Flood Causes, Effects, and Solutions - Chennai, India

Varun Bhargava | Allan Kapoor
CP 204C | Spring 2016

Background

In late 2015, South India suffered from severe flooding when the 2014-16 El Niño exacerbated the annual northeast monsoon. The flooding is estimated to have caused $2-15 billion in damages and over 500 deaths. Chennai, the capital of Tamil Nadu, with a population of over 7 million, experienced its worst flood in over a century. Large parts of the city were inundated for weeks until waters began to recede on December 4th. The flood's severity has been attributed to decades of poor urban planning, which resulted in unregulated sprawl that covered the region's natural drainage systems and outpaced the build-out and capacity of the city's drainage infrastructure. Floods in developing cities are becoming increasingly common due to climate change and rapid urbanization. This necessitates a shift in storm water management, from the traditional "big pipes" conveyance approach to a "storage approach" focusing on natural drainage, surface permeability, and retention. Our project examines the primary cause of flooding - the rapid increase in surface impermeability, the flood's effects - reduced access to critical services during inundation, and a possible solution - siting floodwater catchment facilities.

Proposed Analysis

Image Processing to understand the region's change in surface permeability over time

Suitability Analysis to determine the optimum locations for flood water catchment facilities

Network Analysis to identify areas that experience decreased hospital access during flood events

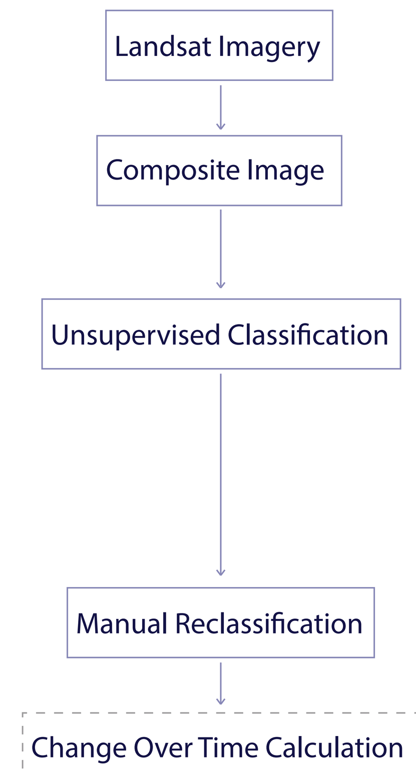
Surface Permeability

Methodology

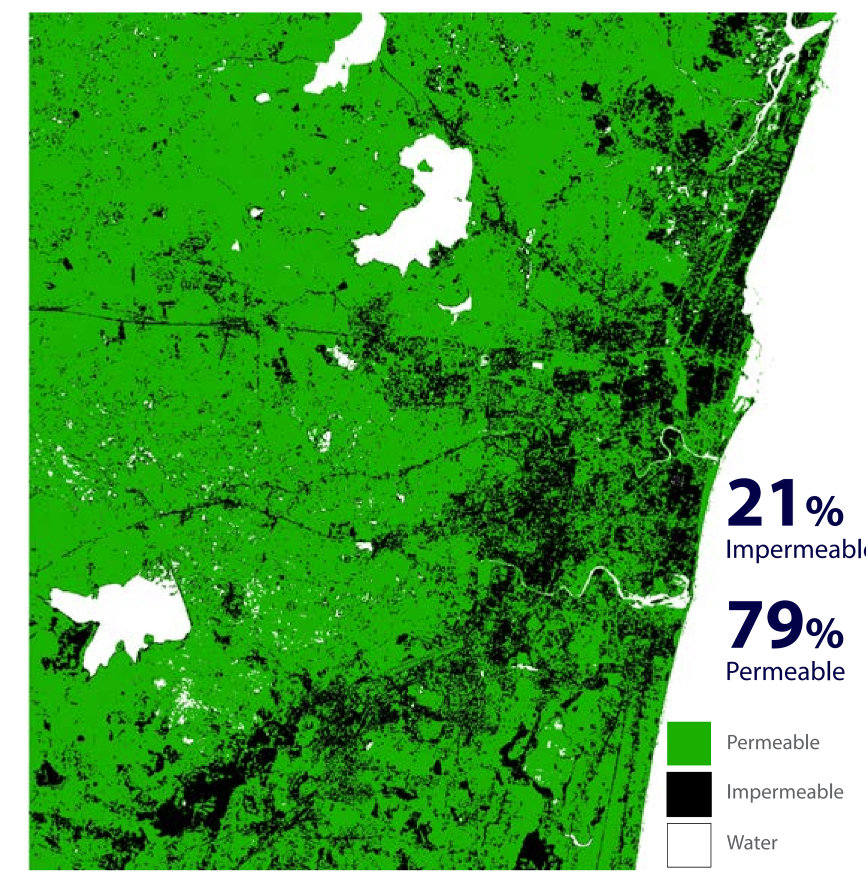
In order to calculate the change in surface permeability over time, we needed comparable multi-band satellite imagery for multiple decades. The highest resolution imagery we could find for Chennai was from the Landsat satellites. We then built composite images for 1992, 2003, and 2013. We used the red and green bands, but dropped blue to maintain clarity, and added near infrared to highlight vegetation. For 2003 and 2013 we also used the thermal band to differentiate between urban and rural spaces, but not for 1992 because Landsat-5 did not have a thermal sensor. We performed an unsupervised classification with 20 classes on each image and then manually reclassified each class by comparing them to the original composite into 3 classes - permeable surface, impermeable surface, and water. Once our images were completed for each year, we calculated percent change in surface area over time for permeable and impermeable surfaces within our study area. Between 1992 and 2013 impermeable surfaces increased by 148% and permeable surfaces decreased by 39%.

Data Sources

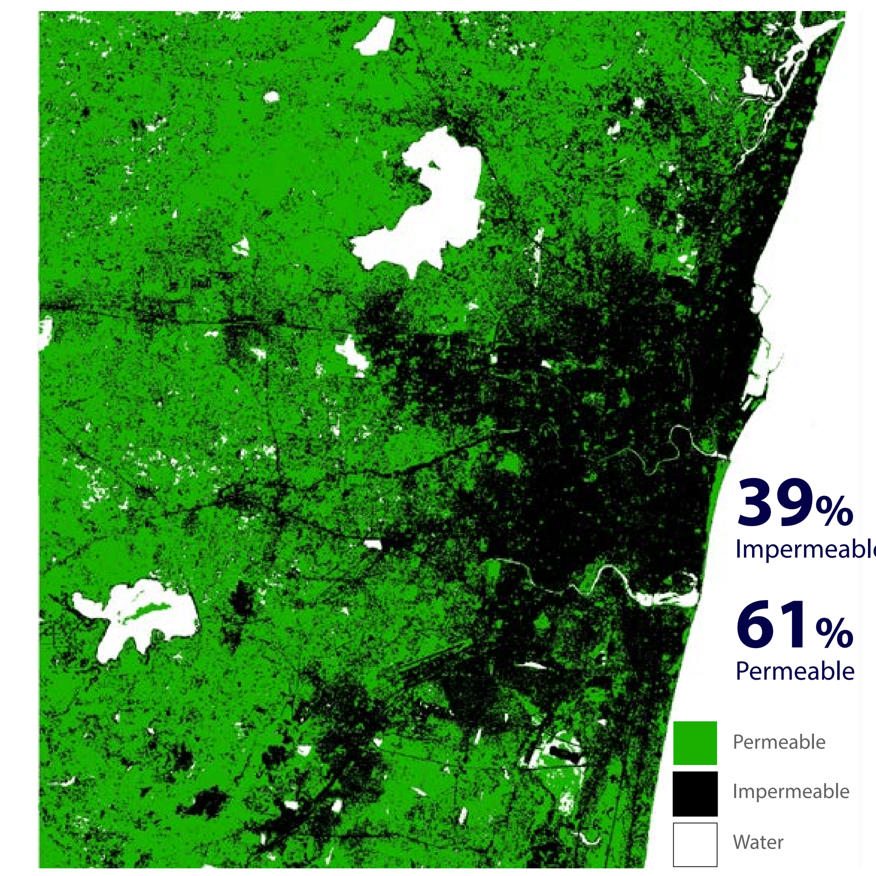
Landsat-5. US Geological Survey. June 1992. http://earthexplorer.usgs.gov/
Landsat-7. US Geological Survey. June 2003. http://earthexplorer.usgs.gov/
Landsat-8. US Geological Survey. June 2013. http://earthexplorer.usgs.gov/



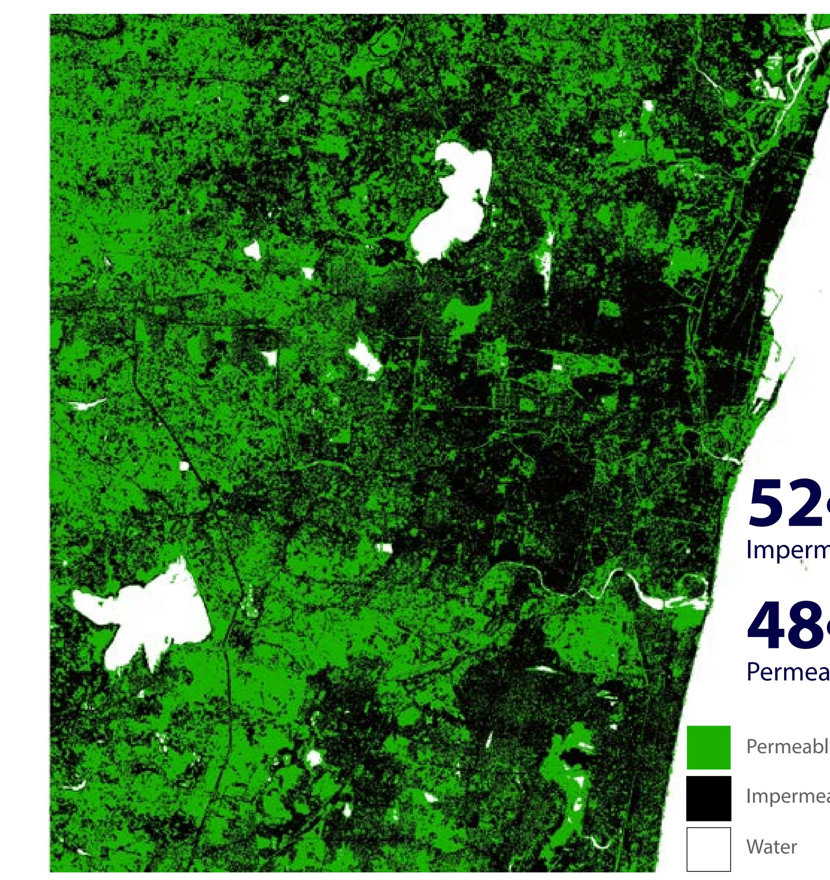
1992



2003



2013



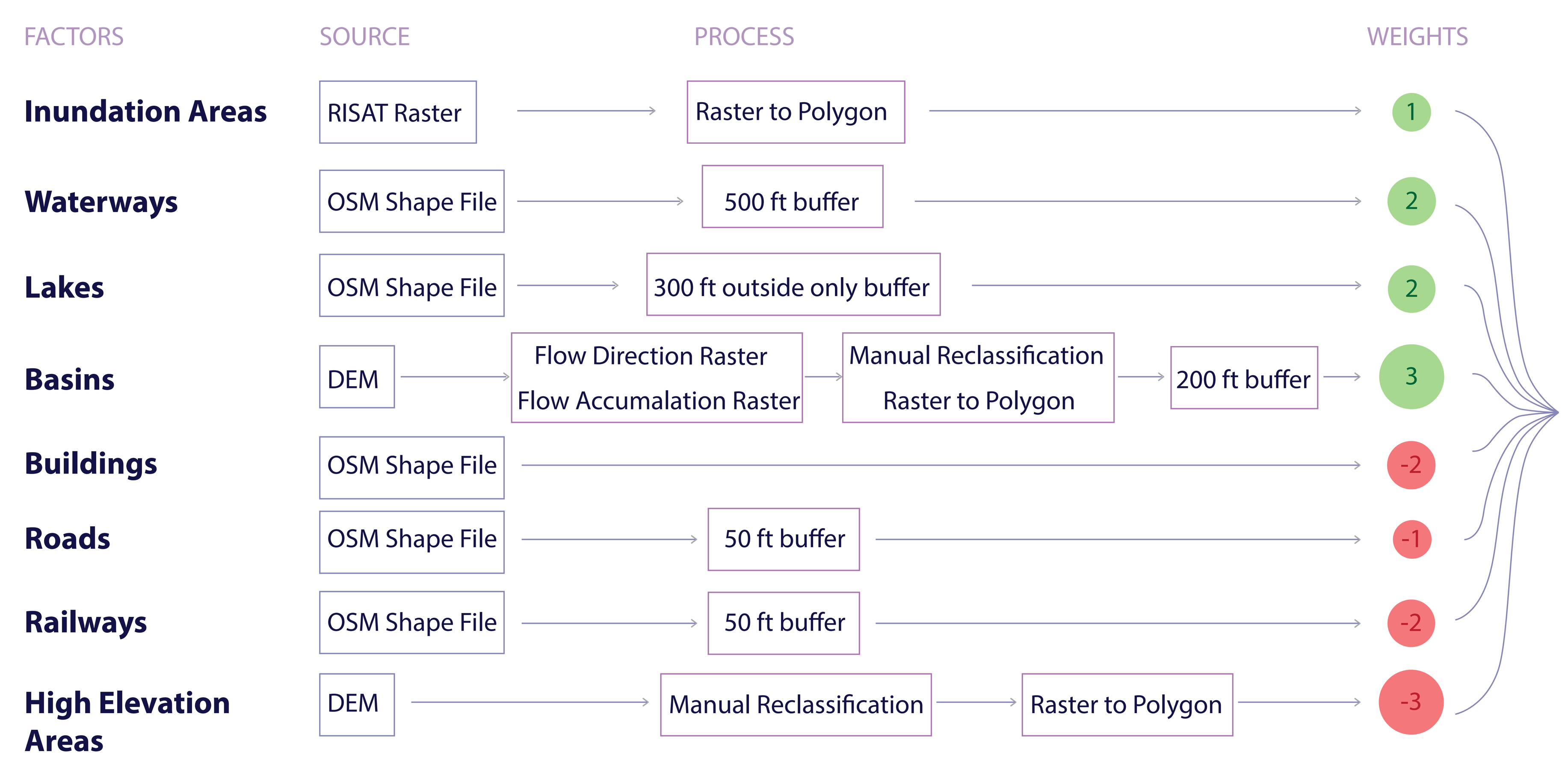
Flood Water Catchment Facilities

Methodology

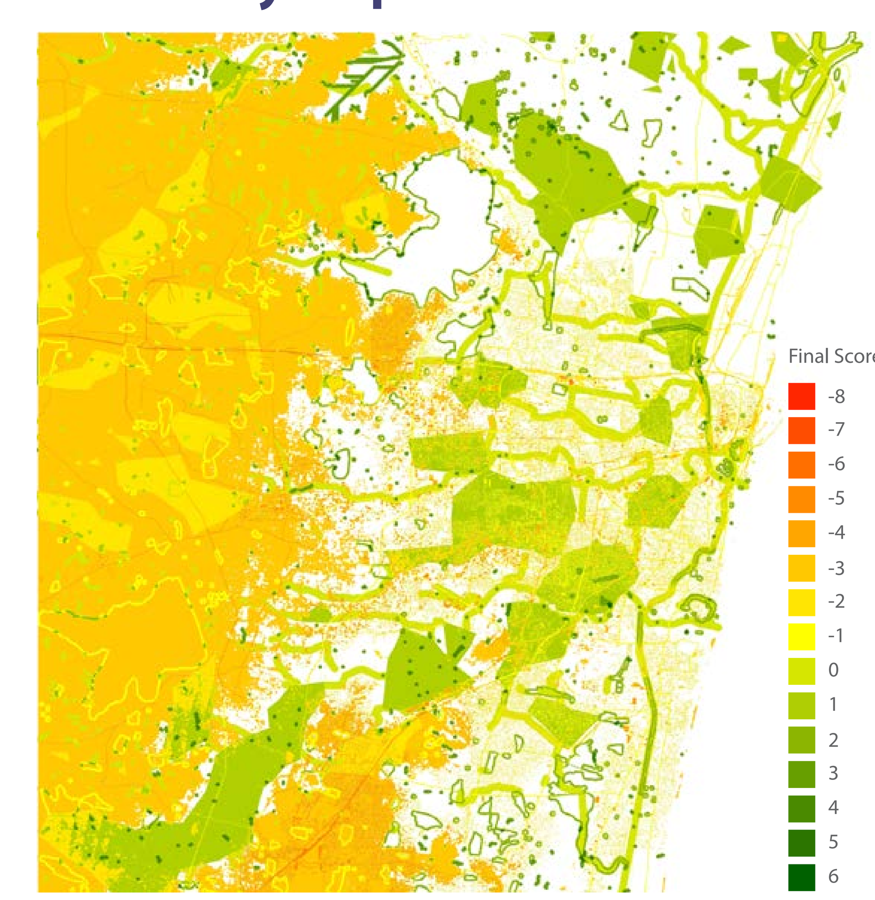
We included factors that reflect the community's needs, such as existing buildings, and critical public infrastructure, such as roads and railways, and assigned a buffer around these to mark them as constraints. We identified basins within the region where water will naturally flow and areas near existing lakes and waterways as opportunity areas. Inundated areas served as an obvious opportunity factor since they are areas where water accumulated during the flood. Weights were assigned to opportunities based on their relative importance to a functioning catchment pond. Weights were assigned to constraints based on their relative importance to Chennai residents and the functions of the city.

Data Sources

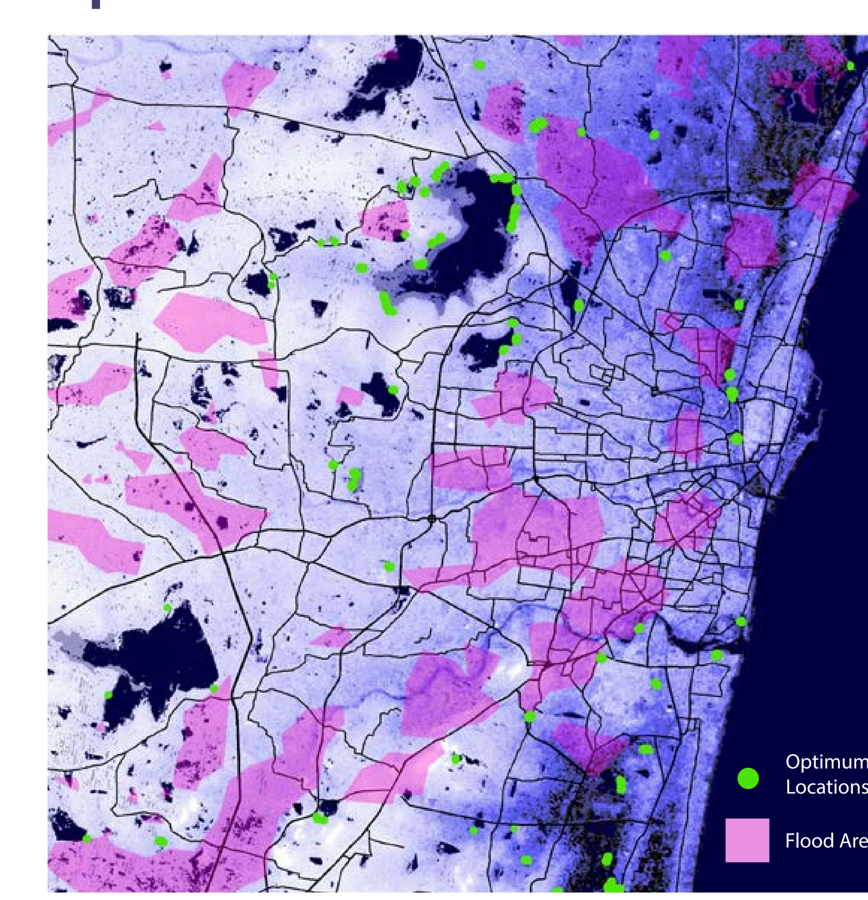
Inundation Areas
RISAT-1. ISRO. 3 Nov 2015. http://bhuvan.nrsc.gov.in/
Infrastructure & Water Features
OpenStreetMap. 10 March 2016. http://download.geofabrik.de/asia/india.html
DEM data:
Cartosat-1. ISRO. 3 Nov 2015. http://bhuvan.nrsc.gov.in/



Suitability Map



Optimum Locations



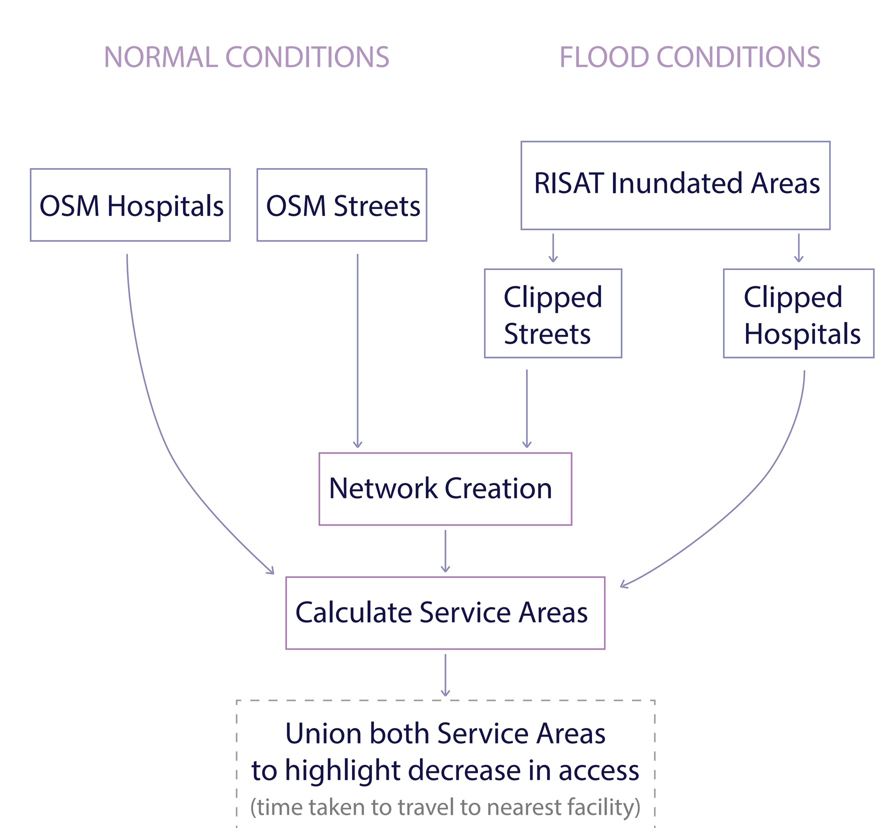
Access to Critical Services

Methodology

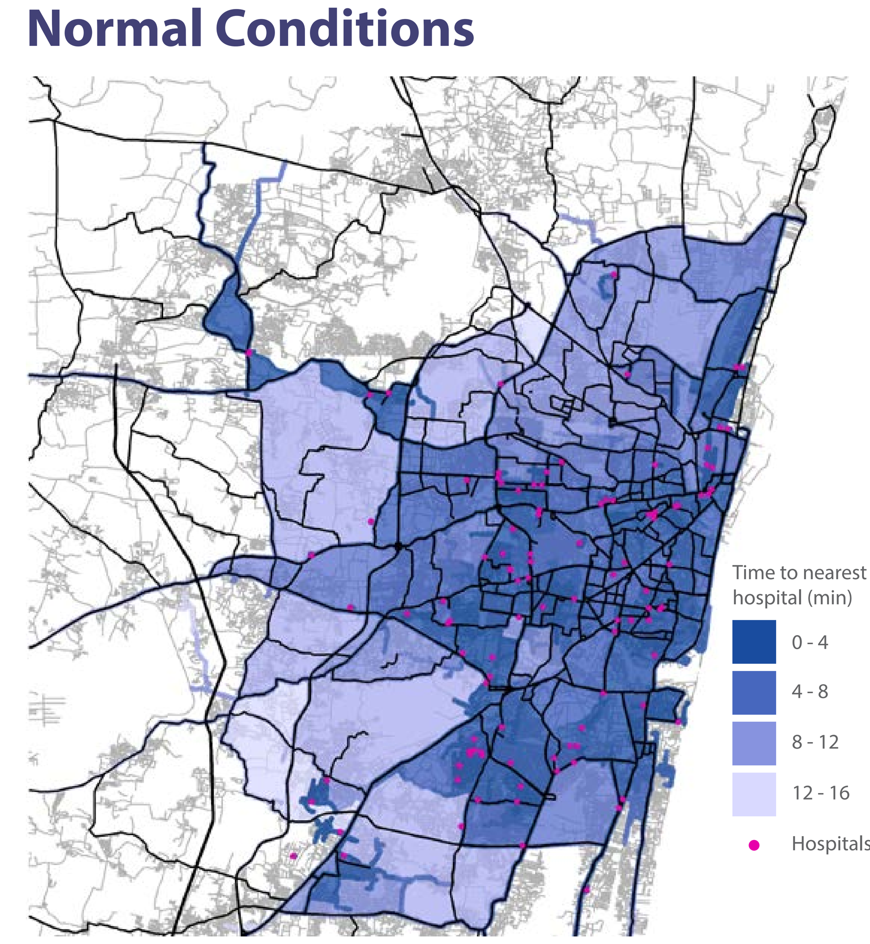
We wanted to assess the impact the flood had on the city of Chennai, particularly how access to vital institutions, such as hospitals, was affected. We created a network out of street data from OpenStreetMap. The streets were classified and speed limits were assigned based on an experiential understanding of the average vehicular speeds in the city. A secondary network was created to emulate flood conditions by clipping the network with the inundated areas layer. A service area analysis was performed on both networks to understand the change in time taken to get to the nearest hospital across the city. The aim was to union the two conditions and create a map highlighting regions that saw the greatest increase in the total time taken to access the nearest hospital. However, due to errors in the original streets layer, we weren't able to get an accurate estimate of the service areas around the hospitals so the final union would have been meaningless.

Data Sources

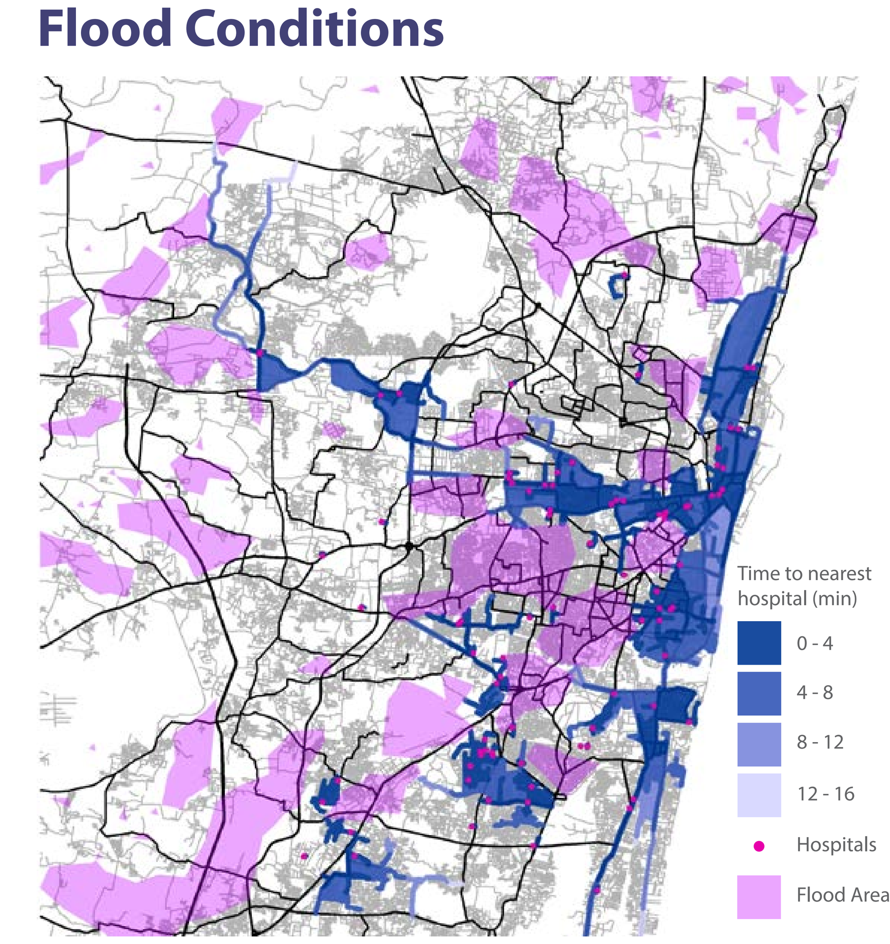
Indundation Areas
RISAT-1. ISRO. 3 Nov 2015. http://bhuvan.nrsc.gov.in/
Road Network
OpenStreetMap. 10 March 2016. http://download.geofabrik.de/asia/india.html



Normal Conditions



Flood Conditions



Limitations

Low Resolution Data

Landsat imagery for the study area was only available at a resolution of 30 meters. A higher resolution would have enabled us to classify with greater accuracy and granularity. Low resolution DEM data, especially for a relatively flat study area, may have contributed to errors in the calculation of basins and high elevation areas for our suitability analysis.

Open Source Data

The lack of up to date government GIS data for streets, buildings, and other physical features forced us to rely on OpenStreetMap, which lacks the rigorous quality control that government data is subjected to. For example, our buildings layer was missing some neighborhoods, especially informal settlements. Most importantly, our streets layer lacked a network configuration file, which resulted in our network ignoring many passable intersections. This prevented us from completing the final step of our network analysis.

All maps in WGS 1984 UTM Zone 44N

0 1 2 4 6 8 Miles