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# Monitoring Future Sea Level Rise and Storm Surge Impacts in Beverly Massachusetts

## Abstract

The goal of this study is to understand the risk to the community of Beverly, Massachusetts brought on by sea level rise coupled with storm surges under a high tide. Sea levels are expected to rise dramatically by the end of the century. With this the majority of coastal areas will become flooded depending on their sea level, displacing millions of people and destroying infrastructure. Using a simple sea level elevation model sea level rise values were mapped for the town of Beverly, Massachusetts to help understand the amount of area that would be affected by flooding.

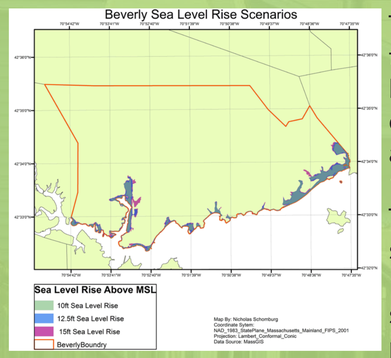
## Methods

When modeling sea level rise in Beverly three different flooding scenarios where created. These scenarios being 10 foot flooding, 12.5 foot flooding and 15 foot flooding under a worst case scenario. All flood values are assuming a high tide, with storm surge, under a full moon. It is important to always consider a worst case scenario and for that reason only the worst case scenarios will be discussed. This study uses public data obtained from the MassGIS website. Most importantly the people affected are examined in this study and secondly infrastructure affected.

The most important part of the data was the elevation model used to assess how flooding would affect the coast of Beverly under different scenarios. This elevation model was created using digital terrain models (DTM), joining them and interpolating (rasterizing) them. A color-ramp was then applied to values using a mask. Polygons were used to mark areas within the flooding. For property and population values operators were used for if property or population intersected the flood polygon.

## Data/ Analysis

Only coastal areas are considered as they are hydrologically connected. Terrain type such as pavement, marsh, grass, gravel, urbanization, forest etc. were not considered although they are important to consider for their water absorption and flow resistance in the case of storm surges coupled with sea level rise.

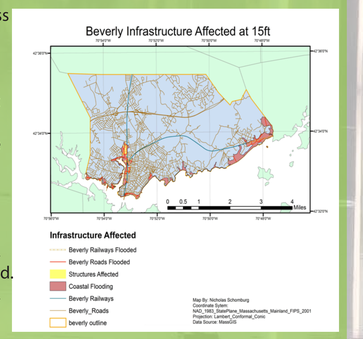


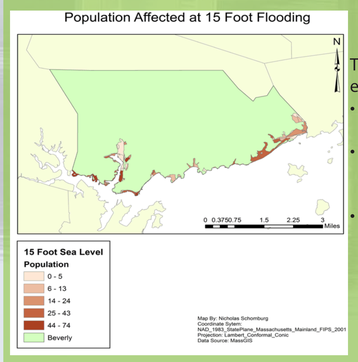

The map to the left shows the town of Beverly with sea level rise being represented by three different color values. The green is a minimal sea level rise scenario at 10ft above normal mean sea level. The blue represents an intermediate sea level rise of 12.5 feet. Finally for the worst case scenario a 15 foot sea level rise is modeled in purple.

- The town of Beverley roughly has an area of 15.41mi$^2$ (straight line measurement).
- A sea level rise of just 10 feet is modeled to cause approximately 0.48mi$^2$ of flooding. This accounts to a 3.11% loss of land.
- A sea level rise of 12.5 feet will cause approximately 0.60mi$^2$ of flooding. This accounts to a 3.89% loss of land.
- Finally, the worst case scenario, a sea level rise of 15 feet will cause a flooding of 0.73mi$^2$. This is a 4.73% loss of land.

In the worst case scenario of 15ft sea level rise there is a loss of land of 467.2 acres (0.73mi$^2$). This is not a large sum compared to the total acreage of Beverly but many expensive homes and businesses lie close to the water's edge in this 467.2 acre area. Property values near the coast also tend to run higher than those further away from the coast. Using tax parcel data from MassGIS the approximate cost of these properties were calculated. Notice that these values far exceed the projected revenue of $110,461,359 for Beverly for the year 2015 (BeverlyMA.gov).

- At 15ft sea level rise a loss of $759,781,650 is predicted.
- At 12.5ft sea level rise a loss of $694,194,600 is predicted.
- At 10ft sea level rise a loss of $635,678,900 is predicted.




The total population for Beverly in 2010 was estimated at 41,882 people.

- At a flood level of 10 feet 486 people are estimated to be affected; representing 1.16% of the population of Beverly.
- At a flood level of 12.5 feet 774 people are estimated to be affected; representing 1.85% of the population of Beverly.
- At a flood level of 15 feet 1138 people are estimated to be affected; representing 2.72% of the population of Beverly.

As shown by the data it does not appear that a proportionally large amount of people will be affected by the flooding. This might be the case immediately but these people will need food and shelter which should be planned for accordingly to make sure any disaster is not a surprise. To be best prepared emergency plans should be made using the worst case scenario.

## Conclusions

Although there is only a 4.73% (0.73mi$^2$) loss of land under the most severe flood conditon of 15 feet the real loss lies with in the amount lives displaced and the overall cost of the land and structures lost. Even at the lowest predicted storm surge level of 10 feet costs of loss could exceed 600% of Beverly's yearly income.

| Infrastructure Type | Status |
|---|---|
| Hospitals | Unaffected |
| Community Health Care Centers | Unaffected |
| Nursing Homes | Unaffected |
| Fire Stations | Unaffected |
| Police Stations | Unaffected |
| MBTA Bus Stops | 2 Affected |
| Trains | Affected All flood levels |
| Schools | 1 School All Flood Levels |
| Roads | Affected |
| Solid Waste | Unaffected |

Fortunately many important areas of infrastructure remain unaffected due to their distant proximity to the coast. Located left is a list of areas of infrastructure which were analyzed while preparing data. The status unaffected reflects the infrastructure being unaffected at all flood levels.

Roads and trains will be affected by flooding and for this reason emergency services should plan alternate routes. Main routes such as 1A are also affected by flooding.

Emergency services should be prepared for the worst case scenario of 15 feet of storm surge flooding and be prepared to relocate those affected. It should not be assumed that flooding will be less than predicted, even to preserve a budget because this can lead to unpreparedness. The top 6 losses of land across all sea level rise levels included low density residential areas, medium density residential areas, industrial zones, beaches, forest and wetlands. Residential areas are of primary concern due to the population that would be displaced.

Credits:
ArcGIS, used to process data and create maps
MassGIS.com (provided all data)
Background Photo: FEMA.Gov