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An Overview of Flood Risk to the Housing Finance Ecosystem

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Introduction

Climate change is increasing both the intensity and frequency of natural disasters, leading to higher economic costs. In an annual report, the National Oceanic and Atmospheric Administration (NOAA) documents the incidence of weather and climate disasters resulting in over $1 billion in damage per event, so called "billion-dollar disasters." The 2019 report shows that over the last decade there were 119 such events, a stark increase compared with the previous three decades (29, 53, and 62 from the 1980s, 1990s, and 2000s, respectively) (NOAA, 2019). The changing risk of natural disasters, flooding in particular, is further demonstrated by the increasing frequency of presidential disaster declarations, of which more than 80 percent have been in response to floods and flood-related events such as hurricanes (Kousky et al., 2018). Although some of the increased costs can be attributed to new and higher value developments in vulnerable areas (Wing et al., 2018), recent research on flood events indicates that historical

[1] Official Request for Input available at: https://www.fhfa.gov/Media/PublicAffairs/Documents/Climate-and-Natural-Disaster-RFI.pdf

[2] Submissions available on FHFA's website at: https://www.fhfa.gov/AboutUs/Contact/Pages/input-submissions.aspx

precipitation changes have contributed to roughly one-third of cumulative flood damages from 1988 to 2017 (Davenport is Davenport, Burke, and Diffenbaugh, 2021). Windstorms, rain events, wildfires, sea level rise, and tropical cyclones all pose risk to the United States housing stock, although flooding poses the most widespread threat (NOAA, 2020). NOAA in 2013 estimated that 40 percent of the U.S. population lives in coastal regions (NOAA, 2013; Owens, 2020), with an additional 40 million (12 percent) living in areas that face fluvial or riverine flood risk (Wing et al., 2018). Therefore, this discussion focuses specifically on climate change-induced increases in flood risk to the housing finance ecosystem.

Discussions on climate risks to financial markets generally classify risk into one of two categories. This categorization of risk is also appropriate in the context of housing finance.

Physical risks: Economic costs of the increasing severity and frequency of climate change-driven weather events as well as more gradual changes, such as sea level rise, may erode the value of financial assets.

- In the context of housing, extreme weather events such as hurricanes, floods, or storm surge may damage or destroy homes. Anticipation of future events may lower home (the asset) values over time as risk becomes more salient.

Transition risks: Economic costs that relate to the adjustment toward a low-carbon economy as well as those that relate to coping with the effects of climate change, whether through mitigation, policy, or abandonment of stranded assets.

- In the context of housing, examples include an abrupt repricing of housing markets, stranded assets from inland retreat, property lost to sea level rise, and municipal budget shortfalls as eroded tax bases couple with increasing mitigation budgets in climate-vulnerable areas.

Whereas immediate physical risks of flooding are borne by individual homeowners and communities in flood-prone areas, the transition risks may be transferred throughout the broader financial system and economy. Individual homeowners who live in flood prone-areas face risks ranging from minor property damage to complete loss of home and equity. Neighborhoods and communities subject to more intense and repetitive flooding events may see an increase in damaged infrastructure, abandoned properties, declining property values, and shrinking tax bases. An abrupt tightening of lending in these communities in response to greater perceived risk could lead to further reductions in property values, creating a negative feedback loop of equity loss, mortgage defaults, home abandonment, and declining property values. Communities with similar flood risk profiles may begin to experience similar cycles of property value declines and disinvestment without an acute flood event as homeowners and mortgage investors seek to reduce their exposure to flood risk before it is too late. Nationally, mortgage guarantors such as Federal Housing Administration (FHA), Ginnie Mae, and the government-sponsored enterprises of Freddie Mac and Fannie Mae (the GSEs) could face above-average losses, and access to credit could be constrained as market participants adapt to new risks.

Although housing units of all types are vulnerable to weather and climate related disasters, this commentary focuses on flood risk to single family (1–4 unit) homes. This discussion applies broadly to the entire U.S. mortgage market, not just U.S. Department of Housing and Urban Development (HUD) or Federal Housing Finance Agency (FHFA)-regulated sectors, unless specifically noted. Questions are in bold, followed by a summary answer. Detailed discussions of the literature, complete with citations, follow the summary. Discussion does not imply HUD endorsement of specific findings or positions.

How is flood risk assessed, and how are climate change and current housing development patterns changing the risk footprint?

Current assessment of flood risk through NFIP flood mapping, insurance premiums, and coverage maximums fail to identify and price flood risk appropriately. This could distort incentives and pricing for home buying and new home building in areas at risk of flooding. Furthermore, climate change is expanding the footprint of land susceptible to flooding, and developers continue to build more homes in the path of current and future floods, increasing exposure.

Research finds that federal flood maps maintained by the Federal Emergency Management Agency (FEMA) are the de facto standard in flood mapping (Kousky et al., 2018) and that this is not due to their superiority, but rather their use in determining flood insurance requirements under the National Flood Insurance Program (NFIP). There are two important sets of maps associated with the NFIP, Flood Insurance Rate Maps (FIRMs) and Special Flood Hazard Areas (SFHAs). FIRMs define and map different flood zones based on their probability of flooding. FEMA designates Zones A and Zones V as SFHAs.[3] SFHAs are areas at risk of flooding by an event that has a 1 percent probability annually, also referred to as a 100-year flood. Market lending requirements stipulate that loans for houses inside SFHAs must have flood insurance if they are backed, securitized, or held by HUD, the Veterans Administration, U.S. Department of Agriculture, the GSEs, or federally regulated lending institutions.

The literature identifies several important shortcomings of the FEMA flood maps that may lead to an underestimation of risk. FEMA flood maps were designed to implement the requirements of the NFIP, not serve as a complete flood risk communication tool (Kousky et al., 2018). Another concern is that although the maps are supposed to be updated every 5 years, many area flood maps rely on outdated data or methodologies (National Research Council, 2015). Some areas, particularly rural and less developed areas, have never been mapped at all, or digitized mapping is not available in all areas, inhibiting local areas to have access to flood risk data.[4] A 2013 U.S. Government Accountability Office (GAO) study on tribal participation in the NFIP found that only 7 percent of tribal communities were participating, in part due to a lack of local flood risk data (GAO, 2013). Furthermore, local governments often work with FEMA through the Cooperating Technical Partners (CTP) program to approve changes in official regulatory flood maps. This process can take years to update a local map and introduces a conflict of interest into the process

[3] SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, & Zones V1-V30 (www.fema.gov).

[4] Exhibit A1 in the appendix shows the age of local area flood maps as well as areas that have not been mapped or still lack digitized mapping (First Street Foundation).

because local officials have a vested interest in reducing risk perception in their communities and preserving property values. FEMA flood maps also fail to capture all types of flood risks, such as stormwater or "pluvial" flooding, which are becoming an increasing threat in developed areas with higher proportions of impervious surfaces.

Another issue with using the NFIP for risk assessment is that housing market participants may interpret insurance premiums as the cost of that risk. In theory, insurance premiums should reflect risk and loss severity for the event insured against and incorporate individual risk factors. Research suggests that NFIP premiums fall short in achieving these objectives. Premiums are largely determined by flood zone, although some house characteristics are used. By one estimate, average premiums fall short of average annual losses by a factor of 4.2 (First Street Foundation, 2021). Furthermore, NFIP coverage is capped at $250,000. With increasing home values and outstanding mortgages balances, potential losses are more likely to exceed this threshold, so even fully compliant insurance may be insufficient to protect homeowners. If homebuyers are using premiums as an assessment of risk, aggregate flood risk will be severely underestimated. On top of these issues, SFHAs are often treated as a binary indicator of flood risk, although flood risk is much more complicated (Kousky, 2018). This suggests that if a property is not located inside an SFHA and the mortgage does not require flood insurance, homeowners may underestimate their exposure to flood risk.

In addition to SFHAs underestimating the flood risk footprint and the cost of flood risk, climate change and housing development patterns are increasing both the risk footprint and risk exposure (Climate Central and Zillow Research, 2019).[5] Although the climate's path over the next 100 years cannot be known with certainty, the scientific community has identified several possible climate trajectories based on different emissions scenarios referred to as Representative Concentration Pathways (RCPs). There are several commonly discussed RCPs on which estimates of changing risk in the literature are often based.[6]

RCP 2.6–Deep emissions cuts, peak by midcentury and reduction by 2100.

RCP 4.5–Moderate emissions cuts, with stabilization before 2100 (Paris Agreement target).

RCP 6.0–High emissions scenario, with stabilization after 2100.

RCP 8.5–Unchecked emissions, extreme scenario.

Future climate trajectory notwithstanding, there is evidence that climate change already is and will continue to exacerbate existing flood risks. Observable effects of climate change such as sea level rise, more intense and more frequent precipitation events, and slower moving tropical cyclones will lead to increased flooding incidence. Warmer waters in the Atlantic and the Gulf of Mexico help tropical cyclones gain intensity and moisture while also slowing down their inland travel. This has led to severe flooding driven by intense rainfall, rather than storm surge, in cases such as Hurricane Harvey in Houston and Hurricane Florence in the Carolinas. Storm surge from tropical

[5] *Risk footprint* refers to the area at risk of flooding, whereas risk exposure refers to the amount or value of houses at risk.

[6] RCP scenarios are as described by the National Oceanic and Atmospheric Administration: https://sos.noaa.gov/datasets/climate-model-temperature-change-rcp-45-2006-2100/

cyclones will also likely increase because it is aided by sea level rise, meaning homes further inland that were previously safe may now be subject to this risk.

Sea-level rise (SLR) poses its own risks outside of tropical events. SLR adds vertical height and lateral reach to coastal tides, leading to more frequent local floods that cover more land for longer stretches of time (Spanger-Siegfried et al., 2017), as shown in exhibit A.2 and exhibit A.3 in the appendix. Increased tidal reach has already led to an increase in coastal flooding (Sweet and Park, 2014). In New York City, floods that were once classified as 1-in-500-year events are already occurring once every 25 years (Kousky et al., 2018), and the large Miami neighborhood of Hialeah experiences chronic street flooding during high tides (Colman, 2020). A 2017 report from the Union of Concerned Scientists finds that an SLR scenario of 4 feet by 2100, consistent with the RCP 4.5, will put more than 490 communities at risk of chronic inundation in the next 40 years, whereas the RCP 6 scenario will leave 670 communities at risk of chronic inundation (Spanger-Siegfried et al., 2017).[7]

Several studies focused on shifting rainfall patterns caused by climate change project increasing flooding in parts of the United States, which leads to higher monetary damages (Kousky et al., 2018; Mallakpour and Villarini, 2015; Prein et al., 2017). Other research utilizing statistical relationships between precipitation and flood damages predicts increasing flood damages with continued global warming (Wobus et al., 2014). However, by disaggregating the increase in flood damages into damages from increased development and damages from increased precipitation, Davenport, Burke, and Diffenbaugh (2021) find evidence that this is already happening.

Whereas climate change increases the geographic footprint of risk, development patterns continue to place more new houses in risk zones, increasing risk exposure even if natural hazard risk remains fixed. One study estimating the present and future flood risk in the United States found that population and the Gross Domestic Product (GDP) growth alone will lead to significant increases in risk exposure (Wing et al., 2018). A team of researchers from online real estate firm Zillow and the non-profit organization Climate Central released a 2018 report comparing new housing growth rates in areas at risk of flooding to safer areas for the 24 coastal states in the United States (Climate Central and Zillow, 2019). The study defines *new homes* as those built after 2009 and before 2017 and uses SLR projections from Kopp et al. (2017) based on the RCP 4.5 scenario to define risk zones. They find that 17,800 new homes that have been built since 2009 will be at risk of flooding during a 10-year-flood event, and 10,500 homes are at risk of flooding during an annual flood event by 2050. They also show that the levels of financial investment in new housing at risk total more than $13 billion for the top 10 states with the most *new homes*, with New Jersey, Florida, and South Carolina reaching $4.61 billion, $3.38 billion, and $1.27 billion, respectively. In addition to the newly constructed homes at risk, 3.4 million existing homes worth approximately $1.75 trillion (today) would be at risk of a 10-year flood event under the RCP 8.5 scenario. This does not include new houses that will continue to be built, so the number of homes and the value at risk will continue to climb without a significant shift in building patterns.

[7] The report defines "communities" as U.S. Census Bureau designated county subdivisions, often distinguishable cities. Ex: Boston, MA; Manhattan, NY; Kiawah Island, SC; Key West, FL.

Demand from institutional real estate investors and insurers has led to a market for commercial flood risk data at the property level, which seeks a more in-depth risk analysis compared with publicly available FEMA flood maps. These companies often include the unmapped risks of stormwater flooding, and they include projected changes in risk based on new development and climate change. There is precedent of various U.S. federal government agencies licensing flood risk data from private data firms for research and regulatory projects.[8]

How do borrower-homebuyers respond to perceived flood risks?

Flood risks can be addressed by several market mechanisms: price discounts, flood mitigation efforts, and flood insurance. Research indicates that markets do price in flood risk, though poorly, overpricing homes by $34 billion nationally. This is due in part to a poor understanding of flood risk and overall weak flood disclosure laws, although there is evidence that the type of buyer may play a role in risk assessment. Individual property level mitigation strategies are often prohibitively expensive, so homeowners generally must rely on community mitigation efforts. On average, homeowners are underinsured against flood risk, due in part to poor understanding of flood risk outside of SFHAs and NFIP flood mapping, an NFIP coverage maximum that falls below replacement costs for many homes, and a lack of real-time tracking of required insurance compliance within SFHAs.

Homebuyers have several ways to respond to perceived flood risk. First, homebuyers may price this risk into the purchase price. In a report on flood risk and the U.S. housing market, Kousky et al. (2018) discuss the literature examining how flood risk is capitalized into home prices. The authors report that a handful of studies find evidence of a discount inside SFHAs (Bernstein, Gustafson, and Lewis, 2019; Bin, Kruse, and Landry, 2008; Daniel, Florax, and Rietveld, 2009; Harrison, Smersh, and Schwartz, 2001; Macdonald et al., 1990); however they note the difficulty in identifying risk effects in coastal areas, given the high amenities found in these locations (Bin and Kruse, 2006; Bin et al., 2008). Beltran, Maddison, and Elliot (2018) perform a meta-analysis of the existing literature that attempts to estimate how flood risk is capitalized into home prices. Covering 37 published studies and 364 point estimates, the authors find estimates of price effects lay anywhere between -75.5 percent (discount) to +61 percent (premium). However, time relative to a flood event and geographical scope seem to play a significant role in determining this capitalization. For instance, homes in coastal regions often sell for higher prices, a result attributed to an inability to control for coastal amenities. Hino and Burke (2020) build on the methodological issues identified in Beltran, Maddison, and Elliot (2018). They use historical FEMA floodplain maps to construct a nationwide panel of floodplain designation, which captures both spatial and temporal variation in flood zone assignment. The authors estimate a national flood zone information discount of 2.1 percent before breaking estimates down into different groupings based on state level flood disclosure laws as well as type of buyer. They ultimately conclude that markets price flood risk into property values, although poorly. To make this assessment, they compare their empirical estimates of the flood zone information discount to two different benchmarks:

[8] For instance, FHFA has purchased a license with First Street Foundation's data, and CoreLogic modeling was used to inform FEMA's Risk Rating 2.0 system.

- Estimates of the present value of the stream of future insurance costs as a percentage of total property value should affect property values by an average of -9.1 percent (-20 percent, -4 percent).
- Estimates of expected flood damages based on NFIP insurance prices should affect prices by 5.1 percent to 10.7 percent, depending on the discount rate.

The authors consider the latter to be the best estimate of flood information discount in an efficient market. By calculating the efficient flood zone discount and the estimated discount for each of the three flood disclosure groupings, the authors conclude housing markets overvalue 3.8 million homes in flood zones by $34 billion. Given that SFHAs act more as a piece of information rather than a complete measure of risk, the authors specify that this figure is an "information discount" rather than a true risk discount.

In contrast to Hino and Burke (2020), who use SFHA designations to determine general flood risk, Bernstein, Gustafson, and Lewis (2019) use the NOAA SLR calculator to determine exposure to sea level rise and estimate the associated price effect in real estate transaction. The estimation strategy defines exposure as any property that would be inundated during a king tide (the highest high tide) under a 6 foot global SLR scenario (consistent with RCP 6) and controls for ZIP Code, distance to the coast, and elevation, in addition to property-specific characteristics. Furthermore, they restrict their sample to transactions from Zillow's ZTRAX dataset for properties within 400 meters of the coast, of which 30 percent are exposed. These properties are then grouped into common bins of 200 foot bands of distance to the coast (0–200, 201–400, etc.) and by 2 meters in elevation. This restriction and binning process eliminates issues in controlling for coastal amenities from previous studies. They find that SLR exposed properties sell at a 6.6 percent discount relative to comparable unexposed properties.

It is important to note that flood risk can only be priced into the market if buyers know about the flood risk. There are no federal flood risk disclosure laws that mandate this information be made available to potential buyers before an offer is made, which may affect the market's ability to capitalize on risks fully. Several studies find evidence that this is the case.

- Chivres and Flores (2002) surveyed a sample of Colorado floodplain homeowners and found that only 8 percent learned about a property's flood risk before they made an offer, whereas 69 percent said they would have changed their offer had they known about this risk and insurance prices beforehand.
- Troy and Romm (2004) found the passage of a stringent law in California that required disclosure of flood risk during real estate transactions increased the price penalty for flood risk.
- Hino and Burke (2020) assess flood information discounts, given different types of disclosure laws, and find that states with the strictest laws have larger discounts.

Although there is wide variation in state-by-state disclosure laws and much opposition from the realtor industry to create federal or state level legislation, there may be momentum from the private and non-profit sectors to making flood risk information more widely available. Online real estate company, Realtor.com, became the first site to disclose information about property level flood risk as well as potential changes in risk brought on by climate change (Hersher and Sommer, 2020). Additionally, private flood risk data firm First Street Foundation published a nationwide flood risk indicator for millions of properties available for free on their website.

In addition to flood risk disclosure laws, different types of buyers may be better suited to ascertain flood risk in the absence of upfront disclosure. Both the Hino and Burke (2020) and Bernstein, Gustafson, and Lewis (2019) studies find evidence of this. Specifically, Bernstein, Gustafson, and Lewis (2019) report that *sophisticated* buyers, proxied for by the use of non-owner occupancy buyers, have found that the SLR exposure discount is concentrated in the sophisticated (non-owner occupied) segment of the market, with discounts averaging near 10 percent. Hino and Burke (2020) also assess flood information discounts by type of buyer, and they find that homes bought by "business" buyers face a much steeper discount of 6.9 percent, whereas those purchased by non-business buyers (regular homeowners) face a 1.8 percent discount.

The literature identifies two primary means by which flood risk may be mitigated once a property has been purchased: physical mitigation and insurance. Although property-level mitigation measures can be taken, such as raising a structure beyond base flood elevation (BFE), these measures are often too expensive for existing homes. Floodplain management as a mitigation strategy is a municipal-level task and a requirement for a community to be eligible for participation in the NFIP. Thus, insurance is the primary tool for individual homeowners to address risk.

The National Flood Insurance Act of 1968 (NFIA) and the Flood Disaster Protection Act (FDPA) of 1973 (and ensuing amendments) govern the provision of flood insurance for federally backed mortgages requiring flood insurance. For decades, the NFIP has been the only option for homeowners to purchase flood insurance due to the private sector's inability to provide affordable coverage. The Biggert-Waters Act of 2012 requires federal regulators to direct lenders to accept private insurance to satisfy the mandatory purchase requirement.[9] The federal regulators jointly issued a final rule to implement this in February 2019. Current regulations of the FHA do not allow private flood insurance to satisfy this requirement. HUD published a proposed rule in November 2020 seeking comments to amend FHA regulations to permit private flood insurance.[10]

In 2018 there were more than 5 million NFIP policies in force nationwide, 4.8 million of which were for residential property. Kousky et al. (2018) estimate that about 4 percent of all primary residential policies come from private insurers. Estimating the rate of coverage for homes located in SFHAs is much more difficult because there is no national database of structures in the SFHAs that can be matched with policies. However, several studies use surveys or county averages to estimate take-up rates at around 50 percent in SFHAs (Kousky, 2018; Kousky and Michel-Kerjan, 2015; Kriesel and Landry, 2004).

[9] The Federal regulators include Federal Reserve Board (FRB), the Federal Deposit Insurance Corporation (FDIC), the Office of the Comptroller of the Currency (OCC), the National Credit Union Administration (NCUA), and the Farm Credit Administration (FCA).

[10] Details on the proposed rule can be found on the Federal Register. The comment period ended Jan. 22, 2021. https://www.hud.gov/sites/dfiles/SFH/documents/6084_P_01_Flood_Insurance_Proposed_Rule_Published_11_6_2020.pdf

In an analysis of flood insurance take-up rates, Kousky and Lingle (2018) provide county estimates of take-up rates for participating counties within SFHAs and identify some trends. Some findings are not surprising. For instance, most policies are concentrated in coastal counties. While they find that some counties have take-up rates as high as 80 percent, the average is closer to 30 percent. They also note the importance of insurance take-up rates outside SFHAs, given that over 75 percent of buildings flooded by Hurricanes Sandy, Irma, and Harvey were outside the SFHA. They did, however, find some instances where the majority of policies in force were outside SFHAs. In the state of Texas, almost 75 percent of policies in force are outside an SFHA. When Hurricane Harvey struck, only 15 percent of homes in Harris County had policies, but over 70 percent of those were outside SFHAs. This provides a sharp contrast to the analysis of HUD-2M Research (2020), which found patterns of hard cutoffs at the SFHA border in Florida and North Carolina. Although this study offers insights into the utilization of the NFIP by county, and there is evidence at the household level that insurance helps recovery (discussed in the following paragraphs), there are no studies that link insurance take-up rates to post-disaster recovery at the community level.

The primary driver of flood insurance seems to be the mandate, although there are exceptions, such as in the state of Texas mentioned previously. In a discussion of the literature estimating flood insurance price elasticity of demand, Kousky (2018) concludes that current studies, which generally find demand is inelastic (Atreya, Ferreira, and Michel-Kerjan, 2015; Kriesel and Landry, 2004; Landry and Jahan-Parvar, 2011), face many methodological challenges that are not adequately addressed. Kousky does point out that the exogenous price increases from 2012 and 2014 legislative actions could provide an opportunity to overcome these issues.

Two studies give insight to the extent of flood insurance compliance for the FHA insured portfolio. A 2020 HUD-sponsored study with 2M Research linked administrative mortgage level data from FHA with FEMA property level insurance policies and damage claims for a 10-year period in Florida and North Carolina. These data allowed researchers to get detailed insight to compliance rates for a sample of the FHA portfolio (HUD-2M Research, 2020). However, the study still had to rely on matching addresses and latitude-longitude coordinates across databases, which is not a perfect strategy for identifying homes that lie in an SFHA because some lots may have only a portion of the property but no physical structure present in the flood area. To account for this, the researchers created two study samples: a conservative sample that excluded such properties, and a more inclusive sample that counted these. They also consider a third measure, including all properties within 600 meters of the SFHA boundary, to capture potential flood risk just outside the boundary.

Results for North Carolina showed that take-up rates inside the SFHA for the more inclusive sample ranged between 20 percent and 25 percent (lower compliance), whereas take-up rates in the more conservative sample ranged from 48 percent to 55 percent. The conservative sample estimates more closely align with estimates from previous studies. Estimates for take up-rates outside SFHAs were almost identical for both classification strategies at around 1 percent.

Results for Florida showed that take-up rates inside the SFHA for the more inclusive sample ranged between 46 percent and 55 percent, whereas take-up rates in the more conservative sample ranged from 65 percent to 68 percent. The inclusive sample estimates more closely align with estimates from previous studies, whereas the conservative estimate is higher. Again, estimates for take-up rates outside SFHAs were almost identical for both classification strategies. However, at over 17 percent, take-up rates outside SFHAs were higher at the beginning of the study window in 2011, but they decreased each year until reaching just over 5 percent in 2019. Although only covering two states, this study provides important information on compliance inside SFHAs for one of the most at-risk states (Florida) as well as providing a methodology for measuring compliance rates.

Furthermore, this study shows the difficulty of conducting this research and highlights the need for a real-time, linked database that matches NFIP policies to the FHA portfolio of loans. Beyond understanding compliance within SFHAs, the stark drop in take-up rates that occurs just outside SFHAs indicates that flood insurance is primarily driven by their requirement and that homeowners treat the boundary as a binary indicator of risk.

A 2021 HUD Inspector General report (Hosking, 2021) evaluated FHA-insured loans originated in 2019 for flood insurance compliance. Using FHA and FEMA data, the report identified a set of properties determined to be at risk of not having mandated flood insurance and reviewed a statistical sample for compliance. The report revealed that at least 3,780 loans worth $940 million that closed and were FHA-insured in 2019 were not eligible for FHA-backed mortgage insurance because they did not have the required NFIP coverage. This was due to loans having private insurance instead of the mandated NFIP coverage, insufficient NFIP coverage, or no coverage at the time the loan was closed. This report recommends a federal data set that tracks NFIP compliance for federal housing portfolios.

How does previous research quantify flood risk to the mortgage finance ecosystem?

There are several layers of risk from climate change to the housing finance ecosystem. The first layer is the physical risk that houses may be damaged or destroyed by a flood. This physical risk is propagated by an increase in default risk and prepayment risk for the mortgages associated with damaged homes, putting secondary market mortgage holders and securitizers at risk. Should a securitizer/guarantor be put in jeopardy in the event of accumulating losses, this risk would then be passed on to mortgage security investors. One estimate of physical risk by a non-profit flood-modeling firm identifies 4.2 million homes at risk, with estimated annualized damages of $20 billion in 2021 and over $32 billion by 2051, assuming RCP 4.5 and risk to a 100-year flood. Quantifying the secondary mortgage market risks requires understanding of the homes at risk for flooding, the outstanding balances on the associated mortgages, flood insurance coverage for at-risk properties, who the second market guarantors are, and how the at-risk mortgages are dispersed throughout the mortgage-backed securities market. Currently, no federal or publicly available databases match flood risk to portfolios of the GSEs or Ginnie Mae, who collectively securitize $7.6 trillion of the $11.5 trillion in outstanding mortgage debt.

The first layer of risk is the direct physical risk to structures that may be damaged or destroyed by a flood. There are several ways to think about quantifying physical exposure:

- Number of homes: how many housing structures may be at risk?
- Total value of homes: what is the cumulative value of homes at risk?

- Population at risk: how many people live in homes that are at risk?

Each of these is an important consideration and provides a slightly different perspective of physical risk, and therefore these should be thought of as complementary metrics rather than competing metrics. Furthermore, risk can be thought of as probability of any flood, or probability of a specific flood type, such as storm surge, precipitation, SLR, etc. The nonprofit firm First Street Foundation (FSF) released a 2021 report providing a national assessment of properties at risk based on their proprietary flood models for all types of flood risk.[11] Their report is a publicly available assessment of physical risk at both the national and the state level, regardless of mortgage or flood insurance status. Assuming the RCP 4.5 scenario, the authors examine current risk exposure as of 2021 and future risk exposure as of 2051 under two risk levels. *Any Flood Risk* refers to a property vulnerable to inundation of 1 centimeter or more to the building in the 500-year return period (0.2 percent annual risk or 1/500) now or in the future. *Substantial Flood Risk* refers to a property vulnerable to inundation of 1 centimeter or more to the building in the 100-year return period (1 percent annual risk or 1/100). For each risk level, they calculate Estimated Average Annual Losses (AAL) and annualized damages. Their national level results are summarized in exhibit 1.[12]

Flood risk in exhibit 1 is based on First Street Foundation's proprietary flood model combined with the U.S. Army Corps of Engineers depth damage functions.[13] To compare their risk assessment to the NFIP's assessment, they break down the substantial flood risk category into properties that lie inside the SFHA and those that lie outside the SFHA. They find that only 1.52 million of the 4.26 million houses they identified as being at risk of a 100-year flood are located inside FEMA-designated SFHAs, a designation intended to represent that same level of risk. This highlights the disparity between commercially available flood modeling and NFIP flood maps.

Exhibit 1

National Single Family Residential Risk Profile 2021 vs 2051 Flooding of any Source

	FSF Model Used	Total Properties at Risk (millions)	FSF Est. AAL		Annualized damage (billions of dollars)	
			2021	2051	2021	2051
Any Flood Risk	1/500 Layer	5.71	$3,548	$5,913	$20.3	$34
Substantial Flood Risk	1/100 Layer	4.26	$4,694	$7,563	$20	$32.3

Source: Table data compiled from First Street Foundation (FSF), The Cost of Climate: America's Growing Flood Risk

As part of the previously discussed HUD-2M Research study, the researchers calculated two measures of the FHA-insured portfolio at risk of flooding. The first was properties inside the SFHA (with a conservative and inclusive sample), and the second was all properties inside the SFHA

[11] Discussion of specific commercial products does not offer endorsement of any company or their products.

[12] AAL are based on the U.S. Army Core of Engineers (USACE) depth damage functions for riverine and storm surge flooding and an internal proprietary "precipitation-induced flooding" depth damage function.

[13] The model description and methodology can be found at https://assets.firststreet.org/uploads/2020/06/FSF_Flood_Model_Technical_Documentation.pdf Disclaimer: "First Street Foundation's flood and climate change risk and damage estimates are based on one or more models designed to approximate risk and are not intended as precise estimates, or to be a comprehensive analysis of all possible flood-related and climate change risks."

and within 600 meters of the boundary. They found that the number of insured properties for both measures increased over the study window, although for both states and both measures the proportion of the overall FHA portfolio remained constant. Exhibit 2 summarizes their findings.

Exhibit 2

At-Risk FHA-Insured Properties for Florida and North Carolina

			Properties within SFHA		Properties within 600 meters of SFHA	
	Year	Total Properties	Total Number	Percent of Portfolio	Total Number	Percent of Portfolio
North Carolina	2011	26,303	1,277	4.9	14,202	54.0
	2019	177,195	8,673	4.9	95,840	54.1
Florida	2011	57,479	12,692	22.1	47,298	82.3
	2019	496,597	101,128	20.4	399,271	80.4

FHA = Federal Housing Administration. SFHA = Special Flood Hazard Area.
Source: Data compiled from HUD-2M Research 2020 study, Flood Insurance Coverage of FHA Single-Family Homes

Similar to the First Street Foundation report, the two different measures of flood risk employed in this study also show stark disparities between risk assessments based on the NFIP flood maps and more broadly defined flood zones. Exhibit 2 also highlights another important trend, that risk is not evenly dispersed across states.

In a study examining the role of flood damage, flood insurance, and performance for mortgages backed by Fannie Mae after Hurricane Harvey, the authors find that out of 302,000 active, current mortgages inside the storm-affected area, 27,000 homes have post-disaster home inspection records (Kousky, Palim, and Pan, 2020). This implies that 8.9 percent of homes in Fannie Mae's Houston-area portfolio were subject to flood damage from Hurricane Harvey, although only 7 percent of these damaged homes were in the SFHA.[14]

What are household/borrower outcomes after a flood event?

There is evidence in the literature that storm damage increases mortgage default risk overall, but flood insurance plays a significant role in determining financial outcomes for households who experience a flood. Homeowners with insurance are less likely to default and more likely to rebuild after a flood compared with those without. However, there is some nuance to these findings. There is evidence that increasing levels of property damage, or whether the lender is local or non-local, influence decisions to rebuild or use insurance payouts to pay off the mortgage and move. Federal aid programs offered through FEMA, HUD, and the Small Business Administration (SBA) can serve as another source of post-disaster resistance.

From the perspective of the GSEs and other mortgage holders/securitizers, default and prepayment both pose a risk to the agencies' ability to guarantee the stream of payments associated with their issues of mortgage-backed securities. Ultimately, it was this burden that put the agencies in financial distress during the subprime crisis (Frame et al., 2015). Therefore, understanding the

[14] Authors own calculations, based on reported results from study.

risk associated with guaranteeing these income streams in light of a climate change-driven crash in regional/national housing values is paramount.

After a flood event, homeowners have options to repair and rebuild or sell and move. The cost of replacing belongings and repairing or rebuilding damaged homes can pose a significant financial challenge to the homeowners' ability to maintain mortgage payments. The primary function of flood insurance is to assist homeowners in this recovery. There are additional programs and sources of financing, such as higher credit utilization or secondary financing, as well as federal assistance. HUD, SBA, and FEMA are the three primary sources of federal assistance.[15]

In response to Presidential Disaster Declarations, HUD's Disaster Recovery Community Development Block Grants (CDBG-DR) provide flexible grants to states and municipalities to administer locally, with a portion of funds dedicated to lower income areas that are less likely to be high-risk flood zones and have lower flood insurance take-up rates (FEMA, 2018, as cited in Kousky et al., 2018).[16] There is evidence from the previously mentioned 2011 HUD study on CDBG-DR use post-Hurricane Katrina that the funds dedicated to lower income areas reach their intended recipients Turnham et al. (2011). Through the Disaster Loan Program administered by SBA, affected business owners and homeowners can apply for low-interest loans to "repair, rehabilitate, or replace property." These loans must be paid back to the federal government with interest, and their primary function is to bring a structure back to a safe condition, not full restoration. Households may also receive direct assistance through FEMA's Individuals and Household Program (IHP). However, grants through this program have a cap of just over $30,000 and have averaged closer to $5,500 (Kousky, 2018), so this is a limited source of financial assistance. Given the approximately 50 percent compliance rate of mandatory flood insurance in the SFHAs and the much lower voluntary take-up rates outside, it is possible that many homeowners with flood damages face significant financial difficulties, which pose risks to mortgage performance. Several studies provide insight into the effect of flood damage on homeowner financial outcomes as well as the role flood insurance and other disaster relief programs play in mitigating negative outcomes.

The previously discussed HUD-2M Research (2020) study considers several relationships between NFIP claims, insurance premiums, and loan performance within the FHA portfolio. Relevant to this discussion, the study team analyzed the effect of a flood insurance claim on loan performance of an FHA-insured mortgage for the subset of loans with active flood insurance policies. Using a logistic regression in which the dependent variable is a binary indicator for the first time a loan was in default, they consider the effects of a flood claim 1 year prior and 2 years prior, for the subsample of mortgages with flood insurance for each state. In summary, for both North Carolina and Florida, the relative likelihood of defaulting in the next year is larger when an FHA-insured property has at least one flood insurance claim in the current year than when the FHA-insured property has no flood insurance claims in the current year. In all three specifications considered, a property with at least one claim in the previous year is 1.6 to 1.8 times more likely to be in default during the current year, significant at the 95 percent confidence level. Only in the specification including controls for

[15] See Kousky et al. (2018) for more detailed discussions on each of these sources of funding.

[16] Funding for CDBG-DR requires additional congressional appropriations because the program does not have standing funding.

monthly payment and monthly effective income does a flood claim 2 years prior have a statistically significant effect of being more than twice as likely to default (at the 95 percent confidence level). This analysis does not include properties without flood insurance, however, so there is no insight to the effect flood insurance has on mortgage outcomes compared to uninsured mortgages.

The 2011 HUD study used a survey of individuals who owned properties in 2005 that were destroyed by Hurricanes Katrina and Rita to examine how CDBG-DR were used in rebuilding in Louisiana, Mississippi, and Texas. Employing a multivariate analysis of factors that influenced the likelihood of rebuilding, the authors found households covered by flood insurance were 37 percent more likely to rebuild after Hurricanes Katrina and Rita compared with households without insurance (Turnham et al., 2011). Homeowners with an active mortgage, however, were 13 percent less likely to rebuild, all other things being equal. The authors further investigated the interaction between these two variables by estimating the effect of having an active mortgage on the decision to rebuild among the fully insured sample; they found that those with a mortgage were more than 11 percent less likely to rebuild, indicating that homeowners may use insurance proceeds to pay off a mortgage and move rather than rebuild, although the study does not draw this conclusion.[17]

In another study focused on Hurricane Katrina, Gallagher and Hartley (2017) looked for a causal effect of the storm on key household finance distress indicators. They found modest evidence of credit card usage for consumption smoothing, increasing balances approximately $500 (15 percent) for the *most-flooded* group compared to *non-flooded*, though such effects are short lived. They also found that the *most-flooded* residents have general debt delinquency rates 10 percent higher than *non-flooded* residents on credit reports, although 2 years later, credit scores were only .06 standard deviations lower. Contrary to expected negative impacts on financial stability, the authors found that total debt decreases for the *most-flooded* residents. They concluded the relatively larger reductions in total debt for the *most-flooded* residents are driven by homeowners using flood insurance to prepay their mortgages rather than rebuild, with two key determinants behind the prepay decision. First, this was most commonly seen in areas where reconstruction costs exceeded pre-storm home values. Second, mortgages that were originated by non-local lenders were more likely to prepay than rebuild.

To examine the role of local versus nonlocal mortgage lenders in borrowers' post-flood outcomes, they categorize local lenders as those whose share of New Orleans-based loans exceed that of the median lender. They found borrowers from nonlocal lenders are more likely to pay down mortgage with insurance claim proceeds compared to borrowers with local lenders. Furthermore, they found that local lenders returned to pre-Katrina lending levels 2 years later, whereas nonlocal lenders largely exited the market. This finding on the role of nonlocal lending institutions in the decision to rebuild adds important context to the discussion on flood damage-induced prepayment risk, as well as the discussion on community resiliency.

Taking a slightly different approach, Kousky, Palim, and Pan (2020) used Hurricane Harvey as a case study and data from Fannie Mae to examine the link between flood insurance, property damage, and mortgage credit risk. Utilizing home-specific, post-damage home inspection data for 30,000 homes, the authors examined risk from the perspective of the credit risk holder (Fannie

[17] All results discussed from this study were statistically significant at least at the 90 percent confidence level.

Mae) in what they claim to be the first paper to quantify the protective benefits of flood insurance on loan performance. When first examining the link between flood damage and mortgage performance, they found that moderately to severely damaged homes are three times more likely to become delinquent after the storm compared to undamaged homes, and they conclude that flood insurance has no short-term effect. Longer-term performance (180 days delinquent/default) depends on insurance coverage. Assuming that property location within an SFHA implies having a flood insurance policy (100 percent compliance) and location outside an SFHA implies no coverage, they compare outcomes for houses inside SFHAs to those outside.[18] They found that for homes inside SFHAs with flood insurance, prepayment rises with property damage by a factor of 2.1 compared to undamaged homes. There is no difference in prepayment for damaged homes outside SFHAs (uninsured homes) compared with undamaged homes, corroborating the results suggesting that insurance coverage leads to prepayment discussed in Gallagher and Hartley (2017). Outside of SFHAs, increasing damage increases the need for loan modification and the likelihood of the mortgage becoming 180 days delinquent or in default 2 years after a storm.

The relative scarcity of studies examining this issue demonstrates the data limitations relating to matching insurance policies directly to mortgage information, which make this problem particularly difficult to study. This further highlights the need for an automated data set linking mortgages to flood insurance policies.

How are mortgage market participants altering their behavior?

Currently, information on flood risk and consequences is asymmetric. This asymmetry results in observable differences in mortgage lending, securitization, and investing decisions by groups. Most importantly, there is evidence that originators may be selling mortgages on properties with higher flood risk to be securitized and keeping less risky mortgages in their own portfolios, transferring the flood risk to the GSEs. There is preliminary evidence that borrowers are structuring their mortgages to protect themselves from equity loss in the event of a destructive storm surge, which also has the effect of transferring risk to the mortgage holders/securitizers. Rating agencies and large institutional investors are incorporating climate risk into their modeling.

Two recent studies examine the behavior of mortgage originators and how specific behaviors are increasing the risk borne by the agencies. First, Ouazad and Khan (2019) explored mortgage lender securitization patterns before and after a flood event that causes over $1 billion in damage and the exploitation of exogenous (with respect to natural disasters) changes in the conforming loan limit. They found that after a billion-dollar event, originators are significantly more likely to increase the share of mortgages originated and securitized right below the conforming loan limit. The authors conclude that they do this in response to learning new information on flood risk, resulting in originators selling higher risk mortgages to agencies for securitization and keeping less risky mortgages on their own books. This offloads increasing amounts of risk to government-

[18] It should be noted that this is a strong assumption given most insurance studies find take-up rates closer to 50 percent (Kousky and Lingle, 2018). However, this overestimation of insurance coverage is likely to bias the estimated effect of coverage on post-flood outcomes downward. Likewise, the assumption of being outside SFHA implying noncoverage is also strong for the Houston area, as Kousky and Lingle (2018) find that Texas has higher than normal non-SFHA. This too may bias the estimates of the effect of insurance downward. With two potential downward biases, the true effect may be larger than reported.

sponsored enterprises. Furthermore, because the GSEs do not currently price in flood risk to their guarantee fees, they are effectively subsidizing the construction and purchasing of homes in areas at increasing risk of flooding due to climate change.

Second, Keenan and Bradt (2020) outlined a theoretical foundation for a process they called "*Underwaterwriting*" (UWW) and then provided empirical evidence for its existence. In this practice, local mortgage lenders utilize advantages in asymmetric information to structure loans to offload the risks from themselves. They showed that in 2009, local banks along Southeast Atlantic and Gulf coasts sold off 43 percent of their mortgages in flood zones, comparable to the share they sold off in areas not at risk of flooding. By 2017, this share had increased to 57 percent in flood zones, whereas the remaining share was relatively flat in less vulnerable neighborhoods. The authors also found that the lenders selling off coastal mortgages the fastest are smaller local banks, which are more likely than large national banks to know which neighborhoods face the greatest climate risk. "*They have their ears to the ground,*" Dr. Keenan said in an interview discussing the article, although this seems to be regionally isolated to the Southeast Atlantic and Gulf coasts. This finding adds additional context to the discussion on the role that local versus nonlocal lending institutions can play in local mortgage markets' response to flooding as discussed in Gallagher and Hartley (2017). Beyond the transference of risk from local lenders to mortgage securitizers, the authors also discuss implications for credit availability in SLR-exposed regions. Specifically, the authors note that in the absence of standardized assessment data, the market advantage of locally concentrated lenders could strengthen as SLR and coastal flooding intensify, leading to an unevenness in mortgage availability and pricing. Furthermore, UWW could cause credit availability to be increasingly constrained because nationally diversified lenders charge higher interest rates to account for locally concentrated lenders' ability to cherry-pick the most credit-worthy borrowers. However, the authors note that, at present, it is likely that upfront yields from points and servicing fees, combined with market share considerations, supersede the need for a climate risk-driven repricing of mortgage credit to account for their current informational disadvantage

Two previously discussed studies (Bernstein, Gustafson, and Lewis, 2019; Hino and Burke, 2020) showed that there is some variation of home purchasing behavior by the type of buyer. It is plausible that sophisticated or institutional home buyers have more robust systems for assessing flood risk and, therefore, a greater willingness to pay. In addition to this, preliminary work by Economist Dr. Amine Ouazad finds evidence that homebuyers in areas subject to storm surge are opting for alternative mortgage products to the standard 30-year mortgage (Ouzad, 2020). In most of the country, 90 percent of mortgages are the standard 30-year fixed rate mortgage. However, since the housing crash, this share has fallen to 80 percent in areas at risk of storm surge, in large part driven by interest-only loans, which accounted for over 10 percent of mortgages in 2016 in these areas compared with 2.6 percent of mortgages elsewhere. Interest-only loans protect borrowers from equity loss in the event of a catastrophic disaster because their monthly payments have not been put toward equity. In an interview, Dr. Ouazad notes that his results are still preliminary and need further work, but says there is reason to think climate risks could be driving this behavior (Flavelle, 2020).[19]

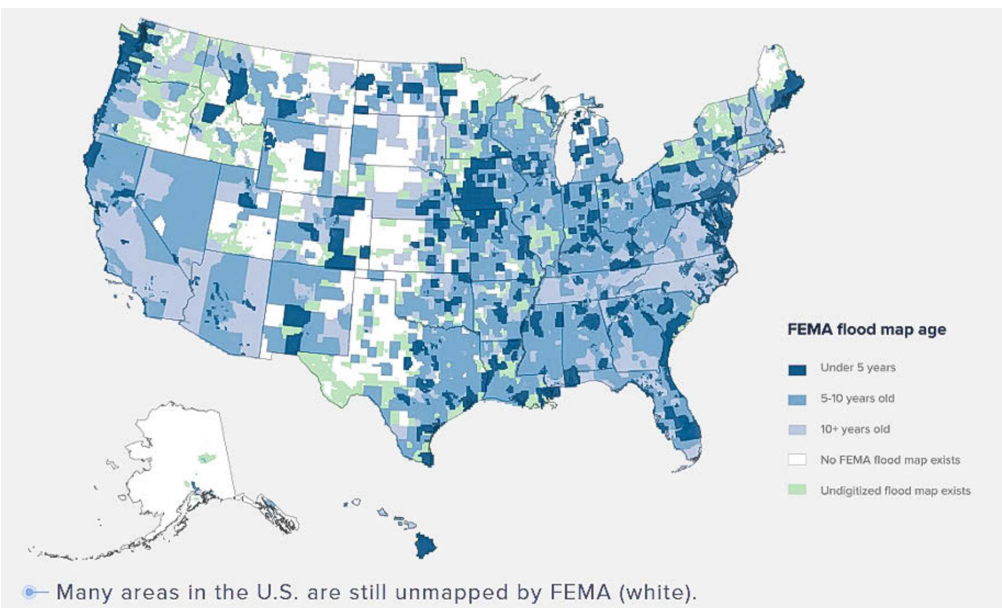
[19] For instance, one alternative explanation could be if these home purchases were for second homes or rental properties, which may be more likely in coastal areas.

As flood risk continues to propagate through the housing finance ecosystem, it moves from homeowners and communities to mortgage holders and securitizers, and finally from securitizers to mortgage security investors. Agency securitizers do not price in flood risk in the guarantee fees they charge or through other means, and flood risk is not yet clearly priced into mortgage-backed securities (MBSs), if at all (Owens, 2020). If investors and rating agencies begin to identify this risk in a disorganized manner, this could lead to an increase in volatility in the otherwise relatively stable mortgage-backed security market, putting millions of investors at risk. In his 2020 letter to CEOs, Larry Fink said, "climate risk is investment risk" (Fink, 2020). With the increase in the number of private sector catastrophe modeling firms and large improvements in modeling capabilities, institutional investors, rating firms, and other entities will be able to develop their own insights into residential mortgage flood risk's downstream risk to MBSs. There is some evidence that investors are already responding to perceived flood risk to the properties underlying MBSs. As covered in a *Politico* article, "When the credit risk transfer market settled after Harvey, the Association of Mortgage Investors, a trade group representing mortgage securities buyers, asked Fannie Mae and Freddie Mac to remove mortgages vulnerable to climate change from those offerings" (Colman, 2020). Fitch Ratings became the first rating agency to announce that it will begin incorporating climate risks into its rating of residential mortgage-backed securities, primarily for mortgage pools based in Florida and California (Duguid, 2019).

Appendix

Exhibit A.1

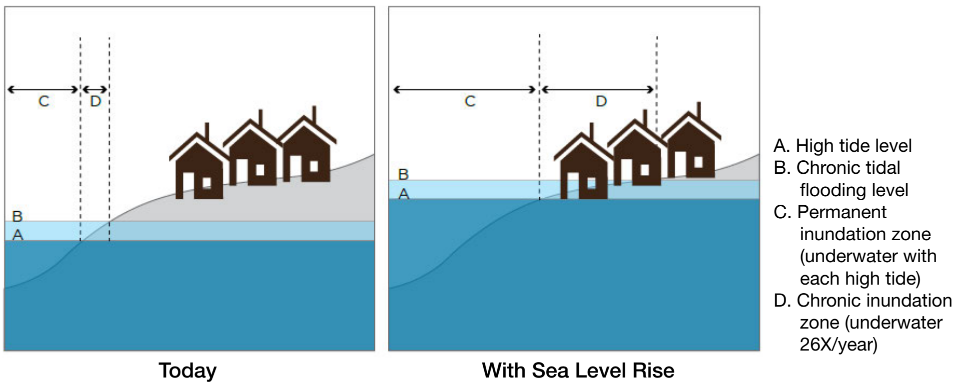
FEMA Flood Map Age



FEMA = Federal Emergency Management Agency.
Source: First Street Foundation report, The Cost of Climate: America's Growing Flood Risk

Exhibit A.2

How Sea Level Rise Causes Chronic Inundation

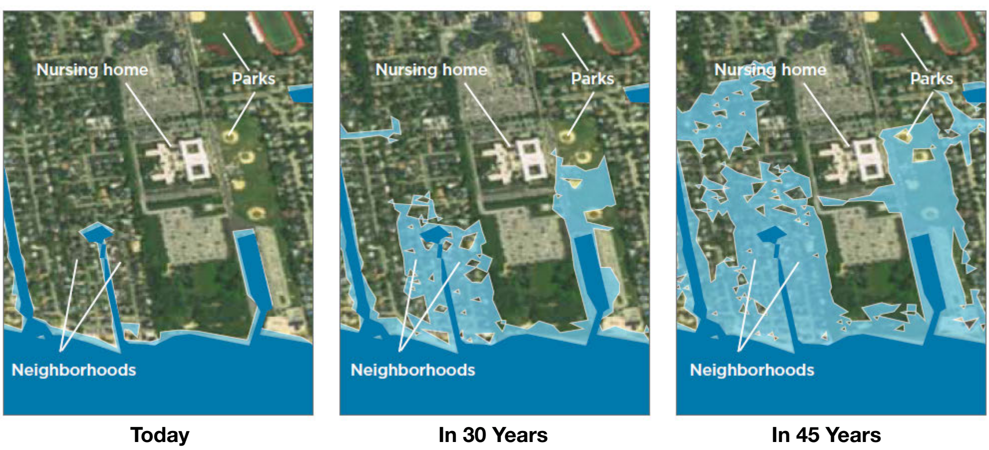


When higher sea levels are aded on top of the normal variations in tide height, the more extreme high tides can reach onto normally dry land. As sea level rises further, this occasional flooding can become chronic, as less extreme tides begin to cause flooding as well. The left panel shows current high tide and the extended reach of extreme tides, which defines a chronic inundation, or limited-use zone. The right panel shows how sea level rise later in the century has expanded the reach of not just extreme tides but also more typical tides such that some land is permanently inundated and a greater portion of the community is chronically flooded.

Source: Union of Concerned Scientists 2017, When Rising Tides Hit Home

Exhibit A.3

How Sea Level Rise Causes Chronic Inundation



As sea level rise extends the zone of chronic inundation deeper into communities, chronic flooding may affect commercial, industrial, and residential areas, along with key infrastructure. The left panel shows the current zone of chronic inundation (light blue) in an East Coast community. The center panel shows the chronic inundation zone in 2045, when a densely developed neighborhood can expect to have to deal with twice monthly saltwater inundation. The right panel shows the chronic inundation zone in 2060, when much of the town's coastal area floods with regularity—a sobering challenge for local and state governments.*

SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, NCES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY

**light gray in the printed version of this issue.*

Source: Union of Concerned Scientists 2017, When Rising Tides Hit Home

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