Pricing storm surge risks in Florida: Implications for determining flood insurance premiums and evaluating mitigation measures

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Pricing storm surge risks in Florida: Implications for determining flood insurance premiums and evaluating mitigation measures

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Abstract

The National Flood Insurance Program (NFIP) has been criticized for inaccurate flood hazard maps and premiums that are not risk-based. By employing granular storm surge data comprised of five different event probabilities with associated flood elevations, surge risk-based premiums for homes in Pensacola, Florida are compared with NFIP premiums that are based on hazard data for only one event probability (1% annual chance floods). By calculating risk-based premiums using granular surge risk data we can determine the cost-effectiveness of elevating homes to mitigate surge risks. Comparing the costs of low-interest mitigation loans with savings in surge risk-based premiums after mitigation illustrates that elevating most Pensacola homes cannot be justified solely with financial benefits in reducing future storm surge related damage.

KEYWORDS: flood risk, National Flood Insurance Program, risk-based flood insurance premiums, storm surge, flood risk mitigation
1. INTRODUCTION

Florida is one of the most flood-prone states in the U.S. because of its low-lying topography, tropical and subtropical climate, and miles of coastline exposed to hurricane and storm surge hazards. According to data published online by the National Flood Insurance Program (NFIP) in May 2017\(^1\), Florida is ranked fifth among all U.S. states for dollar amounts of flood insurance claims since the inception of the NFIP in 1968. One-sixth of Florida’s NFIP claims are from Escambia County, although this county has only 1.5% of Florida’s population (according to the U.S. Census Bureau population estimates for July 2016\(^2\)). Located in the northwestern-most extent of the Florida panhandle, the study area for this research is the City of Pensacola, which is the county seat of Escambia County. In this paper we focus on risk-based flood insurance premiums, how premiums could be reduced via mitigation measures, and whether investments in mitigation would be cost-effective in Pensacola.

The NFIP has been criticized because it does not charge premiums that accurately reflect flood risk.\(^{(1)}\) NFIP rates are set according to flood zone characteristics for the entire nation\(^{(2,3,4)}\) which results in policies that may be underpriced or overpriced with respect to the actual risk. Underpricing insurance conveys a false sense of security to policyholders that their flood risk is lower than it may actually be.\(^{(5)}\) NFIP digital flood insurance rate maps (DFIRMs)\(^3\) show flood zones with annual probabilities of only 1% and 0.2% (corresponding to 100- and 500-year floods, respectively), because NFIP premiums are based largely on structures’ coincidence with either of these two zones. The annual 1% chance flood zones are called the Special Flood Hazard Areas (SFHAs), and there are regulatory requirements for properties within SFHAs to purchase NFIP insurance if the property has a federally-insured mortgage.\(^{(6)}\) Within

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\(^{1}\) National Flood Insurance Program (NFIP) loss statistics can be found at https://bsa.nfipstat.fema.gov/reports/1040.htm.
\(^{2}\) County-level population and ranks can be searched in U.S. Census Bureau quick facts at https://www.census.gov/quickfacts/.
\(^{3}\) See Appendix A for a list of the NFIP flood zones that appear in DFIRMs and their definitions.
SFHAs, the stillwater flood elevations for 1% annual chance events, called base flood elevations (BFEs), are delineated. Two cross-subsidies of the NFIP result from methods used to create DFIRMs. One cross-subsidy occurs among policies in the 0.2% annual chance/500-year flood zones, which are called X500 zones in the DFIRMs. Policies in X500 zones are not based on structure elevation, thus there is an implicit subsidy from structures in X500 zones with higher elevations to structures with lower elevations because flood risks are lower for structures with higher elevations.

A second cross-subsidy from the DFIRMs occurs in A zones, which are SFHAs without wave action hazards. The A zones include areas at risk to wave action hazards less than three feet, but rates within A zones are based only on the BFE. As stated above, the BFE represents stillwater flood elevation and thus does not include wave heights, as waves have motion. Ignoring wave hazards in A zone rating results in implicit cross-subsidies from policies for structures without any risk to wave hazards to policies covering structures at risk to wave hazards less than three feet. Cross-subsidies might support one of the NFIP’s primary original goals, which is to provide affordable flood insurance to all U.S. homeowners. However, providing subsidized flood insurance hampers motivation for homeowners to take action to mitigate their flood risk since in return they will receive a smaller insurance price discount (if any at all) than if they were charged a premium that was risk-based.

Previous research has established that granular flood risk data are necessary for accurately estimating expected losses for structures and risk-based insurance premiums. Specifically, DFIRMs that show BFEs only in the 1% annual probability flood zones are insufficient for accurate flood risk assessments. For example, Messner et al. (2007) recommend flood hazard models with six flood probabilities, while Tate et al. (2016) employed ten flood probabilities. There is no specific guidance for a minimum or
optimal number of flood probabilities that are necessary to accurately model flood risks for all study areas, but FEMA recognizes that annual 1% and 0.2% annual chance flood zones are not sufficiently granular for accurate flood risk assessments and specifying risk-based flood insurance premiums.\(^{(11)}\)

Treating the annual 1% chance flood zone as a homogeneous risk zone is erroneous because there are other probabilities of risk within this zone, and technology exists today to produce more granular flood risk assessments.\(^{(2)}\)

Because granular flood risk data for Pensacola are unavailable as of this writing, we have employed granular storm surge data for Escambia County to estimate surge risk-based insurance premiums. The storm surge data include surge elevations for the 10%, 4%, 2%, 1% and 0.2% annual chance events. We estimate premiums based on surge risks for single-family homes in the City of Pensacola and Sanders Beach. To estimate risk-based surge premiums, we implement an expected annual average losses (AAL) approach, as others have done.\(^{(2,9,10)}\) We use two different depth-damage functions to illustrate the sensitivity of calculated surge risk-based premiums to the choice of depth-damage function.

For this study, Sanders Beach is defined as the 2010 census tract near downtown Pensacola that mostly encompasses the waterfront Sanders Beach neighborhood, and this tract is entirely within the Pensacola city limits. We used the NFIP manual (October 2016 version)\(^{(12)}\) to estimate NFIP premiums. Figure 1 shows the location of Sanders Beach within the Pensacola city limits, and the location of Escambia County in northwest Florida. We compare NFIP premiums to surge risk-based premiums. Since NFIP premiums are based mainly on whether the insured home is within or outside SFHAs in the DFIRM, the comparisons of NFIP premiums with surge premiums are grouped by homes within and outside SFHAs.
(i.e., within SFHAs are 1% annual chance/all A flood zones, and outside SFHAs are 0.2% annual chance/X500 flood zones).

![Location map of the Sanders beach tract within the Pensacola city limits, and Escambia County in northwest Florida.](image)

**Figure 1.** Location map of the Sanders beach tract within the Pensacola city limits, and Escambia County in northwest Florida.

We employ future surge risk data for years 2042, 2067, 2092, and 2100 to estimate surge risk-based premiums for future years with sea level rise. The first three of these years were chosen because they are 25, 50, and 75 years from the present year of 2017; and 2100 is the recommended year for planning flood mitigation projects in communities that participate in the NFIP Community Rating System (CRS). The CRS is an NFIP program that rewards NFIP communities for implementing stricter

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4 Years 2042, 2067, 2092, and 2100 were chosen for future conditions surge with sea level rise analysis because of how the sea level rise estimation tool we used is designed: the tool is a web form located at [http://www.corpsclimate.us/ccaceslcurves.cfm](http://www.corpsclimate.us/ccaceslcurves.cfm) in which users input the initial year and intervals, going out to the maximum year of 2100. This web-based tool, hosted by the U.S. Army Corps of Engineers, is what is recommended by the most recent version of the Community Rating System (CRS) handbook (located at [https://www.fema.gov/media-library-data/1493905477815-d794671adeed5beab6a6304d8ba0b207/633300_2017_CRS_Coordinators_Manual_508.pdf](https://www.fema.gov/media-library-data/1493905477815-d794671adeed5beab6a6304d8ba0b207/633300_2017_CRS_Coordinators_Manual_508.pdf)).
floodplain regulations than minimum NFIP regulations. Efforts to assess future conditions and potential increases in flood risks are not currently being undertaken by FEMA\(^5\), but flood risk assessments generally examine both current and future risks.\(^8\)

The cost-effectiveness of home elevation as a flood mitigation strategy is assessed by calculating costs to elevate homes\(^6\) in Sanders Beach and Pensacola by four and eight feet to lessen flood risks and reduce surge risk-based insurance premiums. We then compare annual loan costs for home elevation with the savings in present-day surge risk-based premiums once homes are elevated. Home elevation is a very effective method of mitigating flood risks and it typically reduces flood insurance premiums.\(^{14}\) However, elevation is particularly costly for structures with slab on-grade foundations,\(^{14}\) and is rarely cost-effective for homes in Sanders Beach and Pensacola since many are constructed on slab on-grade foundations.

The analyses implemented herein are designed to answer the following research questions:

1. How do surge risk-based premiums compare with NFIP premiums for single-family homes in Sanders Beach and Pensacola using more granular storm surge data than the flood zones delineated in FEMA DFIRMs?

2. How do storm surge risk-based premiums vary with different depth-damage functions for the present year and the future using sea level rise estimates?

\(^5\) While FEMA does not assess future conditions, they have guidelines to support and guide local communities who want to use future-conditions hydrology. More information is available at [https://www.fema.gov/final-guidelines-using-future-conditions-hydrology](https://www.fema.gov/final-guidelines-using-future-conditions-hydrology) (last accessed 7 June 2017).

\(^6\) See Appendix B for figures used to estimate total costs of elevating homes.
3. For what types of homes do the savings in surge risk-based premiums from elevating homes in Sanders Beach and Pensacola make this a cost-effective method of flood risk mitigation?

2. DATA AND METHODS

2.1 Data Sources

The data used in our analyses originated from the Escambia County Property Appraiser (ECPA), Escambia County Geographic Information Systems (GIS), the City of Pensacola, the Northwest Florida Water Management District (NWFWMMD), Florida Department of Emergency Management, and the Federal Emergency Management Agency (FEMA).

2.2 Geospatial Analysis

The geospatial procedures were implemented with ArcGIS version 10.2.2. First, parcel attributes required to estimate flood risk and exposure from the ECPA’s 2015 parcel dataset were joined to the parcel outlines. The parcel attributes relevant to determining flood risk included improvements values, year of construction, foundation and frame types, number of floors, and heated area in square feet. Next, we spatially joined building footprints within the Pensacola city limits to the single-family parcels that contained them to assign the parcel attributes to the building footprints. Then, we intersected the buildings within parcels feature class with the effective flood zones from the 2006 FEMA Digital Flood Insurance Rate Map (DFIRM) for Escambia County to attribute buildings with a DFIRM flood zone. The DFIRM for Escambia County is published as an ArcGIS geodatabase that can be downloaded at FEMA Flood Map Service Center. Buildings within the 1% annual chance flood zones, denoted as A zones in DFIRMs, were attributed with the 1% annual chance flood elevation (BFE) they coincided with. For

7 FEMA Flood Map Service Center is located at https://msc.fema.gov/portal.
8 The annual 1% chance flood zones in NFIP DFIRMs without wave action hazards are called A, AE, AH, AO, AR, and A1-A99; and are collectively referred to as A zones throughout this paper.
buildings within A zones that were not attributed with BFEs, we interpolated the BFE based on the BFE line feature class that is part of the DFIRM geodatabase. We used the Escambia County Flood Risk Study (15) that accompanies the 2006 effective DFIRM to guide BFE line interpolation to attribute buildings with BFEs, as instructed in the NFIP manual. (12)

The final step involved attributing building footprints with first floor elevation (FFE) information, most of which was based on elevation statistics from the LiDAR-derived digital elevation model (DEM) from the NWFWMD (collected in 2006). The average elevation of the DEM within each building footprint was chosen as a basis to estimate FFES of single-family homes, except for homes that had a geocoded elevation certificate from the City of Pensacola Building Inspections Department. We received 25 residential elevation certificates from the City, but were not able to geocode all of them, mostly because they were for very new homes that did not appear in the 2015 parcel dataset. We were able to match 16 elevation certificates confidently with records in the ECPA parcels and Pensacola building footprints. Because there is not significant variation in elevation within the Pensacola building footprints (9), we chose to use the average of the elevations within building footprints. For the remainder (18,383 building footprints within single-family home parcels) that did not have a geocoded elevation certificate, we applied the following assumptions to estimate FFE based on average elevation and foundation type (10) according to the ECPA parcel data:

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9 The range of elevation values within the 18,399 Pensacola building footprints we examined has an average of 1.50 feet with a standard deviation of 1.61. Although there are 79 building footprints with an elevation range over 10 feet, this represents only 0.4% of our 18,399 building footprints.

10 Email communication with an Appraisal Supervisor at ECPA provided the following information on foundation types listed in the ECPA data: a slab above grade foundation is built up by 3 blocks or more, typically for sloped lots; and a wood foundation with a subfloor is an elevated home on pilings or crawlspace. Assumptions 1 and 2 listed on this page are minimum heights based on our understanding of these foundations types from our communications with personnel at the ECPA. Assumptions 3 and 4 are somewhat arbitrary, but piling homes usually have higher foundations than crawlspace homes. There are no minimum elevation requirements for homes outside SFHAs, so without many elevation certificates we made these estimates of FFES.
1. If foundation type is slab above grade, then add 2 feet to the average elevation of the DEM within the building footprint to estimate FFE. According to the ECPA, slab above grade foundations are elevated at least 3 blocks, and a standard block is 8 inches high.

2. If foundation type is slab on grade, then simply use the average elevation of the DEM within building footprint as FFE.

3. If foundation type is pilings, then add 6 feet to average elevation of the DEM within building footprint to estimate FFE.

4. If foundation type is wood with a subfloor, then add 3 feet to average elevation of the DEM within building footprint to estimate FFE. Wood with subfloors, according to the ECPA data, are elevated homes not on a slab.

Once FFEs had been estimated for all single-family homes in Pensacola, we intersected the building footprints with surge risk data called U-Surge. Based on observations from the National Oceanic and Atmospheric Administration (NOAA), tide gauges and other data sources, storm surge data from 1900 to 2016 for Escambia County were analyzed and used to develop the U-Surge dataset for our study area. The U-Surge dataset was produced from a regression analysis of water level (storm tide height) as the dependent variable and frequency (return period) as the independent variable, and involved conversion of all high water marks to one common vertical datum (NAVD88) to enable statistical analysis.\(^{16,17,18,19}\)

U-Surge data for surge risks (water elevations and probabilities) in Pensacola for the year 2017 were utilized for analysis. The U-surge data are more granular than DFIRM data because surge hazards are disaggregated into annual probabilities of 10%, 4%, 2%, 1%, and 0.2%. Each annual surge probability event has a corresponding surge height, as shown in Table 1 (in feet). Homes that coincide with surge hazards were attributed with the minimum surge elevation based on all annual probability events, and
then all surge elevations that were higher were also attributed to the homes to calculate the total surge risk for homes. For example, if a home is coincident with the surge elevation corresponding to the 2% annual surge event, then we can assume it is also vulnerable to the 1% and 0.2% annual chance events.

Future conditions of surge hazards with sea level rise were also assessed for years 2042, 2067, 2092, and 2100 by applying the NOAA Intermediate-High scenario\textsuperscript{11} and using the web-based tool provided by the U.S. Army Corps of Engineers (USACE), as recommended in the NFIP CRS manual.\textsuperscript{13} Table 2 shows the sea level rise figures in feet for each NOAA scenario.

\textsuperscript{11} The latest version of the CRS manual (updated May 4, 2017)\textsuperscript{13} recommends that floodplain managers in CRS communities use the NOAA Intermediate-High scenario out to 2100 for project planning in order to be potentially eligible for the maximum credit for these planning activities for flood risk reduction. This CRS manual planning guidance is the rationale for our choice of the NOAA Intermediate-High Scenario in our sea-level rise estimates.
Table 1. Stillwater surge elevations in feet for each probability event for Pensacola relative to NAVD88 (North Atlantic Vertical Datum of 1988) for year 2017. Storm tide return levels based on observed data from 1900-2016 (117 years) for the Pensacola area. (Source: U-Surge. 2017 Marine Weather & Climate [https://www.u-surge.net/pensacola.html]).

<table>
<thead>
<tr>
<th>Annual probabilities of surge events</th>
<th>Stillwater surge elevation (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>4.91</td>
</tr>
<tr>
<td>4%</td>
<td>8.50</td>
</tr>
<tr>
<td>2%</td>
<td>11.21</td>
</tr>
<tr>
<td>1%</td>
<td>13.92</td>
</tr>
<tr>
<td>0.2%</td>
<td>20.21</td>
</tr>
</tbody>
</table>
Table 2. Sea level rise scenarios (in feet) for Pensacola for 2017, 2042, 2067, 2092 and 2100 according to National Oceanic and Atmospheric Administration (NOAA) (see http://corpsclimate.us/ccaceslcurves.cfm).

<table>
<thead>
<tr>
<th>Year</th>
<th>NOAA Low</th>
<th>NOAA Int. Low</th>
<th>NOAA Int. High*</th>
<th>NOAA High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2042</td>
<td>0.2</td>
<td>0.3</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>2067</td>
<td>0.3</td>
<td>0.8</td>
<td>1.8</td>
<td>2.9</td>
</tr>
<tr>
<td>2092</td>
<td>0.5</td>
<td>1.4</td>
<td>3.2</td>
<td>5.3</td>
</tr>
<tr>
<td>2100</td>
<td>0.6</td>
<td>1.6</td>
<td>3.7</td>
<td>6.2</td>
</tr>
</tbody>
</table>

*In this report, we use the NOAA Intermediate High scenario for each year into the future by adding the number of feet of estimated sea level rise to current surge water elevations. For example, for all estimations for the year 2042 we add 0.7 feet to all surge elevations.

2.3 Determining Surge Risk-Based Insurance Premiums

To estimate average annual expected losses (AAL) from stillwater surge hazards for homes in Pensacola and corresponding risk-based insurance premiums, we applied two different depth-damage functions from the Hazus\textsuperscript{12} software package that estimate percentages of the dollar values of damage to building and contents given certain depths of water inside homes.\textsuperscript{13} (\textsuperscript{20}) We assess how our results vary according

\textsuperscript{12} Hazus is software developed by FEMA that has a nationally applicable standardized methodology for estimating potential losses from earthquakes, floods, and hurricanes (https://www.fema.gov/hazus).

\textsuperscript{13} Depth-damage functions are developed for each type of occupancy class (e.g., residential single-family), and vary for foundation types (basement or no basement), and number of stories/floors in the building. The two depth-damage functions we employ in this study are based on occupancy type, presence of a basement, number of
to two different depth-damage functions without making a judgment on the most appropriate one to use. We used the FIA/FIA modified function\textsuperscript{14} since it is the default for the Hazus program, and the US Army Corps of Engineers (USACE) Institute of Water Resources (IWR) function because it does not involve specifics based on any geographic region of the United States.

We implemented calculations using the IBM SPSS Statistics software (version 24) to estimate damages to homes and contents based on our selected depth-damage functions. To estimate homes’ vulnerability to storm surge hazards, we subtract the homes’ FFEs from the surge water elevations they coincide with to obtain the water depths inside the homes for each flood frequency/probability surge event for years 2017, 2042, 2067, 2092, and 2100. We computed AALs for all homes vulnerable to surge risks according to the equation found in the Hazus Technical Manual (version 2.1, page 14-38):

\[
AAL = \left[ \left( f_{10} - f_{25} \right) \times \left( \frac{L_{10} + L_{25}}{2} \right) \right] + \left[ \left( f_{25} - f_{50} \right) \times \left( \frac{L_{25} + L_{50}}{2} \right) \right] + \left[ \left( f_{50} - f_{100} \right) \times \left( \frac{L_{50} + L_{100}}{2} \right) \right] + \left[ \left( f_{100} - f_{500} \right) \times \left( \frac{L_{100} + L_{500}}{2} \right) \right] + \left( f_{500} \times L_{500} \right)
\]

where \( f_{10} = 1/10 \) (frequency/probability of a 10-year flood event) and \( L_{10} \) are the losses attributable to the 10-year event (expressed as percentages of building and contents).

The AAL equation is based on the annual probability of each flood with the corresponding flood depths inside the home, and the damage to buildings and contents attributed to each depth of water inside homes (rounded to nearest whole foot) according to the selected depth-damage function. We used the floors, and flood zones (A or V zones) for the FIA/FIA modified functions. Depth-damage functions are developed from engineering studies and observed damage and claims data, and more information on depth-damage functions can be found in Chapter 5 of the Hazus Technical Manual (version 2.1).\textsuperscript{20}\textsuperscript{14} FIA is the same agency that is now called the Federal Insurance and Mitigation Administration (FIMA).

\textsuperscript{14} FIA is the same agency that is now called the Federal Insurance and Mitigation Administration (FIMA).
improvements values from the 2015 ECPA parcel data as building values, and we assumed that contents values were half of the building values. The results of the AAL computations for homes at risk of surge hazards were used as the surge risk-based pure premiums. We assumed a $0 deductible for our surge premiums.

2.4 Estimating NFIP Premiums

To compare NFIP premiums with surge risk-based premiums, we applied the NFIP rate-setting methods using the October 2016 NFIP manual.\(^\text{12}\) For building coverage amounts, we used building values according to the improvements values\(^\text{15}\) from the 2015 ECPA data. Contents coverages were assumed to be half of building values, and we imposed NFIP limits on coverage.\(^\text{16}\) The flood risk data for each single-family home were from the 2006 Escambia County DFIRM. We omitted consideration of different deductibles and deductible factors\(^\text{17}\), fees and surcharges. We assumed that all homes were owner-occupied so that we could compute building and contents premiums for primary residences using the NFIP rating tables.\(^\text{12}\)

For homes within SFHAs, which are all A zones in the DFIRM, NFIP premiums are rated as either pre- or post-flood insurance rate map (FIRM). Pre-FIRM rating can be used when the date of home construction is prior to when the community entered the NFIP and received its first FIRM, and for Pensacola this date is September 15, 1977. Communities typically had no minimum floodplain construction standards prior to entering the NFIP, therefore homes built prior to the first FIRM for their community probably have

\(^{15}\) In the ECPA data, improvements values are the values of anything on a parcel that is not land value (e.g., buildings, driveways, and other built structures).

\(^{16}\) NFIP residential coverage limits for building and contents are $250,000 and $100,000, respectively.

\(^{17}\) We used a deductible factor of 1 for all premium calculations, which equates to a $1,000/$1,000 deductible for building/contents for post-FIRM structures, and a $2,000/$2,000 deductible for building/contents for pre-FIRM structures (according to the October 2016 NFIP manual page RATE 18).
FFE$s$ that are below the regulatory BFE$s$. Pre-FIRM premiums are considered subsidized according to FEMA. Post-FIRM rates involve homes’ foundation types and FFE$s$ with respect to the BFE for the zone in which they are located. We estimated pre- or post-FIRM rates based on year of home construction\textsuperscript{18}: if the home was built in 1977 or earlier we used pre-FIRM rates, and post-FIRM rates were used for homes built in 1978 and later.

For homes within X500 zones, which are the annual 0.2\% chance flood zones, we estimate NFIP premiums using both Preferred Risk Policy (PRP) and Standard Policy rates. Homes outside SFHAs may be eligible for relatively inexpensive PRP premiums if they meet several conditions\textsuperscript{19}. If X500 zone homes do not meet the criteria for PRP eligibility, then they are rated with Standard Policy rates. There are no considerations of structures’ FFE$s$ in any X500 zone premiums, and there are no flood elevations delineated within X500 zones.

We do not consider NFIP premiums to be risk-based, but the premiums we estimate are generally likely to be higher than actual NFIP premiums charged for many policies in Pensacola that are subsidized for reasons other than pre-FIRM subsidization. We also assume that coverages are for full building replacement values (and contents coverages are half of building values) while policyholders may actually request less building and contents coverages to lower their premiums.

\textsuperscript{18} We do not have the dates of home construction, only the years. Therefore we apply pre-FIRM rates for homes built in 1977 or earlier and post-FIRM rates to homes built in 1978 or later.

\textsuperscript{19} A home in an X, B, or C flood zone can obtain a PRP if none of the following conditions apply within any 10-year period: (a) 2 flood insurance claim payments for separate losses, each more than $1,000; or (b) 3 or more flood insurance claim payments for separate losses, regardless of amount; or (c) 2 Federal flood disaster relief payments (including loans and grants) for separate occurrences, each more than $1,000; or (d) 3 Federal flood disaster relief payments (including loans and grants) for separate occurrences, regardless of amount; or (3) 1 flood insurance claim payment and 1 Federal flood disaster relief payment (including loans and grants), each for separate losses and each more than $1,000.
For both surge risk-based premiums and NFIP premiums, we estimate pure premiums, defined as the dollar amounts that reflect flood-related damage only from storm surge. These premiums do not include loading factors that reflect an insurance company’s overhead, administrative costs, fees or other expenses.

2.5 Assessing Flood Risk Mitigation Costs and Benefits

Once we computed NFIP and surge risk-based premiums, we analyzed home elevation as a mitigation action. Elevating a home in place is the most straightforward method of mitigating flood risk and lowering flood insurance premiums. Based on the FEMA publication P-312,[14] we estimated costs to elevate homes with two types of foundations and frames: slab foundations and open foundations with crawlspace, and wood and masonry frames.20 We estimated the costs and benefits of elevating homes’ FFES by four and eight feet.

To assess whether elevation is a cost-effective method of flood risk mitigation, we examined surge risk-based premiums before elevating, and combined annual costs of mitigation loans with 30-year terms and 1% annual interest rates with reduced surge premiums after elevating. Specifically, benefit-cost ratios are computed as ratios of the savings in surge risk-based premiums after elevation relative to the costs of mitigation loans for elevating homes by four or eight feet. We then examined the characteristics of homes with benefit-cost ratios of 0.9 or more, since a benefit-cost ratio of 1 indicates cost-effectiveness.

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20 The cost estimates for elevating these two types of foundations and frames per square foot of home footprint are found in Table 3-3 on page 3-20 of publication P-213.
We estimated surge risk-based premiums and mitigation costs for all single-family homes in Pensacola, and cost-benefit ratios for homes at risk to surge hazards. We single out the Sanders Beach 2010 census tract for a more detailed analysis because it is more vulnerable than other parts of the city to surge and sea-level rise, has modest property values and contains both A and X500 NFIP flood zones according to the 2006 DFIRM.

3. RESULTS AND DISCUSSION

3.1 Comparison of NFIP and Surge Risk-Based Insurance Premiums for Sanders Beach and Pensacola

Figure 2 depicts average annual normalized premiums (i.e., annual premium per $100 of building and contents coverage) by NFIP flood zones for single-family homes in Sanders Beach based on both NFIP and surge risk-based rating methods. Figure 3 shows average annual normalized (i.e., per $100 of building and contents coverage) premiums for Pensacola homes by NFIP flood zone based on both NFIP and surge risk-based methods.

We present the normalized premiums in Figures 2 and 3 with averages based on the NFIP flood zones in which the homes are located. A zones are the 1% annual chance/100-year flood zones, also called SFHAs in the NFIP DFIRMs, and X500 zones are outside SFHAs but subject to 0.2% annual chance/500-year flood risks. Additionally, in Figures 2 and 3 we show average pre-FIRM premiums separately from average post-FIRM premiums for A zone/SFHA homes because the rates are calculated differently, but the pre-FIRM and post-FIRM rate calculations for X500 zone homes are identical and thus averaged altogether. Pre-FIRM rates were used for A zone homes built in 1977 or prior, and we use post-FIRM rates for A zone homes built in 1978 and later.
Figure 2. Average annual normalized NFIP and surge risk-based premiums for single-family homes by flood zone in Sanders Beach. Normalized premiums are the total premiums for building and contents coverage per $100 of building and contents coverage. Building coverage is assumed to be assessed building (improvements) value based on the 2015 ECPA data, and contents coverage is assumed to be half of building coverage. In Sanders Beach, there are 418 homes in X500 zones, and 60 homes in A zones.
Figure 3. Average annual normalized NFIP and surge risk-based premiums for single-family homes by flood zone in Pensacola. Normalized premiums are the total premiums for building and contents coverage per $100 of building and contents coverage. Building coverage is assumed to be assessed building (improvements) value based on the 2015 ECPA data, and contents coverage is assumed to be half of building coverage. In Pensacola, there are 298 A zone homes and 18,106 X500 zone homes. There are 3 homes in Pensacola in VE zones but we have omitted them from analyses.

As expected, PRP-rated premiums in both Sanders Beach and Pensacola are very low since they reflect discounted rates for homes outside SFHAs. On the other hand, X500 zone Standard Policy premiums are costly. It would be helpful to know how many X500 zone Standard Policies actually exist in Pensacola since homeowners in X500 zones may simply drop their NFIP coverage if they lose PRP rate eligibility. Average X500 zone Standard Policy premiums are very similar to average normalized pre-FIRM A zone...
premiums. The X500 zone rates are similar to pre-FIRM A zone rates, and since there is no variation in pre-FIRM or X500 rates due to homes’ FFEs, we could expect X500 normalized average premiums to be similar to that for pre-FIRM A zone policies.

For A zone homes, average post-FIRM NFIP rates are lower than average surge risk-based premiums based on both depth-damage functions in both Sanders Beach and Pensacola. In contrast, pre-FIRM average normalized premiums for A zone homes are higher than average post-FIRM NFIP rates, and pre-FIRM averages fall in between the average surge risk-based premiums based on the two different depth-damage functions. Average normalized NFIP X500 zone Standard Policy premiums are much higher than average surge risk-based premiums for X500 zone homes in both Sanders Beach and Pensacola. We observe evidence of cross-subsidization of NFIP premiums between A and X500 zone premiums because average A zone post-FIRM NFIP rates are significantly lower than average surge risk-based premiums for A zone homes, and average X500 zone Standard Policy NFIP rates are much higher than surge risk-based premiums for X500 zone homes.

We did not expect NFIP pre-FIRM A zone premiums to be higher than post-FIRM rates because pre-FIRM policies are considered subsidized, as pre-FIRM homes are rated without FFE information because they were built before the community in which they are located joined the NFIP. Pre-FIRM homes are rated without FFE information to avoid penalizing homeowners, since their homes’ FFE may be below the NFIP regulatory BFE. However, our post-FIRM premiums are based on homes’ FFE data that were estimated with a series of assumptions as explained above. If pre-FIRM homes in Pensacola generally have FFEs that are below the regulatory BFE in the DFIRM, then their pre-FIRM rates would be lower than post-FIRM rates. Homeowners with pre-FIRM homes are encouraged to obtain an elevation certificate for
their property to assess whether pre- or post-FIRM rating is less expensive since they are able to choose the more favorable rate.

Average normalized surge risk-based premiums are higher for A zone homes in Sanders Beach relative to Pensacola because a greater proportion of Sanders Beach A zone homes are at risk to surge hazards than in Pensacola. Conversely, there are more X500 zone homes in Pensacola at risk to surge than X500 zone homes in Sanders Beach, as reflected in the higher average surge risk-based premiums for Pensacola X500 zone homes.

Some observed differences in normalized NFIP premiums between homes in Sanders Beach and Pensacola can be attributed to differences in summary statistics shown in Table 3. The average home values for Sanders Beach are lower than in Pensacola. NFIP basic rates apply for the first $60,000 of residential building coverage, and basic contents rates apply for the first $25,000 of contents coverages. Additional NFIP rates, which are much lower than basic rates, apply for residential building coverage in excess of $60,000 up to the limit of $250,000; and additional rates for contents coverage are for amounts over $25,000 up to the limit of $100,000. Lower home values in Sanders Beach cause a greater proportion of the total building and contents coverage values to be subject to the higher basic NFIP rates, and thus result in higher average normalized NFIP premiums for Sanders Beach homes relative to Pensacola homes.
Table 3. Summary statistics for single-family homes in Sanders Beach and Pensacola.

<table>
<thead>
<tr>
<th>Sanders Beach homes</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>building replacement value</td>
<td>478</td>
<td>$7,815</td>
<td>$1,014,492</td>
<td>$64,455</td>
<td>$86,166</td>
</tr>
<tr>
<td>contents replacement value</td>
<td>478</td>
<td>$3,908</td>
<td>$507,246</td>
<td>$32,228</td>
<td>$43,083</td>
</tr>
<tr>
<td>year built</td>
<td>478</td>
<td>1865</td>
<td>2014</td>
<td>1942</td>
<td>32</td>
</tr>
<tr>
<td>heated square feet</td>
<td>478</td>
<td>247</td>
<td>6236</td>
<td>1466</td>
<td>902</td>
</tr>
<tr>
<td>FFE</td>
<td>478</td>
<td>5.76</td>
<td>71.66</td>
<td>27.60</td>
<td>12.99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pensacola homes</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>building replacement value</td>
<td>18,399</td>
<td>$1,056</td>
<td>$2,935,885</td>
<td>$87,674</td>
<td>$87,488</td>
</tr>
<tr>
<td>contents replacement value</td>
<td>18,399</td>
<td>$528</td>
<td>$1,467,943</td>
<td>$43,837</td>
<td>$43,744</td>
</tr>
<tr>
<td>year built</td>
<td>18,399</td>
<td>1810</td>
<td>2015</td>
<td>1962</td>
<td>24</td>
</tr>
<tr>
<td>heated square feet</td>
<td>18,399</td>
<td>168</td>
<td>12725</td>
<td>1760</td>
<td>817</td>
</tr>
<tr>
<td>FFE</td>
<td>18,399</td>
<td>3.81</td>
<td>128.25</td>
<td>71.83</td>
<td>27.44</td>
</tr>
</tbody>
</table>

3.2 Comparison of Present and Future Surge Risk-based Premiums for Sanders Beach and Pensacola

The granular surge risk data for 2017, 2042, 2067, 2092, and 2100 were utilized to calculate surge risk-based premiums for the present and future with sea level rise. Figure 4 shows normalized surge risk-based premiums for 2017, 2042, 2067, 2092, and 2100 for Sanders Beach homes based on the two depth-damage functions we employed. Figure 5 shows present and future normalized surge risk-based premiums for Pensacola homes. As with Figures 2 and 3, average normalized premiums shown in Figures 4 and 5 are based on the total premiums per $100 of building and contents coverages.
The surge risk-based premiums for Sanders Beach and Pensacola homes highlight large differences between the FIA and USACE IWR depth-damage functions. In Figure 6, we have plotted the FIA and USACE IWR depth-damage functions for single-family residential buildings with one story and no basement to illustrate how they vary in estimated losses from flood depths inside buildings. It is evident in Figure 6 how the FIA function underestimates losses from the same flood depths relative to the USACE IWR function, resulting in lower surge premiums based on the FIA function in Figures 4 and 5 for Sanders Beach and Pensacola homes. Previous research demonstrates that an important challenge of flood risk assessment is precisely specifying flood damages due to uncertainties in depth-damage curves.\[21\]

Despite the differences in premiums calculated between the two depth-damage functions, all surge risk-based premiums are increasing going forward into the future as sea level is rising. Figures 4 and 5 also show that averages of surge risk-based premiums are higher for homes in Sanders Beach than for Pensacola homes.
Figure 4. Sanders Beach homes average normalized surge risk-based premiums (per $100 of building and contents coverage) for 2017, 2042, 2067, 2092, and 2100 based on the FIA and USACE IWR depth-damage functions. (n=89 homes at risk of surge hazards)
Figure 5. Pensacola homes average normalized surge risk-based premiums (per $100 of building and contents coverage) for 2017, 2042, 2067, 2092, and 2100 based on the FIA and USACE IWR depth-damage functions. (n= 906 homes at risk of surge hazards)
Figure 6. Depth-damage functions for single-family residential buildings with one story and no basement according to the FIA and USACE IWR. Damages are expressed as percentages of building values lost to feet of flood water in homes.

3.3 Mitigation Costs and Benefits

The costs and benefits of mitigating homes against flood risks were examined by estimating the costs of elevating single-family homes in Sanders Beach and Pensacola by four and eight feet. In Figures 7 through 10, we show the total average annual surge risk-based premiums (in contrast to normalized premiums per $100 coverage) for 2017 and in future years for the FIA and USACE IWR functions plotted with lines and points, and the average mitigation loan costs and premiums after elevating homes are shown with stacked bars. Sanders Beach results are shown in Figures 7 and 8, while those for Pensacola homes are shown in Figures 9 and 10. Similar to observations in Figures 4 and 5, going into the future years with sea level rise results in increasing surge risk-based premiums. The mitigation loans are paid off by 2067 because we estimated 30-year loan terms at 1% interest rates. It is more cost-effective to
elevate homes by eight feet rather than four because the most of the costs of elevating a home are incurred when raising it by the first foot with the marginal costs of raising each additional foot being very low. Additionally, the savings in surge risk-based premiums are much greater with higher elevations. If a homeowner is investing in home elevation, they should elevate as high as possible to ensure that this mitigation action protects the home against flood risks into the future with sea level rise.

Although the surge risks are greater (by proportion of homes at risk) in Sanders Beach than in Pensacola, the mitigation costs are lower for Sanders Beach homes because the areas of homes (heated square footage) in Sanders Beach are lower than those in Pensacola, and costs of elevation are lower for smaller area homes. Table 3 shows that the average heated area of Sanders Beach homes is 1,466 square feet compared to an average of 1,760 feet for Pensacola homes.
Figure 7. Average annual surge risk-based premiums for Sanders Beach homes before mitigation according to the FIA function plotted with lines and points, and average annual loan costs to elevate homes by 4 feet (on the left) and 8 feet (on the right) with premiums after elevating homes by 4 and 8 feet according to the FIA function plotted with stacked bars for 2017, 2042, 2067, 2092, and 2100.

Annual loan costs to elevate homes in Pensacola by 4 and 8 feet were estimated for a 30-year term loan at 1% interest.
Figure 8. Average annual surge risk-based premiums for Sanders Beach homes before mitigation according to the USACE IWR function plotted with lines and points, and average annual loan costs to elevate homes by 4 feet (on the left) and 8 feet (on the right) with premiums after elevating homes by 4 and 8 feet according to the USACE IWR function plotted with stacked bars for 2017, 2042, 2067, 2092, and 2100. Annual loan costs to elevate homes in Pensacola by 4 and 8 feet were estimated for a 30-year term loan at 1% interest.
Figure 9. Average annual surge risk-based premiums for Pensacola homes before mitigation according to the FIA function plotted with lines and points, and average annual loan costs to elevate homes by 4 feet (on the left) and 8 feet (on the right) with premiums after elevating homes by 4 and 8 feet according to the FIA function plotted with stacked bars for 2017, 2042, 2067, 2092, and 2100. Annual loan costs to elevate homes in Pensacola by 4 and 8 feet were estimated for a 30-year term loan at 1% interest.
Figure 10. Average annual surge risk-based premiums for Pensacola homes before mitigation according to the USACE IWR function plotted with lines and points, and average annual loan costs to elevate homes by 4 feet (on the left) and 8 feet (on the right) with premiums after elevating homes by 4 and 8 feet according to the USACE IWR function plotted with stacked bars for 2017, 2042, 2067, 2092, and 2100. Annual loan costs to elevate homes in Pensacola by 4 and 8 feet were estimated for a 30-year term loan at 1% interest.

To better assess the cost-effectiveness of home elevation as a flood risk mitigation strategy, we computed benefit-cost ratios for homes at risk to surge hazards in 2017 using the surge premiums that were estimated using the USACE IWR function for elevating homes by four and eight feet. Benefits were computed as the savings in annual surge risk-based premiums after elevating houses in 2017,

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21 The benefit-cost ratios were computed based on results of the USACE IWR functions to make the strongest possible case for mitigation: there are greater savings in premiums after mitigation relative to loan costs with premiums based on the USACE IWR functions than those based on the FIA functions.
relative to the 2017 surge risk-based premiums before elevating; and costs were the annual loan costs for a 30-year term at 1% interest. Table 4 shows the average costs of elevating homes by four and eight feet, and average benefit-cost ratios for elevating homes in Sanders Beach and Pensacola by four and eight feet.

**Table 4.** Average total costs of elevating homes by four and eight feet, and average benefit-cost ratios for elevating homes at risk of surge flooding in Sanders Beach and Pensacola by four and eight feet.

<table>
<thead>
<tr>
<th></th>
<th>Average cost to elevate home by 4’</th>
<th>Average benefit-cost ratio based on USACE IWR function for elevating home by 4’</th>
<th>Average cost to elevate home by 8’</th>
<th>Average benefit-cost ratio based on USACE IWR function for elevating home by 8’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanders Beach</td>
<td>$84,029</td>
<td>0.2222</td>
<td>$91,556</td>
<td>0.2969</td>
</tr>
<tr>
<td>(n=89)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pensacola</td>
<td>$115,069</td>
<td>0.1557</td>
<td>$125,550</td>
<td>0.2166</td>
</tr>
<tr>
<td>(n=904)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The key finding of our analyses is that home elevation as a method of mitigating flood risks in Sanders Beach and Pensacola is not cost-effective for most homes since the average benefit-cost ratios are well below 1. There are 28 of 904 homes in Pensacola that have benefit-cost ratios over 0.9 if elevated by eight feet. Ten of these 28 homes have slab foundations, and the other 18 have open foundations with crawlspace. Elevating open foundation homes is much less expensive than slab foundation homes. However a striking finding is that these 28 homes with benefit-cost ratios of 0.9 or more have high building values, with the average being $442,545.
If surge risks are held constant, high building values increase the savings in surge premiums with elevation, while loan costs are independent of building values so the benefit-cost ratios for mitigation loans will favor those with higher property values. Future research should consider loans with 0% interest for low-income households to elevate their homes to help make this mitigation measure a more affordable option. If low-interest mitigation loans have longer repayment period such as being tied directly to the mortgage, then the annual loan payments are likely to be reduced, thus making the mitigation measure more attractive.

4. CONCLUSIONS AND RECOMMENDATIONS

To conclude, we address the three research questions posed above.

1. How do surge risk-based premiums compare with NFIP premiums for single-family homes in Sanders Beach and Pensacola using more granular storm surge data than the flood zones delineated in FEMA Digital Insurance Rate Maps (DFIRMs)?

We have employed a series of analyses to demonstrate that NFIP rate-setting methods are not risk-based. While this conclusion is not new, we have illustrated how flood risk data that is more granular than 1% and 0.2% annual probabilities currently used to characterize flood zones in DFIRMs can be used to estimate risk-based flood insurance premiums with the AAL approach.

Our results indicate that NFIP premiums are cross-subsidized between A and X500 zone policies: for homes in Sanders Beach and Pensacola, surge risk-based premiums based on the USACE IWR depth-damage function for A zones are higher than NFIP pre- and post-FIRM A zone premiums, while NFIP Standard Policy X500 zone premiums are higher than the surge risk-based premiums for X500 zone homes. We are not able to determine whether this cross-subsidization is intentional. Although
subsidization keeps premiums low for high-risk homes, it is an inefficient way to manage a flood insurance program. In fact, it could eventually make the NFIP portfolio dense with undercharged high-risk policies if private insurers cherry-pick the low risk properties that would be charged higher than risk-based premiums by the NFIP. To better convey accurate flood risk information to homeowners and to motivate investments in mitigation, flood insurance premiums should be risk-based. However risk-based insurance premiums require flood risk data that are more granular than the singular annual 1% chance zone.

Rating flood insurance premiums with a structure-specific risk-based approach as we have done here would encourage homeowners to invest in cost-effective mitigation actions which would lower their premiums and the financial responsibility of governments in responding to flood disasters. Accurate structure-specific flood risk requires structures’ FFEs in addition to granular flood risk data. Efforts to make obtaining FFE information less expensive and easier are required. It is promising to see authorization of a $500 credit for homeowners who obtain elevation certificates for NFIP rating in the NFIP reauthorization and reform bill from Senator Menendez’s office.

2. How do storm surge risk-based premiums vary with different depth-damage functions for the present year and the future with sea level rise?

We employed the depth-damage functions from the FIA and the USACE IWR to estimate surge risk-based premiums. Using different depth-damage functions in our surge risk-based premium estimations resulted in significantly different premiums. More research is required to develop more accurate depth-

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damage functions, and the importance of the choice of depth-damage functions for loss estimation must be emphasized.

As expected, future surge risk-based premiums increased consistently with sea level rise using both depth-damage functions. We recommend that the NFIP incorporate future conditions into their rate-setting and flood hazard mapping procedures with a recognition that there is uncertainty in estimating the magnitude of sea level rise over time.

3. For what types of houses in Sanders Beach and Pensacola are elevation a cost-effective method of flood risk mitigation in the present and future?

The results of our cost-benefit analyses indicate that elevating homes in Pensacola and Sanders Beach is not a cost-effective method to mitigate flood hazards for most structures if the only type of benefits we examine are savings in surge risk-based premiums. Nevertheless, homes with smaller areas and open foundations (not slabs) are likely to be cost-effective to elevate. Elevating homes to higher heights is more cost-effective because most of the expense of home elevation is associated with the first few inches of elevation. Many houses in Pensacola have slab foundations which are the most expensive type of foundation to elevate. It should be noted that there are concerns in elevating homes with any type of foundation: one cannot know if a home is constructed sturdily enough to withstand the stresses of elevation until it is attempted. Older homes may not fare as well as newer homes in an elevation project.

Elevating homes by more than four feet would achieve lower benefits than would actually be realized if one uses NFIP rating methods, since the FEMA does not calculate any additional savings in premiums for homes with FFEs more than 4 feet above the regulatory BFE. Furthermore, the benefit of elevating
homes only applies to homes in SFHAs. To encourage mitigation, NFIP rating procedures must incorporate the benefits for elevating homes above four feet above BFE for areas inside SFHAs, and should include rates based on FFE information for homes outside SFHAs. Additionally, we used the FEMA P-312\(^{(12)}\) as a guide for estimating the costs of elevating homes, and these are rough estimates for the entire United States. The costs of elevating homes in Pensacola could be lower or higher than what we estimated.

Future research should obtain estimates of home elevation costs that are more specific to the study area, instead of using national averages to estimate costs. Other mitigation options in addition to home elevation should be explored in future research, such as building flood walls around the home, and elevating electrical and plumbing utilities. Methods of addressing affordability of risk-based insurance pricing should be investigated, such as insurance designs with high deductibles to reduce premiums, and systems of vouchers coupled with long-term mitigation loans to spread upfront costs of mitigation over the length of mortgages. Risk-based flood insurance premiums could be linked to cost-effective mitigation activities in ways that are transparent to homeowners, so that homeowners are motivated to invest in flood mitigation to save on premiums and losses to floods.
5. REFERENCES

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10.1111/risa.12740


APPENDIX A: NFIP FLOOD ZONES APPEARING IN FLOOD INSURANCE RATE MAPS (FIRMs) AND DEFINITIONS

<table>
<thead>
<tr>
<th>Zone A</th>
<th>The 100-year or base floodplain. There are six types of A Zones:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The base floodplain mapped by approximate methods, i.e., BFES are not determined. This is often called an unnumbered A Zone or an approximate A Zone</td>
</tr>
<tr>
<td>A1-30</td>
<td>These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).</td>
</tr>
<tr>
<td>AE</td>
<td>The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones</td>
</tr>
<tr>
<td>AO</td>
<td>The base floodplain with sheet flow, ponding, or shallow flooding. Base flood depths (feet above ground) are provided.</td>
</tr>
<tr>
<td>AH</td>
<td>Shallow flooding base floodplain. BFES are provided.</td>
</tr>
<tr>
<td>A99</td>
<td>Area to be protected from base flood by levees or Federal Flood Protection Systems under construction. BFES are not determined.</td>
</tr>
<tr>
<td>AR</td>
<td>The base floodplain that results from the decertification of a previously accredited flood protection system that is in the process of being restored to provide a 100-year or greater level of flood protection.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High Risk Coastal Areas</th>
<th>Zone V and VE</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.</td>
<td></td>
</tr>
<tr>
<td>VE</td>
<td>Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moderate to Low Risk Areas</th>
<th>Zone B and Zone X (shaded) referred to as Zone X500 in paper.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from the 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.</td>
</tr>
</tbody>
</table>

Note that the special Flood Hazard Area (SFHA) includes only A and V Zones.

## APPENDIX B: COST ESTIMATES USED TO CALCULATE TOTAL COSTS OF ELEVATING SINGLE-FAMILY HOMES TO MITIGATE FLOOD RISKS

### Approximate Square Foot Costs of Elevating a Home

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Existing Foundation</th>
<th>Elevate on</th>
<th>Cost (per square foot of house)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuous Foundation Walls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame house (for frame house with brick veneer)</td>
<td>Basement or Crawlspace</td>
<td>2 feet</td>
<td>$29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 feet</td>
<td>$32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 feet</td>
<td>$37</td>
</tr>
<tr>
<td>Masonry</td>
<td>Baseline or Crawlspace</td>
<td>2 feet</td>
<td>$60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 feet</td>
<td>$63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 feet</td>
<td>$68</td>
</tr>
</tbody>
</table>

### Source: