WATER, MEGACITIES AND GLOBAL CHANGE

MUMBAI

Case of Greater Mumbai

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Part A

CHAPTER 1
Geography, History, Resources, Infrastructure and Economy

1.1: Introduction

Mumbai, the largest City in India, is also its financial capital. The population of the city grew at a compound rate of 1.8 percent from 1941 to 2001. However, it is now showing signs of stabilization with less than five percent population growth in the last decade.

a. Geography and history

Mumbai, population 12.4 million (2011), was originally a group of seven fishermen's islands gifted by Portugal to England when a Portuguese princess married the King of England! The town started growing after the British shifted their headquarters on the Indian west coast to Mumbai in 1686. The original seven islands, which were joined to each other through a causeway project called Hornby Vellard during 1782 to 1838, now form the Mumbai City District (island city). These areas are covered in Wards A to G in the map on page 2. Four other islands, including a large island called Salsette, now form the Mumbai Suburban District. (Wards H to R in the map)

During the last few years, the city has experienced extremely high rainfall on individual days during the monsoons causing fears of inundation in low-lying areas. The National Action Plan for Climate Changei (NAPCC, 2008) has projected an increase in temperature by about two degrees Celsius over the next fifty years and increase in the average rainfall by about twenty percent over the next twenty years. Flood management during the monsoons has thus emerged as arguably the most serious challenge before the civic administration.

b. The city, its economy and priorities

The City Council (Municipal Corporation of Greater Mumbai- MCGM) encompasses both City and suburbs and today three-fourth of the population of Greater Mumbai lives in the suburbs. Mumbai houses the headquarters of the Reserve Bank of India (India's Federal Reserve) and of two largest stock exchanges (bourses) of India. The ports of Mumbai and New Mumbai (called Jawaharlal Nehru Port Trust) are two large ports in India. Mumbai contributes the largest collection of both the Direct and Indirect Taxes in India and it is

thus rightly called India's Financial Capital.

Although Mumbai is one of the four main metropolises in India, it enjoys a dominating primacy in the Marathi-speaking state of Maharashtra. With 0.12 per cent area of the state of Maharashtra, it has 13% population of the state, 37% urban population, 48% of registered working factories and 52% of average daily industrial employment of the state. Financial activities are even greater with 87% Joint Stock companies of the state headquartered in Mumbai. This is why the Marathi people resisted the creation of Mumbai as a separate centrally administered territory during the late fifties and 105 citizens died from police firing during 1955-57 in a political unrest that resulted in a new Marathi-speaking Maharashtra state with Mumbai as its capital.

Figure 1: Map of Mumbai with Location of Storm Water Pumping Stations

Although fifty-six percent of Mumbai's citizens live in slums, the inequalities are not extreme and the conditions of life in slums are better than many poverty-stricken Indian villages. In other words, nobody starves in Mumbai and every one can get some education and health cover! As for most large metropolises there is continued rural-urban migration towards Mumbai. The Gini Coefficient of income inequality in Mumbai is 0.34, much lower than that of Johannesburg (0.75), Sao Paulo (0.61), Mexico City (0.55) or Accra (0.50). It is the same as Indian National average and is higher than that of Bangalore (0.32), Pune (0.21) or Beijing (0.22)![ii]

In a City Council election, the citizens voted the following priorities as their expectations from the City Council. It is thus seen that citizens are particularly dissatisfied by the conditions of roads in the city, which get badly battered both by the heavy traffic as well as heavy lashing (2500 mm of rainfall) during the four monsoon months. Recently, the Bombay High Court (Yes! The name of the High Court is still Bombay) has declared 'good roads' as a Fundamental Right of the citizens[iii] and has directed the Municipal Corporation of Greater Mumbai to ensure that the roads are in good condition.

Table 1: Perceived top needs of citizens in Mumbai as revealed by a survey[iv]
(By a daily newspaper in Mumbai in 2007: more recent surveys were not so specific!)

S. No.	Priority	Percentage of citizens -Voting for priority
	Road repairs/ paving to be expedited	86%
	Better medical facilities in City	79%
	Improved garbage collection	78%
	Cleaning up of drains and sewerage	76%
	Clean water supply in suburbs	75%
	General cleanliness to prevent diseases	73%
	24-hour water supply	71%
	Faster disaster management	69%
	Greater transparency in administration	64%
	Greater transparency in fund utilization	59%
	More trees to be planted	53%
	More schools	53%
	More open spaces and gardens	50%
	Expedite major projects like storm water drainage	49%
	More powers to BMC Commissioner	48%

1.2: Ecology

a. Precipitation

The ecology of Mumbai is driven in part by the large amount of precipitation that falls in the city. The following table compares the average precipitation in mm and the number of days of precipitation in some major cities of the world. (Data collected from Internet figures)

Table 2: Precipitation patterns of some major cities of the worldv

S. No.	Name of the City	Average annual precipitation in mm	Average number of days of precipitation
1	Cairo	22	5
2	Paris	585	164
3	London	594	107
4	Beijing	623	66
5	Washington D.C.	991	112
6	Rio de Janeiro	1093	131
7	Tokyo	1563	104
8	Hong Kong	2209	130
9	Singapore	2273	180
10	Mumbai	2413	104

Thus Mumbai gets a rainfall four times that of Paris in only sixty-three percent of the days, which are concentrated in the Monsoon months from June to September.

The topography of the island city is relatively flat with some reclaimed areas between the islands precariously close to the mean sea level (MSL). Some of the underpasses under the railway lines and roads are actually below sea level during high tide, therefore water pumps need to be deployed to drain out water during monsoons. The city is saucer-shaped with some areas in the middle being lower than the High Tide Line (HTL). Thus,

when water accumulates at these points during monsoons, it is difficult to drain it by water pumps as the level of water elsewhere is higher.

The Mithi River, which is actually the outflow of the largest lake within Mumbai, the Vihar lake, has many interesting features. The river divides the western suburbs of Mumbai facing the Arabian Sea from the eastern suburbs facing the mainland Maharashtra and Thane Creek. Near its mouth, it also divides the original island city of Mumbai from its western suburbs. Bandra-Kurla Complex (BKC), the new commercial centre of Mumbai is a reclaimed area from the muddy and slushy banks of the Mithi river. The river gets its water overflow of the Vihar and Tulsi lakes only during the monsoon months. Waste water from both the suburbs and the northern part of the city is released in the river in a rather uncontrolled manner throughout the year. The last six kilometres of the river are subjected to considerable tidal action. Flooding from the Mithi River had caused considerable damage (Rs. 2.47 billion) in Mumbai during the 2005 floods. Flood protection by proper training of its riverbanks is thus a high priority for the city administration. There are many smaller rivulets in the suburbs that carry both flood water and waste water. Training of their courses and desilting them before monsoons is a key function of the Municipal Corporation with necessary management during the months of April and May to reduce the risk and impact of flooding.

Table 3:
Mumbai: Topography, rainfall and storm water drainage system

Greater Mumbai has two administrative districts- Island City formed by merger of seven islands and the suburban districts formed by merger of four islands
Surrounded by Arabian Sea to the west and Thane Creek to the East
Rainfall Characteristics: Average annual rainfall: 2400 mm Rainfall for the year 2010: 3500 mm (46% higher than average) Rainfall for the year 2011: 2900 mm (21% higher than average) Rainfall in the years from 2012 to 1014: 2400 mm (average) Rainfall in the year 2015: 1765 mm (26% below average) 35 to 40% of the annual rainfall occurs in just three or four events.
Legacy Storm Water Drainage System: Gravity system without pumping arrangement Number of catchments-121 System more than 100 years old Designed for 25 mm rainfall and Run-off coefficient of 0.5

b. Land and reclamation

The seven islands comprising Mumbai City were joined together by a sea wall called Hornby Vellard, named after the then Governor of Bombay, Hornby. The intervening shallow areas were subsequently reclaimed, giving to the city a saucer-like structure. This reclaimed area was systematically planned through Town Planning Schemes that gave Mumbai relatively straight and wide roads! Mumbai Port Trust also had its own reclamation of land from the sea mainly through the Apollo Reclamation scheme. About one-eighth (750 hectares) of the Mumbai City district area is the land reclaimed and also owned by the Mumbai Port Trust on the eastern waterfront. There are persistent demands that this land should be released for development on the lines of London Docklands. The Ministry of Shipping of the Government of India is studying the matter.

Another major reclamation on the western water front of the island City was under a scheme undertaken by the then provincial government of Bombay with a name Back-bay Reclamation Scheme. Reclamation of eight blocks was originally intended under the Back-bay Reclamation but the scheme was stopped during the 1930s after reclamation of four blocks. Two more blocks were reclaimed during the 1970s and further reclamation was completely stopped in 1978 due to criticism that the scheme was shifting the main commercial area to one extreme end of the city besides creating environmental hazards. The Apollo Reclamation and the Back-bay Reclamation schemes house some of the most important buildings in Mumbai like the Taj Mahal Hotel, Air India Building, the Maharashtra State Government's secretariat and Council Hall.

A large area in the city (2152 hectares) adjoining the creeks and the sea is inundated by sea water during high tides. This area is classified as Salt Pan land. This land is today not available for development. The Government of India has constituted a Group of Ministers to examine how this land can be protected and released for development.

A serious limitation on the development of lands on waterfronts was imposed by the Coastal Zone Regulation (CRZ) of the Environment Protection Act, 1991. Under this regulation land abutting the sea (classified as CRZ-I) cannot be developed and land on the landward side of an existing road (CRZ-II) has restrictions on development if it is located within a distance of 500 metres from the waterfront. Under the CRZ Notification 2011, this restriction is reduced to a shorter distance of 100 metres for the areas facing bays and not the main sea.

CHAPTER 2
Institutional framework

2.1: Governance structure

In India, there is a three-tier governance structure: the central government (Government of India in New Delhi), the state government (in Mumbai's case, the Government of Maharashtra in Mumbai) and the local government (MCGM) in Mumbai. The City and suburbs send six Members of Parliament (M.P.s) to the National parliament, 33 members to state legislative assembly and also elect 227 elected municipal councillors, who constitute the Municipal Corporation. All the three bodies are elected for a period of five years, however the elections to all three may not be held in the same year. The City Council (MCGM) elects a Mayor for a period of two and a half years. There is City Manager type administration in Mumbai. The municipal commissioner (City Manager) is a very senior officer from the Indian Administrative Service from the cadre of officers of the Government of Maharashtra. He is appointed as Municipal Commissioner by the state government for a period of three years. Although the municipal commissioner is appointed by the state government, he is answerable to the elected councillors and if they pass a 'No Confidence' motion against the Commissioner with a five-eighth majority, the state government is obliged to withdraw the commissioner and replace him by another officer.

2.2: Water Supply

Water Supply and Sewerage in a majority of Indian cities is handled by state government parastatals usually called Water Supply and Sewerage Boards. Thus the City Councils of Delhi in northern India, Kolkata in eastern India, and Chennai, Bangalore and Hyderabad in southern India, do not handle the work of water supply and sewerage. There are separate Water Supply and Sewerage Boards to discharge this function. However, in Mumbai and other cities like Ahmedabad and Pune in western India, water supply and sewerage is an obligatory function of the City Councils. Nevertheless, water supply and sewerage is given a separate sub-budget called 'G-budget' within the overall budget of the MCGM. Thus, the Municipal Commissioner (City Manager) supervises the water supply and sewerage function in Mumbai, just as he supervises other municipal functions like solid waste management, roads, storm water drainage, elementary education and public health. For water supply and sewerage, he is assisted by an Additional Municipal Commissioner and several engineers under the Hydraulic Engineer and Chief Engineer (Water Projects). The Commissioner has to obtain approvals of the MCGM or its committees for all major works. The Regional Planning Authority, the Mumbai Metropolitan Regional Development Authority (MMRDA) has no direct role since water supply is a municipal function.

There are numerous governance advantages in keeping water supply and sewerage as a City Council function. The councillors, who have to face elections every five years, impart a direct political accountability to water supply along with other municipal functions. In fact, water supply is often the main subject producing maximum public outcry and complaints if there is even a little slackness or disruption in its supply. The public takes it for granted that the drinking water supply should be smooth and normal and any disruption can invite even physical attacks on the water supply engineers. This is why water supply is monitored very carefully so as to cause minimal disruption. It is true that on the whole, the public is unhappier with conditions of roads in Mumbai (Reference: Table 1) and there have been court litigations asking for better roads. However, the tolerance level of public about deficiency in water supply is the lowest. Community participation in water supply is largely achieved at the ward office level whenever there is any deficiency in supply since ward offices are within a walking distance for most consumers.

Table 4: Water Supply Sources for Mumbai: Present and future sources

S.No.	Source	Yield in thousand m3/day
	Present sources	
1	Vihar	90
2	Tulsi	18
3	Tansa	455
4	Vaitarana	455
5	Upper Vaitarana	635
6	Bhatsa	2020
7	Middle Vaitarana	455
	Total (Existing)	4128
	Future sources	
8	Gargai	440
9	Pinjal	865
10	Damanganga	1586
	Total (Future)	2891
	TOTAL	7019

When the Mumbai city was very small, piped water supply from two lakes, namely Vihar and Tulsi, within the boundaries of present Greater Mumbai, was enough to supply water to the city. Today more than 97 percent of 3900 million litres per day of water comes from large lakes created through dams on rivers in the neighbouring Thane district of Maharashtra state located on the North-East side of Mumbai city. The Water Resources Department of the state government of Maharashtra allots these sources to individual

municipal corporations. These dams were built from 1955 onwards and are at a distance of about 100 km. A majority of these dams were constructed by the MCGM itself, although two large dams belong to the state Water Resources (Irrigation) department. Capital expenditure on water supply projects is shared with central and state governments. However, no external funding has been asked for during the last many years. An advantage enjoyed by Mumbai city is that all these lakes are at a higher altitude than the city, which as noted is mostly at sea level. Thus, most of the water flow to the city is through gravity and the power bill for pumping is not very large. In this respect, Mumbai city is blessed in view of its being a coastal city with the western Ghat mountains at a distance of less than 100 km. There are other cities in India where water needs to be pumped by electricity against gravity for scores of kilometers and this pushes the cost of water to unreasonably high levels. Water is further treated with pre-chlorination, alum dosing, settling, filtration and post-chlorination before supplying to customers. There is substantial cross-subsidy in this sector. Industrial and commercial users subsidize the slum-dwellers and other poor. While deciding the water pricing for different categories of consumers, the municipal corporation keeps the price higher than the cost price for the industrial and commercial consumers so that it can supply water at cheaper and lower than the cost price rates to the slum-dweller and other poor consumers.

The price of water to the poorest domestic consumers in Mumbai at about 8 US cents per m3 and is one of the lowest in the world. The cost of production is about 25 US cents per m3. This compares extremely well with the cost of $5 per m3 in Boston and 3.3 Euros per m3 in Francevi! However, bottled mineral water usually costs Rs. 10 a litre i.e. about US $ 16 per m3, more than two thousand times that of tap water! This cost includes wastewater collection, treatment and taxes as well as fixed costs. Most of the households usually use tap water for drinking and cooking purposes but many households further purify it through a membrane system like Aqua Guard. Many middle class consumers do not insist on bottled water in their offices or in restaurants although in high-end offices it is becoming fashionable to offer bottled water to visitors.

As far as total quantity of water entering Mumbai City is concerned, it is just about adequate for its population. The planning for new sources of water supply for Mumbai is, till recently, a race between rising population and additional water brought in the city. However, there is a great scope for improvement particularly at the micro-level i.e. distribution level. The Water Distribution Improvement Programme (Sujal Mumbai) is underway addressing the following main issues: water distribution network upgrade to provide continuous supply, reduction in UFW (unaccounted for water)/ NRW (non-revenue water), universal metering (to improve information and water billing), telescopic tariff structure for water consumption (to aid in water conservation) and 24x7 water supply (to provide resilience to supply to all customers).

Until recently, the large number of non-functional meters was a bane of water supply administration in Mumbai, with the result that water bills reverted to being determined by the diameter of the connection. Out of the old meters only about half are working today. However, five years back, the MCGM installed new meters with regular monitoring. Almost eighty percent of the new meters are working.

In addition, there are more than 12000 wells in Mumbai, out of which about 5000 are dug wells and 7000 are bore wells. These are used to supply tanker water to needy consumers and for gardening purposes. The bore water, however, is often untreated and unsuitable for drinking. The total contribution of these groundwater sources may not be more than two percent of the total water supply.

On the whole, both the quantity and quality of drinking water supplied to the city of Greater Mumbai is one of the best in India. Although there are stray cases of contamination of water in slums and older areas of the city, tap water is fairly safe to drink. However, in many upscale establishments, it is fashionable to drink bottled water. In a Mumbai restaurant, one of the first questions asked is whether the guest wants bottled water or tap water, the latter is usually free of cost.

Table 5: Main challenges in water supply sector

1	Quantity	3900 thousand m3 of water is quite adequate for the population. Moreover, with only five percent growth in the last decade, the population is showing signs of stabilization. Nevertheless, future projects are planned for a higher population.
2	Quality	There are occasional complaints of contamination. However, with an improvement in sewerage and storm water drainage there has been considerable reduction in the pollution load.
3	Non Revenue Water	On a high side- about 30 percent
4	Way Ahead	Moving towards 24x7 supply. Equitable distribution of water Reduction of non-revenue water Improvement of information management (GIS, Customer's database, Customer Relationship Management and Customer Information System, Assets Management

2.3: Sewerage

Mumbai is divided in seven sewerage zones, two in the city and five in the suburbs, for collection, conveyance and disposal of sewerage. Sewage collection system comprising gravity underground sewer network and online satellite pumping station are grouped in such a way that the entire quantity of sewage collected from that zone is delivered to the terminal point in that zone. However, only about 65 percent of the population of Greater Mumbai is covered with sewerage network and many slums are yet to be covered. Sewerage tax is recovered through water bills and it is usually sixty percent of the water bill. Wherever water meters are functional, the consumers get the water bills based on the reading; wherever water bills are dysfunctional the water bills are charged as a percentage of property tax. The sewerage tax is added as sixty percent of water tax to the same bill for properties that are connected with sewerage.

Many of the Sewage Treatment Plants in Mumbai are quite old and the quality of treated sewage leaves much to be desired. The Love Grove Plant was commissioned in 1880 and the Dadar plant in 1938, although these were subsequently upgraded. The Colaba Love Grove and Bandra sewage treatment plants discharge the treated effluents about three kilometers into the sea through marine outfalls, while Aerated Lagoon technology is used at Versova, Ghatkopar and Bhandup Sewage Treatment Plants. Unlike the mainland Indian cities like Delhi, Hyderabad and Pune, there is little scope for recycling the waste water for agricultural/ mining purposes in Mumbai city since the city is at sea level and it would be uneconomical to pump the waste water against gravity for irrigating lands for agricultural purposes.

Table 6: Flow data of treatment plants under Chief Engineer (Sewerage Operations), MCGM, Mumbai

Sr. No.	Name of Sewage treatment plant	Year of commissioning	Average volume of sewage treated in dry weather	Average volume of sewage treated in wet weather
1	Colaba WWTF	1988	25 thousand m3/day	33 thousand m3/day
2	Love Grove WWTF	1991	400 to 450 thousand m3/day	800 to 850 thousand m3/day
3	EPS abd WWTF Bandra Zone	2003	450 to 500 thousand m3/day	750 to 800 thousand m3/day

4	Charkop STP	1992	4.5 thousand m3/day	9 thousand m3/day
5	Versova WWTF and lagoons	1998	85 thousand m3/day	110 thousand m3/day
6	Malad WWTF	1998	138 thousand m3/day	212 thousand m3/day
7	Ghatkopar WWTF and lagoons	2003	125 thousand m3/day	167 thousand m3/day
8	Bhandup WWTF and lagoon	2003	128 thousand m3/day	183 thousand m3/day

A major landmark called the Mumbai Sewage Disposal Project I (MSDP-I) was completed in 2009. The up-gradation of sewage treatment has resulted in improvement in coastal water quality, health benefits through reduced water pollution, aesthetical benefits like reduction of odour and floating debris and increased fish yields reported by fishermen. However, some expectations of a world-class city sewerage are yet unfulfilled. These expectations include completion of sanitary sewerage network in the unsewered areas in Mumbai; creation of treatment and disposal system in such a way that the effluent meets the environmental regulations and connecting the flow from the slums into the duly completed conveyance system. It is also necessary to ensure that the sullage and sewage is not allowed to enter into underground storm water drains in city and open drains in suburb.

2.4: Storm Water Drainage

Mumbai gets an annual rainfall of about 2500 mm spread over only four monsoon months. Singapore also gets a similar rainfall. However, the rainfall in Singapore is more evenly distributed over the entire year. This makes it necessary in Mumbai to have storm water drains that can carry almost four times more water than in Singapore. These drains remain idle for the remaining eight months and it is not uncommon for drains to become solid waste disposal receptors during the dry period. Cleaning of these drains is a major pre-monsoon exercise for Mumbai.

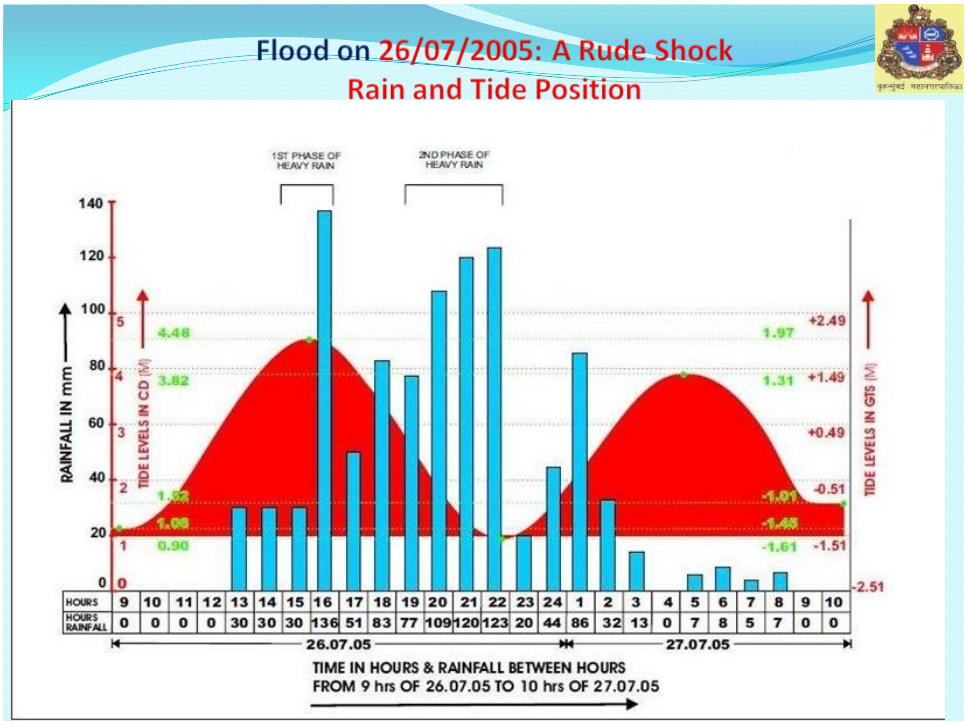
Figure 2: Widening of storm water drains

Irla Nallah before widening

Irla Nallah after widening

In Mumbai during monsoons, many a time the hourly rainfall exceeds 50 mm per hour. Most of the drains in city are covered drains but the suburbs continue to have many open drains. Although a large storm water drainage project is under way, the improvements will not be able to withstand a very heavy rainfall of more than 100 mm per hour coinciding with a high tide as it happened on 26th July 2005 (Mumbai's signature event). It often happens that even with a 100 mm rainfall in a day, some low-lying areas of the city are water-logged for a few hours until the drainage system can discharge the water.

Figure 3: Rain and high tide position on the 26th July 2005



In island city the storm water drainage system is mostly underground, whereas in the suburbs the system is open ditches and channels. The storm water drainage system was designed with the design intensity of 25 mm per hour rainfall with an average run off coefficient of 0.5. It is now observed that the intensity of rainfall sometimes exceeds 100 mm per hour, multiple times during an event and in a day. On 26 July 2005 the highest intensity was 136 mm per hour. While designing the older storm water drainage works, the run-off coefficient was presumed to be 0.5 since it was expected that 50 percent of the water would be absorbed in the sub-soil. However, while designing the new storm water drains, the run-off coefficient is considered to be to be 1.0, i.e. it is presumed that no water will be absorbed in the subsoil and the entire quantity of storm-water will have to be drained off through the drains.

2.5: Disaster Management

For the last decade the disaster management plan of MCGM has revolved around the likelihood of flooding on the scale of the fateful day of 26th July 2005. Floods were caused by the heaviest rainfall (more than 900 mm) ever to lash the metropolis in a single day! More than 150 people died in Mumbai, 85 due to landslides, 50 by drowning, 33 due to wall collapse, and ten by electrocution. Another 247 persons died due to water related diseases like leptospirosis and gastroenteritis as an aftermath of floods. The number of dead buffaloes was 1307 and sheep and goat was about 15000. A total of 50000 residential and 40000 commercial buildings and 30000 vehicles were damaged. The total loss to Mumbai's economy was estimated at Rs. 2.47 billion.

Local train movement came to a halt by 2:30 pm due to the water logged tracks, the subsequent train disruption led to increased vehicular traffic on roads. A large number of people were stranded on the road, lost their homes and many walked for long distances back home from work that evening. Water logging and submergence of certain low lying pockets such as Dharavi, Bandra-Kurla Complex, Milan Subway brought the traffic to a grinding halt.

Figure 4: Photographs from the 2005 flood

Kurla

Flyover bridge

Bandra


Wadala

The situation worsened when the cell-phone networks broke down around 5 p.m. and landlines were only partially functional. Adding to the chaos was the lack of public information. Radio stations and many television channels did not receive any weather

warnings or alerts by the civic agencies. The Meteorological department blamed it on unavailability of sophisticated weather radars which would have given a 3-hour prior warning. (Doppler radars have been subsequently installed in Mumbai by the Meteorological department.) Because of high tides the flood situation kept on aggravating throughout the night.

Due to submergence of power stations and substations, suburban power supply was suspended from the evening of the 26th July, it was restored only after the flood waters receded. In fact, restoration of power supply in suburbs took about four days because of damaged equipment.

Thousands of children were stranded due to flooding and could not reach home for up to 24 hours. The following two days were declared as school and college holidays by the state government to allow time for recovery. However, Mumbai city recovered from the shock quickly and within a couple of days the life had returned to normalcy. Handling of Mumbai floods was compared favourably with the handling New Orleans floods due to Hurricane Katrina only a month later where the recovery time was longer. The event of the 26th July 2005 brought the need of effective disaster management into a sharp focus. Therefore, every summer, the highest priority of the civic administration is the planning for the monsoons.

The rain water caused the foul sewage system to overflow and all water lines were contaminated. The government ordered all communities to chlorinate the water tanks of individual societies. Thousands of animal carcasses floated in the flood waters raising the risk and concern about possibility of disease. The media issued reports warning of the threat of waterborne diseases, hospitals and health centres geared up to distribute free medicines to check any outbreak.

The municipal machinery mobilized and ensured safe evacuation of people in boats and buses. Shelter was provided to them in public buildings and schools. Massive relief and rehabilitation measures had to be undertaken to recover from this major disaster.

In mid-June 2015 another big storm hit the area with 284 mm rainfall in a single day on the 19th June. Water accumulated on the suburban rail tracks and the trains stopped. Offices and schools were closed and students were asked to go home. However, it is our general observation that any city in India comes to a standstill when it gets ten times the average daily rainfall!

Part B

CHAPTER 3
Climate Change

3.1: Effect of Climate Change

The Environmental Vulnerability Index (EVI)vii devised by the SOPAC (South Pacific Applied Geosciences Commission), UNEP and others to characterize the relative severity of various types of environmental issues suffered by 243 enumerated individual nations and other geographies, has listed India in the 'Extremely Vulnerable' category. However, it is worth noting that Italy, Japan and Singapore are listed as more vulnerable than India. The predicted consequences of climate change are expected to exacerbate the city's ongoing vulnerability to flooding if urgent measures are not taken to improve storm water drainage systems and shore up other flood control measures.

Coming to specifics, the Impact Estimates made by the Peterson Institute of International Economics, Washington D.Cviii in 2007, expect a 3 degree Celsius rise in average temperature during the current century for south-western India that includes Mumbai. The same estimates also anticipate that the average annual daily rainfall will increase by 0.34 mm, an increase of less than 2%. This would work out to be an annual increase by 124 mm or less than 5% of the current 2400 mm. As far as Mumbai city is concerned, this increase in rainfall is unlikely to significantly change the problems associated with heavy monsoon events. However, an increase in average rainfall would reduce the risk of water shortages since the lakes supplying water will be filled up. The increase in average temperature would make Mumbai as hot as Chennai, the southern Indian city! According to average temperatures in India on www.current results.com, the average maximum temperature for Mumbai is 31 degrees and that for Chennai 33 degrees Celsius. The scale and significance of these increases does not certainly point to a catastrophe for Mumbai!

A World Bank Reportix, 'Turn Down the Heat- Why a 4 degree centigrade warmer world must be avoided', released in Nov 2012 observes that the likelihood of 4 degree centigrade warning being reached or exceeded this century has increased in the absence of near-term actions and further commitments to reduce emissions. The report reaffirms that in the absence of further mitigation action there is a 40 percent chance of warming exceeding 4 degrees centigrade by 2100 and a 10 percent chance of it exceeding 5 degrees in the same period. Unusual and unprecedented heat extremes and rainfall regime changes are two consequences that will affect the coastal cities in India. Thus while

an increase of temperature by 2 degrees appears certain and unavoidable, our efforts could be focused on controlling higher increases in temperature.

The report causing a major concern in academic circles is the risk consultancy Maplecroft's reportx. According to this report, five cities with maximum risk of economic fallout up to the year 2025, are Dhaka, Mumbai, Manila, Bangkok and Kolkata, incidentally all coastal Asian cities in the equatorial region. The consultancy says that the rankings are based on each city's exposure to greater flooding, storms, drought, wildfires and so on.

During the summer of 2015, India witnessed an extreme heat wave that claimed more than 2200 lives. Meteorology department projected that this will be followed up by a relatively weak monsoon. The Earth Sciences Minister of India has gone on record that both of these are signs of climate change. However, unless this trend is seen for a decade or more, it would be hasty to attribute an individual year's heat wave or weak monsoon to climate change! Annual fluctuations in the mean temperatures and rainfall are common and expected- it is the weather after all! The 2015 heat wave and the irregularity of rainfall are also not seen to be catastrophic, but does not replace the need for better sanitation, storm drainage and flood protection for Mumbai.

3.2: Field situation and National Action Plan for Climate Change (NAPCC)[xi]

During the 20th century there has been an increase of 17 cm in sea level and now the sea level is rising faster. While the sea level in Mumbai was increasing at the rate of 1.3 mm per year earlier, it is now increasing at the rate of 3.1 mm per yearxii. However, the sea level rise is countered by sedimentation. These changes have not so far had a significant impact on water supply and sewerage sectors in Mumbai. However, it is now more common to attribute floods, high tides during monsoons and intense rainfall for shorter duration followed by long dry spell, to climate change. A five-year old study by the disaster management cell of MCGM (2009) had shown that although the number of days with rainfall of more than 75 mm has not increased substantially, a more recent study by MCGM (2015) shows that during the last five years, the number of days with more than 50 mm rainfall has increased. In any case, over the past ten years the number of days of flooding has increased. More flooding could be primarily due to increased imperviousness of Mumbai area as a result of more construction in the city. The challenge before the city administration is therefore to quickly drain off the rain water to the sea, particularly when there is a high tide. MCGM has undertaken several measures to strengthen the storm water management during monsoons. The number of pumping stations for both sewerage and storm water drainage have been increased thus reducing the risk of

flooding in low-lying areas. To prevent landslides, 288 retaining walls have been constructed on hill slopes and dangerous buildings have been identified for remedial action. The Mumbai Building Repairs Board, a parastatal of the state government carries out repairs to the old and dilapidated residential buildings.

The National Action Plan for Climate Change (NAPCC) carried out a sea-level analysis for Maharashtra Coastline. The global mean sea level is projected to increase by 300 mms to 550 mms by the end of the 21st century for a medium range climate change scenario. The range for Maharashtra coastline is 240 mm to 660 mm. These predictions also include increase in wave heights and wind speeds, more storms and storm surges. As these changes will increase the risk of flooding, the local governments on the nation's coastline have started taking preparatory action.

The changes in climate are also projected to have adverse effects on the population, primarily by increasing the number of days when malaria transmission will be more likely along with increased risk of water-borne diseases. This will require strengthening of health infrastructure and reinforcing the need for more secondary and tertiary facilities in the hitherto uncovered areas. To cater for this requirement, the MCGM has decided to set up a new Medical College in the now populous western suburbs.

The Climate Change will also affect local flora and fauna, such as loss of mangroves, fish and associated biota due to increased inundation of marsh lands by sea water and the subsequent increased salinity of water. Preservation of mangroves from the increasing population has been attempted by a ban on their destruction. The mangroves have also been declared as reserved forests under the Indian Forest Act, 1865.

CHAPTER 4
Innovations in Technology and management

4.1: Problems and solutions

At the national level many innovative schemes have been undertaken to counter the effects of drought and unpredictability of monsoons. Jal Yukta Shivar Abhiyanxiii (Watering of agricultural lands) is a scheme to fight drought, undertaken in Maharashtra and replicated in Rajasthan, for conservation of water on a watershed basis. This programme aims to make 5000 villages free of water-scarcity every year and to make the entire state drought free by 2019 and to harvest rainwater within the village boundary. The 'One drop scheme' is another scheme for conservation of water taken up in Odisha, a state on the eastern coast of India. However, as far as Mumbai city is concerned, usually

there is sufficient rainfall in the catchment area and there is enough reservoir storage (lakes) capacity, thus water supply remains relatively more secure. However, the main challenge is how to improve the distribution and to provide 24x7 supply to all.

In Mumbai, the total non-revenue water (NRW) is of the order of 24 to 33 per cent, which needs to be brought down to 10 to 12 per cent. Without this reduction, a 24x7 water supply for Mumbai is a distant dream. It is difficult to keep water distribution lines full of water in Mumbai for 24x7 supply, as 50 percent population lives in slums. There is no space for constructing suction and overhead tanks in these areas. The city's terrain has a lot of variations since many portions were reclaimed from the gaps between the seven islands and these are much lower than hill tops. The present goal, achieved in two wards, is 24x7 water supply up to suction tank level of individual buildings. To take this up to each consumer, MCGM will have to provide a very sophisticated and pressure sensitive water distribution network and hydro-pneumatic system for every building due to their elevation difference. This will shift the entire responsibility of operation and maintenance including the cost of pumping up to the consumer end to MCGM. The city's experiment of providing hydro-pneumatic control systems failed in Malad area due to technical, operational and maintenance reasons. In Nagpur city of Maharashtra, which is much smaller and flatter, 24x7 water supply has been achieved under the guidance of the French Company Veolia. The average per capita consumption in Mumbai is 190 lpcd (litres per capita per day), comparable to world class cities. However, the slum-dwellers get only 50 lpcd of water every day and a few elite consumers get up to 600 lpcd. Although the metered connections are 75 percent, a number of slum dwellers pick up water from common stand-posts. Conversion of these to metered community connections is an ongoing process. However, a leak detection and repair programme is a must, particularly in the slum areas.

Greater Mumbai witnessed a very rapid rate of growth of population during the later part of the twentieth century, however the growth has slowed down in the last decade. The following table shows the growth in population of Greater Mumbai over the last fifty years.

Table 7: Increase in the population of MCGM
(From Census Reports of the Registrar-General and Census Commissioner of India)

Year	Population of MCGM (millions)
1961	4.1
1971	5.9
1981	8.2
1991	9.9
2001	11.9
2011	12.4

The unauthorized housing sector, which includes some slums and the shanties, get water supply on humanitarian grounds. The removal of hutments on the water supply trunk mains is a major challenge before the administration. However, a number of hutments on the pipelines have been resettled elsewhere in the past few years.

In sewerage management, taking the entire flow from slums into the duly completed conveyance system is a major challenge. The treatment and disposal systems are to be so improved as to comply with the pollution control norms. The prevention of leakages and the choking of drains need a lot of improvement.

4.2: Subsidiarity and participation by community-

Although Greater Mumbai has a single city council, the headquarters find it very difficult to remain in touch with its 12 million people. The city is, therefore, divided into twenty-four wards with local government offices. Wards have populations ranging from 300000 to one million. Day to day operations and maintenance of municipal works is handled by these offices. Active participation and engagement with citizens is ensured through the elected councilors from the ward and direct contact between the citizens and the ward offices. Resident Welfare Associations called ALMs (Advance Locality Management) are active in many wards of Mumbai. Day to day problems in water supply connections, connections to new buildings, complaints of sewer overflow and overflowing of storm water drains are handled by the Assistant Commissioners stationed in Ward Offices. During heavy rains and water-logging the ward office, being on the front line of response, decides to install more pumps. Any local grievances not redressed promptly are taken to the Municipal Commissioner in the headquarters on Lokshahi Din (Democracy Day) in the first week of every month.

The community also participates through numerous NGOs in disaster management. During 2005 floods, NGOs and Social organizations arranged food packets and drinking water for stranded people and helped the municipal machinery in clearing of animal carcasses and garbage. Many NGOs have trained swimmers as their members, they step in when there is even a little flooding in the city. The City Fire Brigade, under the Municipal Corporation, is also trained to tackle other situations of disaster management like floods and cyclones.

4.3: City Master Plan

In India, the city development plan (D.P.) is a proposed land-use plan for a twenty-year period. Development Control Rules (D.C. Rules) that govern the Floor Space Index (FSI)/ Floor Area Ratio (FAR) are approved first by the Municipal Corporation and then by the state government along with a new Development Plan. Under the Maharashtra Regional Town Planning Act, 1966, a new Development Plan is to be prepared after every twenty

years. The new D.P. prepared in 2014 for Mumbai has bogged down into a quagmire of controversies as there were some visible mistakes and controversial suggestions. An Officer on Special Duty and the Municipal Corporation are examining each suggestion in the Plan.

In India, it is very common to make very ambitious development plans that cannot be implemented during the twenty years life of the plan. For example, the 1967 D.P. was implemented to the extent of only 25 percent. The land prices in Mumbai have sky-rocketed to such an extent that the Municipal Corporation finds it impossible to acquire lands reserved for public purpose by paying a fair compensation to the owner. Therefore, it was necessary to add to the 1991 D.P. the concept of TDR (Transferable Development Rights) where the owner can get equivalent development rights elsewhere in the city. However, only 13 percent of the land under reservations was acquired for public purpose during the last twenty years, out of which almost eighty percent was acquired through the instrument of TDR.

Water Supply and Sewerage Plan is not a part of the Development Plan (D.P.) of a city, which is a land use plan prepared under the Maharashtra Regional and Town Planning Act, 1966. The D.P. prescribes the land use of lays down the Floor Space Index (Floor Area Ratio) for each user. Recently the Bombay High Court has passed an order (in a particular case of rental housing) restricting the government from approving higher Floor Space Index without ascertaining the infrastructure available. On the other hand, future projects for augmentation of Water Supply are identified in consultation with the Water Resources department i.e. the Irrigation Department of the state government. In case of Mumbai city, water sources located to the north-eastern side of the city in Thane district are identified for future development of water supply. Water sources located on the south-eastern side are identified for the new town i.e. the Municipal Corporation of New Mumbai.

The restrictions on coastal development in the development plan in a way ensure that buildings are not constructed dangerously close to the water bodies.

4.4: Desalination, recycling and artificial rains-

Although desalination of sea water is often discussed as a possible solution to augment the water supply of Mumbai city, it continues to be very expensive when compared with existing water sources and is an unfeasible proposition for Mumbai. The cost of desalination of water is almost ten times the average cost of lake water being supplied in Mumbai and would also use substantial amounts of energy versus supply of lake water by gravity. The southern state of Tamil Nadu, where the capital Chennai faces an acute water

shortage, has many ongoing and commissioned projects. However, the first five operational RO-based desalination plants in Chennai were producing only 0.5 thousand m3/day of freshwater and that too, costing about Rs. 70 per m3, more than seven times the cost of lake water brought to Mumbai. Both membrane-based and thermal-based desalination continues to be much more expensive than the natural water in Mumbai. In India desalination is a viable option only in the water scarce areas!

Recycling of treated water is also not popular in Mumbai since there are hardly any primary sector activities like agriculture or mine washeries where such water could be used. As fresh water is easily available, the Indian mind is quite conservative against the use of treated water in kitchen or for bathing. There is very little scope for personal gardens for most of the households in Mumbai. In cities that are upstream to good agricultural lands, treated water is often used for agriculture. However, as natural water is cheap in Mumbai, there has not been much effort to treat either the sullage from kitchen sink (grey water) or sewage or toilet water (black water).

Whenever the monsoon rains are delayed, there is talk in Mumbai of inducing artificial rains by seeding rain-bearing clouds. This was actually attempted on a small scale during the past few years. These attempts have not proved particularly successful.

In Mumbai, when it rains, it pours! Thus, not many buildings take up rain-water harvesting since wells usually get water without harvesting. However, the quality of well water is not very good for drinking or cooking purposes.

4.5: Disaster management-

From the Disaster Management point of view, Mumbai Emergency Management Exercise (MEMEX) undertakes a series of rigorous training and workshops focusing on evacuation, pre-hospital care, hospital care, and disaster preparedness.

The current preventive work comprises the widening of water outflows in rivers like the Mithi, other rivulets and water drains. As far as storm water drainage in Mumbai is concerned, planning, designing and implementation of holistic scheme of pumping stations, holding ponds, retaining structures with new design criteria to prevent flooding when the intensity of rainfall is 50 mm per hour or more for 10 hours, are all covered in the plan.

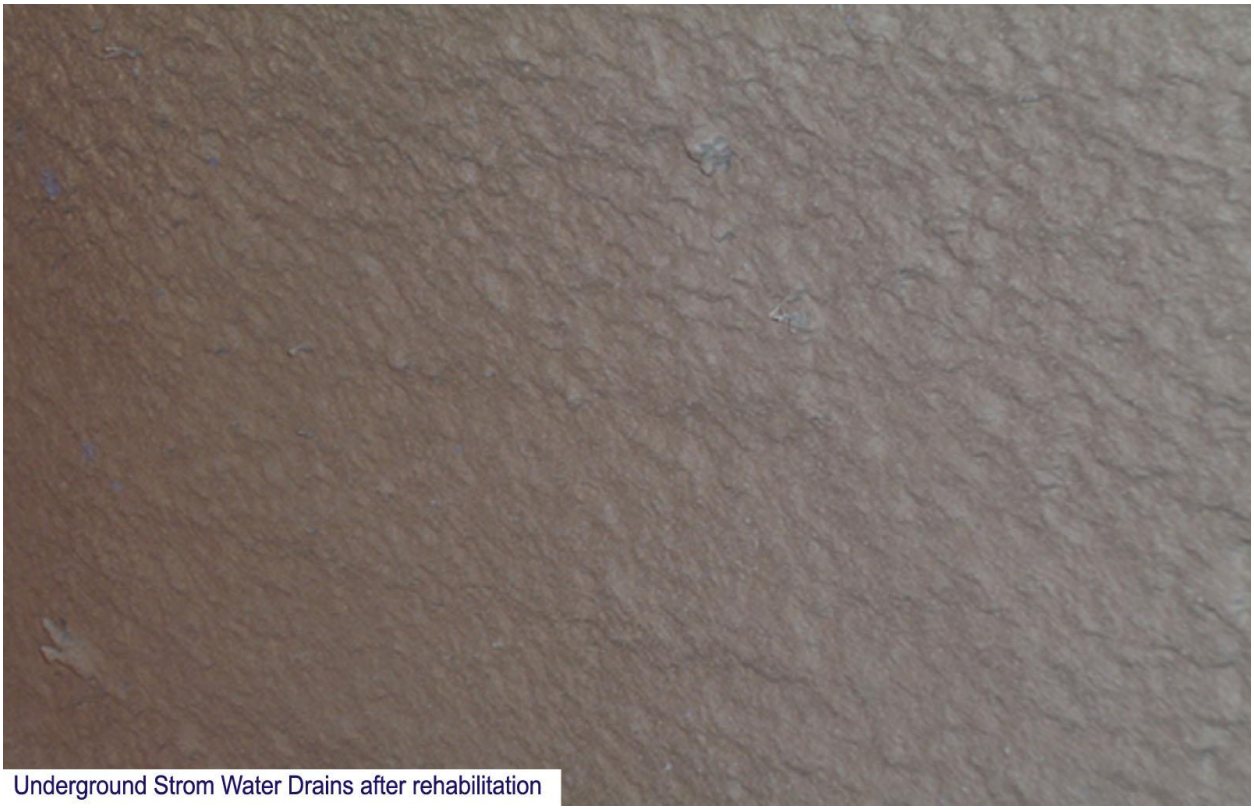
Figure 5: Rehabilitation of underground storm water drains

Pathe Bapurao Road before rehabilitation

Pathe Bapurao Road after rehabilitation

Figure 6: Rehabilitation of underground storm water drains

Underground Strom Water Drains before rehabilitation



Underground Strom Water Drains after rehabilitation

Large parts of Mumbai City were reclaimed from the sea when the original seven islands were joined together. Thus the city has many areas that are marginally above the mean sea level. The high tides in Mumbai are almost 5 metres higher than the mean sea level (MSL). During the four monsoon months of June to September, the administration has to be very vigilant and it has to ensure close coordination with the Meteorological department, particularly if heavy rains are predicted to coincide with high tide.

4.6: The summer of 2016

The lakes supplying drinking water to Mumbai received deficient rainfall during the monsoon of 2015 and a 20 per cent cut had to be applied to Mumbai's potable water supply. Swimming pools were closed down and cricket matches under the Indian Premier League were shifted out of Maharashtra state under a court order as the green pitches were considered as water guzzlers. However, barring sporadic complaints of short supply due to low pressure in elevated areas, there are no major complaints of inadequacy of water for basic needs in Mumbai city. As the slums in Mumbai are often located on marginal lands, water pressure is low in some of them.

The summer of 2016 was particularly harsh in India. Phalodi in Jodhpur district of Rajasthan registered the highest recorded temperature ever in India at 51 degrees Celsius. 28000 villages in Maharashtra are reeling under drought. A small (about 300,000 population) Municipal Corporation City called Latur, about 500 km from Mumbai was supplied water by railway tankers through 50-wagon train rakes. This was the first time that water was transported on a large scale by train in India.

Although the effect of water cut in Mumbai is nowhere as serious as in Latur, the Municipal Corporation of Greater Mumbai (MCGM) has taken several measures to augment its water supply against likely occurrence of poor monsoon in future. MCGM has worked to increase the water supply by 255 m3 from August 2016 onwards. This additional water will come from lake tapping, improving the existing water distribution network in catchment areas and setting up recycling facilities at water treatment plants.

MCGM currently draws 1590 m3/day from the Vaitarana water system through three dams called Upper Vaitarana, Middle Vaitarana and Lower Vaitarana. The old pipeline is being replaced by a new tunnel, which has been constructed as part of MCGM's lake tapping experiment. This should be able to draw an extra 40 m3/day, making the total available water from the three dams as 1630 m3/day.

MCGM gets bulk of its water supply from the Bhatsa dam. The water distributing system has been improved at Pise pumping station enabling MCGM to draw 2015 m3/day instead

of 1910 m3/day at present. MCGM has also set up two water recycling plants at Pise pumping station and a water treatment plant at Bhandup, which should provide 60 m3/day and 50 m3/day respectively. It is important to note that all the above efficiency gains have been made indigenously by MCGM engineers.

4.7: Conclusion

On the whole, Mumbai faces multiple challenges related to rural-urban migration and the development of a robust infrastructure to support this growing population. Water supply sources are good but distribution to all of the city's populace is a challenge. The monsoon weather experienced by Mumbai and the low lying coastal nature of the city continues to put it at significant flooding risk. Monsoon preparedness has become a systematic annual exercise so that the city does not come to a grinding halt as a result of heavy rains and sea water flooding! Climate Change predictions are yet to induce an urgency or a systematic action by the city administration.

Figure 7: Widening of open storm water drains

Kranti Nagar near Mumbai International Airport Culvert before widening

Kranti Nagar near Mumbai International Airport Culvert after widening

[i] www.moef.nic.in/sites/default/files/Pg01-52_2.pdf
[ii] For Indian cities, shodhganga.inflibnet.ac.in/bitstream/10603/36111/9/chapter%206-pdf by S. Tripathi: for International cities www.unhabitata.org.jo/en/up/Upload/2233036_pages%20from%20Report-English-rd-2-pdf
[iii] In the High Court of Judicature at Bombay, Ordinary Civil Jurisdiction, suo motu Public Interest Litigation No. 71 of 2013, Order pronounced on 20 May 2015
[iv] This is from the personal notes of co-author Dr. Jairaj Phatak, who was appointed as Municipal Commissioner, Mumbai in May 2007. This was a survey by a newspaper immediately after municipal elections of 2007. We are sorry that we could not get the date and other details of the newspaper in spite of our best efforts!
[v] www.statcon.gc.ca/tables-tableux/sum-som/lo!/csto1/phys08a-eng.htm
[vi] Dardel.info/EauAnglais.html
[vii] www.vulnerabilityindex.net
[viii] William Cline: Global Warming and Agriculture: Impact Assessment for country
[ix] www.worldbank.org
[x] https://maplecroft.com/portfolio/new.analysis/2013/10/30/31-global-economic-output-forecast-face-or-extreme-climate-change-risks-2025
[xi] www.moef.nic.in/sites/default/files/Pg01-52_2.pdf
[xii] Climate Institute-Oceans and sea level rise; www.climate.org/topics/sea-level
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