Flood Risk Assessment of Pune

Key Objectives

The hypothesis to test was: T**<u>he risk of flooding increased as Pune has expanded over time.</u>** Here the term 'expanded' refers to the increase in **population and the area occupied by the city**. Since Pune as a whole is quite a large area to study, we limited ourselves to the Baner-Balewadi area, as described below.

Area Under Study

The region under study was the **Baner-Balewadi** area. Geographically, the area is bounded by **Pashan Hill** to the south, **NH48** to the west and **Mula river** to the north and north-east. The total area is approximately **86,20,731 square metres** or **8.62 square kilometres.**

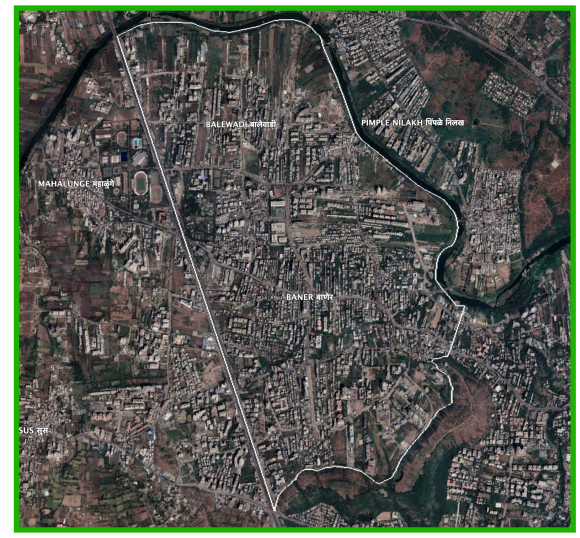

Fig 1: *Satellite view of Baner-Balewadi Area as of 2023*

Indicators Used in This Study

In this study, the main factors we considered was the **amount of surface runoff generated** in a given rainfall event, and the **drainage density** (drainage density is the total length of all the water canals flowing in the drainage basin divided by the total area of the basin). We feel that both of these parameters change as a city develops - the surface runoff generated increases, as does the drainage density. An increase in both increases the peak volumetric flow of water in a major river nearby (Mula River in this case), which increases the chances that it will burst its banks.

Surface runoff generation: **Impervious surface area** (denoted by ISA) refers to the area of land through which water cannot percolate into the groundwater, and therefore, contributes to surface runoff. This includes transport infrastructure, such as roads, sidewalks, building and house roofs, parking, most housing societies and most educational institutes. **Non-impervious surface area** (denoted by NISA) refers to the area of land through which water can percolate, and therefore, does not contribute surface runoff. This includes forests, farmland, barren land and hill slopes.

Different land uses generate different amounts of surface runoff, and therefore we assign a certain number, called the **runoff coefficient** to different land uses. It is defined to be the ratio of the total volume of surface runoff generated to the total volume of rainfall, and is therefore directly proportional to the amount of surface runoff. In this study, we treat all ISA to have a runoff **coefficient of 0.9** and all NISA to have a runoff **coefficient of 0.5**.

Primary Data Generated (Part 1): Land Use (NISA/ISA)

We tracked the change in the NISA (and also the ISA) over three years - **March 2013**, **February 2014** and **May 2023**. The data was gathered using **historic satellite imagery** form **Google Earth Pro,** which is summarised by the table below, and Figures 2 to 4

Month/Year	Total ISA (in sq m)	Total NISA (in sq m)	% of ISA	% of NISA	Change in % ISA
Mar/2013	44,17,290	42,03,441	51.24	48.76	N/A
Feb/2104	46,80,209	39,40,522	54.29	45.71	3.05
May/2023	62,70,801	23,49,930	72.24	27.76	17.95

Fig 2: NISA as of Mar 2013

Fig 3: NISA as of Feb 2014

Fig 4: NISA as of May 2023

Conclusions Part 1

In the above diagrams, the white polygons (green in the case of May 2023) denote the NISA. From the table, we can clearly tell that **the NISA has increased form 2013 to 2023.** However, the average increases in the ISA per year form 2014 to 2023 is 1,76,732 m^2, which is lower than the increase form 2013 to 2014. This suggests that the rate of growth of ISA has been slowing down over time.

Throughout the three years, the greatest concentration of NISA has been in the **north (towards Mula river)** or towards the **south (towards Pashan hill)**. The development close to Baner road (central Baner) as slowly decreased with time as it is becoming more and more saturated.

Rainfall Simulation

Using this data, we calculated the **expected surface runoff generation rates** (denoted R), that is, in a rainfall event of a given intensity (based on category of rainfall) how much volume of surface runoff would be generated per unit time. The greater the R, the greater the risk of flooding (as mentioned earlier). This was calculated by using the **rational runoff model,** which is summarised by the equation below:

Rate of Runoff Generated (R) = **Runoff Coefficient (C)** times **Area of Land Under Study (A)** times **Intensity of Rainfall (I)**

Based upon the intensity of rainfall (in mm/hr), we divided the rainfall into three categories: Light Rainfall (up until 2.6 mm/hr), Moderate (2.6 mm/hr to 7.5 mm/hr) and Heavy Rainfall (7.5 mm/hr to 50 mm/hr). In order to calculate the runoff generation rate for different varieties of rainfall for different years, we calculated the quantity C times A for the ISA and NISA for all three years:

Month/Year	ISA times C (in m^2)	NISA times C (in m^2)	Total ISA + NISA times C (in m^2)
Mar/2013	39,75,561	25,22,065	64,97,626
Feb/2014	42,12,188	23,64,313	65,76,501
May/2023	56,43,720	14,09,958	70,53,678

Now we are ready to *simulate* rainfall events in the three years

	Light Rainfall UB/ Moderate Rainfall LB	Moderate Rainfall UB/Heavy Rainfall LB	Heavy Rainfall UB
Mar/2013	4.69	13.54	90.26
Feb/2014	4.75	13.70	91.34
May/2023	5.10	14.70	97.97

In this table, LB and UB stands for lower bound and upper bound respectively. The table gives the rate of runoff generation for a specific year and rainfall type in *metre cubed per second.*

Conclusions Part 2

According to the calculations, **there has been an increase in the runoff rates for all types of rainfall from 2013 to 2023**. For light rainfall UB, there as been an **8.74% increase** in R from 2013 to 2023, an **8.55% increase** for moderate rainfall UB and an **8.54% increase** for heavy rainfall UB. However, one may note that **the increase in R has not been as drastic as the increase ISA.**

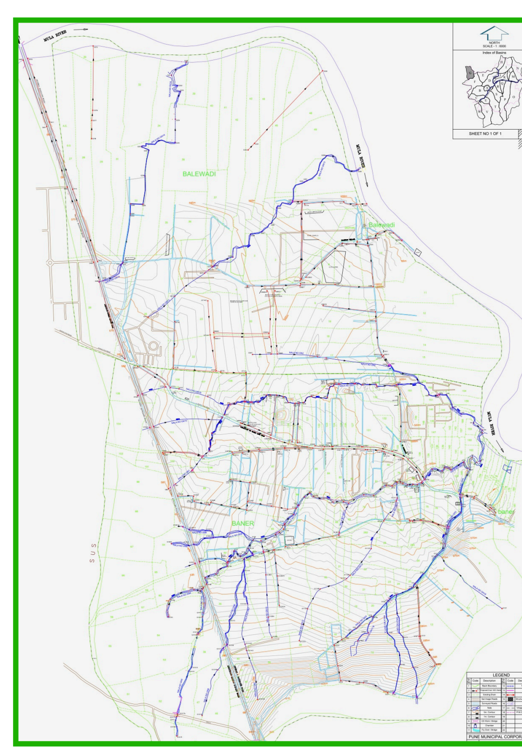

Fig 5: Nala Map of Baner-Balelwadi Area by PMC

Secondary Data Generated (Part 2): Drainage Density

As discussed earlier, **a high drainage density increases the peak volumetric flow rate in a nearby river**. We calculated the drainage density using a Nala basin map produced by the PMC (Fig 5). We physically measured the lengths of all the nalas, by using the scale of the map (and a ruler) and divided it by the area of the drainage basin. **The final value is 0.83 km^-1.** As per the classification of drainage densities, **this value is low** (between 0.81 and 1.62, but above very low) and *would have been always low throughout the history of Pune.* We can therefore conclude that **the drainage density of this area does play a large role in increasing the peak flow rate.**

Grand Conclusion

The risk of flooding has increased in the Baner Balewadi Area form 2013 to 2023. This is due to an increase in the impervious surface area, which has lead to higher runoff generation rates in a given rainfall event, which ultimately increases the peak volumetric flow rate of water in the Mula River. The drainage density is low and as always remained low throughout the development of Pune, and did not play a role in increasing the flood risk.