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**Work In Progress Report: Los Angeles’ Sea Level Vulnerability Index**

1. **Introduction:**

According to the Federal Emergency Management Agency (FEMA) and the National Flood Insurance Program (NFIP), floods are by far the most common natural disaster in the world - with the United States being no exception – accounting for 43% of all recorded disaster events (FEMA, 2010). Besides being the most frequent form of natural disaster, floods are also considered to be the most costly; of the United States’ top ten most costly natural disasters of all time, 8 of them were flood-related (Muhlbaum & Korsh, 2021). Furthermore, it is important to consider how flooding is related to other forms of natural disasters. The same paper released by FEMA and the NOAA states that “Ninety percent of all natural disasters in the U.S. involve flooding” (FEMA, 2010). Within the context of increasing temperatures due to climate change, flooding events will only continue to become more frequent and extensive in the future, so identifying the communities who are currently most at-risk is the utmost priority in terms of climate mitigation.

1. **Motivation and Literature Review:**

As a native Angelino, I have high stakes in the health of the environment and the people of Los Angeles. Pursuing my Bachelor’s at Cornell University, I studied Environment and Sustainability, hoping to learn of a more practical way to assist my community in terms of climate change adaptation. This led me to the complex world of GIS and data science, where I currently reside – rendering visualizations that reveal deeper insights into data and the complexities of systems.

According to a report published by the NOAA just two months ago, Los Angeles -as well as many other coastal areas in the country- will experience “frequent flooding, degraded infrastructure, and other profound challenges as sea levels rise by as much as 1 foot by 2050” (NOAA, 2022). Besides being associated with structural damage and loss of life, flooding events also pose threats to public and environmental health, presenting challenges to the economic, social, and environmental systems within the City. In terms of economics, Los Angeles stands to lose a lot. The city owns, operates, and maintains crucial coastal infrastructure – including two power and wastewater treatment plants and the Port of LA – which is already considered vulnerable to flooding and sea level rise. The Port of LA is a huge economic hub for not just the City, but for all of California and the rest of the United States as well; the port handles 40% of the entire country’s container trading and employs one in every eight people in the city (MDS, 2015). Additionally, Los Angeles’ economy is heavily reliant on beach tourism, raking in over 42 million people per year, and constituting over 17 billion dollars generated (Grifman et al, 2015). For a ten-year flooding event (10% chance of happening every year) with the one foot rise in sea level expected by 2050, building losses are projected to be close to over 800 million dollars, over half of which being residential and affecting individuals and families. These costs have yet to be felt in the present, so the City can still forgo some of them through mitigative and adaptive strategies.

When looking at the social side of things, sea level rise and flooding will have profound consequences. For one, in the Sea Level Rise Vulnerability Study conducted by USC, Los Angeles’ cultural assets (I.e. museums and cultural centers) are deemed “highly vulnerable” to sea level rise because damage can affect the buildings’ resources and the buildings themselves. This threat to cultural assets presents a unique problem to the City, since these places represent areas of social cohesion and are often times used as locations for temporary relief from natural disaster events (Grifman et al, 2015). Secondly, the City’s demographic makeup is extremely diverse and varies spatially; of the 4 million Angelinos, 26% are White, 8% Black, 50% Latino/Hispanic, 16% Asian, 1% Native American, and the rest two or more races. Of this population, 12.8% do not have health insurance and 18% are currently living in poverty (U.S. Census Bureau, 2022). This is generally why climate change yields harsher impacts for people of color than for white people; increased rates of genetic health predispositions, like asthma, and are less likely, statistically, to have the money or resources necessary to improve or flee from their conditions (Fears & Grandoni, 2021). With this, and the spatial components within Los Angeles’ demographic data, it can be assumed that certain populations will be disproportionately affected by sea level rise. This will be heavily considered when calculating Social Vulnerability to sea level rise.

Something that most people fail to mention when assessing Los Angeles’ status in dealing with climate change adaptation is the fact that the City is entirely fossil fuel reliant. Speaking as an Angelino, you really cannot get anywhere in the City unless you have a car or someone who is willing to drive you; the public transportation system is highly inefficient and undeveloped. Because of this, Los Angeles is riddled with both smog and impervious surfaces, thus reducing the land’s natural ability to deal with excess water and creating the ideal scenarios for flooding and contaminated drinking/recreational water (Grifman et al, 2015). The contamination of drinking/recreational water, through flood runoff pushing toxic waste and water-borne pathogens into bodies of water that we source from, is something that will be more present in communities with dilapidated infrastructure and sewage systems, further exacerbating the social preconditions of poverty previously discussed (Fears & Grandoni, 2021). Other human health complications that can arise from flooding and sea level rise include: electrocution, carbon monoxide poisoning, trauma/mental health issues, mold inhalation, starvation, hypothermia, and drowning. People who need physical assistance at home, or who need electricity or heating for medical purposes- often times, these are people of color or people with physical or mental disabilities - will be the most likely victims of these health complications.

The health of the City’s natural resources and environment is also put at risk due to sea level rise and its associated effects. The majority of Los Angeles’ coastal zone is urbanized, making urban waste like trash or harmful chemicals abundant and close to important ecological assets. During the case of a flooding event derived from sea level rise, this urban waste is carried into our oceans, rivers, and streams where it contributes to environmental degradation and subsequent biodiversity loss. This is a positive feedback loop dilemma since the decline in environmental health, as a result of flooding, reduces the environment’s ability to deal with inundated water. Additionally, the World Health Organization states that this decline in biodiversity has implications on humans as well, “affecting livelihoods, income, local migration, and...exacerbate political conflict” (World Health Organization, 2015). The only ecological asset that lies within the City’s direct jurisdiction is the Ballona Wetlands Ecological Preserve, a 600- acre reserve (largest remaining wetland in Los Angeles County) which provides vital ecosystem services for Los Angeles and its people, such as nutrient cycling, wave attenuation, species protection, and water purification. The Ballona Wetlands Ecological Preserve also creates opportunities for aesthetic, cultural, educational, recreational, and research use, making it a critical asset for the City. In my experience growing up in Los Angeles and frequenting this area on educational field trips/trash clean-ups, this preserve marked one of the only places where I could be completely enthralled by nature and is probably where my passion for the environment stems from. In consideration of the goal of this paper being to highlight areas of the City that are most vulnerable to sea level rise, neighborhood proximity to the Ballona Wetlands Ecological Preserve will be a feature used in my vulnerability model, as it factors into how well a neighborhood is prepared for a flooding event.

Due to the aforementioned reasons, flooding has disproportionate impacts on certain neighborhoods, inherently making some areas of the City more at-risk to sea level rise than others. Currently, sea level rise already poses a clear and present risk to Los Angeles, and this will continue to worsen in the decades to come unless immediate action is taken by the City to mitigate or adapt to the effects of climate change. In order to optimize where this action should first take place, I will consult expert literature regarding sea level rise and social vulnerability to inform a model that calculates Sea Level Rise Vulnerability (Index) for each Census tract in Los Angeles. This model will attempt to be as holistic as possible, taking into consideration the multi- faceted impacts of flooding/sea level rise. Using a plethora of open data sets – including ACS demographic data, historic and current sea level rise data, proximity/point data, and land use/raster data –, as well as R, I will create three separate maps to support my narrative: 1) map of physical vulnerability to sea level rise (proximity, elevation, and % of impervious surfaces), 2) map of social vulnerability to sea level rise (race, income, house value, genetic health predispositions like asthma), and 3) a classification map that splits Census tracts into four different colors depending on if they have high social and physical vulnerability, high physical vulnerability but low social vulnerability, high social vulnerability but low physical vulnerability, and low social and physical vulnerability. The final deliverable will be in the form of an executive-style briefing in which I explain my motivation, methods, and findings to the City of Los Angeles and persuade them to implement a particular strategy (ex. Seawalls or green infrastructure) in the area that I highlight as having the most vulnerability.

1. **Methods:**

As discussed in Motivation and Literature Review, I will be using a variety of open data sources to produce features that I think, based on my review of expert literature, contribute most to a neighborhood being labeled “vulnerable” to sea level rise. Using these features, I will try to calculate each Census tract in Los Angeles’ social, physical, and overall vulnerability to sea level rise. In order to better delineate between these features and what they represent, I have included my drafted definitions of social vulnerability and physical vulnerability.

**Social Vulnerability:**

Social vulnerability is the susceptibility of an individual or social group to the negative impacts of natural hazards and disasters due to characteristics that influence one’s ability to prepare, respond, cope, or recover from a disaster (FEMA, 2020). These characteristics include financial situation, health, age, communicative abilities, and lack of access to life necessities. Historically discriminatory and racist policies, like redlining, also place low-income and minority communities more at risk of experiencing disasters. According to the Federal Emergency Management Agency’s *Guide to Expanding Mitigation,* these are the populations who will be disproportionately affected by sea level rise:

* + Underserved communities with a low socioeconomic status
  + People of color
  + Tribal and first nation communities
  + Women
  + Members of the LGBTQ+ community
  + Individuals experiencing homelessness or displacement
  + Populations over the age of 65 or under the age of 5
  + Populations with limited English proficiency
  + Service workers and migrant laborers
  + Populations with limited cognitive or physical abilities
  + Institutionalized populations, such as those in prisons and nursing homes, or individuals going through reentry
  + Renters

The Center of Disease Control also has its own way of calculating Social Vulnerability in which it uses United States Census data to examine social vulnerability at the Census tract level for 15 social factors (broken up into four groups), including:

1) Socioeconomic status

* + - Below poverty
    - Unemployed
    - Per capita income
    - Educational attainment

2) Household Composition and Disability

* + - 65 or older
    - 17 or younger
    - older than age 5 with disability
    - single-parent households

3) Minority Status and Language

* + - minority
    - speaks English “less than well”

4) Housing Type and Transportation

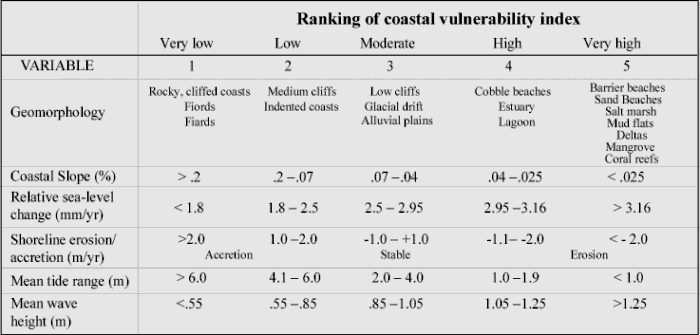
* + - multi-unit structures
    - mobile homes
    - crowding
    - no vehicle
    - group quarters/co-ops

Using the FEMA and CDC models for social vulnerability as inspiration, and based on Los Angeles’ unique context, I decided to use the following social factors in my social vulnerability calculation:

* + Racial context
  + Immigrants and migrant laborers
  + Populations with limited English proficiency
  + Single-parent households
  + Educational attainment
  + Unemployment
  + Per capita income
  + Below poverty
  + Individuals experiencing homelessness or displacement
  + Populations over the age of 65 or under the age of 5
  + Populations with limited cognitive or physical abilities
  + Institutionalized populations, such as those in prisons and nursing homes, or individuals going through reentry
  + Renters
  + Individuals with lack of vehicle access
  + Number of cultural centers
  + Redlining

**Physical Vulnerability:**

A landmark paper published in 1994 by Gornitz et al established the Coastal Vulnerability Index (CVI), which highlights six physical variables that contribute to an area’s vulnerability to sea level rise. The table below shows these variables, their descriptions, and their relative weights:



Using these variables as my initial physical vulnerability framework, I made a new model to calculate CVI, including the following factors (some data is not made publicly available, so this is the best I can do):

* + % of green space/infrastructure/tree canopy
  + Proximity to water
  + Elevation
  + Mean wave height
  + Relative sea level change
  + Proximity to medical assistance locations (ex. Hospital, urgent care)
  + Proximity to Ballona Wetlands Ecological Preserve
  + % property ownership or land use (ex. residential, commercial)

I HAVE NOT HAD TIME TO START CODING YET, BUT WILL HAVE INITIAL MAPS BY PRESENTATION DATE. I AM PROUD OF THE WORK THAT I PUT INTO THIS AND BECAUSE I WROTE PRETTY MUCH EVERYTHING FOR THE PAPER ALREADY (BESIDES FINDINGS AND RECOMMENDATIONS SECTIONS), I CAN SPEND THE REST OF THE SEMESTER FOCUSING ON THE CODING AND VISUALIZING (THE EASIEST PART). I WILL USE NOAA LOCAL AND HISTORIC SEA LEVEL RISE DATA, ACS CENSUS DEMOGRAPHIC DATA, AND OPEN-SOURCED POINT/POLYGON DATA FOR PROXIMITY TO HOSPITALS, BALLONA WETLANDS, ETC (ALL OF WHICH IN MY GITHUB REPOSITORY ALREADY).

1. **Results/Findings:**
2. **Recommendations:**

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