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# Mumbai Monsoon Floods – 2005 Impacts and Possible Mitigations

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**Abstract**

*Mumbai, the largest megalopolis with 18 million plus population on the west coast of India was subjected to a devastating flash flood on 26 July 2005 due to monsoon rainfall. Although various reasons such as development of an off-shore vortex along the coast, northward movement of Tropical Convergence Zone and offshore convection are attributed for this unprecedented rainfall, the actual weather condition that led to this highly localised rainfall still remains an enigma. The city received an average of 944 mm of rainfall on a single day leading to choking of the poorly maintained drainage system in the city. Spatial patterns indicated that a maximum rainfall of about 1045 mm occurred around the Vihar Lake region whereas the Colaba region received a minimum of about 734 mm. As a consequence, about 452 people died due to various causes such as drowning, landslide, stampede, trapping in the vehicles, electrocution, wall collapse and disease, etc. In addition, the economic loss of $ 690 million was estimated. In the present paper the nature of this natural disaster and its implications were discussed along with the remedial measures to be taken to minimize the damage in case of such hazards in future.*

**Key Words:** Mumbai, Floods, Heavy Rains, Rainfall, Vortex, Southwest monsoon

## Introduction

India, which lies between 8° N and 37° N latitude and 68° E and 97° E longitude, experiences three major seasons : winter, summer and the monsoon. Winter months (November-March) are bright and pleasant, with snowfall in the northern Himalaya Mountains. Summer time (April-June) is hot in most parts of India, and it is then that the numerous hill resorts provide cool retreat. During the monsoon, rainfall is heavy along the west coast between June and September, and along the east coast between October and December.

## Background: Cyclonic Rainfall and flooding

India is more susceptible to floods due to heavy rains associated with monsoon and cyclonic activity. The coastal areas are more susceptible to heavy cyclonic rainfall than the interior parts. As the cyclone builds up it begins to move and sustained by a steady flow of warm, moist air. The strongest winds and heaviest rains are found in the towering clouds which merge into a wall about 20-30 km from the storm's centre. Winds around the eye can reach the speeds of up to 200 km/h, and a fully developed cyclone pumps out about two million tonnes of air per second. As a result, more rain occur within a day in a particular region than what it receives in a year. The coastal States namely Tamilnadu, Andhra Pradesh, Orissa and West Bengal along the east coast and the Gujarat State along the west coast are repeatedly ravaged by cyclones and associated gale winds and floods (National Institute of Disaster Management, 2006). The severe cyclonic storm that lashed the low-lying coastal zone of the Krishna Delta region in Andhra Pradesh during 1977 led to a 5-meter-high tidal wave that reached about 10 km inland, while drowning over 8,500 people and 40,000 cattle. Ten years later, in 1987, the Andhra Pradesh coast was again affected by a cyclone and an associated flood. Although the loss of life was minimal, the damage to transport and communication systems was notable (National Institute of Disaster Management, 2006). The cyclone of 1996 flooded the croplands in the East Godavari district of Andhra Pradesh State causing massive economic loss to the agriculture sector. Similarly, West Bengal had also experienced floods during 1993 and 1994 cyclones that caused many deaths and much property damage (National Institute of Disaster Management, 2006). The super cyclone of Orissa during 1999, in which the gales wind speed reached record levels of 260 km/hr to 310 km/hr, tidal submergence and floods killed approximately 10,000 people while displacing millions (Tynkkynen, 2000). In addition, the entire communication system was disrupted and at one point of time during the cyclone, helicopters became the only means of transportation to most of the flooded areas.

On the west coast, Gujarat State is more prone to cyclones. The 1998 cyclone caused great industrial loss in addition to human and property loss. The giant industries, like the Reliance Industries Ltd., were also severely affected by this natural hazard. The state government corporations also reported major losses in production due to this cyclone (Times Foundation, 2006).

## Background: Monsoon Rains and Flooding

Apart from the cyclonic effect, floods induced by monsoon rainfall also cause severe damage in India. These gigantic wind systems result from the differential heating of the Indian Ocean and the Himalaya-Tibetan Plateau. During summer (June-September) the moist laden winds blow from southwest and during winter they blow from the northeast (November-February). Of the two, the summer monsoon is more significant as the Indian subcontinent receives 70% of its annual rainfall during this season.

In general, the southwest monsoonal rainfall is quite heavy due to the presence of the Western Ghats, in the western Peninsular India, which runs over 1600 km parallel to and about 50 km inland from the west coast. The western edge of this mountain range is a fault scarp with an average elevation of 1,200 metres. It obstructs the rain-bearing clouds. As a result of this orographic effect

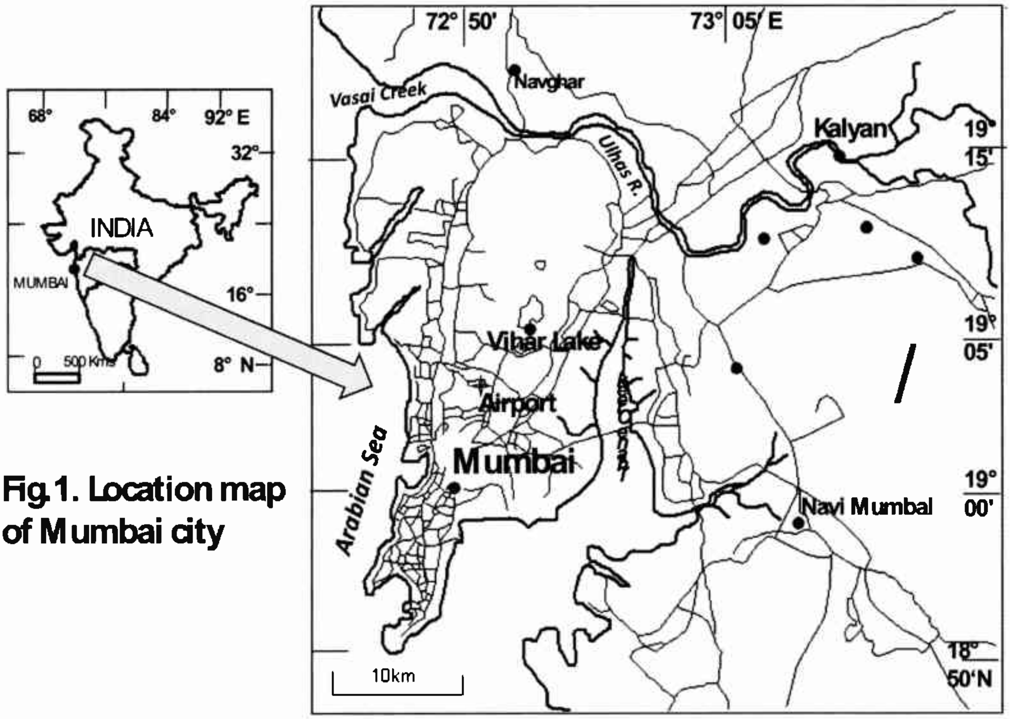



**Fig.1. Location map of Mumbai city**

**Table 1: Extreme Rainfall Events over India during Summer Monsoon**

| No. | Station | Date and Year | Amount of rainfall in cm |
|---|---|---|---|
| 1 | Cherrapunji (northeast) | June 14, 1876 | 116.8 |
| 2 | Kassuli (northwest) | June 18 1899 | 99.8 |
| 3 | Cherrapunji (northeast) | July 10 1912 | 99.8 |
| 4 | Dharampur (west coast) | July 2, 1941 | 98.7 |
| 5 | Mousinram (northeast) | July 10 1952 | 98.9 |
| 6 | Cherrapunji (northeast) | September 13 1974 | 98.5 |
| 7 | Santacruz (west coast) | July 26, 2005 | 94.4 |

the windward coastal regions of Western Ghats receive more rainfall than the regions that lie on the leeward side.

The onset of the summer monsoon is characterized by a sudden increase of rainfall associated with decrease of temperatures and increase of humidity. After the onset phase, the rainfall fluctuates within the season with alternating active and weak phases. Studies indicate that maximum amount of rainfall occurs over northeast India and along the west coast (Rao, 1976). Table 1 shows heavy rainfall events of close to 100 cm on a single day that have occurred in India during southwest monsoon season during the past 130 years.

The floods are commonly associated with snowmelt in the Himalayan region, however, the floods caused by cyclones and monsoon rainfall is more destructive.

In 2005, the states of Gujarat and Maharashtra were affected by drastic floods, which caused both human and economic loss. Of these, the Mumbai (Mahârashtra) floods were most devastating.

The aim of this paper is to review the nature and distribution of the heavy rainfall that occurred in Mumbai on 26 July 2005 and its impact on the city.

## Study Area

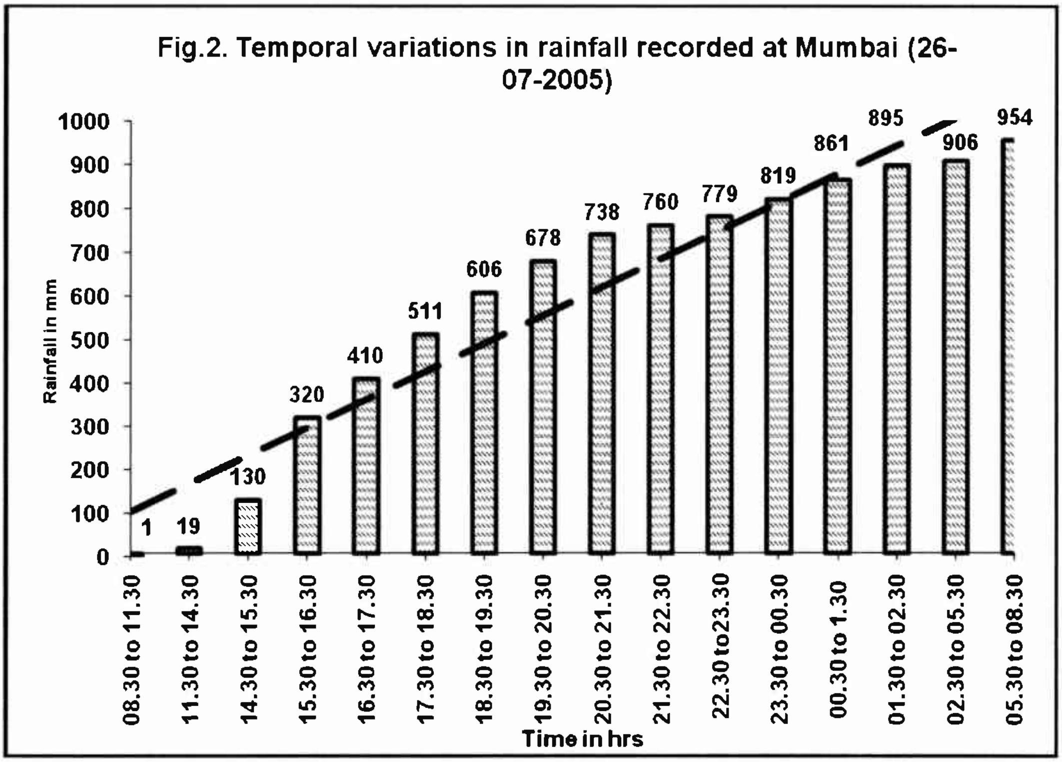
Mumbai city of Maharashtra State on the west coast of India is located in Shasti Island which was known as Salsette Island in Portuguese. Shasti Island is located right at the tip of the Ulhas River (Fig.1). The coastline of the city is indented with numerous bays and tidal creeks criss-crossing the area. Much of Mumbai is close to sea level with an average elevation of about 8 m, except the northern hilly part of the city, which has peak elevation of 450 m. The city spreads over an area about 468 $km^2$. The eastern part of Shasti Island is covered with extensive mangrove swamps. Sanjay Gandhi National Park, located at about 40 km north of Mumbai, consists of approximately 104 $km^2$ of protected forest. This dense forest reduced the impact of the flood that occurred on July 26, 2005 to a large extent as a buffer (Urban Green Belts, 2005). The population exposed to this natural calamity was about 13 million, with a density of about 29,000 persons per square kilometre.

The city experiences a tropical climate with two main seasons, the humid and the dry season. The humid season (March–October), is characterized by high humidity and temperatures of over 86° F (30° C). The total annual average rainfall received by the city is 1916 mm out of which more than 70% occurs during the southwest monsoon season, i.e., between June and September. Record annual rainfall totals for the city 345.2 cm during 1954. The Mumbai rains of 26 July 2005, 94.4 cm, are highest rainfall recorded on a single day.

During, the dry season (November-February) Mumbai is characterized by moderate levels of humidity and warm to cool weather. Cold northerly winds are bring a mild chill during January and February. Annual temperatures range between 52 °F (11 °C) and 100 °F (38 °C).

## Possible Causes of the Heavy Rains

As previously mentioned, the onset of the summer monsoon is associated with a sudden increase of rainfall and a decrease in temperature along the coastal areas of India. In certain occasions rainfall exceeds 20 cm per day. Historical data for more than hundred years indicates that Mumbai




has received more than 20 cm of rainfall in a single day on 20 occasions and more than 30 cm on 13 occasions (Table.2). The highest recorded rainfall previous to July 2005 was about 57 cm on July 4, 1974 (Ramachandran, 2005).

These intensive rainfall events are confined to smaller areas of a few kilometres and are attributed to mesoscale convective systems (Bhaskara Rao and Hari Prasad, 2005). Due to the paucity of sufficient weather observation points, it is difficult to assess their genesis. It has been suggested that the occurrence of an offshore trough along the west coast led to the origin of mesoscale convective systems.

**Table 2: Heavy rainfall events of Mumbai**

| No. | Locality | Time | Quantity in cm |
|---|---|---|---|
| 1 | Colaba | September 9, 1930 | Above 50 |
| 2 | Colaba | July 4, 1974 | 57.66 |
| 3 | Colaba | July 1, 1984 | 54.43 |
| 4 | Santacruz | June 10, 1991 | 39.9 |

The rainfall that occurred on 26 July 2005 in Mumbai was extremely localized and continued for four days. Rainfall was most intense through the afternoon (Figure.2). This outburst of rain caused heavy flooding and inundated most of the localities of Mumbai (Gupta, 2006). In addition to the human loss, the floods also hurt the country's economy, as Mumbai is

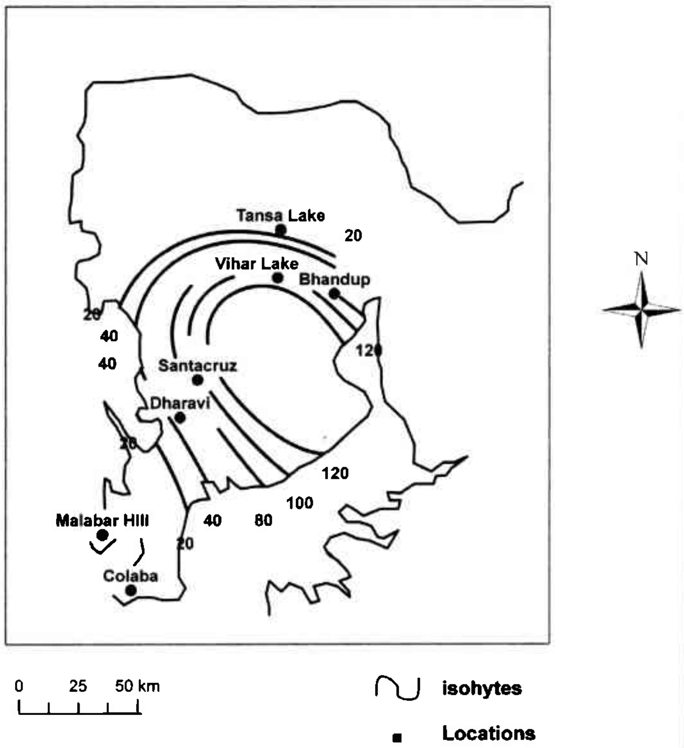



**Fig.3.Spatial Pattern of rainfall in Mumbai, during 26th July, 2005**

the commercial capital of India. The rainfall was spread over 20 to 30 km$^2$ area. Hence, this can be treated as a mesoscale event rather than a synoptic scale phenomenon. The rainfall varied greatly in different points of the city (Fig.3). Intensity ranged from 104 mm of rainfall at Vihar Lake region and 7 cm at Colaba region (Table.3)

Clearly these were areas of both also high and low rainfall on that particular day.

Various reasons have been suggested for the heavy rains in Mumbai. Initially, they were attributed to the formation of an offshore vortex. Such a vortex is usually

**Table 3: Rainfall in Mumbai on 26 July 2005, by locality**

| No. | Locality | Amount in cm |
|---|---|---|
| 1 | Colaba | 7.34 |
| 2 | Malabar Hill | 7.40 |
| 3 | Bhira | 12.10 |
| 4 | Dharavi | 49.90 |
| 5 | Santacruz | 94.40 |
| 6 | Bhandup | 81.50 |
| 7 | Vihar Lake | 104.50 |
| 8 | Tansa Lake | 5.00 |

caused by the mountain orography present along the coastline, which results in a high-pressure gradient from the coast to the hills, preventing the westerlies from the sea to be able to go inland. They end up circulating close to the shore, sometimes leading to the formation of vortices offshore (Ramachandran, 2005). In Mumbai, this resulted in low pressure and the strong winds shot up high resulting in a heavy downpour and thunderstorms (Jain, 2005). However, data from the satellite images and the terrestrial weather stations do not indicate any evidence of an offshore vortex (Ramachandran, 2005). A similar conclusion ruling out the possibility of an offshore vortex being responsible for the intense rainfall over Mumbai was based on the interpretation of the QuickSCAT satellite data which showed strong westerly winds over eastern Arabian Sea along the west coast from Gujarat (north of Mumbai) to north Karnataka (south of Mumbai), but not any offshore vortex (Bohra et al., 2006). The other possible reasons for this localized intense rainfall over such a small zone of Mumbai city have been attributed to northward movement of the Tropical Convergence Zone and offshore convection that are expected to cause heavy rainfall and thunderstorm activity and strong squalls, respectively as happened on that day (Ramachandran, 2005). Although the actual confluence of weather conditions that might have led to this unprecedented heavy rainfall is not yet known, the important observation on that day was that the cloud column was 15-km-thick as against the normal height of 6 to 7 km. It was this extraordinarily thick column of cloud that might have caused the heavy downpour leading to the unprecedented floods in the city (Jain, 2005). In fact, detection of a 15-km-deep cloud system, as Ramachandran (2005) succinctly put it, should itself have been a clue to an impending heavy rainfall and probably even sufficient to be on the alert.

## Cause of Heavy Floods

The Mumbai flood can be termed as an urban flash flood since there was a heavy downpour in a short period of time. Such floods, however, can be avoided if the municipal authorities can assess the cause and effect and take necessary measures to prevent them in time. According to a report of the Upper Parramatta River Catchment Trust (2005), the reasons for the floods were: (1) Overflowing of creeks, improper and inadequate drainage systems, sewers spillage due to illegal connections, floodplain encroachments, high density land uses and increased impervious areas limiting absorption of water into soil and thus leading to increased runoff (Upper Parramatta River Catchment Trust Report, 2005). If measures were taken to counter these effects, the flooding would not have been as bad as it was on that day.

## Consequences of the Flood

### *Mortality*

These floods have affected the health of Mumbai population in several ways . The total officially-declared deaths were with different causes of floods (National Disaster Management Division 2005). The spatial pattern of the deaths due to various causes during this flood event in Mumbai city reveals the severity of the rain.

Most of the people were killed in a landslide at the Saki Naka area of Mumbai. The deaths due to stampede were the result of a false rumour of an approaching tsunami in the low-lying slum areas of Vile Parle area where people rushed to higher ground in a panic. Further, 16 persons were stranded and suffocated in their cars on roads as water levels suddenly rose. A collapsed wall in a school led to five deaths (Fig.4).

Rainwater, the major source of drinking water in Mumbai, was contaminated as standard water purification methods were not possible to purify the increased volume of water caused by flooding (Wikipedia, 2005). The drinking water contamination had caused considerable long-term diseases such as hepatitis, dermatitis and possible rodent-born diseases as well as short-term illnesses such as fever, conjunctivitis, gastrointestinal illness, nose and throat infections. The traumatic experience also led to physical and psychological problems for many others in the city.

The most serious among all the ailments has been Leptospirosis, a disease people contacted by wading through water that

**Fig. 4: Mortality due to flooding in Mumbai during July 2006**

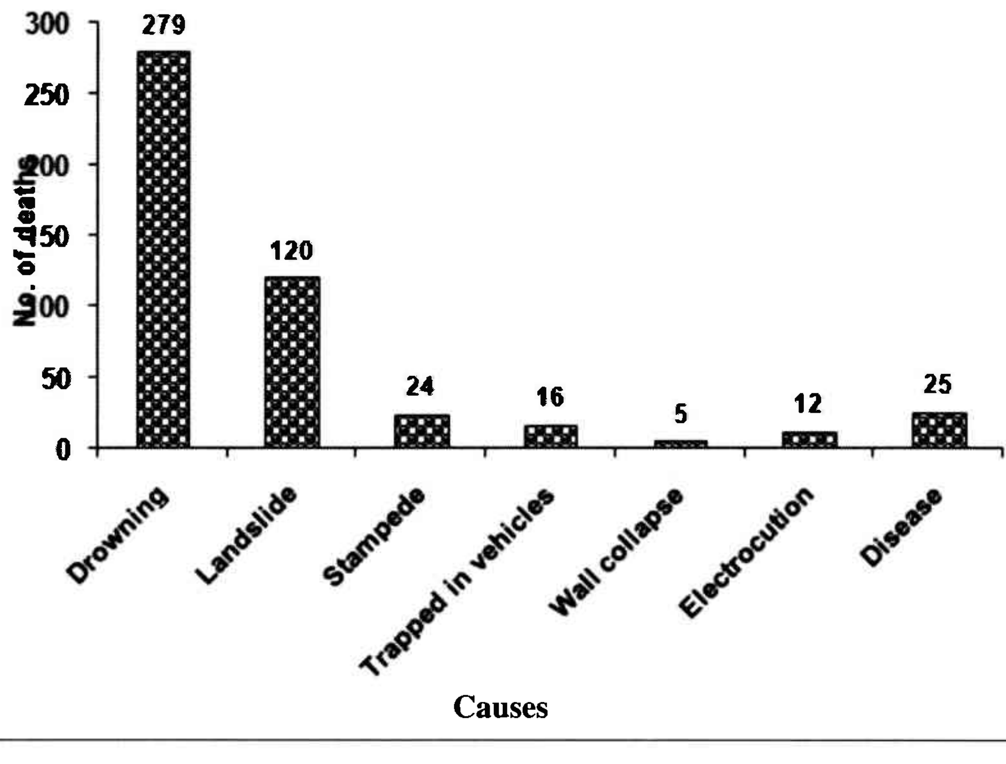


**Table 5: Prevalence of Diseases during Mumbai monsoon floods**

| No. | Name of the Disease | Number of Persons Affected |
|---|---|---|
| 1 | Gastroenteritis | 1318 |
| 2 | Hepatitis | 194 |
| 3 | Enteric fever, Typhoid | 53 |
| 4 | Malaria | 406 |
| 5 | Dengue | 49 |
| 6 | Leptospirosis | 197 |
| 7 | Fevers (unknown cause) | 1044 |

*Source: http://mdmu.maharashtra.gov.in/pdf/Flood/statusreport.pdf*

is infected by animal urine (Nandy, 2005) (Table 5).

*Financial Effects*

Reports indicate that financial loss of approximately $690 million due to these floods (Nandy 2006). These losses include public and private property. Small scale industries in Mumbai had to shut down as workers could not get to work during the rains and flooding. Mumbai has a strong influence on the stock market of the entire country and interruption of production caused the shares of several leading companies to drop. Other substantial losses have been reported from several parts of Mumbai including life, property, business and costly equipment from small scale industries. Several homes were destroyed, noteably those in slum areas. The government has taken initiatives to aid those who have lost homes.

Many buildings, bridges and roads were weakened or partially damaged. These areas may become completely invisible if the flood reoccurs in the near future. Floods resulted in traffic jams ranging from a few hours to a couple of days, bringing the city to a halt, disrupting both the communication system and the drainage system. Mumbai was reported to have a loss of 15321 head of cattle, most of which were buffalos, thereby affecting the milk industry (Maharashtra Govt., 2005). The prices of most of the commodities rose significantly. The central government came forward to offer financial assistance and provided the services of the paramilitary forces to assist those in need of protection. (China Daily, 2005).

*Ecological Effects*

Sanjay Gandhi National Park was severely affected, causing a total loss of $60,000 due to these rains. Water levels reached a height of five feet above the ground level and approximately 50 trees were uprooted and washed away. Mangrove ecosystem along the Mithi River and Mahim Creek were also damaged due to the rains. The Mithi River flooded over its banks and deposited dark mud on the neighboring land area. The roads were also damaged badly by these mudflows (Rediff News, 2005).

## Measures to Reduce the Intensity of Floods

Though floods due to heavy rains cannot be prevented, their intensity can be reduced by taking appropriate measures. The following are some of the measures that can be adopted:

1. Replacement of old drainage pipes with a more sophisticated system. The system should have separate pipelines for sewer and storm water drainage. The government will have to invest at least $270 million to implement this new urban drainage system
2. Prevention of encroachment along the Mithi River could improve better drainage. Proper floodplain management, which includes accurate floodplain mapping using Geographic Information Systems and remote sensing, and
3. Provision of early warning mechanisms in flood prone areas, so that inhabitants can take preventive measures such as evacuation.

## Conclusions

Mumbai is indeed a natural hazard zone associated with extreme monsoon weather. The extent of damage is huge in terms of human as well as economic points of view. To reduce the impact of the hazard, appropriate measures are essential. If both central and state governments work together and develop systemic and scientific solutions, there will be less need for compensations after such calamities. Proper floodplain management through accurate mapping of such plains will aid in reducing the damage caused by floods.

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