USING GEOGRAPHICAL INFORMATION SYSTEMS TO ESTIMATE POPULATION IN SPECIAL FLOOD HAZARD AREAS AND COASTAL LANDS AND STRUCTURES THAT WILL BE AFFECTED BY SEA LEVEL RISE IN PUERTO RICO

Prepared by: Wanda I. Crespo Acevedo, Roberto Moyano Flores, Estudios Técnicos, Inc.
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INTRODUCTION

Puerto Rico is located in the Caribbean region, between the Atlantic Ocean and the Caribbean Sea. It is comprised of a main island, two smaller populated islands (Vieques and Culebra), and other uninhabited islands and cays. The island of Puerto Rico has an approximate area of 3,429 square miles.

Puerto Rico is organized in 78 municipalities and has a population of 3,583,073.[1] Most of the population (61.8% or 2,215,574) lives in the 44 coastal municipalities, which also houses critical infrastructure, as well as activity centers and natural habitats that are important to the island's economy and residents' livelihoods.

At present, the island is susceptible to tropical storms and hurricanes, winter swells, floods, and coastal erosion, among other risks. Many of the infrastructure and residential, commercial and industrial activities occur in low-lying coastal areas, which are currently susceptible to flooding. Sea level rise may increase the vulnerability of these coastal populations and assets.

This document presents the results of a spatial analysis conducted to explore current vulnerabilities due to flooding, and future threats to land and coastal structures resulting from sea level rise.

[1] Source: U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates.

ESTIMATING POPULATION CHARACTERISTICS IN SPECIAL FLOOD HAZARD AREAS

To assess current vulnerabilities, populations living in areas subject to flooding were estimated, and a preliminary socioeconomic profile was generated.

Population living in FEMA Flood Zones

Methodology:

Data sources:

The following data layers were used to estimate the population living in FEMA flood zones:

- Census Data: U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates. Retrieved from [https://factfinder.census.gov].
- Census Geospatial Layer: 2016 TIGER/Line Geodatabases (machine readable data files) prepared by the U.S. Census Bureau, 2016. Retrieved from: [https://www.census.gov/].
- FEMA. National Flood Hazard Layer, 2016. Retrieved from: [https://catalog.data.gov/].

Process:

Using ESRI's ArcGIS Desktop 10 with the ArcView license of ArcMap, the first step was to intersect the National Flood Hazard Layer (NFHL) with the Census Block Groups Feature Class. Given that Census and FEMA boundaries are not identical, areal weighting was used. This is a spatial interpolation method which assumes that population is distributed homogeneously throughout a unit (i.e. population was distributed homogeneously in each census block group). With the resulting table, the area of every Flood Zone that falls inside a Block Group was divided by the total area of the Block Group. This gives the proportion of the area in the Block Group that intersects each flood zone. This was done in order to calculate the amount of the variable not in the entire Block Group, but in the area of the Block Group which is part of a Flood Zone.

This factor was then applied to the Total Population for every Block Group in Puerto Rico. The flood zones considered were A, A99, AE, AH, AO, D, VE. The X flood zone was not considered because it is determined to be outside 500-year floodplain or to be outside the 1% annual chance floodplains.

Limitations:

- Process limitations: Estimates assume that the population is distributed homogeneously throughout the Census Block Groups, even though distribution is rarely, if ever, homogenous.
- Data limitations: The FEMA-FIRMs are prepared for insurance purposes and not for planning purposes. As a result, the maps do not consider, for example, the combined coastal and riverine flooding hazards, nor the coastal erosion. FIRMS are prepared as part of the NFIP which is a federal program that enables property owners in participating communities to purchase insurance protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damages.

Results: Estimates of population vulnerable to flooding

Approximately, 15% of the population in Puerto Rico (524,469 people) lives in areas subject to flooding. It is estimated that 908,579 (13.1%) of this population is under 18 years and 596,280 (15%) is over 65 years. Of this population, 94,456 do not have a high school diploma.

There are 88,100 households under the poverty level (6.4% of the 1,376,532 households in Puerto Rico). The median household income of the population living in flood prone areas ($20,887) is higher ($1,537 more) than the median for Puerto Rico ($19,350). Per capita income is $11,161, which is $233 lower than Puerto Rico's $11,394.

There are 60,333 families with a single householder living in flood prone areas, which constitutes 15.9% of all such families in Puerto Rico (379,966). Of the 15.9% of households with a single householder, 80 % (48,471) are households with a female householder with no husband present.

It is estimated that 401,145 people (11.5% of Puerto Rico's total population) live in AE zones. These are defined as "the areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods".[2] This zone represents riverine flood and also it extends from the landward VE zone limit to the limits of the 100-year flood from coastal sources, or until it reaches the confluence with riverine flood sources. 56,114 people live in areas susceptible to storm surge (VE zone), also known as the coastal high hazard areas.

[2] Source:https://www.fema.gov/zone-ae-and-a1-30

Table 1. Population profile

	Puerto Rico's population in flood zones	Population under 18 years living in flood zones	Population 65 years or over living in flood zones	Households under poverty level	Median HHLD income	Per capita income	Families with a single householder	Families with a female householder no husband present	Education (people with no high school diploma)
Flood zones (Source: FEMA. National Flood Hazard Layer, 2016)									
A	41,090	9,590	6,549	6,508	$21,960.62	$10,651.34	4,131	3,244	7,696
AE	401,145	91,534	68,352	65,756	$21,484.93	$11,205.36	47,176	38,042	71,352
VE	56,114	11,489	10,698	9,653	$19,400.50	$11,723.17	5,568	4,276	11,033
Zonas (A, A99, AE, AH, AO, D, VE)	524,469	118,658	90,314	88,100	$20,886.79	$11,160.66	60,333	48,471	94,456

Source: U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates.

FEMA. National Flood Hazard Layer, 2016.

ESTIMATES OF LAND IN PUERTO RICO THAT WILL BE FLOODED BY SEA LEVEL RISE

Future land and property losses in the coastal zone due to sea level rise were estimated using the National Oceanic and Atmospheric Administration (NOAA), Coastal Services Center Sea Level Rise Data for the following scenarios:

- Low risk- considers an increase in 2 ft (~0.5 meter)
- Medium risk- 3 ft. (1 meter) and
- High risk- 6ft- (2 meters).

Methodology:

Data sources:

- Administrative boundaries: PR Planning Board, Legal Boundaries of Municipalities updated version October 2015. Retrieved from: [http://www2.pr.gov/]
- Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), Coastal Services Center (CSC). NOAA Coastal Services Center Sea Level Rise Data: 6 ft Sea Level Rise Inundation Extent, 2012. Retrieved from: [https://coast.noaa.gov/]

Process:

- Using ESRI's ArcGIS Desktop 10 with the ArcView license of ArcMap, the Sea Level Rise (SLR) layer was intersected with the Municipalities layer. The area of the resulting layer was calculated in order to get the area potentially susceptible to sea level rise.

Limitations:

Sea level rise estimates illustrate the scale of potential flooding, not the exact location, and do not consider changes in the coastline such as erosion, subsidence, accretion, or future construction. Water levels are relative to Mean Higher High Water (MHHW) (excludes wind driven tides). In addition, it does not consider other physical and natural factors such as current flooding and it assumes present conditions will persist, which will not be the case. The digital elevation model used to map sea level rise does not incorporate a detailed pipe network analysis, or engineering grade hydrologic analysis (for example, culverts and ditches may not be incorporated resulting in incorrectly mapped areas).

Results

Under a low risk scenario, it is estimated that 97 square kilometer of the coasts will be inundated. Under a high risk scenario, 321 square kilometers or 3.6% of the coastline will be affected. Results are detailed in the following table.

Table 2. Coastal lands that will be affected by sea level rise

SLR Scenarios	Meters^2	Miles^2	KM^2	% of coastal land that will be flooded by SLR
Low (0.5 meter) (2 feet)	96,501,881	37	97	1.1%
Medium (1 meter) (3 feet)	145,803,437	56	146	1.6%
High (2 meters) (6 feet)	321,075,518	124	321	3.6%

ESTIMATES OF STRUCTURES AND COASTAL INFRASTRUCTURE SUBJECT TO SEAL LEVEL RISE

Methodology

Data sources:

- Municipal Revenue Collection Center, geospatial layer of "Structures". Information supplied February 2016.
- Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), Coastal Services Center (CSC). NOAA Coastal Services Center Sea Level Rise Data: 1-6 ft Sea Level Rise Inundation Extent, 2012. Retrieved from: [https://coast.noaa.gov/]

Process:

Using ESRI's ArcGIS Desktop 10 with the ArcView license of ArcMap, the Sea Level Rise (SLR) layer was intersected with the Structures layer. The number of resulting polygons was filtered as to avoid double-counting. The result was the total number of Structures potentially subject to sea level rise.

To estimate the present value of structures, a 3% inflation rate was used which is based on Puerto Rico's Planning Board GNP deflator.

Limitations:

Data from the CRIM does not provide information on the type of structure, which makes it difficult to quantify or identify structures by their use.

In addition, the data provides the structures' value as of the year 1954. To convert the value of the structure to 2017 dollar, a 3% price increase was applied to the original value.

Furthermore, the appraisal reflects the replacement cost of the structure and does not reflect the actual market value. However, this is the best available information, based on official government data.

Results

Under a low risk scenario, 8,213 structures located in coastal areas would be affected. Under a two meter increase 50,728 structures would be affected, and approximately $11.8 billion or 14% of all property value in the coastal zone is potentially at risk.

Table 3. Coastal structures that will be affected by sea level rise

Scenarios	Number of structures that could be affected
Low (0.5 meter) (2 feet)	8,213
Medium (1 meter) (3 feet)	16,137
High (2 meters) (6 feet)	50,728

Table 4. Value of coastal structures that will be affected under a 6ft scenario

	Value in 1954	Estimated value in 2017
Median value of structures that will be impacted by a 6 ft. slr	$ 8,601	$ 55,372
Total value of structures in Puerto Rico impacted by a 6 ft slr	$ 1,826,558,246	$ 11,759,224,511
Total value of structures in Puerto Rico	$ 12,609,000,000	$ 81,177,000,000
% of value the total value of structures	14%	14%