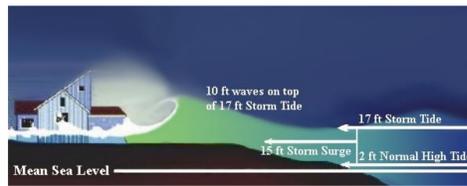


# Vulnerability on the Cape: How are residents in Yarmouth affected by hurricane storm surge?

## Background

As our oceans continue to warm due to climate change, coastal storms and hurricanes will increase in intensity and frequency. Coastal communities have higher population densities on average, so the vulnerability of these residents to natural disasters such as hurricanes and the resulting storm surges will increase as well. Storm surge is defined as the abnormal rise in water level, above the normal astronomical tide, caused by a storm and is often the greatest threat to property and life from the storm.



Source: National Oceanic and Atmospheric Administration (NOAA)



Study area: Yarmouth, Cape Cod

The town of Yarmouth is in the center of the arm of Cape Cod, with Dennis to the east and Barnstable to the west. Yarmouth, along with the rest of Cape Cod, is a low-lying coastal region with long stretches of coastline and many bays and estuaries. The 24 square mile town has a total population of

23,760 as of the 2010 census. In order to better understand the relationship between storm surge inundation zones and population density of communities in Yarmouth, a spatial model is employed so that planners, regulators, and responders can be better equipped to make decisions regarding disaster preparation and adaptation.

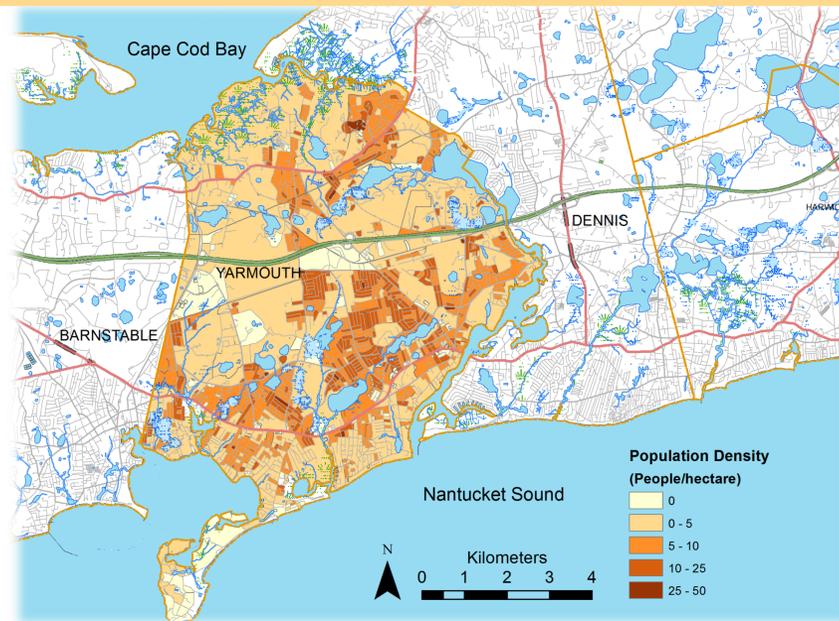
## Methodology

This model represents Yarmouth residents, using block data from the Decennial Census of Population and Housing, to determine the proportion of the population affected by the four categories of storm surge. I intend to estimate the number of residents in Yarmouth affected by each level of hurricane surge. The spatial mechanism that ties this together is the rising water levels through movement of the water above the normal tide level and onto streets, buildings, and homes where residents dwell.

This model employs the hurricane surge inundation layer, from the Army Corps of Engineers, which is based on worst-case storm surge inundation scenarios developed by the National Hurricane Center, from Category 1 to 4 hurricanes. The next layer included was the 2010 Census block data, which allows us to summarize the total number of residents affected by each category of hurricane storm surge. After inputting the datasets, the model used the select by attribute tool to only select blocks from within the town of Yarmouth. Then the copy features tool and make feature layer tool was employed to create a subset of these blocks for the study, and another select by attribute tool was used for each category of hurricane surge. These two layers when then fed into the select by location tool and the intersect function was used to select blocks "with their center in" the associated hurricane surge categories to tabulate the total number of residents affected by each of the four categories.

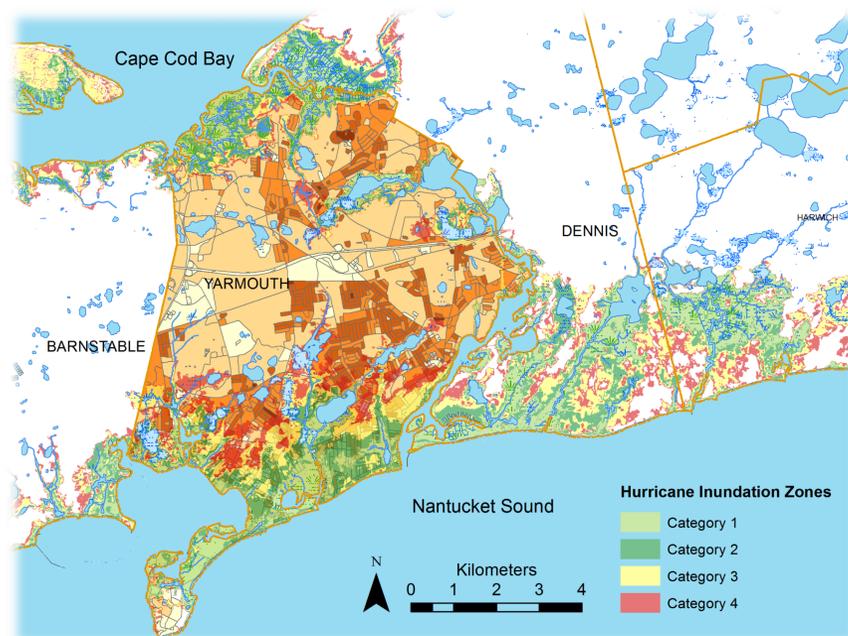
Cartographer: Carla Curle, NUTR 231, May 2016

## Resident Population Density



The map above used normalization of the Yarmouth population by block level aggregation to generate a people per hectare scale. Based on visual inspection, the highest density regions are clustered in the south-east section of the Yarmouth region, with a border of lower density blocks on the southern-most and northern-most coastlines.

## Hurricane Inundation Zones



The map above overlays the hurricane surge inundation layer on the population density layer to reveal regions affected by the four categories. It is important to note that Category 4 impacts all residents in the lower category zones, because as the water level rises from the storm, it covers this land and continues farther inland.

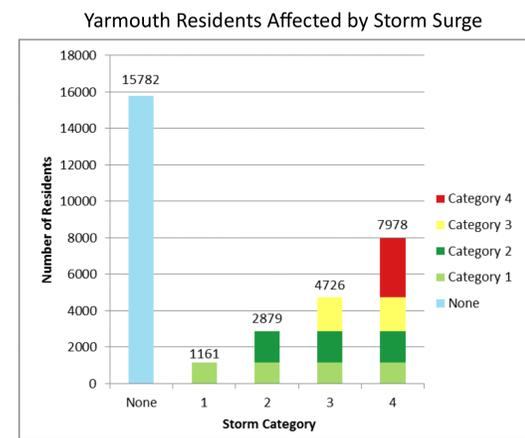
## Results

Based on the spatial tabulation, a total of 7,978 residents (34%) are affected by one or more categories of storm surge and 15,782 residents (66%) are living in an area not affected by one or more of the storm surge zones.

Within the group of residents affected:

- 15% are affected by Category 1
- 36% affected by Category 2
- 59% by Category 3
- 100% by Category 4

All residents who are affected by Category 1 storms will also be affected by the higher category storms, so this aggregation technique was used in the selection and tabulation.



## Limitations and Future Research

In terms of modeling this relationship, the data has some setbacks. I used the block level household data because it is the most granular population data available, and provides us with more precise estimates, but we cannot use the income data because it is not represented at this level. There are also concerns with granularity of the intersect tool, since the "has centroid in" function was used to capture the number of residents affected by each category of hurricane surge. Some census blocks may lie partially inside a hurricane inundation zone, but since this function was used, it may overestimate the number of residents affected. Additionally, data is based on 2010 estimates, so it does not represent the most recent resident levels. The hurricane surge inundation layer is based on modeling done by the Army Corps and does not necessarily take into account changes in surge caused by climate change.

For future research, bringing in datasets such as property parcel value and type of land use would allow for a more exhaustive vulnerability assessment. A comparison of the different towns around Cape Cod would also be useful to allow the region's planners to focus resources to the most vulnerable areas.

## Sources

Projected Coordinate System: Massachusetts State Plane Mainland Zone

Census Blocks, 2010, Decennial Census of Population and Housing; published by U.S. Census Bureau <http://www.census.gov/geo/maps-data/data/tiger-data.html>, accessed April 22 2016.

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Lin, Ning, et al. "Physically based assessment of hurricane surge threat under climate change." *Nature Climate Change* 2.6 (2012): 462-467.

National Hurricane Center. National Oceanic and Atmospheric Administration. <http://www.nhc.noaa.gov/surge/>

