# Climate Change Implications for Humboldt County Coastal Communities

INTEGRATING SOCIOECONOMIC ISSUES WITH SEA LEVEL INUNDATION

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## Abstract:

In the event of sea level rise, Humboldt County communities will find themselves susceptible to various levels of inundation. The level of inundation will vary according to different climatic events. As a result, it is important to model the various levels of inundation and how they will affect different land use categories. This study compares the current sea level to a conservative estimate of a two meter rise. It then analyzes potential sea level increases of seven, fifteen, and twenty-two meters above current levels. This data was overlaid with land use parcels for Humboldt County to determine the land use areas that are the most vulnerable to sea level inundation.

The data used for this study was Digital Elevation Models from GeoCommunity and the "parcels" shapefile from Humboldt County GIS.

The analysis for this study took into consideration the various socioeconomic and demographic aspects of the community to determine the populations that would be impacted by the rising sea levels. The informational data used for this analysis was acquired from the

Environmental Protection Agency's website.

This study showed that Arcata will be the most susceptible to sea level rise in terms of the degree of inundation, as well as, having the highest proportion of a low-income population in the Humboldt County coastal area.

It is important to be able to model various degrees of sea level rise to help determine the necessary planning and policy initiatives to maintain infrastructure, business, and other social aspects of the community. This study provides a spatial analysis that may help the community create short-term adaptations, as well as, work towards longterm mitigation goals.

## Introduction:

According to the Intergovernmental Panel on Climate Change's third report, experts suggest that global temperatures may increase from current levels at a rate of 2.5 degrees Fahrenheit to 10.4 degrees Fahrenheit by 2100 (Kubasek, 2014). The increase in global temperatures is expected to increase sea levels. The height at which sea levels will rise may vary according to the degree to which temperatures will rise. In the event of sea level rise, it is important for researchers to model the different projected levels of inundation so that planners and policy makers may establish short-term and long-term mitigation and adaptation plans. Living on the north coast, our communities are likely to be impacted by sea level rise. Therefore, it is also important to understand the ways in which various inundation levels will affect different land use categories. On top of that, this analysis may be used to understand the ways in which people living below the poverty level may be disproportionately affected by sea level rise. This information may be used to help bring awareness to environmental justice issues in our community.

Because Humboldt County coastal communities have relied on a method of sea level manipulation to help promote agriculture and other developments, those methods are going to need to be reinforced or other mitigation methods will need to occur. One of the methods of manipulation is a series of dikes that were built between 1890 and 1915 (Laird, 2015). Between the aging dikes and non-commissioned railroad beds, 75% of the shoreline in Humboldt County is manufactured (Laird, 2015). As a result, sea level rise may have very

influential consequences on the societal and natural constructs of Humboldt County communities. These inundation models allow for planners and policy makers to prioritize areas that are at greatest risk, and to ensure limited funding is allocated accordingly. With the socioeconomic aspect of the project also being used in analysis, planners and policymakers will also be able to ensure that the funding does not neglect to protect those in lower income levels, but rather work towards adapting our area to sea level inundation in a practical and just manner.

## Methods





Figure 1 Flowchart outlining the processes taken during analysis. The Humboldt DEM and Land Parcel flowcharts were mimicked from David Gwenzi's Lab 9 methodology section.

## Data Acquisition:

The first step in this project was to acquire Digital Elevation Models from "Geo Community.com". The DEMs that were used were specific to the Humboldt County Coastal region. Eleven data sets were chosen. The data was in a tar.gz file format and therefore needed to be unzipped (the .gz was unzipped followed by the .tar). This data was exported to a new file format with the DEMs being specified as Raster data and given names comprehensive to this project and analysis. The new Raster data were named: NorthArcata.img, SouthArcata.img, Eureka.img, Ferndale.img, Fortuna.img, Honeydew.img, Piercy.img, Petrolia.img, ShelterCove.img, and Trinidad.img.

The spatial reference system was projected as NAD 27 UTM Zone 10 North.

#### Data integration

Next, the eleven raster data sets needed to undergo the Mosaic function to allow them to be analyzed as one individual raster data set. Once the data sets were visible as one layer, inundation levels were able to be calculated. Using information from NASA and National Geographic, we were able to understand the potential sea level rise in meters pertaining to specific events. First of all, a layer was created in which the current sea level was visible. This layer was referred to as "Salt Water". With the information from the current sea level, we were able to analyze the potential increases in sea level rise using the raster calculator. The way in which this was completed was by subtracting "salt water" from the level of inundation that we were interested in analyzing. The first inundation level was a conservative estimate, with sea levels predicted to rise two meters. The second inundation level is an estimate based upon the Greenland ice sheet melting. In the event that the ice sheet was to melt, sea levels would rise by an estimated seven meters. The third estimate was based upon Antarctic ice caps melting resulting in a potential inundation level of 15 meters. The last estimated inundation level was referred to as the "Doomsday" scenario in which both the Greenland ice sheets and the Antarctic ice caps melted. The potential inundation level for this event would be 22 meters.

The "Doomsday" layer was converted from a raster to a shapefile by "selecting by attribute", "grid code=1".

#### Data Analysis

The importance of sea level rise in the Humboldt County area is especially important when analyzing it according to different land use categories. The land use categories were downloaded from the Humboldt GIS website. Once unzipped the categories were applied to the layers with the various inundation levels. The land parcels were summarized, and with that USE\_CODES were added to the summary table and their values were set. The tables were joined and the layer was converted from a polygon to a raster so that there was one Land Use raster. The land use categories are as follows: "City", "Agriculture", "Residential", "Commercial", "Industrial", "Recreational", "Tribal", "Public", "Other".

## Results

The Boolean Values represent true (1) and false (0) occurrences of inundation within Humboldt County's coastal regions. At the current sea level, the water in Humboldt Bay and the Eel River are contained, however, a sea level rise of two meters would result in the cities of South Arcata, Eureka, and Fortuna being overwhelmed with ocean water. When sea level rises seven meters, the Arcata Bottoms are flooded and the Eel River has begun flooding the City of Ferndale. At a fifteen meter sea level rise, the City of Eureka is now under water with levels reaching the edge of Cutten. Also, a fifteen meter rise would result in Trinidad's scenic drive concaving, and Arcata, Ferndale, and Fortuna are almost entirely submerged under water. When "Doomsday" strikes at twenty-two meters, every coastal town is submerged under water and the cities and towns further inland are now affected. In all four land use maps, the adverse environmental effects caused by sea level rise will primarily target agricultural land in Fortuna and Ferndale. Ferndale in particular, provides Humboldt County with most of its farming, dairy, and timber production. Without these main components, the City's economic status will plummet and the poverty status will increase. Because Arcata and Eureka align the Humboldt Bay, their infrastructure would be compromised and current businesses and political structures would be unable to maintain their residences here.

## Inundation and Land Use Maps

Found on the following pages, is the original sea level map as well as the four types of sea level rise that will adversely affect Humboldt County by the year 2100. To determine how Humboldt County's parcels have been divided, the County has developed land use codes. These codes can be found in Table **1** below.

Use_Code	
Value	Land Use
0	No Change
1	City
2	Agriculture
3	Residential
4	Commercial
5	Industrial
6	Recreational
7	Tribal
8	Public
9	Other

Table 1 Land use parcels in Humboldt County.



Figure 2 Current (2016) Sea Levels for Humboldt County Coastal Communities. Map created by C.Brown and S.Weeks



Figure 3 On the left is the model for conservative estimates for two-meter sea level rise above current levels. On the right, displays land use categories affected by a two meter sea level rise. Map created by C.Brown and S.weeks.



Figure 4 To the left, Model for seven meter sea level rise resulting from the Greenland Ice Sheet melting. To the right, displays land use categories affected by a seven meter sea level rise. Map created by C.Brown and S.weeks.



Figure 5 To the left, Model for fifteen meter sea level rise resulting from Antarctic ice caps melting. To the right, displays land use categories resulting from a fifteen meter increase in sea level rise. Map created by C.Brown and S.weeks.



Figure 6 To the left, Model for "Doomsday" scenario in which there is a twenty-two meter increase in sea level from current 2016 levels. To the right, Display of land use categories affected by a twenty-two meter increase in sea level rise. Map created by C.Brown and S.Weeks.

## Discussion:

## Socioeconomics and Climate Change

To perform this research, we acquired data online from the EPA's Environmental Justice

Screening and Mapping Tool (Version 2016), which allowed our group to select site-

specific locations *Figure* **7**.



Figure 7 displays a screenshot of the EPA's Environmental Justice Mapping Tool (Version, 2016).

The locations we chose to study included main areas affected by the Doomsday inundation analysis. Humboldt County communities were selected based on the data collected in the analysis and they included: Shelter Cove, Petrolia, Fortuna, Eureka, Arcata, and McKinleyville. The mapping tool allows researchers to scan a map and pick a specific location to generate a data report for a given area. After selecting a specific location, we were then able to look at the "demographic indicators" tab which provides information pertaining to low-income populations, as well as, the minority populations in the concerned areas of inundation.

The demographic indicators acquired from the EPA's website are based upon a comparison to the USA Percentile. We focused our research on five specific communities in Humboldt County, California. Shelter cove had an 84% low-income population with a minority population of 17 % (Figure 8). Petrolia had a low-income population at 59% with minority population at 44% (Figure 9). Eureka had a low-income level of 68% with a minority population at 44% (Figure 10). Arcata had a low-income population of 88% and minority population of 49% (Figure 11). McKinleyville had a low-income population of 51% and minority population of 39%. (Figure 12). Fortuna had a low-income population of 59% and minority population of 44% (Figure 13).



Figure8: Shelter Cove

### Figure 10: Eureka



#### Figure 11: Arcata



#### Figure 12: Fortuna



#### Figure 13: McKinleyville



Based off this data it is easy to see the distribution of socioeconomic populations along the Humboldt County coastline. The highest low-income populations were Arcata, Shelter-Cove and Eureka. However, the other cities in the analysis were all over 50% of the US average. The minority population was not as high but it was still 49% in Arcata with the other cities not trailing far behind. Using this data in comparison to the modeled sea level inundation, it is apparent that there exist environmental justice concerns due to lower income and minorities being disproportionately impacted by sea level rise when basing the information on the U.S. percentile. As a result, there will need to be a disaster and infrastructure plan put in place to provide communities with a comprehensive response to the rise of sea level due to climate change. Furthermore, these policies must reflect the needs of these communities at the regional and local level

#### **Problems with Project**

Originally, our project was suppose to encompass not only sea level rise but rainfall inundation as well. Unfortunately even with the assistance of both the teacher and outside tutors we were unable to locate the data necessary to calculate and map for rainfall. Due to this our project shifted direction, instead of focusing on rainfall we wanted to focus on the effects of Climate Change. Which is of course how we came to our final product.

The second problem we encountered was with Humboldt County DEM's. When collecting the DEM's to mosaic together it became evident that sparsely populated areas did not have DEM data. As such, we pieced together the areas that did have DEM's and therefore focused our work on the coastal areas. We found the lack of DEM's for major waterways and other rural areas troubling, due to city and county planners being unable to access this important information. According to our analysis, sea level rise also affects many other hydrological aspects of the county's topography (such as rivers), and without the necessary DEM's, communities near these waterways will be especially vulnerable to the hazardous risks associated with inundation.

## Conclusion:

According to this analysis, the Humboldt County coastal communities run a high risk of flooding from sea level rise. The modeled levels of inundation provide local governments with a spatial analysis that will allow them to prioritize especially vulnerable areas within Humboldt County. One area that is especially vulnerable is Arcata. Arcata has the greatest risk of inundation, and the socioeconomic data reflects a very high low-income population of 88%, compared to the U.S. percentile. Most of the low-income populations within the areas of inundation concern were 50% (if not more) over the US percentile. Rising sea level is a major environmental justice concern for Humboldt County coastal communities. Furthermore, it is estimated that a 5.3 ft increase in sea levels for Humboldt County would likely overwhelm the county's dike system (Laird, 2015). Based on our analysis, a conservative projection for sea level rise over the next 100 years is 6.5ft. Therefore, adaptation strategies need to be immediately implemented in order to avoid catastrophe.

Our team's objective was to integrate geospatial science with environmental justice concerns and thereby highlight the complexity of climate change impacts on local environments. Based on these finding and populations shown currently at risk, we urge planners and policymakers to use this data to assist them in ensuring that the funding does not neglect to protect those in lower income levels, but rather work towards adapting our area to sea level inundation in a practical and just manner. In conclusion, this analysis has shown that at-risk areas of inundation have significant economic disparities which must be taken into account during decision making procedures so that planners and policy makers may promote more resilient coastal communities.

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