Urban Floods: Case Study of Chennai

T. Sundarmoorthy, Lalitha Ramadurai and N.G. Anuthaman

Profile of the City

Tamil Nadu constitutes the south-eastern extremity of the Indian peninsula. Chennai is the capital city of the State, besides being an important district. The district city is one of the metropolitan cities of India, which serves as the gateway of the culture of South India. It has emerged as a cosmopolitan city playing an important role in the historical, cultural and intellectual development of India, representing the distinct components of the Dravidian civilisation.

History

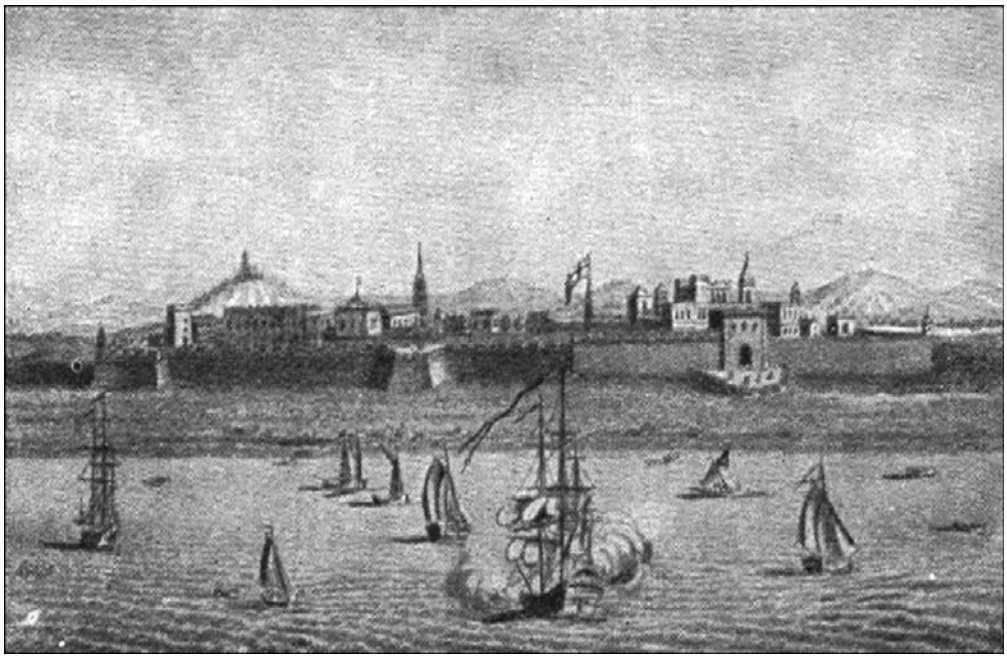
The city of Chennai came into being due to a strategic necessity and historical accident. It symbolises the rise of British power in South India by setting up and consolidation of the East India Company in the 17th century with its headquarters at Fort

St.George in Chennai as a trading centre. Within 350 years, a few scattered villages (important ones being Mylapore, Triplicane and Chennai Patnam) have developed into a modern metropolitan city without shedding its traditional customs, religious outlook and other traditions.

Chennai, originally known as Madras Patnam, was a cluster of villages, perched amidst paddy fields, bordered by palm trees. The Pallavas, the Cholas, the Pandyas and the Vijaynagar Empire - all the popular dynasties of South India - have had an influence over the city.

The origin of the metropolitan city started in 1639, when Francis Day and Andrew Cogan, two merchants of the East India Company, started a factory-cum-trading post here. A settlement was built to serve as the control centre and it was completed on 23rd April 1640 and was named as St. George's fort. The native town, officially called George Town, was established outside the ramparts of the fort. In the later part of the 17th century, Chennai steadily progressed under many Governors during the regime of Governor Elihi Yale (1687-92); the most important event was the formation of the

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



Fort St.George

institution of a mayor and Corporation for the city of Chennai.

In 1746, Chennai, along with Fort St George, came under the sway of the French, who ransacked the town and the nearby villages. The British again got command over Chennai in 1749, attributable to the Treaty of *Aix-la-Chappell*. Under the British rule, Chennai went under drastic changes, to become a prominent city with strong naval base.

With the introduction of railways in the late 19th century, Chennai got linked with other important cities like Mumbai and Kolkata. Facilities of trade and communication in the city boosted, connecting it with the hinterland too. Chennai was the only city of India that was attacked during the World War.

When India became independent in 1947, Chennai city was declared as the capital of Madras State, which was later renamed as the state of Tamilnadu in 1968. In 1997, the Government of Tamil Nadu officially changed the name of Madras to Chennai.

Central Railway Station - 1925

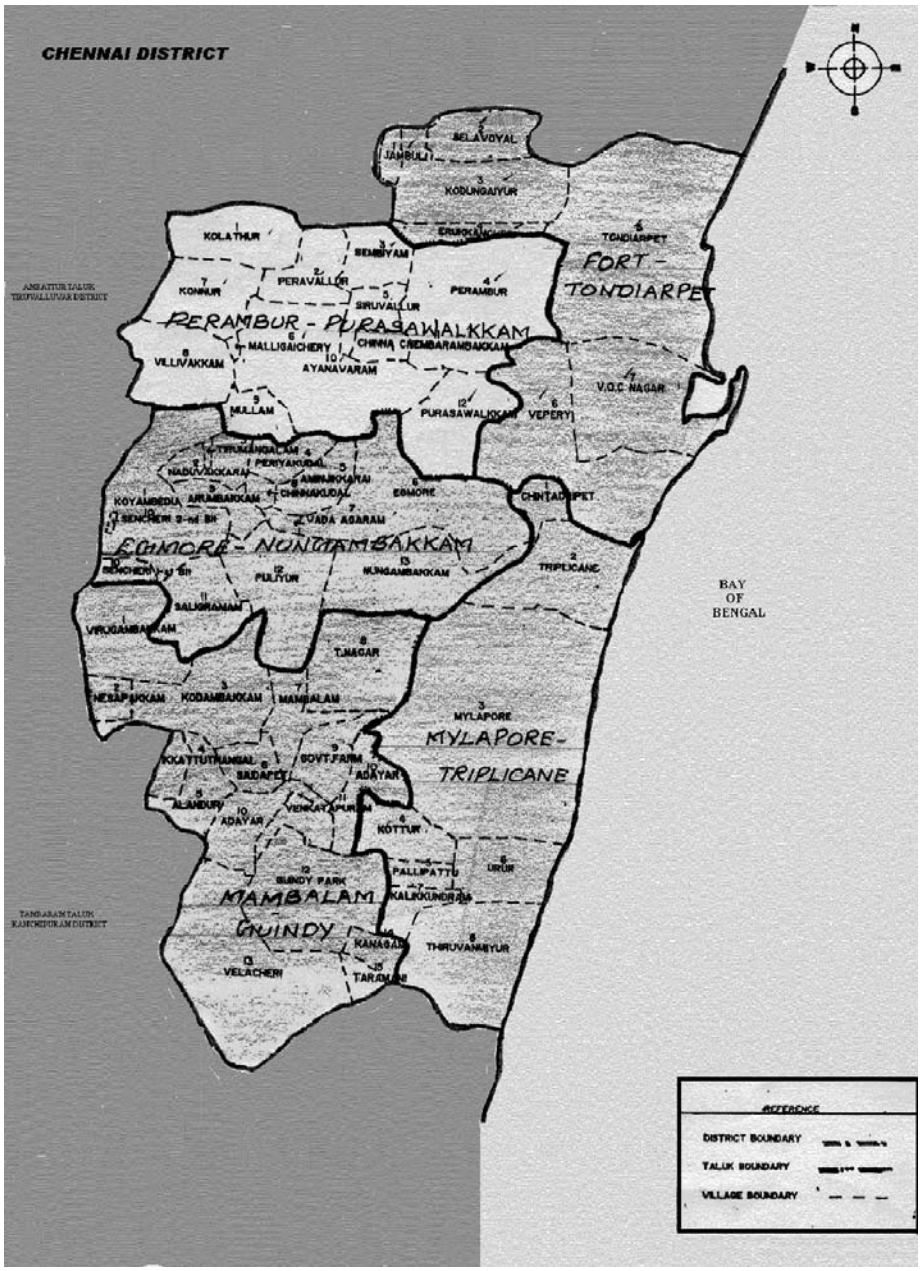
Topography

Chennai is situated on the north-east end of Tamil Nadu on the coast of Bay of Bengal. It lies between 12o50'49" and 13o17'24" of the northern latitude and 79o59'53" and 80o20'12" of the southern longitude.

The topography of Chennai city is extremely flat, with very few isolated hillocks in the south-west near St.Thomas Mount, Pallavaram and Tambaram. The average elevation of about 6.7 meters (20 feet). The land stretches nearly 25.60 kms along the Bay coast from Tiruvanmiyur in the south to Thiruvottiyur in the north and runs inland in a rugged semi-circular fashion. The city is bounded on the east by the Bay of Bengal and on the remaining three sides by Kanchipuram and Thiruvallur districts.

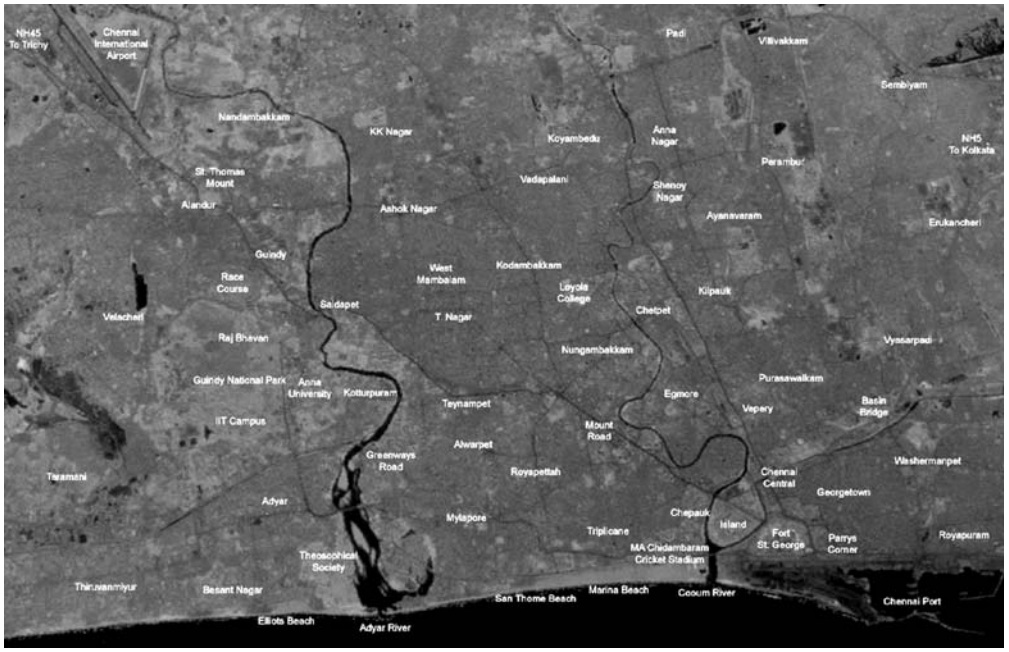
Vegetation

Some centuries back the only vegetation in Chennai was *Albizia amara* and *Acacia* species. But due to the introduction of innumerable foreign species, today we have varied vegetation and thick forests abound in places like Guindy, Tambaram, Vandalur, etc.



Chennai District Map

(Source: http://www.chennai.tn.nic.in/chnmap.htm)



Satellite image of Chennai

Some common trees of Chennai are - *Albizia lebbeck*, *Lannea coromandelica*, *Syzygium cumini* and ornamental / avenue trees like *Bauhinia purpurea*, *Cassia fistula, Delonix regia* and *Peltophorum pterocarpum*. The estuary of the Adyar river, parts of the Buckingham canal and the back waters of Ennore have a small portion of tidal mangrove vegetation where *Avicennia officinalis* is the only mangrove tree species growing. Most of the trees found in Madras (Chennai) today are alien species introduced by the British.

Climate

Climate lies on the thermal equator and is also coastal, which prevents extreme variation in seasonal temperature. For most of the year, the weather is hot and humid. The hottest part of the year is late May and early June, known locally as *Kathiri Veyyil*, with maximum temperatures around 38 - 42 °C (100 - 107 °F). The coolest part of the year is January- February, with minimum temperatures around 19 - 20 °C (66 - 68 °F). The most prevailing winds in Chennai are the south-westerly between May and September and the North-easterly during the rest of the year.

Monthly Averages - Temperature of Chennai

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Average High (°C)	28	31	33	36	38	37	35	34	34	32	29	28	32.9
Average Low (°C)	20	21	23	26	27	27	26	26	25	24	22	21	24

(*Source: Weather.com - The Weather Channel Interactive*)

Rainfall

The city gets most of its seasonal rainfall from the north-east monsoon winds, from mid-September to mid-December.The average annual rainfall is about 1,300 mm (51 inches). The mean rainy days are about 52 days.

Monthly Average Rainfall (in mm) at Redhills, Cholavaram & Poondi (Average)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2003	0	0	5	5	6	26	141	139	103	231	98	56	**810**
2004	30	0	0	7	229	50	51	37	191	275	297	5	**1171**
2005	0	0	9	101	32	52	84	119	207	590	514	501	**2208**
2006	0	0	28	31	22	139	55	113	172	420	224	36	**1240**
2007	0	6	0	12	19	68	245	271	175	265	118	270	**1449**
2008	85	6	189	0	28	128	89	2	-	-	-	-	**527**

(Source: http://www.chennaimetrowater.tn.nic.in/AVGRAIN.HTM)

24 Hours Maximum Rainfall Recorded in Chennai

The table below gives the extreme case of daily maximum rainfall recorded in Chennai basin. This shows the monsoon in some years where one day's rainfall is equal to one season's rainfall.

Date	Rainfall (mm)
21-10-1846	520
24-10-1857	460
26-05-1952	450
25-11-1976	452
13-11-1985	347
14-06-1996	348
27-10-2005	400
02-12-2005	320

Demography & Settlement Patterns

Over the last 350 years, Chennai has evolved from a group of fishing hamlets and villages into the administrative and commercial centre of the Madras Presidency during the colonial period, and the capital of the State of Tamil Nadu after independence.

Chennai is today the fourth largest metropolis in India, with a geographical spread of 170.98 sq. km. or 17,098 hectares. The Chennai Metropolitan Area (CMA) comprising of the city of Chennai and contiguous areas around was notified in 1974. It extends over 1189 sq.km. and includes Chennai City Corporation area (Chennai District), 16 Municipalities, 20 Town Panchayats and 214 villages forming part of 10 Panchayat Unions (in Thiruvallur and Kancheepuram districts).

The growth of the city is well reflected in the growth of the urban population as well.The population of Madras in 1871 was 3,67,552; in 1881 - 4,05,848; 1891 - 4,52, 518 and in 1901 - 5, 09,346. The table below gives the growth of city's population since 1901.

Growth of Population in Chennai City (1901-2001)

	1901	**1911**	**1921**	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**	2001
Population (Lakhs)	5.41	5.56	5.78	7.13	8.65	14.27	17.49	24.69	32.85	38.43	43.44
Area (sq.km.)	68.17	68.17	68.17	68.17	77.21	128.83	128.83	176	176	176	
Rate of growth of population* (in percent)	--	0.27	0.39	2.12	0.69	0.11	2.06	3.51	0.27	1.58	1.23
Population density per hectare	80	82	85	105	112	111	136	192	187	218	247

*Note: Arrived for a unit area for the purpose of comparison since the city extent varied over time. (The figures given area for the decade ended with that year.

(*Source: Census of India*)

Growth of Population in CMA (1971 -2001)

	Population (in lakhs)				Annual Rate of Growth (%)			Area (sq. km.)	Density per Hectare in 2001
	1971	**1981**	**1991**	**2001**	**71-81**	**81-91**	**91-01**		
Chennai City	26.42	32.85	38.43	43.44	2.20	1.58	1.23	176	247
Municipalities	4.84	8.14	11.84	15.81	5.24	3.80	2.91	240	66
Town Panc hayats	1.11	1.64	2.71	3.86	4.43	4.94	3.62	156	25
Panchayat Unions	2.67	3.38	5.20	7.31	2.40	4.38	3.58	617	12
CMA Total	35.04	46.01	58.18	70.41	2.76	2.37	1.93	1189	59

(*Source: Census of India*)

The population of Chennai, which had stabilized at around half a million at the turn of the century recorded maximum growth rates of more than 2% during the decades 1951-61 and 1961-71. The reasons for this rapid growth rate can be attributed to industrial developments and increase in economic activities and employment opportunities in the city and its suburbs attracting large migrant population.

The negative growth during 1971-81 is normally attributed to the annexation of lesser dense (then) Panchayat areas in 1978 viz. Velacheri, Taramani, Kanagam, Thiruvanmiyur, Kodambakkam, Saligramam, Koyambedu, Senjery, Thirumangalam, Virugambakkam, Nesapakkam, Kolathur, Villivakkam, Konnur, Erukkanchery, Jambuli, Kodungaiyur, Selaivoyal, comprising about 47 sq. km.

The city corporation area consists of 155 divisions with within 10 zones (Zone No. I to X) presently. The number of these divisions and its extent varied over time. Hence, for the purpose of comparison, the demographic details have been arrived for the years 1971, 1981 and 1991 keeping the 155 Corporation division boundaries in 2001 as the basis.

Chennai City - Population Growth in Corporation Zones, 1971 - 2001

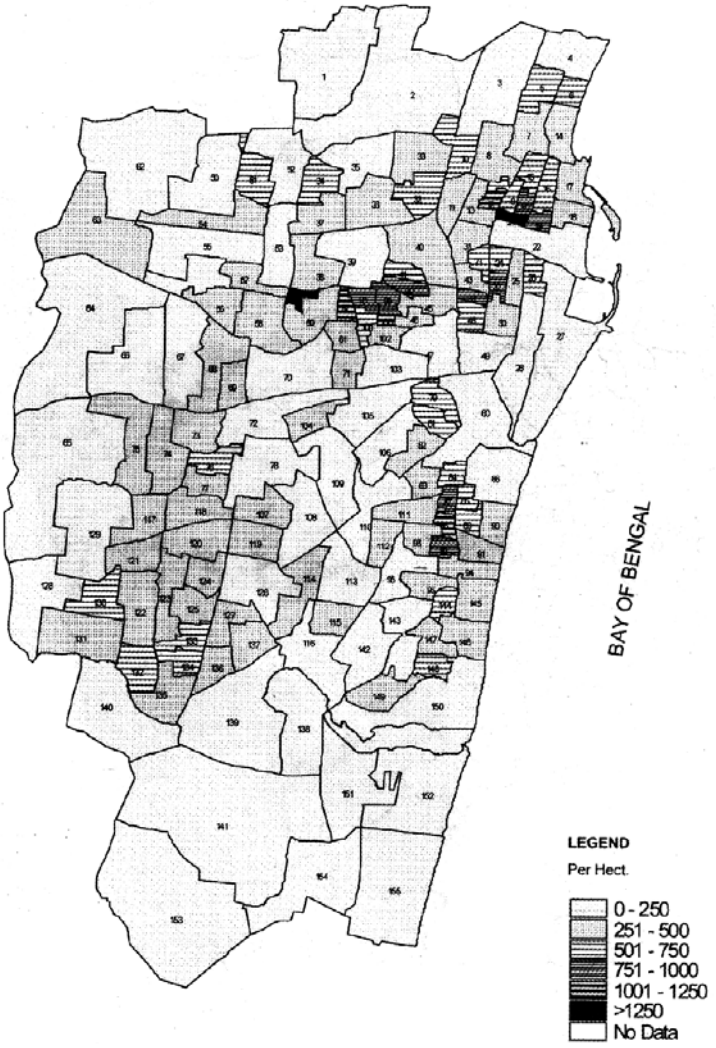
Zone Nos.	Corporation Zone	Area (sq. km.)	Population (in Lakhs)				Annual Rate of Growth (%)		Density per Hectare in 2001	
			1971	1981	1991	2001	71-81	81-91	91-01	
I	Tondiarpet	17.30	2.01	2.69	3.72	4.10	2.95	3.28	1.00	243
II	Basin Bridge	11.52	3.59	3.52	3.27	3.76	-0.21	-0.74	1.40	335
III	Pulianthope	13.51	3.34	4.13	4.31	4.60	2.13	0.44	0.64	349
IV	Ayanavaram	19.76	2.22	3.58	4.12	4.97	4.89	1.42	1.89	258
V	Kilpauk	26.38	2.18	3.45	4.94	5.42	4.68	3.66	0.93	211
VI	Ice-House	10.15	3.27	3.49	3.20	3.42	0.63	-0.84	0.65	346
VII	Nungambakkam	12.90	2.91	3.09	3.20	3.48	0.61	0.35	0.83	277
VIII	Kodambakkam	13.00	2.48	3.33	4.39	4.66	2.96	2.81	0.61	368
IX	Saidapaet	23.56	1.89	2.61	3.33	4.15	3.25	2.48	2.23	180
X	Mylapore	27.92	2.50	2.97	3.95	4.88	1.70	2.89	2.13	180
	City Total	176.00	26.42	32.85	38.43	43.44	2.20	1.58	1.23	247

(*Source: Census of India*)

Population growth in different zones within city Corporation area is found to be not uniform and its rate varied from 0.61% to 2.23%. The locus of new residential development is the south and the west, in an ever-growing semi-circle with the centre gradually moving southward. Saidapet and Mylapore zones have recorded growth rate exceeding 2% during 1991 - 2001.

Chennai's population today has grown to more than four millions, the most rapid growth having taken place in the peripheral zones of the city and in the suburbs. The draft second Master Plan of the Chennai Metropolitan Development Authority (CMDA) estimates that the city's population will increase to about 6 million by 2011. *(Source: http://www.hindu.com/2007/04/12/stories/2007041213350400.htm).*

The city is one of the high density cities in India. Its density varies from 180 persons per hectare in Saidapet and Mylapore Corporation Zones and 368 persons per hectare in Kodmbakkam zones within the Corporation limits. The gross density for Chennai city is 247 persons per hectare.



Chennai City - Gross Density of Population 2001

(***Source : CMDA***)

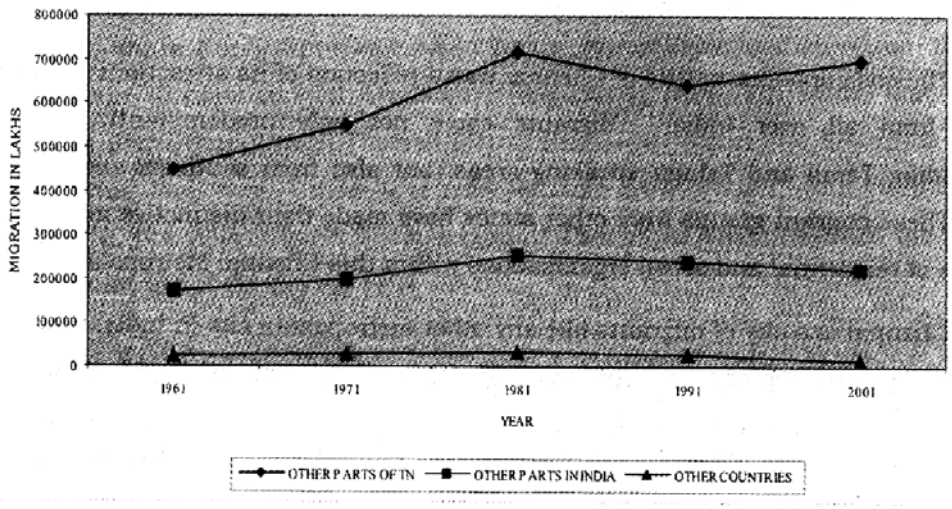
The majority of the population in Chennai are Tamilians and Tamil is the primary language. The average literacy rate is 80.14%, much higher than the national average of 64.5%.The sex ratio is 951 females for every 1,000 males, again better than the national average.

Chennai also has a large migrant population, who come from other parts of Tamil Nadu and the rest of the country. As of 2001, out of the 937,000 migrants (21.57% of its population) in the city, 74.5% were from other parts of the state, 23.8% were from rest of India and 1.7% were from outside the country.

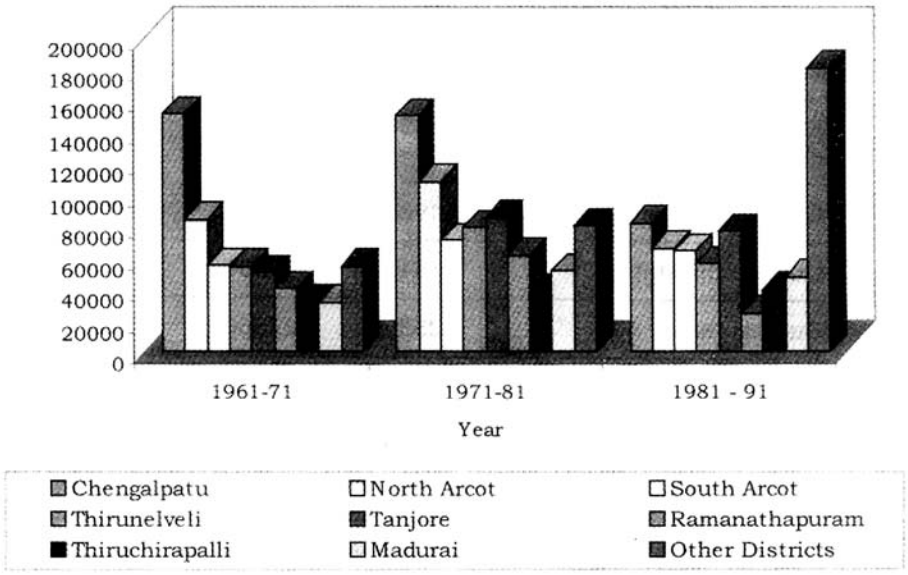
Migration to Chennai City

Year	Total Population	Total Migrants to the city from								% of Total Migrants to the Total Population
		Other parts of T.N.		Other parts of India		Other Countries		Un-classifiable	Total Migrants	
		No.	%	No.	%	No.	%			
1961	17.29	4.47	69.45	1.71	26.60	0.25	3.90	-	6.44	37.24
1971	24.69	5.51	70.61	2.00	25.63	0.29	3.76	-	7.80	31.59
1981	32.84	7.19	71.28	2.55	25.31	0.34	3.41	-	10.08	30.70
1991	38.43	6.44	70.51	2.42	26.47	0.28	3.01	0.04	9.18	23.90
2001	43.44	6.98	74.49	2.23	23.81	0.16	1.71	-	9.37	21.57

(*Source: Census of India, 1961, 1971, 1981, 1991 Social & Cultural Tabl*e)



Migration to Chennai City 1961- 2001



Number of Migrants to Chennai

Slums in Chennai

The vast majority of people who migrated to Chennai were attracted to the city due to oppurtunities available as well as the comforts offered by modernisation. Most belonged to working class and found it difficult to secure accomodation with their meagre means. So, they squatted on every open space available. Chennai city has the fourth largest population of slum dwellers among the cities of India, with about 8,20,000 people (18.6 % of its population) living in slum conditions.

Slum Areas on River Margins

There are three major watercourses in the Chennai city and the banks of all the three are encroached. The slum families are living there without any basic amenities and are subjected to annual flooding. They often pollute the water courses.

Slums along Feeder Canals

Feeder Canals like Mambalam - Nandanam Canal, Otteri Nullah and Captain Cotton Canal, etc. are encroached on either sides preventing the free flow of water and causes stagnation of water during the rainy season in nearby residential areas. It has been identified that 5,288 families are living on the margins of these channels.

Slums on the banks of the Cooum River

Table: Slum Famlies along rivers

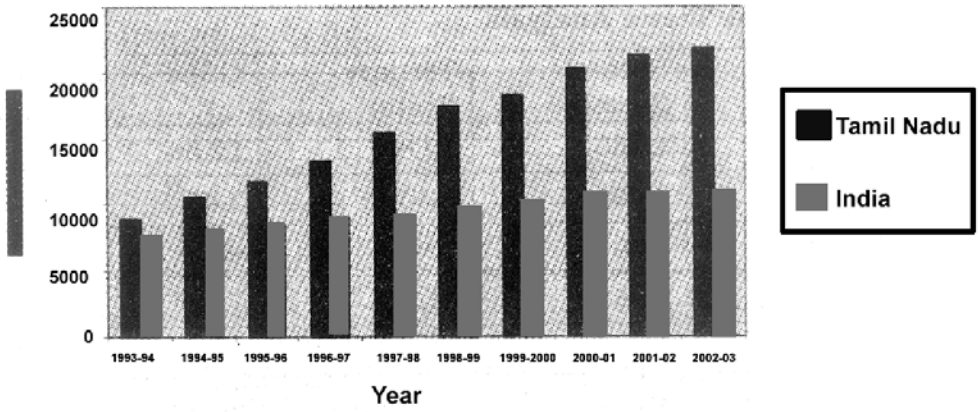
No.	River	No. of Slum Families
1.	Cooum	8432
2.	Buckingham Canal	15,733
3.	Adyar	6757
	Total	**30,922**

Socio-economic Profile

The economic base of the Chennai City had shifted from trade and commerce to administration and services by the early part of the 20th Century. In the post independence period, manufacturing became an important sector and Chennai Metropolitan Area (CMA) continues to be the most important industrial center in the State.

Today, Chennai has a diversified economic base anchored by the automobile, hardware manufacturing, healthcare and financial services industries. Recent trend shows that the economic structure of the city is tertiarised with growing contribution by Information Technology / Information Technology Enabling Service / Business Process Outsourcing (BPO) Industries. Chennai is perhaps the only city in India to have all the top 10 IT Indian Multi National Companies and the 3 IT majors viz. Infosys, Tata Consultancy Services Ltd. and Wipro which have acquired lands in and around Chennai to meet their expansion plans.

The city alone accounts for 10.94 percent of the State Income. Estimating the income in the areas of Kancheepuram and Thiruvallur District, which fall within CMA, based on proportion of population, roughly, it works out to 2.8 percent and 2.5 percent respectively. These show that CMA accounts for 16.21 percent of the state income from all sectors.



Percaptia Income of Tamil Nadu and India at current prices

Income Estimates - NDDP (Net District Domestic Product) at current price

S. No.	District	At current prices 1999-2000 (Rs. in Lakhs)
1	Chennai	12,48,833
2	Kancheepuram	8,24,702
3	Thiruvallur	4,96,671
4	Tamil Nadu State	1,14,30,943

(*Source: CMDA*)

As of 2001, the total workforce in Chennai was about 1.5 million, which was 31.79% of its population.

Chennai's culture reflects its diverse population. Though smaller in comparison to other metropolitan cities of India, has had a cultural identity of its own that is unique, yet obvious. The city is best known for its Carnatic music and classical dance called Bharathanatyam.The city is also famous for its ancient Hindu temples including the famous Kapaleeshwarar temple at Mylapore. With buildings and churches built during the British period, Chennai has also imbibed the European culture like no other city in India.

Occupational Structure CMA - 1991 and 2001

1991			2001		
	Chennai City	CMA		Chennai City	CMA
Total Workers	1173062	1675512	**Total Workers**	1488364	2519278
Main Workers	1171739	1669213	**Main Workers**	1380757	2284457
Main Cultivators	883	19778	**Main Cultivators**	15149	33170
Main Agriculture Labourers	199	70085	**Main Agriculture**	5849	33390
Fishing and Forest	9982	15422	**Main Household**	25836	43394
Mining	1245	3484	**Main others**	1333923	2174503
Manufacturing Household	7683	20271	**Marginal Workers**	107607	234821
Manufacturing and others	275916	423253	**Marginal Cultivators**	2026	5728
Main Construction	74856	104913	**Marginal Agricultural**	1233	22681
Main Trade	300928	372672	**Marginal Household**	5156	10511
Main Transport	125853	166648	**Marginal others**	99192	195901
Main others	374194	472687	**Non-Workers**	2855281	4859201
Marginal Workers	1323	6299			
Non-Workers	2668334	3753958			

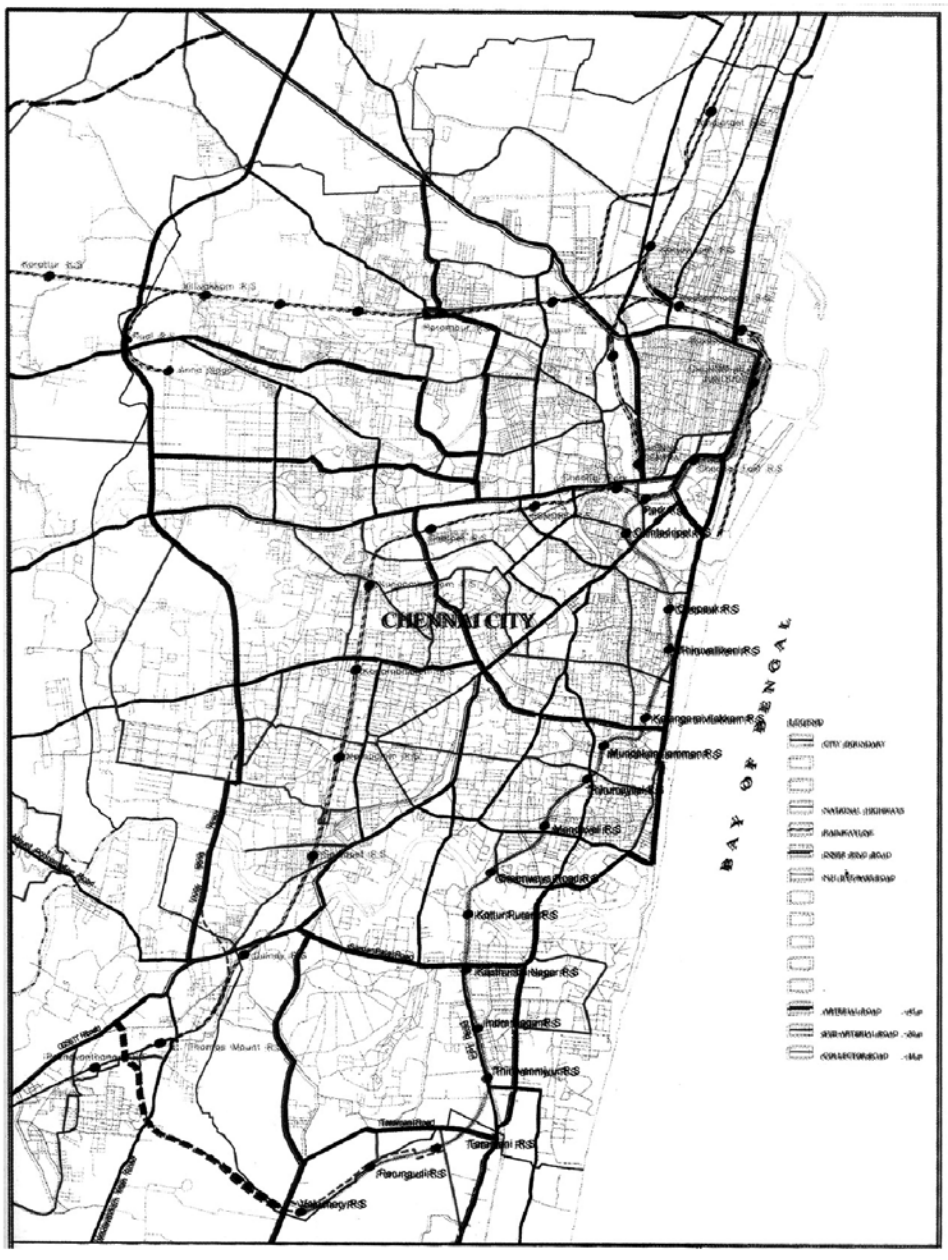
(*Source : Census of India*)

City Infrastructure

Every city is highly reliant on infrastructure. In recent years, the city of Chennai has experienced a complete turnover in its all round infrastructure. But at present we will confine only to those infrastructure facilities connected to flooding and water logging.

Roads

The road network of Chennai is dominated by a radial pattern converging at George Town, which is the main Central Business District (CBD) of the CMA. The road network



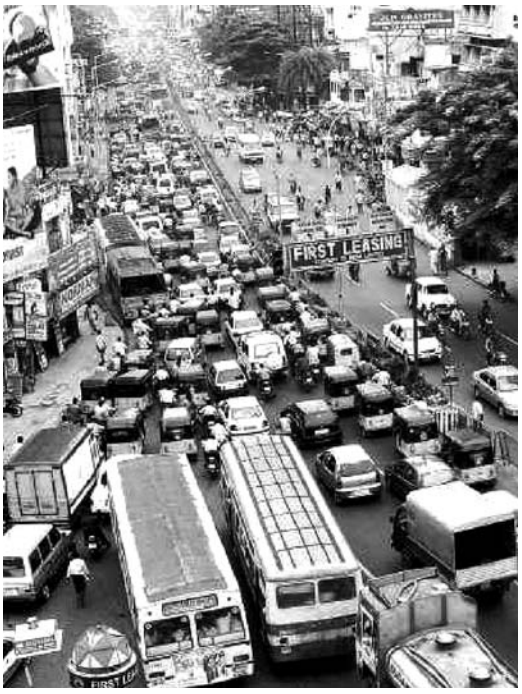
Chennai City Road Network

(Source: http://www.chennaicorporation.gov.in/departments/roads/abstract.htm)

is primarily based on the four National Highways, leading to Calcutta (NH5), Bangalore (NH4), Thiruvallur (NH 205) and Trichy (NH 45). In addition to these, Arcot Road, Kamarajar Salai, Thiruvottiyur High Road, Old Mahabalipuram Road and East Coast Road are the other important radial roads in CMA. The total length of roads in Chennai city is 2,847 km.

The rapid growth of population and increasing number of motorised and non-motorised vehicles put the city's road network into a complex problem. On an average, about 425 new vehicles are put on roads every day without corresponding increase in motorable road space. The increase in road space accounts for only 3 to 4% of the total area, the value of very low order when compared with 11% in Bangkok and 20-25% in developed cities such as London, Paris or New York.

Arterial roads leading to CBD carrying heavy traffic due to concentration of commercial, industrial and other employment-related activities in the CBD are highly congested. Other major roads are also congested. Capacity of almost all roads in the present system is reduced due to poor quality of riding surface, inadequate pedestrian pavement, poor lighting conditions and lack of properly designed intersections.



Traffic jam on Mount Road

Sewage

In early 1890, surface drains in the city were connected to pumping stations and the wastewater conveyed for disposal away from inhabitation. The proposal for comprehensive drainage scheme to cater to the needs of a topographically flat, fast growing city was formulated in 1907 and works were initiated in 1910 and completed during 1914 in stages.

The systems were designed for the population of 6.5 lakhs expected in 1961 at 114 lit. per capita per day of water supply. The system originally consisted of a network of force mains and brick gravity sewers served by 3 Pumping Stations at Royapuram, Purasaiwalkam and Napier Park and ultimately discharging wastewater into the sea at Kasimedu on the Northeastern boundary of the City.

A fundamental change to this system was made in 1956 by laying a force main to divert part of the sewage discharged from the Purasaiwalkam pumping station to Kodungaiyur where the sewage farm was started. Thereafter a comprehensive wastewater management scheme was formulated. The implementation of these schemes commenced in 1961 and had undergone modifications periodically commensurate with the system requirements of an expanding city and the growing population. The wastewater system for the city has been divided into five drainage zones. These zones of macro systems covering the entire city had independent zonal collections, conveyance, treatment and disposal facilities.

Zone-I of sewerage system forms the oldest part of the city and is in the north eastern portion of the city bounded by Bay of Bengal to the East, the city limits to the North, the Buckingham Canal to the West and Pycrofts Road to the South. It covers the areas of Tondaiarpet, Washermenpet, Royapuram, George Town, Chindadripet etc. The sewage collected from this Zone-I is drained to the treatment plant located at Kodungaiyur (Zone-I Plant) which was commissioned in 1991 for the capacity of 80 MLD.

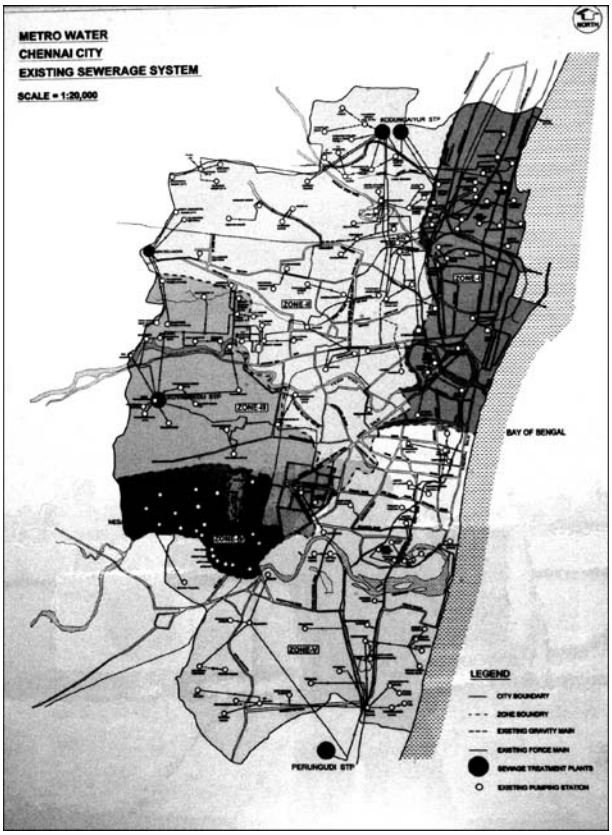
Zone-II is the largest of the five macro systems and serves the central and northern portions of the city. It is bounded by the Buckingham Canal in the East and the corporation limits in the North. The area served are Nungambakkam, Chetpet, Kilpauk, Egmore, Purasaiwalkam, Ayanavaram, Perambur, Vyasarpadi, Sembium, Kolathur, Periyar Nagar, Jawahar Nagar and Kodungaiyur etc. The wastewater generated in these zones is drained into the treatment plant at Kodungaiyur (Zone-II Plant) which was commissioned in the year 1989 for the capacity of 80 MLD.

Zone-III lies between Zone-II and Zone-IV to the west. It comprises Thyagaraya Nagar, Kodambakkam, Arumbakkam, Anna Nagar and Koyambedu. The wastewater generated in this zone is conveyed to the treatment plant at Koyambedu (Zone-III Plant),

which was commissioned in the year 1978 for the capacity of 34 MLD.

Zone-IV is the smallest of the macro systems lying to the southwest of the city. The areas covered are Ashok Nagar, Saidapet, Jafferkhanpet, K.K. Nagar and Nesapakkam. The wastewater generated in this zone is conveyed to the treatment plant at Nesapakkam (Zone-IV Plant) which was commissioned in the year 1974 for the capacity of 23 MLD.

Zone-V is the second largest of the five macro systems and is to the south of the city, which is bifurcated by the Adyar River. Areas covered are Ice House, Mylapore, Adyar, Guindy, Velacherry, Gandhi Nagar, Indra Nagar, etc. The wastewater collected in this zone is conveyed to the treatment plant at Perungudi (Zone-V Plant) which was commissioned for primary treatment only in the year 1980 for the capacity of 45 MLD.



Metro Water Chennai City Existing Sewerage System

(Source: http://www.chennaimetrowater.tn.nic.in)

The Master Plan for Wastewater Management (Sewerage) was formulated in 1978 to serve the population expected in 2008. Extension of sewer systems to the newly developed Areas and improvements to the existing system were carried out based on this Master Plan. During 1989-1991 proposals were formulated for short term and long term improvements to the sewerage interceptor system, sewage pumping stations, pumping mains and sewage treatment plants. The works were carried out in stages for improvement to the collection system, pumping stations and sewage treatment plants. At Villivakkam, a small treatment plant of 5 MLD capacity developed by the Housing Board for SIDCO Nagar of Villivakkam was taken over by C.M.W.S.S. Board during 1984 and is being maintained.

The Master Plan was updated in 1991 to cater to the needs of population expected in 2021 and the proposal envisages improvement to (a) sewage collection and conveyance system in the City which includes strengthening of the existing collection system for all zones, strengthening the existing conveyance system including force main, improvement to critical sewage pumping stations, provision of collection and conveyance system for un-sewered areas, (b) the sewage treatment and disposal facilities. The works were executed in stages according to the priority by mobilizing funds in-house by Metrowater.

The detailed design and engineering for sewage collection & conveyance and for the sewage treatment & disposal were finalized through independent consultants during 1995-1998 for expanding the capacity of sewage collection, conveyance system and treatment & disposal arrangements to meet the requirement for the population expected in 2021 and due to increase in the availability of water under Krishna Water Supply Scheme.The total estimated cost of the proposal was about Rs.1,300.00 crore.

Based on this detailed design and engineering, project proposals were formulated for implementation under Chennai City River Conservation Project in the year 2000 at the estimated cost of Rs.720.00 crore as first phase for 2011 sewage flow. The proposal consists of laying of interceptors 59.2 km. improvements to 28 nos. of pumping stations, construction of 3 nos. of new pumping stations and laying of sewage pumping mains 28.85 km. gravity conveying main 17.3 km. and expansion of sewage treatment capacity for 264 MLD. These works were commenced in January 2001 and completed in August 2006.

The improvement works to the old treatment plants were carried out during the year 2001 to maintain the treatment capacity as follows:

S.No.	Treatment Plant	Treatment Capacity in MLD
1	Kodungaiyur Zone - I	80
2	Kodungaiyur - Zone II	80
3	Koyambedu Zone - III	34
4	Nesapakkam Zone - IV	23
5	Villivakkam Zone - V	54
	Total	222

Newly constructed Sewage Treatment Plants:

S.No.	Treatment Plant	Treatment Capacity in MLD
1	Kodungaiyur Zone - I & II	110
2	Koyambedu Zone - III	60
3	Nesapakkam Zone - IV	40
4	Perungudi - Zone V	54
	Total	264

(*Source: http://www.chennaimetrowater.tn.nic.in*)

The present capacity of the treatment plant is 486 MLD.

Sewage Treatment Plant at Kodungaiyur

(Source: http://www.hinduonnet.com)

Due to the enhancement of capacity of the 28 sewage pumping stations and construction of 3 new pumping stations, the pumping capacity has been increased from 440 MLD to 575 MLD. The capacity of the sewerage treatment plants has been increased from 222 MLD to 486 MLD and the sewage overflow and untreated sewage entering the waterways have been reduced.

In the sewage treatment process, bio-gas is produced and is being used to produce power to run the plants. This incidentally reduces the discharge of Green House Gas into the atmosphere and provides for Carbon Trading. CMWSS Board has adopted Clean Development Mechanism (CDM) which is likely to generate revenue in the range of Rs.3.50 to Rs.4.00 crore per annum.

The growth in the sewerage services compared to 1978 when the C.M.W.S.S. Board is given below:

Details	1978	March 2007
Area Covered	74%	99%
No. of dwellings with sewer Connections	1,14,000	5,15,560
Length of sewer mains	1,223 km.	2,663 km.
No. of pumping stations	58	180
Treatment Plants	3 Nos.	5 Nos.
Treatment Capacity	57 mld	486mld

(*Source: http://www.chennaimetrowater.tn.nic.in/operationmain_main.htm)*)

As the capacity of sewers was limited, during rainy days they became surcharged due to ingress of storm water. Any surplus of sewage in excess of pumping stations capacity was drained into the nearby natural water courses of the city viz. Cooum river, Adyar river, Buckingham canal and Otteri Nalla.

Drainage

Waterways in Chennai

Rivers

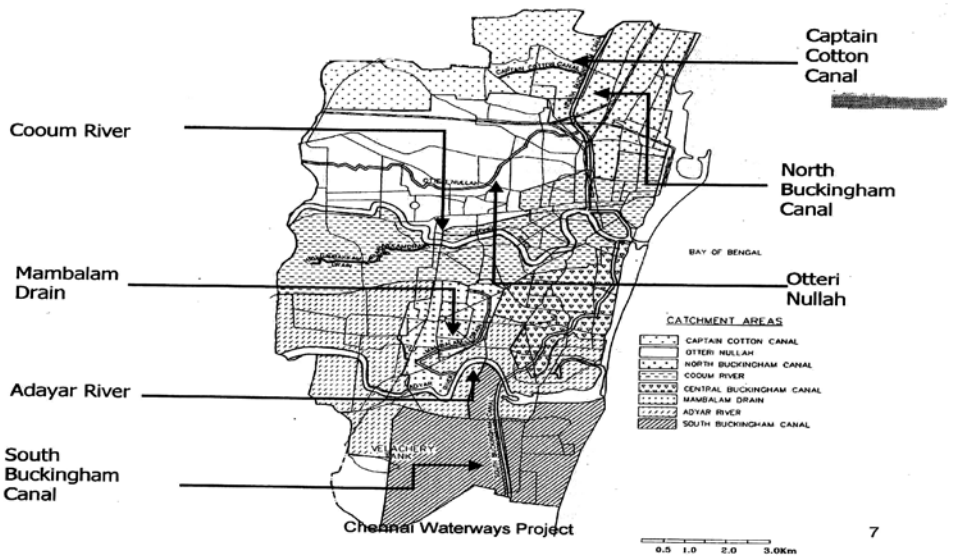
The city is traversed by languid streams namely the Cooum and Adyar. Cooum runs through the heart of the city and enters the sea in-between the University of Madras buildings and the Fort. St. George underneath the Napier Bridge, while the latter wends its way through the southern part of the city and enters the sea near Adyar.

Chennai District - Drainage Map

These two rivers are almost stagnant and do not carry enough water except during rainy seasons. During the rest of the year, they act as a carrier of wastewater from sewage treatment plants and others. The TNPCB periodically monitors the water quality of the rivers. According to the findings, the waterbodies are polluted and not suitable for any designated use.

Waterways in Chennai (maintained by the Public Works Department of Tamilnadu)		
Waterway	**Length in City**	**Length in CMA**
Cooum River	18.26	40.0
Adyar River	14.60	24.0
North Buckingham Canal	7.1	17.1
Central Buckingham Canal	7.2	7.2
South Buckingham Canal	4.2	16.1
Otteri Nullah	8.7	8.7
Virugambakkam-Arumbakkam Drain	6.36	6.36

(*Source: CMDA & http://www.chennaicorporation.gov.in/departments/storm-water-drain/introduction.htm#intro*)



Chennai Waterways

Waterways Basin-wise Sewage generation (Year 2000)			
S.No.	**Waterway**	**Drainage Area (Sq.km.)**	**Sewerage Generation (MLD)**
1.	Adyar River	12	87
2.	Cooum River	20	92
3.	Buckingham Canal		
	North	10	83
	Central	5	46
	South	2	29
4.	Captain Cotton Canal	10	47
5.	Otteri Nullah	24	129
6.	Mambalam Drain	6	19
	Total	**89**	**532**

(*Source: TNPCB*)

The Cooum and Adyar rivers play a major role during floods. River Cooum collects surplus from about 75 tanks in its catchment within CMA and Adyar river collects surplus from about 450 tanks in its catchment, apart from overflows from the Chembarambakkam tank.

Lakes

Chennai and its suburbs also once boasted of over 150 small and big waterbodies. Today the numbers of waterbodies in Chennai have been reduced to a mere 46, thanks to all the onslaught of development. The lakes, which were earlier used as water source for irrigation and now, serve as flood accommodators. Apart from these lakes there are a large number of ponds in CMA.

List of Lakes in Chennai

S.No	Name of the Lake	Location	Area (in hectares)
1.	Adambakkam Lake	Adambakkam	100.82
2.	Ambattur Lake	Ambattur	-
3.	Annanur Lake	Annanur	-
4.	Avadi Lake	Avadi	11.15
5.	Ayanambakkam Lake	Ayanambakkam	-
6.	Chetpet Lake		-

S.No	Name of the Lake	Location	Area (in hectares)
7.	Chitlapakkam Lake	Chitlapakkam	18.0
8.	Chittheri Lake	Thiruneermalai	21.66
9.	Gowrivakkam Lake		-
10.	Hasthinapuram Lake	Hasthinapuram	-
11.	Irumbuliyur Lake		-
12.	Katcherimalai Quarry	Old Pallavaram	1.2
13.	Kilkattalai Lake	Kilkattalai	-
14.	Korattur Lake	Korattur	816.32
15.	Kovilambakkam Lake	Kovilambakkam	4.00
16.	Madhavaram - Manali Lake	Madhavaram	28.0
17.	Madipakkam Lake	Madipakkam	-
18.	Maduravoyal Lake	Maduravoyal	-
19.	Maduvankarai Lake	Velachery	0.468
20.	Moovarasanpattu Lake	Moovarasanpettai	14.88
21.	Mugappair Lake	Muggapair	-
22.	Naina Lake	Thiruneermalai	-
23.	Narayanapuram Lake	Narayanapuram	-
24.	Nimilichery Lake	Chrompet	-
25.	Paleripattu Lake	Paleripattu	-
26.	Palkudam Lake	Old Pallavaram	-
27.	Pallikaranai Lake	Pallikaranai	400
28.	Parithipattu Lake	Avadi	83.67
29.	Peerkankaranai Lake	Peerkankaranai	-
30.	Periya Lake	Chrompet	-
31.	Periya Lake	Tambaram west	18.78
32.	Periya Lake	Thiruneermalai	76.61
33.	Perungudi Lake	Perungudi	-
34.	Puzhal Lake	Red Hills	-
35.	Puzhudhivakkam Lake	Puzhudhivakkam	-
36.	Ramapuram Lake	Ramapuram	-
37.	Rettai Lake	Madhavaram / Kolathur	-
38.	Rettai Lake	Porur	-
39.	Sekadu Lake	Sekadu	120.0
40.	Selaiyur Lake	Selaiyur	-
41.	Sunnambu Kolathur Lake	Pallikaranai	-
42.	Thirusulam Lake	Thirusulam	-
43.	Vannan Eri	Tambaram	
44.	Velachery Lake	Velachery	147.06
45.	Vilingiyambakkam Lake	Vilinjiyambakkam	40.0

Madhuravayal Lake

Chetpet Lake

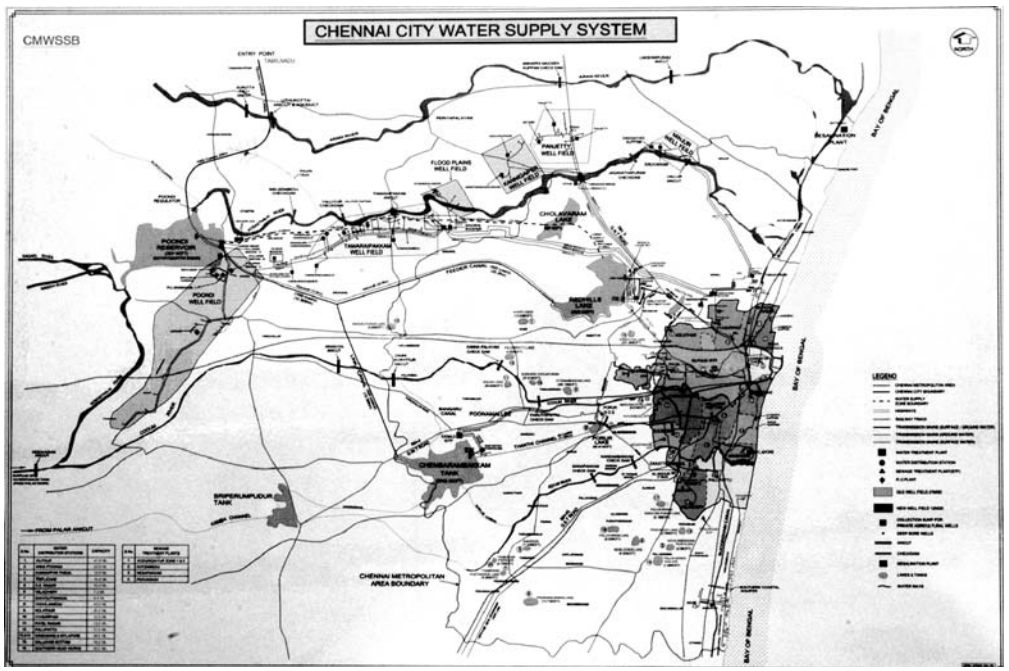
Perungudi Lake

Moovarasampet Lake

Tanks

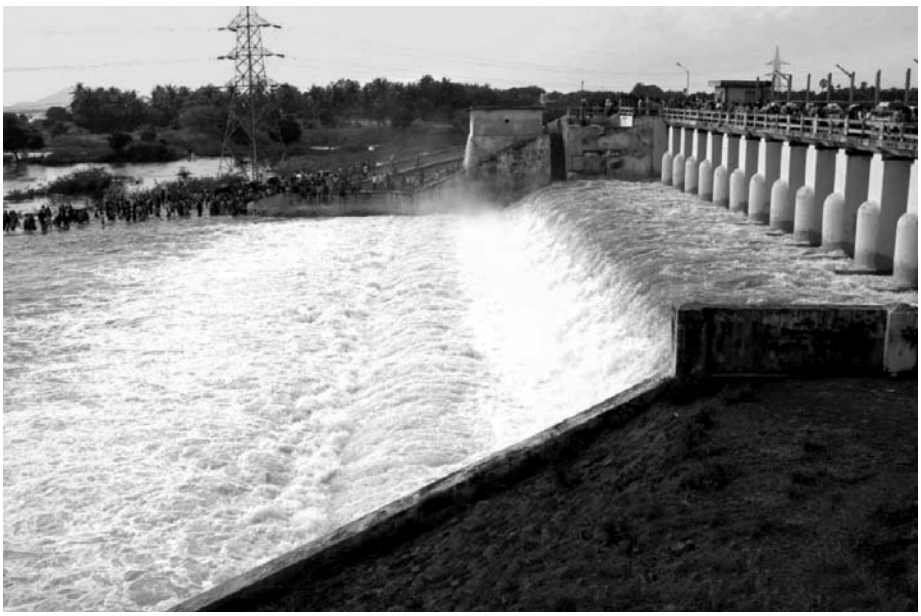
Tanks were an integral part of India's famous and highly evolved traditional water mnagement systems. In areas (particularly the Deccan peninsula) where the rivers are not snow-fed, the different kinds of tanks - percolation ponds, natural lakes, artificial reservoirs and temple tanks - proved to be of great use.

The Sholavaram tank, Red Hills tank and Chembarambakkam tank are the major tanks in the CMA. Red Hills tank is the main source of water supply to the Chennai city and during storm events water is released to Red Hills surplus channel, which enters the Kosasthalaiyar river and discharges into the sea. Its maximum storage capacity is 3,285 Mft3 (93 Mm3). Sholavaram Tank is the secondary storage tank receiving water from the Poondi Reservoir via Poondi Feeder Canal to supply Red Hills Tank. Chembarambakkam Tank has recently been developed as one of the sources for water supply to Chennai City and has maximum storage capacity of 103Mft^3.



Chennai Water Supply Map

Red Hill Reservoir



Chembarambakkam Reservoir

Poondi Reservoir

(Pictures Courtesy: http://www.chennaimetrowater.tn.nic.in)

Temple Tanks

While the tanks and artificial reservoirs were used for activities like irrigation, washing, etc, the temple tanks were sanctified and the waters were drawn only in times of drought.

These tanks were revered no less than the temple itself. Their waters (*tirtham*) are believed to cleanse all sins. In fact, devotees are required to wash their hands and feet in the temple tank before entering the temple. The waters are also used to perform the daily ritual bath (*abishekam*) of the temple deity. Annual float festivals (t*eppotsavam* in Tamil) are conducted in the tanks, wherein the idol of the deity is floated around the tank on a decorated raft. (called 't*eppam*' in Tamil).

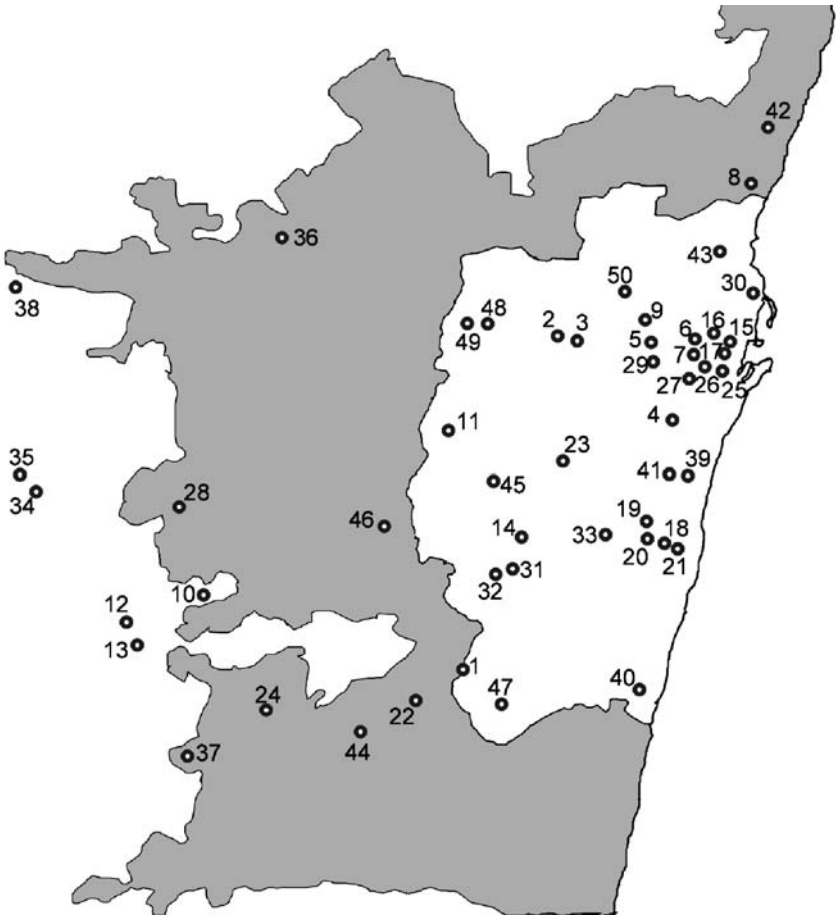
Since the water from the temple tanks was not extracted for everyday chores, they served the vital purpose of recharging the underground aquifers. They reduce the runoff and enhance the water stagnation time, which ensures sufficient water in the domestic wells during the summer months.

***Teppotsavam at* Sri Kapalishwara temple tank, Chennai**

C.P.R. Environmental Education Centre took up a survey of 50 temple tanks in Chennai during 2004. The visual survey and recording of information was accompanied, in several places, by water analysis for both physical and chemical.

	Location of Temple Tanks in Chennai (Survey by CPREEC)	
S.No.	**Location**	**Name of Temple**
1.	Adambakkam	Nandheeswarar Temple
2.	Ayanavaram	Parashuramalingeshwarar Temple
3.	Ayanavaram	Kashi Vishwanathar Temple
4.	Chintadripet	Adhipureeswarar Temple
5.	Choolai	Angala Parameshwari Amman Temple
6.	George Town	Kashi Vishwanathar Temple
7.	George Town	Kachchaleeshwarar Temple
8.	Kaaladipet	Kalyana Varadharaja Perumal Temple
9.	Kosapet	Kandaswamy Temple
10.	Kovur	Sundareshwarar Temple
11.	Koyambedu	KurungalishwararTemple
12.	Kundrathur	Murugan Temple

13.	Kundrathur	Vada Nageshwarar Temple
14.	Mambalam	Kothandaramar Temple
15.	Mannady	Krishnan Temple
16.	Mannady	Chengazhunir Pillaiyar Temple
17.	Muthialpet	Mallikeshwarar Temple
18.	Mylapore	Kapalishwarar Temple
19.	Mylapore	Virupakshishwarar Temple
20.	Mylapore	Madhava Perumal Temple
21.	Mylapore	Adi Kesava Perumal Temple
22.	Nanganallur	ArdhanarishwararTemple
23.	Nungambakkam	Agastishwarar Prasanna Venkatesha Perumal Temple
24.	Pammal	Arkishwarar Temple
25.	Park Town	Ekambareshwarar Temple
26.	Park Town	Kandaswamy Temple
27.	Parry's Corner	Chenna Kesava Perumal Temple
28.	Poonamallee	Sri Varadaraja Perumal Temple
29.	Purasawalkam	Gangadishwarar Temple
30.	Royapuram	Angala Parameshwari Temple
31.	Saidapet	Karanishwarar Temple
32.	Saidapet	Prasanna Venkata Narasimha Perumal Temple
33.	Teynampet	Balasubramania Swami Temple
34.	Thirumazhisai	jagannathaPerumalTemple
35.	Thirumazhisai	Othandishwarar Temple
36.	Thirumullaivoyal	Masilamanishwarar Temple
37.	Thiruneermalai	Ranganatha Perumal Temple
38.	Thiruvatteeswaranpetai	Bhaktavatsala Perumal Temple
39.	Thiruvallikeni	Parthasarathi Temple
40.	Thiruvanmiyur	Marundishwarar Temple
41.	Thiruvatteeswaranpettai	Thiruvatteeswarar Temple
42.	Thiruvotriyur	Tyagarajaswami Temple
43.	Thondaiyarpet	Arunachaleswarar Temple
44.	Thrisoolam	Thrisoolanather Temple
45.	Vadapalani	Palani Andavar Temple
46.	Valasaravakkam	Agastishwarar Temple
47.	Velachery	Dandishwarar Temple
48.	Villivakkam	Sowmiya Damodara Perumal Temple
49.	Villivakkam	AgastishwararTemple
50.	Vyasarpadi	RavishwararTemple



Location of Temple Tanks in Chennai

Presently, most of the temple tanks in Chennai have fallen into a state of repair and disuse due to one of the following reasons:

- ✦ Unchecked extraction and blocking of inlet ducts (either by unplanned construction or litter) has led to the drying up of some of the temple tanks.
- ✦ Pressures on the land have lead to the encroachment of these dried out tanks. For example, in Chennai, the famous Dandishwarar temple tank has been drained and is used as a dumping yard for waste and defecation.
- ✦ Also, the tanks have become sinks for sewage and garbage of the neighbourhood.
- ✦ Those tanks that still have water have been invaded by various kinds of weeds, rendering them unfit for use.

Angala Parameshwari Temple Tank, Royapuram

Thrisoolanather Temple Tank, Thrisoolam

Dandishwar Temple Tank, Velachery

Canals & Other Channels

Like any region in South India with agricultural lands, CMA also has a network of canals and channels within its boundary. The Buckingham - the most important one - was constructed during the year 1806. It enters CMA at Athipattu village, passes through the Chennai City and leaves CMA at Semmencheri village. It finally connects to Ongur River at Yedayanthittu Kaliveli near Cheyyar. Its total length is 418 kms and in CMA its runs through 40Kms. It runs in the North South direction and connects all the major three rivers in CMA.

The canal was originally formed as a navigation channel and even served as an inland waterway till 1954. But within CMA for various reasons it now only serves as a draining channel for water from the Araniar, the Kosasthaliyar, the Cooum and the Adyar rivers before draining into the sea. It also collects storm flood from various storm water drain systems in west Chennai, including Kodungaiyur drain, Otteri Nallah, Captain Cotton canal.

The Otteri Nullah is a channel to accommodate flood, which originates from a place called Otteri near Padi, flows through the city at Anna Nagar, Kilpauk, Purasawalkam, and Perambur and joins Buckingham Canal near Basin Bridge.

Virugambakkam-Arumbakkam Drain originates near Oragadam passes through Virugambakkam-Arumbakkam area of the city and joins into Cooum River.

The Corporation maintains 16 canals of 27.92 km., criss-crossing the city. Rainwater runoff gets drained through storm water drain network & canals and reaches the see via four waterways - Otteri Nullah, Buckingham Canal, Adyar River and Cooum River - running across the city.

List of Canals maintained by the Corporation of Chennai

S.No.	Name of the Canal	Starting Point	Ending at	Length (kms.)
1.	Kodungaiyur Canal	Moolakadai	Buckingham Canal	5.235
2.	Link Canal	Captain Cotton Canal	Kodungaiyur Canal	0.485
3.	Captain Cotton Canal	GNT Road at Sharma Nagar	Buckingham Canal	3.000
4.	Vyasarpadi Canal	Dr. Ambedkar College Road	Captain Cotton Canal	1.265
5.	Egankipuram Canal	Perambur Railway Station	Otteri Nullah	1.272
6.	Jawahar Canal	Madavaram High Road	Captain Cotton Canal	1.272
7.	T.V.S.Canal	SIDCO Industrial Estate	Otteri Nullah	1.753
8.	Trustpuram Canal	Arcot Road	Cooum River	1.486
9.	Nungambakkam Canal	Nungambakkam High Road	Cooum River	1.410
10.	Mambalam Canal	Valluvar Kottam	Adyar River	5.890
11.	Nandanam Canal	Mambalam Canal	Adyar River	1.020
12.	Reddikuppam Canal	Aranganathan Subway	Mambalam Canal	0.471
13.	Jafferkhanpet Canal	Jafferkhanpet Main Road	Adyar River	0.612
14.	M.G.R. Nagar Canal	Dr. Ramasamy Salai	Adyar River	1.749
15.	Chellammal College Canal	Anna Salai	Adyar River	0.365
16.	Raj Bhavan Canal **Total**	Raj Bhavan	Velachery Lake	1.138 **27. 921**

(*Source: www.chennaicorporation.gov.in*)

Storm Water Drains

Geographically Chennai is a plain terrain and lacks natural gradient for free run off. This necessitates an effective storm water drainage system. The Corporation of Chennai has developed and maintains a storm water drain network of 855 km in the city. The storm water drainage system can be largely divided into:

Micro Drainage System

The collector and feeder drains laid along the roads mainly to collect and convey storm water are called Micro system. These drains discharge directly into the macro systems. The micro drainage systems are constructed and maintained by the local bodies - Chennai Corporation in Chennai city, Municipalities, Town Panchayats and Panchayat Unions (in Chennai Metropolitan Area)

Macro Drainage System and Carrier System

The storm water, treated / untreated effluents from industries and commercial establishments are collected by the macro drainage system, which in turn is connected with major water ways referred to as carrier systems. Some of the macro drains and carrier system are under the control of the Public Works Department (PWD).

Composition & Characteristics of Solid Wastes	
Physical	
Paper	8.38 %
Rags	3.11 %
Organic Matter	51.34 %
Plastics	7.48 %
Metals	0.19 %
Rubber & Leather	0.19 %
Inert	26.01 %
Glass	0.29 %
Coconut	2.48 %
Timber / Wood	0.50 %
Bones	0.01 %
Chemical	
Moisture Content	47.00 %
pH Value	6.20 - 8.10 %
Volatile Matter at 550 %	42.62 %
Carbon	24.72 %
Nitrogen Content	0.88 %
Phosphorous P2O3	0.44 %
Potassium K2O	0.89 %
C / N Ratio	29.25
Calorofic Value in Kj/kg	

Waste Generati	
Residential	68 %
Commercial	16 %
Halls, Schools, Institutions	14 %
Industrial	2 %
Hospitals & Clinics	Separately disposed by Hospitals.

(*Source: CMDA & http://www.chennaicorporation.gov.in/departments/solid-waste-management/index.htm*)

2.4 Solid Waste Management

The Corporation of Chennai is the agency responsible for solid waste management in the city corporation area. Chennai Corporation area is divided in to 10 zones and each zone is further sub divided in to about 15 Divisions totaling to 155 Divisions.

According to Census 2001, the average per capita solid waste generated with in the city is estimated to be about 585 grams. It has been estimated that 3200 tonnes of solid waste is generated in these 10 zones in the city area daily and in addition Chennai Corporation also handles about 500 tonnes of building debris.

As seen from the above table, the Municipal Solid Waste of Chennai contains higher moisture content, small percentage of recyclable materials and more of compostable (organic matter) and inert materials. These characteristics show the low potential for applying refuse derived fuel and waste to energy (i.e. incineration) processing option due to the low combustibles, high moisture and high inert contents of the wastes. However, they indicate high potential for composting of solid wastes.

Present System of Waste Handling in Chennai

Headed by the Superintendent Engineer of the Department of Solid Waste Management, Corporation of Chennai looks after removal of solid wastes in the city. Door to door collection of garbage is practiced in most parts of the city except certain zones. NGOs, neighbourhood associations and other bodies assist communities to collect a solid waste that is deposited in dustbins, which are cleared by the Chennai Corporation.

Solid wastes from the Chennai Corporation area is taken to the Transfer Stations and from there it is finally disposed off at two designated disposal sites viz. Kodungaiyur located in the northern part of the city and Perungudi in the south. Both the sites are located in low lying areas and are adjacent to the Metro water sewage treatment works. About 45% of the total solid waste generated is disposed at Kodungaiiyur and the remaining at the Perungudi sites.

Garbage being burnt at the Perungudi landfill site
(Source : http://www.hindu.com)

Land Use Change

Urban Land use through the ages

Madras in 1600

Madras in 1600 was formed of scattered settlements separated by long distances. Each settlement grew around a nucleus of a temple and has its own history. The most important area at that time was Mylapore. There were small settlements in Purasawalkam, Thiruvatteeswaranpetta, Egmore, Nungambakkam, and Saidapet. Among the suburbs, Tiruvottiyur, Velachery, Tiruneermalai, Mangadu, Padi, Poonamallee, Kunnathur, Ayanavarum, Vyasarpadi, Villivakkam, Ambattur, Koyambedu etc. already existed. Each of these villages was self-contained and had its own agricultural production and household industries.

Madras being on the coast, had many sand ridges, but during the 16th century the level of the sea rose and inundated lands within the settlements. When the sea withdrew, lagoons and ridges were left behind. The lagoons took some time to become filled in and the sandy ridges were places of safety where new temples and settlements were established.

Madras in 1700

The Cooum River and the Elambore River or North River which flows into the Cooum at its mouth were running very close to each other (near the Central Jail area) and during floods they inundated the whole area. The two rivers were linked by a cut, at this point, to equalise the floods in the rivers. A bridge was constructed in 1710 across the cut between the two rivers. The Principal road to Egmore from that time up to 1931 had been the road in front of the present Central Jail. In this era there was a lot of building activity (a redoubt at Egmore, a bridge and churches at the Fort and many private buildings in and around the Fort).

Due to congestion inside the Fort, the British constructed some garden houses in what is known as Peddanaickenpet. In 1733 there was a lot of congestion in George Town and the weaving Community started settling in Chintadripet area and Collepetta near Tiruvottiyur since abundant open space was available for weaving. The washer men who were in the Mint area then moved towards the west. The Potters from this area moved outside the Fort on the north side and formed a new colony (Kosapet).

Because the British started living along Cooum River, roads were laid to give access to them and thus Marshalls Road, Halls Road, Montieth Road and Casa Major Road all became thoroughfares even in 1798. Mowbrays Road and Royapettah High Road were formed to give access to these people.

During this time, the British found that Triplicane was a good area for settlement and a large number of people moved there. The presence of the Nawab of Arcot increased the economic prosperity of the area and more and more Muslims settled in Triplicane

Madras in 1800

After the founding of the Corporation, conservancy and improvement of the City were begun. The City was divided into 8 Divisions. The broad-gauge line from Royapuram to Arcot was laid in 1864. Central station was formed in 1872 and linked to the main line. By 1861 the British authorities realised the necessity of a harbour. A pier was constructed in 1862 and further development took place from 1868 onwards.

The formation of Royapuram station in 1862 induced people to move northwards and settle in Royapuram. The railway line passed through the present Perambur area, which had so far been lying as swampy waste because of its low level. The introduction of the railway line gave development potential to the hitherto uninhabited place. From 1850 onwards, the necessity of providing recreational facilities was perceived. Many parks such as the Peoples Park, Napier Park and Richardson Park were created in this period. A Museum and a Zoo were also established.

Before 1800, the roads were in a radial pattern, but after 1810 ring roads were developed inside the City. Mount Road was important and access to it was given from Triplicane High Road, Chamiers Road, Edwards Elliot's Road and Royapettah High Road. To the North of Mount Road, Pantheon Road, Halls Road, Marshalls Road, Spur II-5 Tank Road and Nungambakkam High Road were formed to serve the new residential areas. Later Brick kiln Road and Perambur Barracks Road connected Poonamallee High Road with Konnur Road, which was extended towards the Railway.

To facilitate trade the harbour was completed in 1896 just to the east of George Town. The building of the harbour was responsible for sand accretion to the south of it and the sea which was washing the ramparts of the Fort at one time was then 2.5 km. away with a wide beach between the land and the sea. A number of public buildings were constructed fronting this beach early in the 19th century, which still add dignity to the city.

Madras in 1900

The important developments during the period 1901 and 1941 were the commissioning of the electrified suburban metre-gauge railway between Beach and Tambaram in 1931 which gave a fillip for the development of the outlying suburban areas as far as Tambaram, and the development of the area occupied by the long tank at Nungambakkam as a planned residential neighbourhood by the Corporation. By 1941 Madras had developed into a provincial metropolis enjoying the best of both worlds - urban amenity and rural atmosphere. It was still primarily an administrative and commercial centre.

The thirty years between 1941 and 1971 saw tremendous growth in population and economic activity in and around the City. The setting up of the Tamil Nadu State Housing Board however, helped in the creation of large residential areas like Anna Nagar on the west and Sastri Nagar on the south. The city's boundary no longer remained well defined. The developments extended into the adjoining areas, particularly, on the north up to Ennore, west up to Avadi and south up to Vandalur. This growth did not take place in a regulated manner nor did it correspond to the available infrastructure facilities. This fact coupled with the rapid growth of population on the one hand and the increase in number of motor vehicles on the other has given rise to the many problems faced by the Metropolis today.

In the last three decades, the agricultural activity within Chennai has become abysmally minimal for various reasons including non-availability of water for irrigation purposes, labour cost, and cost of agricultural inputs. In the northern wedge between

GNT Road and T.P.P. Road, because ayacut rights of Puzhal and Redhills lakes had been cancelled and local water sources are not adequate, the agricultural activity in these areas is very minimal.

Similar is the position in the northwestern wedge between CTH Road and GNT Road, which lie in the catchment area of these lakes, which are the main sources of water supply to the city. The Chembarambakkam lake, another large lake in CMA, is being converted as another source for city water supply and very minimal agriculture activity is being carried out in its ayacut area which lie in the south-western wedge. In the southern wedge between Old Mamallapuram Road and GST Road only in few pockets to a limited extent the agriculture activity in the south of Tambaram - Madipakkam Road continue.

Land Use under the First Master Plan

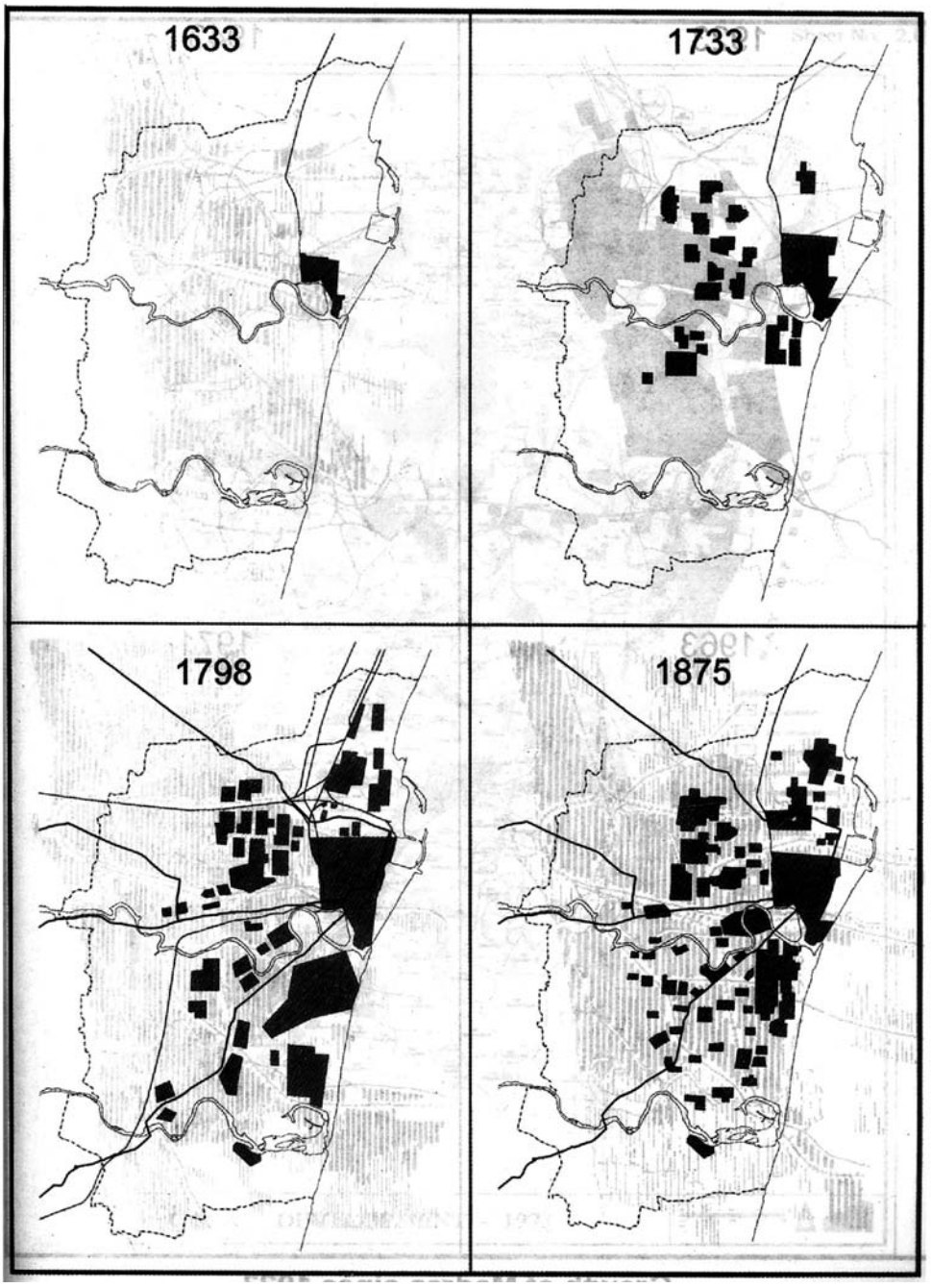
The First Master Plan for the Chennai Metropolitan Area (CMA) was prepared during 1973-75 and approved in 1976. It was then estimated that, by 2001, the CMA will have a total population of 7.1 million, including four million in Chennai city. The Master Plan laid down policies and programmes for the over all development of the CMA. It was the basic document for the infrastructure agencies like Metrowater, highways Department inplanning and provision of infrastructure by them within the CMA.

The plan recommended that development projects would need to be oriented towards raising the levels of income both at the State level and metropolitan level. To achieve this, the Master Plan also suggested large-scale industrialisation, strengthening of service and light type industries with medium range employment and increasing tertiary sector employment.

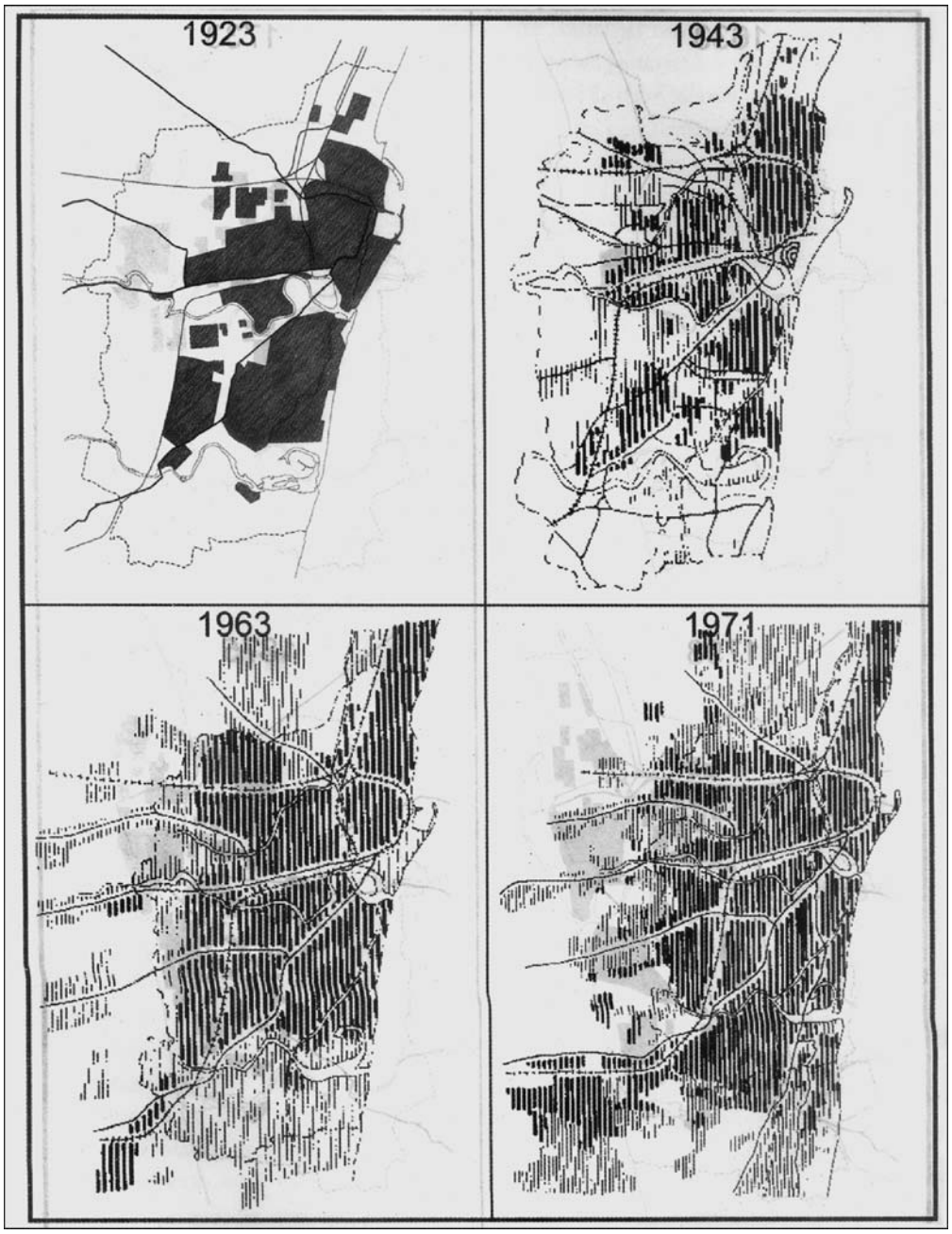
Location of large-scale industries in the hinterland of CMA to satisfy the employment needs of the resident population was recommended. The only way to regulate economic activity, it reasoned, was to optimise the use of the existing infrastructure facilities and plan their expansion to meet future needs by regulating land use and building activities. It favoured decentralizing economic and industrial activities into proposed nodes and satellite towns.

The important projects identified in the FMP were: Mass Rapid Transit System (from Manali to Tiruvanmiyur), electrified suburban system between Chennai and Tiruvallur and Chennai and Minjur, construction of circular railway, construction of combined railway terminals and widening of major arterial roads within the city.

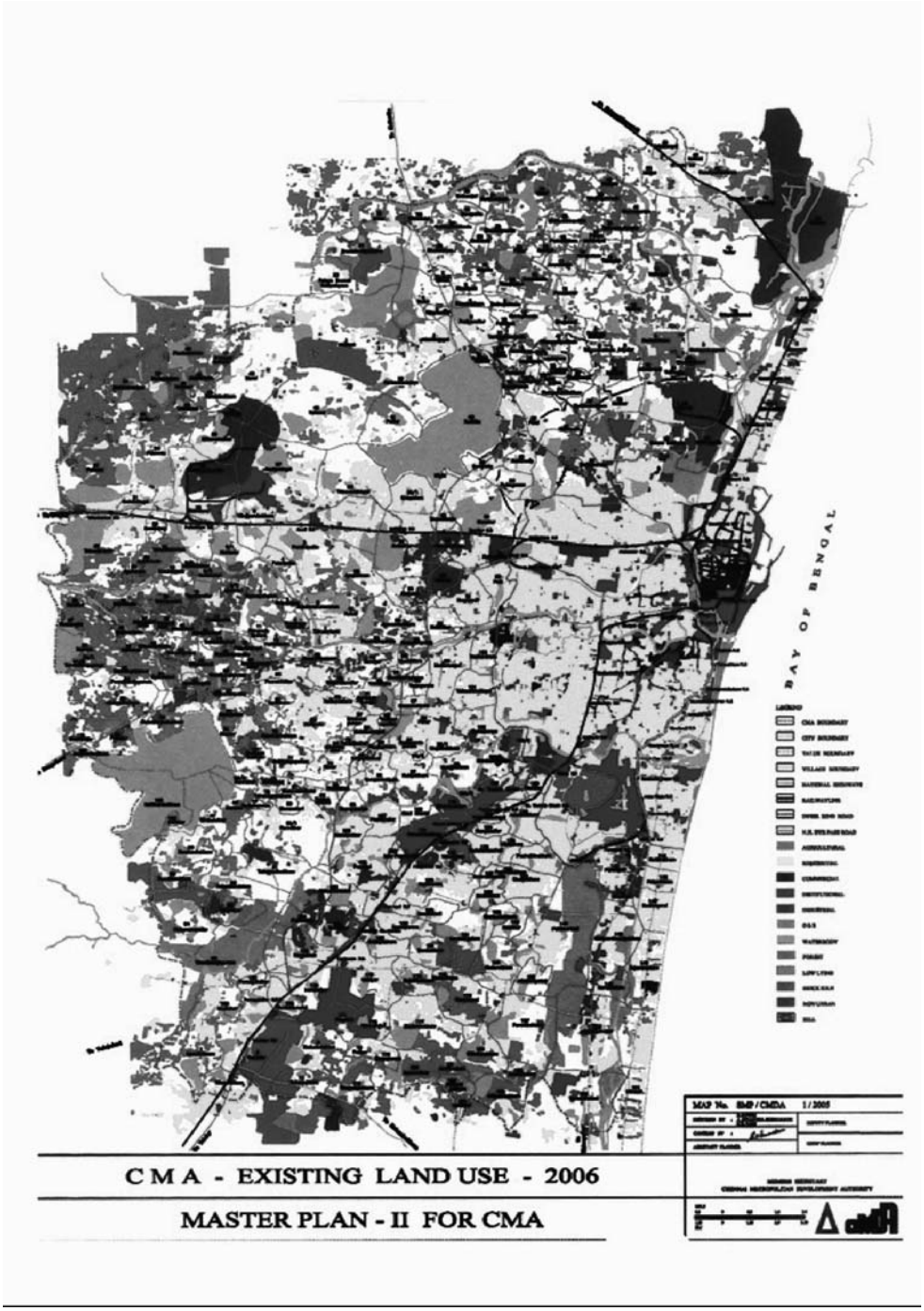
Replacement of level crossings, construction of an Inner Ring Road, Intermediate Ring Road and Outer Ring Road and construction of three bus and truck terminals on the radial corridors at the junctions of Outer Ring Road were the other projects

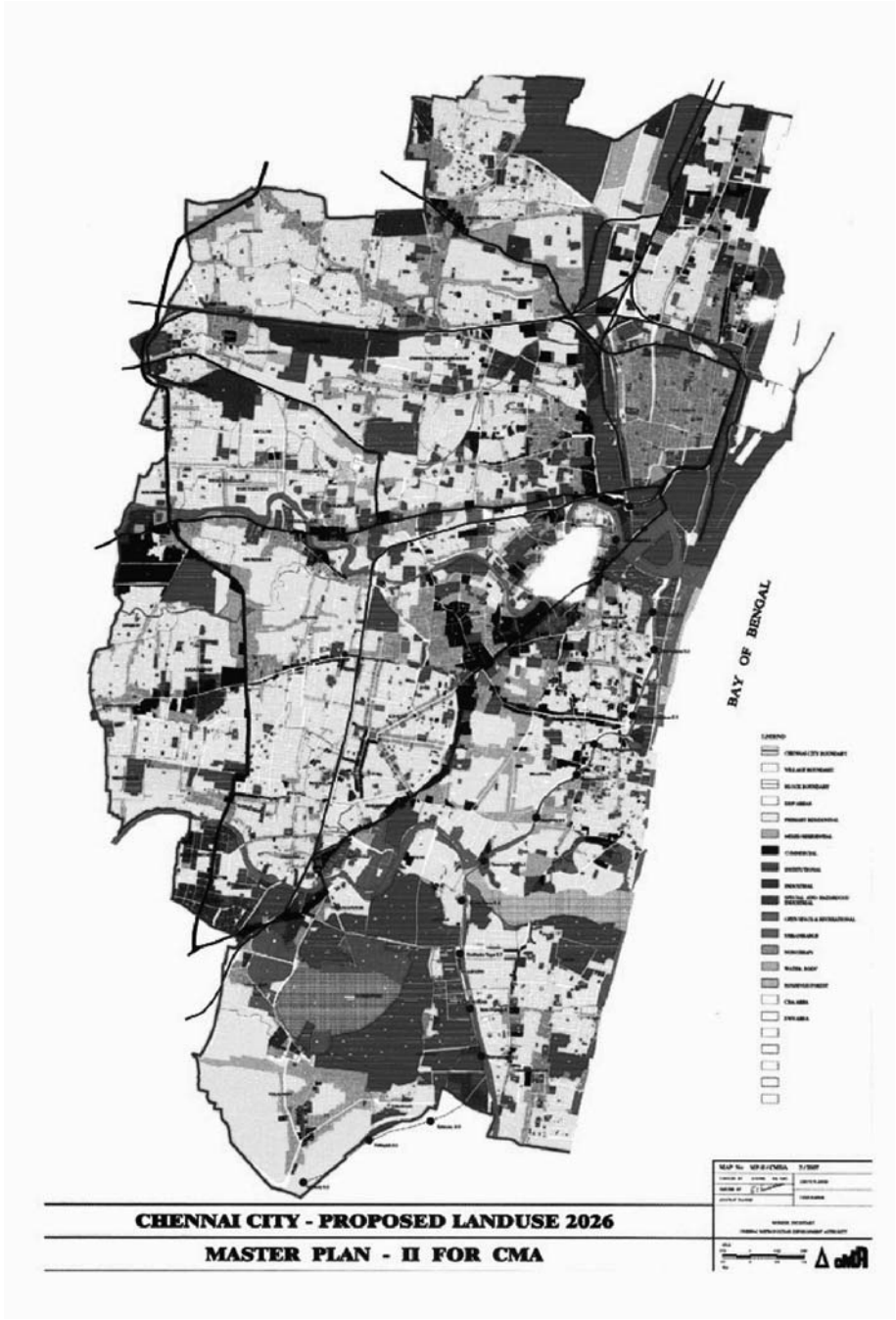


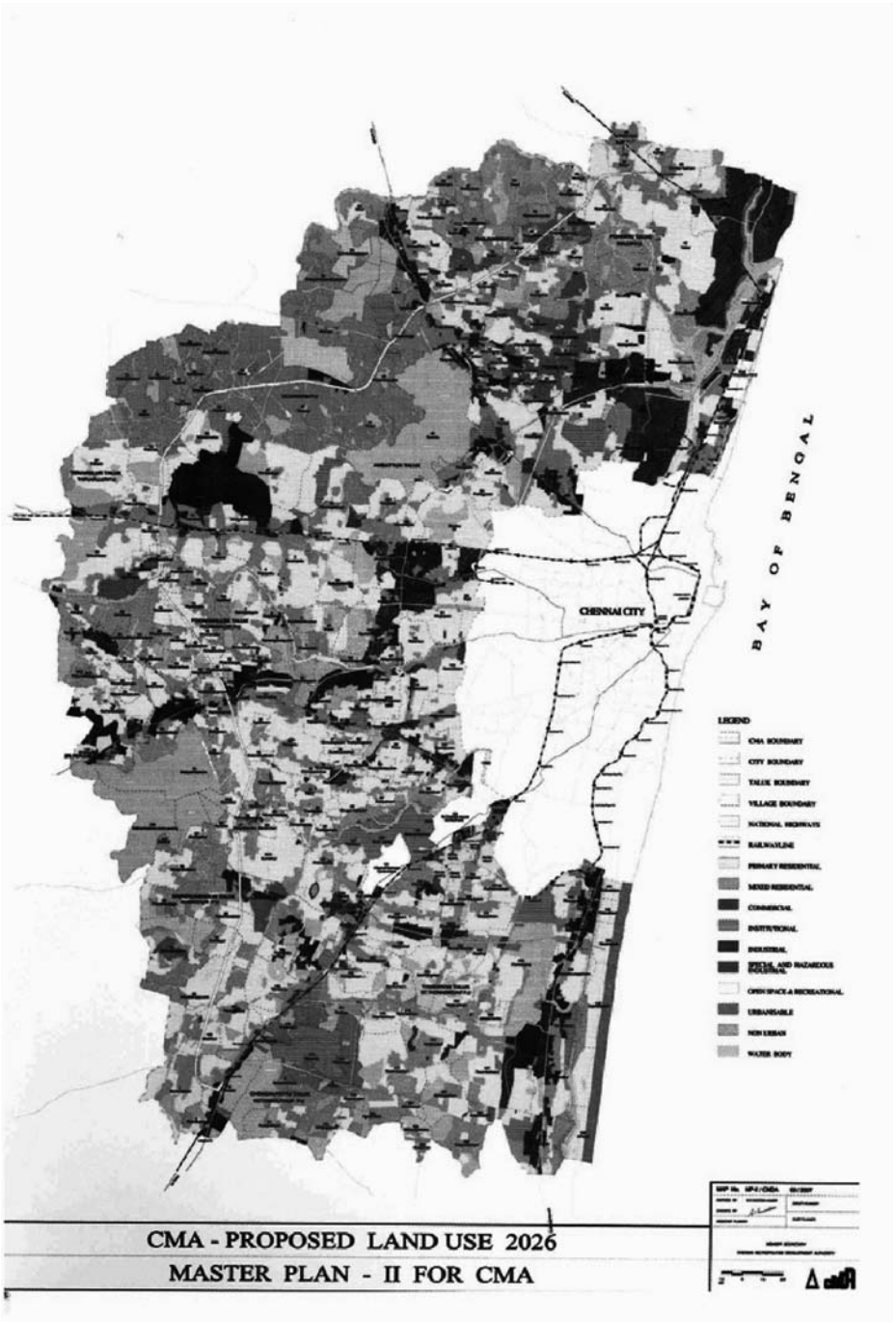
Growth of Madras since 1633



Growth of Madras since 1923


BAY OF BENGAL
CMA - EXISTING LAND USE - 2006
MASTER PLAN - II FOR CMA


BAY OF BENGAL
CHENNAI CITY - PROPOSED LANDUSE 2026
MASTER PLAN - II FOR CMA


BAY OF BENGAL
CHENNAI CITY
LEGEND
CMA - PROPOSED LAND USE 2026
MASTER PLAN - II FOR CMA

Land Use Details - I Master Plan (1975) and Existing Land Use

S.No.	Land Use	Proposed in I Master Plan				In 2001			
		Chennai City		Rest of CMA		Chennai City		Rest of CMA	
		Extent in Hectares	%	Extent in Hectares	%	Extent in Hectares	%	Extent in Hectares	%
1.	Residential	8082	48.57	32256	30.48	9293	52.94	20833	19.92
2.	Commercial	973	5.85	895	0.86	1238	7.05	378	0.36
3.	Industrial	1107	6.66	6362	6.11	890	5.07	6419	6.14
4.	Institutional	2746	16.51	4935	4.74	3180	18.11	2876	2.75
5.	Open Space and Recreational	3254	14.55	7767	7.46	364	2.07	200	0.19
6.	Agriculture	-	-	50924	48.91	94	0.53	12257	11.72
7.	Non-urban	476	2.86	979	0.44	82	0.47	1689	1.61
8.	Others	-	-	-	-	2413	13.75 1	59953	57.31

Land Use - 2006

	Extent in Hec.	%	Extent in Hec.	%
Residential	9523.18	54.25	22876.51	21.87
Commercial	1244.81	7.09	390.04	0.37
Industrial	908.42	5.17	6563.40	6.28
Institutional	3243.39	18.48	3144.35	3.01
Open Space and Recreational	366.43	2.09	200.26	0.19
Agriculture	99.29	0.57	12469.65	11.92
Non-urban	82.46	0.47	2433.30	2.33
Others (Vacant, Forest, Hills, Low-lying, Waterbodies, etc.)	2086.93	11.89	56506.60	54.03

suggested. Assuming the water demand at 227 lpcd and, recognising the severe limitations that prevailed then, the FMP suggested that detailed studies be taken up and programmes for meeting the future demand worked out on that basis.

Noting the severe housing requirements then, the FMP recommended taking up a

massive housing programme by acquiring about 12,000 hect. (120 sq.km.) at urban nodes and satellite towns; most of the new housing by public agencies to be provided in the urban nodes.

The land use plan was enforced through a set of regulations under Development Control Rules, which formed part of the First Master Plan. Any person intending to make any development is required to apply under Section 49 of the Tamil Nadu Town and Country Planning Act, 1971, and obtain Planning Permission. The structure proposed was of radial pattern with city as hub. The main elements of the strategy were:

(a) Restriction of density and population growth in the city;
(b) Restriction of industrial and commercial developments within CMA.
(c) Encouragement of growth along the major transport corridors and development of urban nodes at Manali, Minjur, Ambattur, Avadi, Alandur and Tambaram.
(d) Dispersal of certain activities from CBD.
(e) Development of satellite towns, beyond CMA at Maraimalai Nagar, Gumidipoondi and Thiruvallur.

The land use zoning classifications as per the Master Plan - I are (i) Primary Residential Use zone, (ii) Mixed Residential Use zone, (iii) Commercial Use Zone, (iv) Light Industrial use zone, (v) General Industrial use zone, (vi) Special and Hazardous Industrial use zone, (vii) Institutional use zone, (viii) Open Space and Recreational Use zone, (ix) Agriculture use zone and (x) Non-urban use zone. Further considering the character of (then) existed developments, the CMA was divided into three areas viz. (i) George Town and Continuous Building Area, (ii) Chennai City, Municipal and Township areas (excluding the areas mentioned in (i)), and (iii) rest of Metropolitan area.

The CMDA has been periodically reviewing the land use zoning part of the plan. When a large number of requests are received in a particular area, comprehensive reclassifications have been made not only for residential activities, but also for industrial activities, such as zoning of about 300 m on either side of Poonamallee By-pass Road, OMR, etc.

In 1980, the Development Control Rules provisions were comprehensively reviewed and amendments made whenever necessary particularly in respect of plot extent for residential and commercial developments.

Floods in the City

Historical Floods

Past Records have shown that there were several catastrophic flooding in Chennai in 1943, 1976 and 1985 caused by heavy rain associated with cyclonic activity. These events

of catastrophic flooding were found to be attributable to failure of the major rivers and other drainage systems.

1943

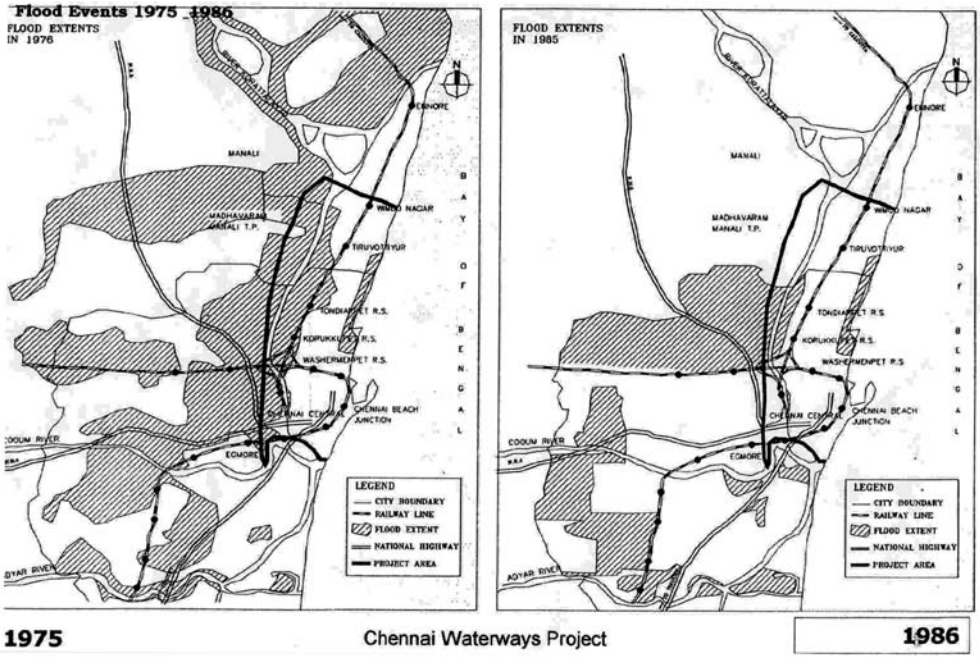
The floods of 1943 damaged the Cooum river badly. Based on the Er.A.R.Venkatachary's report the Govt. had improved the Cooum river and provided a sand pump at the river mouth for removal of sand bar.

1976

In 1976, Adyar, Kosathalayar and Cooum caused heavy flooding of several low-lying areas, and breaches in the bank resulted in heavy damages to the Housing Board Colony. Er.P. Sivalingam Committee had given it's recommendations for prevention of further damages from floods and recommended schemes worth about Rs.12 Crores to be implemented then under priority and schemes worth Rs.10 Crores in the long run (at the 1970's rates).

1985

In November 1985, a rainfall of 727 mm in a span of three days leading to flooding and water logging in many parts of the city.



Recent Floods in Chennai – Detailed Account

2002

October -November

Heavy rains lashed several coastal districts of Tamilnadu including Chennai between October 30 & November 2, 2002. On October 31, Meenambakkam, a southern suburb, received 12.7 cm in just three hours in the evening, while Nungambakkam recorded 7.4 cm. On November 2, 2002, Nungambakkam recorded 16 cm and Meenambakkamrecorded the highest rainfall of 20 cm. The heavy rainfall was attributed to a trough of low pressure, which extended from the Gulf of Mannar to the southwest bay off the Tamil Nadir coast.

Flooding at Madipakkam in 2002

Immediate Impacts

- Many residential areas became `islands' and contact with the outside world was virtually cut off.
- The rains paralysed many parts of the city, leaving thousands of commuters stranded on major roads, scores of vehicles stalled and train and bus services suspended for hours.
- Several parts of North Chennai were heavily inundated with water.
- Water logging also in New Ambattur Industrial Estate Road and at Tirumangalam Police Station, Red hills and Kolathur.

- Anna Salai, Kamarajar Salai, Poonamalee High Road, the three major arteries in the city, and the Inner Ring Road were all choked by flooding of stretches.
- Perambur and Vyasarpadi subways totally submereged - cutting off arterial traffic. In these places, two-wheelers were transported on fish-carts. Doraisamy and Madley road subways were also under couple of feet of water.
- The water-logging on the railway track near Guindy resulted in local train services getting affected. While the EMU services from the Beach station were turned back at Saidapet, those from Tambaram were turned back at St.Thomas Mount. Even some long distance trains were delayed.
- The entire area around the Egmore Railway Station was flooded.
- Water entered several households of Vijaya Nagar and Ram Nagar in Velachery.
- The Keelkattalai bus terminus was covered with sheet of water.
- Severe inundation was also witnessed on Sullivan Garden Road in Mylapore.
- A woman died when she stepped on a live wire on the flooded Sait Colony II Cross Street, Egmore

2004

November

Chennai experienced heavy showers on November 5, 2004. The city about 6 cm rainfall within a period of 24 hours.

On Novermber 12, 2004 due to a trough of low pressure formed over the southwest Bay of Bengal. While Nungambakkam recorded a rainfall of 8 cm and Meenambakkam 5 cm between 8.30 a.m. and 5.30 p.m.

Velacherry

Tiruvottiyur High Road

Immediate Impacts

- Traffic in many parts of the city was affected due to water logging. Motorists had to negotiate knee-deep water on General Patters Road, Royapettah, and many vehicles were trapped in low-lying areas such as Zam Bazaar in Triplicane.
- Stretches of the Poonamallee High Road and Pantheon Road in Egmore were under sheets of water.
- Parts of Velachery and the road from the bus terminus leading to Pallikaranai were badly affected after two days of heavy rain. The road near the bus terminus was flooded and traffic was severely crippled. At Velachery, flooding in several areas forced some schools to declare a holiday.
- In Perungudi and Taramani areas, the road surface has been eroded badly in front of American International School, causing major traffic problems.
- In north Chennai, the Tiruvottiyur bus terminus was flooded and Tiruvottiyur high road suffered severe damage.
- Many slum areas in Tondiarpet were completely inundated.

2005

October

During the north-east monsoon of 2005, a deep depression over Bay of Bengal brought torrential rains in Chennai. The city received 42 cm of rainfall between 8.30 a.m. on 26th Oct 2005 and midnight on 27th October 2005. An additional 18.70 cms was received on October 28, 2005.

Immediate Impacts

- Several low-lying areas, especially in northern Chennai were completely inundated. The worst was Kargil Nagar locality.
- At least 50,000 people in Chennai were shifted to relief centres.
- Schools and colleges remained closed and government offices and private establishments reported thin attendance.
- Buses operated with a skeleton staff.
- Train services were crippled following flooding of the tracks. All trains leaving Chennai were cancelled and those coming into the city stopped at suburban stations, inconveniencing thousands of passengers.
- Flight schedules were disrupted early in the morning.
- The Tamil Nadu Electricity Board, as a precautionary step to avoid electrocution, disconnected power supply in heavily-flooded areas.

- Water logging and uprooted trees created traffic jams in the morning.
- Telecommunication came under strain as the mobile networks were fully jammed and landlines failed in some exchanges.
- Two persons electrocuted in Chennai.
- On November 6, 2005 , six women died and several others injured in a stampede at Dr.Ambedkar Arts College at Vyasarpadi in North CHennai when flood-affected residents made a dash to a relief distribution centre.

November

Around the 20th of November, a depression was formed over southwest Bay of Bengal and generated heavy spells of rain over the coastal parts of Tamilnadu including Chennai over a period of 4-5 days. Between November 21-22, Tambaram recorded 8 cm, Meenambakkam registered 7 cm while Nungambakkam received about 4 cm.

On November 26, Nungambakkam recorded 5.3 mm of rainfall and Meenambakkam received 0.5 mm of rainfall between 8.30 a.m. and 5.30 p.m. The incessant rains lead to flooding in many parts of the city.

Immediate Impacts

- Many areas in the city including Mogappair, Kilpauk and Perambur were flooded with rainwater.
- There was water-logging in parts of western Tambaram. The vast area between Mudichur Road and Tambaram-Somangalam Road was completely inundated.
- The Selaiyur Lake overflowed and flooded areas around Velachery-Tambaram Main Road, throwing traffic out of gear for a couple of hours. The floodwater entered several houses in Selaiyur and Adhi Nagar. Selaiyur police station was also inundated. Water let out from the lake inundated several areas such as Thiruvalluvar Nagar and Ramakrishnapuram in nearby Chitlapakkam.
- Most roads in West Velachery were lying under a sheet of water with the flooding entering into a number of homes at Andal Nagar, AGS Colony, MGR Nagar, Ram Nagar North Extension, Padmavathi Nagar and Muruga Nagar.
- Houses in Mahakavi Bharathi Nagar, Perungalathur are surrounded by waist high water for days now.

December

A cyclonic storm developed in the Bay of Bengal at about 350-400 km east southeast of Chennai. Though the cyclonic system weakened into a well-marked low-pressure area, Chennai and its neighbouring areas experienced heavy rainfall. Numgambakkam in

recorded 23.4 cm rainfall and Meenambakkam 28.2. Tiruvallur district north of CHennai recived 23 cm and CHengalpattu in Kanchipuram to the south reported 15 cm in 24 hours.(between 8:30 am on Decmber 02, 2005 - 8:30 a.m. December 03, 2005). Tambaram, the southern suburb received the maximum rainfall in the state - 31.4 over 24 hours. With the reservoirs already full from the rains during October, heavy flooding gripped the entire city.

Immediate Impacts

- The city's two rivers Cooum and Adyar were in spate forcing thousands of people living along their course to flee their homes. Atleast 75,000 persons were moved to 140 relief camps.
- Houses in Kotturpuram, Ramavaram, Manapakkam were submerged in about 6-7 feet of water. In some parts, residents commuted by boat to buy essentials.
- Stretches of interior roads in Virugambakkam, Arumbakkam, Madipakkam-Taramani and Koyambedu areas were water-logged.
- In Ambattur industrial estate, work was badly affected in 500 of the 2000 units.
- Arterial roads such as the Poonamalle High road, Kodambakkam High road, Arcot Road, Santhome HIgh road were flooded, resulting in heavy trafiic jams.
- Traffic pile-up due to flooding also acute in T.Nagar - vehicle users were stranded in knee-deep water for nearly an hour.
- Purasawalkam High Road and Millers Road were in knee-deep water, while most of Gandhi Irwin Road in Egmore was submerged. Arunachala Naicken Street in Chintadripet was also under water.
- A portion of Inner Ring Road near Tirumangalam junction and the Annanagar West terminus was under water. The Central and East Avenues of Korattur on the city's outskirts and the adjoining streets were in knee-deep water.
- The national highway near Sriperumbudur was water logged, buses from Chennai to Bangalore were diverted via Chengalpattu.
- In the southern suburbs, houses were damaged near lakes such as 'Pazhaya Eri' Moovarasampet, Keelkattalai, Zamin Raayapettai `periya eri', Hasthinapuram and Nemilichery and Selaiyur lakes.
- Water entered the Chennai airport, flooding the departure and arrival halls and the conveyor belt area. Inside Anna International Terminal, water logging was noticed up to the baggage scanning x-ray machines, resulting in the late departure of over 12 international flights, with delays ranging from one to three hours. In the domestic airport, the delay in the departures and arrivals of flights ranged from one to two hours.

- Four dead - Two persons were electrocuted and another two including a child were drowned.
- On December 18, 2005, atleast 42 people were killed and 37 seriously injured in a stampede at a flood relief centre (Arignar Anna School in MGR Nagar) in South Chennai when a crowd of 4000 gathered to collect food coupons.

Kotturpuram

Seetharam Nagar Velachery

Stranded passengers at Central Station

Adyar Bridge

2006

October

On October 27-29, 2006, torrential rains hit several parts of Tamilnadu due to a low pressure that developed in the Bay of Bengal. Some areas that received high amounts of rainfall were in and around Chennai.

On the 27th alone, Tamaraipakkam - one of the catchments for the city reservoirs, recorded 15 cm while Meenambakkam and Red Hills received 14 cm each. Sriperumpudur, Tambaram, Ponneri and Tiruvallur recorded 11 cm each, whereas

Sirkazhi, Parangipettai and Ramanthapuram received 10 cm. The entire city was thrown out of gear with roads getting flooded and public transport being disrupted.

Immediate Impacts

- Water entered homes Ambattur, Vepery, Kolathur, Valasaravakkam and T.Nagar
- The southern suburbs especially Madipakkam, Ullagaram and Perungudi were badly hit. Clogged drains in these areas resulted in water stagnation up to three feet on the streets. The day's worst affected areas were Kubera Nagar and Kubera Nagar Extension, Madipakkam, which resembled an island.
- Residential areas in western Velachery including Saraswathi Nagar, AG's Colony, Netaji Colony, Lakshmi Nagar and Ram Nagar Second Street, V.G.P. Selva Nagar, Annai Indira Nagar and Anna Nagar Extension were flooded with rainwater.
- Several areas falling under Ambattur municipality such as Ram Nagar, Vijayalakshmipuram, Padi Kuppam Road, Ambattur Industrial Estate and Korattur were also flooded.
- Kargil Nagar in north Chennai was covered with two feet of water.
- The stretch from Retteri to Padi junction on Inner Ring Road, Second Avenue at Anna Nagar, Poonamallee High Road, Taylors Road and Dr. Radhakrishnan Salai were flooded with rainwater.
- In Old Washermenpet, two persons were injured when they fell off their bike on Pensioners' Street, 4th Lane, which was under knee-deep water.
- One person drowned in Adyar near Ekkaduthangal off Guindy.
- Several roads in Valasaravakkam lay under water a foot deep, and residential areas such as Sree Lakshmi Nagar, AKR Nagar and Radha Nagar were completely inundated.
- Perambur and Kellys in central Chennai were inundated.
- Ganesapuram subway, which was thoroughly waterlogged, was closed for vehicle traffic and police were regulating the chaotic traffic coming from Vyasarpadi through Stephenson Road and other streets.
- Five of the Metropolitan Transport Corporation's (MTC) - Ambattur, Ennore, Iyappanthangal, Tambaram and Tiruvottiyur - depots reeled under heavy flooding, leading to depleted bus services on Friday. Lakhs of commuters who depend on the MTC's 2,100 plus buses in the metropolis were left to suffer, sometimes for hours, waiting for a bus. — were flooded. The worst affected was the Ambattur depot, which lay under nearly three feet of water.
- All mainline trains to Chennai Egmore from southern districts arrived at least an

hour late due to signal failures between Tiruchi and Egmore. Similarly trains that left Chennai Egmore on Thursday reached their destinations behind schedule.

- Due to water logging on the track between Basin Bridge and Chennai Central, long-distance trains had to be detained at Basin Bridge. They were brought to Chennai Central after the rainwater drained. Suburban services were also hit because of the continuous rain.

Poonamalle High Road

Porur

Kargil Nagar

6th Avenue, Anna Nagar

Govt. declared holiday for all schools on October 27th 2006

Villivakkam Bus Terminus

Perungudi

Fort Station Road

Poonamalle High Road

2007

January

On January 29, 2007, few residential areas of Chennai including Bhanu Nagar, Saraswathy Nagar, Venkateswara Nagar extension and Ayyappa Nagar in Ambattur located on the periphery of the Red Hills lake on Saturday. The lake has been receiving inflow from Poondi reservoir to increase its storage for a few months now. As the inflow into the lake increased, the water spread also increased.

October

On October 28, heavy rains lashed the city of Chennai. Between 8.30 a.m. and 8.30 p.m. on October 28, the Meteorological Observatory in Nungambakkam recorded 11.8 cm rainfall, while the observatory at Meenambakkam recorded 11.7 cm.

- The heavy rains left several roads under water and led to fallen trees. Traffic on P. T. Rajan Salai and Ramasamy Salai in K. K. Nagar, R. K. Mutt Road in Mylapore and at Tirumurthi Nagar near Nungambakkam High Road came to a standstill for a while after trees fell.
- Arterial roads, including Dr. Ambedkar Road in Vyasarpadi, were flooded. The Vyasarpadi Jeeva Railway Station subway was under 2-3 foot deep water.

- Several parts of Perambur were covered with more than knee-deep water.
- Power cuts lasting for few hours were reported from many parts of the city.
- Arterial roads in Velachery and nearby localities were left battered and bruised. Rainwater stagnated on large swathes of Velachery Main Road between the Vijayanagar Bus Terminus and the Gurunanak College.
- The Taramani Link Road and Medavakkam Main Road was also inundated.
- A tree fell across the railway tracks near Perungalathur delaying several trains.
- October 29 was declared a holiday for all schools in the city.

Radhakrishnan Salai, Mylapore

Vyasarpadi

Slums inundate at Saidapet

Vyasarpadi Subway

Kargil Nagar

Taramani

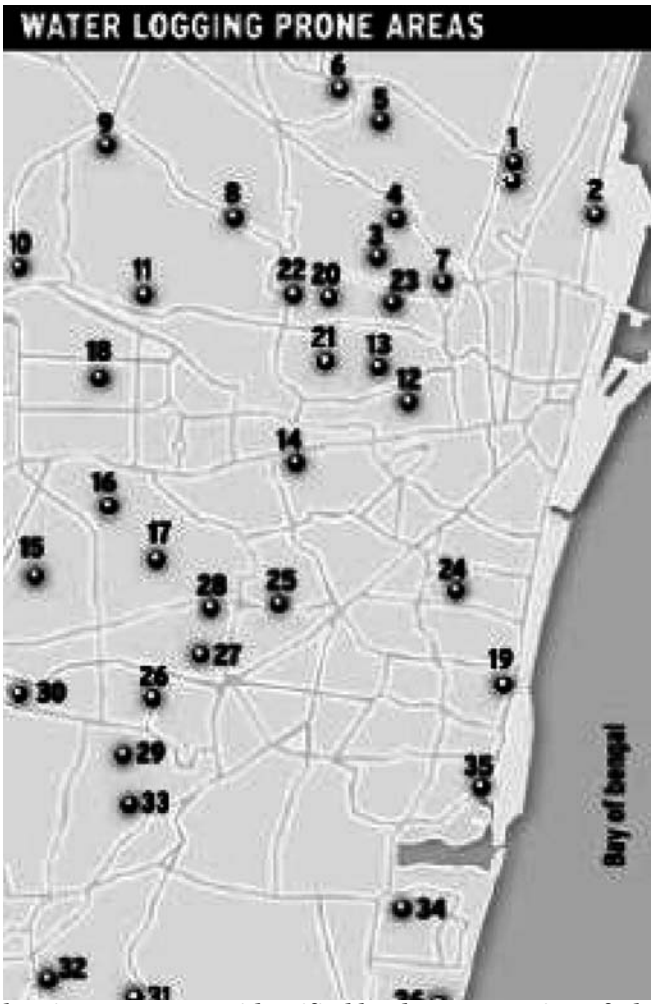
Flood Vulnerability

From the flood hazard map of India, it is seen that no area in Tamilnadu falls in the risk zone. But within a local body area, particularly with reference to an area's proximity to a major drainage system like rivers, canals and other waterbodies like lakes, and further with reference to contour levels / low-lying areas, flood prone areas mapping has to be done.

In Chennai Metropolitan Area (CMA), there are a few areas along the rivers and canals and low-lying areas, which are susceptible to flooding / inundation. The Chennai Corporation has identified 36 localities within the city that are prone to inundation during the monsoon.

The localities identified are: 1. Tondiarpet; 2. Royapuram; 3. MKB Nagar; 4. Sathyamoorthy Nagar; 5. Kannadasan Nagar; 6. Muthamizh Nagar; 7. Pulianthope; 8. Perambur; 9. Kolathur; 10. Villivakkam; 11. Ayanavaram; 12. Choolai; 13. Periamet; 14. T.P. Chathram; 15. Virugambakkam; 16. Arumbakkam; 17. Choolaimedu; 18. Anna Nagar; 19. Ice House; 20. Nammalwarpet; 21. Purasawalkam; 22. S.S. Puram; 23. Kosapet; 24. Mirsahibpet; 25. Valluvar Kottam; 26. Mambalam; 27. Rangarajapuram; 28. Trustpuram; 29. Ashok Nagar; 30. K.K Nagar; 31. East Velachery; 32. West Velachery; 33. Saidapet; 34. Adyar; 35. Foreshore Estate and 36. Tiruvanmiyur.

These parts of the city get inundated each year during the October - January, which is when the north-east monsoons hit the state. Even relatively short bursts of intense rainfall are sufficient to cause local flooding in these parts. .



Water logging prone areas identified by the Corporation of Chennai

(Source: http://www.hinduonnet.com/2007/08/09/stories/2007080955880600.htm)

Factors Responsible for the Floods in Chennai

The analysis of the meteorological data clearly shows that the reason for the increase of floods in Chennai is not based on a long or medium-term trend reflecting increasing precipitation amounts at the eastern coast of India. In fact there is no significant upwards nor downwards trend to identify during the last 200 years. The last 20 years are characterised by a decrease of annual precipitation, although the number of floods affecting the inhabitants of Chennai is increasing.

(A. Drescher et. al, Risg Assessment of Extreme Precipitation in the Coastal areas of Chennai)

Listed below are some factors responsible for floods in Chennai city and its suburbs even under conditions of moderate precipitation.

Uncontrolled Urban Sprawl & Loss of Natural drainage

Uncontrolled urban sprawl has a number of important consequences with regards to urban floods. Out of necessity, spatial development and water were closely interwoven to historic cities. Watersheds were left intact and were often further developed with the objective to harvest rainwater and mitigate floods.

Chennai's natural terrain allowed for floods to drain into the watercourses of north Chennai including the Kosastaliyar, the Buckingham Canal, Otteri nullah and the Captain Cotton Canal. Cutting across the metropolis is the river Cooum and channels that lead into this river. In the South is the Adyar river. Further south is the massive flood plain that stretches from the fringes of Keelkattalai extending into the Pallikkaranai marsh-Velachery Lake, down to the Okkiyam Madagu and Buckingham Canal.

Historically, the growth of the city was also supported by a system of irrigation links and tanks. According to historical records the state had a tank for every 3.3 sq. km area. In Chennai alone, it is estimated that there were 352 tanks though no systematic study has been made.

(*Source: http://www.hinduonnet.com/2003/06/25/stories/2003062508490300.htm)*

Since the beginning of the 20th Century, Chennai has witnessed a steady deterioration of and decrease in water bodies and open spaces. Several people settled down in lake areas and in dry beds of water bodies. The reason being that it is cheaper to buy land and build a small shelter on. Over the years, these houses have been getting bigger. The Government itself, over the years, has built tenements in such areas. For instance, officials concede that the State Housing Board has built colonies on the sites, which were once part of Velachery and Mogappair lakes. Here too, the reason remains the same - less expenditure for government to take over the land.

Natural drainage channels too have been blocked and urban lakes have been filled upon and encroached upon. The rapid growth of the metropolis - planned and unplanned - has resulted in the filling up of substantial portions of this once well-managed water management system.

The Cooum, Adyar and the Buckingam canal today are highly degraded and polluted. They are heavily silted up and narrowed down due to encroachments. The Sludge disposal consultancy study conducted in 1994 has revealed that contamination of waterways and

anaerobic digestion of waste water in the waterways has led to accumulation of sludge causing hindrance to the hydraulic functyionning of the water ways.

The Cooum river narrowed down by encroachments

(Source : http://www.hindu.com/2008/04/21/stories/2008042158880300.htm)

The highly polluted Captain Cotton Canal

Another classic example of degradation of wetlands is the slow disappearance of the Pallikaranai marsh on the outskirts of Chennai. Pallikranai was once a rich wetland spreading over 5,000 hectares, extending from Velachery to Sholinganallur in the east and Jalladampet in the west. It was home to several hundred species of flora and fauna. The marshland also served as an important retention area for strong precipitation during the monsoon.

Garbage being dumped at Pallikaranai

Around the mid-1990s, the Tambaram - Velachery Highway was re-laid. Thanks to this well-laid road, the area has been blessed with enviable development. However, in proportion to this development, the marsh lost its value as a well-balanced ecosystem. Normless constructions and inflow of sewage and other pollutants stripped the swamp of a large extent of land and also of its the fauna and flora.

These constructions, effected without regard for the natural contours of the wetland, have resulted in the clogging of the natural conduits in the marshland. The result, the runoff into the low-lying marshland gets blocked and in the recent times aggravated the frequency and intensity of floods in and around the marshland. Residents in the Velachery - Madipakkam - Nanganallur belt face recurrent floods every year. A number of factors contribute to the inundation. Veerangal Odai, a canal that carries floodwater from areas including Nanganallur and Adambakkam into the Pallikaranai swamp, is not properly linked to the swamp. It terminates abruptly about 2 km before the swamp and this aggravates the problem. Another factor is the lack of enough culverts to enable draining of floodwater from Velachery into the swamp.

The Koyambedu marshland was another wetland that died on the pedestal of development. About 15 years ago the area used to have a lot of wild growth attracting a large number of birds. During monsoon, rainwater used to get stored in the marsh and

it helped in maintaining the groundwater table in the western parts of the city. A few years ago, the marshland was taken over by the Government for housing the vegetable and fruit markets and bus terminus.

Koyambedu wetland converted into the Moffusil Bus Stand

The Adyar creek, originating near the Chettinad Palace, and then meandering through Foreshore Estate and ending at Mandavelipakkam has today been reduced to half its original size - 100 acres. The ingress of the sea through this creek has been arrested because of the silt that has formed at its mouth due to the dumping of garbage and the line of encroachments, especially at the Karpagam Avenue bridge. The fragments that have fallen from a dilapidated footbridge also clog the creek. Due to all these factors, the local fishermen are denied an easy fishing option and the area is also deprived of a natural flood control mechanism.

Satellite Image of the Adyar Creek

Lakes, ponds, canals and tanks have also been encroached upon. The Korattur Lake, a prime source of water for Ambattur Municipality has turned into a reservoir of sullage. Spread over 996 acres with a capacity of 232 million cubic feet, it is one of the largest water bodies in the Ambattur circle. The water body, which was used for irrigation and earlier supplemented the city's drinking water supply, has shrunk in size due to dumping of refuse. It is now partly covered with hyacinth and choked with debris, including industrial effluents.

Storm water drain carrying sewage

During the 2005 floods, Thiruvalluvar Nagar in Mugalivakkam near Porur was submerged under 2 - 3 feet of water. The waterlogging was primarily due to the shrinking of the Manapakkam channel. The channel - once 40 feet wide - drains surplus water from the Porur lake as well as the storm water into the Adyar river at Manapakkam. Due to encroachments and poor maintenance, the flow of water was nil, resulting in the flooding.

(Source: http://www.hinduonnet.com/2005/12/15/stories/2005121518380300.htm)

Temple tanks - a man-made feature in the water management system, are today degraded backyard spaces. The water inlets to the tanks have been completely cut-off - either by constructional activities or with debris and litter. This loss of tanks would result in flooding, as in the case of Vyasarpadi, where 16 tanks were taken over.

Inadequacy of Storm water Drainage System & Lack of maintenance

Chennai City has only about 855 km of storm drain as compared to 2,847 km of urban roads. Besides this inadequacy, the problem of water logging in Chennai gets aggravated every year because drains were not maintained properly. Originally meant to carry rainwater during monsoon period, the drains should remain dry during other seasons. But they are found with water stagnation throughout the year often leading to mosquito menace. Thus, most of the existing ones too have become nothing more than conduits of sewage and solid wastes.

The consumer culture, to which the fast developing Chennai belongs, further adds to the woes of the city. Plastics are often major constituents in the packaging of all kinds of consumer goods. Once the product is unwrapped, the discarded packaging frequently becomes a major contributor to the storm water stream, thereby exacerbating the floods.

Increase in Impermeable Surfaces

Continuous and unplanned growth of the city has covered up open spaces, which have earlier facilitated free flow of storm water. Urban areas including Chennai characterized by high area under impervious surfaces such as roads, pavements, houses and so on. High rates of development along with the loss of soft landscape can lead to high surface water run-off rates. Moreover, there is a tendency in middle and high-class residential areas to pave roads whenever possible. This results in flash floods in low-lying areas even after moderate precipitation.

Lack of Co-ordination between agencies involved in flood control

A number of agencies are responsible for management of storm water in the city. These agencies often blame each other for this lack of maintenance.

Agency	Responsibility
Chennai Metropolitan Development Authority (CMDA)	Project Packaging, Management, Monitoring and Co-ordination
Public Works Department (PWD)	Plan, design and Implementation of Macro-drainage systems (Rivers, Tanks and Surplus Channels)
Chennai Municipal Corporation (CMC)	Plan, design and Implementation of Micro drainage works (Storm water drains)
Tamilnadu Slum Cl;earance board (TNSCB)	Planning, design and construction of storm water in slum resettlement
Tamilnadu Housing Board (TNHB)	Planning, design and construction of storm water on their housing colonies.

The lack of a unified flood control implementing agency that integrates the function of the Chennai Corporation, the CMDA, the CMWSSB and the Slum Clearance Board to carry forward strategies throughout the year, rather than just before the monsoons.

Efforts made to mitigate and manage the Floods

Flood Alleviation Project, 1998

The Government accorded approval for Flood Alleviation Scheme under G.O.Ms.No.321, HUD dated 12/08/1998 for implementing the structural measures in 4 packages with a total cost of Rs.300 crores. The aim of the project was to alleviate the perennial problem caused due to flooding and to improve the environment.

Important Objectives of the Project:

- To ensure and maintain adequate flow in the arterial drainage system
- To prevent and remove impediments to drainage
- To provide safeguards against tidal and fluvial flooding
- To improve all macro drainage networks covering major waterways and canals within CMA and micro drainage network covering storm water drainage network within Chennai City. Improvement measures include desilting of the waterways in the CMA, resectioning and strengthening of the banks, provision of flood protection measures. Structural measures like replacing all old bridges, improvement of existing drains and provision of pumping arrangements and plugging of sewer outfalls into the waterways.

- Further an important component of this scheme was the relocation and rehabilitation (R&R) of encroachers living on the waterways.
- The macro drainage works like structural measures were implemented by Public Works Department and the Resettlement and Rehabilitation works are implemented by Tamilnadu Slum Clearance Board. The CMDA as the nodal agency helps to obtain funding from HUDCO and co-ordinates the implementation of the project. The project is being implemented with 70% of the cost as loan from HUDCO and the remaining 30% from the Government budgetary support as grant. Government will repay the loan through budgetary provisions.
- The macro drainage works were grouped into four packages based on their geographical existence and based on different water courses in CMA and also to obtain loan for better implementation and management.

Package - I

Improvements to waterways in Chennai (Coovum River, Virugambakkam - Arumbakkam Drain and Otteri Nullah) and Resettlement and Rehabilitation;

Package - II

Improvements to waterways in Chennai Buckingham Canal

Package-III

Improvements to waterways in Chennai Adyar & Flood Banks of Kosatalayar

Package-IV

Improvements to waterways in rest of Chennai Metropolitan Area and sandbar removal at the mouth of Coovum River and Adyar River

Cleaning up of the Velachery Lake

Project Progress

The projects have been taken up in phases for execution and up to mid-2005 they have been executed including an expenditure of about Rs.106 Cores.

1. Under R&R Component implemented by TNSCB 3000 tenements had been constructed at Okkiam Thoraipakkam to resettle the slums in the flood alleviation project along 'B' Canal and Adyar river.
2. Desilting of South Buckingham Canal, construction of retaining wall, formation of jeep track along the banks and construction of 10 vents in North Buckingham Canal, repairs to its linings had been completed.
3. Construction of flood defences and resection of the rivers Kosasthalaiyar had been completed.
4. In respect of Adyar river, construction of flood defences and resection works are nearing completion except for the desilting work in the East of the Thiru Vi Ka Bridge.
5. Works in Ambattur Tank Surplus Course, Madhavaram Tank Right Flank Surplus Course and Pallikkaranai
6. 70% of the works in respect of the Red Hills Surplus Course works have been completed; remaining works in this Course and the works in Madhavaram Tank, Chembarambakkam Tank, Korattur Tank Surplus Courses are to be completed after required lands are acquired. Improvements to Otteri Nallah, Virugambakkam - Arumbakkam drain had been completed.
7. Drainage relief works to Velachery area is nearing completion except for the court stayed short stretches.
8. Improvement to the Cooum river from sea mouth to Periyar bridge have been completed and from Periyar bridge to Koyambedu will be taken up after completion of R&R works.
9. The Micro Drainage works to the tune of Rs.43 crores have been implemented by the Chennai Corporation for improvement of the drainage system in Chennai Corporation area integrating with the Macro Drainage System.

Clean up storm water drain in Nanganallur

Chennai City River Conservation Project (CCRCP), 2000

In order to improve the conditions of waterways in Chennai a comprehensive package of projects with an estimated outlay of Rs. 1,700 crores was prepared. The projects proposed included sludge removal and disposal from waterway banks, improvement of macro drainage network in the catchments, improvements of micro drainage network in the the city, improving the water quality of rivers and waterway, strengthening urban drainage network in the city, construction of sewage flow interceptors and treatment facilities. It was posed to Government of India for funding under the National river Conservation Programme. Out of the proposed , the Government of India approved in the year 2000 the schemes for interception, diversion and treatment in Chennai at a cost of Rs. 491.52 crores and it was implemented by Chennai Metropolitan Water Supply and Sewage Board (CMWSSB). In addition, the remaining works to the cost of Rs. 228.63 crores was taken up by the CMWSSB.

Second Master Plan Provisions

Drainage

1. All the structural and non-structural measures recommended in the Madras Metro Flood Relief (MMFR) / Storm Water Drainage (SWD) Master Plan Study Report of 1992-93 should be implemented to alleviate the existing flood problems and also to ensure prevention in future during the plan period (considering more than 50% of

the 2026 population is proposed to be accommodated in the rest of CMA, and the City will also get densified additionally by 35%.).

Structural Measures Recommendations

S. No.	Structural Works	Cost (Rs. in million)
1.	Pallikkaranai Scheme	160
2.	Flood defences and channel improvement on the Cooum	348
3.	Flood defences and channel improvement on the Buckingham Canal	96
4.	Flood defences and channel improvement on the Otteri Nullah	125
5.	Flood defences and channel improvement on the Captain Cotton Canal	20
6.	Flood defences and channel improvement on the Madhavaram Surplus Channel	10
7.	Flood defences and channel improvement on the Red Hills Surplus Channel	215
8.	Flood defences on the south side of the Kosasthalaiyar	50
9.	Manali Township drainage and flood protection	40
10.	Urban storm water rehabilitation and repairs	35

All cost estimates are preliminary - year 1993

Non-structural Structures Recommendations

1. Designated floodways on the North side of the Kosasthalaiyar with associated planning controls and flood warning/evacuation procedures.
2. Design guidelines for drainage systems
3. Planning and regulatory controls to prevent development in old tank beds unless adequate flood defence measures are in place
4. Planning and regulatory controls to prevent encroachment of squatter settlements in old tank beds and watercourses
5. Provision of good facilities (vehicles, communications) for flood emergency management
6. Public education (e.g. to prevent solid waste dumping in urban drains)
7. Flood risk mapping
2. In CMA, all the lakes vested with the departments/agencies (such as Revenue

departments, etc) other than PWD, should be transferred to PWD for its proper maintenance. Further, all these lakes and major drainage system within CMA should be brought under the control of a separate Division/Circle in PWD, which should be, in-charge of continuous planning and implementation of flood alleviation projects and maintenance of these water bodies.

3. The lakes / water bodies should be protected from encroachments and existing encroachments should be evicted by the departments/agency concerned bringing the water bodies to its original state.
4. The lakes may be developed not only as a flood accommodator and for ground water recharge, but also as open space with trees as wooded areas.
5. Drainage system around Pallikaranai area has to be designed taking into account of the I.T. development and also future developments in the area.

Sewage

Under Ground Sewerage Scheme in the Urban Local Bodies

CMWSS Board has been appointed as a nodal agency to implement under ground sewerage schemes in the urban areas adjacent to the city. Under Ground Sewerage Schemes have already been implemented in Alandur and Valasaravakkam municipality and are under various stages of implementation in Ambattur (Part), Pallavaram, Thiruvottriyur and Madhavaram (Phase-I) municipalities. In case of Ullagaram-Puzhudivakkam, the board has prepared the plan and submitted to the municipality for arranging funds under JNNURM.

Detailed Project Reports (DPR) are under preparation for 6 municipalities, namely Maduravoil, Kathivakkam, Madhavaram (Phase-II), Avadi, Ambattur (Left out Area), Tambaram, Porur Town Panchayat and Ramapuram and Manapakkam Village Panchayats.

For the following adjacent urbanized local bodies (5 Municipalities, 17 Town Panchayats, 22 Village Panchayats and one Cantonment) CMWSS Board has invited tenders to prepare Detailed Project Report for providing Under Ground Sewerage Scheme. On finalization of Detailed Project Report the work will be taken up in Phases under JNNURM Scheme.

Municipalities	1. Poonamalle 2. Thiruverkaddu 3.Pammal 4.Anakaputhur 5. Manali
Town Panchayats	1. Chinnasekkadu 2. Meenambakkam 3. Naravarikuppam 4. Thiruninravur 5. Minjur 6. Thirumazhisai 7. Mangadu 8. Nandambakkam 9. Puzhal 10. Kundrathur 11. Perungalathur 12. Peerkankaranai 13. Chitlapakkam 14. Sembakkam 15. Madampakkam 16. Perungudi 17. Pallikaranai.
Village Panchayats	1. Kottivakkam 2. Mugalivakkam 3. Pozhichalur 4. Cowlbazaar 5. Kilkattalai 6. Nerkundram 7. Ayanambakkam 8. Madipakkam 9. Neelankarai 10. Okkium-Thoraipakkam 11. Injambakkam 12. Koilambakkam 13. Medavakkam 14. Karapakkam 15. Iyyappanthangal 16. Ayapakkam 17. Vanagaram 18. Nolambur 19. Kattupakkam 20. Seneerkuppam 21. Mathur 22. Palavakkam.
Cantonment	1. St. Thomas Mount

Construction of Additional Sewage Treatment Plant at IT Corridor

South Chennai is witnessing rapid growth and development especially due to IT and IT-based industries and associated housing projects. The present capacity of Perungudi Treatment plant is not adequate to match the growing needs. Therefore, it is proposed to construct an additional 54 MLD capacity Sewage Treatment Plant at Perungudi. The proposal has been approved by the Government of India under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) at an estimated cost of Rs.31.48 crore by JNNURM. The work will be taken up during the current year and will be completed in 18 months.

Improvements to the sewerage facilities in Guindy Thiru Vi Ka Industrial Estate

Guindy Thiru vi ka Industrial Estate Manufacturer's Association's long-pending request for rehabilitating and upgrading the sewerage system has been accepted and accordingly the project has been sanctioned at an estimated cost of Rs.6.95 crores. The work has been commenced during December 2006 and will be completed.

Strategies for flood control at Chennai

1. Encroachments and obstructions to the waterways are indeed the main causes for floods in the city. The level of encroachment has increased manifold between 1985 and 2005. Clearing the encroachments is essential to provide relief.

2. Identifying lakes, water bodies and their flood channels both inlets and outlets.
3. Shrinking of marshlands are causing floods in Chennai. Clear demarcation of areas where no development or encroachment can be allowed.
4. Revival of temple tanks and other small tanks in Chennai.
5. Detailed Development Plans need to show the pathway of the flood carrier through every neighbourhood. If building a road across a waterway or lake is unavoidable, plan the required number of siphons and their size to carry huge flood levels.
6. Avoid narrow roads in new layouts. The minimum road widths should be a minimum 33 ft., so that there is enough space for storm water drains, and a clearly demarcated and isolated sewage system.
7. The local communities should be involved in the protection to protect lakes, rivers and water bodies. Make them responsible for the lake upkeep. People living near water should be imparted knowledge about water as a natural resource and methods by which water may be preserved and conserved. In short, they should be made water literate. Government should facilitate the process by providing technical assistance and part-funding.
8. Vigorously continue the desilting operations and river water conservation projects so that sewage fallout into water bodies is completely avoided.
9. The use of Geographic Information System (GIS), Global Positioning System (GPS) and Remote Sensing (RS) data to plan drainage for Chennai is essential. Appropriate action should be taken at the earliest.

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