Urban Flood Inundation in Mumbai

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Background

- Urban areas are flooded due to intense rain within the city, due to flooding from rivers or high sea level, or because of a failure of the drainage system itself.
- However, in the urban context, flooding as a result of heavy and short-term rainfall is the most relevant.
- Thus it is of interest to study the effect of different rainfall intensities on flooding in the area for urban planning purposes.
- The average annual rainfall of Mumbai is about 2140 mm with monsoon rainfall contributing for 96% of the total annual rainfall.
- During this period, it usually rains during 0.5-2hours and sometimes up to 4 hours uniformly over the city and severe flooding occurs in many parts of the city

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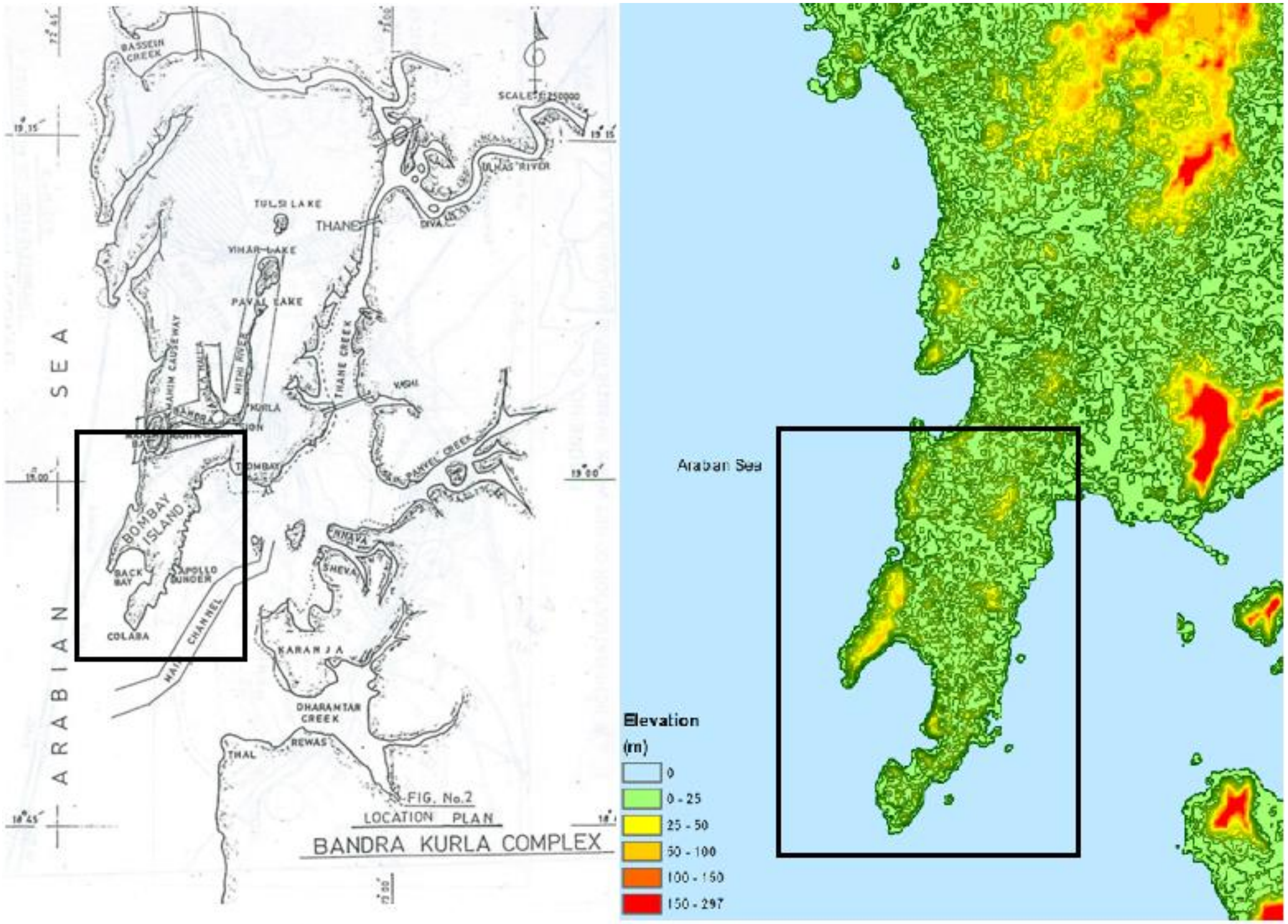
- In the present study we have used MIKE 21 as modelling platform for simulation of floods in the metropolitan areas of Mumbai.
- The objective of this paper is to estimate the flooding caused by large storms. The purpose was to find out flooded areas after 1 day of rainfall simulation using historical rainfall events.
- MIKE 21 is used to determine the overland flow in the urban part of the catchment.
- The MIKE 21 simulation is performed on the largest storm events in the period 1951-2004.
- The 10 min rainfall data is applied on publicly available ASTER DEM data for simulation of floods in the area

Study Area

- Mumbai (18° 58′ 30″ N 72° 49′ 33″ E) is located in south-western part of India.
- Mumbai is a cluster of seven islands.
- Mumbai is lined by the Arabian Sea on the western side, and also being intercepted by the Mahim, Mahul and Thane creeks, along with the Mithi, Dahisar, Poisar and Oshiwara rivers and their respective tributaries.
- It is to be noted that the tidal impacts are not considered in the modelling.
- Tidal impacts are important for Mumbai as they have great impact on outflow of water from the city and consequent water logging.
- The data for tidal fluctuations was not available and thus they were not considered.

Study Area



A B

(a) Mumbai metropolitan area, Greater Mumbai, India, (Central water and power research station 2006)
(b) DEM of metropolitan areas of Mumbai indicating ground elevation in the study area

Rainfall Data

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- For this study, daily rainfall data was obtained from India Meteorological Department (IMD) for data period 1951-2004.
- Statistical analysis for extreme values was then performed to choose sample events for flood modelling.
- The 8 largest storms were used for simulation of flooding in the area.
- A representative rainfall from the threshold level was chosen at an interval to simulate different intensities of rainfall during the day.
- A map of flooded areas during 26 June 2005 event (Fact finding committee 2005 floods) and areas designated as flood prone by (Municipal Corporation of Greater Mumbai 2005) were used for comparison of model results with observed flooding events.

Rainfall Data

Rainfall Event (day)	Date	Maximum (mm/day)	Median (mm/day)	Mean (mm/day)	Root Mean Square (mm/day)	Standard deviation (mm/day)	Skewness
170mm	28/7/1979	1008	158	191	263	181	0.55
180mm	3/8/1976	1296	144	204	309	232	0.77
190mm	21/7/1996	2074	158	217	353	279	0.63
200mm	6/9/1991	1166	194	227	325	232	0.43
220mm	10/7/1958	1224	209	261	362	251	0.62
240mm	18/6/1953	3758	166	271	487	405	0.78
260mm	3/7/1974	1080	238	292	395	266	0.61
290mm	26/6/2002	2909	245	328	512	393	0.64

Statistics of rainfall data chosen for flood modelling.

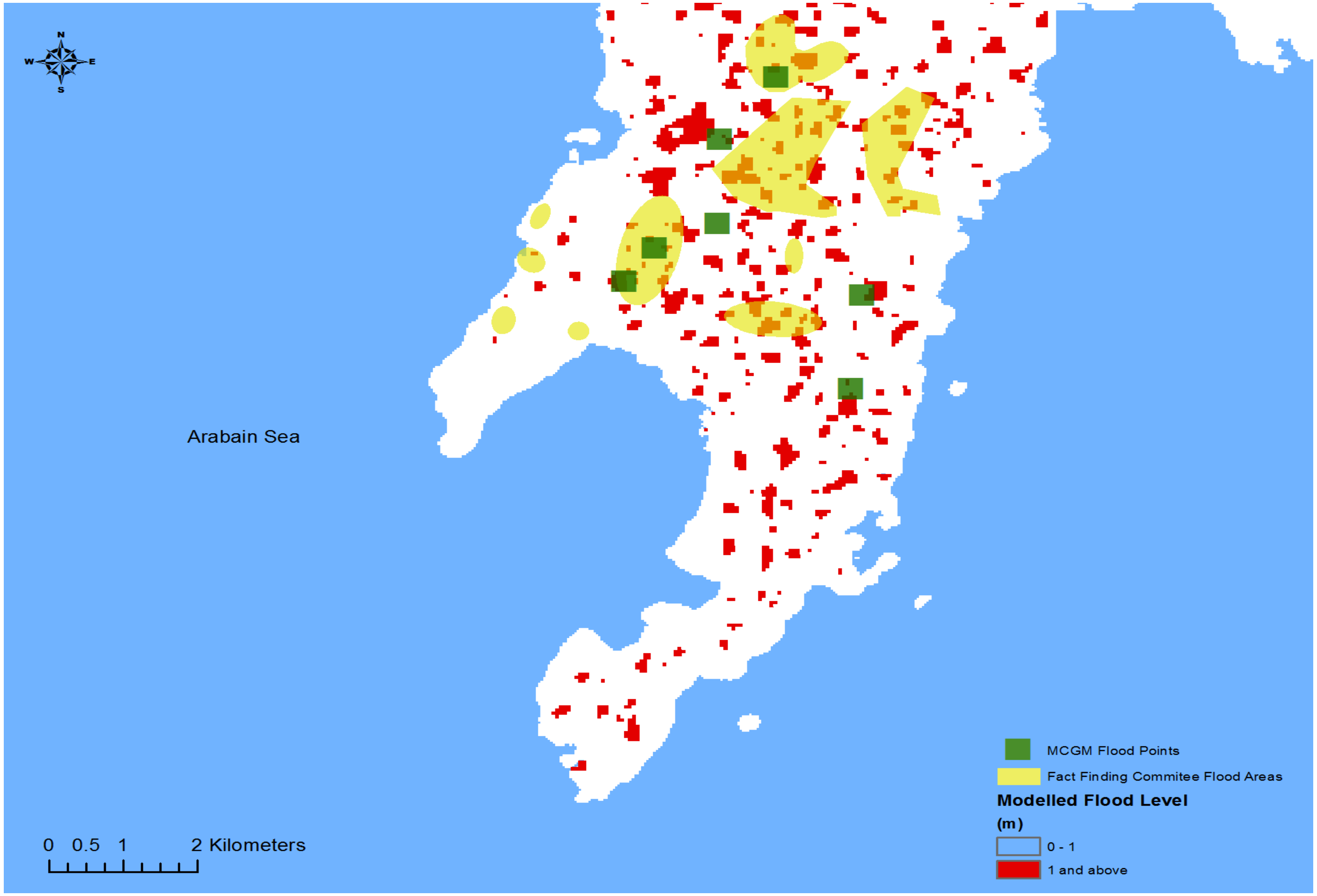
Topographic Information

- A 25m-grid resolution DEM is obtained from ASTER Project for setting up the flood model.
- DEM is the digital elevation model of the area indication surface elevation at each grid point as presented earlier.
- The ASTER GDEM is the only DEM that covers the entire land surface of the Earth at high resolution.
- It is widely used in geographical information studies across the world.
- The DEM data for study area is processed at 25m resolutions for filling up of missing values in the area using ARCGIS, which then in turn is used for preparation of bathymetry of the study area.

Model Comparison

- There is limited information available about the historically flooded areas in Mumbai.
- The model results are thus compared using publicly available flood map (Fact finding committee 2005 floods) and areas designated as flood prone by (Municipal Corporation of Greater Mumbai 2005) in a 2005 report.
- It was observed that most of the areas, which are historically flooded, are also simulated as flooded in the modelling results.
- Further, it was noted that the model has predicted some areas with flooding more than 1m where flooding was not reported by the Fact Finding Committee for the 2005 flood.

Model Comparison



Comparative flood map of the study area with modelled flooded areas and those presented in earlier studies.

Model Comparison

- One reason for such difference may be related to the resolution of data used in the model.
- We have used 30m digital elevation model (DEM) public data in the present study while information about the data source resolution and processing method for compared maps is unavailable.
- Moreover, the maps presented in earlier studies did not provide information on the depth of water accumulated in the flooded areas thus no comparison with simulated water depths could be made.
- No drainage network influence was included in the model, since such information was not available.

Model Results

- It was observed that there is flooding in each and every part of city.
- It was also visually observed by the authors by a site visit and using Google Earth, that there is very few infiltration surfaces in the city and the poor natural drainage of the city.
- The natural topography and location of the area does not help to evacuate the surface runoff (flat area by the sea, outlet of a river, reclaimed land, and swamp, whatever natural cause that made the area of Mumbai a natural floodplain).
- If we consider the different scenario results we would understand the flooding in the areas is directly related to amount and intensity of rainfall received in the area.
- The flood levels are evenly increasing in all the rainfall scenarios and are occurring in the same areas, owing to usage of same DEM for calculations.

Model Results

Rainfall Event	Maximum Water depth (m)
170mm	5.19
180mm	5.26
190mm	5.46
200mm	5.52
220mm	5.84
240mm	5.84
260mm	6.08
290mm	6.17

Computational statistics of all simulations in 1 day model run

Rainfall Event	B: Final volume in model area *					C: Total inflow **	E: Continuity balance = B-A-C+D ***
	Hydrology processes	Water depth correction	Volume in wet area	Volume in dry area	Total		
170mm	63783858	26	63858858	420	63859278	63783884	0.09
180mm	66988130	36	67063418	142	67063560	66988166	0.08
190mm	72642728	96	72717527	691	72718219	72642824	0.05
200mm	75469397	199	75544482	509	75544992	75469597	0.09
220mm	86741523	144	86816698	364	86817062	86741667	0.09
240mm	87759350	216	87834817	144	87834961	87759566	0.03
260mm	96157999	324	96233181	536	96233717	96158323	0.15
290mm	109435307	870	109511249	323	109511573	109436178	0.06

* Final volume in model area (B) from inflow sources and open boundaries inflow is 0 m^3 for all events
** Total Inflow (C) from outflow sinks and open boundaries is 0 m^3 for all events
***Initial Volume (A) is constant at 75394.52 m^3 and total outflow (D) is 0 m^3 for all rain events

Water Balance for all the four simulation in 1-day model run (values in m^3)

Conclusion

- Comparison of modelled flood areas with the observations sheds light on the key aspects of flood modelling in the area including need for need and information for such a study.
- The maps presented in earlier studies are not providing information on key criteria's; such as spatial and temporal extent, flooding depth etc.; that can be compared with the present model.
- The presented model is able to cover all the areas (spatially) as presented/observed by other studies but the extent of flooding is less than the observations owing to lack of information and bare DEM without any urban infrastructure.

Conclusion

- The study has revealed that there are parts in the city, which are under huge threat of flooding when it rains owing to heavy rainfall events, flat gradient and impervious surfaces.
- The problem with flooding can be expected to increase due to rapid expansion of the city and depletion of pervious surfaces.
- The water depth in all the simulations under consideration is reaching height of more than 1m in each case and goes up to 6m of water for the most severe rainfall event.
- The results of present study can be used by municipal authorities to focus on area, which are under instantaneous and serious stress of flooding, for better management practices.