underwent basic and cosmetic changes in the mid 1990s along with growth of infrastructural facilities, which earned Surat the tag of being one of the cleanliest cities of the country. But lack of a viable transport system, has left the city with a crumbling face. In the absence of any traffic planning, over 7.5 lakh vehicles leave the city roads gasping for space. The public transport services have remained as they were years back and need for a proper system to cater to the growing population is felt overwhelming. For industrialists, with lack of an airport in the second largest city of the state, business travels abroad still mean taking a flight from Mumbai or Ahmedabad".

– Surat Forum : Times of India, May 22, 2001.

Recent efforts at better management of the road network in the city have resulted in effective widening of the main corridors of the city. The roads in the city cover an area of 28.29 sq. km, which is about 25 percent of the total area of SMC. So far, 80 Percent of the area of the city has been effectively connected through a total length of 1133.37 km. of road network. Of this, 93.5 percent of the roads are surfaced mostly with asphalt. The region is characterized by "black cotton soil with high shrinkage and swelling" and high rainfall. These are the major causes for the unsatisfactory condition of the asphalt roads in the city. Keeping this in view, SMC has come up with a proposal to change the major arterial road network into a cement concrete road. The conversion of asphalt road in to C.C. Roads has been started in the city since 2004. In the first phase, The Surat- Dumas Road was selected. The other roads selected in this year are: Surat-Navasari Road and Kadodara Road. In the next phase, major ring roads and corridors, important link roads, roads wider than 24.39 m. are proposed to be changed to CC roads; the total cost of this work will be Rs. 4409.96 million.

Major Radial Roads/ Corridors

Major Radial Roads/ Corridors

Existing bridges across river tapi	
1	Hope Bridge adjoining Nehru Bridge (1877)
2	Railway Bridge No. 452 near Utran (1915)
3	Nehru Bridge Near Chowk Bazar (1966)
4	Katargam-Amroli Bridge (1982)
5	Sardar Vallabhbhai Patel Bridge near Atwa Gate (1991)
6	Morarji Desai Setu near Singanpore (1995)
7	Swami Vivekanand Bridge near Makai Pool (1996)
8	SH 167 & SH 168 connecting bridge near Nana Varachha (2001)

*Figures in parenthesis indicate the year of completion and commissioning

Bridges/ flyovers

Existing Road Network as on 31-3-2004

Roads	Length (km)	Percentage
Surfaced roads	1080.12	95.3
Black topped	1059	93.44
WBM	19.677	1.74
Concrete	1.319	0.1
Un-surfaced Roads	53.250	4.6
Total Length of roads	1133.37	100

At present there are 37 major and minor bridges and two underpass ways in the city. Of them eight bridges are across River Tapi at various locations. There are three fly over bridges in the Surat city.

The Bridge Cell of SMC carries out the construction and maintenance of bridges, culverts, underpasses, flyovers and road over bridges within SMC limits.

Two major bridges across the River Tapi are planned to be constructed within a span of three years each. While the one at Ved-Dabholi shall start during this year (2005-06) the other one near Paanch Pandav bungalow, Athwalines shall start in 2006-07. The construction of two major fly-overs road over bridge will be completed during 2006-07 and the other fly over on the Ring Road near Majura-Udhana Gate, will be completed during 2007- 08.

In addition, several fly overs and bridges are proposed on major and busy junctions/routes to ease traffic congestion and for easy movement of vehicles; thereby reducing air/noise pollution also.

In SUDA area there are two major bridges across river Tapi and 15 bridges across various creeks. The current network of roads in the city comprising asphalt, WBM, concrete and un-surfaced roads covers 8.46 km. per sq. km. of the corporation area accounting for a per capita road length of 0.40 m. On an average, the area covered by the present network is around 25.20 percent of the total area of the corporation.

Major Issues:

- Improper connectivity in peripheral areas
- Major operation & maintenance costs on roads
- Discontinuity in Ring Road and major roads
- Encroachments and Informal activities on major corridors of the city
- Lack of consideration for future growth patterns in planning for roads outside SMC

Sewerage

Emerging Issues

- **Outdated sewerage system in the walled city area, Athwa, Umra and Adajan**
- **Mixing of sewage with storm water and solid waste in several areas**
- **Low number of sewer connections**
- **Very low nil per-capita cost recovery**
- **Unavailability of comprehensive wastewater system in Industrial Area.**

Future Requirements

Surat Municipal Corporation has prepared a master plan for comprehensive sewerage system (more than 1000 km of sewers and 6 sewage treatment works) to serve not only the domestic and commercial, but also the industrial developments for the year 2021. Wastewater generated from all this development is to be collected by a network of underground sewers and pumping stations and conveyed to sewage treatment works for physical and biological treatment to meet the parameters prescribed by the GPCB before discharge into the nearest watercourse.

Sewerage Network

The comprehensive sewerage system designed for the city of Surat as per the master plan is expected to be in place by the end of 2006. Phase wise execution of the master plan will cover not only the present population of the city but also the population expected by the year 2021. Complete area coverage is expected to be achieved by 2006. This is apart from the revitalisation of the entire sewerage network in the central zone, where the present system is outdated. Complete revitalisation of the system in the central zone is to be completed by 2010.

At present, there is no drainage system exists in the Pandesara GIDC area, which leads to the flowing industrial wastewater open into the open surface water body.

Indicators

Total sewerage Generation	390 MLD
Area served to total area	92.19 %
Population served to total population	97.11%
Treatment capacity/Total Sewage Generated	100.00%

Zone	Area (Sq. km)	Area Coverage (%)		
		2005	2011	2021
Central	8.18	100	100	100
North	20.54	95.0	100	100
East	13.86	96.8	100	100
West	19.63	74.6	100	100
South	21.70	90.0	100	100
South-East	8.60	96.9	100	100
South-West	14.96	98.6	100	100
Total	112.274	92.19	100	100

Sewerage Pumping Stations

With the newly proposed sewerage pumping stations at Jahangirabad and Jahangirpura-Pisad, the sewerage pumping stations will total to 30. These are expected to cater to the needs of the population of the city till 2021. After the completion of the gravity mains that diverts the sewerage generated in the central zone to the Singanpore and Bhatar STPs, the sewerage pumping stations at Salabatpura and Saiyadpura shall be abandoned. Hence the total number of sewerage pumping stations in the city will be 28. Few of the existing sewage pumping stations i.e. Athwa, Umra, Adajan, Salabatpura shall be rehabilitated. In, Pandesara GIDC area a sewage pumping station exists. However, practically very little wastewater is collected, as there is no comprehensive drainage system exists.

Sewerage Treatment Plants

As per the master plan, to cater to the needs of the present population sewerage treatment plants have been constructed at Singanpore and Bamroli-Vadod. But to cater to the needs of the population in 2011 and 2021, the treatment capacities of these plants need to be augmented without the necessity of new treatment plants. Augmentation of Bhatar STP to 120 MLD and Karanj STP to 100 MLD has been recently completed, is under run since 2003 and the Singanpore STP is operational at present with a capacity of 100 MLD. For Pandesara GIDC area, there is no facility for common effluent treatment plant. Hence, the industrial wastewater directly flows to the nearby creek.

Indicators

Collection Performance (% Collected to Generated)	98.1%
Total vehicle capacity to total waste generated	108.5%
Trips per vehicle of Existing Fleet	-
% of total waste put to recycle reuse	-

Solid Waste Management

Processing and Disposal of Waste

Processing and disposal met hods like

incineration etc. are not used in Surat. Land available for treatment and disposal of waste, where the land filling is carried out, is about 10 km from the city.

The life expectancy of land for the treatment and disposal of waste is 30 years at the Khajod final disposal site. There is sanitary landfill cell created and the cell is ready for its use for disposal of inert material obtained at the end of treatment process of MSW Treatment. One Bio-Medical Waste Treatment Plant is working on a BOOT basis from 2003.

Solid waste Generation (Metric Tons)

Zone	Area	Solid waste Generation		
	(Sq. km)	2001	2011	2021
Central	8.18	150.1	139.5	116.2
North	20.54	121.7	179.1	220.6
East	13.86	210.7	295.9	337.7
West	19.63	90.9	166.3	224.5
South	26.01	177.6	291.45	383.1
South East	9.1	59.2	97.15	127.7
South West	14.96	73.2	108.7	139.9
Total	112.28	883.5	1278.0	1549.7

Solid Waste Management in Suda Area:

- To provide Dust Bins.
- To have collection system from each house.
- To provide transfer station.
- To provide vehicles for Transportation of solid waste.
- Develop landfill site for systematic disposal of solid waste including segregation of the waste.
- The scheme will be provided for 67 T.P. Schemes at a cost of Rs. 80 Crores.
- SUDA has identified and reserved land of 24 lacs sq.mtr for solid waste and garbage disposal.

Drainage System

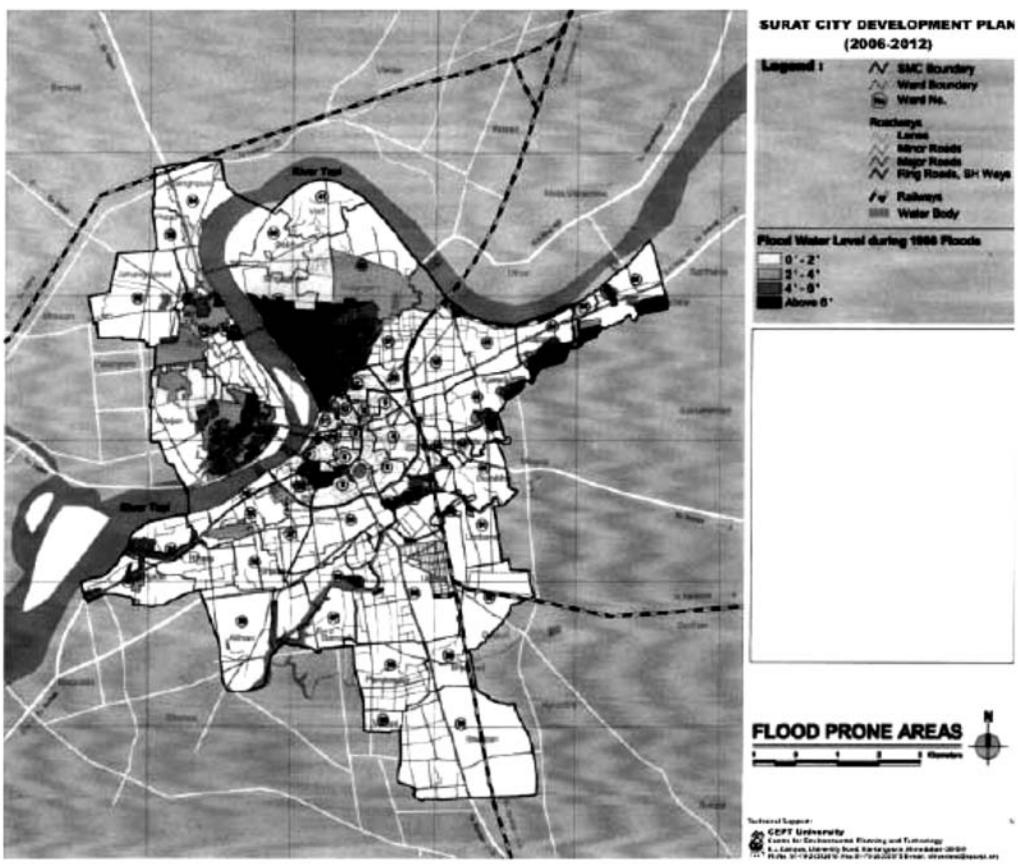
Due to its location on banks of the River Tapi near the estuary of the Arabian Sea, the land drainage in Surat City is relatively poor and in the past, during the monsoon months, many areas of Surat city suffered temporary flooding and blockage of storm water.

The monsoon in the region is seasonal and is active between the months of June to December. Rainfall during this period can be extremely intense. Hence, the SMC has laid an extensive network of storm water drains in the entire city.

Existing Situation

The gentle slope of the city has greatly aided in the natural storm water drainage. 85% of the city is covered with a storm water drainage network, but well built leader lines to support the natural system are lacking in most parts of the town except in the well-developed areas. Generally, the storm water flows through un-built open surface drains and joins the nearby khadi or the River Tapi. These drains discharge storm water in to the River Tapi at 16 locations in 5 zones of the municipal corporation. The storm water outlets provided backwater entry to the floodwaters of

River Tapi and thereby caused temporary flooding of areas from which they were carrying out storm waters. Hence, it was felt necessary to provide flood protection gates at the outlets of storm water drains. SMC completed the construction of flood protection gates at 15 locations in the year 1999 at a total cost of Rs.210 lakhs. These works were completed in 3 months. A total of 22 cast iron manually operated vertical sliding gates were provided. Normally, these gates are kept open, but at the time of heavy floods in the River Tapi, these gates are closed to prevent the entry of floodwater in to the city. At present the area outside Municipal Corporation does not have any storm water drainage system. SUDA has proposed storm water drainage system covering 68 TP schemes to be developed.



Flood Protection Scheme of River Tapi

After the ravaging floods of the River Tapi in 1968, the Government of Gujarat had decided to have a flood protection scheme to protect Surat city and its adjoining area. It was planned to provide flood protection for a total of 46.85 km. on both banks. The Tapi embankment scheme was designed for a 10 lakh cusecs flood, which is inclusive of 1.5 lakh cusecs discharge, contributed from the catchment between the Ukai Dam which is about 80 km. upstream of Surat city. The flood protection works consist of raising of both banks of the river by construction of an earthen embankment/ brick masonry retaining walls with/without river slope pitching and also by constructing sluice regulators across natural creeks/drains etc. meeting the River Tapi.

The major part of the scheme was executed by the Government of Gujarat from 1971 to 1995 at a total cost of Rs.1542 lakhs. But the long delay in completion of the project proved fatal during the floods of 1994 and 1998. The works of embankment/sluice regulators at village Chhaprabhatha, Variav and Tunki were not completed. with technical guidance from the Narmada and Water Resources Department of the Government of Gujarat, SMC executed the flood protection works, which fall within the Surat city limit. The project cost of Rs.2406 lakhs is being borne equally by the Government of Gujarat and SMC. Initially, SMC will execute the works from its own resources and later on, the Government of Gujarat will reimburse its 50 percent share within 3-5 years depending upon the availability of funds. The works of the first phase have already been completed by SMC and the remaining works are proposed to be taken up only after finalisation of the scheme/ design-drawings etc. by the Irrigation Department of the Government of Gujarat.

Emerging Issues

Mixing of Sewer and Storm Water Drains

With a very small number of sewerage connections in the city, large amounts of sewage are let out illegally into the storm water drains. The closed drains of the city amount to only 20.3 percent of the total length of surfaced roads. Solid waste is also dumped into the natural drains of the city in many areas near the slums. Due to this, the city witnesses frequent flooding of roads during the monsoon.

Delay in Implementation of the Flood Protection Scheme

The flood protection scheme of the River Tapi that started in 1971 is still under progress. This long delay on the part of the Government of Gujarat proved fatal during the floods of 1994 and 1998. A large portion of the scheme falling under the city limits is still pending and is largely dependent on the availability of funds with SMC as the reimbursement from the Government is expected to come only at a later stage.

Silting of Khadis and Open Storm Water Drains

The city has the advantage of a good natural drainage pattern, which is not, unfortunately, exploited properly. Silting and constriction due to uncontrolled solid waste dumping and encroachments by the poor on the banks have interrupted the flow of wastewater and storm waters, thus, causing them to spill into neighbouring areas. Never has there been an attempt to desilt and clean the natural drains of the city. The open storm water drains are in a similar condition, with sewerage waters getting mixed with them at places.

Indicators

Storm Drain network/Total Road Length	30.6%
Closed Drains length/ Total Surfaced Road Length	20.3 %

Zone Wise Storm Water Drains

Zone	Area (Sq. km)	Total Length (km)	
	2001	2005	2011
Central		34.14	39.94
North		48.44	59.42
East		57.47	68.50
West		75.00	93.80
South		20.13	24.13
South-East		34.00	39.50
South-West		52.36	75.79
Total		321.53	401.08

Future Requirements

The Surat Municipal Corporation has appreciated the importance of an effective storm water drainage wherein the current and future needs point to effective roadside storm water lines. This is in consideration of the fact that apart from draining the storm water they also help in maintaining the condition of the road surface. A total length of 532 km of present storm water drains are to be extended to a minimum of 401.076 km by 2011 to effectively control flooding during the monsoon. This is also expected to assist the flood protection scheme of the River Tapi by reducing the sudden pressure on the system during emergencies.

Storm Water Drainage in the Peripheral Areas (Suda Area)

Due to its location on banks of the river Tapi and on the bank of river Mindhola near the estuary of the Arabian Sea, the land drainage in SUDA area is relatively poor. In monsoon months, during heavy rains many areas of SUDA suffer flooding. Till now, such flooding was not posing a major problem as major part was agricultural area. With rapid development of SUDA area, it is necessary to see that the storm water is disposed off as early as possible to exert only minimum hardships on residential, commercial and industrial area.

Due to paucity of funds, normally low priority is being given to the costly project of disposal of storm water. Moreover, as the area is located on the banks of the river, there are number of natural creeks which meander at number of places. It is possible to provide systematic underground system of storm water disposal, unless storm water drain in place of these creeks are

properly planned on the roads of TP Schemes, as by preparing TP Schemes at many places the land falling under portion of the schemes are allotted to final plot holders. Now, as the TP

Schemes are being prepared and finalized gradually the road network is also finalized which facilitates to provide storm water drain. Initially projects are prepared for Vesu and Pal-Palanpor area at a cost of Rs. 60 crores covering the total area of 1800 Ha. It is proposed to cover the major part of the SUDA area by efficient network of storm water disposal at a cost of Rs. 176 crores over a period of 7 years. The project becomes costlier, as the same is to be designed keeping in view the disposal points which are mainly in river, the latter is not only in tidal range but also has to face abnormal floods. To prevent the flood water entering into SUDA area, provisions are to be made for flood gates at disposal points.

Floods in the City

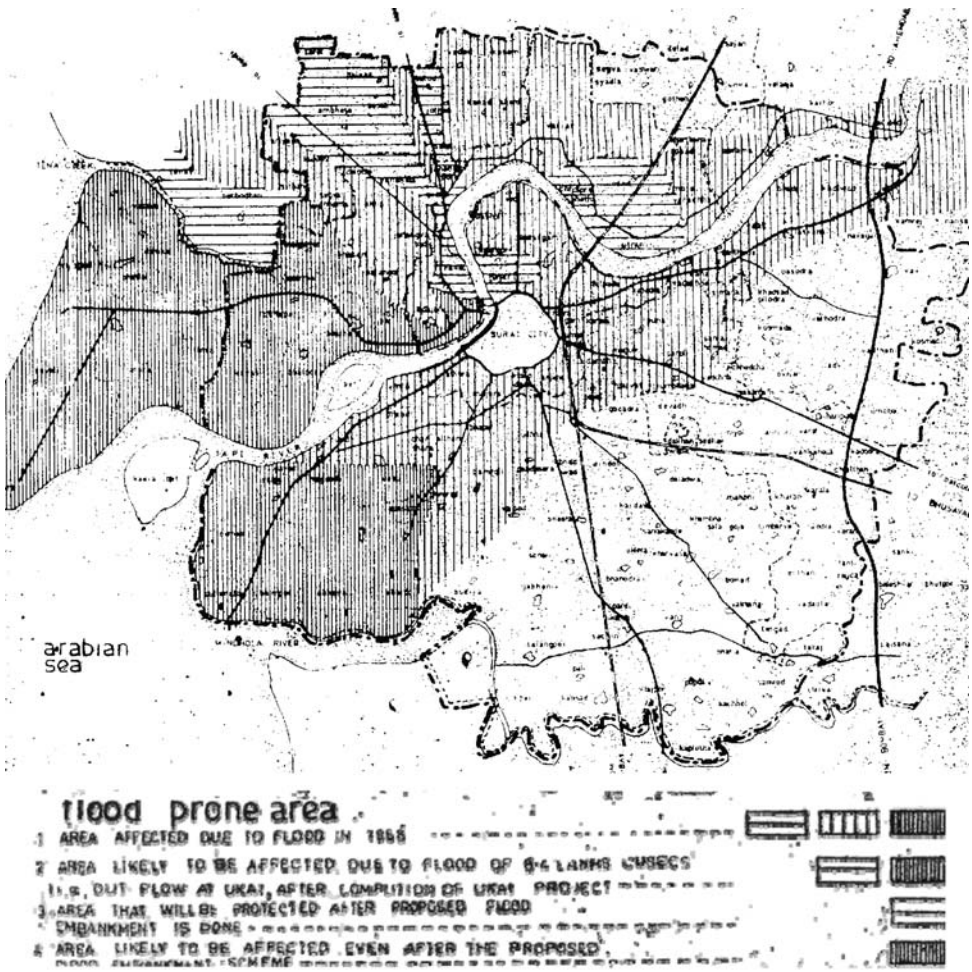
Year-wise Area to be Covered Under Storm Water Drains in SUDA Area

Year	Area in Ha.
2006	285
2006-07	2385
2007-08	2385
2008-09	2385
2009-10	480
2010-11	240
2011-12	240
Total	8400

Natural Hazard

Flood Prone Areas

Development of Surat in the past has been affected a number of times due top the high flood in Tapi, until recently until the Ukai project was complete. Now this area is safe from floods upto 18.5 lakh cusecs of water. The height of the Nehru Bridge on Tapi within the city is one of the controlling points for the further strengthening of the flood embankment. Ukai reservoir is designed to a gross storage of 6.9 million acres feet at FRL 345. During floods, this can be raised to a height of about 351 to hold the excess of about 1 million acres feet.



Map showing flood prone areas

Source: SUDA DP1

The above figure shows the typically low-lying areas in the region. According to the flood embankment scheme the development of Rander, Adajan is still under flood-affected zone. The walled city areas have few pockets of low-lying areas such as Navasari bazaar, etc get flooded in the monsoon season. The areas on the other side of the railway line towards the southern side of Kamrej.

Flood history

Year	Flood Flow(Lakh Cusecs)
1968	15.5
1994	3.5
1998	7.5
2006	10

Surat: General Flood History

History of Floods in Surat

Located at appoint where the river meets sea, Surat is flood prone since centuries. Available data and various flood maps recognize this fact. The cty earlier witnessed a major floods of varying intensities in 1737, 1782 april, 1835 and 1837 aug-sept, 1949 and 1968 aug sept, 1944 aug, 1954 sept, 1959 and 1968 aug-sept, 1998 sept, 2002 sept and the recent flood of 2006 aug. evidently the period between july to sept has generally been period of flooding. During this period, the rains lash south Gujarat and the upstream regions through which tapi meanders its way to finally meet the sea near Magdalla, dumas and Hazira confluence.

Available Data of Floods in Surat

indicate a broad pattern of regularity in occurrence. Since 1869 upto 1884 on average the city was flooded every 2 and a half years, followed by a pronounced fall in frequency upto 1914. this went again with frequency rising to an average of a flood every three and half years during 1914-49, the corresponding average of floods came to once every four years followed by their occurrence every six years between 1979-2006. Such regularity indicates natural tendency for tapi to flood especially its downstream settlements including the city of surat. Duringthe last 6 decades, the years that have witnessed consecutive floods are 1994 and 1945, 1958 and 1959, 1968 and 1969 and 1982, 1983 and 1984.

While floods in surat have often been due to heavy rains in the upstream regions, they have also been compounded y the unpredictable storms in the tapi basin. Together, these add to uncertainty in the recurrence pattern. Flood having intensity of 23 lakh cusecs may actually occur within a few years or a flood of a much lesser intensity of even less than 5 lakh cusecs may not occur even within the next ten years. This is particularly because changes in the climatic have increasingly been getting erratic in magnitude and extent. Given this, while it is rather difficult to predict the intensity of future floods, it is hardly difficult to visualise that the overall vulnerability of the city and its region has increased manifold over time. Needless to say, that this has serious implications on the socio-economic and the changing geomorphological fabric of the city. Given the indiscriminate growth of city in terms of residences, activities, infrastructure, encroachments and a swelling population on one hand and reclaiming parts of the floodplain, the delta and adding structures on the land unable to carry such interventions, the frequency, magnitude and duration of floods have indeed increased during the last few decades.

A Discussion of 'Causes': Natural or Human?

Natural factors:

Heavy precipitation in the catchment

Even with differential precipitation rate in the larger catchement of a smaller tributary may lead to heavy flooding

Cyclonic storms

As in the case of 1959 and 1968 floods. These type of floods remain very uncertain

Effects of tides and silting

Silting in gulf of cambay due to tapi and narmada bringing hue quantities of silt causes floodwaters rise higher and thereby extended inundation

Low bankful capacities

Data on past floods indicate that surat city and some adjoining villages remain safe upto a limit of 5.8-6 lakh cusecs discharge

Human induced factors:

Effects of railway embankment

Barrier created by western railway line from Bombay to Ahmedabad

Effects of city growth

Due to growth related activities spaces that have been natural flood routes have been covered up. e.g.

- Hazira Master Plan
- Airport Development Project
- Aaliya Bet Development Proposal
- Convention Center for Chamber of Commerce

- Satellite Township of Abhva

It is significant to note here that two most important documents viz. Vision 2020 for the city and CDP 2006-12 hardly takes into cognisance the implications of their development strategies in terms of floods and their impacts. Due to claimed and reclaimed lands, the floods in surat can get aggravated even at lower quantum of discharge, as low as a level of 5 lakh cusecs.

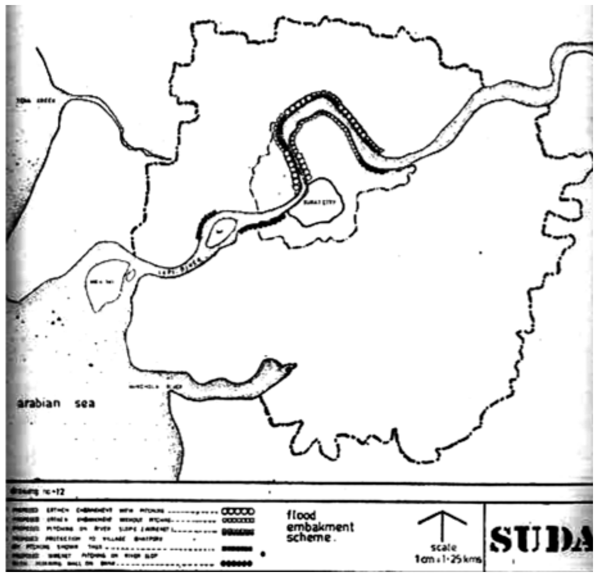
Projects of misplaced priorities with potential of increase vulnerability to floods:

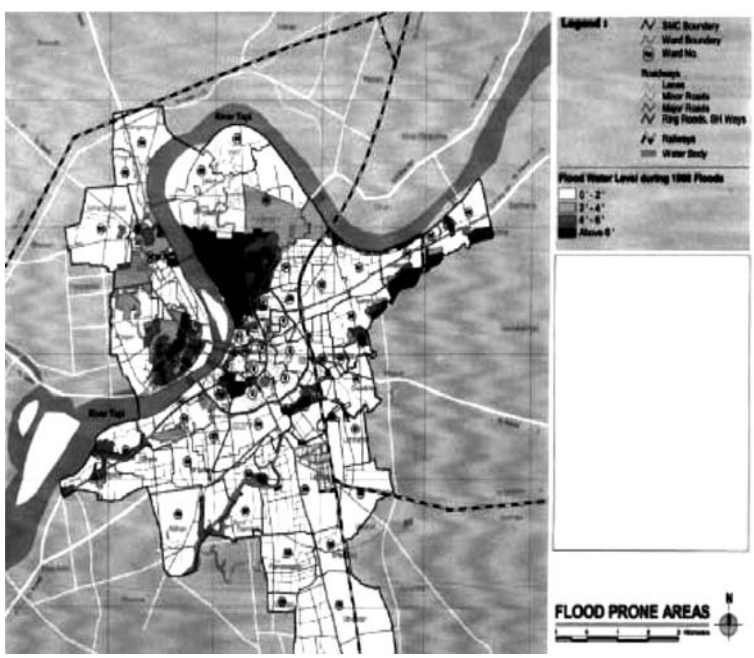
Riverfront project: aimed at constricting the width of the river

Singanpore weir project funded by Hazira industries: an offence under relevant regulations as it comes under the CRZ norms. The afflux caused by weir leads to capacity reduction of the embankments. This afflux generated has been so significant that the entire design of the embankment was being revised since 2004. Data related to such afflux is given below:

Afflux induced by Singanpore weir (1998 floods)

Flow in lakh cusecs	Afflux in mertres (CWPRS estimates)	Afflux in metres (actual in 1998 floods)
4	1.90	2.20
5	1.77	3.07
6	1.65	3.25
7	1.33	3.63
8	1.10	-
10	1.10	-





A Plate from the SUDA DP Report: 1980

Flood Prone Areas 1998, (*Source: Surat CDP)*
Map showing flood affected areas-2006, and the SUDA boundary

Source: DPVIC Pvt. Ltd. Surat

Flood is mapped only within the boundaries of the SMC – in 1998. The Surat 2006 floods have caused a loss of approximately Rs. 20,000 Crores (as predicted) besides the invaluable loss of lives.

Strategies for Future

Short Term Measures

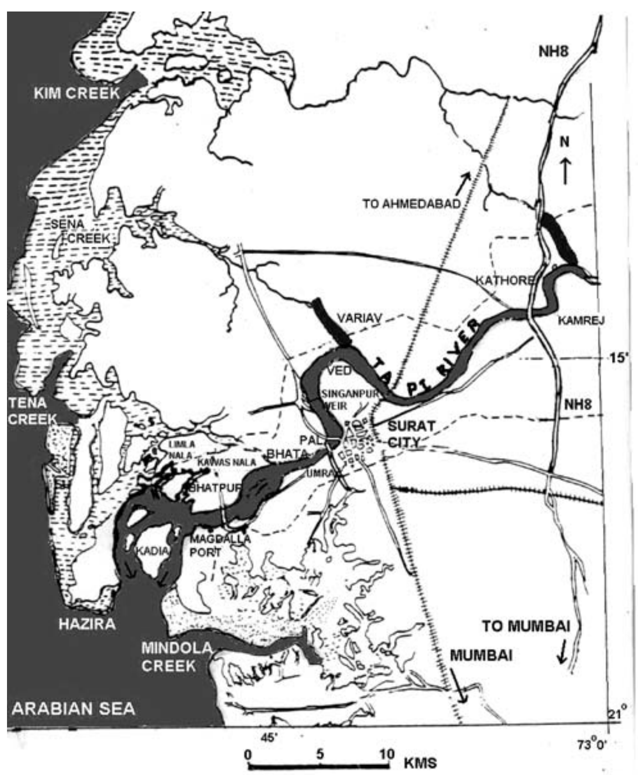
1. Every reservoir is operated as per the rule book prescribed. It is essential to follow the rule book without any deviation, to manage the water quantities of the reservoir. It is imperative that the Ukai Reservoir rule book is to be followed. Unnecessary storing the excess water towards the end of the monsoon season reduces the flood absorption capacity of the reservoir and poses a potential flood hazard. It is even recommended to reduce the maximum URL by 2 to 3 meter for

the September month, as compared to the present prescribed level.

2. A network of warning sirens is to be installed in the flood prone areas of the region. These should be able to warn the public at large, giving at least 5 hours time to act for protection. This should have linkage with releases from Ukai Reservoir.
3. Detailed contour map (levels) of the city should be properly marked on the distinct objects in the city with colour codes indicating different water levels during different intensities of floods (depending upon the flood releases from Ukai Reservoir).
4. River training works and flood control works should be completed on priority.

Long Term Measures

1. In order to reduce the releases from the Ukai Reservoir, diversion canals at the appropriate locations on its upstream should be provided. Two suggested



locations are indicated below.

(Reference : CWPRS, Pune)

2. It is necessary to develop a mathematical model for flood routing for the entire Tapi River Channel Network.
3. The encroachments along the banks of the river have to be removed.
4. The present rule book for Ukai Reservoir can be reviewed and can be transformed to comprehensive guidelines encompassing the alternatives and their scope of operation during emergency situations and at the same time providing the water optimally so as to support the socio-economic life of Surat City.
5. It is also recommended to provide partial flood embankments from Nehru bridge to Magdalla bridge on both the banks.
6. A state of the art ***Flood forecasting and Flood Management Centre*** specifically for the Surat City, is needed to be established. At the same time disaster management cell of SMC / local authority needs to be strengthened.
7. Physical model studies on flow control structures should be encouraged.
8. It is necessary to formulate long term legislative policies with regard to water allocation to different sectors and to empower the Catchment Management

Flood Disaster Mitigation and Management:
A Synthesis and Key Lessons

Anil Kumar Gupta

There is an increasing trend worldwide in the number of disasters and their total economic impacts. Flooding causes over one-third of the total estimated costs and is responsible for two thirds of people affected by natural disasters. Over 90% of people affected by natural disasters worldwide live in Asia, as the countries in Asia with large populations are particularly prone to recurrent flooding. Many disaster planners, responders and also civil engineers categorically argue that 'urban flooding' is much different from 'rural flooding' and are correct to great extent - while examining their interest and roles. However, scientific and mitigation implications draw some classic but re-enforcing components of flood disaster management - that are almost same in understanding of floods as disaster - be it in the city, villages, croplands, industrial estates or other countryside areas. 'Floods' are natural disasters, undoubtedly, and as ecological factors and part of environmental dynamics, can and usually turns into 'humanitarian disaster'.

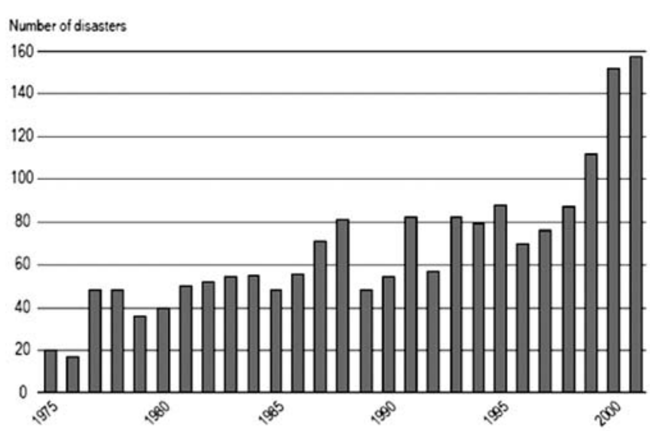


Figure 1. Number of disasters attributed to floods *(Source: EMDAT, CRED).*

* The paper is a summary synthesis from the final technical reports of Urban Flood Case Studies Project of National Institute of Disaster Management (A. K. Gupta & P. G. Dhar Chakrabarti, Disaster & Development, 3(1): 1-14, 2009).

Floods – in Making of a Humanitarian Disaster

'Flood' is excess above threshold of carrying capacity, and is the same in case of 'water' - too much, prolonged, inundating, and causing damage to property, environment and people, referring flood disaster in humanitarian response and relief context. Environmental-changes as drivers of hydro-meteorological disasters and impacts that create 'humanitarian disaster' has been summarised in the figure 2. Environmental hazards that drive the changes in climate, geo-morphological, hydrological and biological setting of the regions create vulnerability of the ecosystems thereby reducing its capacity to cope with major shifts in energy or matter (water) profiles. A structural disaster can be triggered by a natural disaster and, if mitigation fails, can develop into a humanitarian disaster. There has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. The most notable amongst them are Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat and Bhopal in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009.

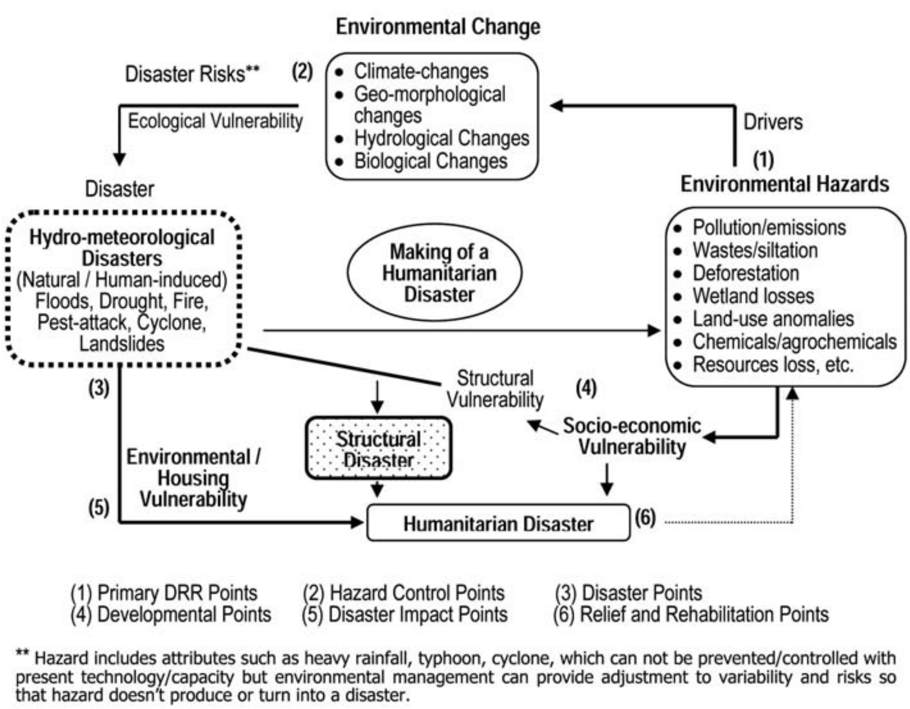


Figure 2. Making of a humanitarian disaster *(Gupta, 2010)*.

Cities may be situated on the coasts, river banks, near downstream/ upstream of dams, inland or in hilly areas. There are several cities which may fall under more than one of these categories. Mumbai city, having an area of 437 km2 with a population of 12 million, came to a complete halt owing to the unprecedented rainfall of 994 mm during the 24 hours starting 08:30 on 26 July 2005. At least 419 people (and 16 000 cattle) were killed as a result of the ensuing flash floods and landslides in Mumbai municipal area, and another 216 as a result of flood-related illnesses. Over 100 000 residential and commercial establishments and 30 000 vehicles were damaged (Gupta, 2007).

Table 1. Common factors of causing floods

	Factors leading to causes of flood	
Causes	**Natural factors**	**Man-made factors**
Silting of the river bed	Due to bank erosion Earthquake loosening the soil	Due to dams, embankments and bunds
Inadequate capacity within the banks	High runoff or rise in the water level Silting of river bed due to bank erosion	High discharge from the river due to silting Decrease in bank height – deforestation
River bank erosion	High discharge of water due to rain Shifting river courses	Decrease in vegetative cover due to deforestation
Flow obstruction and change in river course	Landslides Falling of the trees	Construction activities in the river bed
Common floods in the main and tributary rivers	Flash flood due to high discharge in the main river	Breaking of bunds constructed on the tributary rivers for irrigation purposes
Poor natural drainage	Obstruction of the natural drainage Absorbing capacity of the soil	High rate of urbanization – pressure on the drainage system
Cyclones	High precipitation Absorbing capacity of the soil	
Retardation of flow and back water effect	High runoff Topography and obstruction of the natural drainage	Inadequate drainage capacity and; Urbanization in the low lying areas
Heavy rainfall	Same as above	Decreasing vegetative cover High urbanization leads to high runoff

Harvey (2007) identified three principal types of flood:

- *Rapid-onset floods* - these include flash floods, tidal surges, floods provoked by cyclones or accompanied by strong winds, high runoff from heavy rainfall, dam bursts and overtopping, canals and rivers bursting their banks; typically water rises to dangerous levels within 48 hours. Urban growth has often happened on floodplain areas, with some areas below the flood level. Flood embankments often protect such areas, but there is a high risk that these are breached, causing devastating urban flooding.
- *Slow-onset floods* - prolonged rainfall causing low-lying areas to gradually become flooded over a period of days or weeks. Urban slum areas may be particularly vulnerable to this type of flooding because there are few drains and the ground is highly compacted, causing pathways and alleys to become streams after heavy downpours, and existing drainage channels or culverts may be blocked by refuse.
- *Annual seasonal flooding* - many communities around the world are flooded annually and may be under water for some considerable time each year. Wet season flooding may affect some areas in lowland and coastal cities for two of more months per year because rain and river water combine to raise levels in former swamp areas. Reclamation of land in such areas tends to exasperate rises in levels. Such areas are also at high risk of storm surges.

Urbanization is rapidly increasing throughout the world. There is large scale migration to cities and town. In India, during 1901 there were 1827 urban agglomerations with a population of 25.85 million which was 10.84% of the then total population, whereas as per 2001 census there are 3768 urban agglomerations/towns covering a population of 285.4 million which works out to about 27.8% of the country's population. As per the same census the cities (population of one million and above) account for 37.8% of the total urban population of the country. A total of 42.6 million people living in 8.2 million households have been enumerated in slums of 640 cities/towns spread across 26 states and union territories in 2001 Census. The slum population constitutes 4 per cent of the total population of the country. Interestingly, share of slums in urban population grown higher in major metro-cities as compared to smaller ones.

Drainage and Water Relief

The development of flood control and drainage in India started on a big scale only after the disastrous floods of 1954. Since then a total length of 26 119 km of drainage channels have been constructed in various States upto March 1985. The National Commission on Floods assessed that a total area of about 40 million ha is liable to floods and drainage congestion (Central Water Commission, now 45 million ha). Out of this, it was estimated that only about 80% or 32 million ha could be afforded reasonable protection. However, it is a major gap that the urban areas under flooding (due to cause other than riverine) and areas affected by mountain/flash floods, coastal floods and dam breach/failure or release are not accounted and is additional to this 45 million ha.

The water storage effect of vegetation, soil, shallow groundwater, wetlands and drainage has a direct impact on the flood level in downstream areas. Each of these storage media retain certain quantities of water for various periods of time and can influence the timing of tributary flows and hence their contribution to a flood event. The storage effect can be likened to a sponge and is dependent on the antecedent conditions and the magnitude of the flood.

The impacts of land-use changes on flood events can be both positive and negative, so predictions are hard to make for a specific watershed. Generally the removal of forest and other natural cover, and the conversion of land to agricultural uses, compacts the soil and reduces infiltration rates, leading to higher flood peaks. Deforestation is believed to have been a significant cause of the catastrophic flooding. Wetlands are a critical element of national and global ecosystems and economies. At the most fundamental level, wetlands are the key part of water-cycle, playing critical roles in maintaining the general health of water-bodies, estuaries, and coastal waters. Wetlands protect the shoreline from wave action, mitigate the impact of floods, absorb pollutants and act as habitats for flora and fauna, including a number of species that are threatened or endangered. Wetlands are important for the maintenance and improvement of the quality of human life. The driving force behind the biodrainage concept is the consumptive water use of plants.

Natural water storage is also generally reduced due to the gradual loss of organic material and soil erosion, once an area is converted to agriculture. Additionally, natural vegetation may transpire moisture to the atmosphere at a greater rate than replacement crops, thereby affecting both the amount of storage available in the soil and the amount of local rainfall. Drainage of wetlands and marshes contributes directly to changes in the timing of runoff, the amount of natural storage in the basin, and the vulnerability of the channel to the erosive forces of water. Even road construction can contribute directly to increased runoff rates through improved drainage as well as the effect of reduced infiltration through the road surface.

It is estimated that in Chennai City more than half of the wetlands have been converted to other uses. Chennai City had about 150 small and big water-bodies in and around the city but today the number has been reduced to 27. There are 31 tanks located at the West, South and Northern catchment area of the swamp release the surplus water during rainy seasons to the swamp. The sustainability of this marshland is linked with vitality and sustenance of these tanks. Moreover the shrinking of wetland will have a natural death of the tanks and vice versa because they belong to a single system of water bodies. The single flow channels that would naturally help in percolation of groundwater and stands as an excellent rain water harvesting model. Evidence reveals that not only the marshland has shrunk, but also the tanks. For instance, the Adambakkam tank, one of the water sources of the swamp has reduced from its original size of 70 hectares to 20 hectares due to encroachments.

Hyderabad Urban Development authority undertook restoration of 87 lakes out of 169 large water bodies as an additional measure by formation of peripheral bund along the shore line of the lake, desilting the lakebed by dredging, strengthening and widening of main bund ,restoration of surplus weirs and sluices, construction of STP for treating the raw sewage and letting the treated water into the lake to maintain the lake water to the desired level, restoration of inflow and outflow channels, diversion of excess sewage by laying pipelines and beautification of lake bunds and periphery with landscaping and plantation.

In Hyderabad, the maximum rainfall intensity during 8?10August was 40mm per hour (Source: NY Apte, India Meteorology Department), the details of flood disaster and damages are given below.

	28-9-2-1908	**23-24 August 2000**	**8 – 10 August 2008**
Rainfall	430 mm	240.5 mm	237 mm
Property Loss/ Worth	80000 houses	35693 houses INR 1350 million	INR 495.2 million
Loss of Life	15000	26	-
Population Affected	600000	200000	150000

Certain critical observations of the disaster and post-disaster situation of the Mumbai floods 2005 have been identified for consideration in future planning and strategies for flood risk management:

- "Off-shore-Vortex" resulted in extremely localized heavy downpour in Mumbai on 26 July 2005.
- Following floods, High Court ordered for installing high-tech Doppler Radar at suitable locations in Mumbai.

- Over confidence of government on Disaster Management Plans and reluctance to synergize crosscutting sectors and stakeholders.
- Inculcation of civic sense to be induced with initial hand holding and further guidance.
- Construction on the flood plains of natural drainage channels, on top of the storm lines made things worst. In many locations, routine cleaning operations are reported to have not been fully undertaken for years.
- Continuous land relaimation in Mumbai for over 300 years (seven islands merged into single landmass) need to be checked/evaluated by experts.
- Easy to understand Costal Regulation Zoning (CRZ) legislation along with its benefits needs wider publicity among the passes.
- Reclaimation of Bandra-Kurla complex is good example of 'bad planninng'. Due to continuous neglect, Mithi river is now a open drain, carrying raw sewage, hazardous industrial waste and garbage.
- Choking of Mithi river, which is providing natural drainage to the city; substantial garbage/solid deposits in drains have major impact on drainage capacity. After the flood 2005, for three weeks, average load of waste lifted was double the normal daily load.

Table 2. Lessons learned from analysis of Mumbai flood 2005 (MCGM)*

Major issue	Causes	Role of local community	Possible solution provider(s)
Unprecedented Rain	Natural forces, global environmental changes	Nil or extremely limited in a broader sense	National/global consensus to mitigate climate change impacts
Failure of weather forecasting	Ill equipped Meteorological Department	Nil	Meteorological Department, other communication agencies
Unplanned development	Political ill-will, planners lack of vision, tremendous population growth and unchecked migration, loose implementation of existing laws, resource constraints with government agencies etc.	Very limited	Collective action from government, private sector, civil society, and community
Reclamation of low lying areas	Government agencies (without scientific approach or due to political pressure), illegal dumping/reclamation by builders and developers, unruly dumping by communities in few places	Very limited	Collective action from government and private sector, stringent implementation with regard to scientific and ecological implications.
Shrinking drainage (inadequate dilapidated drainage system)	Community, government, builders, illegal activities	Somewhat limited	Local government, planning bodies, and communities

Negligence in cleaning sewers and drainages	MCGM	Somewhat limited	MCGM (private sector may be involved if needed)
Encroaching the areas of hills and mangroves (decrease in mangroves, wetlands, forest cover)	Planning agencies; builders' lobby; in rare cases slums and squatters also	Somewhat limited	Stringent policy/legislation for protecting such eco-sensitive areas by government along with very strict implementation
Disregard for city streets, lanes and sewers	Mainly lack of civic sense among communities, also illegal activities (dumping, digging etc) by industries, dairies, restaurants, hospitals and other establishments etc.	Very strong	Communities, Civil society organizations, private sector, academic/research institutions, etc.
Violation of Coastal Regulation Zone (CRZ) rules	Politicians influencing planning and development agencies for selfish gains, sometimes communities also violate	Somewhat limited	Politicians, builders, civil society, private sector etc. with community as important partner
Choking up of rivers and drains	Communities; illegal activities of various players from formal and informal sector; illicit business activities, even politically influenced decisions of government agencies	Strong (with equally responsible other stakeholders)	Communities, civil society, private sector etc., Strict legal interventions (i.e. ban on use of plastic thinner than 50 microns)
Lack of disaster preparedness	Mainly government (specially failure to recognize communities' role)	Very strong (collectively with other stakeholders)	Disaster management require multi-stakeholder partnership
Shrinking of Mithi river (reduced to one third of its original size)	Government planning agencies, illegal activities, informal community	Somewhat limited	Time-bound intervention (both technical and non-technical) from all responsible actors government, civic society, community etc.

**MCGM - Municipal Corporation of Greater Mumbai.*

Integrated Flood Management

"Mitigation (for flood disaster risk) is expected to encompass broad framework of pre-disaster human-interventions against risk so as to minimize the disaster or its impacts. On other hand, mitigation is sum of actions to ensure overall sustainable development taking into account disaster management as a core component" and 'flood resistance' as the key objective. Resistance (to floods) has 3 main aspects:

a) Flood avoidance (prevention of occurrence and control including diversion/levee and relief, flood safe location/zoning)
b) Flood tolerance (resistant housing/infrastructure - design and materials, lifestyles)
c) Flood resilience (preparedness in place - awareness/training, warning, response and relief resources - shelters, stocks, etc.)

Definition of Mitigation as per Disaster Management Act (2005) is to quote "mitigation' means measures aimed at reducing risk, impact or effects of a disaster or threatening disaster situation" (Chapter 1, section 2.(i)). Thus, 'mitigation' is a broad framework and the plan can be developed for implementation during 'short-term', 'medium-term' and long-term' basis based on priority issues and critical concerns (figure 3).

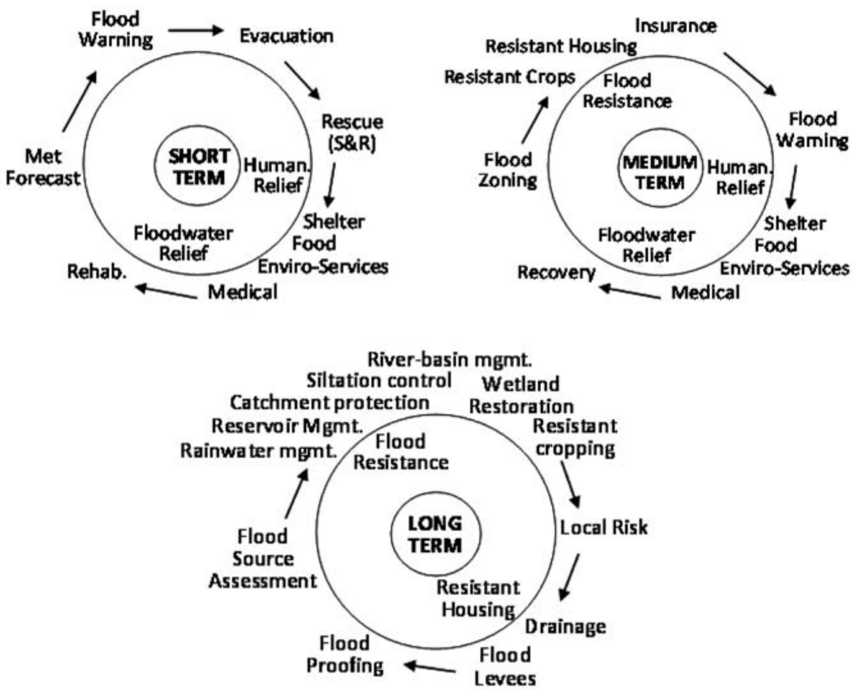


Figure 3. Flood disaster management framework

Hydro-meteorological data and accurate forecasts are of no value if the forecasts do not reach users and if decisions are not made as to the appropriate actions required. Hydrological forecasts and hydraulic conditions must be disseminated so that decisions can be made and actions taken to reduce the impact of the pending event. Decision support refers to everything from forecasts reaching decision makers such as a mayor of a flood-prone community to the operator of a flood-control structure. For decision support to be effective, advanced planning must define prescribed actions linked to forecasted values. One of the greatest advances in radar technology as far as weather forecasters are concerned is the use of Doppler techniques which are available for operation in various frequency bands. The data sets from Doppler weather radar are available in fine temporal and spatial resolution which is critical for predicting severe weather events in near real time particularly estimation rainfall rate and its accumulation. Heavy rainfall in the range of 150 km may be estimated with a very high accuracy with calibration radar with ground truths. Most important factor is that Doppler weather radar has the capability of quick updating of rainfall data on real time and disseminate same to a centre location which may not possible with any other observing systems.

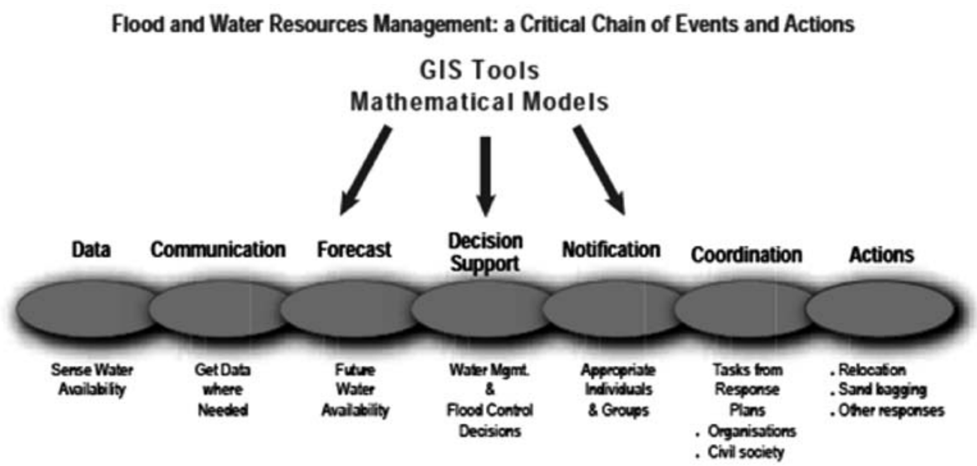


Figure 4. Integrated flood forecasting, warning and response system

Dr. Madhavrao Chitale committee (Fact Finding Mission, 2005-06. Govt. of Maharashtra) to investigated the Mumbai flood incident, in its volume 1, wrote a note on significance of ecosystem services in Mumbai floods context:

"(1) Ecosystem in and around Mumbai is under stress and is continuously deteriorating. It is necessary that a systematic aquatic ecosystem rejuvenation program to deal with the issue of "accumulated contaminated sediments" in the ecosystem is undertaken and the accumulated pollutants are systematically dredged out so that a newer healthy ecosystem gets progressively instituted. There is a great urgency of incorporating the activities of designing and commissioning the different components of the ecosystem infrastructure with a systematic river front development programs for the major rivers and the estuaries. (2) The scrutiny and investigation, which followed the floods in Mumbai, revealed that environmental governance of Mumbai has been far from satisfactory. While the developmental and planning agencies renamed rivers and streams as nallahs and in some cases even removed them from the developmental programme's maps; environmental regulatory authorities did not take exception to derogatory treatment given to environmental and ecological systems and sub-systems by citizens, civic administrators, and elected representatives. Standards of disposal of effluents into rivers were prescribed suitable for nallahs rather than reinstating the river status to the streams. For example, India's Water (Prevention and Control of Pollution) Act of 1974 and Environment Protection Act of 1986 aim at maintaining wholesomeness of rivers. The State Pollution Control Board Shall facilitate implementation of India's environmental policy in a proactive manner and ensure compliance of environmental regulations by the municipal corporation".

Environmental Services During Flood Disasters

Specific lessons can be identified for both planning prior to a potential emergency, and response to an emergency. These are two distinct stages of a flood management programme, yet they are closely linked, as planning directly affects the effectiveness of responses. Different agencies are likely to be involved at different stages of an emergency, and it is important that they communicate and collaborate with each other, sharing information regularly. Agencies responding to an emergency need to plan their exit strategy carefully, and exchange of information is of particular importance when there is a transfer of responsibility from one agency to another, such as when relief agencies arrive or depart. Urban floods systematically affect the poorest (immigrants, new settlers, and people living in un-planned and areas vulnerable to flooding).

Vectors such as flies, mosquitoes and rats are insects or animals that can transmit disease-causing bacteria or other organisms from one host to another. Following a flood, conditions may be favourable to the survival and reproduction of vectors, and pathogenic organisms may also be widespread in the environment. Transmission of diseases by vectors is therefore likely to be a serious health risk within affected communities. Sites designated for disposal of wastes should be in uninhabited areas, away from centres of population, and with good access for vehicles. Safe water supplies, good sanitation, and effective hygiene promotion can all contribute to vector control, but additional responses may also be needed, in the form of medical diagnosis and treatment following infection, chemical or biological control of vectors, safe excreta disposal and personal protection.

Table 3. Priority responses for those affected by flooding

Those who stay in their homes	Those who relocate to official shelters	Those who relocate to unofficial shelters	Those who stay with host families
Arrange distribution of safe water during the flood phase (from regular distribution system, rainwater collection or compact water treatment unit ❶). Provide safe excreta disposal. Arrange distribution of appropriate NFIs. Provide water quality testing services, or advice and information on water quality. Communicate appropriate hygiene messages to those remaining in their homes based on ongoing dialogue to understand barriers to change and feasible actions. Rehabilitate WASH infrastructure as soon as possible (desludging wells, boreholes and latrines, repairing electromechanical equipment, etc.)	Arrange distribution of adequate quantities of safe water. Provide or procure additional latrines with handwashing facilities and ensure care and maintenance. Encourage local people to assist with clearing debris, possibly under cash for work programmes, as part of hygiene promotion response. Arrange distribution of essential and appropriate NFIs Ensure ongoing dialogue with the population to promote optimal use of facilities, handwashing and management of diarrhoea. Rehabilitate infrastructure, including electromechanical plant, as soon as possible.	Provide emergency/ temporary water supplies, and emergency/temporary sanitation (chemical toilets, for example.) but without permanent infrastructure. Provide containers for water storage. Provide advocacy assistance to obtain permissions for people to remain in unofficial locations. Arrange distribution of essential and appropriate NFIs Ensure ongoing dialogue with the population to promote optimal use of facilities, handwashing and management of diarrhoea.	Arrange distribution of adequate quantities of safe water, with increased supplies to meet additional demands. Identify host families, and provide assistance to both hosts and guests, to encourage people to continue staying. Arrange distribution of essential and appropriate NFIs Ensure those affected are aware of how to reduce hygiene risks. Provide additional, tools, materials and support to host families for water supply and sanitation (e.g. containers for storage of water). Provide tools and facilities for collection of flood debris and household wastes. Rehabilitate WASH infrastructure as soon as possible (desludging wells, boreholes and latrines, repairing electromechanical equipment, etc.)

WASH - Water, sanitation and hygiene; NFI - Non food items.

Note: If household water treatment is promoted this requires preparedness, promotion and distribution of equipment prior to the emergency.

Disaster Risk Reduction activities should attempt to identify those who are most vulnerable, and pay particular attention to them. Most publications concentrate on short-term responses, rather than addressing longer-term needs; and on providing support to those who relocate to official shelters following floods. Very little has therefore been written about resettlement after urban floods, on providing support to host families that provide shelter for friends or relatives following urban floods, or on appropriate responses to support those who remain in their homes during floods.

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