Mainstreaming Sea Level Rise Preparedness in Local Planning and Policy on Maryland's Eastern Shore

A report by the Eastern Shore Land Conservancy on behalf of
the Eastern Shore Climate Adaptation

January, 2019

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[1] This report was commissioned by the Eastern Shore Land Conservancy on behalf of the Eastern Shore Climate Adaptation Partnership (ESCAP). The main body of the report was written by Eastern Shore Land Conservancy coastal resilience specialist James Bass. Flood vulnerability studies were written by Eastern Shore Regional GIS Cooperative director Dr. Michael Scott. The Higher Standards report was written by Jessica Grannis et al. with the Georgetown Climate Center. The Capital Improvement Planning report was written by Brandy Espinola and Kristel Sheesley with the University of Maryland Environmental Finance Center.

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Cover photo: David Harp, Chesapeake Photos

I - Executive Summary

Coastal flooding is not a new phenomenon on the Eastern Shore of Maryland. However, current modeling by the U.S. Geologic Survey (USGS) indicates that sea level is rising in the Chesapeake Bay nearly twice as fast as the global rate. The risk of flood damage from coastal storms is growing as sea levels rise and development encroaches on shorelines. While the region's historical vulnerability to flood events is understood and accounted for by planners, the coastal floodplain of the 21st century will look and behave very differently than it used to. The goal of this report is to clarify these new flood risks by assessing several scenarios that consider rising sea levels in the Chesapeake Bay and its tributaries.

This report is intended: 1) to inform decision makers and residents about local risks associated with the combination of sea level rise and coastal storm flooding; and 2) to guide communities towards policies and practices that will reduce flood and sea level rise risk. The report provides local government leaders and staff with data, analyses, policy options, and implementation guidance.

Partners in the development of this report include the Eastern Shore Regional GIS Cooperative (ESRGC), the Georgetown Climate Center, and the University of Maryland Environmental Finance Center. This report is the result of a yearlong planning process aimed at assisting ESCAP communities in preparing for sea level rise impacts. Using a "science to solutions" process, the project team combined geospatial data and economic information to assess risk and vulnerability to flood and sea level rise (SLR) impacts. These findings were the foundation of community adaptation workshops, which informed the recommendations and model language, provided herein.

The rates of sea level rise used in this report – approximately 2 feet by the year 2050 and 6 feet by the year 2100 – are based on extensive research by the U.S. Army Corps of Engineers and closely match projections included in the Maryland Climate Commission's "Sea Level Rise: Projections for Maryland 2018." Specific sea level rise rates used for each jurisdiction in this study are listed in Section VI.

A series of community adaptation workshops for local elected leaders and planning staff were held to ground truth the analyses performed by the Eastern Shore Regional GIS Cooperative. Local concerns about flooding were discussed, including:

1. A need for expanded freeboard requirements
2. Recognition that 1% chance storms seem to be occurring more frequently and extreme weather events are increasing in severity
3. Acknowledgement that sea level rise is reducing the margin of safety afforded by existing floodplain management practices (ordinances, building codes, policies, etc.). Stronger practices are needed to maintain and improve the margin of safety in the region's housing stock.

The workshops also gathered potential strategies for local jurisdictions to reduce sea level rise and flood risks. The Georgetown Climate Center and UMD Environmental Finance Center responded to the comments from the workshop participants and compiled specific policy options and practices that will help local officials plan for sea level rise impacts in their community. The recommendations that were prioritized by ESCAP members during the community adaptation workshops include:

1. Conduct a resilience assessment prior to undertaking new capital investment projects
2. Develop a multi-year maintenance and upgrade plan for infrastructure and other assets
3. Integrate resilience into capital improvement planning

4. Expand the regulatory floodplain
5. Enact three-foot freeboard requirements in all building codes
6. Regulate Coastal A zones as V zones

Flood risk is changing across the Eastern Shore. The strategies included in this report will help communities build a greater margin of safety against coastal storms. While the 2050 and 2100 scenarios seem far off, the buildings where residents will live and work in those future years are being built today. Now is the time to build in the protections that the Eastern Shore's building stock and infrastructure need to weather new flood risks.

II - Introduction

The purpose of this report is to identify and illustrate risk associated with sea level rise on Maryland's Eastern Shore, and to provide guidance to local governments seeking to incorporate evolving flood risk into local plans and decision-making. The fundamental intent underlying all elements of this report is a "science to solutions" process, drawing on multiple disciplines to inform a broad and interconnected array of findings and recommendations based on scientific and policy-based research.

The data contained in this report is an innovative look at the impacts of flooding on Maryland's Eastern Shore in the coming years. By overlaying storm surge inundation with scenarios of anticipated sea level rise (SLR), this analysis provides critical new information to planners and decision makers by estimating the costs in dollars of several expected flood scenarios.

Upon publication of this report, jurisdictions participating in the Eastern Shore Climate Adaptation Partnership (ESCAP) should be informed and empowered to have more substantial conversations and planning initiatives that involve planning and zoning, floodplain management, economic development, emergency management, housing, public health, transportation, and more. By utilizing a science-to-solutions approach, local decision makers will be empowered by rich, complex information distilled into simple messages and tangible recommendations. These recommendations will enable change that will protect Eastern Shore communities for years to come.

ESCAP communities are the primary audience for this report. ESCAP is a network of county and municipal government staff working in collaboration with representatives of state government, academic institutions, and not-for-profit organizations to understand, plan for, and reduce the costs of impacts of climate and sea level rise impacts.

The scope of work for this project was designed to advance priorities stated by multiple ESCAP jurisdictions in their official planning documents and vulnerability assessments. By identifying and aggregating needs across the region, this project demonstrates the ESCAP's ability to provide data, analysis, and guidance products more cost-efficiently than jurisdictions could achieve individually.

III - Vulnerability Assessment for Sea Level Rise and Flood Events

Maryland's Eastern Shore is naturally vulnerable to elevated water levels and heavy rainstorms. Sitting on the Chesapeake Bay and housing numerous tributaries, the area has low-lying areas that are exposed to both coastal and riverine flooding. Climate change is exacerbating environmental conditions and increasing the risk of certain natural hazards. This section examines how climate change is altering the risk of flooding today and in the future.

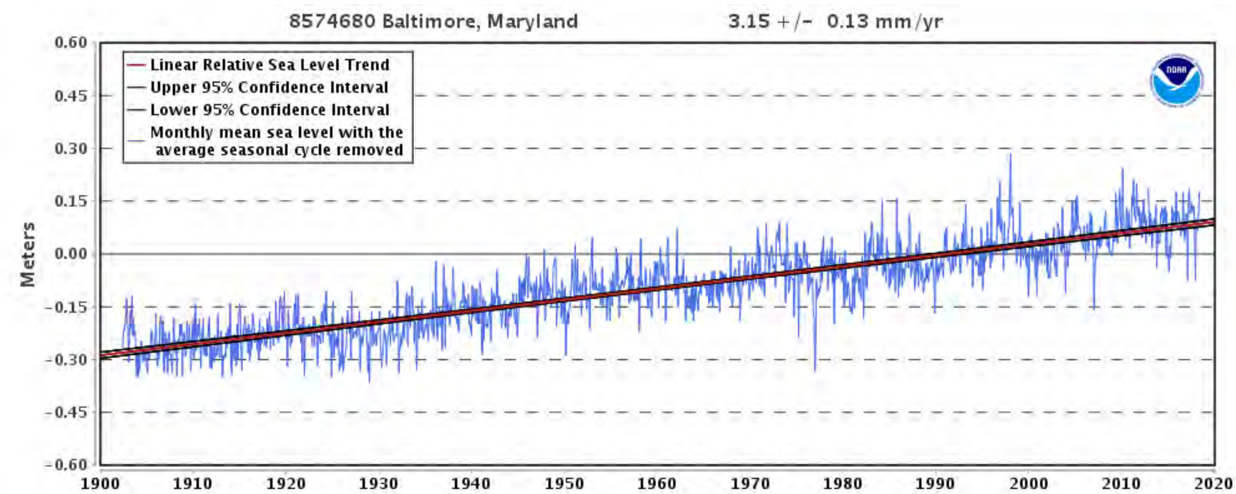
Sea level rise, observed and perceived

Water levels around the globe vary naturally on daily, monthly, annual, and multiyear scales. Locally, water levels are rising for three reasons. First, the volume of water in the ocean changes. In the past 100 years, the volume of water in the oceans is increasing due to inputs of freshwater from melting glaciers and land-based ice sheets, and due to expansion of seawater as it warms. Secondly, water levels appear to be rising because the Chesapeake region as a whole is sinking, a phenomenon known as subsidence. This subsidence is primarily an ongoing reaction of the Earth's crust to the retreat of the Laurentian Ice Sheet following the last ice age. Land subsidence accounts for approximately half of the observed sea level rise in some ESCAP jurisdictions over the last 100 years. Groundwater extraction for drinking water and agriculture has been shown to accelerate subsidence in other parts of the world, though no such studies are known to exist for Maryland's Eastern Shore. Finally, changes in ocean dynamics, such as a weakening of the Gulf Stream Current, can cause ocean water rise along the U.S. Atlantic seaboard. Climate change is expected to increase the relative effects of ice melt, thermal expansion of seawater, and ocean dynamics in coming years.

Tide gauge records

Globally, sea level has risen an average of half a foot in the past century. In the Chesapeake Bay region, relative sea level rise has been double the global average, due to the additional effect of land subsidence. Spanning more than 110 years, the NOAA tide gauge at Baltimore Harbor has one of the longest data records in North America. The chart shows a clear trend of rising water elevation, amounting to nearly 13 inches in the past 100 years.

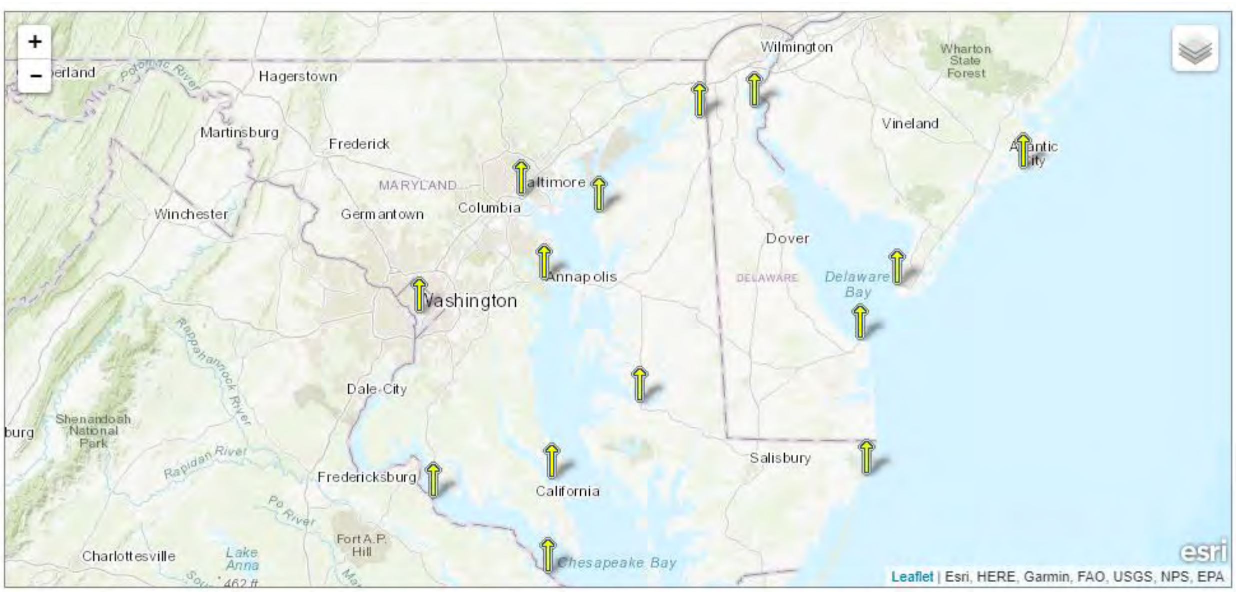
Fig. 1: Mean Sea Level Trend for Baltimore, MD



Source: NOAA. http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8574680

When looking regionally, a trend can be seen. Due to the combination of land subsidence and sea level rise mentioned above, tide gauges across the Chesapeake and mid-Atlantic indicate relative water level rise of 3 to 6 mm/year (1 to 2 feet/century). These rates are the highest of the entire Atlantic seaboard and among the highest worldwide.

Fig. 2: Chesapeake and Mid-Atlantic Relative Sea Level Trends for NOAA Tide Gauges



The map above illustrates relative sea level trends , with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

Source: NOAA. https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Sea level rise projections

Rates of sea level rise will vary slightly across the Eastern Shore due to the topography of the land and the Chesapeake Bay. Below is a table provided indicating SLR rates at several tide gauges in the Chesapeake and its tributaries.

Tidal Station	2050 MSL*	2050 MHHW	2100 MSL	2100 MHHW**
Annapolis	2.08	2.79	5.70	6.41
Baltimore	2.01	2.87	5.59	6.45
Solomons Island	2.10	2.82	5.76	6.48
Cambridge	2.11	3.13	5.78	6.80
Chesapeake City	1.98	3.63	5.56	7.21
Washington DC	2.21	3.83	5.78	7.40
Ocean City	2.06	3.25	5.86	7.05

Source: ESRGC *Mean Sea Level ** Mean Higher High Water

Storm surge inundation

Tropical storms and hurricanes generate a bulge of seawater known as storm surge that travels ahead of the storm. Height of the storm surge depends on the strength of the storm, with stronger storms producing larger surges. As a storm makes landfall in the Chesapeake region, the storm surge is pushed northward up the Chesapeake Bay and into its tributaries. As the upper Bay narrows, the storm surge bulge becomes more confined, squeezing the water upward and amplifying the surge height.

Storm surge is in addition to normal tidal cycles. The sum of storm surge plus tide level is known as the storm tide. Storms making landfall at or near high tide will have higher storm tides and greater flooding potential than if landfall occurred at low tide.

Storm surge is exacerbated by sea level rise. As still-water levels rise due to climate change, the starting level for storm surge becomes higher. This enables weaker storms to achieve the same flood levels that once required a stronger storm to achieve. For example, in 2003 Isabel, a tropical storm at landfall, brought 4 to 9 feet of storm surge to the Mid and Upper Eastern Shore. Despite being a weaker storm, Isabel was able to reach approximately the same flood level as the Great Chesapeake-Potomac Hurricane of 1933 because sea level rose about 8 inches during the seventy years between storms. Isabel, a weaker storm with smaller storm surge, was able to cause the same level of flooding because the starting water level had been elevated by sea level rise.

In the future, as sea level continues to rise, storm surge flooding could become more common – not because tropical storms are more frequent, but because the combination of surge and sea level rise will enable weaker storms (ones that used to pass without significant flood impacts) to cause significant flooding. Today's preparations for a Category 2 hurricane, may only offer protection against a Category 1 storm in future decades. When stronger hurricanes do occur, sea level rise will enable flood impacts that the region has not encountered in recorded history.

Damage data

The following figures are a multi-jurisdictional overview of damage estimates for each of the ESRGC planning scenarios. They are intended to graphically show the region's vulnerability in both number of buildings and cost in flood damage. Note that the numbers in figure 4 reflect actual damage cost, which is substantially lower than replacement or insurance cost.

Scenarios analyzed below include:

- Year 2015 (baseline): no flood, 1% chance storm, 0.2% chance storm
- Year 2050: no flood (accounting for approximately 2 ft. sea level rise), 1% chance storm
- Year 2100: no flood (accounting for approximately 6 ft. sea level rise), 1% chance storm

More information on ESRGC's modeling can be found in Section IV of this report. For more detail on each county, see Appendix C from the Eastern Shore Regional GIS Cooperative.

Fig. 3: Count of vulnerable buildings for sea level and flooding scenarios

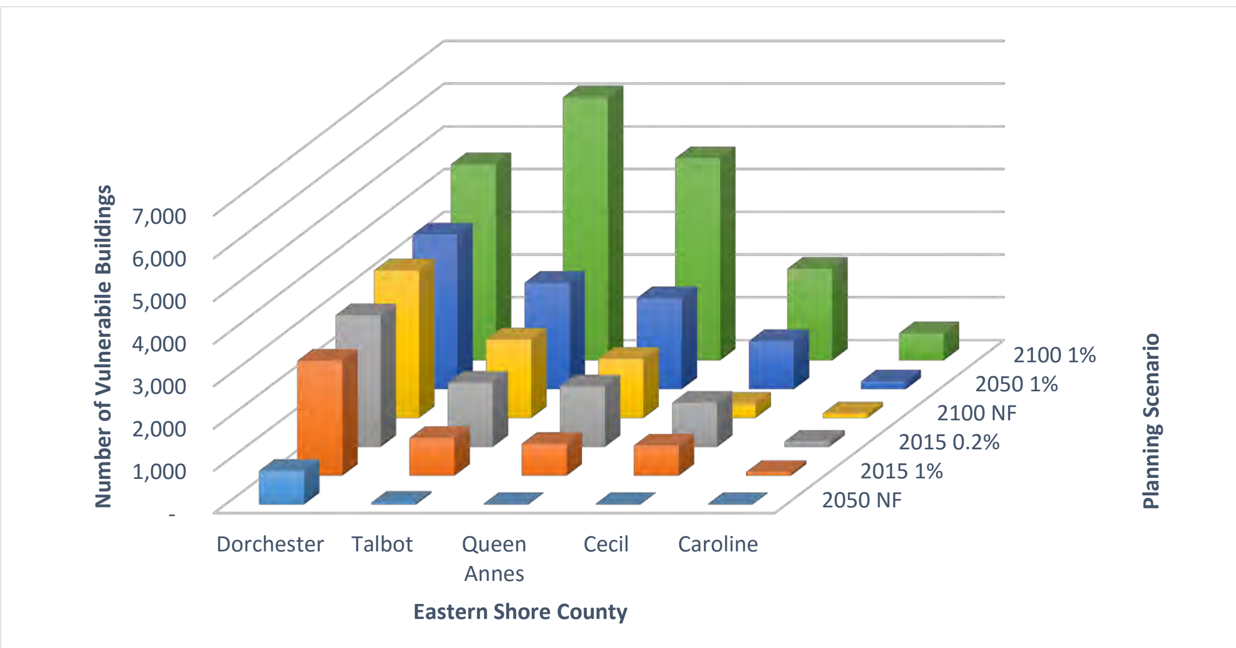
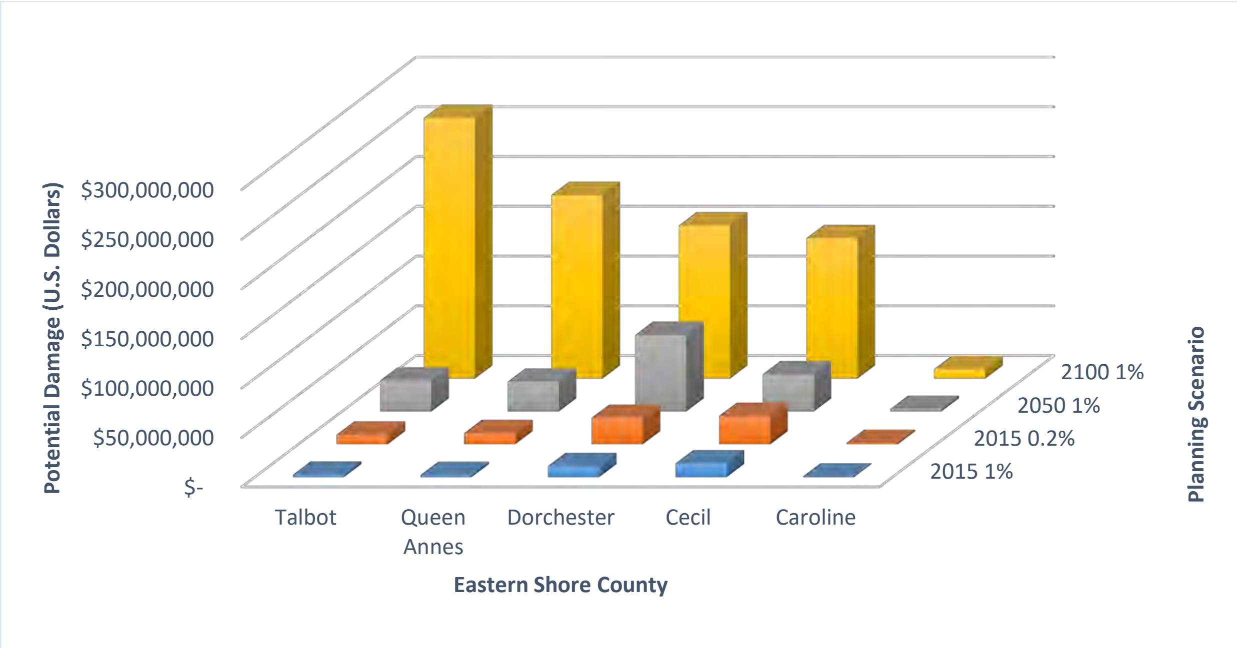


Fig. 4: Potential damage to buildings under each scenario



Key messages

Region-wide Messages:

- The window of opportunity to make policy adjustments that adapt communities to sea level rise is still open in most of the region…
    - Only 63 buildings are expected to be constantly wet by 2050, but that excludes Dorchester, which will have 790 wet buildings.
- …but the window is closing fast.
    - Today, a 1% chance storm impacts $1.2B in property/contents values and causes $30M in damage.
    - In 2050, that same storm affects $2.8B of property value and causes $178M in damage (2016 dollars).
- A tropical storm in 2100 causing damage comparable to Hurricane Isabel will fundamentally change the landscape of the Eastern Shore if we are not prepared by then.
    - More than 15% of buildings will be impacted, worth $5.8B, with expected damages of $751M.

Cecil County:

- The narrowing and shallowing that occurs in the northern Chesapeake Bay creates high vulnerability to coastal flooding.
- The window of opportunity is considerably wider in Cecil County than lower on the Eastern Shore.

Queen Anne's County

- Development pressure has the county on an edge, with damage exposure jumping starkly as storm severity increases (a 0.2% chance event has 5 times the impact on property as a 1% chance storm).
- The impact of future flood events will be felt more heavily by the commercial sector than in other counties due to commercial development patterns.

Caroline County

- Because land values in Caroline have been historically less than in neighboring counties, there will likely be increased development pressure in the coming decades – both a potential threat and an opportunity to build right the first time.

Talbot County

- Topography and past floodplain management practices built a margin of safety into the building stock.
    - Only 39 buildings are impacted by sea level rise in 2050.
- However, once the margin of safety is breached, the results are the worst in the region.
    - Nearly 30% of all buildings in Talbot could be impacted by a 1% chance event in 2100

Dorchester County

- This study does little to challenge the notion of Dorchester being the "Most Vulnerable to Flooding on the Eastern Seaboard"
- The future impact of SLR is lower than in other counties due to the extreme significance of *current* potential for harm from flooding
    - Right now, almost 17% of the buildings in the county are threatened by a 1% chance event. In 2050, that "only" rises to 22.6%.
    - The damage does increase significantly though, from $11M to $66M

Floodplain management practices

As indicated by the data above, current floodplain management practices are providing protection sufficient for today's 1% chance flood. Relatively limited damage is caused by today's 1% and 0.2% chance floods, both in terms of impacted structures and property value lost. A tipping point is being approached, however, which will fundamentally change the way local governments manage their floodplain. Sea level rise models are improving regularly. The confidence in the projections for 2050 is sufficient for planners and decision makers to take action. Projections for the year 2100 vary in magnitude but still serve important roles in guiding long-term planning for infrastructure siting and future development. It is important to note that each new study published over the last decade has revised sea level projections for 2100 upward, anticipating water levels which are higher and more intrusive than the studies that preceded them.

As sea levels approach the modeled 2050 and 2100 inundation levels, the damage and loss levels increase significantly. There is time, however, for local jurisdictions to prepare their communities for the eventual increase in inundation. By acting now upon the recommendations listed in Section 5 of this report existing codes can be updated, new standards can be developed, and communities can change the way capital planning is approached so that safety, sustainability, and resilience are characteristics of every new initiative in the future.

IV - Science to Solutions Process

Science to Solutions background

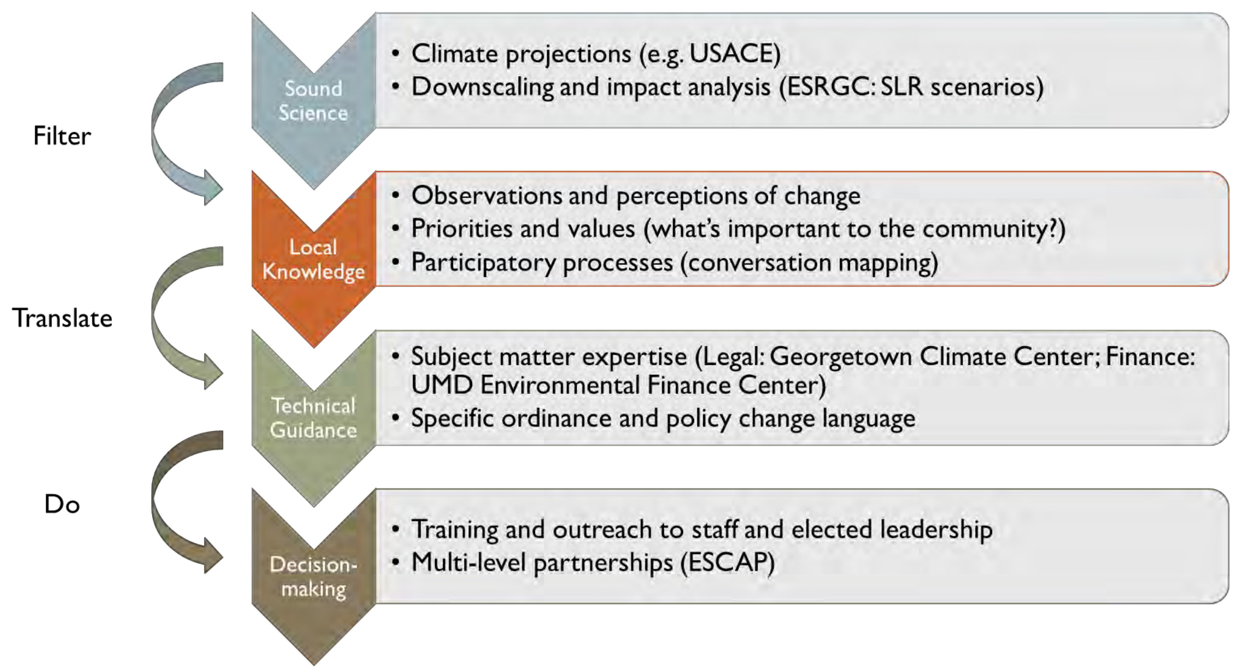
The goal of the science to solutions process is to implement decisions at the local level, which are built soundly upon scientific data via a three-step process.

Step one involves taking data from scientists and applying a local filter in order to verify or "ground truth" the data's relevance. The filtering process involves knowledgeable voices at the local level who can paint a picture of the community. The goal is to have a thorough understanding not only of the data being used, but how it will be applied in context.

Step two is to translate this filtered science into technical guidance. Subject-matter experts ensure the data is applied properly to the needs of the community. Guidance may include draft codes, specific ordinances, policy change language, implementation recommendations, and case studies.

Finally, step three is to act upon the newly developed technical guidance. By filtering and translating, communities can undertake new or expanded actions which are rooted in science and have been developed based on local context.

Fig. 5: The Science to Solutions process



Hazard mitigation alignment

The genesis of this project was rooted in a hazard mitigation planning activity undertaken by several ESCAP communities. In a "mitigation crosswalk," communities identified similar or shared priorities across their individual local hazard mitigation plans. Integrating resilience into capital investment planning and flood prevention/stormwater management were the top two items that were common among four of the six ESCAP counties. The identification of these two shared action items led the ESCAP to recognize the need for a regional project addressing both complex flood data as well as recommendations for planning and decision-making.

GIS modeling

To develop detailed geospatial information systems (GIS) data for use by its member communities, the ESCAP contracted the services of the Eastern Shore Regional GIS Cooperative (ESRGC) at Salisbury University. Analysis was conducted for five counties and included multiple scenarios, including:

- 2015 – baseline (no flooding), 1% chance, and 0.2% chance floods
    - *Note: this report refers to 1% and 0.2% chance floods, storms, or events. The more-commonly used analogs to these terms are "100-year" and "500-year" floods. ESLC believes these more commonly used terms to be increasingly misleading and dangerous in the face of changing climate and sea level; look no further than Ellicott City, MD, to see a 0.2% event occurring more frequently than every 500 years.*
- 2050 and 2100 – sea level rise projections, plus 1% chance flood

ESRGC analysis also included property and infrastructure impacts, including:

- Number of flooded structures
- Cumulative damage value (in dollars)
- Number and length of inundated road segments

Upon completion of analysis, ESRGC conducted GIS training for county and town staff. This in-depth workshop addressed project methodology, results, limitations, and key messages to communicate. The fundamental conclusion of this GIS data is that the Eastern Shore will soon reach a critical juncture for mitigating sea level rise and action is required now to address it.

Workshops

In addition to the GIS training, the ESCAP conducted additional workshops for local government staff and leaders. These workshops engaged participants in comprehensive discussions of the new GIS data and its implications for flood vulnerability and risk management. The workshops utilized the tool "Game of Floods," a public education activity developed by Marin County, California, to enable creative thinking about the local impacts of climate change and sea level rise. In the game, players must work as a team to develop adaptation strategies for their hypothetical community while working with real-world factors such as project costs, voters' concerns, equity issues, private property impacts, and environmental impacts.

The first workshop held by ESCAP used the work of ESRGC to set the stage for Game of Floods. By playing the game with ESCAP members, the group was able to think of sea level rise issues in Maryland in new and creative ways. Members were divided into three teams, with each team assigned a unique set of resources and challenges. The distribution and allocation of these resources led to the most valuable lessons in adaptation planning. For example, one group had ample funding to implement adaptation measures in their scenario community while another group with insufficient funding had to think critically about the prioritization of community assets at every turn. These differences drove home for all participating ESCAP members the complexity of the issues central to conversations about climate and sea level rise.

The second and third ESCAP workshops conducted in conjunction with the ESRGC study were community adaptation workshops geared towards understanding the vulnerabilities, key messages, and action options for each jurisdiction. These workshops were designed to allow participants in each county to react to and discuss the data presentations, key messages, and implications for floodplain management, building codes, ordinances, and capital investment planning.

Key results from the community adaptation workshops include:

- A need for expanded freeboard requirements
- Recognition that 1% chance storms seem to be occurring more frequently and extreme weather events are increasing in severity
- Acknowledgement that sea level rise is reducing the margin of safety afforded by existing floodplain management practices (ordinances, building codes, policies, etc.). Stronger practices are needed to maintain and improve the margin of safety in the region's housing stock.

More information on these key results can be found in Section V of this report.

Technical guidance

Supportive guidance documents have been produced by the Georgetown Climate Center (Georgetown University Law School) and the Environmental Finance Center (University of Maryland). The planning and policy recommendations contained in these reports are intended for use by the local government members of ESCAP and are the product of the community adaptation workshops referenced above, as well as literature reviews and research into best practices nationwide. These documents are intended to address and incorporate community concerns identified by ESCAP members as well as to highlight opportunities to elevate standards for future floodplain management and capital investment planning.

The guidance documents from the Environmental Finance Center and the Georgetown Climate Center present best practices for embedding climate risk assessment into planning processes at the municipal and county level. For capital improvement, these are cost-effective means of building community resilience to climate-related threats. For regulatory standards, these are comprehensive and innovative ways to enhance resilience to flooding due to sea level rise. Drawing on ESCAP member input, resilience literature, and case studies from other jurisdictions around the country, these documents offers a suite of planning and management options for Eastern Shore communities to consider as they seek to improve the climate-readiness of their existing assets, future capital investments, and the regulatory standards of their community.

V – Recommendations

The recommendations below are taken from the reports written by the Georgetown Climate Center and the University of Maryland Environmental Finance Center. Items listed in bold came as a direct result of input received by ESCAP members at community adaptation workshops, with the rest supporting these priority recommendations and providing planning tools for future use.

Georgetown Climate Center

Regulatory Options:

- **Expand regulatory floodplain**
- **Resilient design standards: enact three-foot freeboard requirements in all building codes; regulate Coastal A zones as V zones**
- Other resilient design standards: critical facilities, prohibitions on fill, size/height restrictions, setbacks
- Cumulative substantial improvement
- Restrictions on new subdivisions
- Critical Areas
- Transferrable Development Rights

Non-regulatory Options:

- Buyouts
- Conservation easements
- Hazard mitigation projects
- Post-disaster redevelopment plans
- Capital improvement planning and budgeting
- State standards
- Regional coordination on CRS

Environmental Finance Center

Conduct a resilience assessment for proposed capital improvement projects prior to making any major new capital investment

Develop a multi-year maintenance and upgrade plan for all capital assets which addresses future sea level projections

Address resilience in capital improvement planning by including criteria for scoring, and prioritizing projects that support local resilience goals

VI – Appendices

Appendix A – Georgetown Climate Center

Appendix B – UMD Environmental Finance Center

Appendix C – Eastern Shore Regional GIS Cooperative

GEORGETOWN CLIMATE CENTER
A Leading Resource for State and Federal Policy

HIGHER STANDARDS: Opportunities for Enhancing Flood Resilience in the Eastern Shore of Maryland

*Prepared by the Georgetown Climate Center**

January 2019

Contents

Summary

This report was prepared by the Georgetown Climate Center (GCC) for the Eastern Shore Climate Adaptation Partnership (ESCAP). ESCAP worked with the Eastern Shore Regional GIS Cooperative to assess sea-level-rise vulnerabilities in Eastern Shore communities and, with GCC and the University of Maryland Environmental Finance Center to identify legal and policy options for enhancing flood resilience in ESCAP jurisdictions. This report presents opportunities for enhancing flood resilience through local floodplain regulations, subdivision regulations, Critical Area programs, and other non-regulatory options including acquisitions, conservation easements, and public education and outreach programs. Case studies highlight how other jurisdictions have used similar approaches to enhance flood resilience. Example regulatory language is provided to help jurisdictions implement these approaches. The report also discusses legal and policy considerations, including the potential to earn points under the Community Rating System, to help jurisdictions assess the feasibility of different options.

1. Introduction

This report provides strategies that local governments in the Eastern Shore of Maryland can consider to help enhance resilience to future flooding as a result of sea-level rise. Maryland's Eastern Shore is one of the most vulnerable regions in the country to future sea-level rise. Sea-level rise (SLR) will inundate low-lying shorelines, exacerbate impacts from extreme events (such as hurricanes and nor'easters) and the erosion of subsiding lands, and will increase flood heights and the geographical extent of flooding.[1] This report was written to inform Eastern Shore jurisdictions that are working to address flood risk at the regional level through the Eastern Shore Climate Adaptation Partnership (ESCAP).

Changes in land-use policies and regulations will be required to address increasing flood risks in ESCAP jurisdictions from sea-level rise. However, the window of opportunity is closing to address these increasing risks through regulatory approaches. Even though it may be decades before Eastern Shore communities see the full brunt of impacts from sea-level rise along their shorelines, land-use policies take many years to implement and take effect. It can take many years to engage in a code update process, and it takes many more years for code changes to affect land-use patterns and the built environment. Newly enacted regulations will only affect new construction and substantial improvements, but many communities on the Eastern Shore have a lot of existing development that is already vulnerable to flood impacts. It may take decades to bring these structures into compliance as nonconformities are phased out, as structures are replaced or damaged.

To help local governments address these challenges, this report highlights higher regulatory standards that Eastern Shore jurisdictions can adopt, in combination with non-regulatory approaches, to reduce increasing flood risks posed by sea levels. Through regulatory approaches, local governments can ensure that fewer people and structures are in harm's way when impacts occur, that developers site and construct new structures to be more resilient to flooding and other impacts, and that redevelopment (particularly after damage from big storm events) is designed to account for increasing flood risks.

Not only will higher standards help communities reduce flood risks, these solutions can also help to counteract another mounting challenge in Eastern Shore communities: rising flood insurance rates. Recent reforms to the National Flood Insurance Program (NFIP) mean that flood insurance rates are on the rise for many homeowners and businesses. However, communities that implement more rigorous floodplain management practices can qualify for flood insurance premium discounts through a subprogram of the NFIP – the Community Rating System (CRS). Many ESCAP jurisdictions either currently participate in the CRS program or are interested in joining. Throughout this report, we highlight where adoption of certain approaches could help jurisdictions earn points under the CRS program. Reduced insurance rates can provide an important economic incentive for improving floodplain management practices and help to build the political support needed to make regulatory changes.

What are ESCAP jurisdictions already doing?

ESCAP jurisdictions have already adopted higher regulatory standards through their floodplain ordinances and building codes. Currently, all ESCAP jurisdictions only apply floodplain regulations to structures in the 100-year floodplain or 1-percent chance floodplain (i.e., A-zones, or areas that have a 1 percent chance of flooding in any given year based upon historic flood data). Many ESCAP jurisdictions have also adopted higher standards for "Coastal A-zone" (CAZ, or areas that experience wave heights of between 1.5 and 3 feet).

Some examples of higher standards that are already being enforced in ESCAP jurisdictions, include:

- The Town of Oxford enforces a 3-foot freeboard requirement and limits fill in the floodplain.
- Dorchester County enforces a 2-foot freeboard requirement, requires V-zone design standards in the CAZ, limits subgrade crawl spaces, and requires continuous footers for foundations through its building code.
- Cecil County enforces a 2-foot freeboard requirement and 3 feet or the 500-year elevation for critical facilities and uses V-zone design standards in the CAZ.

In addition to these higher standards, this report suggests additional climate-smart practices that ESCAP jurisdictions could adopt to further enhance flood resilience in Eastern Shore communities.

What more could be done in ESCAP jurisdictions?

This section describes both regulatory and non-regulatory strategies that could be implemented in ESCAP jurisdictions to ensure a comprehensive approach for enhancing flood resilience.

1. Expand regulatory floodplain

The Flood Insurance Rate Maps (FIRMs) that communities use to regulate development in flood-prone areas do not accurately account for changing flood risks as a result of sea-level rise because these maps are developed using only *historical* flood data. As shown by the flood vulnerability studies for the Eastern Shore of Maryland, SLR will increase flood elevations and the lateral extent of flooding in ESCAP communities. And because all of the ESCAP communities currently base floodplain regulations on FIRMs, existing and new development in floodplains will not be designed or sited to account for these increasing flood risks. Communities can counteract these deficiencies in the floodplain maps by expanding the lateral extent of the regulatory flood zone boundaries and requiring that more structures comply with local floodplain regulations. In addition to the 1-percent chance floodplain, FIRMs also designate the 500-year floodplain or 0.2-percent chance floodplain (i.e., areas with a 0.2 percent chance of flooding), and ESCAP jurisdictions now have SLR maps that could potentially be used for regulatory purposes (however, jurisdictions should carefully design their approach to avoid potential legal risks, discussed below).

Options:

- ***Use the 0.2-percent chance floodplain:*** For jurisdictions where the 0.2-percent chance floodplain is a good proxy for increasing flood risks as a result of sea-level rise, expanding floodplain regulations to the 0.2-percent chance floodplain may be the simplest approach. By doing so, new development and redevelopment of "substantially improved"[2] structures in the 0.2-percent chance floodplain will be required to comply with the design standards included in the local floodplain ordinance, such as requirements that structures be elevated or floodproofed (to the 0.2 percent chance flood elevation or other design flood elevation). This will ensure some additional measure of flood protection for structures that are at current risk of flooding and that will be subject to increased risks in the near-term as SLR increases flood heights and drives flooding further inland. To fully implement this option, however, Maryland communities may need to work with state agencies or FEMA to make flood elevation transects available for the 0.2-percent chance flood event. Although FIRMs designate the boundaries of the 0.2-percent chance floodplain, in most cases the maps do not establish flood elevations for the 0.2-percent chance flood event. This information often must be found in the Flood Insurance Study for the jurisdiction.

Baltimore, Maryland amended their floodplain ordinance (in 2014) to extend floodplain regulations to the 500-year floodplain and added new flood resilience measures. The ordinance:

- requires two feet of freeboard above the 1-percent chance flood elevation for new and redeveloped structures in the riverine floodplain (3 feet for critical facilities),
- designates a Flood Resilience Area in the coastal floodplain requiring structures to be elevated to two-feet above the highest identified elevation in the city's Flood Insurance Study (and 3 feet for critical facilities),
- requires elevation of plumbing and electrical systems, and
- prohibits new or substantially improved structures in the city's floodway.[3]

Cedar Falls, Iowa, in the aftermath of catastrophic flooding in 2008, amended its ordinance to extend floodplain regulations to the 0.2-percent chance floodplain, to prohibit new subdivisions in the 0.2-percent chance floodplain, and to restrict fill and prohibit letters of map revision in the 0.2-percent chance floodplain. The town also coupled these regulatory programs with a buyout program to purchase frequently flooded homes and to create green space to reduce flood risks.[4]

- ***Establish a community-wide floodplain:*** Some of the smaller municipalities in the Eastern Shore could consider applying floodplain regulations to the whole community. This approach better accounts for changing flood risks from sea-level rise, but also mitigates the "in vs. out" challenge posed by current floodplain regulations – where a line on a map determines whether you are "in" the floodplain (and therefore need to mitigate flood risks to the property) or "out" of the floodplain (and can build at grade, but may still face risk of flood damage during more intense storm events).

- ***Establish a "SLR Floodplain":*** Jurisdictions could also adopt SLR maps (e.g., 100-year floodplain in consideration of 2050 sea-level rise estimates) as their regulatory floodplain map (or even as an advisory option in the short-term). This approach may be a little more technically challenging because the jurisdiction will need to ensure that the maps are readily available to inform permitting officials, developers, and property owners. Elevation requirements will also need to be established for areas outside of FEMA mapped flood zones. Jurisdictions will also want to adopt findings to establish the public health, safety and welfare justifications for these higher standards (discussed below).

Durham, New Hampshire established an "Advisory Climate Change Risk Area" to identify waterfront areas vulnerable to future threats from climate change and projected sea-level rise (of up to 3.9 feet). The town recommends (but does not require) that new development and substantial improvements to existing structures elevate structures two feet above the highest grade of the site to account for future sea-level rise and to apply other resilient design best practices.[5]

Example ordinance language

- 500-year floodplain: The general requirements of this section apply to all development proposed within the 500-Year Floodplain. The five-hundred year flood is defined as the flood that has 0.2 percent chance of being equaled or in any given year. The five-hundred year floodplain (500-Year Floodplain) is defined as the areas subject to the 500-year (0.2 percent chance) flood that have a moderate risk of flooding and are located outside the community's delineated special flood hazard area. See also definitions of flood zones Zone B and Zone X (shaded).

- Flood Resilience Area: (1) The Flood Resilience Area comprises those lands within a tidal floodplain that: (i) due to hurricanes, tropical storms, and the rising Bay are subject to a 0.2 percent chance of flooding in any given year; and (ii) lie in areas where detailed study data are available. (2) The Flood Resilience Area appears: (i) on the Flood Insurance Rate Map, as that part of the tidal floodplain that is designated Zone X ("areas of 0.2 percent annual chance flood"); and (ii) in the Flood Insurance Study's {"Transect Data"}, under the column heading "0.2 percent annual chance"[6]

Considerations

CRS:

- Under ***Activity 412.a***, communities can receive up to 350 points for conducting new studies of flooding that meet FEMA standards, including in areas not mapped by FEMA or for areas where higher standards above FEMA requirements will be implemented.

- Under ***Activity 412.c***, communities can receive up to 60 points when a new study is reviewed by an independent entity (usually a state agency) for quality assurance.

- Under ***Activity 412.d***, communities can earn up to 200 points for developing and making accessible floodplain maps developed to one or more higher standards.

- Under ***Activity 442.a***, communities can receive up to 160 points for creating and maintaining map systems that improve a community's access to and quality of data and update flood and FIRM data.[7]

Legal:

In enacting new higher standards, particularly where the jurisdiction is expanding flood zone boundaries beyond FEMA delineated flood zones, local governments will want to add findings to their floodplain ordinance establishing the public purpose served by taking these actions. In particular, jurisdictions will need to ensure compliance with federal and state Constitutional substantive due process protections for property owners, where courts require that regulations be "rationally related to a legitimate public interest."[8] Courts are typically very deferential to local governments' policy decisions and only prohibit irrational decisionmaking. In order to insulate new regulations from legal challenges, local governments should explicitly state the rationales for amending the floodplain ordinance (i.e., the public safety, health and welfare purposes served by enacting regulations to address future impacts from SLR). Findings explain the public purposes served by the regulatory changes and anticipate legal challenges. In the event a law is challenged, the court will look to the findings in the ordinance to evaluate the reasonableness of the law and to determine whether the law is consistent with constitutional protections.

Local regulations that use established flood zones (i.e., 0.2-percent chance flood zones) to add protections for increased flood risks from SLR are likely to survive any substantive due process challenge. These areas have a risk of flooding as demonstrated by the floodplain models used by FEMA to develop Flood Insurance Studies and FIRMs for the jurisdiction. However, where a jurisdiction uses future sea-level rise maps that include areas outside of flood zones depicted on FIRMs, policymakers will want to articulate clear public policy rationales for warranting a more precautionary approach to regulating for future flood risks (as adopting sea-level rise maps could potentially impose floodplain regulations on structures that have no past history of flooding).

Maryland courts have said that local governments may consider the needs of the "reasonably foreseeable future."[9] The test articulated by the court seems to permit consideration of future conditions so long as they are sufficiently documented. Sea-level rise will clearly increase risks in tidally influenced floodplains, thus justifying increased regulations in FEMA mapped flood zones. This sea-level rise vulnerability study for Eastern Shore communities also helps to demonstrate the scientific basis and modeling that was completed to assess future flood risks in

ESCAP jurisdictions. Language from this study and other state studies (such as updated sea-level rise projections developed by the Scientific and Technical Working Group of the Maryland Climate Change Commission[10]) could be used to develop model findings to support adoption of regulations to enhance resilience of the built environment to future sea-level rise.

Example ordinance language

Findings:

- "Coastal systems are inherently dynamic; coastal landforms shift with changing conditions of water levels, waves, and winds. Changes to coastal landforms will increase risks to coastal development as sea levels rise and natural flood protections are eroded away or drown. Development in coastal high hazard areas[11] is especially vulnerable to increased impacts because it is subject to wind and wave damage from storm events, higher base flood elevations, and inundation.
- Under any scenario of increasing sea levels, development in coastal high hazard areas will increase the harm of development to coastal ecosystems as coastal resources are squeezed by rising seas on one side and coastal development on the other. Rising sea levels will also expose development in coastal high hazard areas to increased risk of damage, increased risk that damaged structures will cause collateral impacts to adjacent structures, and risks to rescue personnel servicing the development.[12]
- FEMA flood maps do not take into account any amount of sea level rise. They are predictions based on historic conditions. The draft FEMA maps are a result of sophisticated engineering modeling, but are based only on historic flood data. FEMA maps do not consider future increases in sea level and population growth and, therefore, may under-represent risk in some, if not all, areas.
- Tide gauge data for Maryland shows that the median rate of relative sea-level rise has accelerated by 0.15 to 0.18 mm/yr2 between 1969 and 2014.
- The latest sea level rise projections for Maryland from the University of Maryland Center for Environmental Science suggest a likely range of 0.8 to 1.6 feet of sea-level rise by 2050 and up to 5.2 feet by 2100.
- Rising seas will cause low-lying coastal areas to become inundated and may exacerbate erosion in some areas. Another key predicted impact of a warming climate is an increase in the frequency and intensity of coastal storms. Rising seas will drive storm surge further inland and may increase base flood elevations.

Purpose:

- To prevent loss or diminution of coastal resources and their natural beneficial functions that contribute to storm and flood damage prevention or pollution prevention, including by allowing them to migrate landward in response to relative sea level rise.
- To restrict or prohibit development in known hazard areas where the provision of public safety may be jeopardized or where public safety personnel may be endangered, thereby minimizing the need for rescue relief efforts associated with flooding and generally undertaken at the expense of the general public and to enable safe access to and from coastal homes and buildings for homeowners and emergency response personnel in order to effectively provide public safety services.
- To be fiscally responsible by minimizing expenditures of public funds for costly flood control and damage recovery projects.
- To help maintain a stable tax base by providing for the sound use and development of flood prone areas, which could minimize prolonged business or economic losses and interruptions caused by structural damage and/or flooding.
- To reduce or prevent public health emergencies resulting from surface and groundwater contamination from inundation of or damage to sewage disposal systems and storage areas for typical household hazardous substances.

- To maintain vegetative buffers to coastal wetlands and water bodies so as to reduce and/or eliminate runoff, and other non-point source discharges of pollutants in order to protect coastal water quality and public health for reasons including the propagation of fish and shellfish, and for recreational purposes.
- To preserve and enhance the community character and amenities of [jurisdiction] and to conserve natural conditions, wildlife and open space for the general welfare of the public and the natural environment.[13]

2. Increase flood resilient design standards

Resilient design techniques require that structures be sited, designed, and constructed to be more resilient to flooding impacts in the face of increasing flood risks (increased flood heights and more frequent flooding). Resilient design standards include freeboard[14] or floodproofing requirements[15] (for non-residential structures), building height and size limits, requirements to elevate mechanical and electrical utilities, setback requirements, among other standards. Stormwater management practices can also be used to reduce flood risks from rain-driven flooding and to reduce pollutant runoff into rivers, streams and the Chesapeake Bay. Resilient design practices can reduce flood damages for individual structures and reduce the impacts of flooding on the broader community. For example, where critical infrastructure is designed and sited to be more resilient to flooding, these facilities can maintain function and continue to provide services during emergencies.

Options:

Common resilient design standards that are often incorporated into local floodplain ordinances include the following options:

- ***Apply V-zone requirements in Coastal A-Zones:*** Many ESCAP jurisdictions have already implemented FEMA's recommended approach by requiring V-Zone design standards in Coastal A-Zones ("CAZ", areas where FEMA has delineated the Limit of Moderate Wave Action (LiMWA) on the community's FIRM) or by adopting updated building codes developed by the International Code Council.[16] This extends V-zone requirements to larger areas of the coast to ensure that structures are designed to withstand damage from wind and waves. Structures must be elevated on pilings or columns on open foundations. Other communities, like Kent County, have gone farther to limit new development in CAZ (see ordinance language below). For communities that have not yet applied V-Zone requirements to their Coastal A-Zones, this would be a simple first step for ensuring that development in the most flood-prone areas is designed to be resilient to wave action and storm surges.

Example language: Coastal high hazard areas (V-Zones and Coastal A Zones): (a) New development shall not be permitted in the Coastal High Hazard Area where the action of wind and waves, in addition to tidal flooding, is a factor unless the applicant demonstrates that: (i) No reasonable alternative exists outside the Coastal High Hazard Area; (ii) The encroachment into the Coastal High Hazard Area is the minimum necessary; (iii) The development will withstand the 100-year wind and water loads without damage; (iv) The development will not create an additional hazard to existing structures; and (v) Any natural dune system will not be disturbed. [17]

- ***Restrict critical facilities in flood hazard areas:*** ESCAP jurisdictions can restrict the building of new or redevelopment of critical facilities in the 1-percent chance or even 0.2-percent chance floodplain. This will ensure that assets that must remain operational during extreme weather events (hospitals, fire and police stations, etc.) are sited in locations where they are at less risk to flood impacts.

Example language: Construction of new or substantially improved critical facilities[18] shall be prohibited in the [special flood hazard area (SFHA, one hundred-year floodplain)]. Construction of new or substantially improved critical facilities shall be, to the extent possible, located outside the limits of the [five hundred-year floodplain]. Construction of new critical facilities may be permissible within the [five hundred-year floodplain], but outside of the [SFHA], if no feasible alternative site is available. Critical facilities constructed within the [500-year] shall have the lowest floor elevated [three] feet at or above the level of the base flood elevation [or one-foot above the approximate five hundred-year flood elevation] at the site, [whichever is greater]. Floodproofing and sealing measures must be taken to ensure that toxic substances will not be displaced by or released into floodwaters. Access routes elevated to or above the level of the base flood elevation shall be provided to all critical facilities to the extent possible."[19]

Definition of Critical Facilities: Buildings and other structures that are intended to remain operational in the event of extreme environmental loading from flood, wind, snow or earthquakes. [Note: See Maryland Building Performance Standards, Sec. 1602 and Table 1604.5.] Critical and essential facilities typically include hospitals, fire stations, police stations, storage of critical records, facilities that handle or store hazardous materials, and similar facilities.

- ***Require freeboard and floodproofing above base flood elevation:*** Currently, NFIP minimum standards require that residential structures be elevated to at or above the base flood elevation (BFE). Freeboard goes beyond the NFIP minimums by requiring that structures are elevated to a specified amount above the BFE – often called the "design flood elevation". Many ESCAP jurisdictions already require 2 to 3 feet of freeboard. For non-residential structures, structures can be required to be constructed with flood resistant materials or protected with sealant up to the design flood elevation (except Maryland state law prohibits dry floodproofing in tidal floodplains).[20] If jurisdictions extend floodplain regulations to the 0.2-percent chance floodplain, they could instead require structures to be elevated to the 0.2-percent chance flood level (or 0.2-percent chance plus freeboard) for new and substantially improved structures.

Example language: Flood Protection Elevation: The elevation of the regulatory flood shall be considered to be the 500-year (0.2%) flood elevation. Flood insurance policies and insurance rates may continue to be evaluated and established based on federal and state laws and regulations. For all other flood regulatory purposes, however, the regulatory elevation shall be the 500-year (0.2%) flood elevation.[21]

- ***Require elevation of mechanical and electrical equipment, where feasible:*** Elevating mechanical and electrical systems in structures (e.g., air conditioners, circuit breaker panels) can protect these expensive systems from damage during flood events and ensure that systems remain operational during flood events.[22]

Example language: Electrical, mechanical and plumbing systems: electric, plumbing, and mechanical systems and their attendant components and equipment, including heaters, furnaces, generators, heat pumps, air conditioners, distribution panels, toilets, showers, sinks, ductwork, and other permanent electrical, plumbing, or mechanical installations, are only permitted at or above the flood-protection elevation. Exceptions: This section does not apply to a system that is designed and installed, in accordance with ASCE 24, to prevent water from entering or accumulating within its components and to resist hydrostatic and hydrodynamic loads and stresses, including the effects of buoyancy, during the occurrence of flooding to the flood-protection elevation.[23] Definitions: "ASCE 24" means ASCE/SEI 24, "Flood Resistant Design and Construction" (American Society of Civil Engineers).

- ***Prohibit fill or require compensatory storage:*** The placement of fill impairs natural floodplain function, including the ability of the floodplain to manage floodwater, improve water quality and provide natural habitats. By prohibiting fill or requiring mitigation where fill in the floodplain is unavoidable, communities can reduce the negative effects to natural floodplain function.

Example language:[24]

- Prohibitions on Fill: Fill shall not be used to elevate structures within the special flood hazard area. (a) Minor grading, and the placement of minor quantities of fill, shall be permitted for landscaping and for drainage purposes under and around buildings and for support of parking slabs, pool decks, patios and walkways. (b) Site preparations shall not alter sand dunes unless an engineering analysis demonstrates that the potential for flood damage is not increased.
- Compensatory Storage: Fill within the area of special flood hazard shall result in no net loss of natural floodplain storage. The volume of the loss of floodwater storage due to filling in the SFHA shall be offset by providing an equal volume of flood storage by excavation or other compensatory measures at or adjacent to the development site.

- ***Restrict heights and sizes of structures in flood hazard areas***: ESCAP jurisdictions can also limit the size and height of new and redeveloped structures in the floodplain to reduce the size and density of development in harm's way. By limiting the size of structures in the floodplain, local governments can reduce the number of people in danger, reduce collateral damage from destroyed structures, and allow for structures to be more easily relocated as natural flood buffers erode and become inundated.[25] Jurisdictions should also consider exempting structures from height or other regulations, where the structure is being elevated to enhance flood resilience and where structural elevation will conflict with height restrictions in local codes.

New York City – After Hurricane Sandy, the City waived height and setback requirements to allow homeowners to comply with higher building elevation requirements adopted to ensure that flood-damaged structures could be rebuilt to higher standards to account for future flood risks from sea-level rise. The waivers were needed because height limits and setback requirements in the City's zoning law hindered the ability of some property owners to elevate structures after the storm.[26]

Considerations

CRS:

- ***Coastal A Zones***: Under ***Activity 432.k***, communities can earn up to 500 points for applying V-zone requirements in CAZs.[27]
- ***Critical Facilities***: Under ***Activity 432.f***, communities can earn up to 80 points for imposing higher regulatory standards to critical facilities.
- ***Freeboard:*** Under ***Activity 432.b***, communities can earn up to 500 points for establishing a 3 foot freeboard requirement and prohibiting fill.
- ***Fill Restrictions:*** Under ***Activity 432.a***, communities can earn up to 280 points for prohibiting fill in the floodplain.

3. Track cumulative substantial improvement

Floodplain ordinances typically require that nonconforming structures be brought into compliance with current regulations when an existing structure is "substantially improved" (including rebuilt after damage) where the cost of the improvement will exceed 50 percent of the structure's pre-construction market value. However, this allows structures to be improved or repaired, sometimes multiple times, without incorporating flood risk mitigation measures, when the damage or improvement to the structure is less than 50 percent of the value. By tracking cumulative substantial improvements (over a specified period, typically 10 years), jurisdictions can require that new mitigation requirements are incorporated when a structure is incrementally improved or repaired over a period of years, when the total cost of the improvement costs over the 10-year period exceed 50 percent of the structure's fair market value.

Considerations

CRS: Under ***Activity 432.d***, communities can earn up to 90 points for requiring compliance with floodplain requirements for cumulative substantial improvements.

Example language:[28]

- Substantial Damage (cumulative substantial damage): Damage of any origin sustained by a building or structure on two (2) or more separate occasions during a 10-year period for which the cumulative costs of restoring the building or structure to its before damaged condition would equal or exceed 50 percent of the market value of the building or structure before the damage occurred. Also used as "substantially damaged" structures.
- Substantial Improvement (cumulative substantial improvement): Any reconstructions, rehabilitations, additions or other improvements of a building or structure over a ten-year period, the cumulative costs of which equals or exceeds 50 percent of the market value of the building or structure before the start of construction of the improvement. The designated 10-year period begins at the date of the initial improvement to the structure. *Source: Adapted from Maryland Model Floodplain Ordinance*
- Substantial improvement: "Incremental improvements shall be considered substantial improvements if within a five year period, they cumulatively meet the definition of substantial improvement." The term "substantial improvement" includes structures that have incurred "substantial damage" or "repetitive loss," regardless of the actual repair work performed. The term "substantial improvement" does not, however, include either: costs of alterations or improvements whose express purpose is the mitigation of future storm damage, provided they do not exceed 50 percent of the market value of the structure over any one-year period; examples of such mitigation include the installation of storm shutters or shatterproof glass, strengthening of roof attachments, floors, or walls, and minor floodproofing.(1) Storm mitigation improvements may be made during the same year as other improvements, but the total cost of improvements of both types that are made over any one-year period may not exceed 50% of the market value of the structure. (2) The annual allowance for storm mitigation improvements is not applicable to any costs associated with a lateral or vertical addition to an existing structure or to the complete replacement of an existing structure.

4. Restrict or condition new subdivisions

Subdivision regulations can be used to limit new development in flood-prone areas and encourage developers to concentrate (or "cluster") development in areas of lower flood risk, helping to preserve open space and natural floodplains.[29] Subdivision permitting can be used to require clustering of development in specific areas of a subdivision, the permanent preservation of natural floodplains, and the elevation of roads and utilities that service new subdivisions.

Augusta, Georgia updated its comprehensive zoning ordinance in 2003 to allow conservation subdivisions (Section 28 D). The city created this ordinance to balance flood resilience and rural growth by limiting development in vulnerable floodplains, wetlands, and riparian habitats while permitting larger "cluster" developments. The subdivision regulations apply to projects with a minimum area of 20 acres and require the permanent protection of at least 40 percent of the overall acreage as green or open space. Additionally, approved conservation subdivisions must include a greenspace management plan and provide for the use, ownership, maintenance, and permanent protection of the newly-created green or open space (i.e., by deed restriction or conservation easement).

Considerations:

CRS: Under ***Activity 422.f*****,** communities can earn up to 250 points for adopting regulations setting aside flood-prone portions of new developments as open space. This credit recognizes a number of regulatory tools that encourage keeping areas of the floodplain undeveloped. Points are distributed on a sliding scale, where maximum credit is given when the entire floodplain in a subdivision is set aside as open space (250 points). Regulations that permit cluster development through subdivisions receive 25 points.

5. Incorporate resilience in Critical Area requirements

The Maryland the Chesapeake Bay Critical Area law, adopted in 1984 by the General Assembly, was the centerpiece of a suite of initiatives aimed at improving the water quality of the Chesapeake Bay; the Act was expended in 2002 to include the Atlantic Coastal Bays.[30] The goals of the Critical Area law are to minimize the negative impacts of new development on water quality, to conserve fish, wildlife and plant habitats, and to establish land use policies that accommodate development even though it may create adverse environmental impacts [31] The law is implemented on a cooperative basis, whereby local governments establish programs through local regulations but are subject to state-level oversight from the Critical Area Commission. The Act requires local governments to create and enforce a local regulatory program within the Critical Area (areas within 1,000 feet of mean high water) pursuant to state-developed criteria.[32] The city of Baltimore, 16 counties and 47 municipalities have each enacted a local Critical Area Program designed to comply with state requirements.

The Act required local governments to map three types of development areas based upon their use and intensity of development as they existed at the time of Program adoption. The three designations are: (1) Intensely Developed Areas (IDA) – areas identified by their concentrated development and little natural habitat. They are composed of at least 20 adjacent acres of primarily residential, commercial, industrial and institutional land uses. Additional development is not restricted, and improving water quality through the implementation of stormwater management practices is the main goal within IDAs. (2) Limited Development Areas (LDAs) – areas characterized by low to moderate amounts of development intensity with some natural areas and habitats. Development and redevelopment is restricted by a 15% lot coverage limit of a lot, parcel or subdivision, although that number may be higher for small grandfathered lots. Clearing of trees, forests and developed woodlands is also limited and mitigation required for clearing in order to maintain and increase forest cover, which provides a variety of environmental benefits. (3) Resource Conservation Areas (RCA) – areas characterized by natural environments and limited intensity of development. Dominant land uses include agriculture, forestry, wetlands, barren land and open space. The provisions of LDAs apply to RCAs, in addition to a one dwelling per 20 acre density requirement in order to minimize higher densities of development in these land resources that must be protected and enhanced. New commercial, industrial and institutional uses are prohibited in the RCA without growth allocation.

In addition to designation of the three Critical Areas described above, a minimum 100-foot Buffer to the shoreline is required and regulated. It may be expanded beyond 100 feet, for the presence of steep slopes, hydric soils, or for a new subdivision in the RCA. The Buffer is intended to be a naturally vegetated area that protects development and natural environments from the other, and to provide a final filtration opportunity before runoff reaches the Bay. A functioning Buffer may also stabilize the shoreline and therefore prevent or reduce erosion, increase habitat, improve water quality, and dampen storm surge impacts. Recognizing the significance of this valuable resource, development and disturbance in the Buffer are not permitted. In the limited circumstances in which it occurs, mitigation is required at varying ratios for specific activities. The mitigation is provided in the form of trees, shrubs and grasses and may help to reduce erosion, dissipate wave energy, capture some flood waters and reduce pollutants from entering the Bay. Some Buffers are mapped specifically as Buffer Modified Areas (BMAs, also known as BEAs and MBAs) in acknowledgement of existing shoreline development and reduced Buffer capacity. BMAs have varying setbacks and mitigation requirements that differ from traditional Buffer requirements.[33]

To address flood risks and enhance resiliency opportunities within their Critical Area programs, ESCAP jurisdictions could consider the following ideas:

- ***Evaluate current Critical Area designations and their vulnerability to coastal hazards*** – Currently, development is most limited within the RCA, thus directing growth towards the LDA and IDA. Those designations are based on growth patterns as they existed in 1985. A jurisdiction could consider evaluating these areas for coastal vulnerability and assess whether those vulnerabilities may justify a change in those designations. The legal mechanisms to do this type of analysis and change would need to be explored with the Critical Area Commission. This report makes no determination as to the feasibility of this suggestion.

- ***Enhance and revise Buffer requirements to address coastal vulnerability*** – As discussed above, the 100-foot Buffer is expanded under specific, defined circumstances in order to reduce erosion and protect both the environment and sensitive habitats and development. The Buffer is protected through very restricted development and enhanced through mitigation requirements. State regulations lay out very specific requirements related to development, mitigation and planting. A local jurisdiction has the authority to propose alternatives to those requirements if they can demonstrate they are at least as effective as the regulations and those requirements are approved by the Commission. A local jurisdiction may consider several innovative ways to utilize Buffer requirements for coastal resilience purposes including altered planting requirements that enhance resiliency of the Buffer and other ideas.

- ***Enhance or expand stormwater management practices*** – Currently, state regulations only necessitate that local jurisdictions require a 10% phosphorous reduction, and thus stormwater management practices, for development in the IDA. Flooding and water retention is a concern in all Critical Area designations, however, especially with increased flooding events and sea level rise. Local jurisdictions may consider expanding this requirement to designations other than the IDA in order to capture greater amounts of water and thus possibly reduce damage potential and nuisance flooding. In an effort to address their nuisance flooding problem, the Town of Oxford has already adopted and implemented this requirement in all designations.

- ***Increase flexibility of uses of Fee-In-Lieu*** – Local jurisdictions collect fee-in-lieus (FILs) of mitigation for a variety of activities when mitigation cannot be met on-site. Those monies are then meant to fund projects of the same type somewhere in the jurisdiction for which is was collected. For example, if Buffer mitigation cannot be planted on the impacted site, funds are collected to plant in the Buffer elsewhere. A jurisdiction might explore the idea of utilizing their collected FILs more creatively, in order to meet both the requirement for which it was collected as well as the growing need for funding of landscape-scale resiliency projects that could benefit the community rather than a single property. Additionally, a jurisdiction might consider partnering with others in order to implement multijurisdictional projects for shoreline enhancement. Neither of these ideas have been pursued yet, and the legal implications would need to be researched first. And as the previous examples specified, coordination and multiple levels of approval would follow. For example, where jurisdictions have updated the Critical Area program, FILs can be used for water-quality enhancement programs outside of the Critical Area boundaries, so long as they are located within a designated "Green Infrastructure Network."

The Critical Area Commission has been working closely with local jurisdictions on a volunteer basis to assess coastal vulnerabilities and resilience opportunities within their Critical Areas. The resulting information is then used to identify potential strategies to incorporate into programs. The Town of Oxford was the first jurisdiction that the Commission collaborated with for these purposes, resulting in several programmatic changes after a community assessment, as well as a coastal hazards risk and opportunity mapping tool and a Coastal Resilience Planning Guide for Critical Area planners. Other towns have since completed similar processes to identify potential next steps, including expansion of Buffer Modified Areas in developed areas that are not vulnerable to SLR and storm surge, or simply having conversations regarding other enhancement opportunities such as creating open space or implementing a tree canopy program. The Commission has also made available illustrations that demonstrate the importance of a planted Buffer for resilience purposes, and planting plans for both hardened and natural shorelines.

6. Establish a Transferable Development Rights (TDR) program

A Transferable Development Rights (TDR) programs could be developed to enable landowners in high-risk areas to sell their development rights to support development in higher ground areas, with less flood risk. To establish a TDR program, ESCAP jurisdictions would need to designate two areas (1) "sending areas" that are a priority for preservation as natural areas or floodplains (i.e., areas with current or future high-flood risk, valuable natural resources, and areas with high potential for future development or subdivision) and (2) "receiving areas" that are appropriate for additional growth (i.e., higher ground areas with lower flood risk and existing supporting infrastructure and services). The jurisdiction would then need to adopt a TDR program allowing landowners in "sending areas" to sever and sell their development rights, where they agree to preserve flood-prone lands as undeveloped open space. Developers in "receiving areas" can then use those development rights to increase densities and intensities of use.[34] In this way, TDR programs create economic incentives for the preservation of flood-prone areas by creating a market for the sale of development rights of vulnerable lands, which can then be used to build additional densities or sometimes more intense uses in "higher ground," more developed areas. To calibrate the market and create needed incentives for the purchase and sale of development rights, jurisdictions often need to amend zoning ordinances to limit allowable densities in both sending and receiving areas.

A TDR program could also be aligned with a jurisdiction's local Critical Area program. The RCA has a density limit of 1 dwelling per 20 acres; this restriction could be used as a way to both preserve land in perpetuity and to encourage the purchase of development rights to allow for greater development. There is already existing authority within regulation to encourage local jurisdictions to develop TDR programs in the RCA.

Alternatively, a Purchase Development Right (PDR) program could be created to designate "sending areas" where the purchase of development rights is allowed to help ensure that undeveloped natural resource areas remain undeveloped. Unlike a TDR program, no "receiving areas" are needed and no additional growth is contemplated in more developed areas.

Pine Barrens TDR Program – A successful TDR program was created in a more rural region of Long Island New York to protect water quality and the ecologically sensitive pine barrens ecosystem. The TDR program was created in Suffolk County and spans three townships (Brookhaven, Riverhead, and Southampton). The program has preserved 60,000 acres of habitat and open space and directed new development to "compatible growth areas" around the townships that have existing development, infrastructure and services. The Pine Barren program, however, is unique in that it was formed by state legislation which created an independent Commission charged with developing and implementing a Comprehensive Land Use Plan that designates preservation areas ("sending areas") and growth areas ("receiving areas"). Elected officials from each town are represented on the Commission board.[35]

Single jurisdiction TDR programs have also successfully been used to preserve agricultural lands in ***Montgomery County, Maryland*** and to limit development on highly erosive lots without access to roadways or septic in ***Malibu, California***.[36]

Considerations:

CRS:

- Under ***Activity 422.e***, jurisdictions can earn up to 70 points for regulations that direct development away from floodplains (such as transfers of development rights or density bonuses), credit is determined based upon the amount of the regulatory floodplain covered by open space incentives.

- Under ***Activity 422.a***, up to 1,450 points can be earned for open space preservation within the regulatory floodplain. Land must be permanently preserved as open space by policy or deed restriction in writing, and the credits earned are impact-adjusted based upon the amount of open space that is preserved in the regulatory floodplain. Active farmland may not be creditable. Additional credits are earned if the land is subject to a deed restriction that prohibits new buildings (422.b) or restored to enhance natural floodplain function (422.c). Low-density zoning restrictions can also be credited under Activity 422.f

Administrative: It can be difficult to create the needed market incentives for the purchase and sale of development rights in more rural communities, where there is not a lot of development pressure and where there is not a strong market for additional density or more intense uses. TDR programs have been most successful in metropolitan regions where strong market incentives can be created for preserving land in more rural regions by driving growth to urban centers surrounding transit and other services, such as in Montgomery County.

Political: Because TDR programs require zoning changes to create the needed market incentives for the purchase of development credits, such programs can be politically challenging to implement because residents often object to changes in allowable densities. Additionally, to create the appropriate incentives, Eastern Shore communities may need to create a regional TDR program to shift development to appropriate "high-ground" urban centers. This may also be politically challenging because one jurisdiction may lose the tax base generated by shifting development to a neighboring jurisdiction. Revenue sharing structures could be considered to mitigate concerns about lost tax base.

7. Non-regulatory options

Regulatory approaches for enhancing flood resilience can also be aligned with non-regulatory programs and policies, including incorporating flood resilience into local plans and capital investment decisions. The following strategies could be used to supplement regulatory approaches in ESCAP communities:

- ***Identify funding sources and prioritize high-risk areas for buyouts:*** ESCAP jurisdictions can identify contiguous parcels that are a priority for acquisition and restoration. Priority properties could include: repetitive loss structures, properties that could provide space for migration of important ecosystems, and properties that could be restored to enhance natural flood risk reduction, open space, or habitats. Land-use or hazard-mitigation plans could be used to analyze and prioritize properties for potential acquisition. Doing so will help jurisdictions direct resources (such as FEMA mitigation grants) when funding becomes available. Jurisdictions could also consider different incentives (and find appropriate funding sources) that could be offered to buy out contiguous properties and to encourage owners in high-risk areas to opt for buyouts when structures are damaged during flood events. By buying out continuous properties, local governments can restore lands to maximize flood protection for upland developments and discontinue services to those areas to increase cost savings. Where jurisdictions have properties that are subject to tax liens, rather than sell properties, jurisdictions could deed restrict properties in high flood risk areas and permanently conserve these properties as open space (while earning CRS credits).

Charlotte-Mecklenburg Stormwater Services, North Carolina is using stormwater utility fees with federal mitigation funding (FEMA mitigation grants) to acquire repetitive loss structures and restore natural floodplain function. These buyouts help reduce flood losses, improve water quality, improve habitats, and provide recreational amenities for residents. The Service estimates some of the buyouts of larger apartment complexes have helped to avoid future losses that would have been 400 percent higher than the costs of the buyouts.[37] A "quick buy" program was created to facilitate buyouts of structures in the immediate aftermath of damage from destructive flooding; and an "orphan" property program was created to use stormwater fees to buy out properties that do not meet federal grant criteria but that are adjacent to other properties that are being bought out with federal funds. The goal of the orphan property buyout program is to encourage the last homeowners living in a high-risk neighborhood to move so that the site can be restored to its natural floodplain function and services can be discontinued to the area, increasing the cost savings to the City and County.[38]

The New York Governor's Office of Storm Recovery designated "Enhanced Buyout Areas" after Hurricane Sandy – areas that were substantially damaged by the storm and that are most susceptible to future flood risks. In these areas the state offered property owners 5 to 15 percent above fair market value for their property to encourage these owners to opt for a buyout and to encourage whole community buyouts so that bought out lands could be restored to enhance flood-risk reduction benefits for upland neighborhoods and services could be discontinued in those areas. The state also offered incentives for property owners that resettled in the same county to minimize the financial implications of buyouts on local governments.[39]

- ***Acquire conservation easements***: ESCAP jurisdictions can similarly identify parcels that are a priority for conservation easements (e.g., agricultural lands that have high potential for sale/subdivision where conservation easements can diversify income stream and help landowners preserve floodplain to reduce flood risks to farmland and adjacent properties). Agricultural easements can also be used to enhance flood resilience by including easement provisions that prohibit development of any structures or accessory structures in the floodplain. A number of state easement purchase programs can be used to purchase conservation easements, including the Maryland Agricultural Land Preservation Foundation (MALPF)[40] and the Maryland Rural Legacy Program.[41] Alternatively, under the Maryland Environmental Trust (MET), easements may also be donated in exchange for income tax or property tax credits.[42] ESCAP jurisdictions could also explore conservation easements to preserve portions of properties with forested floodplains and intact hydrology systems in exchange for property tax credits offered under these programs.

North Carolina used conservation easements as part of a larger voluntary buyout program in the aftermath of Hurricane Floyd in 1999, in which the state suffered over $1 billion in losses to crops, livestock, and farm buildings. Under the North Carolina Swine Floodplain Buyout Program,[43] the state invested more than $18 million in purchasing conservation easements on 43 farms in the 100-year floodplain, spanning 1,218 acres and 106 waste lagoons. Using funds from the state's Clean Water Management Trust Fund, which provides grant assistance to local governments and nonprofits for the protection of surface waters, the state purchased developmental rights from farmers, placing easements on the land by banning swine farming and lagoons. The program placed a permanent conservation easement on lands containing hog facilities, but permitted continued uses of the property for low-intensity agricultural use, including pasture-based beef production and vegetable farming.[44] Within the easement area, the program prohibited non-agricultural development, the use of feedlots, and the depositing of swine waste in the easement area. Locations for the storage of hazardous materials and mixing areas were restricted in order to minimize the potential for water pollution from leaks, spills, and flooding. The program also required the implementation of a soil and water conservation plan for the area within the 100-year floodplain; a permanent, 50-foot forested riparian buffer on perennial and intermittent streams; and a 35-foot grassed filter strip on all field ditches. In comparison with Hurricane Floyd, which killed over 21,000 hogs and flooded 55 waste lagoons in 1999, the damage resulting from Hurricane Matthew in 2016 was a fraction of that of Hurricane Floyd, with just under 3,000 hogs killed and 14 waste lagoons flooded, due in large part to a successful state buyout program that has continued in the aftermath of Hurricane Florence in 2018.[45]

- ***Fund hazard mitigation projects:*** ESCAP jurisdictions can incorporate consideration of sea-level rise in local hazard mitigation plans and use these planning projects to identify priority mitigation projects for implementation with FEMA funding (including funding from the Pre-Disaster Mitigation (PDM) and Hazard Mitigation Grant Program (HMGP)) in the aftermath of a disaster. Mitigation projects can include structural elevation and reconstruction-mitigation grants, or buyouts and acquisitions.

Gloucester County, Virginia manages a flood risk mitigation program that works with the state and federal departments of emergency management to both buy out and acquire and elevate homes that have experienced (or could experience) damage from flooding and storms.[46] Given the high level of interest in this voluntary program, the county ranks eligible properties according to criteria including benefits to wetlands, creation of open space, and flood risk reduction (e.g., properties that have suffered repetitive losses, residential properties, and properties on previously acquired lots or with access to natural resources, etc.). For acquisitions, the County also requires that all properties comply with an "Open Space Hazard Mitigation Management Plan" (Open Space HMP).[47] Bought-out properties must meet the Open Space HMP's requirements to preserve open space and mitigate flood risk to life and property.[48] The Open Space HMP must be consistent with County's Hazard Mitigation Program, Floodplain Ordinance, and Comprehensive Plan.[49]

- ***Develop a post-disaster redevelopment plan***: Post-disaster redevelopment plans guide how a community will recover and rebuild after a major disaster. Redevelopment plans can be integrated with hazard mitigation planning and local comprehensive planning. The State of Florida requires post-disaster redevelopment planning and provides best practices and guidance for developing redevelopment plans.[50] ESCAP jurisdictions or the ESCAP region could develop a post-disaster redevelopment plan to identify opportunities to enhance resilience during disaster recovery efforts and to prioritize use of disaster recovery funding.

> ***Sarasota County, Florida*** developed a Post-Disaster Redevelopment Plan to guide long-term recovery and redevelopment decisions after a flood or other natural disaster. The Plan was designed to align with other relevant plans and codes including the County's local comprehensive plan, hazard mitigation, and transportation plan. The Plan identified recovery strategies based upon a vulnerability assessment looking at critical facilities and populations at-risk of impacts from natural hazards. The Plan also evaluated how flood risks will change given sea-level-rise projections for the region. Finally, the Plan includes both pre- and post-disaster action items for four core sectors: housing and planning; infrastructure, public facilities and public safety; economic redevelopment; and environmental restoration. Action items and milestones are also provided based upon different stages of response and recovery include pre-disaster coordination, post-disaster activation, emergency response, short-term recovery, and long-term redevelopment.[51]

- ***Consider sea-level rise in capital investments and budgeting:*** Maryland local governments have been delegated authority to administer their own finances. Capital budgeting and planning requirements are typically specified in local statutes or provisions in the local charter.[52] Maryland jurisdictions must have capital budgets approved by the local elected bodies, but these budgets can be amended by a vote of the elected officials. There are no state law requirements for capital improvement planning, but local codes or charters may require development of a capital improvement plan to set spending priorities over a period of years (typically 5 to 6 years).[53] ESCAP jurisdictions could align capital investment and budgeting to advance flood resilience projects (e.g., setting aside funds to acquire repetitive loss structures, restore wetlands and floodplains to enhance natural flood risk reduction, or to direct investments in higher ground "receiving areas" where jurisdictions want to drive economic development and growth out of harm's way). ESCAP jurisdictions could also develop routine procedures to examine the potential for flood damages to community assets, such as roads, bridges, culverts, water and sewer lines during regular maintenance and use these assessments in capital improvement planning processes to prioritize high-risk assets for future resilience investments. Opportunities to incorporate adaptation in capital planning and budgeting is explored in more detail in the accompanying report contributed by the University of Maryland Environmental Finance Center.

- ***Encourage better alignment of State minimum floodplain standards***: ESCAP jurisdictions could also encourage the State to update and align state minimum floodplain development standards for both coastal and riverine floodplains. Maryland has a one-foot freeboard requirement for its non-tidal floodplains, meaning that structures in these areas must be elevated one foot above the base flood elevation under state law. However, state law does not require freeboard in tidal floodplains—regulation of tidal floodplains is delegated to local governments who have sole discretion to require freeboard.[54] By aligning state law, local governments can reduce the complexity of floodplain regulations and a state-imposed freeboard requirement will provide political cover to local jurisdictions.

- ***Coordinate Regionally on Community Rating System (CRS) activities:*** ESCAP jurisdictions participating in the Community Rating System can further enhance flood resilience in their communities by collaborating with other CRS communities to pursue CRS activities at a regional scale. Pathways for regional coordination around CRS include developing a multi-jurisdictional regional Program for Public Information (PPI) to help ESCAP members coordinate messaging around flood risk and resilience, which will increase the CRS credits that ESCAP jurisdiction earn for local community outreach activities. ESCAP members could also adopt a regional coordinator – or "circuit rider" – approach for providing technical assistance to local governments on CRS participation. In sharing information and other resources around the CRS, particularly in areas with similar flood hazards, ESCAP jurisdictions could enhance opportunities to maximize the CRS credits earned in individual jurisdictions while also enhancing regional flood resilience.

The Cape Cod Cooperative Extension[55] in Barnstable County, MA provides resources on floodplain management to fifteen towns on the Cape Cod peninsula. With funding assistance from the Woods Hole Sea Grant, in 2015 the county hired a regional CRS coordinator to provide both technical and administrative assistance to towns entering or continuing to participate in the CRS. By Spring 2018, nine towns in Barnstable County were participating in the CRS; three towns were waiting on pending applications, and the remaining four towns had expressed interest in joining. In addition to leading the development of regional CRS projects and identifying opportunities for garnering credit for CRS activities, the regional coordinator was able to translate for local elected officials the CRS credits earned into dollars saved, thereby helping to generated buy-in from elected officials on CRS participation.

The Atlantic/Cape May Coastal Coalition in southeast New Jersey recently formed a 13-member multi-jurisdiction Program for Public Information (PPI), one of the largest in the country. Initially formed in the aftermath of Hurricane Sandy to focus on hurricane recovery efforts, the Coalition sought to collaborate on the PPI as part of a larger strategy to increase the region's flood resilience and to enhance an already-high level of participation in the CRS among jurisdictions in the region. Thirteen municipal members formed a PPI committee to share best practices, identify common outreach topics and flood risk messaging, and catalogue outreach projects. The Regional PPI helped the jurisdictions cultivate partnerships with private entities in the region, like a local utility, that supported the initiative by including flood resilience outreach materials with utility mailers.

Conclusion

Although ESCAP jurisdictions have taken steps to reduce flood risks in their communities, this region will see increasing flood risks with rising sea levels. Additional steps can be taken to reduce risks to people, properties, and local economies. This report includes legal and policy approaches for enhancing flood resilience that were identified as priority options for consideration by ESCAP members, including options for: expanding the regulatory floodplain; increasing flood resilient design standards; tracking cumulative substantial improvements; establishing a TDR program; integrating resilience in Critical Area programs; funding buyouts, conservation easements, and hazard mitigation projects; developing a post-disaster redevelopment plan; considering sea-level rise in capital investments and budgeting; encouraging better alignment of state minimum floodplain standards; and coordinating regionally on CRS activities. This list highlights feasible strategies for reducing flood risks that could be adopted in ESCAP communities to begin to prepare for future sea-level

ENDNOTES

* This report was written by staff of the Georgetown Climate Center including the Center's adaptation program director, Jessica Grannis; institute associate, Katie Spidalieri, and climate fellow at Georgetown's Harrison Institute for Public Law, Jennifer Li. Research and editorial support were provided by Kate McCormick, GCC law fellow, and Georgetown law students, Julius Pak and Nicholas Malin.

1 *See* Eastern Shore Flood vulnerability studies, completed by Eastern Shore Regional GIS Cooperative director Dr. Michael Scott.

2 "Substantially improved" includes both improvement and repair of damage where the cost to improve exceeds 50 percent of the structure's market value. *See e.g.* Anne Arundel County, Md., Code, art. 16, § 1-101 (90) (2005).

3 Baltimore, Md. Municipal Code art. 7, §3-1.

4 https://www.georgetownclimate.org/files/report/Case%20Studies%20in%20Floodplain%20Regulation%206-3-final.pdf

5 Town of Durham, Article XV Flood Hazard Overlay District, Sec. 175-83.C https://www.ci.durham.nh.us/sites/default/files/fileattachments/planning/page/21491/article_xv.pdf

6 Adapted from Baltimore's Floodplain Ordinance at Sec. 2.2(g).

7 Additional map data can include the following to add up to the maximum 160 points: 20 points for showing SFHA boundaries, corporate limits, streets and parcel or lot boundaries; 26 points for a GIS layer that shows buildings/building footprints and new construction information; 12 points for showing floodways or coastal high hazard areas; 12 points for showing base flood elevations; up to 10 points for including FIRM zone attributes; 10 points for showing the 500-year floodplain elevations or boundaries; up to 12 points for displaying other hazards, such as subsidence or soils unsuitable for septic fields; 8-10 points for including GIS contour lines; 6 points for including updated floodplain data in the tax assessment database; 6 points for overlays for all FIRMS in effect after the date of a community's application to join the CRS; 8 points for other overlays or data used to support regulation or mitigation programs; 14 points for areas with natural floodplain functions, such as wetlands and riparian habitats; and 14 points for including building elevation data.

8 This standard derives from judicial interpretations of state and federal constitutional clauses that prohibit governments from "depriv[ing] anyone of life, liberty, or property without due process of law." U.S. CONST. amend XIV, § 1; *see also* Beverly Bank v. Illinois Dep't of Transp., 579 N.E.2d 815, 821 (Ill. 1991). The test, as originally articulated by the Supreme Court of the United States, requires that ordinances must have "substantial relation to public health, safety, morals or general welfare." Village of Euclid v. Ambler Realty, Co., 272 U.S. at 395 (1926). Although the precise test may vary in name, the basic substance of a court's analysis is essentially the same across jurisdictions. *See generally* Ziegler, RATHKOPF'S THE LAW OF ZONING AND PLANNING § 3:17 (4th ed. 2010).

9 In *Jacobs v. County Board of Appeals for Baltimore County*, the court stated "it is universally recognized, in those jurisdictions where zoning has been established, that zoning is not static, and the zoning authorities, either in adopting a comprehensive zoning plan or in granting a reclassification, may take into consideration needs of the reasonably foreseeable future." 198 A.2d 900, 902 (Md.1964). Jacobs, 198 A.2d 900, 902 (Md. 1964).

10 The Maryland Commission on Climate Change Act of 2015 requires updated sea-level rise projections and maps of areas that will be vulnerable to flooding for Maryland's coastal areas every five years. Md. Code, Environment, § 2-1306. Updated projections were published in 2018. University of Maryland, Center for Environmental Science, Sea-Level Rise Projections for Maryland 2018, available at: https://www.umces.edu/sea-level-rise-projections

11 *See* definition in Anne Arundel County Ordinance § 16-2-103 for "coastal high hazard areas [include] coastal floodplains, zones V9, V10, V11, and V12 with an elevation number (EL-) on the flood insurance rate maps and subject to inundation by high-velocity waters and wave action based on a detailed wave height study." Anne Arundel County, Md., Code art. 16, § 2-103 (2005) *available at* http://www.amlegal.com/nxt/gateway.dll/Maryland/annearundelco_md/annearundelcountycode2005?f=templates$fn=default.htm$3.0$vid=amlegal:annearundelco_md (last visited Sept. 29, 2011).

12 Adapted from 06-096 Me. Code R. § 355(1) Coastal Sand Dune Rules (2004) *available at* http://www.maine.gov/sos/cec/rules/06/096/096c355.doc (last visited Sept. 28, 2011).

13 Adapted from Sea Grant Model Bylaw, at 22-23, art. 2, available at http://www.floods.org/ace-files/documentlibrary/State_Local%20Resources%20and%20Tools/Best%20Practices/Sea_Grant_Coastal_Floodplain_Bylaw_Model_12_14_09.pdf.

14 FEMA defines freeboard as: "Freeboard is a factor of safety usually expressed in feet above a flood level for purposes of floodplain management. "Freeboard" tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed. Freeboard is not required by NFIP standards, but communities are encouraged to adopt at least a one-foot freeboard to account for the one-foot rise built into the concept of designating a floodway and the encroachment requirements where floodways have not been designated. Freeboard results in significantly lower flood insurance rates due to lower flood risk. https://www.fema.gov/freeboard.

[15] FEMA defines floodproofing as: "Any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents. The National Flood Insurance Program (NFIP) allows a new or substantially improved non-residential building in an A Zone (Zone A, AE, A1-30, AR, AO or AH) to have a lowest floor below the Base Flood Elevation (BFE), provided that the design and methods of construction have been certified by a registered professional engineer or architect as being dry floodproofed in accordance with established criteria." https://www.fema.gov/floodproofing.

[16] Observations from previous storms have shown that structures located in the CAZ, inland of the V-zone, experience significant damage from storm surge from moderate wave heights of 1.5 to 3 feet. Therefore, FEMA recommends that communities extend V-zone regulations to these areas. FEMA defines coastal A-zones as areas of the SFHAs seaward of the limit of moderate wave action ("LiMWA"). FEMA, *Homeowner's Guide to Retrofitting: Six Ways to Protect Your Home from Flooding* at 3-1; 3.2.4 (2d ed. Dec. 2009), *available at* http://www.fema.gov/library/viewRecord.do?id=1420. The 2015 version of the International Building Codes also require V-zone design standards in Coastal A-zones. Therefore, CAZ requirements can be enforced by adopting the 2015 model building codes developed by the International Code Council. https://www.fema.gov/media-library-data/1446030649587-10e447987a16b1313253361ed0871a46/2015_Icodes_Flood_Provisions_508_v2.pdf

[17] Adapted from Kent County, Maryland Code, Floodplain Management Chapter, Section 182-11.

[18] Critical facility means "Public utility building or facility means a structure, use or land designed and maintained as a public or private utility or service facility which qualifies as a public service corporation under [state code definition] for the provision of services like gas, electric, telephone, radio, television, water, and sewer or a municipal utility or service facility." Town of Chatham, Mass., Protective Bylaw, § II(B)(82) (1998) *available at* http://chathamma.virtualtownhall.net/Public_documents/chathamma_CommDev/Zbylaw.pdf (last visited Sept. 29, 2011).

Maryland's state model ordinance defines as: Critical and Essential Facilities: Buildings and other structures that are intended to remain operational in the event of extreme environmental loading from flood, wind, snow or earthquakes. [Note: See Maryland Building Performance Standards, Sec. 1602 and Table 1604.5.] Critical and essential facilities typically include hospitals, fire stations, police stations, storage of critical records, facilities that handle or store hazardous materials, and similar facilities.

[19] *Practice Notes:* Many ESCAP jurisdictions currently prohibit construction of critical facilities in coastal high hazard areas. This restriction could be extended to Coastal A-zones, the 1-percent chance floodplain or even the 0.2-percent chance floodplain, whatever is most feasible in that community. In order to use this provision the ordinance should define "critical facility", "special flood hazard area" and "500-year flood elevation". Policymakers may need to provide instruction on how 500-year flood elevations are to be calculated. Policymakers should consider how these provisions may affect compliance with American with Disabilities Act and historic preservation requirements. Public facilities must be accessible to persons with disabilities and where critical public facilities need to be elevated to comply with higher regulatory standards, maintaining access may require installation of ramps and/or elevators, which may increase the costs of retrofit, design, and construction. Policymakers should also consider the effect on existing facilities in the areas where the higher regulatory standards will apply.

[20] Maryland delegated authority to local governments to participate in the National Flood Insurance Program by enacting the Flood Hazard Management Act of 1976, Md. Envir Code §§ 5-801 *et seq.* (1995). The Act requires local governments to develop flood management plans and implementing regulations for the 100-year floodplain. *Id.* at § 5-803(d)(1)-(g)(1). The Maryland Department of Environment (MDE) has regulatory authority over non-tidal wetlands, defined to include the 100-year floodplain for non-tidal waters. Md. Code Regs. 26.17.04.01. Within the non-tidal floodplain, MDE requires 1-foot of freeboard. *Id.* at. 26.17.04.07. However, because authority to regulated tidal floodplains has been delegated to local governments, state agencies cannot impose a freeboard requirement in tidal floodplains without additional authority from the state legislature. Md. *Comprehensive Strategy,* ch. 5 at 13.

[21] Adapted from Cedar Falls Zoning Ordinance, Sec. 29-156 (definition of "floodway fringe") (Jan. 31, 2018).

[22] FEMA, Homeowner's Guide to Retrofitting: Six Ways to Protect Your Home from Flooding. https://www.fema.gov/media-library-data/1404150306122-7fa382623802512d66e4835281547fd0/FEMA_P312_Chap_9.pdf

[23] Adapted from Baltimore Natural Resource Code, Art. 7, Div. 1 at Sec. 3-10.

[24] *See* Maryland Model Floodplain Ordinance and Assoc. of State Floodplain Mngrs, Higher Standards Reference Guide at 4 (March 2013), https://www.floods.org/ace-files/documentlibrary/committees/3-13_Higher_Standards_in_Floodplain_Management2.pdf.

[25] See NOAA Planning Guide at 65.

[26] For a discussion of the flood resilience provisions adopted to inform recovery efforts after Sandy, see *New York City's Risk Landscape: A Guide to Natural Hazard Mitigation*, Chapter 4.3 Flooding at pp. 79-81, *available at* https://www1.nyc.gov/assets/em/downloads/pdf/hazard_mitigation/nycs_risk_landscape_chapter_4.3_flooding.pdf

[27] For communities with a coastal floodplain, the extension of V zone regulations and/or enclosure limitations into a designated Coastal A Zone (CAZ) is rewarded. To receive credit, communities must first designate a Coastal A Zone (a coastal SFHA not mapped as a Zone V) as a zone subject to wave action. The activity provides 500 points if all V Zone requirements are applied to buildings in the CAZ, plus an additional 150 points if regulations prohibit breakaway walls and enclosures greater than 299 square feet below base flood elevation. *CRS Manual* 430-32—432-35.

[28] Adapted from Fort Myers Beach, Fla., Land Development Code, ch. 6, § 405 (2008).

[29] Local governments in Maryland are authorized to adopt subdivision regulations under the state enabling statute, which permits the use of subdivision regulations to control development and manage growth, reduce erosion, and increase flood protection. By clustering development in upland areas, governments can increase the resiliency of development while allowing for full economic use of property, thereby reducing the potential for takings challenges. Some jurisdictions have already developed clustered development programs to promote other land-use objectives; these programs could be used as models to implement a program to address sea-level rise.

[30] Md. Code Ann., Nat. Res. § 8-1801

[31] Md. Code Ann., Nat. Res. § 8-1808(b)

[32] Md. Code Ann., Nat. Res. § 8-1807.1801. *See* also Md. Dep't of Natural Res., Critical Area Commission homepage, http://www.dnr.state.md.us/criticalarea/index.asp (last visited Sept. 28 2011).

[33] MD. CODE REGS. 27.01.09.01 §E(3) (2011).

[34] Maryland Department of Planning, *Transfer of Development Rights Committee Report* (April 2016), http://www.planning.maryland.gov/Pages/OurWork/envr-planning/transfer-dev-rights.aspx

[35] https://pb.state.ny.us/our-work/credit-program-tdr/program-overview/

[36] For a more detailed discussion of these and other TDR programs see Georgetown Climate Center, *Sea Level Rise Adaptation Toolkit* at pp. 57-59 (Oct. 2011), https://www.georgetownclimate.org/files/report/Adaptation_Tool_Kit_SLR.pdf.

[37] https://charlottenc.gov/StormWater/Projects/Pages/ChantillyEcologicalSanctuaryatBriarCreek.aspx

[38] https://charlottenc.gov/StormWater/Flooding/Pages/FloodplainBuyoutProgram.aspx

[39] New York Governor's Office of Storm Recovery, *NY Rising Buyout and Acquisition Program Policy Manual* at 15 (April, 2015 version 3), https://stormrecovery.ny.gov/sites/default/files/uploads/po_20150415_buyout_and_acquisition_policy_manual_final_v3.pdf

[40] Established in 1977, the Maryland Agricultural Land Protection Foundation (MALPF**)** remains one of the most prominent *purchase of agricultural conservation easement* (PACE) programs (also known as *purchase of development rights*, or PDR) in the country. Using public funds to purchase development rights on parcels of land, PACE programs like MALPF create conservation easements on the land even while the land remains in private ownership. By 2016, MALPF has spent over $682 million on 2,218 easements across more than 300,000 acres of farmland in Maryland. In addition to the state PACE program, local government programs have also been successfully used to preserve farmland and discourage sprawl. For example, since its creation in 2006, Cecil County's local PDR program -- modeled after the MALPF program and funded by the County Recordation Tax -- has protected 12 farms on 997 acres. *See* Maryland Agricultural Land Preservation Foundation, https://mda.maryland.gov/malpf/Pages/Overview.aspx. *See also* Cecil Land Trust, https://www.cecillandtrust.org/selling-an-easement.html.

[41] The Maryland Rural Legacy Program provides funding to preserve rural areas for agricultural, recreational, and environmental uses. The program has allotted over $300 million to preserve over 86 thousand acres of land across Maryland, designating large, continuous tracts of land as Rural Legacy Areas within which landowners may apply to sell an easement. All counties in Maryland have a least one Rural Legacy area; in the Eastern Shore, the Eastern Shore Land Conservancy (ESLC) created the Agricultural Security Corridor Rural Legacy Area, which spans 45,781 acres across five counties: Caroline, Cecil, Dorchester, Kent, and Talbot. For a full list of Maryland's approved Rural Legacy Areas, *see* http://dnr.maryland.gov/land/Pages/RuralLegacy/All-Rural-Legacy-Areas.aspx (listing approved RLAs by county)

[42] Landowners in the Eastern Shore may qualify for significant income tax and property tax credits through the Maryland Environmental Trust (MET) program, which works with state and local agencies as well as land trusts to acquire and maintain conservation easements, with preference for land that is productive farmland, contiguous to other open space property, and the protection of which would discourage sprawling development. The MET program is the primary recipient of donated conservation easements in Maryland and remains one of the oldest and largest land trusts in the country, protecting over 129,000 acres of open space. Landowners who donate an easement through the MET program and its pass-through entities may receive up to $5,000 in tax credits. While there is no fixed minimum parcel size, the MET and cooperating land trusts prioritize donations on parcels greater than 25 acres. *See* Conservation Easement Policies of the Maryland Environmental Trust (2016), Maryland Department of Natural Resources, https://dnr.maryland.gov/met/Documents/Easement_Criteria.pdf.

[43] Swine Floodplain Buyout, North Carolina Department of Agriculture and Natural Resources, https://www.ncagr.gov/SWC/easementprograms/SwineFloodplainBuyout.html.

[44] Id. *See also* Adam Wagner, *Could NC buy out more hog farms after Matthew's floods?*, Star News Online (Apr. 3, 2017), https://www.starnewsonline.com/news/20170403/could-nc-buy-out-more-hog-farms-after-matthews-floods.

[45] *Hurricane Matthew impact was minimal for our industry, and buyout program continues*, NC Pork Council (Sept. 11, 2018), http://www.ncpork.org/buyout/.

[46] *Adaptation Stories: Managed Retreat*, ADAPT VIRGINIA, https://www.arcgis.com/apps/MapJournal/index.html?appid=bea8d4142fcf47bc90078e845e296d64#.

[47] Gloucester County Open Space Hazard Mitigation Plan (Nov. 2014), *available at* https://www.gloucesterva.info/DocumentCenter/View/1666/Hazard-Mitigation-Open-Space-Plan-PDF.

[48] *Id*. at 1-2.

[49] *Id*. at 1.

[50] Florida Statute Section 163.3178, comprehensive community plans must include an objective to establish a Post-Disaster Redevelopment Plan. The State released a best-practices guide book titled *Post-Disaster Redevelopment Planning: A Guide for Florida Communities*.

[51] https://www.scgov.net/Home/ShowDocument?id=34542.

[52] POWERS OF LOCAL GOVERNMENT, MLG MD-CLE 3-1 , 3-125-28.

[53] E.g., Baltimore County has requirements for the development of six-year capital improvement plans

[54] Maryland empowered its local governments to participate in the NFIP Maryland by enacting the Flood Hazard Management Act of 1976, MD. CODE ANN., ENVIR. §§ 5-801 *et seq.* (1995). The Act requires local governments to develop flood management plans and implementing regulations for the 100-year floodplain. *Id*. at § 5-803(d)(1)-(g)(1). The Maryland Department of Environment (MDE) has regulatory authority over non-tidal wetlands, defined to include the 100-year floodplain for non-tidal waters. MD. CODE REGS. 26.17.04.01. Within the non-tidal floodplain, MDE requires 1-foot of freeboard. *Id.* at. 26.17.04.07. However, because authority to regulated tidal floodplains has been delegated to local governments, state agencies cannot impose a freeboard requirement in tidal floodplains without additional authority from the state legislature. Md. *Comprehensive Strategy,* ch. *5* at 13.

[55] In-depth analysis of regional initiatives around CRS and recommendations for how ESCAP jurisdictions may pursue similar approaches in the Eastern Shore to advance CRS participation were also made available in case studies prepared by the Georgetown Climate Center.

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GEORGETOWN CLIMATE CENTER

Integrating Resilience into Local Capital Improvement Programs

Best Practices for Maryland's Eastern Shore Communities

Prepared by the University of Maryland Environmental Finance Center | December 2018

Contents

Introduction

This document presents best practices for embedding climate risk assessments into capital improvement planning processes at the municipal and county level, as a cost-effective means of building community resilience to climate-related threats. Drawing on available literature as well as case studies from jurisdictions around the country, this document is a companion to the Eastern Shore Land Conservancy's report *Mainstreaming Sea Level Rise Preparedness in Local Planning and Processes on Maryland's Eastern Shore*, which has been developed for jurisdictions participating in the Eastern Shore Climate Adaptation Partnership (ESCAP).

As the ESLC report details, current climate projections indicate that Maryland's Eastern Shore will experience increased coastal and riverine flooding in coming decades, due to a number of trends including rising sea levels, land subsidence, and heavier precipitation. These and other effects of a changing climate could impact not only community health and safety but also the integrity of public infrastructure such as municipal buildings and vehicles, water and wastewater infrastructure, communications networks, and transportation system assets.

"As a waterfront town, it was not a luxury but a necessity to begin management of the obvious issues in order to maintain a resilient community."
Cheryl Lewis, Town Administrator, Oxford, MD

For public infrastructure in ESCAP communities to weather these changing environmental conditions, it will be important for jurisdictions to assess the ability of existing assets to withstand current and future stresses, and to plan for these assets' rehabilitation, relocation and/or replacement as needed. It will also be critical for new capital investments to be made so that infrastructure is located and designed to withstand climate risks expected over the lifetime of the asset.

ESCAP communities already conduct capital investment and asset management planning for infrastructure and facilities such as roads, bridges, buildings, water and wastewater systems, and emergency response vehicles. Embedding climate vulnerability considerations into existing capital planning and financing processes is a practical and cost-effective tool for local governments to ensure that these assets continue to function as expected and to build community resilience over the near- and long-term. Benefits of such an integrated planning approach include minimizing service disruptions by preparing for problems before they become emergencies, enabling investments to be aligned with local priorities, and making the best use of limited public funds.

The Importance of Capital Improvement Planning

Capital improvement planning is a process for projecting, budgeting, and financing the development and maintenance of public infrastructure and other fixed assets. To aid this process, many local jurisdictions use a Capital Improvement Program (CIP) framework, through which future capital needs are systematically identified, budgeted, and prioritized for investment. Typically spanning a five- to ten-year planning horizon and updated annually, CIPs enable jurisdictions to project and account for capital expenditures, align investments with community priorities, and ensure the efficient delivery of critical services.

While the CIP process differs from one jurisdiction to the next, general steps in the process include:

- **Establish an administrative framework** for the CIP, including planning horizon, timeline, stakeholder involvement, departmental oversight, and project request process
- **Define the CIP's policy framework**, including criteria for project inclusion, scoring or evaluation criteria, and processes for prioritizing expenditures
- **Conduct an inventory of existing assets**, including their current condition, schedule for repair or replacement, and status of previously approved projects
- **Assess the jurisdiction's financial capacity**, including tax rate, debt service and operating expenditures, available debt capacity, and external funding opportunities
- **Compile, evaluate, and rank project requests**, including project justification, cost, net effect on the operating budget, and implementation schedule
- **Prepare and adopt a capital plan and budget**, including operating expenditures, revenues, contract costs, reserve funds, known debt service commitments, and funding to pay for projects
- **Implement, monitor, and evaluate** budget expenditures

The State of Maryland permits but does not require local governments to develop CIPs. If a jurisdiction does have a CIP, the procedures for establishing it are usually spelled out in the local government charter. According to the Maryland Municipal League, most counties and large municipalities in Maryland utilize some form of formal CIP process, while many small and mid-sized communities do not.[1] Of the six counties participating in ESCAP, five implement a formal CIP process (see Table 1, page 5).

CIPs help jurisdictions prioritize capital expenditures, forecast spending over time, minimize failures of critical infrastructure, and inform residents of needed improvements.

[1] Jim Peck, Maryland Municipal League. 11/19/18. Communication with EFC.

The benefits of utilizing a CIP can be significant, even and perhaps especially for small jurisdictions.[2] CIPs can help reduce costs enabling capital projects to be bundled, coordinated, or phased so that they achieve multiple goals at once (this concept is often referred to as "dig once"[3] and a good example is incorporating green infrastructure elements into road repair projects). CIPs also enable a community to anticipate needs before assets fail and require expensive emergency repair or replacement, and they foster a proactive procurement process whereby communities have ample time to solicit and select the most competitive bids. Most importantly, capital improvement planning encourages communities to identify strategic goals and make public investments that advance those goals.[4]

The CIP is a natural avenue through which local governments may prepare for and respond to climate risk.

With these built-in coordination and planning benefits, the CIP is a natural avenue through which local governments may prepare for and respond to climate risk. The CIP framework can be used to identify existing assets that need to be relocated, retrofitted, or assigned altered maintenance regimes based on climate risk. It can also be used to ensure that new facilities and infrastructure – including any climate adaptation projects – are designed and located to be resilient to risks expected over the asset's lifetime, including flooding, precipitation, and elevated temperatures. For example, a CIP's policy framework may include project section criteria that excludes or disincentivizes investment in new facilities located in flood-prone or otherwise high-risk geographic areas.

What Are ESCAP Jurisdictions Already Doing?

EFC surveyed the six counties that comprise ESCAP to determine their utilization of capital improvement planning processes as well as whether they are currently undertaking efforts to integrate climate resilience into these processes. Results are presented in Table 1, below.

Jurisdictions vary in how they plan and fund capital needs; some conduct only informal means of identifying and prioritizing expenditures while others have more complex and institutionalized processes. In broad outline, however, the common elements of a capital investment process in most ESCAP counties include the following steps: county department supervisors submit capital project requests to the county finance or budget manager; proposed projects are reviewed by a

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[2] Examples of small jurisdictions that utilize a CIP process include Galena, Illinois (population 3,327, CIP projects as small as $10,000) and Temple, New Hampshire (population 1,366, CIP projects as small as $5,000)

[3] See: Alliance for the Chesapeake Bay. 2017. *Streamlining Integrated Infrastructure Investment "Dig Once" Strategy Development Workshop Report*. Available: https://www.chesapeakebay.net/documents/GI_Integration_Final_Workshop_Report.pdf

[4] Berube, Cavin. Moore Engineering. "5 Reasons Every Town Needs a Capital Improvement Plan." Accessed 11/1/18: https://www.mooreengineeringinc.com/2018/03/28/5-reasons-town-capital-improvement-plan/

small group or committee to determine consistency with jurisdiction's goals; and draft budgets are publicly reviewed and then approved by elected officials.

Table 1. ESCAP Counties' Use of Capital Improvement Programs

Jurisdiction	Capital Improvement Program and Planning Horizon	Minimum Project Budget for Inclusion in CIP	Factors Guiding Funding Prioritization	Resilience Elements
Talbot County	5-year CIP			
Cecil County	5-year CIP	$100,000	Informal scoring process based on County goals and priorities	Informal consideration given to resilience or sustainability; some resilience projects included such as stormwater retention ponds, energy conservation, and wastewater treatment plant siting (two recent WWTP upgrade projects included floodproofing system components or relocating them outside the regulatory floodplain).
Caroline County	5-year CIP	$5,000	Informal scoring process based on County goals and priorities	No consideration given to resilience or sustainability; some resilience projects included such as stormwater improvements.
Queen Anne's County	6-year CIP			
Dorchester County	No formal CIP; annual capital budget	$5,000	Informal scoring process based on County goals and priorities	Informal consideration given to resilience or sustainability; Pubic Safety Director and County Manager have started educating department heads and recommend that they start to consider climate change factors in their future project proposals.
Kent County			Informal scoring process with consideration given to projects that are consistent with the Comprehensive Plan and, when possible, current ordinances.	

Best Practices for Incorporating Resilience into CIPs

While most ESCAP counties conduct capital improvement planning and some are beginning to consider climate risk, opportunity exists for ESCAP jurisdictions to more explicitly incorporate anticipated climate risk into planning and investment processes; to assess the ability of existing assets to withstand changing environmental conditions; and to proactively plan and fund climate-ready infrastructure.

Because ESCAP jurisdictions have varying degrees of readiness and capacity to engage in this type of planning and investment, it will be important for communities to begin with a self-assessment to choose the appropriate point of entry. Municipalities that do not yet conduct formal CIP planning (or other planning such as hazard mitigation or emergency management) may need to start there. This could be a good opportunity to collaborate with neighboring jurisdictions, to draw on the expertise of those that are further ahead or to pool capacity with other under-resourced communities.

Acknowledging that the ESCAP community is a diverse audience, below are several best practices and case studies for Eastern Shore jurisdictions to consider as they seek to improve the climate-readiness of their existing assets and future investments.

Incorporate resilience goals into comprehensive plans

Before a community can embed resilience goals into its capital planning process, it must affirm climate readiness as a priority and establish adaptation goals. This may be done through the development of a dedicated resilience plan at the regional, county, or local level, but in ESCAP communities it may be more feasible to adapt existing plans, such as comprehensive, long-range, master, and/or strategic plans.[5] Hazard mitigation and emergency management plans should also incorporate climate-related risks and strategies, adapting as new data and projections become available.

The first step is for the community to affirm a commitment to resilience and define adaptation goals.

The advantages of integrating hazard mitigation and comprehensive land use plans are becoming increasingly well recognized.[6] With examples of such integrated plan-making – including local examples such as Lewes, Delaware[7] – this approach may find a receptive audience in ESCAP communities. Whatever the avenue, it is important that resilience goal-setting occur via a process of meaningful public engagement. This ensures that strategies reflect shared viewpoints and it increases the likelihood of support for future project funding and implementation.

[5] These plans provide the foundation for land use and zoning regulations, which should also be updated to support new resilience goals. For example, zoning regulations could limit new development in flood-prone areas.

[6] See: FEMA. July 2014. *Plan Integration Guide.* Available: http://www.caloes.ca.gov/HazardMitigationSite/Documents/005-Plan%20Integration%20Guide%207-14.pdf

[7] City of Lewes, DE. June 2011. Hazard Mitigation and Climate Adaptation Action Plan. Available: http://www.ci.lewes.de.us/pdfs/Lewes_Hazard_Mitigation_and_CLimate_Adaptation_Action_Plan_FinalDraft_8-2011.pdf

Require CIP to align with community resilience goals

Once resilience goals are affirmed and defined, ESCAP jurisdictions may then adopt policies to encourage or require CIPs and capital budgets to be consistent with these goals as spelled out in the relevant community plan. This requirement may be specified in the CIP's policy framework and/or in the relevant section of the local government charter.

In its 2014 *Plan Integration* guidance document,[8] the Federal Emergency Management Agency (FEMA) offers the following checklist related to CIP and infrastructure policies, which may be useful in assessing policies and determining necessary revision or augmentation:

- Does the capital improvement program provide funding for hazard mitigation projects identified in the Hazard Mitigation Plan or include mitigation as a component to a redevelopment, renovation, or development project (e.g., replacing a courthouse roof, elevating a water treatment plant)?
- Does the Capital Improvement Plan limit or prohibit expenditures on projects that would encourage new development or additional development in areas vulnerable to natural hazards?
- Does the community have infrastructure policies that limit extension of existing infrastructure, facilities, and/or services that would encourage development in areas vulnerable to natural hazards?
- Do community policies limit public expenditures in Coastal High Hazard Areas (e.g., limit expenditures to necessary repairs to maintain in current condition public safety needs, services to existing residents, recreation, and open space uses)?

CASE STUDIES

Queen Anne's County, Maryland. Queen Anne's County has begun incorporating sea level rise projections and coastal vulnerability assessments into its planning processes. The County has developed short-, medium-, and long-term strategies to build resilience, grouped into six categories: avoid, accommodate, protect, retreat, build adaptive capacity, and no action. County departments are encouraged to incorporate sea level rise into all applicable capital improvement design projects, specifically with regard to the upgrades of roads, bridges, water and wastewater facilitates, and other affected capital projects.[9]

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[8] FEMA. July 2014. *Plan Integration Guide*. Available: http://www.caloes.ca.gov/HazardMitigationSite/Documents/005-Plan%20Integration%20Guide%207-14.pdf

[9] Queen Anne's County, MD. March 2016. *Sea Level Rise and Coastal Vulnerability Assessment and Implementation Plan.* Available: https://www.qac.org/DocumentCenter/View/5456/QAC-Sea-Level-Rise-and-Coastal-Vulnerability-Assessment-and-Implementati?bidId=

Baltimore, Maryland. Baltimore's Disaster Preparedness and Planning Project (DP3) and its Sustainability Plan both articulate citywide goals related to climate resilience (the Sustainability Plan is currently undergoing an update to the 2009 version, to incorporate a stronger focus on climate change).[10] These goals inform the city's CIP plan, which spans a six-year timeframe and is updated annually. When evaluating projects to include in the CIP, Baltimore's Planning Commission considers alignment with the Sustainability Plan as an official evaluation criterion, and support of the DP3 as an added bonus, especially when these projects might reduce the City's insurance premium.[11]

Boston, Massachusetts. Climate preparedness is a core element of Boston's strategic plan, "Imagine Boston 2030," and it is the exclusive focus of "Climate Ready Boston," the city's comprehensive effort to prepare for climate impacts at the city and neighborhood scale. Both of these initiatives are used to guide capital investment in Boston. Capital project proposals are submitted by city departments to Boston's Office of Management and Budget (OMB), which cross-checks proposals against stated city goals in order to determine inclusion in the CIP.

When developing capital project proposals, city departments are encouraged to incorporate climate data from the city's flood risk maps and neighborhood resilience plans developed through Climate Ready Boston. Further, OMB encourages cross-departmental collaborations – especially between the Environmental Department and the Planning and Development Agency – to ensure that project designs support climate goals, and it holds regular budget meetings to inform city departments of assets that are vulnerable to climate risk.[12]

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[10] Baltimore Office of Sustainability. "Sustainability Plan" website. Last accessed 12/6/18: https://www.baltimoresustainability.org/plans/sustainability-plan/

[11] Kristen Ahearn, Baltimore City Department of Planning. 11/7/18. Communication with EFC.

[12] City of Boston. *Imagine Boston 2030:* A Plan for the Future of Boston. Available: https://s20222.pcdn.co/wp-content/uploads/2017/11/Imagine%20Boston%202030_%20Spreads.pdf
and City of Boston. "Climate Ready Boston" website. Last accessed 12/6/18: https://www.boston.gov/departments/environment/climate-ready-boston

It is important to note that the process of adopting local climate goals depends on access to sound climate data. While climate projections necessarily involve some degree of uncertainty, reasonable models can afford a clear-sighted understanding of local impacts under a range of possible future scenarios. ESCAP communities are fortunate to have access to such data, via Salisbury University's sea-level rise projections developed as part of the above-referenced *Mainstreaming Sea Level Rise on Maryland's Eastern Shore* initiative. These inundation maps should be used, in combination with other available climate data, to assess specific vulnerabilities at the appropriate planning scale: regional, county, and/or sub-county.

Add climate resilience to CIP scoring criteria

To determine which capital improvement projects will be prioritized for limited available funding, the CIP framework typically includes the establishment of a set of evaluation criteria by which proposals may be gauged. These criteria are often weighted to reflect their relative importance. Once projects are submitted, the CIP evaluation team reviews each proposal and assigns numeric scores within each evaluation category, based on how well the proposed project aligns with criteria. Scores are summed within and then across categories to determine the final project score, and projects are ranked accordingly. For equally-scored projects, budgetary considerations may determine how they are prioritized. CIP policy may allow for changes when unexpected events require a lower-priority project to be funded before a higher-priority one.

Resilience may be incorporated into this scoring process in a general way, with points given for projects that advance the community's resilience to climate risks, as determined subjectively by evaluators. Or it may be incorporated more specifically, by enumerating detailed resilience goals within evaluation criteria. Another option is to award bonus points for projects that proactively advance desired outcomes, such as:

- Reducing the risk of losses from flooding
- Relocating or rehabilitating a critical and vulnerable asset or facility
- Constructing adaptation projects identified in the community's hazard mitigation, resilience or other relevant plan

This approach incentivizes climate-ready projects, by awarding points (and therefore funding priority) to proposals that incorporate resilience elements. An alternative would be to disqualify any project that is inconsistent with resilience goals, such as proposals to construct new facilities in high-risk areas or to repair existing vulnerable assets beyond what is necessary to maintain a basic level of service.

CASE STUDIES

Oakland, California. Oakland's CIP utilizes an evaluation scorecard that was developed through extensive public input, in order to ensure a prioritization process that is fair, transparent, and based on shared community goals. The scorecard includes nine weighted prioritization factors:

- Equity: Investment in underserved communities (16 points)
- Health/Safety: Improve safety and encourage healthy living (16 points)
- Economy: Benefit small Oakland businesses and create local job opportunities (13 points)
- Existing Conditions: Renovate or replace broken or outdated City property (13 points)
- Environment: Improve the environment and **address climate change** (11 points)
- Required Work: Areas where the city may be held financially and legally responsible (10 points)
- Improvement: Build new and upgrade a city-owned property (8 points)
- Collaboration: Combine city projects to save time and money (8 points)
- Project Readiness: Ready-to-go projects without delay (5 points) [13]

Highland Park, New Jersey. The Borough of Highland Park's CIP uses a scoring framework that is intended to enable straightforward prioritization of capital projects. Project proposals are required to detail alignment with ten criteria across four categories: project characteristics, technical consideration, time considerations, and public health and safety. The criteria scores are summed and weighted within each category and then across categories to determine the final rank (see Figure 1, below). A stated priority of Highland Park's CIP is to improve resiliency of current infrastructure systems, and proposed projects are required to specify their potential contribution to improving the town's resilience within the "project characteristics" category.[14]

[13] City of Oakland, CA. "Oakland's Capital Improvement Program (CIP)" website. Last accessed 12/6/18: https://www.oaklandca.gov/topics/capital-improvement-program

[14] Borough of Highland Park, NJ. September 2015. *Capital Improvement Plan: Highland Park New Jersey*. Available: http://www.hpboro.com/DocumentCenter/View/2800

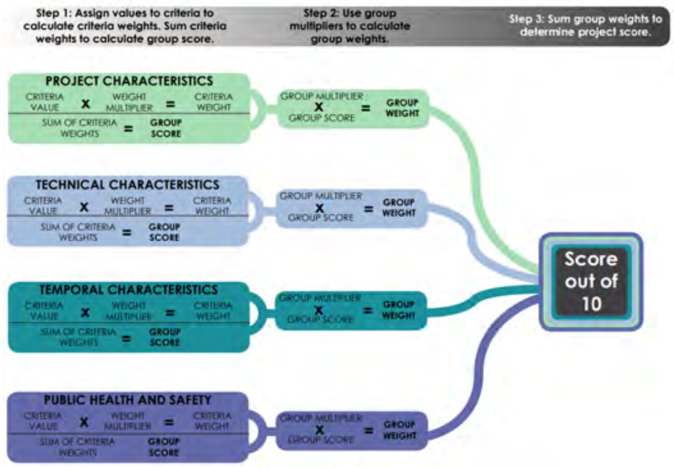


Figure 1. Highland Park, NJ's CIP evaluation framework.

Use the CIP to encourage cross-departmental collaboration

A community CIP is by nature a collaborative process that requires involvement of multiple departments (or, in smaller jurisdictions, multiple staff members). The process offers the opportunity for even greater cross-departmental collaboration and coordination, including among sectors that do not typically work together. A CIP program should be designed to have broad representation in all its phases, including developing the CIP framework and scoring criteria, designing and submitting projects, scoring and prioritizing proposals, and implementing and evaluating projects.

In addition to planning, public works, and finance departments, good candidates for a CIP team include staff working in emergency management, hazard mitigation, stormwater, environmental management, and sustainability, as applicable. Members of the general public may be recruited to complement government staff in fulfilling particular CIP-related roles, especially proposal evaluation and scoring.

Such collaboration can achieve cost savings by enabling projects to be bundled and/or staged in time- and cost-efficient ways. Importantly, bringing hazard mitigation and environmental management voices to the CIP planning table enables these perspectives to be integrated into decisions around community infrastructure investments – an important step toward making investments that can withstand current and future environmental conditions.

Significant knowledge-building can occur through such collaboration within a jurisdiction. Additional gains may be achieved through peer-sharing *across* communities, as well as by bringing in external experts for formal staff training in needed topic areas.

CASE STUDIES

Ann Arbor, Michigan. Ann Arbor's CIP process is structured to encourage cross-departmental coordination. Rather than each department proposing projects, the City develops teams of stakeholders around specific asset areas (transportation, water, etc.) to propose projects within that topic area. Teams are comprised of individuals from various City departments, and the CIP manager and a representative from the City's sustainability office attend all team meetings to ensure coordination.[15]

Miami-Dade County, Florida. Miami-Dade has proposed an "enhanced capital planning" process through which external experts would work with city staff across departments to develop climate adaptation pathways – broad sets of strategies with potential for sweeping impact. Within each pathway, specific projects would then be identified and prioritized based on their ability to offer multiple co-benefits and reduce costs.[16]

New Orleans, Louisiana. As part of New Orleans' public budgeting process, the City brought in experts from other cities to train staff in various departments on how resilience and equity could be incorporated into departmental operations and budgeting. Each department responded with assessments and goal-setting on ways in which it could incorporate these values to a greater degree.[17]

Require vulnerability assessments for proposed projects

A step beyond awarding priority points to projects that are climate-ready is to require *all* projects to complete a vulnerability assessment before they may be proposed for inclusion in a CIP. This process would make use of existing climate data and maps (such as recent flood

[15] City of Ann Arbor, MI. 2018. *2018-2023 CIP Summary*. Available: https://www.a2gov.org/departments/systems-planning/programs/Documents/EXECUTIVE_SUMMARY_FY2018-2023.pdf
[16] Miami-Dade County, FL. September 2016. *Recommendations for an Enhanced Capital Plan.* Available: https://www.miamidade.gov/green/library/sea-level-rise-capital-plan.pdf
[17] City of New Orleans, LA. *2018 Annual Operating Budget.* Available: https://nola.gov/city/2018-proposed-budget-book_1211pm/

studies) to evaluate the extent and nature of a particular facility's vulnerability to environmental conditions expected over the asset's lifetime. In cases in which

For existing equipment and infrastructure, vulnerability assessments should be folded into the asset management component of a CIP planning process, and/or such assessment may be required before an asset can be eligible for repairs or upgrades above a certain dollar threshold. The goal would be to ensure that climate projections are considered in all capital expenditures, related to any element of an asset including its design, siting, and operation.

CASE STUDIES

San Francisco, California. The City and County of San Francisco have developed a guidance document to help incorporate climate risk into capital planning across all government departments. It puts forth a common approach that may be used to assess vulnerabilities and integrate adaptation strategies, which departments are expected to use prior to proposing a project for funding consideration.[18]

New York, New York. New York's Climate Resiliency Design Guidelines are designed to help city staff incorporate climate change data into all capital projects, from design to installation. According to the Guidelines, all projects should be designed to withstand increasing heat and precipitation over the asset's lifetime and others may require design adaptation for storm surge and sea level rise based on their location and criticality.[19, 20]

[18] City and County of San Francisco, CA. 2014. *Guidance for Incorporating Sea Level Rise into Capital Planning In San Francisco: Assessing Vulnerability and Risk to Support Adaptation.* Available: http://onesanfrancisco.org/sites/default/files/inline-files/Guidance-for-Incorporating-Sea-Level-Rise-into-Capital-Planning1.pdf

[19] New York City Mayor's Office of Recovery and Resiliency. 2018. *Climate Resiliency Design Guidelines*. Available: https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf

[20] New York City Planning. 2018. *The New York City Waterfront Revitalization Program Climate Change Adaptation Guidance.* Available: https://www1.nyc.gov/assets/planning/download/pdf/applicants/wrp/revisions-2017/policy-62-guidance-document-nov2018.pdf

Resource Guide

Below are resources available to help communities learn more about the concepts discussed in this document and take steps toward improving the climate-readiness of existing and future capital assets.

Case Studies and Models

New York City Mayor's Office of Recovery and Resiliency. 2018. *Climate Resiliency Design Guidelines*.
https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf

City and County of San Francisco, CA. 2015. *Guidance for Incorporating Sea Level Rise into Capital Planning In San Francisco: Assessing Vulnerability and Risk to Support Adaptation.*
http://onesanfrancisco.org/sites/default/files/inline-files/Guidance-for-Incorporating-Sea-Level-Rise-into-Capital-Planning1.pdf

City of Lewes, DE. June 2011. *Hazard Mitigation and Climate Adaptation Action Plan.*
http://www.ci.lewes.de.us/pdfs/Lewes_Hazard_Mitigation_and_CLimate_Adaptation_Action_Plan_FinalDraft_8-2011.pdf

Capital Improvement Planning and Asset Management

Government Finance Officers Association. Capital Improvement Planning & Budgeting Resource Center. http://www.gfoa.org/capital-improvement-planning-budgeting-resource-center

Offers best practices and resources for basic capital improvement planning.

Southwest Environmental Finance Center and New England Environmental Finance Center. 2016. *Asset Management for Stormwater.* https://mostcenter.org/asset-management-stormwater

Primer on maintaining stormwater infrastructure with an "asset management" approach, which involves thinking about community assets in a strategic way so that they are sustained over the long term at the lowest overall life cycle cost while meeting the needs of the community.

MOST Center. Asset Management for Stormwater course. https://mostcenter.org/courses/asset-management-stormwater

Free course online course that provides overview of the components necessary to implement a comprehensive asset management program, with concepts applying beyond stormwater.

Plan Integration

FEMA. July 2014. *Plan Integration Guide.* http://www.caloes.ca.gov/HazardMitigationSite/Documents/005-Plan%20Integration%20Guide%207-14.pdf

Guide for communities to integrate hazard mitigation principles and actions into community plans and planning mechanisms.

National Association of Development Organizations (NADO). CEDS Resilience Library. https://www.nado.org/resources/ceds-library/

Resources for and examples of communities integrating resilience and hazard mitigation with comprehensive economic development plans (CEDs).

ICLEI. Adaptation Database and Planning Tool. https://www.cakex.org/tools/adaptation-database-and-planning-tool-adapt

Online tool that guides local government users through ICLEI's "Five Milestones for Climate Adaptation" planning process. Walks users through the process of assessing vulnerabilities, setting resiliency goals, and developing plans that integrate into existing hazard and comprehensive planning efforts.

Local Resilience Planning

Climate.gov

Promotes public understanding of climate science and climate-related events through videos, stories, images, and data visualizations.

Georgetown Climate Center Adaptation Clearinghouse. https://www.adaptationclearinghouse.org/

Online database and networking site that serves policymakers and others who are working to help communities adapt to climate change.

ICLEI Climate Adaptation and Community Resilience Resilient Communities Program. http://icleiusa.org/programs/climate-preparedness/

Fee-for-service package for local governments undertaking detailed climate adaptation planning.

Merrill, S. et al. 2008. "Planners and Climate Action: An Approach for Communities." *Maine Policy Review.* https://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1141&context=mpr

Brief overview of responsibilities that local officials face in ensuring that their towns are adequately prepared for climate challenges. Provides some of the arguments that underlie planners' obligations and suggests a means to categorize necessary responses over time.

NOAA Coastal Inundation Toolkit. https://coast.noaa.gov/digitalcoast/training/coastal-inundation-toolkit.html

Tools and information to help communities understand and address coastal flooding.

US Global Change Research Program. 2014. *National Climate Assessment Report.*

Assesses the impacts of climate change on the US, including on specific sectors such as energy, water and land use. Profiles mitigation and adaptation responses.

<u>Funding and Finance</u>

ICLEI. 2011. *Financing the Resilient City: A demand driven approach to development, disaster risk reduction, and climate adaptation.* https://resilientcities2019.iclei.org/wp-content/uploads/Report-Financing_Resilient_City-Final.pdf

Provides a conceptual framework for better understanding how to integrate climate and other risk reduction measures in urban areas and systems. Calls for more locally responsive climate financing investment strategies and instruments. Discusses climate financing for adaptation and how it can be mobilized, leveraged, and innovated for the local level.

New England Environmental Finance Center. 2009. *Preserving Assets in At-Risk Municipalities: Financial Strategies for Climate Change Adaptation.* https://digitalcommons.usm.maine.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1000&context=climatechange

Intended to help municipalities identify courses of action and steps they might take toward increasing their resilience, especially regarding financial resources that will need to be allocated toward the various strategies identified.

US EPA. 2008. *Guidebook of Financial Tools: Paying for Environmental Systems.*

Provides an overview of financial options available to fund local environmental programs, including climate adaptation.

Funding Sources for CIP Implementation

Funding to implement projects in a jurisdiction's CIP typically come from the general fund / general tax revenues. Given the cost of making existing and future infrastructure climate-ready, local governments will likely need to access additional funding sources as well as financing mechanisms that make dollars stretch as far as possible. Below is a brief description of funding sources and financing mechanisms that may be available to implement CIP projects.

Pay-as-you-go financing entails funding capital projects with cash on hand, from general fund allocations, surplus revenues, unreserved funds, and/or specific tax levies dedicated to capital improvements. Advantages of this method include that it entails no interest costs, long-term obligations, or impacts on the government's ability to issue debt in the future. Disadvantages include the possibility of insufficient funding for capital needs, yearly fluctuations in funding, and lack of intergenerational equity in paying for projects that will benefit future residents.

Debt financing involves borrowing funds to finance capital needs. Government-issued bonds allow localities to acquire assets as needed rather than waiting until a sufficient amount of cash has been accumulated. Four main types of bonds include general obligation bonds, revenue bonds, special assessment bonds, and tax increment financing bonds. Smaller governments most commonly issue general obligations bonds, which may be secured by an unlimited tax pledge.

Lease-purchase agreements can be used for capital equipment and facilities. In these arrangements, local governments create specifications for a needed project and work with a financial institution or other private vendor to complete construction. The facility or equipment is then leased over a specified number of years until it is owned by the public entity.

Grants and state / federal aid are funding sources available to municipalities for a specific purpose or project. The funding does not have to be paid back; however matching funds may be required.

Impact fees and exactions are funds paid by developers for capital improvements associated with a new development. These fees are usually negotiated on a project-by-project basis.

Revolving loan programs such as State Revolving Funds are available on a competitive basis to local governments, providing no- or low-interest rate loans for eligible projects.

Joint financing is a mechanism through which two or more counties / municipalities partner to fund mutually beneficial projects. County office buildings, sanitary landfills, and ambulance and fire services are good candidates for joint financing.

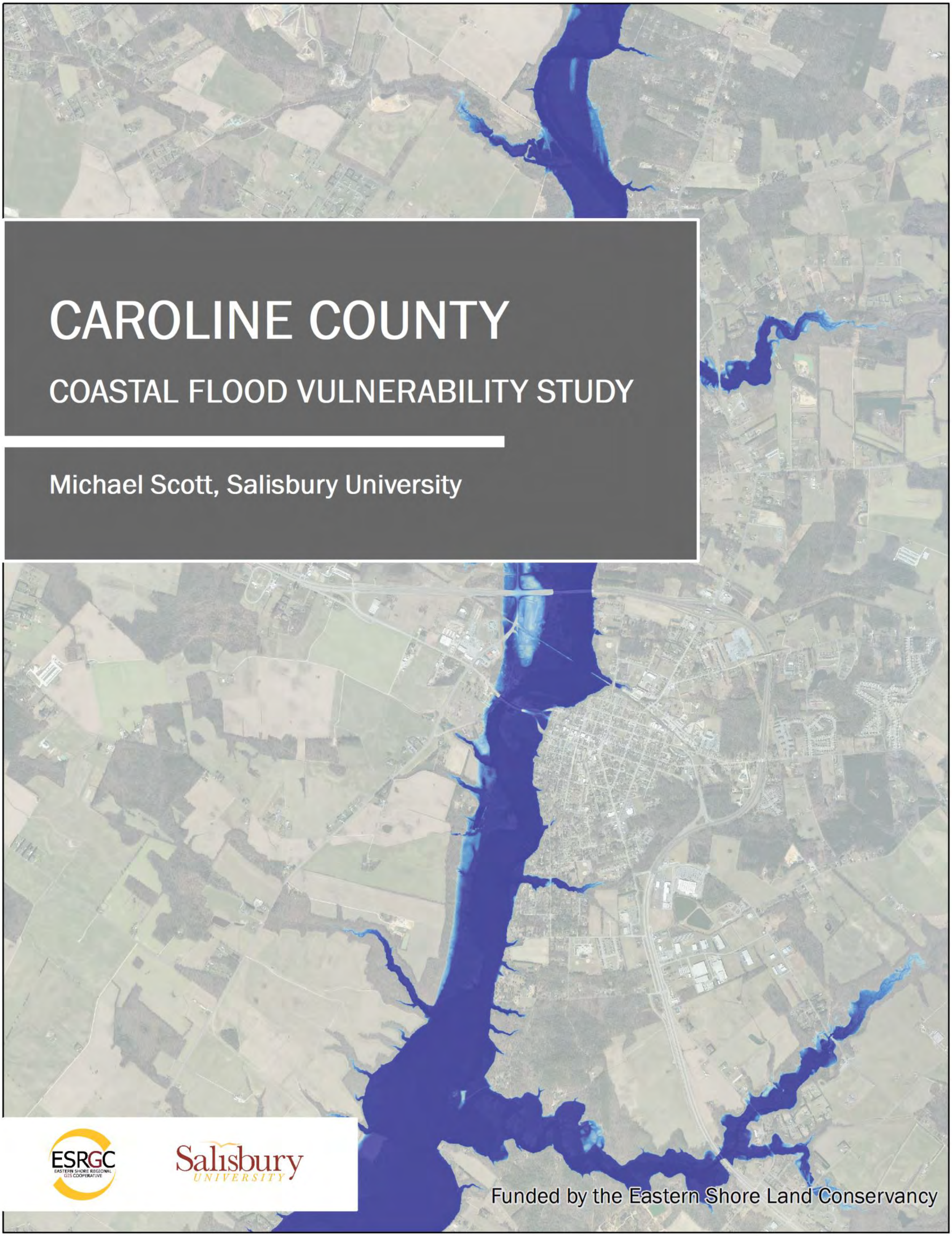
Public-private partnerships are contractual arrangements between a government entity and a private firm to design, build, operate and/or maintain a public good or service. While projects must still be paid for with public funds, public-private partnerships can enable results to be achieved more quickly and cost-effectively than would otherwise be possible.

Private financing includes donations of capital and/or assets from private sector entities. Such contributions can be facilitated by the jurisdiction proactively identifying capital needs and pursuing contributions from corporations and/or individuals. The use of **private equity capital markets** to complement public funding for projects is emerging as an innovative and promising financing concept; see the forthcoming Environmental Finance Advisory Board report *Illustrative Private Equity Capital Model: Chesapeake Bay Water Quality Project*.

CAROLINE COUNTY

COASTAL FLOOD VULNERABILITY STUDY

Michael Scott, Salisbury University



Funded by the Eastern Shore Land Conservancy

Executive Summary

Given the topography and historical development patterns of Maryland's Eastern Shore, the potential for damage from periodic flood events caused by coastal storms and extreme high tides is well-known. What is uncertain is the degree to which the vulnerability of Eastern Shore communities is increasing as sea levels change in the Chesapeake Bay and its tributaries. Therefore, the goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. The methods employed in this research are considered best practices, are accepted by FEMA and provide a consistent framework for assessing risk from floods. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the county and help make informed decisions about mitigation measures to reduce the potential impacts. Having said that, we recommend that the damage statistics in this report be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Results of the analysis predict that 82 buildings (worth $14.0 million in the structure and its contents combined) would feel the impacts of a 1%-chance flood in Caroline County, with 18 of them experiencing more than 10% damage, for a total predicted damage of $643,190. Those 18 moderately or severely damaged structures represent 22% of the total number of vulnerable buildings but they represent nearly 81.9% of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits. The much more severe 0.2%-chance flood impacts 117 buildings in the county valued at $20.2 million with 33 damaged moderately with a total potential damage of $1.4 million. Given that greater than 35% of the potential damage from a 1% chance flood event comes from commercial buildings, instigating mitigation actions that are targeted at Caroline County business owners might yield the best results.

In Caroline County, the magnitude of predicted sea level rise for the remainder of this century is typical for the DelMarVa Peninsula. The US Army Corps of Engineers expects an estimated mean sea level increase in the county of 2.11 ft by 2050 and 5.78 ft by 2100. Thankfully, the sea level rise itself will impact very few buildings in 2050 – only 4 (worth $837,350 in structure and contents). But by 2100, this increases to 105 structures worth $17.9 million. On the other hand, the degree of potential damage from sea level rise inundation in 2100 is modest – only $1.3 million or $12,686 per building. This indicates a certain level of flood-resistance built into Caroline County, most likely from a lack of development intensity in the southeastern part of the county.

However, when the 1% chance flood is combined with the predicted sea level rise, the vulnerability of the County's built environment is raised considerably. In 2050, the 1% chance flood is predicted to impact 184 buildings (a 224% increase over the same scenario today), worth $35.8 million (a 255% increase from today) and potentially

causing $2.4 million in flood damage (a 3.7x increase from 2015). The same flood in 2100 could impact 633 buildings (a 344% increase from 2050) worth $103.2 million in value (a 288% increase from 2050) and cost a potential $9.5 million in damage (about a 4x increase over the same estimate in 2050).

Several conclusions can be made regarding the question of coastal flooding vulnerability in Caroline County. It is certainly true that Caroline County is the least vulnerable to sea level rise and coastal flooding of any county on Maryland's Eastern Shore. Its lack of direct access to the Chesapeake Bay assures that. However, it would be a mistake to think that this threat is not worth mitigating. While only 0.6% of Caroline County's 14,539 improved structures are vulnerable to a flood threat today, that increases 8-fold to 4.4% in 2100. Additionally, southern Caroline County has not seen the development pressure that Queen Anne's and Talbot Counties have – yet. It does seem inevitable as the trends of suburbanization continue, the relatively inexpensive land along very scenic rivers are likely primed for development. It is very fair to say that sea level change will take Caroline County from one that does not have a significant coastal flood threat to one that does. That adjustment, and its impact on development expectations, is going to take some time to internalize. The relative good news is that Caroline County does have some time to adjust. If they do, and implement flood-smart building strategies before the situation has a chance to escalate, they can escape the worst of the flooding impacts and likely attract residents and businesses who have decided that building along the edge of the Bay no longer makes economic sense.

Introduction and Study Context

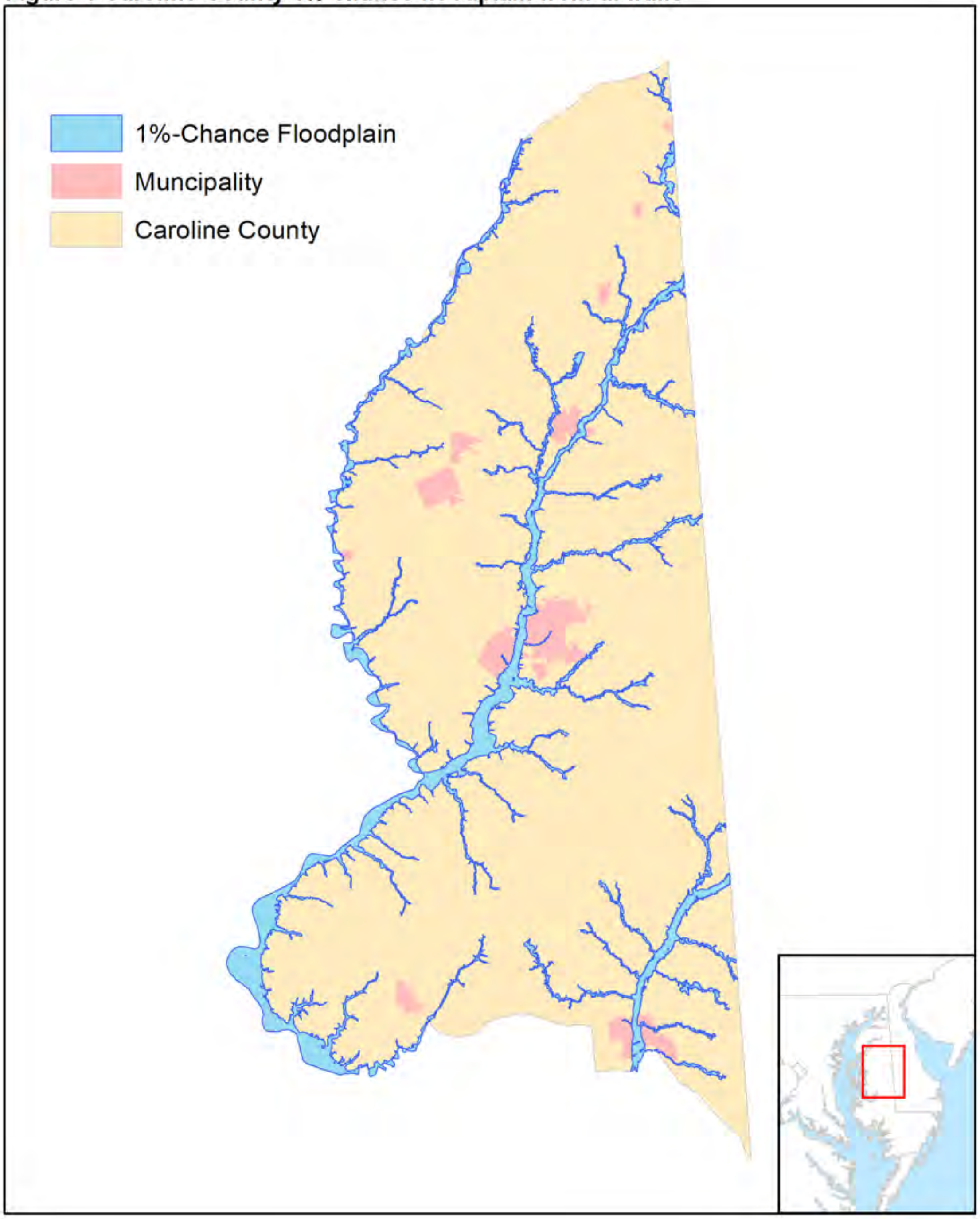
Flooding occurs when rivers, creeks, streams, ditches, or other water bodies receive more water that they can handle from rain, snowmelt, storm surge, or excessive high tides. The excess water flows over adjacent banks or beaches/marshes and into the adjacent floodplain. As many as 85 percent of the natural hazard disasters across the United States have been attributed to flooding.

This document presents the results of a coastal flood vulnerability study of Caroline County, Maryland conducted by Dr. Michael Scott of Salisbury University at the request of the Eastern Shore Land Conservancy in Easton, Maryland. The goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. Specifically, using flood depth data calculated on behalf of the Maryland State Highway Administration, the flood scenarios of a 1% chance flood in 2015, a 0.2% chance flood in 2015, no periodic flooding in 2050, a 1% chance flood in 2050, no periodic flooding in 2100, and a 1% chance flood in 2100 were evaluated versus the location and value of buildings in Caroline County. The results are an accounting of the potential damage from periodic flooding, exacerbated by future sea level change. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the count and help make informed decisions about mitigation measures to reduce the potential impacts.

Caroline County's Floodplain

The following map (Figure 1) depicts the 1% chance floodplains within Caroline County, as designated by FEMA on the Flood Insurance Rate Maps or FIRMs. The 1% chance flood (formerly referred to as the 100-year flood) is a flood which has a 1 percent chance of being equaled or exceeded in any given year (MDE, *Maryland Floodplain Manager's Handbook*). Caroline County can experience riverine flooding as a result of excessive rainfall in a matter of hours, such as from a severe thunderstorm. Additionally, some soils can become saturated over a longer period of time and reduce their absorption potential. Riverine flooding can affect any of the rivers and streams in the County but primarily affects the non-tidal or brackish portions of the streams that feed the Chesapeake Bay. Tidal flooding in Caroline County usually occurs as a result of tropical storms (including hurricanes) as well as the combination of high astronomical tides with a northeast wind. Caroline County has 7.7% of its land area in the 1% chance floodplain.

Figure 1 Caroline County 1% chance floodplain from dFIRMs



While Caroline County is clearly vulnerable to both riverine and coastal/tidal flooding, only tidal flooding is considered in this vulnerability study. It is entirely possible that those areas in the county beyond the tidal flooding extent will experience a change in their flooding occurrence if the consensus predictions of global climate change come to pass. Current research suggests that extreme rainstorms (as well as extreme droughts) will become more common (National Climate Assessment, 2014).

Flood Measurement

There are two US Geological Survey gauging stations within the County and one other close by. There are no National Weather Service Advanced Hydrologic Prediction Service hydrographs and no National Oceanographic and Atmospheric Administration tide gauges in the County (Table 1). Measurements of stream discharge, river stage, and tide height are critical to the prediction of flood events.

Table 1. River gauges, hydrographs and tide gauges in/near Caroline County

Agency	ID Number	Station Name	Real-Time or Daily
USGS	01491500	Tuckahoe Creek near Ruthsburg	Real-time
USGS	01491000	Choptank River near Greensboro	Real-time
USGS	01488500	Marshyhope Creek near Adamsville, DE	Real-time

Flood Levels

Using the Flood Insurance Studies (FIS) of Caroline County, published by FEMA effective January 16, 2015, the following table (Table 2) reports the flood elevations for the key flooding sources.

Table 2. Flood elevations for coastal event (Units are NAVD 1988 feet)

Flooding Source and Location	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHOPTANK RIVER				
At confluence of Hunting Creek	4.0	4.8	5.2	6.2

Hazards from Floods

Flooding causes $6 billion in average annual losses in the United States annually and account for an average of 140 casualties annually (USGS, “Flood Hazards – A National Threat,” 2006). While most people’s vision of the threat from flooding may include being swept away or buildings being structurally impacted, there are actually a number of hazards associated with flooding that occur both during and after an event.

During the Flood

While a flood event is underway, citizens will be faced with a number of threats. The hydraulic power of water is significant and walking through as little as 6 inches of moving water is dangerous because of the possibility of losing stable footing. Driving through flood water is the cause of many flood deaths each year. As little as one foot of water can float many cars and two feet of rushing water can carry away most vehicles including SUVs. That fact, combined with an inability for drivers to judge the depth of flood water, as well as the potential for flood waters to rise quickly without warning, makes driving through flood water a very unwise action.

In addition to being swept away, flood water itself is to be avoided. Because of leaking industrial containers, household chemicals, and gas stations, it is not healthy to even touch the flood water without protective equipment and clothing. Downed power lines, flooded electric breaker panels, and other sources of electricity are a significant threat during a flood. One should also be prepared for the outbreak of fire. Electric sparks often cause fire to erupt and because of the inability of firefighting personnel to respond, a fire can quickly burn out of control.

After the Flood

Cleaning up after a flood can also expose citizens to a number of threats. For example, electrical circuits or electrical equipment could pose a danger, particularly if the ground is wet. Buildings that have been exposed to floodwater may exhibit structural instability of walkways, stairs, floors, and possibly roofs. Flood waters often dislodge and carry hazardous material containers such as tanks, pipes, and drums. They may be leaking or simply very heavy and unstable. The combination of chemical contamination and the likely release of untreated sewage (necessary when the sewage treatment plant is overwhelmed with flood-swelled effluent) mean that drinking water supplies can be unusable. Fire continues to be a very real threat after a flood. First-responders could be occupied with more pressing emergencies and traditional fire suppression equipment may be inoperable, but there may be mobility problems that keep fire-fighting equipment to reach an outbreak. Finally, there is the mental toll of being involved in a disaster. Continued long hours of work, combined with emotional and physical exhaustion and losses from damaged homes and temporary job layoffs, can create a highly stressful situation for citizens. People exposed to these stressful conditions have an increased risk of injury and emotional crisis, and are more vulnerable to stress-induced illnesses and disease.

Impact to Buildings

Fortunately, the number of people killed or injured during floods each year is relatively small. The built environment within the floodplain, however, is likely to bear the brunt of a flood’s impact. Whether the water is moving or standing, the exposure of buildings to flood water could cause a great deal of damage. If the water is moving, the differing hydraulic pressure inside the building vs. outside can cause the walls and foundation to buckle and fail. If the water is standing for any length of time, even materials above the flood height will become saturated with flood water as the flood water is absorbed (known as wicking). Certainly, most of the contents of flooded buildings that were located at or below the flood height will need to be discarded. This includes carpet, furniture, electronic equipment, and other household or commercial items. In most cases it is not simply the fact that the objects have become wet but since the flood water brings with it sediment and chemicals, it makes it nearly impossible to recover all but the most precious/heirloom items.

Flood Vulnerability Assessment

The goal of mitigation is to increase the flood resistance of a community, so that the residents and businesses will become less susceptible to future exposures to flooding, thereby resulting in fewer losses. A key component of reducing future losses is to first have a clear understanding of the current threats, the current probability that those threats would occur, and the potential for loss from those threats. The Vulnerability Assessment is a crucial first step in the process as it is an organized and coordinated process of assessing potential hazards, their risk of occurring, and the possible impact of an event.

Study Method

The Vulnerability Assessment was conducted using the method developed for HAZUS-MH, FEMA's loss estimation software, to assess the County's built environment to versus flood vulnerability. HAZUS-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide credible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards, including floods, hurricane winds and earthquakes. The methodology supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

The primary input to any vulnerability assessment is a "depth of flood" grid. This flood depth grid was created using an elevation grid derived from LiDAR measurements. By incorporating the polygons of the 1% chance floodplain from the FIRMs, the coastal flood elevations from the Flood Insurance Study as well as the current elevation grid, HAZUS-MH was able to create a flood depth grid with a reasonable precision for the 1% (Figure 2) and 0.2%-chance (Figure 3) coastal flood scenarios with Caroline County's current mean sea level. In addition, areas predicted to be inundated by a higher mean sea level in 2050 (Figure 4) and 2100 (Figure 5) were also modeled. Finally, the depth of flood for the 1%-chance event was mapped using the 2050 (Figure 6) and 2100 (Figure 7) predicted sea-levels. For the full detail of how these depth grids were created, please see "GIS Data Products to Support Climate Change Adaptation Planning: Caroline County, Maryland" at http://www.esrgc.org/mapServices/.

Figure 2 Predicted flood depths for Caroline County 1% chance floodplain at MSL in 2015

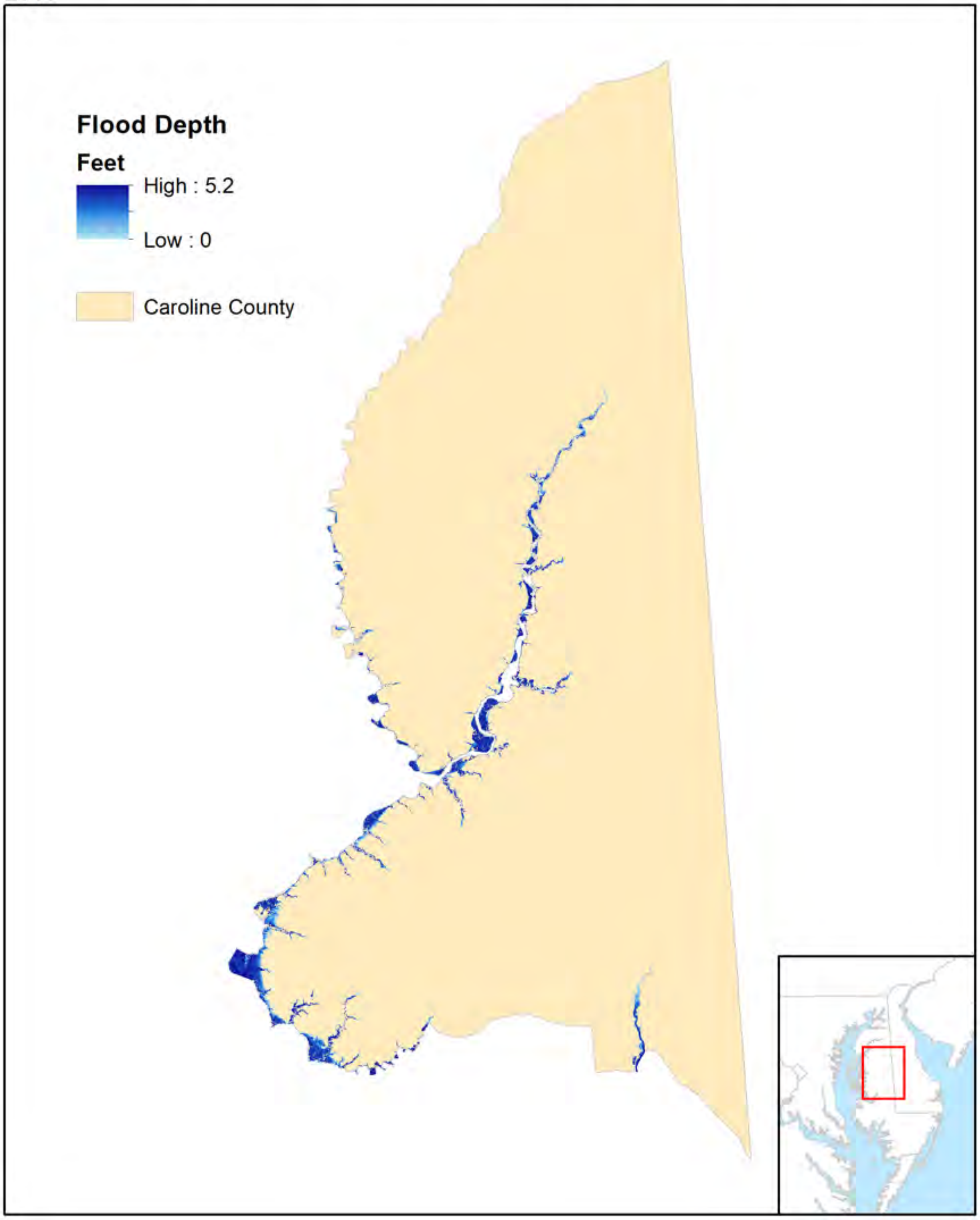


Figure 3 Predicted flood depths for Caroline County 0.2% chance floodplain at MSL in 2015

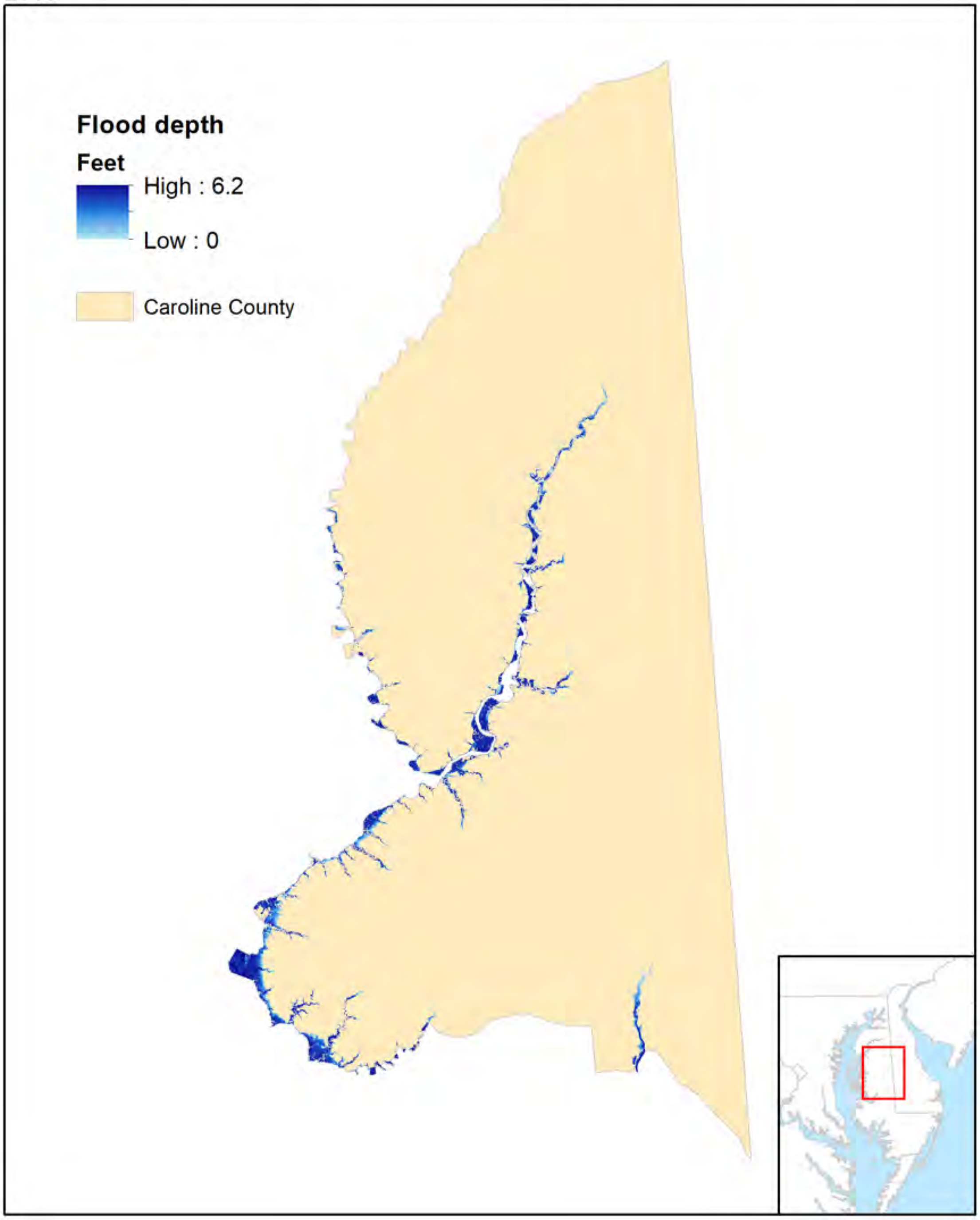


Figure 4 Predicted depth of MSL inundation in Caroline County in 2050

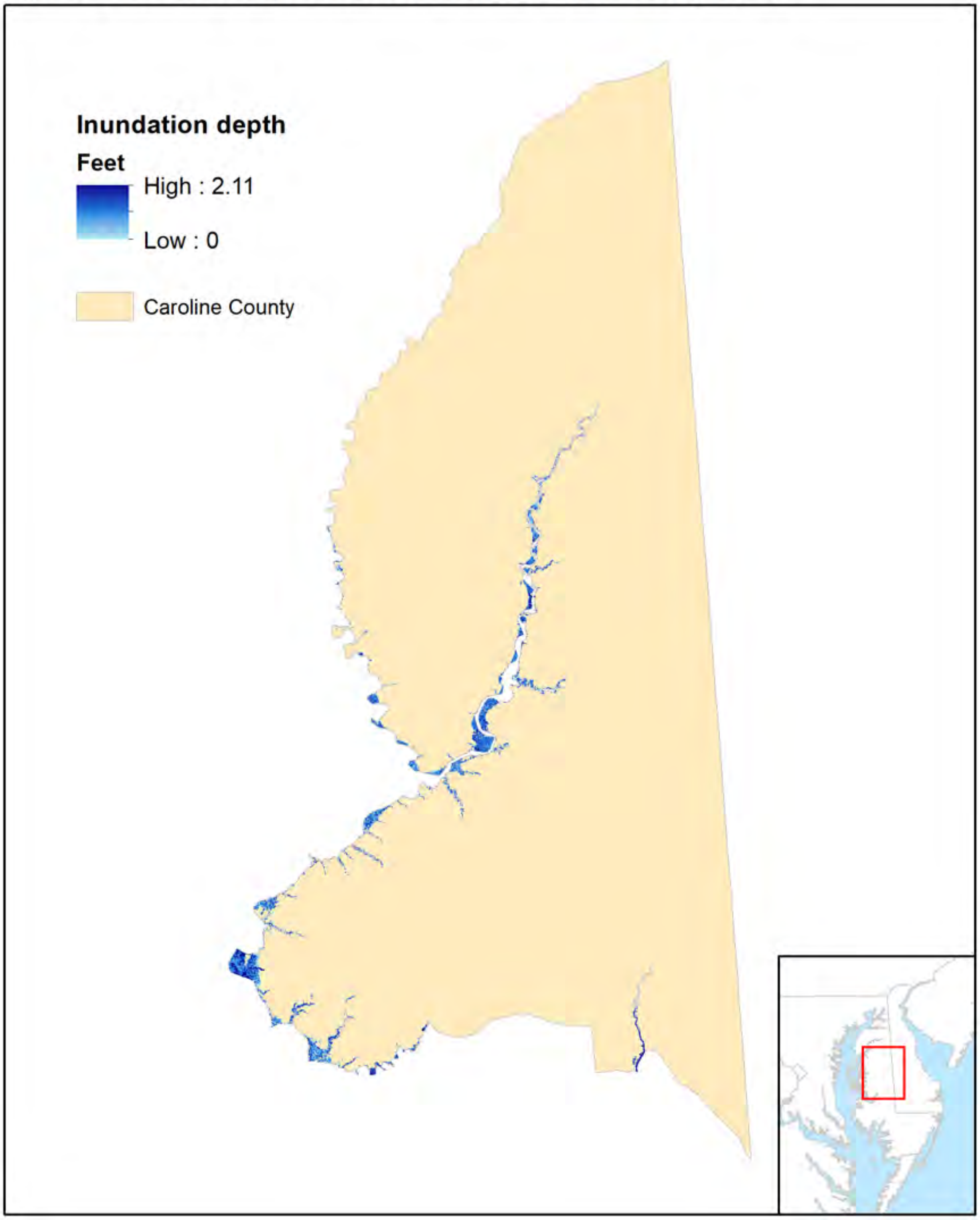


Figure 5 Predicted depth of MSL inundation in Caroline County in 2100

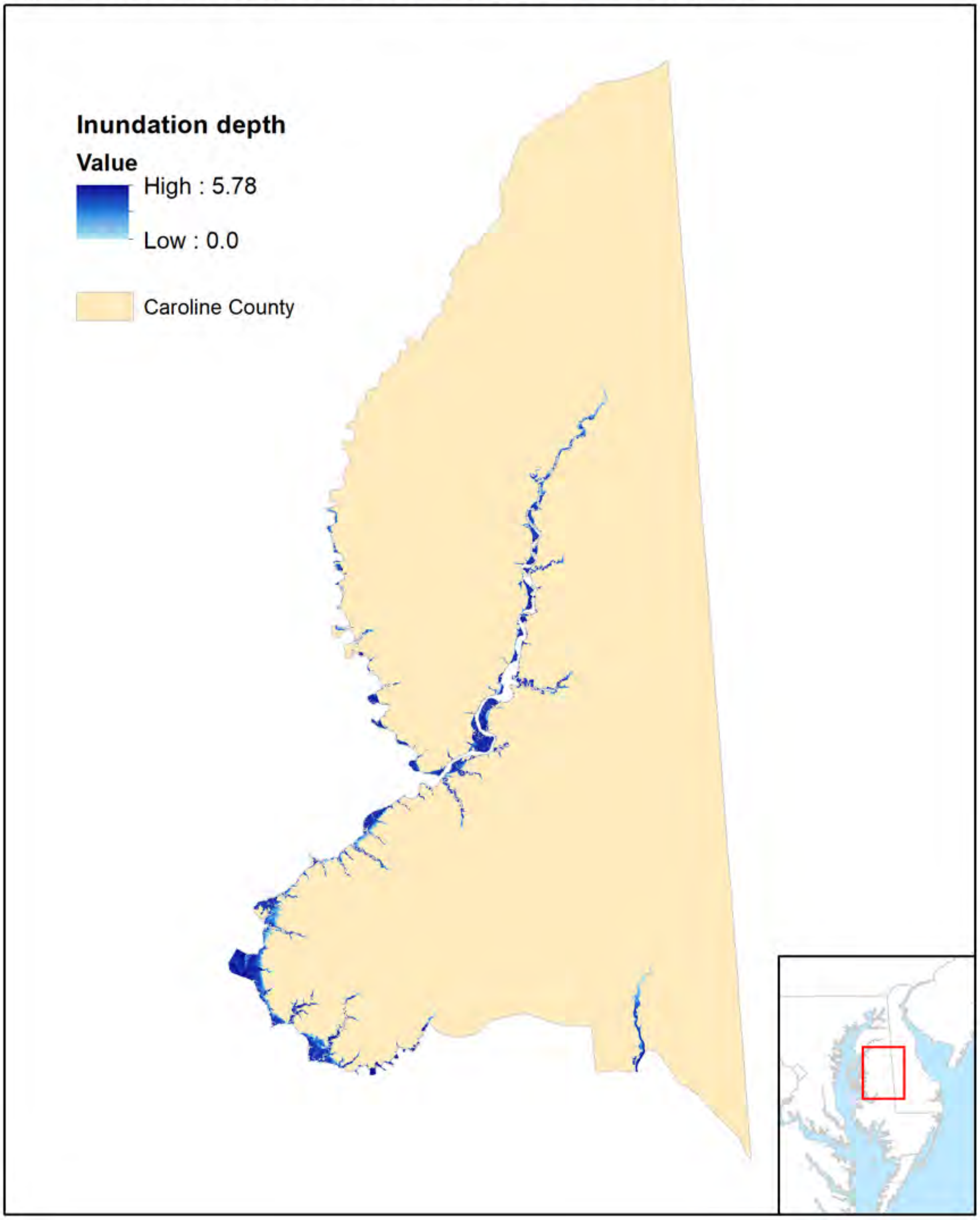


Figure 6 Predicted flood depths for Caroline County 1% chance floodplain at MSL in 2050

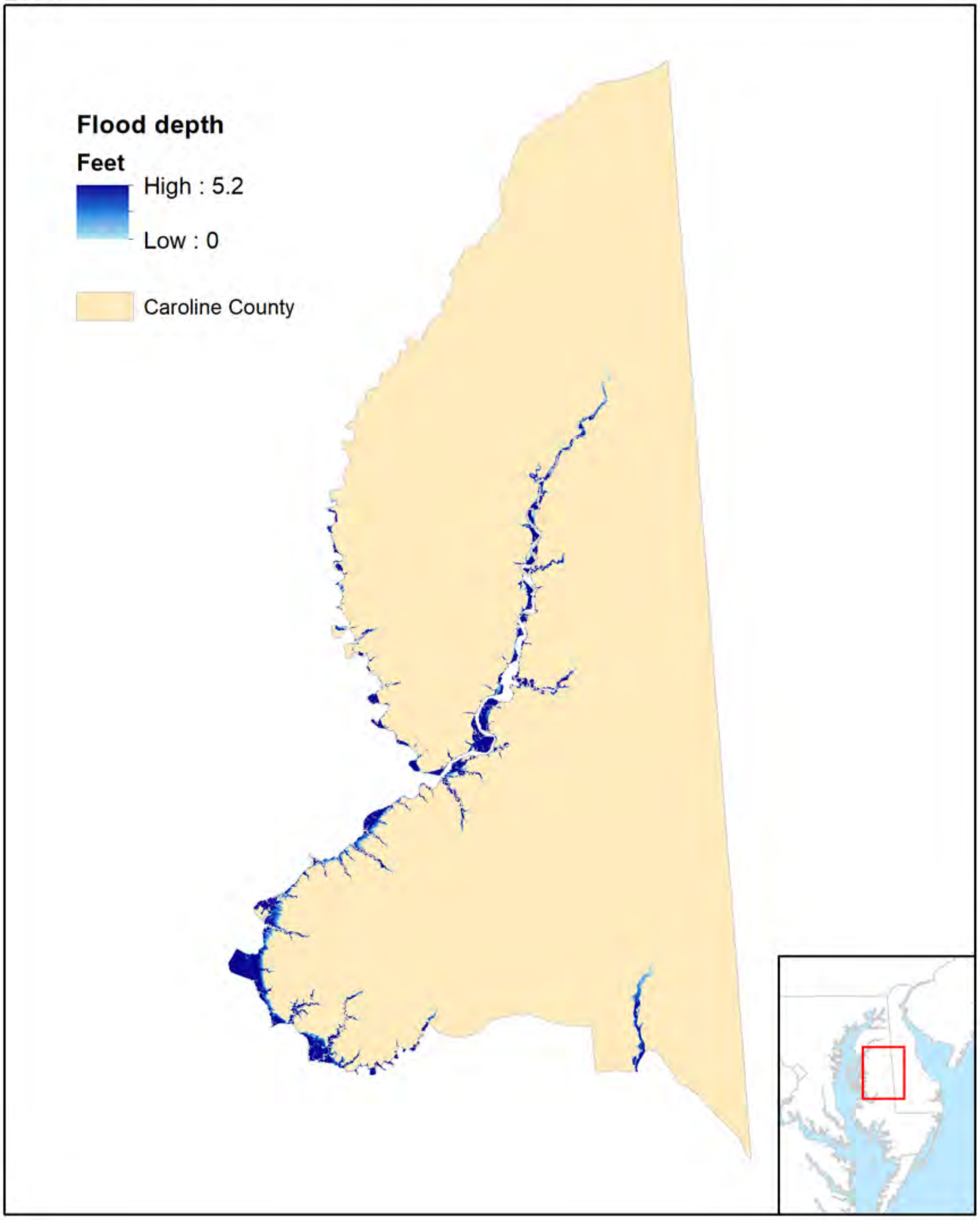
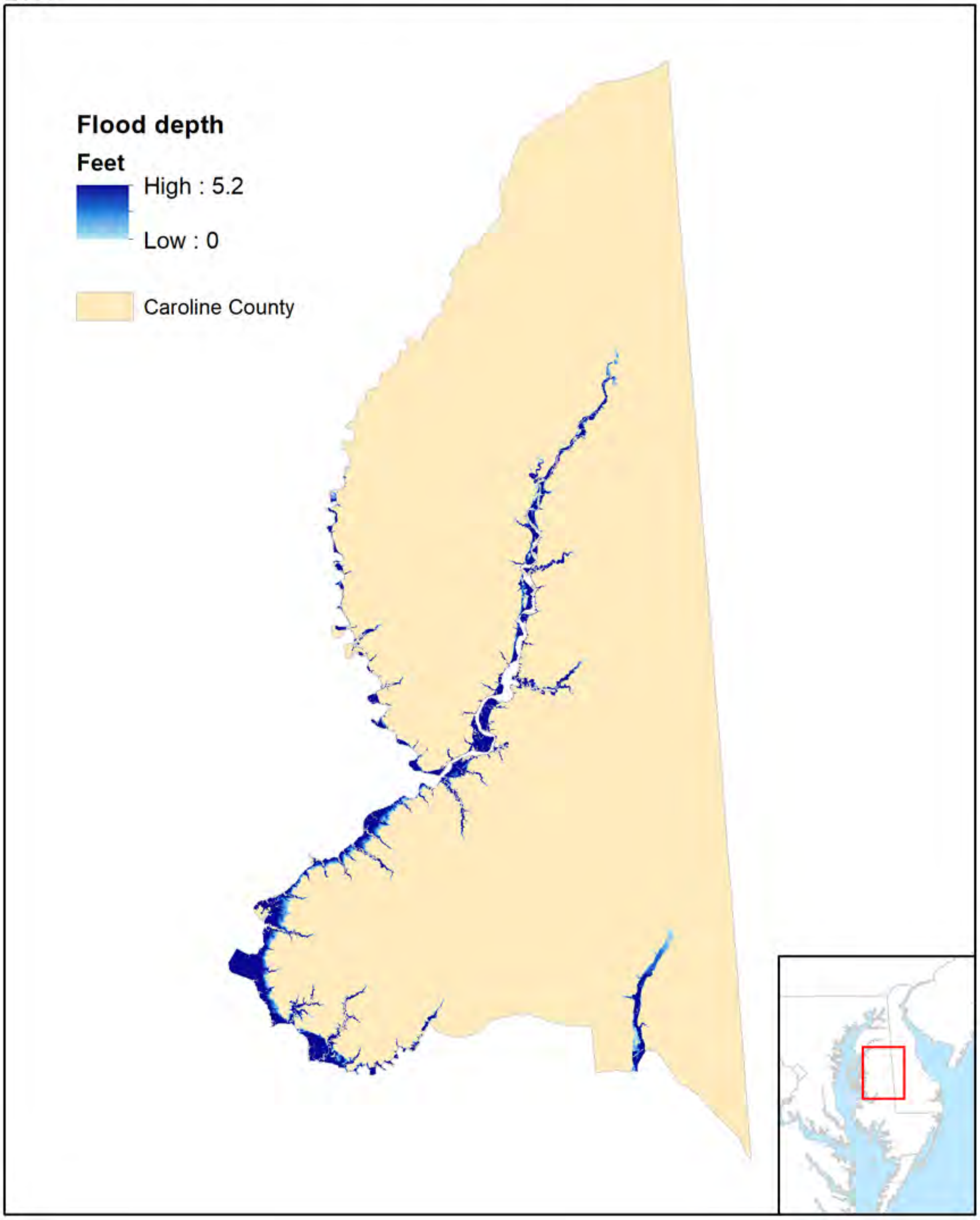


Figure 7 Predicted flood depths for Caroline County 1% chance floodplain at MSL in 2100



Using these flood depth grids, those buildings that are vulnerable to flood water, and the degree to which they are vulnerable, were determined. Fortunately, Caroline County maintains a set of "addressable" building footprint polygons, separate from any outbuildings. Next, the average depth of flood water for each modeling scenario was calculated for each building by converting the depth grids to depth points and intersecting the building footprints and the depth points. Caroline County's 2015 tax parcels were then digitally overlaid, thus assigning attributes such as total assessed value of the improvements, the land use of the parcel (residential, commercial, etc), and the structure style (1 story, 2 story, apartments, etc) to the building footprint. Because the foundation heights are unknown, an assumption of a 24" foundation was made. Using that assumed foundation height, the flood depth above the first finished floor was calculated. The total value of the building and its contents was found, using industry-standard estimates of the contents value based on the use of the building (i.e. residential contents are 50% of the building value, while commercial contents are 100% of the building value). Finally, using the depth-damage curves provided by FEMA via the HAZUS-MH software, the potential damage percentage, and therefore the potential damage to both the building and its contents in 2015 dollars, for each building for each flood scenario was estimated.

It is important to note when viewing the following results that the numbers generated carry with them a degree of uncertainty. Nearly every component (the ground elevations, the flood heights, the foundation heights, the assessed value, etc.) has confidence constraints of various magnitudes. The HAZUS-MH model itself is a simplified version of the complex engineering models used to create the flood insurance rate maps. Having said that, considerable research has been conducted to review HAZUS-MH analysis results after an event and have found that the software does a reasonably good job of both predicting the depth of flood as well as the insured losses. But was with any simulation analysis, we recommend that these damage statistics be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Flood Results for Present-Day (2015)

The results of the analysis indicate that there are 82 buildings predicted to be impacted by a 1% chance flood in Caroline County (Table 3). However, a majority of them (53) would only experience minor nuisance flooding in this scenario; 18 (22%) would experience greater than 10% damage. Thus, the overall predicted damage percentage from this flood level is 4.6% of the total value of the structures and contents ($643,190 of damage from $14.0 million in value). When standardized per building, those buildings that are predicted to incur incidental damage are also the most valuable (an average of $179,528 per building damaged less than 10% vs $141,539 per building that are damaged 10% or greater). It is also worth noting that a significant mitigation opportunity exists. There are only 2 buildings predicted to be damaged between 20 and 40% in the 1% chance event. That represents less than 3% of the total number of vulnerable buildings but they represent over 45% of the potential damage in the county from the 1% chance flood. Working to make those two structures less vulnerable to flooding should yield considerable financial benefits.

The spatial distribution of the structures vulnerable to the 1%-chance flood event follows a predictable pattern, all along the Choptank River (Figure 8). While there are a few in Greensboro and in West Denton, the majority are found in and around Providence Landing, Tanyard, and the village of Choptank – all in southeastern Caroline County.

The very severe 0.2% chance flood event represents a current worst-case scenario for Caroline County (Table 4). In such an event, 117 buildings would be impacted with 33 impacted moderately (10 – 50%). The total value of the structures and their contents that are vulnerable to flooding expands to $20.2 million and the potential damage is calculated to be $1.4 million, or 2.2x that of the 1% chance event. The number of buildings that are minimally affected (62) drops by more than 11% as a percentage of the total vulnerable buildings (64.6% in 1%-chance scenario vs. 53.0% in the 0.2%-chance). This indicates that in such a severe flood, the water is reaching many structures not previously impacted. These people tend to be less prepared for flooding because in less severe flood magnitudes, water does not reach them.

Table 3. Potential damage to structures/contents from a 1% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	53	64.6%	$9,314,354	$175,742	$804	$161	0.1%
1 - 10%	11	13.4%	$2,175,452	$197,768	$115,615	$10,510	18.0%
10 - 20%	16	19.5%	$1,579,502	$98,719	$233,196	$14,575	36.3%
20 - 30%	1	1.2%	$459,600	$459,600	$107,636	$107,636	16.7%
30 - 40%	1	1.2%	$508,600	$508,600	$185,938	$185,938	28.9%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	82	100.0%	$14,037,508	$171,189	$643,190	$18,917	100.0%

Note: All dollar values are from 2015 tax assessments.

Figure 8 Spatial distribution of vulnerable structures in Caroline County 1% chance flood at MSL in 2015 (n=82)

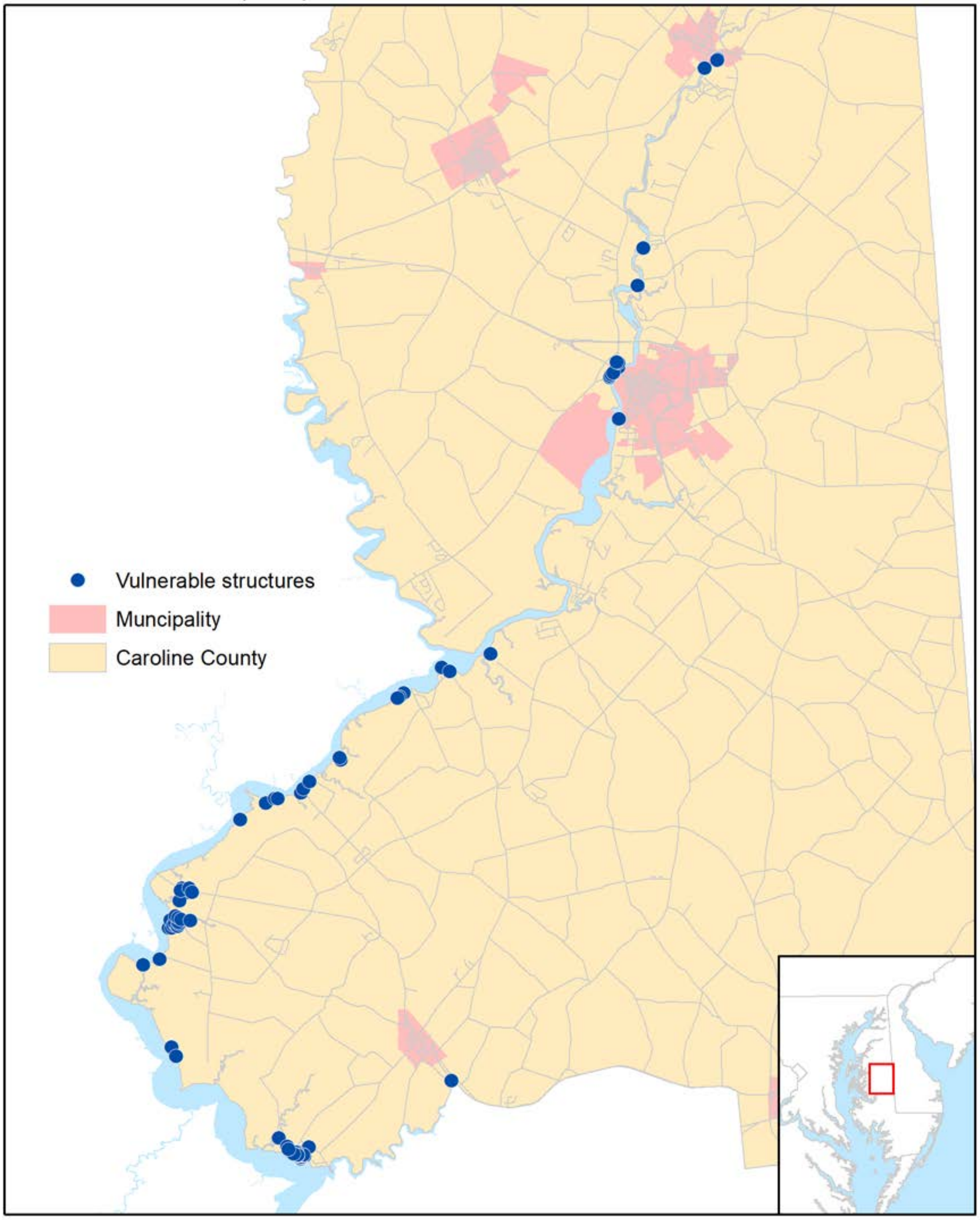


Table 4. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	62	53.0%	$11,228,705	$134,281	$8,184	$818	0.6%
1 - 10%	22	18.8%	$3,112,807	$141,491	$170,420	$7,746	12.0%
10 - 20%	19	16.2%	$2,715,302	$142,911	$341,959	$17,998	24.1%
20 - 30%	12	10.3%	$2,195,502	$182,958	$536,485	$44,707	37.8%
30 - 40%	1	0.9%	$459,600	$459,600	$139,808	$139,808	9.8%
40 – 50%	1	0.9%	$508,600	$508,600	$224,083	$224,083	15.8%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	117	100.0%	$20,220,516	$172,825	$1,420,939	$21,861	100.0%

Note: All dollar values are from 2015 tax assessments.

When the potential damage was also examined with respect to land use, it was found that no matter the scenario, the vast majority all of buildings vulnerable to flooding in Caroline County were residential, ranging from 79.3% in the 1% chance scenario (Table 5) to 81.2% in the 0.2% chance scenario (Table 6). The second largest category was commercial buildings, ranging from 15.9% in the 1% chance scenario to 13.7% in the 0.2% chance scenario. In the 1% chance scenario, the majority of the damage (47.7%) comes from residential buildings, which is to be expected given the number of residential buildings affected. However, given that (relatively) few commercial buildings are predicted to be impacted, it is concerning that they account for 35.6% of the predicted damage. This suggests that suggesting mitigation actions that are targeted at Caroline County business owners might yield the best results.

Table 5. Potential damage to structures/contents from a 1% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	65	79.3%	$10,877,052	$306,734	2.8%	47.7%
Commercial	13	15.9%	$1,472,604	$228,819	15.5%	35.6%
Government	3	3.7%	$1,639,602	$107,636	6.6%	16.7%
Industry	1	1.2%	$48,250	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	82	100.0%	$14,037,508	$643,190	4.6%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 6. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	95	81.2%	$16,009,258	$703,394	4.4%	49.5%
Commercial	16	13.7%	$2,516,804	$281,471	11.2%	19.8%
Government	5	4.3%	$1,646,204	$436,074	26.5%	30.7%
Industry	1	0.9%	$48,250	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	117	100.0%	$20,220,516	$1,420,939	7.0%	100.0%

Note: All dollar values are from 2015 tax assessments.

One final way to break down the countywide vulnerability results is to examine them by property value. The following tables explore the vulnerability of the buildings based on the values of the structure and its contents (Tables 7 & 8). Each flooding scenario presents remarkably consistent results and thus there are some overall impressions. First, in both flood scenarios, the mid-range valuable properties ($400K -$1M) suffer more damage, relative to their value. However, in the more extreme 0.2% chance scenario, more valuable properties ($1M - $2M) generate the most damage. Because we are dealing with such small numbers (just 1 property in the previous category), no reasonable generalizations can be drawn. One conclusion that can be made is that the damage from both scenarios is distributed more or less evenly across all property value categories. This suggests that these floods will damage many different areas and are felt by working-class, middle-class, and upper-class neighborhoods alike.

Table 7. Potential damage to structures/contents from a 1% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	12	14.6%	$173,883	$2,876	1.7%	0.4%
$50 - $100	25	30.5%	$1,792,400	$80,940	4.5%	12.6%
$100 - $200	25	30.5%	$3,652,650	$155,411	4.3%	24.2%
$200 - $300	6	7.3%	$1,343,850	$35,555	2.6%	5.5%
$300 - $400	7	8.5%	$2,579,100	$78,833	3.1%	13.6%
$400 - $500	1	1.2%	$459,600	$107,636	23.4%	16.7%
$500 - $1,000	5	6.1%	$2,856,025	$185,938	6.5%	28.9%
$1,000 - $2,000	1	1.2%	$1,118,000	$0	0.0%	0.0%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	82	100.0%	$14,037,508	$643,190	4.6%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 8. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	20	17.1%	$272,241	$14,887	5.5%	1.0%
$50 - $100	32	27.4%	$2,268,350	$162,045	7.1%	11.4%
$100 - $200	32	27.4%	$4,748,400	$275,296	5.8%	19.4%
$200 - $300	12	10.3%	$2,772,550	$146,658	5.3%	10.3%
$300 - $400	10	8.5%	$3,669,450	$139,514	3.8%	9.8%
$400 - $500	3	2.6%	$1,381,500	$139,808	10.1%	9.8%
$500 - $1,000	7	6.0%	$3,928,025	$246,465	6.3%	17.3%
$1,000 - $2,000	1	0.1%	$1,180,000	$296,265	25.1%	20.8%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	117	100.0%	$20,220,516	$1,420,939	7.0%	100.0%

Note: All dollar values are from 2015 tax assessments

Sea level Rise Inundation in 2050 and 2100

Unfortunately, we know that the water levels in the Chesapeake Bay that feed this periodic tidal flooding are not static – they are quite dynamic. Scientists at the USGS estimate that mean sea level in the Bay was about 2 feet lower when Captain John Smith first mapped it in 1608 (Larsen, 1998; https://pubs.usgs.gov/fs/fs102-98/). The Mid-Atlantic region is predicted to be one of the most affected by sea level change going forward because of the presence of the combination of eustatic sea level rise, thermal expansion of sea water as the earth warms, the slowdown of the North Atlantic gyre, and the subsidence of the land surface from the glacial isostatic rebound. The current sea level trend, measured from 1937 to 2015 at the Solomons Island tide gauge is 3.74 mm/year or 1.23 ft in 100 years.

However, scientists do not think that a linear trend will continue. The rate is expected to increase. The models used in this flood mitigation plan follow the same method used by the Maryland State Highway Administration to document the potential flood vulnerability of the road infrastructure from periodic flooding in 2050 and 2100. For that method, the "high" estimates of sea level change from the US Army Corps of Engineers was chosen as the appropriate planning scenario. For Caroline County, this means the USACE expects an estimated mean sea level increase of 2.11 ft by 2050 and 5.78 ft by 2100 (Figures 4 & 5).

Using these elevated mean sea levels of 2050 and 2100, additional analyses were conducted of the vulnerability of the built environment from only inundation without any periodic flooding. It should be noted that these inundation damage estimates are not particularly appropriate for non-periodic flooding. They are included here primarily for comparison's sake. If the buildings predicted to be inundated constantly by a rise in mean sea level were not elevated beyond the reach of the water, the damage done to them would be a great deal more severe.

As the 2050 mean sea level inundation results show (Table 9), Caroline County is largely protected. Only 4 buildings are predicted to experience water in the footprint of their structure and all of them are not predicted to be damaged to any quantifiable degree. These are building footprints intersecting with less than 6" of water. The spatial distribution of the properties shows three in West Denton and one at Gilpin Point (Figure 9). By 2100, the situation has changed dramatically – the number of buildings at risk from inundation increased 26x, from 4 in 2050 to 105 in 2100 (Table 10). Those 105 buildings represent $17.9 million in structure and content value. Again, the prediction of damage in the scenario is very uncertain as the processes that cause inundation damage are quite different than periodic flood damage. However, an overall damage rate of 7.4% is very concerning. With regard to the spatial distribution of the structures predicted to be inundated in 2100 (Figure 10), the pattern is remarkably consistent with those areas subject to the 0.2%-chance flood in 2015.

Table 9. Potential damage to structures/contents from mean sea level inundation in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	4	100.0%	$837,350	$209,337	$0	$0	0.0%
1 - 10%	0	0.0%	$0	$0	$0	$0	0.0%
10 - 20%	0	0.0%	$0	$0	$0	$0	0.0%
20 - 30%	0	0.0%	$0	$0	$0	$0	0.0%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	4	100.0%	$837,350	$209,337	$0	$0	100.0%

Note: All dollar values are from 2015 tax assessments

Table 10. Potential damage to structures/contents from mean sea level inundation in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	52	49.5%	$9,331,183	$179,446	$0	$0	0.0%
1 - 10%	27	25.7%	$4,203,825	$155,697	$323,781	$11,992	24.3%
10 - 20%	15	14.3%	$1,399,454	$93,297	$208,213	$13,881	15.6%
20 - 30%	10	9.5%	$2,500,950	$250,095	$590,308	$59,031	44.3%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	1	0.1%	$508,600	$508,600	$209,713	$209,713	15.7%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	105	100.0%	$17,944,012	$170,895	$1,332,015	$12,686	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 9 Spatial distribution of vulnerable structures in Caroline County, no flood at MSL in 2050 (n=4)

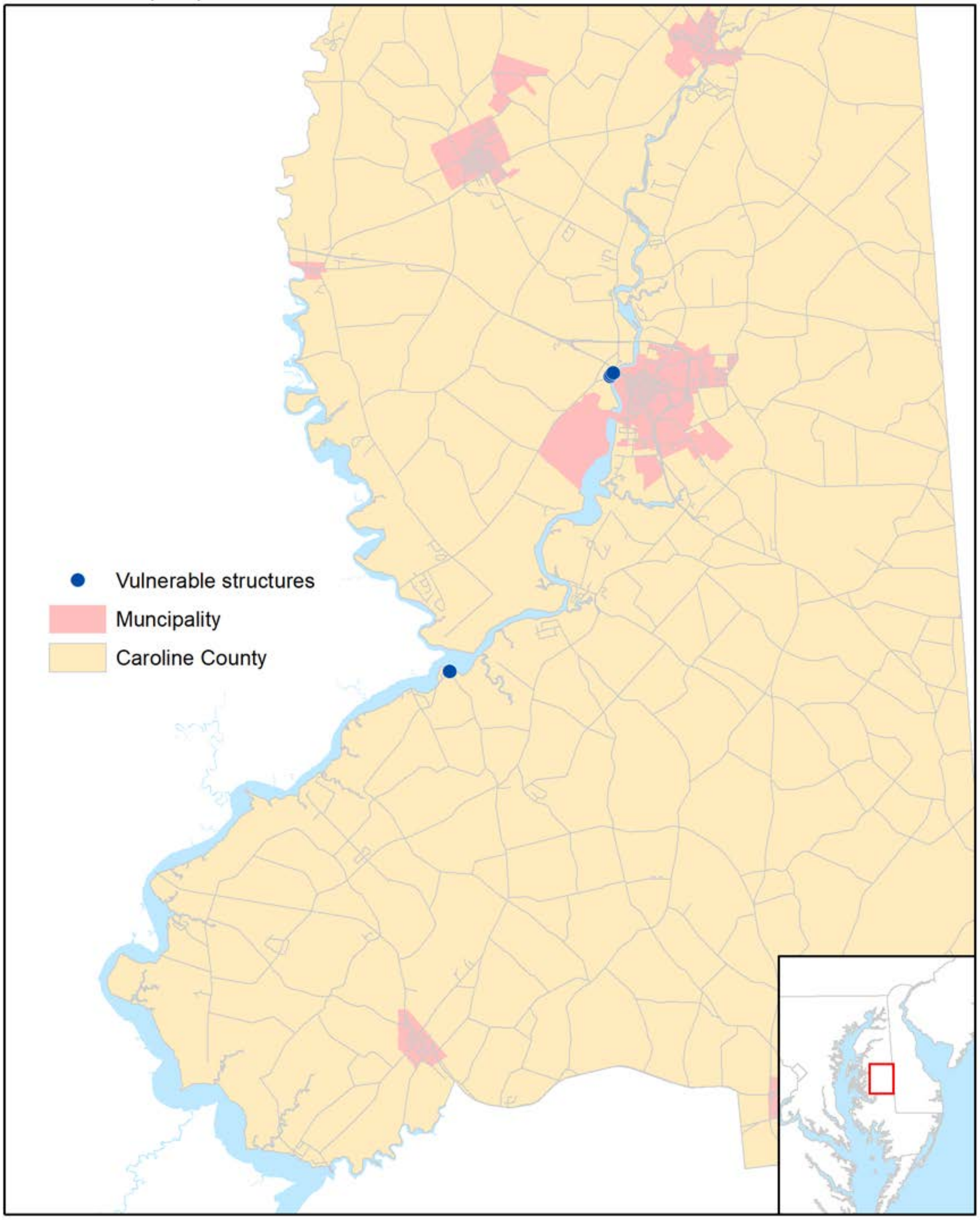
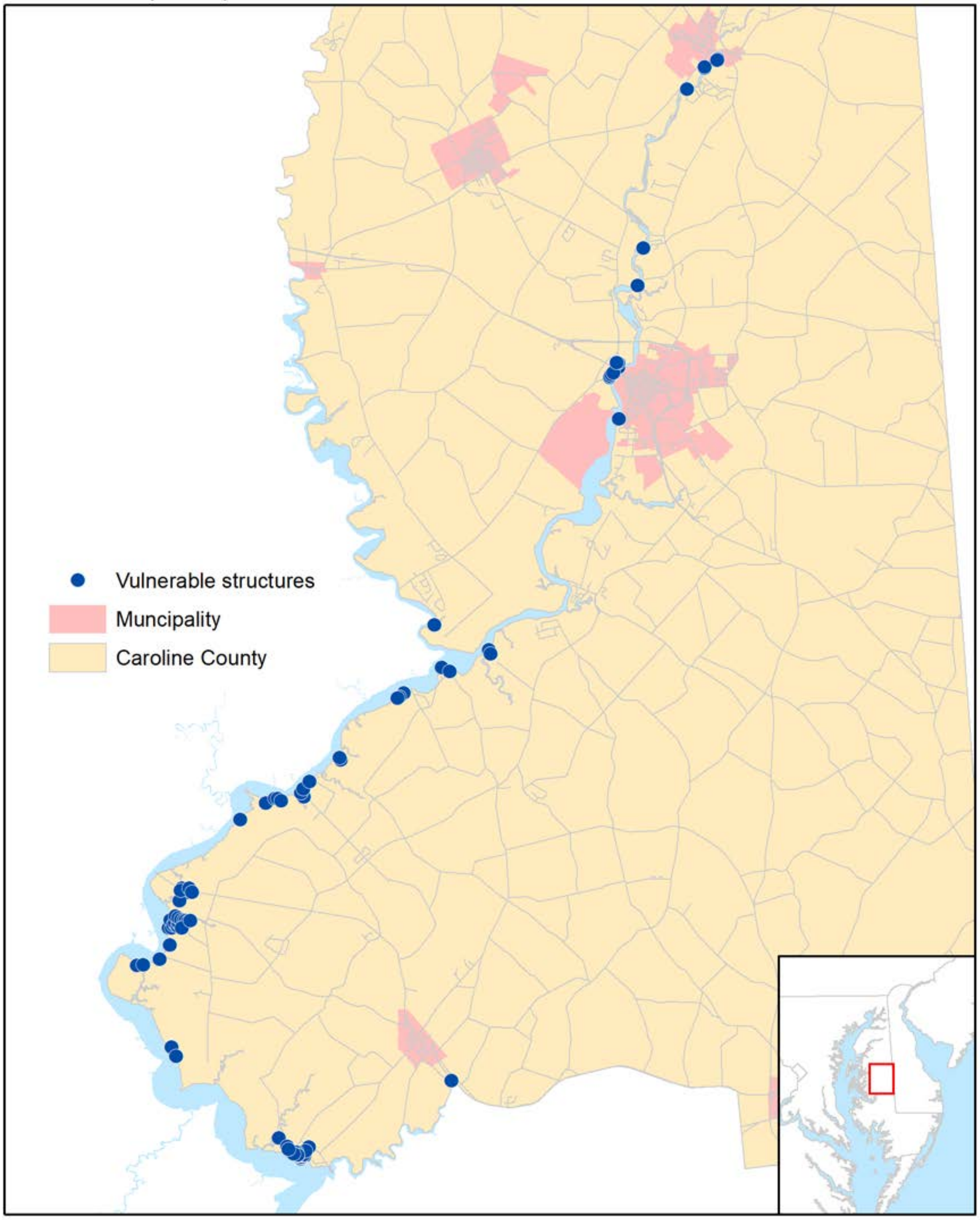


Figure 10 Spatial distribution of vulnerable structures in Caroline County, no flood at MSL in 2100 (n=105)



When considering the inundation amount versus the use of buildings, the impact from sea level change in 2050 was 25% residential and 75% commercial (Table 11). Of course, with such a small number of buildings, this division should be viewed with skepticism. By 2100 however, it becomes clear that sea level change in Caroline County will be disproportionately felt by residents, with 81% of all of structures being inundated as residential (Table 12). Interestingly, the government properties of Caroline County bear a disproportionate damage burden, given their (relatively) small exposure.

Table 11. Potential damage to structures/contents from mean sea level inundation in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1	25.0%	$175,950	$0	0.0%	0.0%
Commercial	3	75.0%	$661,400	$0	0.0%	0.0%
Government	0	0.0%	$0	$0	0.0%	0.0%
Industry	0	0.0%	$0	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	4	100.0%	$837,350	$0	0.0%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 12. Potential damage to structures/contents from mean sea level inundation in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	85	81.0%	$13,995,356	$694,659	4.9%	52.2%
Commercial	15	14.3%	$2,254,204	$262,859	11.7%	19.7%
Government	4	3.8%	$1,646,202	$374,496	22.7%	28.1%
Industry	1	0.1%	$48,250	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	105	100.0%	$17,944,012	$1,332,015	7.4%	100.0%

Note: All dollar values are from 2015 tax assessments.

When examining the vulnerability of Caroline County's structure by the property value, the results in 2050 show no significant pattern (Table 13). In 2100 however (Table 14), the results are bimodal. A bit over one-third of the damage from sea level inundation will be experienced by modest properties ($50K - $200K) and a bit over one-third of the damage will be felt by relatively valuable properties ($500K - $2M). Those modest homes will be unlikely to have the financial resources to mitigate the potential threat, but the more expensive properties may have a larger impact on Caroline County's economy.

Table 13. Potential damage to structures/contents from mean sea level inundation in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	0	0.0%	$0	$0	0.0%	0.0%
$50 - $100	2	50.0%	$152,800	$0	0.0%	0.0%
$100 - $200	1	25.0%	$175,950	$0	0.0%	0.0%
$200 - $300	0	0.0%	$0	$0	0.0%	0.0%
$300 - $400	0	0.0%	$0	$0	0.0%	0.0%
$400 - $500	0	0.0%	$0	$0	0.0%	0.0%
$500 - $1,000	1	25.0%	$508,600	$0	0.0%	0.0%
$1,000 - $2,000	0	0.0%	$0	$0	0.0%	0.0%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	4	100.0%	$837,350	$0	0.0%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 14. Potential damage to structures/contents from mean sea level inundation in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	17	16.2%	$243,437	$12,921	5.3%	0.9%
$50 - $100	31	29.5%	$2,207,150	$157,333	7.1%	11.8%
$100 - $200	30	28.6%	$4,466,850	$334,255	7.5%	25.1%
$200 - $300	9	8.6%	$2,091,300	$119,908	5.7%	9.0%
$300 - $400	8	7.6%	$2,880,000	$123,387	4.3%	9.3%
$400 - $500	2	0.2%	$947,250	$127,234	13.4%	9.6%
$500 - $1,000	7	0.7%	$3,928,025	$209,713	5.3%	15.7%
$1,000 - $2,000	1	0.1%	$1,118,000	$247,262	22.1%	18.6%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	105	100.0%	$17,944,012	$1,332,015	7.4%	100.0%

Note: All dollar values are from 2015 tax assessments

In the event that the USACE's predictions come to pass, the 2.11 ft rise in MSL will significantly impact the flood vulnerability of Caroline County (Table 15). In the 1%-chance flood scenario, the number of buildings impacted will increase by over 224% (from 82 to 184). Additionally, the number of buildings with moderate-severe damage (between 30 – 50%), spiked by 6x, rising from 1 to 6 and from a total value of $508,600 to nearly $2.2 million. Thankfully, only 1 is predicted to be severely damaged (greater than 50%). The total amount of building and contents value vulnerable to flooding will more than double from $14.0 million to $35.8 million and the amount of potential damage will increase 3.7x from $643,190 to $2.4 million. The spatial distribution of these vulnerable structures show the encroachment of many of the developed areas along the Choptank River, Tuckahoe Creek, and Hunting Creek.

Of course, the prediction for the year 2100 (5.78 ft increase in MSL) must be considered highly uncertain. However, as of this writing, there is a growing consensus in the scientific community that the SLC estimates are more than likely too conservative, rather than too aggressive. Until that consensus solidifies, the current USACE estimate is still reasonable for planning purposes. Obviously, sea level being 5.7 ft higher in Caroline County 82 years from now will significantly impact much of the vulnerable coastal development (Table 16). The number of vulnerable buildings will increase by 772% (from 82 in 2015 to 633 in 2100), with about one-tenth of those buildings damaged greater than 30%. The number predicted to be severely damaged will go from 0 in 2015 to 1 in 2050 to 4 in 2100. While the amount of building and contents value vulnerable to flooding will increase 7.4x, from $14.0 million to $103.2 billion, the amount of potential damage will more than 14.8x from $643,190 to $9.5 million. The spatial distribution shows no appreciable change from the areas that are currently vulnerable – it is just that the flood waters both reach further inland increases in the number of structures potentially impacted in Caroline County but also increases the depth of flooding for those structures that are vulnerable now, increasing their potential damage (Figure 12).

Table 15. Potential damage to structures/contents from a 1% chance flood event in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	95	51.6%	$19,452,816	$204,766	$443	$40	0.0%
1 - 10%	30	16.3%	$7,069,997	$235,667	$388,191	$12,940	16.2%
10 - 20%	36	19.6%	$5,205,155	$144,588	$731,380	$20,316	30.6%
20 - 30%	16	8.7%	$1,822,600	$113,912	$475,280	$29,705	19.9%
30 - 40%	6	3.3%	$2,248,004	$374,667	$792,515	$132,086	33.1%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	1	0.1%	$8,850	$8,850	$4,751	$4,751	0.2%
Total	184	100.0%	$35,807,422	$194,606	$2,392,560	$23,926	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 11 Spatial distribution of vulnerable structures in Caroline County, 1% chance flood at MSL in 2050 (n=184)

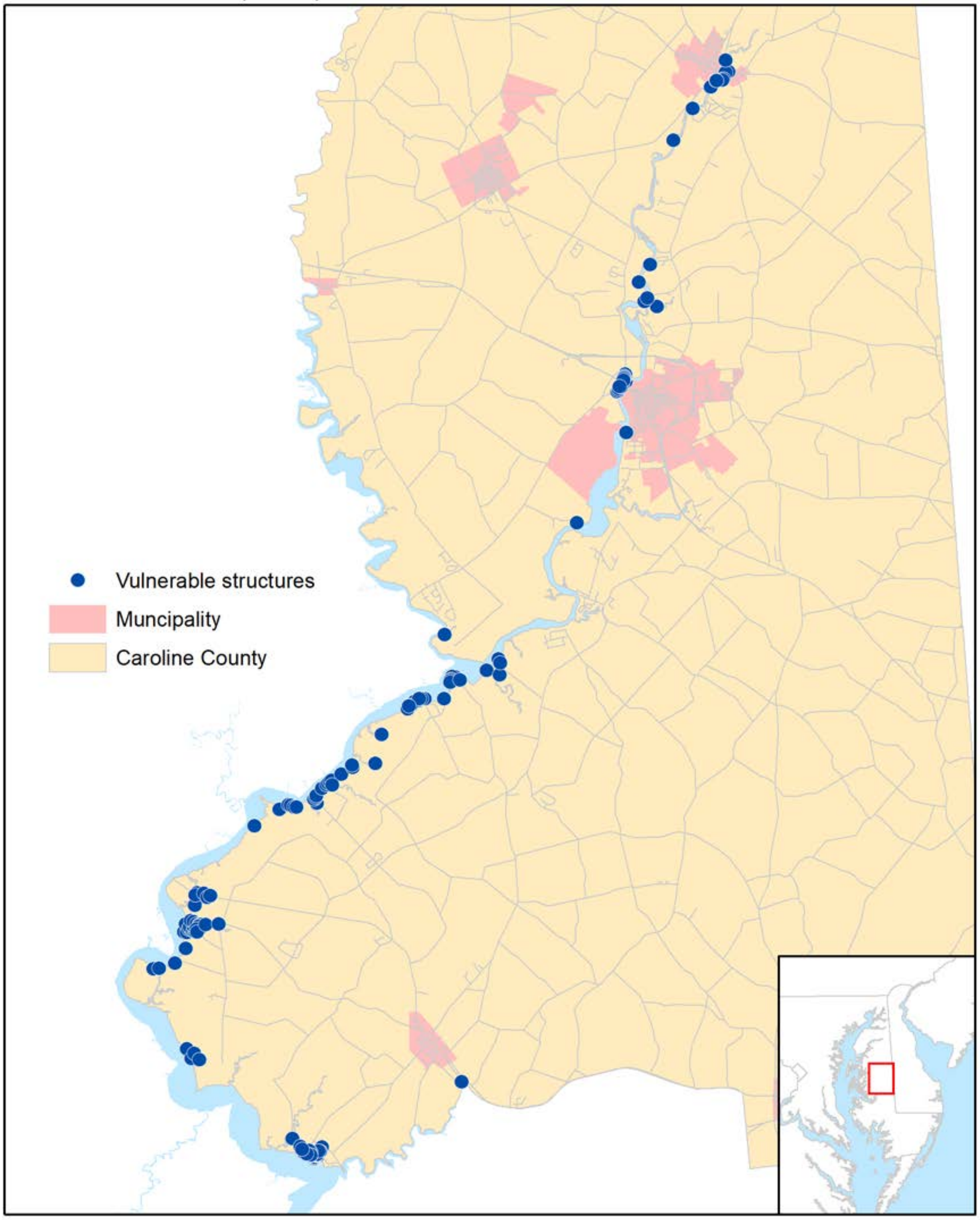


Table 16. Potential damage to structures/contents from a 1% chance flood event in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	292	46.1%	$50,557,170	$173,141	$9,392	$32	0.1%
1 - 10%	83	13.1%	$12,656,335	$152,486	$777,365	$9,366	8.1%
10 - 20%	121	19.1%	$21,194,725	$175,163	$3,351,498	$27,698	35.1%
20 - 30%	76	12.0%	$11,520,656	$151,588	$2,797,651	$36,811	29.3%
30 - 40%	51	8.1%	$5,218,566	$102,325	$1,696,557	$33,266	17.8%
40 – 50%	6	0.9%	$1,816,225	$302,704	$754,267	$125,711	7.9%
50% or more	4	0.6%	$232,350	$58,087	$162,983	$40,746	1.7%
Total	633	100.0%	$103,196,027	$163,027	$9,549,711	$15,086	100.0%

Note: All dollar values are from 2015 tax assessments

As for the spatial distribution of the flood threat in the two sea level change scenarios, it is a reasonable generalization to say that one can simply expect existing flood prone areas to flood more often, can expect deeper flood water when it does flood, and that areas adjacent to currently threatened areas are most likely to be newly-inundated. Maps of the 1% chance flood in 2050 and 2100 in the Tanyard area on the Choptank River in the southern part of the county have been included as an example of what most vulnerable areas in Caroline County could expect (Figures 8 & 9). In the comparison of 2015 and 2050, the predicted 1% chance flood includes more buildings as vulnerable that are adjacent to the current flood area. But primarily, the 1% flood in 2050 will be more severe than today, thus yielding many more buildings in higher predicted damage categories. By contrast, the comparison of 2015 and 2100 shows not only a significantly more severe 1% chance flood, but a significant expansion of the vulnerable zone. The data from this analysis will be delivered to County officials so that they can map any area of the county this way, but Tanyard’s patterns are very typical of other areas in the county.

Figure 12 Spatial distribution of vulnerable structures in Caroline County, 1% chance flood at MSL in 2100 (n=633)

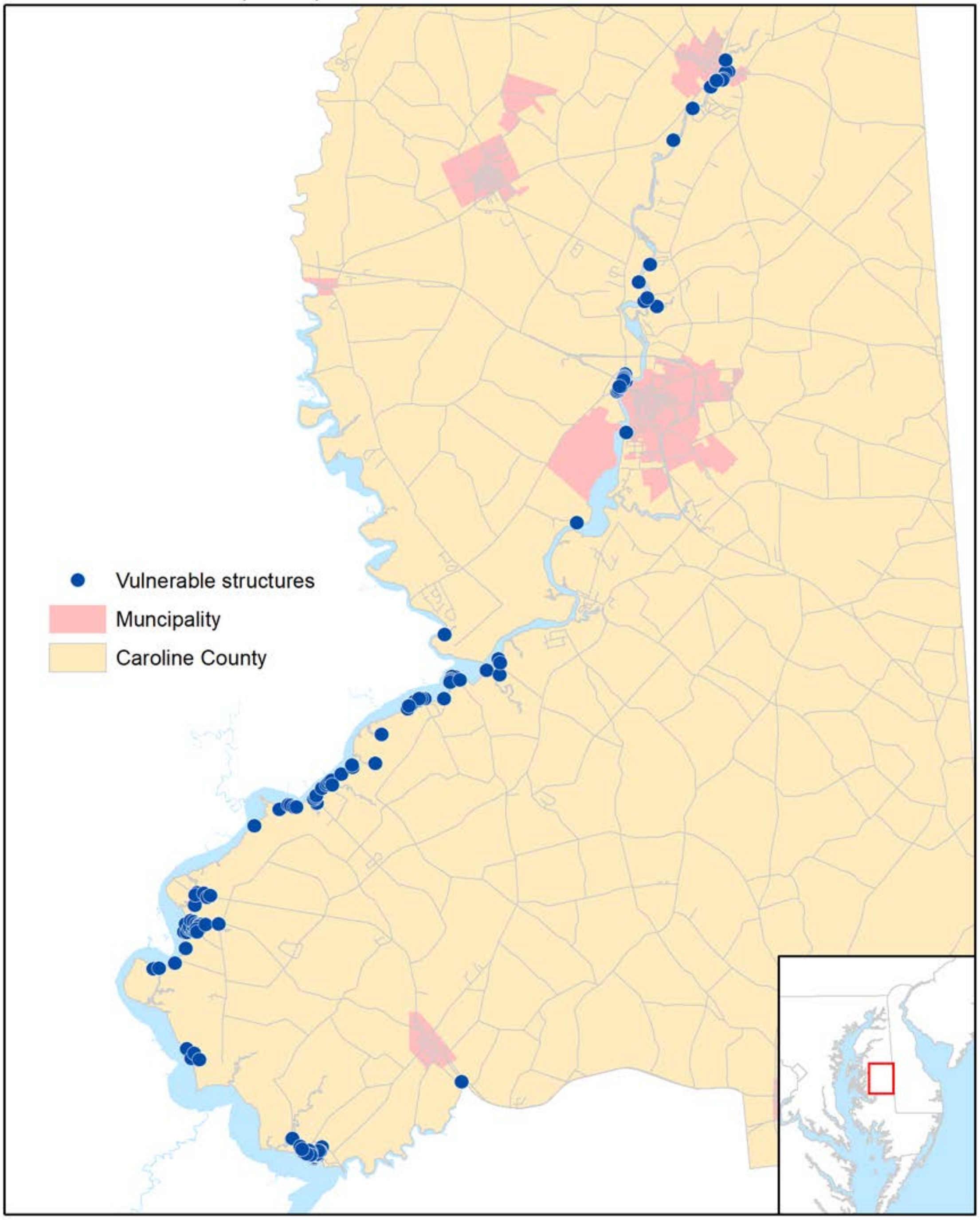


Figure 13 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2050, Tanyard, Maryland

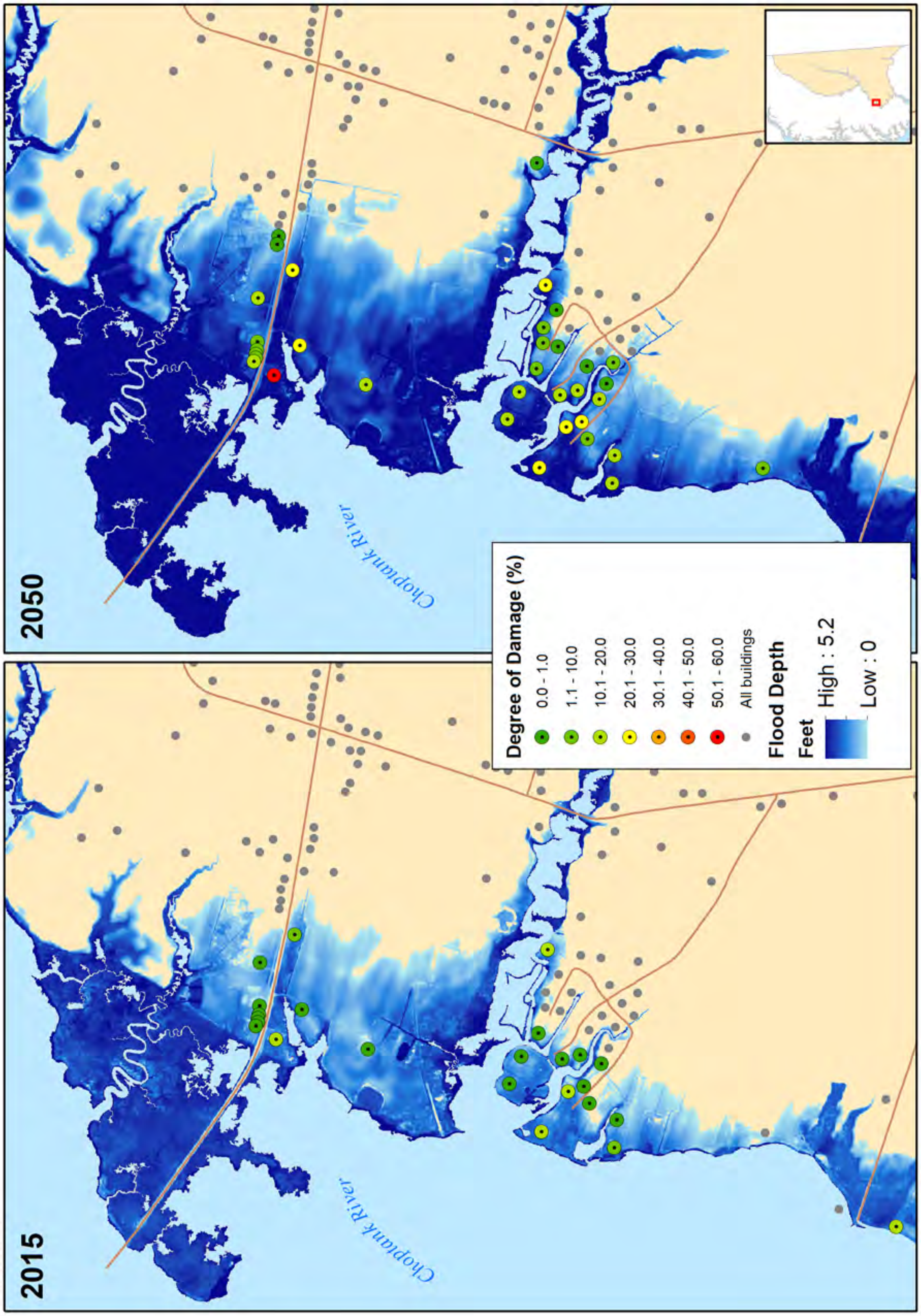
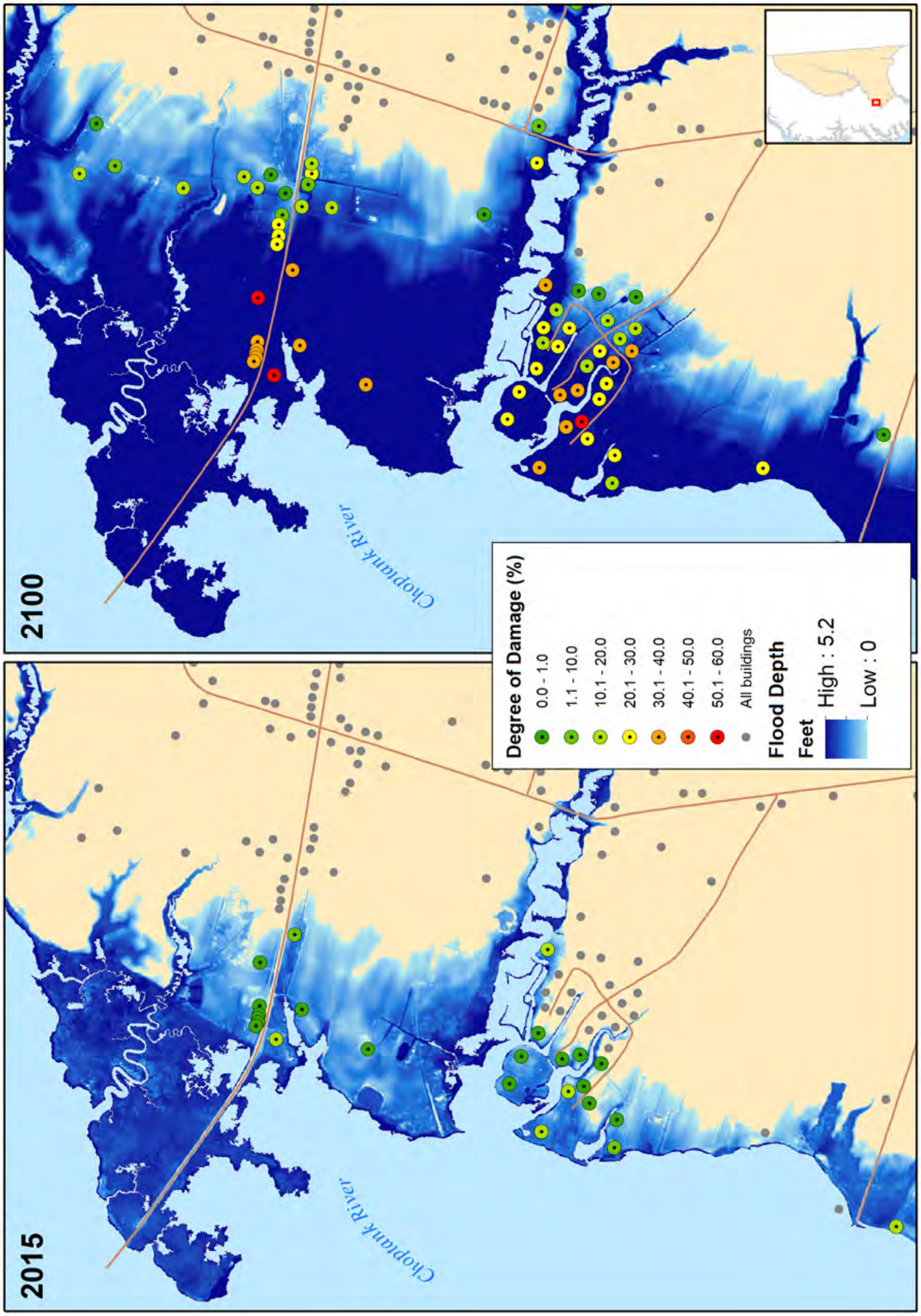


Figure 14 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2100, Tanyard, Maryland



The patterns of damage from flooding in the future when considering the use of the property are very similar to the results in 2015 (Table 17 and 18). The primary differences are that the flood event in 2050 pulls in 2 religious buildings that were not previously vulnerable (with a value of $4.4 million) and the 1% flood event in 2100 impacts an additional 4 religious buildings and 2 agricultural buildings. The other key takeaway is that nearly 65% of the flood damage in 2050 will be residential, rather than a large commercial impact in 2015. That shift of burden away from commercial, governmental, and industrial land uses toward residential strengthens by 2100, with 81.2% of all of the structures impacted and 76.3% of all of the damage is coming from the residential sector.

Table 17. Potential damage to structures/contents from a 1% chance flood event in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	145	78.8%	$24,886,308	$1,538,427	6.2%	64.3%
Commercial	30	16.3%	$4,816,808	$290,663	6.0%	12.1%
Government	6	3.3%	$1,646,206	$563,471	34.2%	23.6%
Industry	1	0.5%	$48,250	$0	0.0%	0.0%
Religious	2	1.1%	$4,409,850	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	184	100.0%	$35,807,422	$2,392,560	6.7%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 18. Potential damage to structures/contents from a 1% chance flood event in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	514	81.2%	$74,224,647	$7,283,518	9.8%	76.3%
Commercial	95	15.0%	$17,472,212	$1,576,323	9.0%	16.5%
Government	12	1.9%	$4,514,212	$681,398	15.1%	7.1%
Industry	4	0.6%	$587,752	$8,338	1.4%	0.1%
Religious	6	0.9%	$6,397,200	$136	0.0%	0.0%
Agricultural	2	0.3%	$4	$0	0.0%	0.0%
Total	633	100.0%	$103,196,027	$9,549,711	9.2%	100.0%

Note: All dollar values are from 2015 tax assessments.

In general, the distribution of vulnerability by property value does not change considerably once sea level change is added in 2050 (Table 19). Of course, the raw numbers of structures increases but the proportion of them that fall into the separate categories are remarkably similar. A divergence happens, however, when looking at the distribution of damage. In a 1%-chance flood scenario in 2050, the damage predicted for the more valuable buildings ($1 million to $2 million) increased from nothing in 2015 to only 16.2% in 2050. This an interesting result as it is the same building impacted in both scenarios but in 2015 the flood is not deep enough to cause damage, but adding the 2.08 ft of sea level makes it so. By 2100, over one-half of the predicted damage from a 1% chance event will be borne by properties worth between $100,000 and $300,000 (Table 20). It is also important to note that these are 2015 property values. If the rate of inflation for the next 85 years is the same as the last 85 ($1 in 1930 is worth $13.96 in 2015, according to the Consumer Price Index), the total property value at risk from flooding would be over $1.4 billion.

Table 19. Potential damage to structures/contents from a 1% chance flood event in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	27	14.7%	$365,147	$29,709	8.1%	1.2%
$50 - $100	49	26.6%	$3,538,800	$290,819	8.2%	12.2%
$100 - $200	57	31.0%	$8,408,400	$637,744	7.6%	26.7%
$200 - $300	20	10.9%	$4,735,750	$299,187	6.3%	12.5%
$300 - $400	13	7.1%	$4,668,300	$233,373	5.0%	9.8%
$400 - $500	5	2.7%	$2,275,550	$209,885	9.2%	8.8%
$500 - $1,000	11	6.0%	$6,226,675	$373,892	6.0%	15.6%
$1,000 - $2,000	1	0.1%	$1,118,000	$387,951	34.7%	16.2%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	1	0.1%	$4,408,800	$0	0.0%	0.0%
Total	184	100.0%	$35,807,422	$2,392,560	6.7%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 20. Potential damage to structures/contents from a 1% chance flood event in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	98	15.5%	$2,042,677	$178,149	8.7%	1.9%
$50 - $100	183	28.9%	$13,193,700	$1,214,043	9.2%	12.7%
$100 - $200	211	33.3%	$30,008,050	$2,855,979	9.5%	29.9%
$200 - $300	67	10.6%	$16,348,550	$1,834,521	11.2%	19.2%
$300 - $400	32	5.1%	$11,192,950	$1,058,442	9.5%	11.1%
$400 - $500	14	2.2%	$6,248,450	$665,834	10.7%	7.0%
$500 - $1,000	21	3.3%	$12,462,000	$1,254,224	10.1%	13.2%
$1,000 - $2,000	6	0.9%	$7,290,850	$488,520	6.7%	5.2%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	1	0.2%	$4,408,800	$0	0.0%	0.0%
Total	633	100.0%	$103,196,027	$9,549,711	9.2%	100.0%

Note: All dollar values are from 2015 tax assessments

Study Caveats

It should not go without mentioning that the prediction of the flood threat with a future sea level change has more than the normal level of uncertainty. Not only are the estimates of sea level change not a foregone conclusion, but the nature of the flood threat itself is likely to change. For example, in a world with oceans that are 2 (or 5) feet higher, the controlling forces (subtropical high pressure systems, ocean upwelling, thermal heat transfer, etc.) of tropical storms are likely to be different. Thus, the periodicity of certain magnitudes of storm events could change. Similarly, this analysis uses statistical/stochastic models, not a dynamic simulations. Therefore, it does not take into account either individual storm parameters or geographic parameters such as land cover or the shape of the near-shore bottom, both of which will impact the flood predication and both are likely to change in a rising sea level scenario.

With regard to vulnerability estimates, there are also a number of important caveats to remember. First, this analysis assumes that all of the built infrastructure would be exactly as one found it in 2015. That is almost certainly not going to be the case, both with new structures being built and older structures being made more flood-resistant as the waters rise. Second, as mentioned above, the potential damage is being evaluated as if property values will not change by 2050 or 2100 – also not the case. Finally, this vulnerability analysis deliberately examined only damage to structural/contents because the relationship between building damage and depth of water is best understood. There are still many other sources of potential vulnerability: infrastructure damage/loss (both to rebuild and its impact on restarting the economy after a disaster), loss of productivity with businesses closed, debris removal, other consumer losses (cars, boats, sheds/garages), and of course, the potential loss of life.

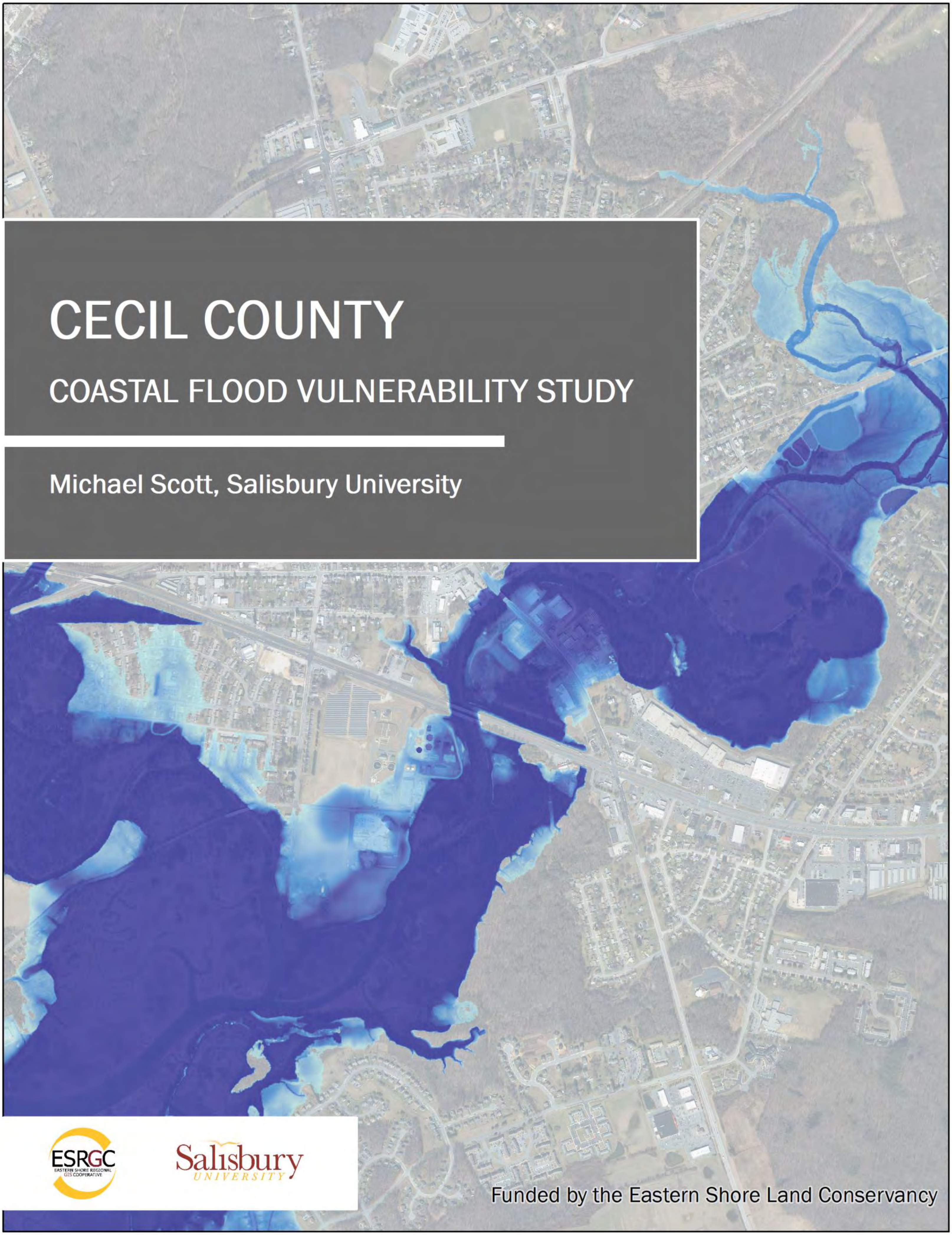
Conclusions

Several conclusions can be made regarding the question of coastal flooding vulnerability in Caroline County. It is certainly true that Caroline County is the least vulnerable to sea level rise and coastal flooding of any county on Maryland's Eastern Shore. Its lack of direct access to the Chesapeake Bay assures that. However, it would be a mistake to think that this threat is not worth mitigating. While only 0.6% of Caroline County's 14,539 improved structures are vulnerable to a flood threat today, that increases 8-fold to 4.4% in 2100. Additionally, southern Caroline County has not seen the development pressure that Queen Anne's and Talbot Counties have – yet. It does seem inevitable as the trends of suburbanization continue, the relatively inexpensive land along very scenic rivers are likely primed for development. It is very fair to say that sea level change will take Caroline County from one that does not have a significant coastal flood threat to one that does. That adjustment, and its impact on development expectations, is going to take some time to internalize. The relative good news is that Caroline County does have some time to adjust. If they do, and implement flood-smart building strategies before the situation has a chance to escalate, they can escape the worst of the flooding impacts and likely attract residents and businesses who have decided that building along the edge of the Bay no longer makes economic sense.

CECIL COUNTY

COASTAL FLOOD VULNERABILITY STUDY

Michael Scott, Salisbury University



ESRGC EASTERN SHORE REGIONAL GIS COOPERATIVE

Salisbury UNIVERSITY

Funded by the Eastern Shore Land Conservancy

Executive Summary

Given the topography and historical development patterns of Maryland's Eastern Shore, the potential for damage from periodic flood events caused by coastal storms and extreme high tides is well-known. What is uncertain is the degree to which the vulnerability of Eastern Shore communities is increasing as sea levels change in the Chesapeake Bay and its tributaries. Therefore, the goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. The methods employed in this research are considered best practices, are accepted by FEMA and provide a consistent framework for assessing risk from floods. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the county and help make informed decisions about mitigation measures to reduce the potential impacts. Having said that, we recommend that the damage statistics in this report be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Results of the analysis predict that 709 buildings (worth $248.7 million in both the structure and its contents) would feel the impacts of a 1%-chance flood in Cecil County, with 270 of them experiencing more than 10% damage, for a total predicted damage of $13.8 million. It is worth noting that a significant mitigation opportunity exists. There are 148 buildings predicted to be damaged between 20 and 30% in the 1% chance event. That represents one-fifth of the total number of vulnerable buildings but they represent nearly two-thirds of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits. The much more severe 0.2%-chance flood impacts 1,037 buildings in the county valued at $326.0 million with 500 damaged moderately with a total potential damage of $28.7 million. Given that greater than 80% of the potentially damaged buildings are residential, instigating mitigation actions that are targeted at Cecil County homeowners might yield the best results.

In Cecil County, the magnitude of predicted sea level rise for the remainder of this century is slightly less than in the middle or lower part of the DelMarVa Peninsula. The US Army Corps of Engineers expects an estimated mean sea level increase in the county of 1.98 ft by 2050 and 5.56 ft by 2100. Thankfully, the sea level rise itself will impact very few buildings – only 10 (worth $3.2 million in structure and contents) by 2050 and 332 (worth $78.2 million). This is because the geomorphological character of Cecil County, located along the eastern edge of the Piedmont Plateau. Because the land rises away quickly from the rivers and the Chesapeake Bay, many structures will be untouched by a few feet of additional sea level.

However, when the 1% chance flood is combined with the predicted sea level rise, the vulnerability of the County's built environment is highlighted. In 2050, the 1% chance flood is predicted to impact 1,132 buildings (a 59.7% increase over the same scenario

today), worth $397.3 million (a 59.8% increase from today) and potentially causing $37.6 million in flood damage (a 172.5% increase from 2015). The same flood in 2100 could impact 2,141 buildings (a 89.1% increase from 2050) worth $650.1 million in value (a 63.6% increase from 2050) and cost a potential $141.3 million in damage (a 275.8% increase over the same estimate in 2050).

This coastal flood vulnerability analysis of Cecil County yields several important conclusions. First, given that Cecil County has several significant sources of flood threat and given that it contains more than 46,375 improved structures, the fact that only 709 (1.5%) are vulnerable to the 1% chance coastal flood is probably a result of historical land use patterns (focused on road/railroad development between Philadelphia and Baltimore) as well as a fortuitous geomorphology. Second, given the potential for sea level rise in the coming decades, the time to redouble the County's efforts to protect its citizens from flooding is now. Being able to avoid a 10-fold increase in flood damage over the next 80 years by taking immediate actions such as strengthening building codes, de-incentivizing flood plain development, and requiring more freeboard (the building height above the flood elevation) should provide a significant return on a property owner's investments. Third, given that the spatial extent of the area likely to be impacted by sea level change is relatively small, public investments in development rights or the property itself should create important buffer zones from the danger. Finally, this analysis shows that Cecil County has some time to adjust to the change in the flood threat. This is positive not only because any adjustments can be implemented gradually and without disruption but also because Cecil County has time for the redevelopment cycle of the next several decades to be guided by flood-smart principles.

Introduction and Study Context

Flooding occurs when rivers, creeks, streams, ditches, or other water bodies receive more water that they can handle from rain, snowmelt, storm surge, or excessive high tides. The excess water flows over adjacent banks or beaches/marshes and into the adjacent floodplain. As many as 85 percent of the natural hazard disasters across the United States have been attributed to flooding.

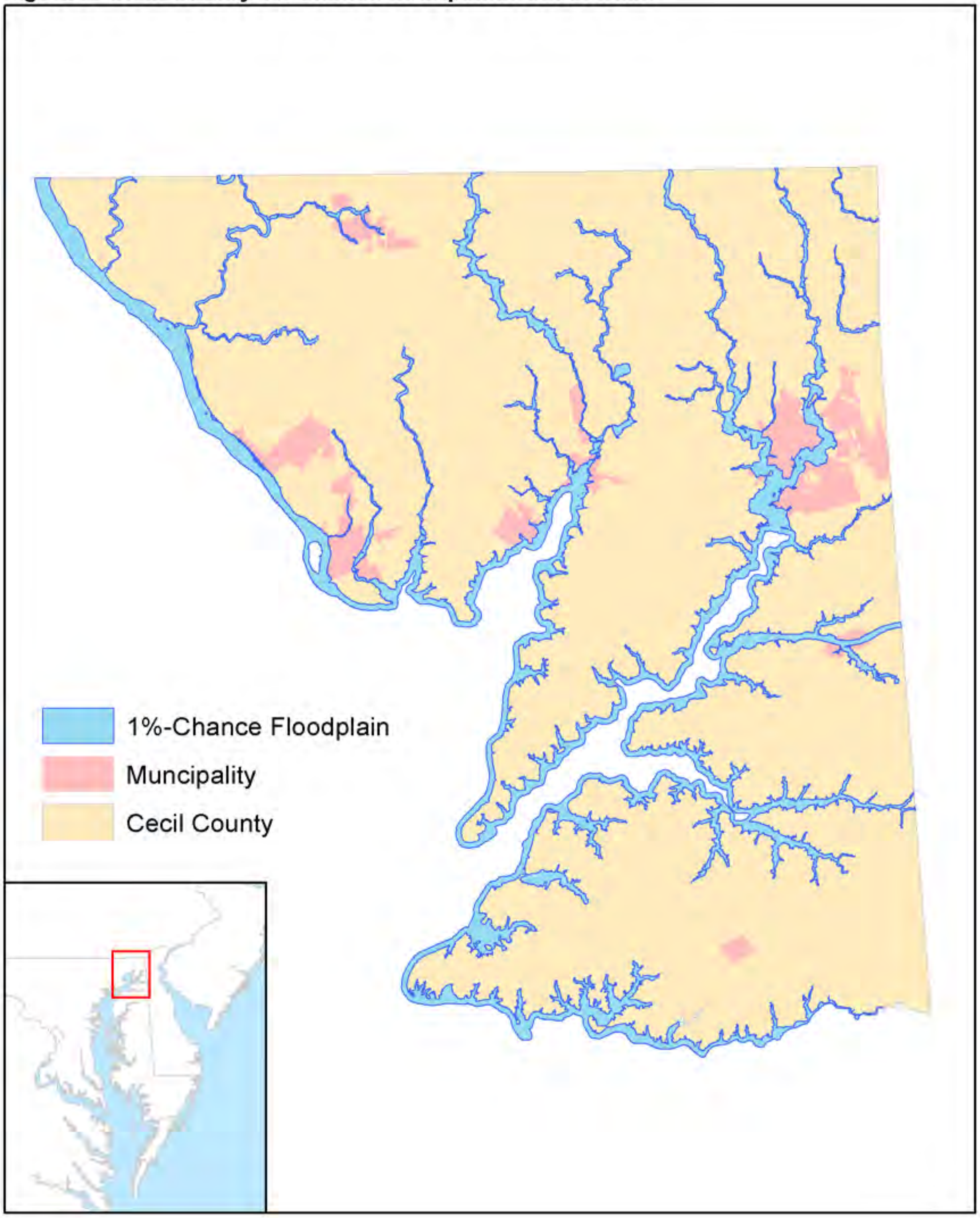
This document presents the results of a coastal flood vulnerability study of Cecil County, Maryland conducted by Dr. Michael Scott of Salisbury University at the request of the Eastern Shore Land Conservancy in Easton, Maryland. The goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. Specifically, using flood depth data calculated on behalf of the Maryland State Highway Administration, the flood scenarios of a 1% chance flood in 2015, a 0.2% chance flood in 2015, no periodic flooding in 2050, a 1% chance flood in 2050, no periodic flooding in 2100, and a 1% chance flood in 2100 were evaluated versus the location and value of buildings in Cecil County. The results are an accounting of the potential damage from periodic flooding, exacerbated by future sea level change. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the county and help make informed decisions about mitigation measures to reduce the potential impacts.

Cecil County's Floodplain

The following map (Figure 1) depicts the 1% chance floodplains within Cecil County, as designated by FEMA on the Flood Insurance Rate Maps or FIRMs. The 1% chance flood (formerly referred to as the 100-year flood) is a flood which has a 1 percent chance of being equaled or exceeded in any given year (MDE, *Maryland Floodplain Manager's Handbook*). Cecil County can experience riverine flooding as a result of excessive rainfall in a matter of hours, such as from a severe thunderstorm. Additionally, some soils can become saturated over a longer period of time and reduce their absorption potential. Riverine flooding can affect any of the rivers and streams in the County but primarily affects the non-tidal or brackish portions of the streams that feed the Chesapeake Bay. Tidal flooding in Cecil County usually occurs as a result of tropical storms (including hurricanes) as well as the combination of high astronomical tides with a northeast wind. Cecil County has 5.4% of its land area in the 1% chance floodplain.

While Cecil County is clearly vulnerable to both riverine and coastal/tidal flooding, only tidal flooding is considered in this vulnerability study. It is entirely possible that those areas in the county beyond the tidal flooding extent will experience a change in their flooding occurrence if the consensus predictions of global climate change come to pass. Current research suggests that extreme rainstorms (as well as extreme droughts) will become more common (National Climate Assessment, 2014).

Figure 1 Cecil County 1% chance floodplain from dFIRMs



Flood Measurement

There are three US Geological Survey gauging stations within the County and several others close by. Three National Weather Service Advanced Hydrologic Prediction Service hydrographs and one National Oceanographic and Atmospheric Administration tide gauge exists in the County (Table 1). Measurements of stream discharge, river stage, and tide height are critical to the prediction of flood events. While recording the water level, the EKMM2 hydrograph does not offer flood level prediction. At the NOAA tide gauge, the average range of the tide is 2.8 ft. The maximum water level ever recorded was 5.46 ft above mean higher high water (MHHW) on September 19, 2003, during Hurricane Isabel. That equals 8.67 ft above MSL, or the approximate equivalent of a 0.2% chance flood.

Table 1. River gauges, hydrographs and tide gauges in Cecil County

Agency	ID Number	Station Name	Real-Time or Daily
USGS	01578310	Susquehanna River at Conowingo	Real-time
USGS	01578475	Octoraro Creek near Richardsmere	Real-time
USGS	01495000	Big Elk Creek at Elk Mills	Real-time
NWS	CNWM2	Susquehanna River at Conowingo Dam	Real-time
NWS	EKMM2	Big Elk Creek at Elk Mills	Real-time
NWS	CHCM2	Chesapeake and Delaware Canal at Chesapeake City	Real-time
NOAA	8573927	Chesapeake City	Real-time

Flood Levels

Using the Flood Insurance Studies (FIS) of Cecil County, published by FEMA effective May 4, 2015, the following table (Table 2) reports the flood elevations for the key flooding sources.

Table 2. Flood elevations for coastal event (Units are NAVD 1988 feet)

Flooding Source and Location	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY				
Mouth of Sassafras River	4.8	6.0	6.5	7.0
Perry Point	5.3	6.7	7.3	8.7
NORTHEAST RIVER				
Town of Charleston	5.3	7.1	8.0	9.7
Town of North East	5.4	7.2	8.1	10.0
ELK RIVER	2.7	4.5	5.4	7.2
Turkey Point	4.9	6.3	6.9	7.9
BOHEMIA RIVER				
Town Point	5.1	6.6	7.3	8.8

Hazards from Floods

Annually, flooding causes $6 billion in average losses in the United States and account for an average of 140 casualties (USGS, "Flood Hazards – A National Threat," 2006). While most people's vision of the threat from flooding may include being swept away or buildings being structurally impacted, there are a number of hazards associated with flooding that occur both during and after an event.

During the Flood

While a flood event is underway, citizens will be faced with a number of threats. The hydraulic power of water is significant and walking through as little as 6 inches of moving water is dangerous because of the possibility of losing stable footing. Driving through flood water is the cause of many flood deaths each year. As little as one foot of water can float many cars and two feet of rushing water can carry away most vehicles including SUVs. That fact, combined with an inability of drivers to judge the depth of flood water, as well as the potential for flood water to rise quickly without warning, makes driving through flood water dangerous.

In addition to being swept away, flood water itself is to be avoided. Because of leaking industrial containers, household chemicals, and gas stations, it is not healthy to even touch the flood water without protective equipment and clothing. Downed power lines, flooded electric breaker panels, and other sources of electricity are a significant threat during a flood. Residents should also be prepared for the outbreak of fire. Electric sparks often cause fire to erupt and because of the inability of firefighting personnel to respond, a fire can quickly burn out of control.

After the Flood

Cleaning up after a flood can also expose citizens to a number of threats. For example, electrical circuits or electrical equipment could pose a danger, particularly if the ground is wet. Buildings that have been exposed to floodwater may exhibit structural instability of walkways, stairs, floors, and possibly roofs. Flood waters often dislodge and carry hazardous material containers such as tanks, pipes, and drums. They may be leaking or simply very heavy and unstable. The combination of chemical contamination and the likely release of untreated sewage (necessary when the sewage treatment plant is overwhelmed with flood-swelled effluent) mean that drinking water supplies can be unusable. Fire continues to be a very real threat after a flood. First-responders could be occupied with more pressing emergencies and traditional fire suppression equipment may be inoperable, but there may also be mobility problems that prevent fire-fighting equipment from reaching an outbreak. Finally, there is the mental toll of being involved in a disaster. Continued long hours of work, combined with emotional and physical exhaustion and losses from damaged homes and temporary job layoffs, can create a highly stressful situation for citizens. People exposed to these stressful conditions have an increased risk of injury and emotional crisis, and are more vulnerable to stress-induced illnesses and disease.

Impact to Buildings

Fortunately, the number of people killed or injured during floods each year is relatively small. The built environment within the floodplain, however, is likely to bear the brunt of a flood's impact. Whether the water is moving or standing, the exposure of buildings to flood water could cause a great deal of damage. If the water is moving, the differing hydraulic pressure inside the building vs. outside can cause the walls and foundation to buckle and fail. If the water is standing for any length of time, even materials above the flood height will become saturated with flood water as the flood water is absorbed (known as wicking). Certainly, most of the contents of flooded buildings that were located at or below the flood height will need to be discarded. This includes carpet, furniture, electronic equipment, and other household or commercial items. In most cases it is not simply the fact that the objects have become wet but since the flood water brings with it sediment and chemicals, it makes it nearly impossible to recover all but the most precious/heirloom items.

Flood Vulnerability Assessment

The goal of mitigation is to increase the flood resistance of a community, so that the residents and businesses will become less susceptible to future exposures to flooding, thereby resulting in fewer losses. A key component of reducing future losses is understanding a community's vulnerability – a concept that combines a clear understanding of the current threats, the current probability that those threats would occur, and the potential for loss from those threats. A vulnerability assessment is an attempt to quantify and map those components so that appropriate mitigation actions can take place that either reduce the threat, decrease the probability that threat would occur, or lessen the loss from that event.

Study Method

The Vulnerability Assessment was conducted using the method developed for HAZUS-MH, FEMA's loss estimation software, to assess the County's built environment to vulnerability to flooding. HAZUS-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide credible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards, including floods, hurricane winds and earthquakes. The methodology supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

The primary input to any vulnerability assessment is a "depth of flood" grid. This flood depth grid was created using an elevation grid derived from LiDAR measurements. By incorporating the polygons of the 1% chance floodplain from the FIRMs, the coastal flood elevations from the Flood Insurance Study as well as the current elevation grid, HAZUS-MH was able to create a flood depth grid with a reasonable precision for the 1% (Figure 2) and 0.2% chance (Figure 3) coastal flood scenarios with Cecil County's current mean sea level. In addition, areas predicted to be inundated by a higher mean sea level in 2050 (Figure 4) and 2100 (Figure 5) were also modeled. Finally, the depth of flood for the 1% chance event was mapped using the 2050 (Figure 6) and 2100 (Figure 7) predicted sea levels. For the full detail of how these depth grids were created, please see "GIS Data Products to Support Climate Change Adaptation Planning: Cecil County, Maryland" at http://www.esrgc.org/mapServices/.

Figure 2 Predicted flood depths for Cecil County, 1% chance flood at MSL in 2015

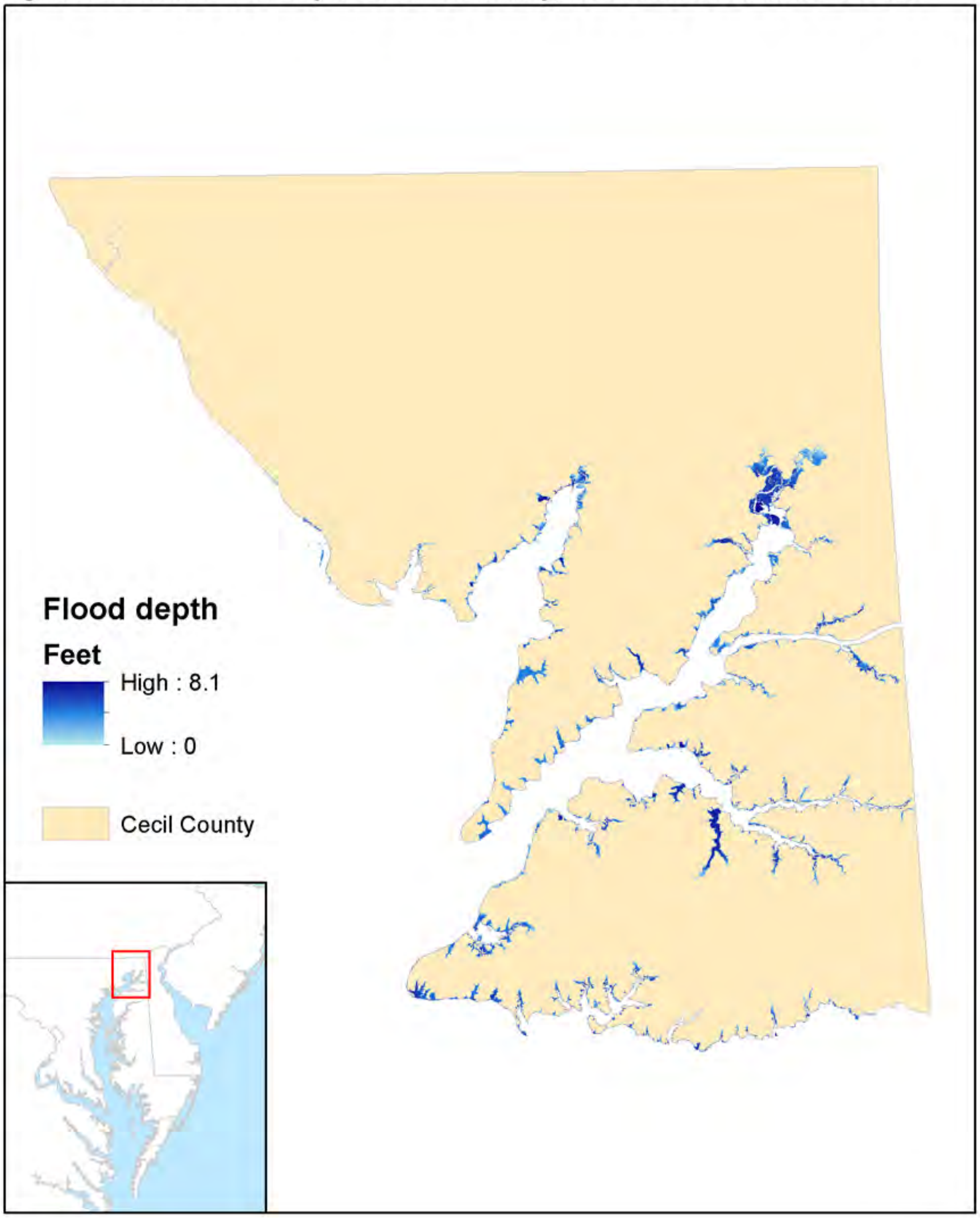


Figure 3 Predicted flood depths for Cecil County, 0.2% chance flood at MSL in 2015

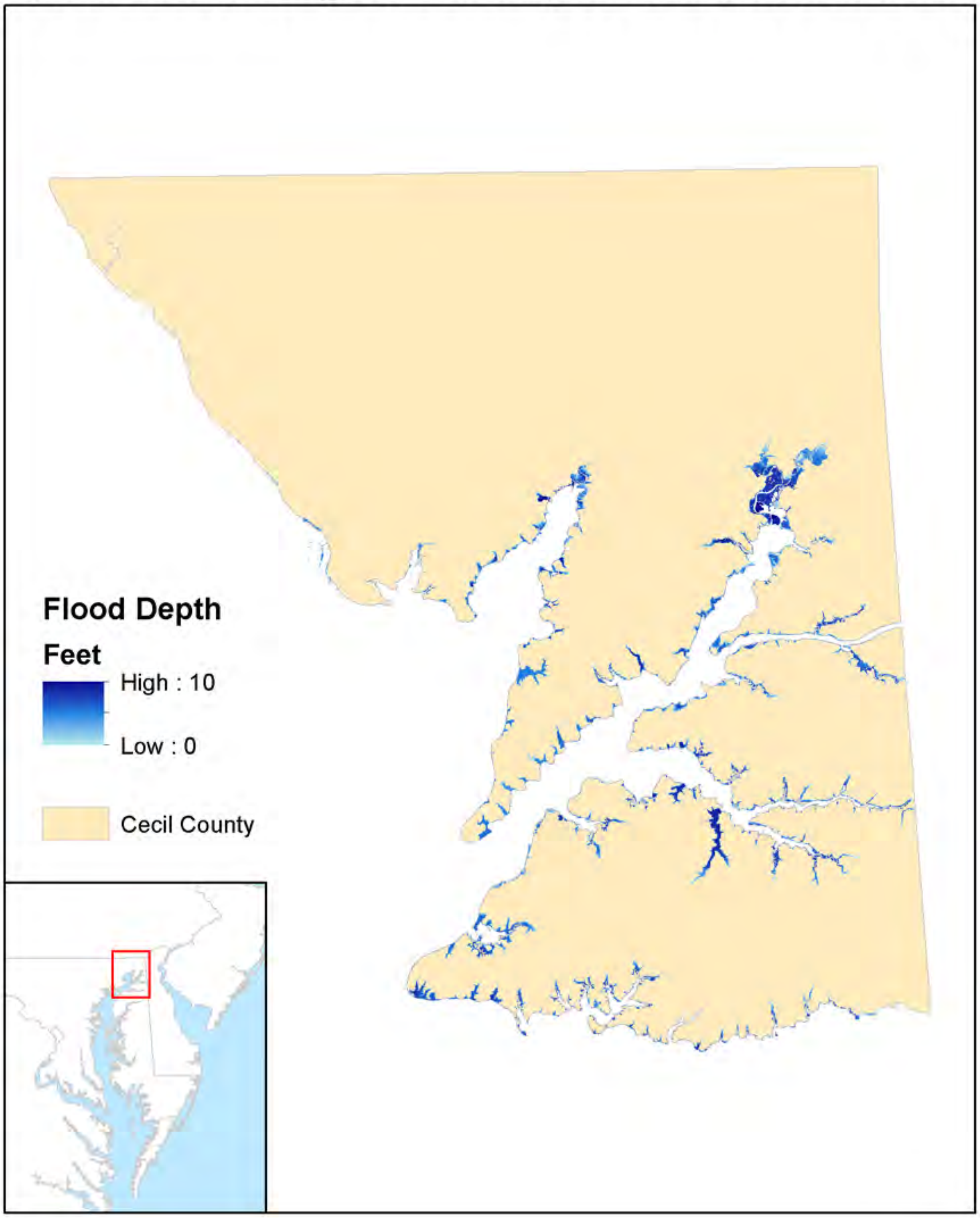


Figure 4 Predicted depth of MSL inundation in Cecil County in 2050

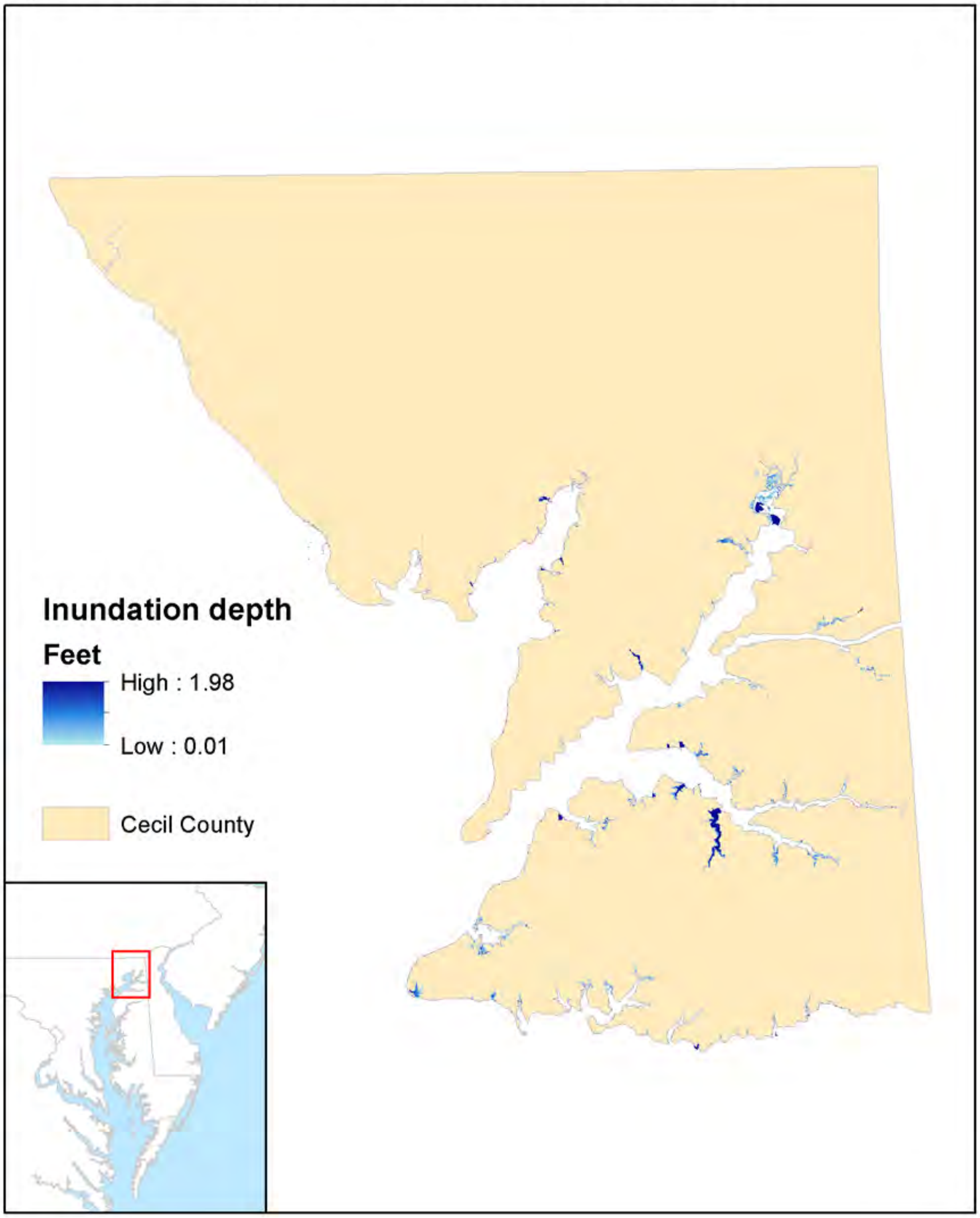


Figure 5 Predicted depth of MSL inundation in Cecil County in 2100

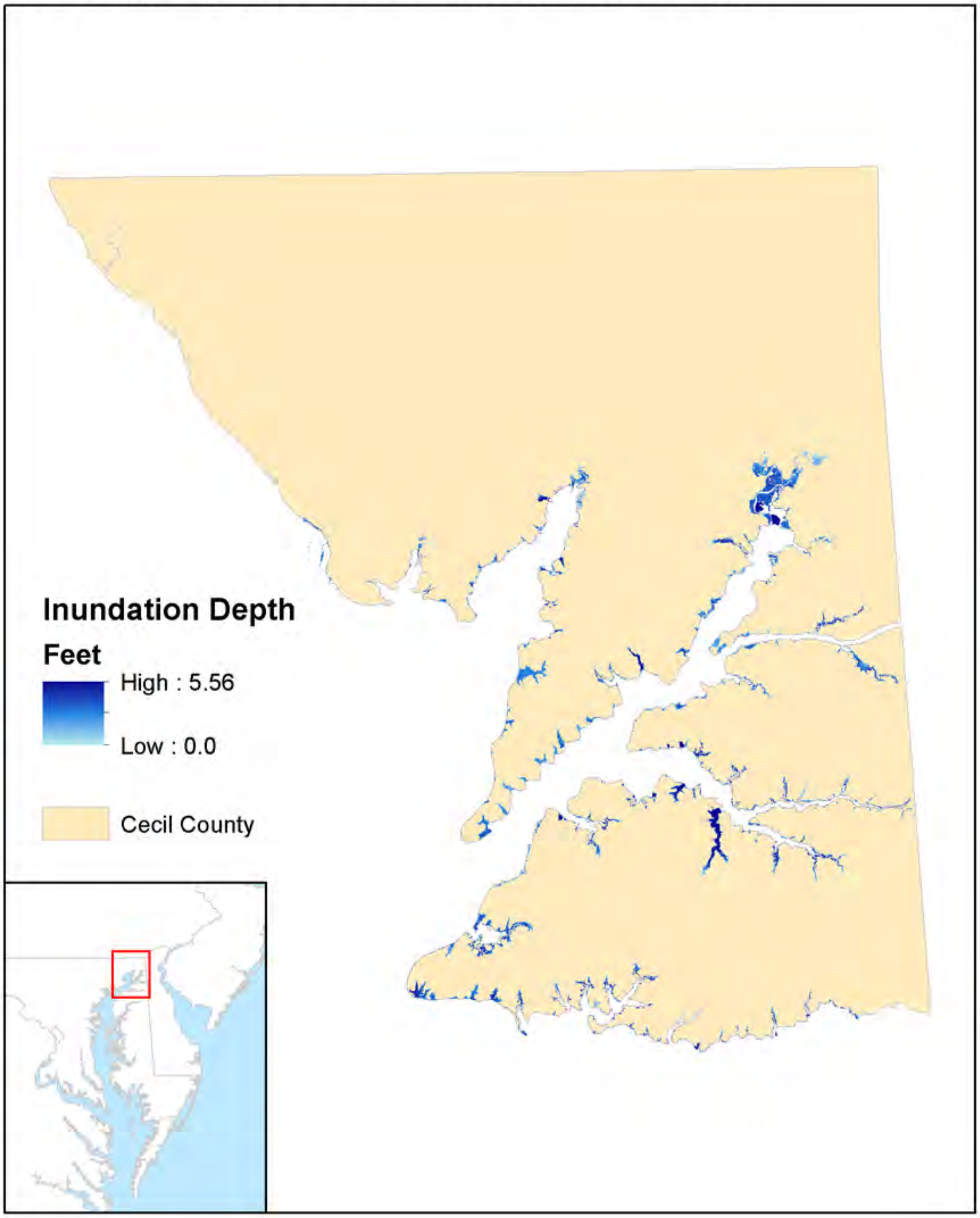


Figure 6 Predicted flood depths for Cecil County, 1% chance flood at MSL in 2050

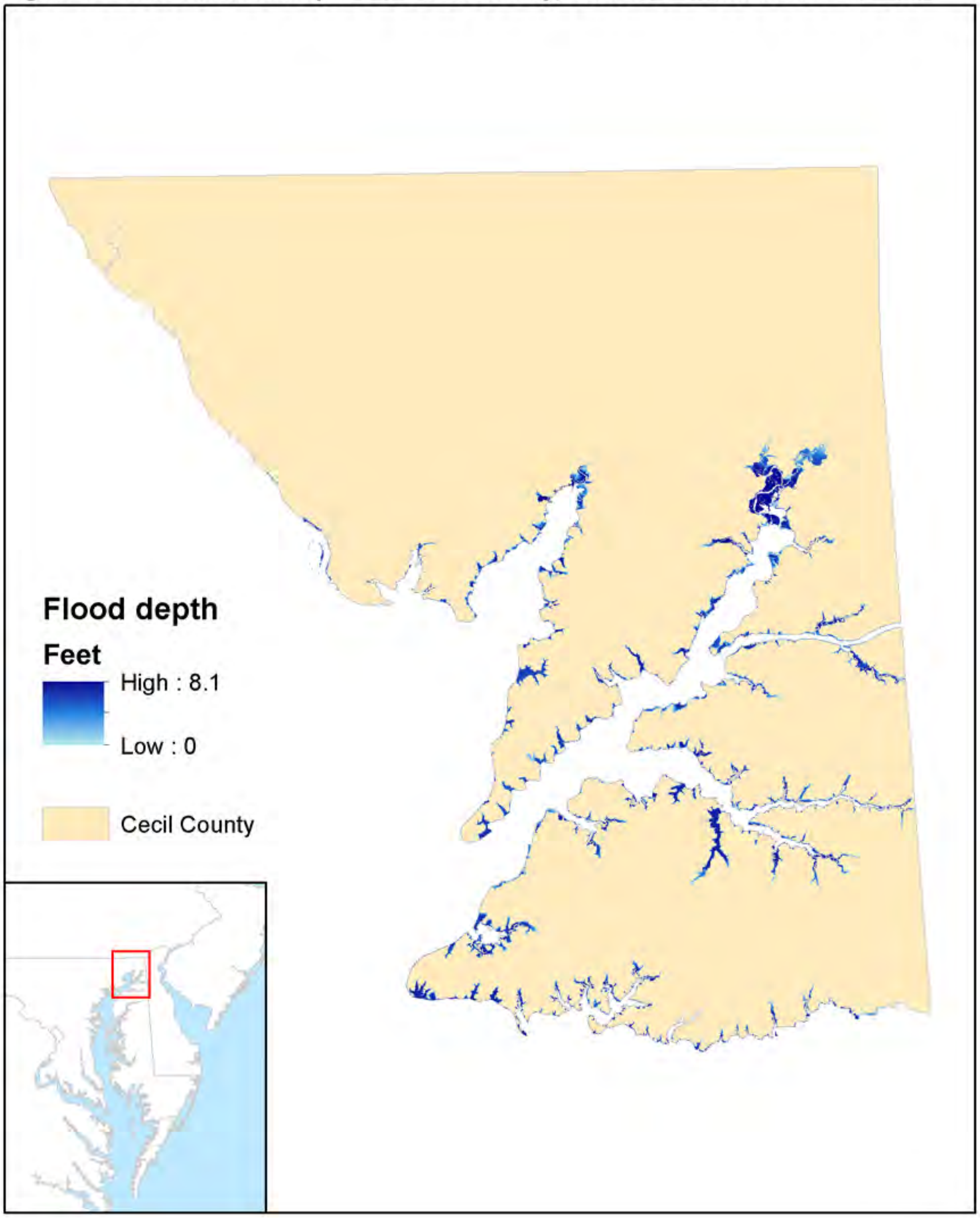
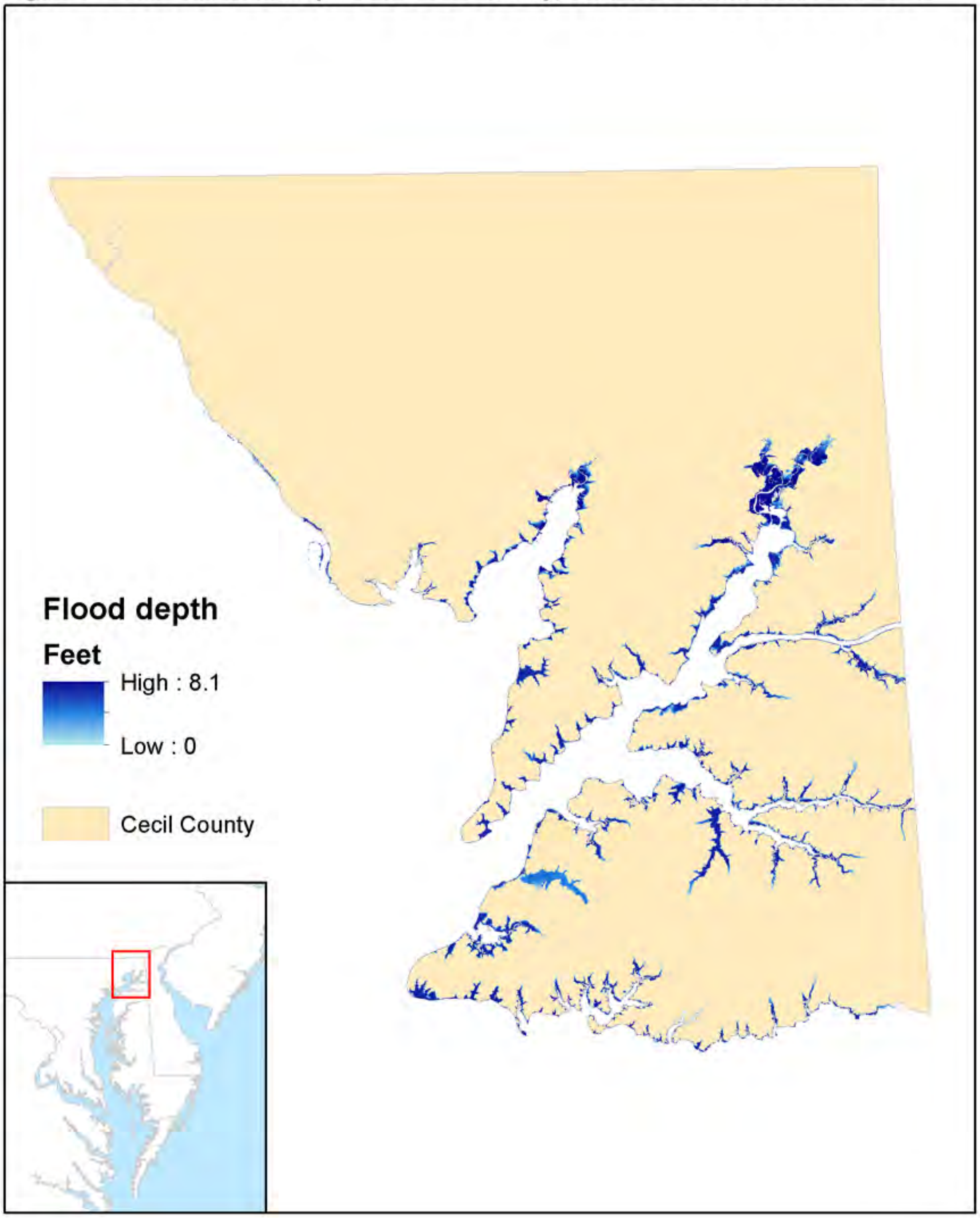


Figure 7 Predicted flood depths for Cecil County, 1% chance flood at MSL in 2100



Using these flood depth grids, those buildings that are vulnerable to flood water, and the degree to which they are vulnerable, were determined. Fortunately, Cecil County maintains a set of "addressable" building footprint polygons, separate from any outbuildings. Unfortunately, there were several placeholder polygons within the layer than needed to be updated before proceedings. Next, the average depth of flood water for each modeling scenario was calculated for each building by converting the depth grids to depth points and intersecting the building footprints and the depth points. Cecil County's 2015 tax parcels were then digitally overlaid, thus assigning attributes such as total assessed value of the improvements, the land use of the parcel (residential, commercial, etc), and the structure style (1 story, 2 story, apartments, etc) to the building footprint. Because the foundation heights are unknown, an assumption of a 24" foundation was made. Using that assumed foundation height, the flood depth above the first finished floor was calculated. The total value of the building and its contents was determined using industry-standard estimates of the contents value based on the use of the building (i.e. residential contents are 50% of the building value, while commercial contents are 100% of the building value). Finally, using the depth-damage curves provided by FEMA via the HAZUS-MH software, the potential damage percentage, and therefore the potential damage to both the building and its contents in 2015 dollars, for each building for each flood scenario was estimated.

It is important to note when viewing the following results that the numbers generated carry with them a degree of uncertainty. Nearly every component (the ground elevations, the flood heights, the foundation heights, the assessed value, etc.) has confidence constraints of various magnitudes. The HAZUS-MH model itself is a simplified version of the complex engineering models used to create the flood insurance rate maps. Having said that, considerable research has been conducted to review HAZUS-MH analysis results after an event and have found that the software does a reasonably good job of both predicting the depth of flood as well as the insured losses. But as with any simulation analysis, we recommend that these damage statistics be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Flood Results for Present-Day (2015)

The results of the analysis indicate that there are 709 buildings predicted to be impacted by a 1% chance flood in Cecil County (Table 3). However, nearly half (349) of them would only experience minor nuisance flooding in this scenario; 270 (38%) would experience greater than 10% damage. Thus, the overall predicted damage percentage from this flood level is 5.6% of the total value of the structures and contents ($13.8 million of damage from $248.7 million in value). When standardized per building, those buildings that are predicted to incur incidental damage are also the most valuable (an average of $488,354 per building vs $223,637 per building that are damaged 10% or greater). This is not surprising given that many of these more expensive structures are in the towns of Elkton, North East, and Charlestown and are on the very edge of the 1% chance floodplain. It is also worth noting that a significant mitigation opportunity exists.

There are 148 buildings predicted to be damaged between 20 and 30% in the 1% chance event. That represents one-fifth of the total number of vulnerable buildings but they represent nearly two-thirds of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits.

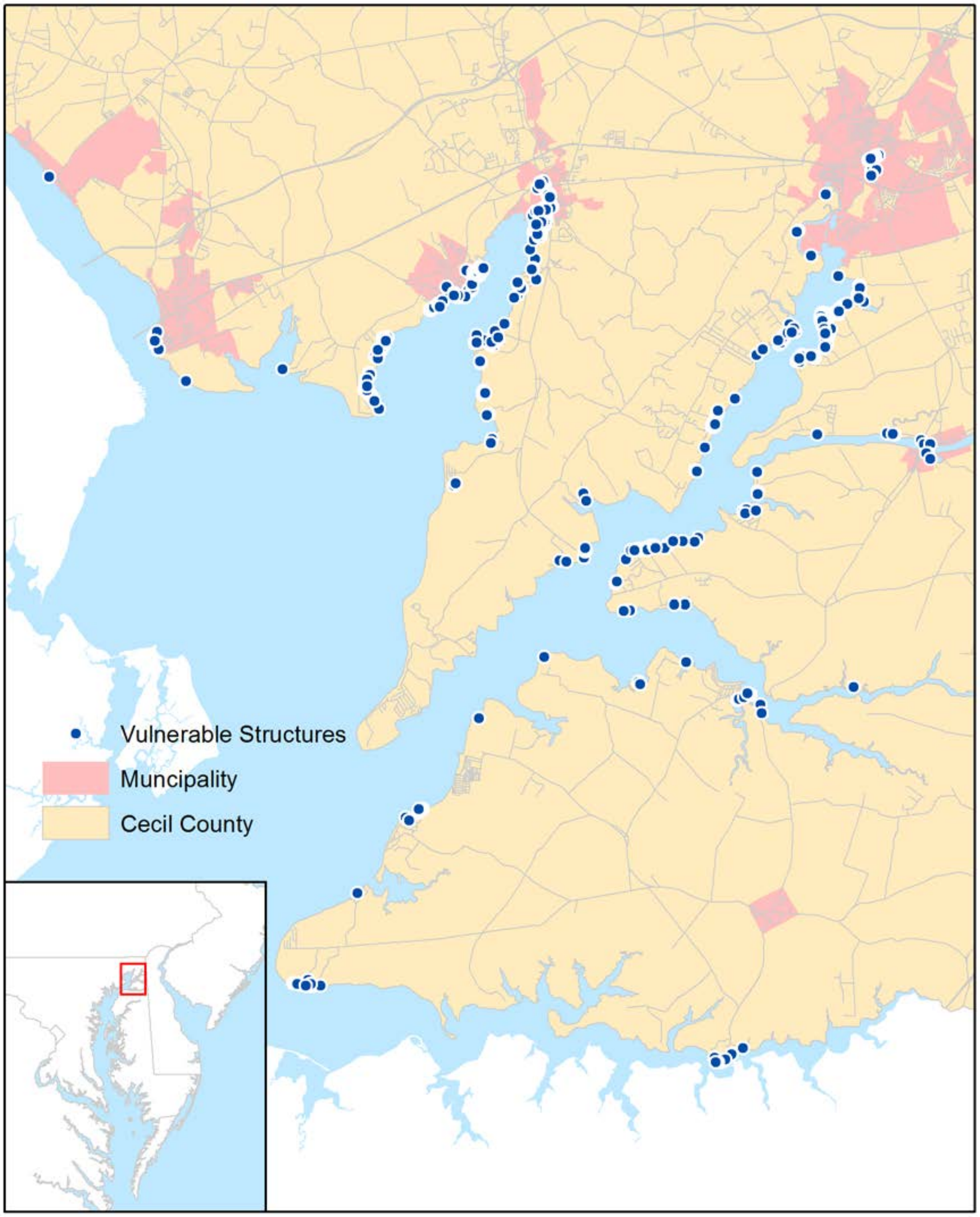
Table 3. Potential damage to structures/contents from a 1% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	349	49.2%	$170,435,386	$488,354	$15,213	$44	0.1%
1 - 10%	90	12.7%	$17,897,138	$198,857	$903,737	$10,042	6.5%
10 - 20%	117	16.5%	$23,316,814	$199,289	$3,474,637	$29,698	25.1%
20 - 30%	148	20.9%	$35,892,575	$242,517	$9,069,087	$61,278	65.6%
30 - 40%	5	0.7%	$1,172,673	$243,535	$360,314	$72,063	2.6%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	709	100.0%	$248,714,587	$350,796	$13,822,987	$19,496	100.0%

Note: All dollar values are from 2015 tax assessments.

The spatial distribution of the structures vulnerable to the 1% chance flood event follows a predictable pattern (Figure 8). The early colonial-era developments that were focused on water transportation for both trade and communication show legacy impacts of building placement. Areas like Carpenter Point and Charlestown on the North East River are good examples. Additionally, water-oriented development areas like Locust Point and Henderson Point also reveal themselves as areas that are vulnerable to flooding.

Figure 8 Spatial distribution of vulnerable structures in Cecil County, 1% chance flood at MSL in 2015 (n= 709)



The very severe 0.2% chance flood event represents a current worst-case scenario for Cecil County (Table 4). In such an event, 1,037 buildings would be impacted with 500 impacted moderately (10 – 50%) and 1 impacted severely (greater than 50% loss). The total value of the structures and their contents that are vulnerable to flooding expands to $325.9 million and the potential damage is calculated to be $28.6 million, or 2.1x that of the 1% chance event. The number of buildings that are minimally affected (426) does not change greatly as a percentage of the total vulnerable buildings (49.2% in 1% chance scenario vs. 41.1% in the 0.2% chance). This indicates that in such a severe flood, the water is reaching many structures not previously impacted. These people tend to be less prepared for flooding because in less severe flood magnitudes, water does not reach them.

Table 4. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	426	41.1%	$194,786,128	$457,244	$12,892	$30	0.0%
1 - 10%	110	10.6%	$18,895,955	$171,781	$1,110,114	$10,092	3.8%
10 - 20%	141	13.6%	$28,835,339	$204,506	$4,530,137	$32,129	15.8%
20 - 30%	248	23.9%	$54,536,817	$219,907	$13,719,023	$55,319	47.8%
30 - 40%	108	10.4%	$27,593,350	$255,494	$8,780,922	$81,305	30.6%
40 – 50%	3	0.3%	$1,295,502	$431,834	$546,930	$182,310	1.9%
50% or more	1	0.1%	$9,450	$9,450	$5,284	$5,284	0.0%
Total	1,037	100.0%	$325,953,543	$314,324	$28,695,304	$27,671	100.0%

Note: All dollar values are from 2015 tax assessments.

When the potential damage was also examined with respect to land use, it was found that no matter the scenario, the vast majority of all buildings vulnerable to flooding in Cecil County were residential, ranging from 84.9% in the 1% chance scenario (Table 5) to 81.8% in the 0.2% chance scenario (Table 6). The second largest category was commercial buildings, ranging from 13.0% in the 1% chance scenario to 16.3% in the 0.2% chance scenario. In the 1% chance scenario, the majority of the damage (88%) comes from residential buildings, which is to be expected given the number of residential buildings affected. That ratio decreases proportionately in the 0.2% chance scenario as the number of commercial properties affected rises. This suggests that instigating mitigation actions that are targeted at Cecil County homeowners might yield the best results.

Table 5. Potential damage to structures/contents from a 1% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	602	84.9%	$118,710,356	$12,158,973	10.2%	88.0%
Commercial	92	13.0%	$43,720,371	$1,442,561	3.3%	10.4%
Government	12	1.7%	$85,903,410	$221,454	0.3%	1.6%
Industry	1	0.1%	$81,500	$0	0.0%	0.0%
Religious	1	0.1%	$252,000	$0	0.0%	0.0%
Agricultural	1	0.1%	$46,950	$0	0.0%	0.0%
Total	709	100.0%	$248,714,587	$13,822,987	5.6%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 6. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	848	81.8%	$162,418,235	$22,815,438	14.0%	79.6%
Commercial	169	16.3%	$57,826,048	$5,332,339	9.2%	18.6%
Government	17	1.6%	$105,328,810	$458,446	0.4%	1.6%
Industry	1	0.1%	$81,500	$13,025	16.0%	0.1%
Religious	1	0.1%	$252,000	$76,056	30.2%	0.3%
Agricultural	1	0.1%	$46,950	$0	0.0%	0.0%
Total	1,037	100.0%	$325,953,543	$28,695,304	4.4%	100.0%

Note: All dollar values are from 2015 tax assessments.

One final way to break down the countywide vulnerability results is to examine them by property value. The following tables explore the vulnerability of the buildings based on the values of the structure and its contents (Tables 7 & 8). While each flooding scenario presents slightly different results, there are some overall conclusions that can be made. First, in the 1% chance flood scenario, the least valuable properties suffer the most damage, relative to their value. Given that the owners of these properties are historically the least likely to have flood insurance, this situation could be debilitating for those property owners. Second, a reasonably large percentage of the total damage from the 1% chance event is generated by expensive properties (both a structure and contents value between $500,000 and $1 million and greater than $3,000,000). This is an opportunity as very few properties are contributing to the overall vulnerability of the county and could be addressed proactively. Finally, with the increase in flood depths in the 0.2% chance scenario, most of the damage percentages remain close to the same. The exception is the $1 million to $2 million category. These are likely (expensive) commercial properties that begin having predicted damage only once the water reaches the depth and extent of the 0.2% chance flood.

Table 7. Potential damage to structures/contents from a 1% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	58	8.2%	$1,229,177	$34,529	28.1%	0.3%
$50 - $100	168	23.7%	$12,794,706	$1,319,306	10.3%	9.5%
$100 - $200	242	34.1%	$36,004,950	$2,526,576	7.0%	18.3%
$200 - $300	88	12.4%	$20,860,430	$2,150,094	10.3%	15.6%
$300 - $400	67	9.4%	$23,180,350	$1,759,832	7.6%	12.7%
$400 - $500	28	3.9%	$12,588,133	$1,221,506	9.7%	8.8%
$500 - $1,000	37	5.2%	$25,084,690	$2,342,291	9.3%	16.9%
$1,000 - $2,000	16	2.3%	$22,029,700	$551,866	2.5%	4.0%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	5	0.7%	$94,942,450	$1,916,986	2.0%	13.9%
Total	709	100.0%	$248,714,587	$13,822,987	5.7%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 8. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	104	10.0%	$2,544,505	$201,547	7.9%	0.7%
$50 - $100	266	25.7%	$20,184,945	$2,546,011	12.6%	8.9%
$100 - $200	338	32.6%	$50,316,550	$5,397,861	10.7%	18.8%
$200 - $300	124	12.0%	$29,737,390	$4,214,900	14.1%	14.7%
$300 - $400	85	8.2%	$29,049,950	$3,958,873	13.6%	13.7%
$400 - $500	37	3.6%	$16,527,433	$1,221,506	7.4%	4.3%
$500 - $1,000	57	5.5%	$39,369,370	$4,416,186	11.2%	15.4%
$1,000 - $2,000	19	1.8%	$25,490,150	$3,238,388	12.7%	11.3%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	7	0.7%	$112,478,250	$2,228,984	2.0%	7.8%
Total	1,037	100.0%	$325,953,543	$28,695,304	4.4%	100.0%

Note: All dollar values are from 2015 tax assessments

Sea level Rise Inundation in 2050 and 2100

Unfortunately, we know that the water levels in the Chesapeake Bay that feed this periodic tidal flooding are not static – they are quite dynamic. Scientists at the USGS estimate that mean sea level in the Bay was about 2 feet lower when Captain John Smith first mapped it in 1608 (Larsen, 1998; https://pubs.usgs.gov/fs/fs102-98/). The Mid-Atlantic region is predicted to be one of the most affected by sea level change going forward because of the presence of the combination of eustatic sea level rise, thermal expansion of sea water as the earth warms, the slowdown of the North Atlantic gyre, and the subsidence of the land surface from the glacial isostatic rebound. The current sea level trend, measured from 1937 to 2015 at the Solomons Island tide gauge is 3.74 mm/year or 1.23 ft in 100 years.

However, scientists do not think that a linear trend will continue. The rate is expected to increase. The models used in this flood mitigation plan follow the same method used by the Maryland State Highway Administration to document the potential flood vulnerability of the road infrastructure from periodic flooding in 2050 and 2100. For that method, the “high” estimates of sea level change from the US Army Corps of Engineers was chosen as the appropriate planning scenario. For Cecil County, this means the USACE expects an estimated mean sea level increase of 1.98 ft by 2050 and 5.56 ft by 2100 (Figures 4 & 5).

Using these elevated mean sea levels of 2050 and 2100, additional analyses were conducted of the vulnerability of the built environment from only inundation without any periodic flooding. It should be noted that these inundation damage estimates are not particularly appropriate for non-periodic flooding. They are included here primarily for comparison's sake. If the buildings predicted to be inundated constantly by a rise in mean sea-level were not elevated beyond the reach of the water, the damage done to them would be a great deal more severe.

As the 2050 mean sea level inundation results show (Table 9), Cecil County is largely protected. Only 10 buildings are predicted to experience flooding in the footprint of their structure and 80% of those are not damaged to any quantifiable degree. These are building footprints intersecting with less than 6" of water. There are two properties in the county that we predict could see significant inundation by 2050. However, in both of those cases, the result is likely from a misalignment of the depth grid and the building footprint and are not a true representation of the vulnerability. The spatial distribution of the properties shows a couple in Charlestown, a few in the Locust Point Area, one in Chesapeake City, and one in Fredericktown (Figure 9). By 2100, the situation has changed dramatically in one respect – the number of buildings at risk from inundation increased 33x, from 10 in 2050 to 332 in 2100 (Table 10). Those 332 buildings represent over $78 million in structure and content value. Again, the prediction of damage in the scenario does not inspire confidence as the processes that cause inundation damage are quite different than periodic flood damage. However, an overall damage rate of 3.0% is very concerning and is about ½ of the 5.6% rate that we expect from a 1% chance flood event in 2015. With regard to the spatial distribution of the structures predicted to be inundated in 2100 (Figure 10), the pattern is remarkably consistent with those areas subject to the 1% chance flood in 2015 (Figure 8)

Table 9. Potential damage to structures/contents from mean sea level inundation in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	8	80.0%	$2,954,100	$369,262	$0	$0	0.0%
1 - 10%	0	0.0%	$0	$0	$0	$0	0.0%
10 - 20%	2	20.0%	$333,900	$166,950	$52,356	$26,178	100.0%
20 - 30%	0	0.0%	$0	$0	$0	$0	0.0%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	10	100.0%	$3,288,000	$222,895	$52,356	$5,236	100.0%

Note: All dollar values are from 2015 tax assessments

Table 10. Potential damage to structures/contents from mean sea level inundation in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	227	68.4%	$53,890,073	$237,401	$7,633	$34	0.3%
1 - 10%	51	15.4%	$16,481,505	$323,167	$985,971	$19,333	42.7%
10 - 20%	41	12.3%	$6,683,742	$163,018	$1,057,340	$25,789	45.8%
20 - 30%	12	3.6%	$1,050,344	$87,529	$231,911	$19,326	10.0%
30 - 40%	1	0.3%	$67,946	$67,946	$24,070	$24,070	1.0%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	332	100.0%	$78,173,611	$211,598	$2,306,925	$6,949	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 9 Spatial distribution of vulnerable structures in Cecil County, no flood event at MSL in 2050 (n=10)

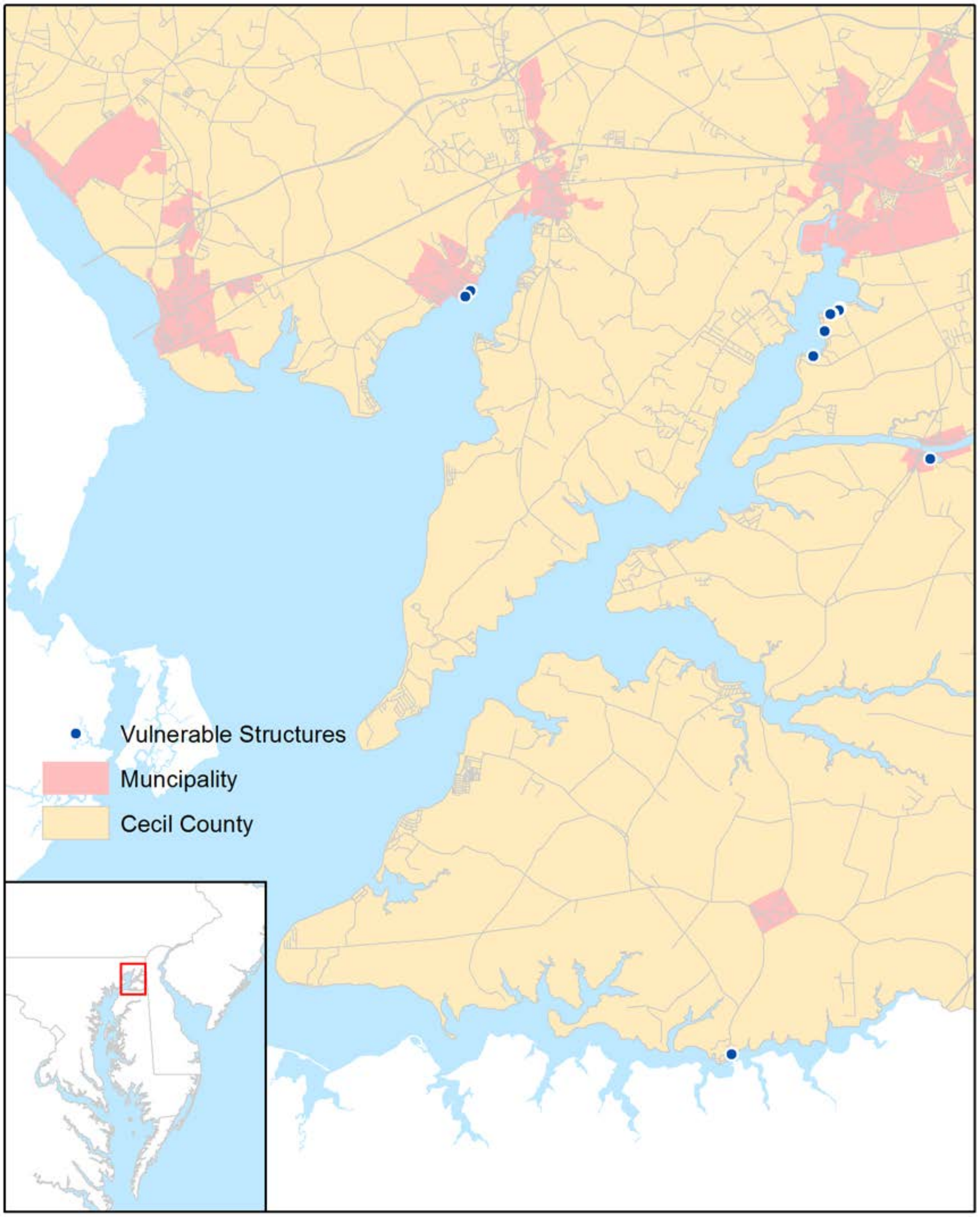
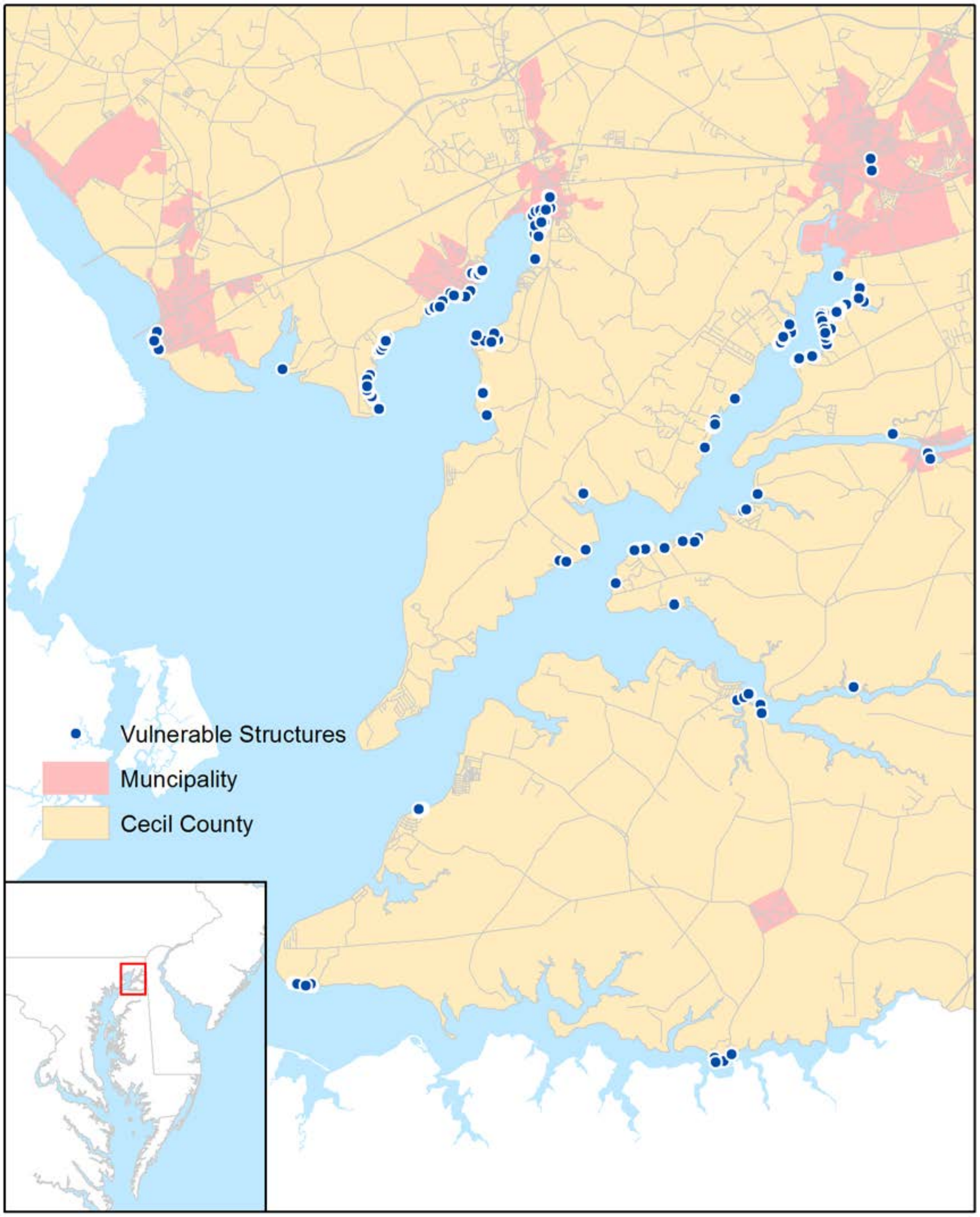


Figure 10 Spatial distribution of vulnerable structures in Cecil County, no flood event at MSL in 2100 (n=332)



With regard to inundation with respect to land use, the impact from sea level change in 2050 was 60% residential and 40% commercial (Table 11). Of course, with such a small number of buildings, this division should be viewed with skepticism. By 2100 however, it becomes clear that sea level change in Cecil County will be disproportionately felt by residents as 90% of all of structures being inundated as residential (Table 12). Perhaps even more concerning, 100% of the predicted damage from sea level inundation will be borne by residents, not any other land-use category.

Table 11. Potential damage to structures/contents from mean sea level inundation in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	6	79.6%	$1,380,300	$52,356	2.3%	21.9%
Commercial	4	16.7%	$1,907,700	$0	6.3%	36.3%
Government	0	0.0%	$0	$0	0.0%	0.0%
Industry	0	0.0%	$0	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	10	100.0%	$3,288,000	$52,356	1.6%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 12. Potential damage to structures/contents from mean sea level inundation in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	299	90.0%	$64,251,157	$2,306,925	3.6%	100.0%
Commercial	25	7.5%	$12,666,096	$0	0.0%	0.0%
Government	6	1.8%	$957,408	$0	0.0%	0.0%
Industry	0	0.0%	$0	$0	0.0%	0.0%
Religious	1	0.3%	$252,000	$0	0.0%	0.0%
Agricultural	1	0.3%	$46,950	$0	0.0%	0.0%
Total	332	100.0%	$78,173,611	$2,306,925	2.9%	100.0%

Note: All dollar values are from 2015 tax assessments.

When examining the vulnerability of Cecil County's structure by the property value, the results in 2050 show no significant pattern, with no one category having more than 3 of the 10 properties predicted to be impacted (Table 13). In 2100 however (Table 14), the results are more dire. Over half of the structures (56.6%) predicted to be impacted by sea level inundation have a structure plus contents value of between $100,000 and $300,000. These are relatively modest homes that are unlikely to have the financial resources to mitigate the potential threat.

Table 13. Potential damage to structures/contents from mean sea level inundation in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	0	0.0%	$0	$0	0.0%	0.0%
$50 - $100	2	20.0%	$118,350	$0	0.0%	0.0%
$100 - $200	3	30.0%	$529,650	$52,356	9.9%	100.0%
$200 - $300	0	0.0%	$0	$0	0.0%	0.0%
$300 - $400	2	20.0%	$691,150	$0	0.0%	0.0%
$400 - $500	1	10.0%	$475,350	$0	0.0%	0.0%
$500 - $1,000	2	20.0%	$1,473,500	$0	0.0%	0.0%
$1,000 - $2,000	0	0.0%	$0	$0	0.0%	0.0%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	10	100.0%	$3,288,000	$52,356	1.6%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 14. Potential damage to structures/contents from mean sea level inundation in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	19	5.7%	$186,924	$664	0.4%	0.0%
$50 - $100	78	23.5%	$5,928,824	$434,983	7.3%	18.9%
$100 - $200	110	33.1%	$16,539,412	$414,205	2.5%	18.0%
$200 - $300	53	16.0%	$12,438,710	$266,639	2.1%	11.6%
$300 - $400	30	9.0%	$10,261,117	$141,928	1.4%	6.2%
$400 - $500	15	4.5%	$6,851,133	$237,335	2.3%	10.3%
$500 - $1,000	21	6.3%	$12,286,940	$296,915	3.5%	12.9%
$1,000 - $2,000	4	1.2%	$5,717,700	$0	0.0%	0.0%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	2	0.6%	$6,962,850	$514,255	7.4%	22.3%
Total	332	100.0%	$78,173,611	$2,306,925	2.9%	100.0%

Note: All dollar values are from 2015 tax assessments

In the event that the USACE's predictions come to pass, the 1.96 ft rise in MSL will significantly impact the flood vulnerability of Cecil County (Table 15). In the 1% chance flood scenario, the number of buildings impacted will increase by over 62% (from 709 to 1,132). Additionally, the number of buildings with moderate-severe damage (between 30 – 50%) will spike by 30x, rising from 5 to 150 and from a total value of $1.1 million to nearly $38 million. Thankfully, only 1 is predicted to be severely damaged (greater than 50%). The total amount of building and contents value vulnerable to flooding will increase from $248.7 million to $397.3 million and the amount of potential damage will nearly triple from $13.8 million to $37.6 million. The spatial distribution of these vulnerable structures show the expansion along the coast of Cecil County, and of particular note, in the towns of North East and Elkton.

Of course, the prediction for the year 2100 (5.56 ft increase in MSL) must be considered highly uncertain. However, as of this writing, there is a growing consensus in the scientific community that the SLC estimates are more than likely too conservative, rather than too aggressive. Until that consensus solidifies, the current USACE estimate is still reasonable for planning purposes. Obviously, sea level being 5.56 ft higher in Cecil County 82 years from now will significantly impact much of the vulnerable coastal development (Table 16). The number of vulnerable buildings will increase by 302% (from 702 in 2015 to 2,141 in 2100), with about third damaged greater than 30%. The number predicted to be severely damaged will go from 0 in 2015 to 1 in 2050 to 57 in 2100. While the amount of building and contents value vulnerable to flooding will increase 2.6x, from $248.7 million to $650.0 million, the amount of potential damage will more than 10x from $13.8 million to $141.2 million. The spatial distribution shows a marked increase in the number of structures potentially impacted along the tidal rivers of Cecil County (Figure 12).

Table 15. Potential damage to structures/contents from a 1% chance flood event in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	448	39.6%	$224,120,831	$500,270	$7,167	$16	0.0%
1 - 10%	124	11.0%	$22,627,895	$182,483	$1,256,093	$10,130	3.3%
10 - 20%	151	20.0%	$58,127,599	$384,951	$10,200,345	$67,552	27.1%
20 - 30%	258	13.3%	$54,634,369	$211,761	$13,761,966	$53,340	36.6%
30 - 40%	145	12.8%	$36,558,793	$252,130	$11,857,037	$81,773	31.5%
40 – 50%	5	0.4%	$1,296,506	$259,301	$561,346	$112,269	1.5%
50% or more	1	0.1%	$9,450	$9,450	$5,688	$5,688	0.0%
Total	1,132	100.0%	$397,375,443	$351,038	$37,649,640	$33,259	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 11 Spatial distribution of vulnerable structures in Cecil County, 1%-chance flood at MSL in 2050 (n=1,132)

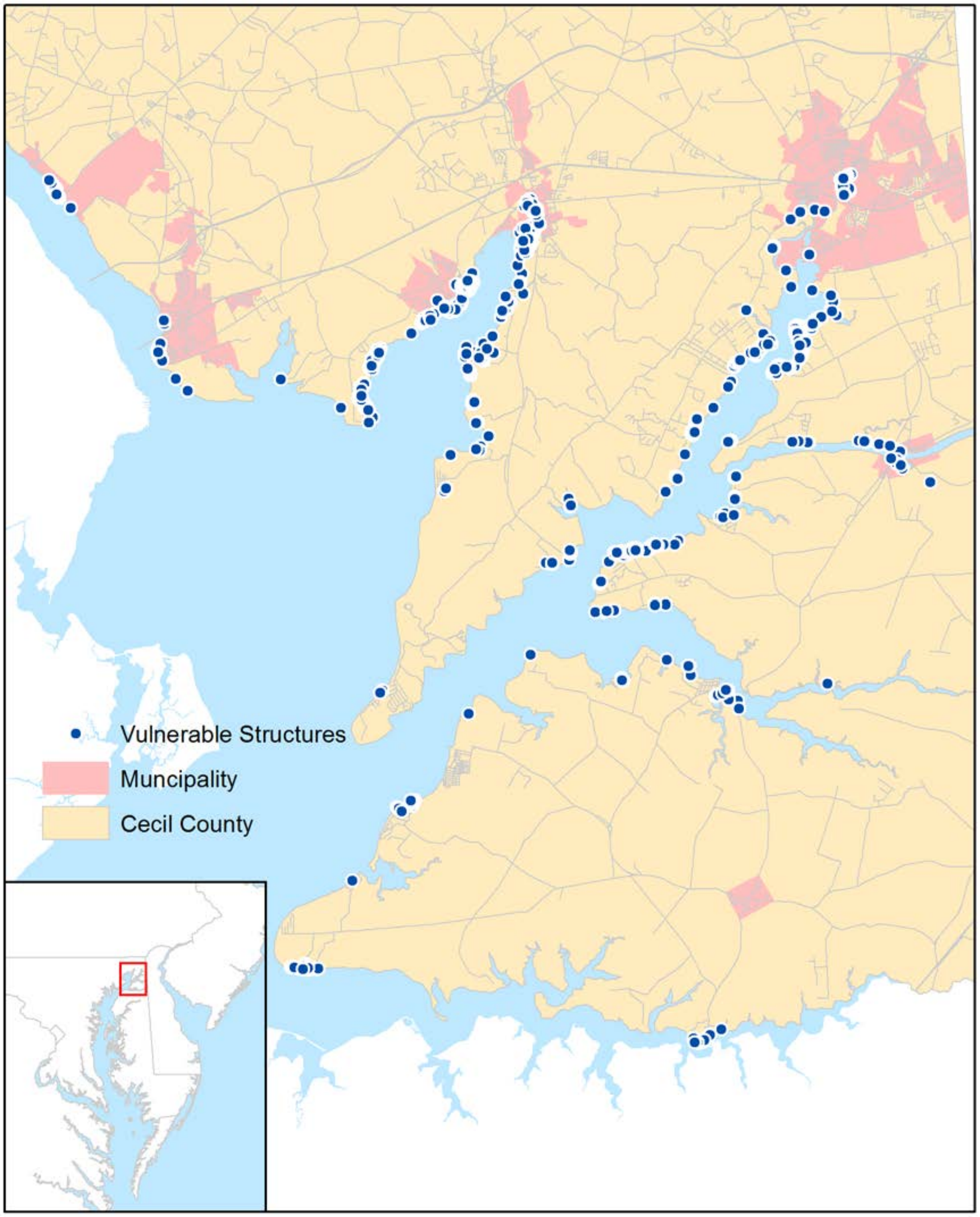


Table 16. Potential damage to structures/contents from a 1% chance flood event in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	576	26.9%	$120,906,686	$209,907	$8,682	$15	0.0%
1 - 10%	184	8.6%	$31,050,763	$168,754	$1,722,555	$9,362	1.2%
10 - 20%	258	12.1%	$106,520,189	$412,869	$18,986,486	$73,591	13.4%
20 - 30%	386	18.0%	$187,114,815	$484,753	$45,904,218	$116,824	32.5%
30 - 40%	630	29.4%	$166,156,013	$263,739	$55,657,375	$88,345	39.4%
40 – 50%	50	2.3%	$21,552,243	$431,045	$9,767,140	$195,343	6.9%
50% or more	57	2.7%	$16,757,671	$293,994	$9.206,823	$161,523	6.5%
Total	2,141	100.0%	$650,058,380	$303,624	$141,253,278	$65,975	100.0%

Note: All dollar values are from 2015 tax assessments

As for the spatial distribution of the flood threat in the two sea level change scenarios, it is a reasonable generalization to say that one can simply expect existing flood prone areas to flood more often, can expect deeper flood water when it does flood, and that areas adjacent to currently threatened areas are most likely to be newly-inundated. Maps of the 1% chance flood in 2050 and 2100 in the Locust Point area on the Elk River have been included as an example of what most areas in Cecil County could expect (Figures 8 & 9). In the comparison of 2015 and 2050, the predicted 1% chance flood includes a few more buildings as vulnerable that are adjacent to the current flood area. But primarily, the 1% flood in 2050 will be more severe than today, thus yielding many more buildings in higher predicted damage categories. By contrast, the comparison of 2015 and 2100 shows not only a significantly more severe 1% chance flood, but a slight expansion of the vulnerable zone. This pattern is actually quite different from what one can expect in the lower Chesapeake Bay. The lack of expansive wetlands and low-lying areas along the Bay means that the spread of the flood zone in Cecil County is more constrained than in other counties. In fact, the most expansion of the flood extent is in the upper tidal areas of the Elk and North East Rivers. The data from this analysis will be delivered to County officials so that they can map any area of the county this way, but Locust Point's patterns are very typical of most other areas in the county.

Figure 12 Spatial distribution of vulnerable structures in Cecil County, 1%-chance flood at MSL in 2100 (n=2,141)

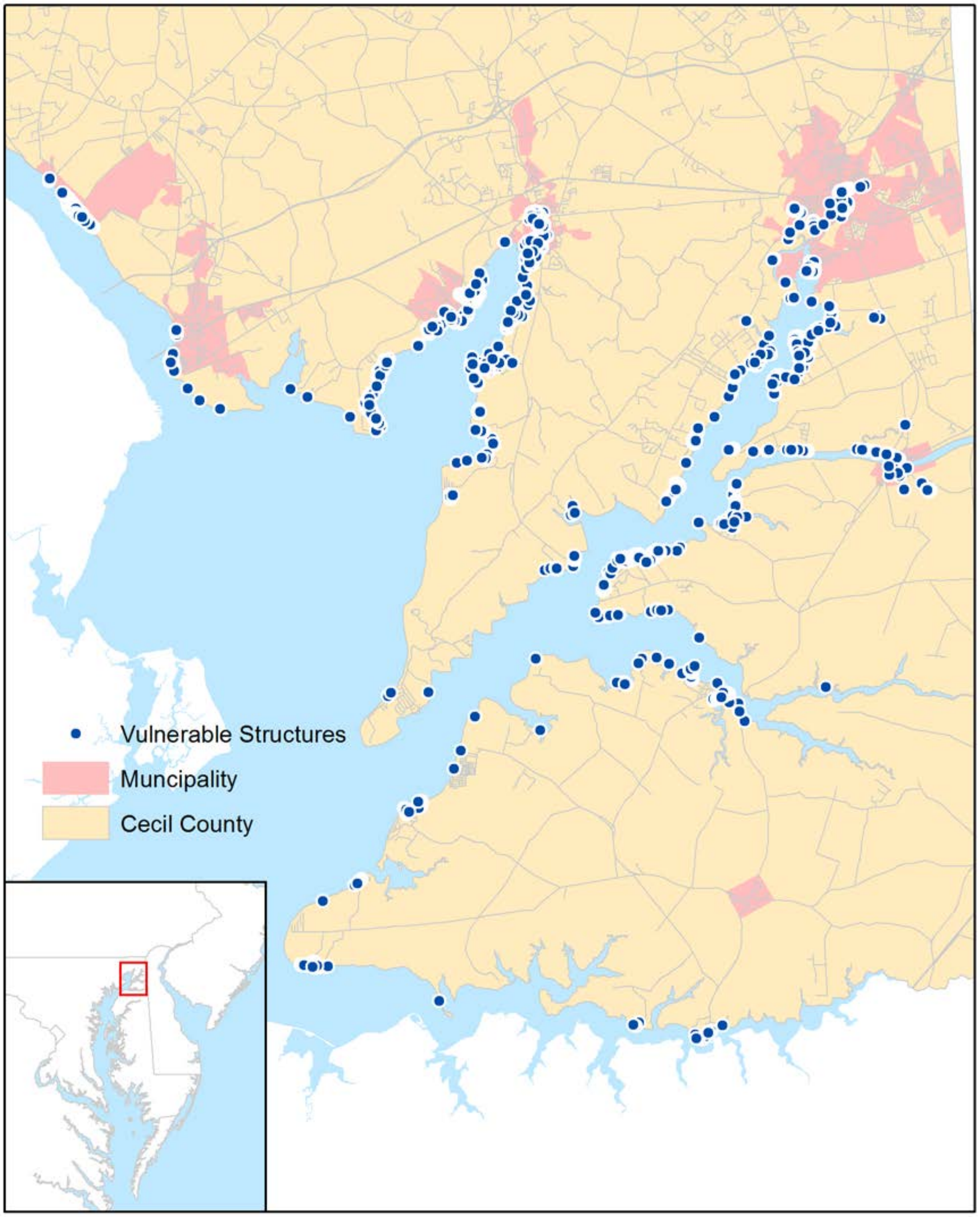


Figure 13 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2050, Locust Point, Maryland

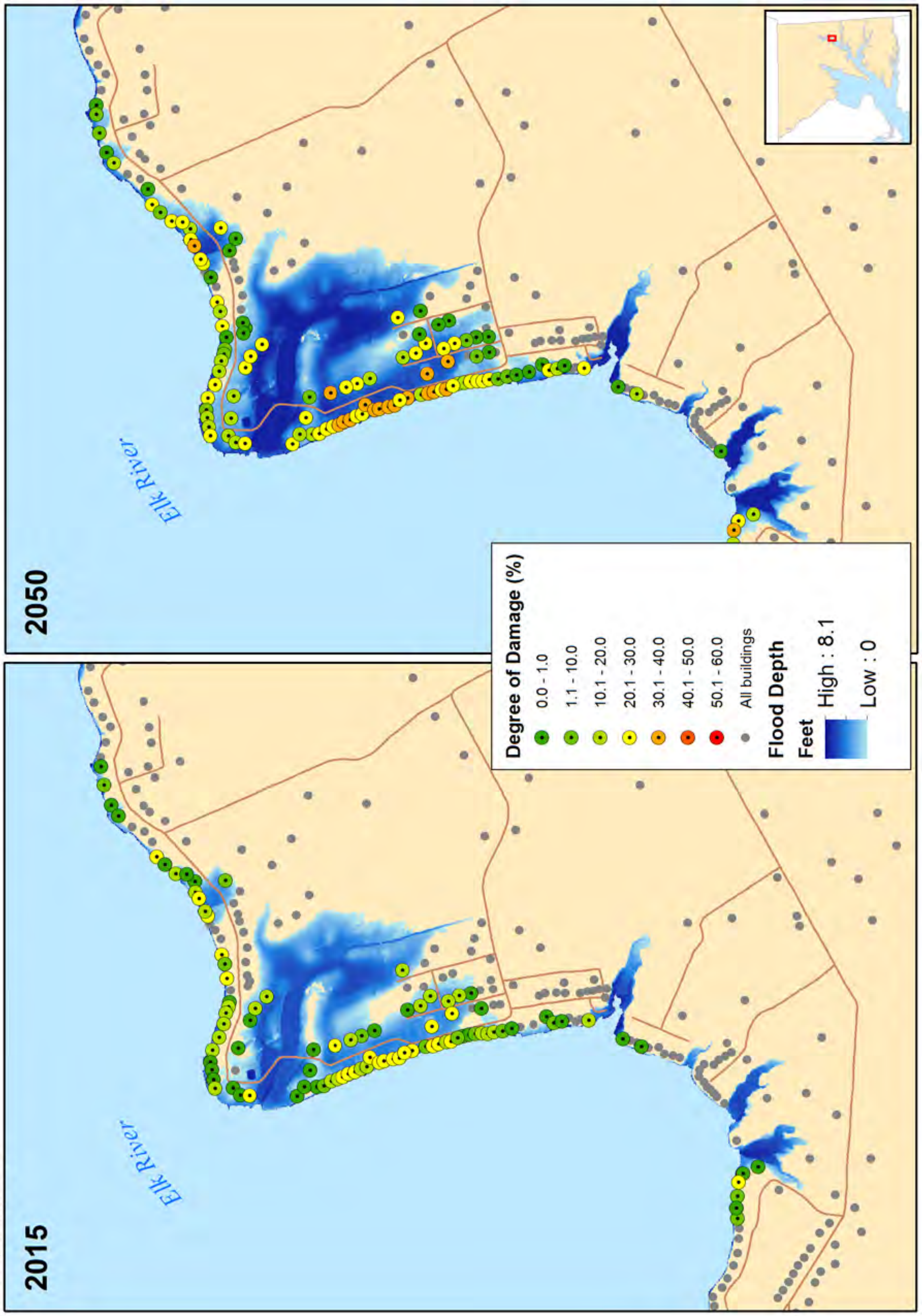
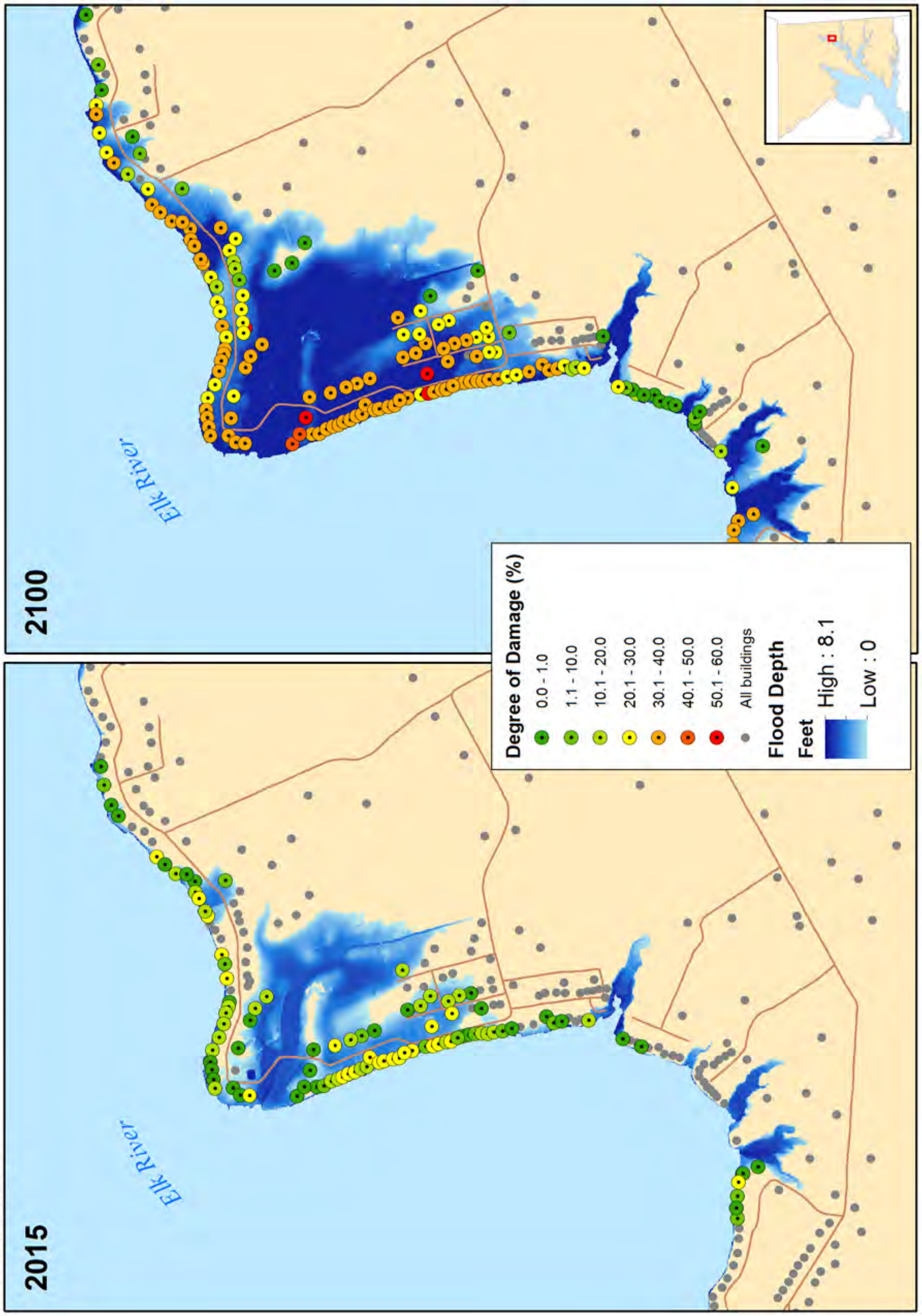


Figure 14 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2100, Locust Point, Maryland



The patterns of damage from flooding in the future when considering the use of the property are very similar to the results in 2015 with a few exceptions (Table 17 and 18). First, there is an industrial site, a church and a farm that were identified as vulnerable in 2015 – by 2050, we predict they will see damage from flooding. Second, in 2100, the increase in sea level seems to have its largest impact on government buildings, taking them from a minimal amount of damage in 2015 to over 40% of all of the county's flood damage in 2100. This is primarily due to the flood waters in 2100 reaching into the center of Elkton where many government buildings are located.

Table 17. Potential damage to structures/contents from a 1% chance flood event in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	935	82.5%	$174,242,529	$25,728,037	14.8%	68.3%
Commercial	174	15.3%	$58,404,252	$6,465,701	11.1%	17.2%
Government	20	1.8%	$164,348,212	$5,352,307	3.3%	14.2%
Industry	1	0.1%	$81,500	$13,364	16.4%	0.0%
Religious	1	0.1%	$252,000	$86,525	34.3%	0.2%
Agricultural	1	0.1%	$46,950	$3,707	7.9%	0.0%
Total	1,132	100.0%	$397,375,443	$37,649,640	9.5%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 18. Potential damage to structures/contents from a 1% chance flood event in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1,798	84.0%	$321,718,528	$61,043,733	19.0%	43.2%
Commercial	299	14.0%	$92,579,338	$23,380,480	25.3%	16.6%
Government	35	1.6%	$233,395,612	$56,634,928	24.3%	40.1%
Industry	3	0.1%	$729,750	$28,536	3.9%	0.0%
Religious	5	0.2%	$1,588,202	$86,525	5.4%	0.1%
Agricultural	1	0.0%	$46,950	$16,575	35.3%	0.0%
Total	2,141	100.0%	$650,058,380	$141,253,278	21.7%	100.0%

Note: All dollar values are from 2015 tax assessments.

In general, the distribution of vulnerability by property value does not change considerably once sea level change is added in 2050 (Table 19). Of course, the raw numbers of structures increases but the proportion of them that fall into the separate categories are remarkably similar. A divergence happens, however, when looking at the distribution of damage. In a 1% chance flood scenario in 2050, the damage predicted for the more valuable buildings ($1 million to $2 million) increased by 6x as a percentage of the overall damage. This result is not unexpected. People who locate relatively expensive homes and businesses will often do so to keep them safe from periodic flooding but are still near the water. As the flood extent expands and the depth increases, these properties are often affected. By 2100, this pattern continues to deepen (Table 20). By then, again the number of properties by value increases considerably but the distribution across the categories remains similar. However, the damage profile shifts to emphasize the very expensive properties. In 2015, 13.9% of all the predicted damage is borne by properties with a structure and contents value of more than $3 million. By 2100, that percentage has jumped to 40.8%. It is also important to note that these are 2015 property values. If the rate of inflation for the next 85 years is the same as the last 85 ($1 in 1930 is worth $13.96 in 2015, according to the Consumer Price Index), the total property value at risk from flooding would be over $900 billion.

Table 19. Potential damage to structures/contents from a 1% chance flood event in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	116	10.2%	$2,755,529	$234,423	8.5%	0.6%
$50 - $100	288	25.4%	$21,807,633	$2,855,771	13.1%	7.6%
$100 - $200	386	34.1%	$57,686,537	$6,416,120	11.1%	17.0%
$200 - $300	133	11.7%	$31,820,140	$4,707,038	14.8%	12.5%
$300 - $400	86	7.6%	$29,611,399	$4,680,803	15.8%	12.4%
$400 - $500	39	3.4%	$17,356,433	$2,826,575	16.2%	7.5%
$500 - $1,000	57	5.0%	$39,369,370	$4,772,128	12.1%	12.7%
$1,000 - $2,000	19	1.7%	$25,490,150	$4,031,072	15.8%	10.7%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	8	0.7%	$171,478,250	$7,125,710	4.1%	18.9%
Total	1,132	100.0%	$397,375,443	$37,649,640	9.5%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 20. Potential damage to structures/contents from a 1% chance flood event in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	252	11.8%	$6,327,640	$1,206,108	19.1%	0.9%
$50 - $100	488	22.8%	$36,380,350	$8,013,320	22.0%	5.7%
$100 - $200	775	36.2%	$115,471,200	$21,235,310	18.4%	15.0%
$200 - $300	297	13.9%	$72,160,140	$10,948,741	15.2%	7.8%
$300 - $400	122	5.7%	$42,164,750	$9,925,118	23.5%	7.0%
$400 - $500	69	3.2%	$30,830,450	$6,009,047	19.5%	4.3%
$500 - $1,000	95	4.4%	$63,178,100	$13,921,051	22.0%	9.9%
$1,000 - $2,000	29	2.7%	$37,924,500	$10,324,591	16.3%	7.3%
$2,000 - $3,000	3	0.1%	$7,275,000	$1,999,543	27.5%	1.4%
More than $3,000	11	0.5%	$283,346,250	$57,670,449	20.3%	40.8%
Total	2,141	100.0%	$650,058,380	$141,253,278	21.7%	100.0%

Note: All dollar values are from 2015 tax assessments

Study Caveats

While it is both a documented fact that sea-levels in the Mid-Atlantic are rising (on average, 3.9 mm per year) and that the rate of sea-level rise is increasing, it should not go without mentioning that the prediction of the flood threat with a future sea level change has more than the normal level of uncertainty. Not only are the estimates of sea level change not a foregone conclusion, but the nature of the flood threat itself is likely to change. For example, in a world with oceans that are 2 (or 5) feet higher, the controlling forces (subtropical high pressure systems, ocean upwelling, thermal heat transfer, etc.) of tropical storms are likely to be different. Thus, the periodicity of certain magnitudes of storm events could change. Similarly, this analysis uses statistical/stochastic models, not a dynamic simulation. Therefore, it does not take into account either individual storm parameters or geographic parameters such as land cover or the shape of the near-shore bottom, both of which will impact the flood predication and both are likely to change in a rising sea level scenario.

With regard to vulnerability estimates, there are also a number of important caveats to remember. First, this analysis assumes that all of the built infrastructure would be exactly as one found it in 2015. That is almost certainly not going to be the case, both with new structures being built and older structures being made more flood-resistant as the waters rise. Second, as mentioned above, the potential damage is being evaluated as if property values will not change by 2050 or 2100 which is also not the case. Finally, this vulnerability analysis deliberately examined only damage to structural/contents because the relationship between building damage and depth of water is best understood. There are still many other sources of potential vulnerability: infrastructure damage/loss (both to rebuild and its impact on restarting the economy after a disaster), loss of productivity with businesses closed, debris removal, other consumer losses (cars, boats, sheds/garages), and of course, the potential loss of life.

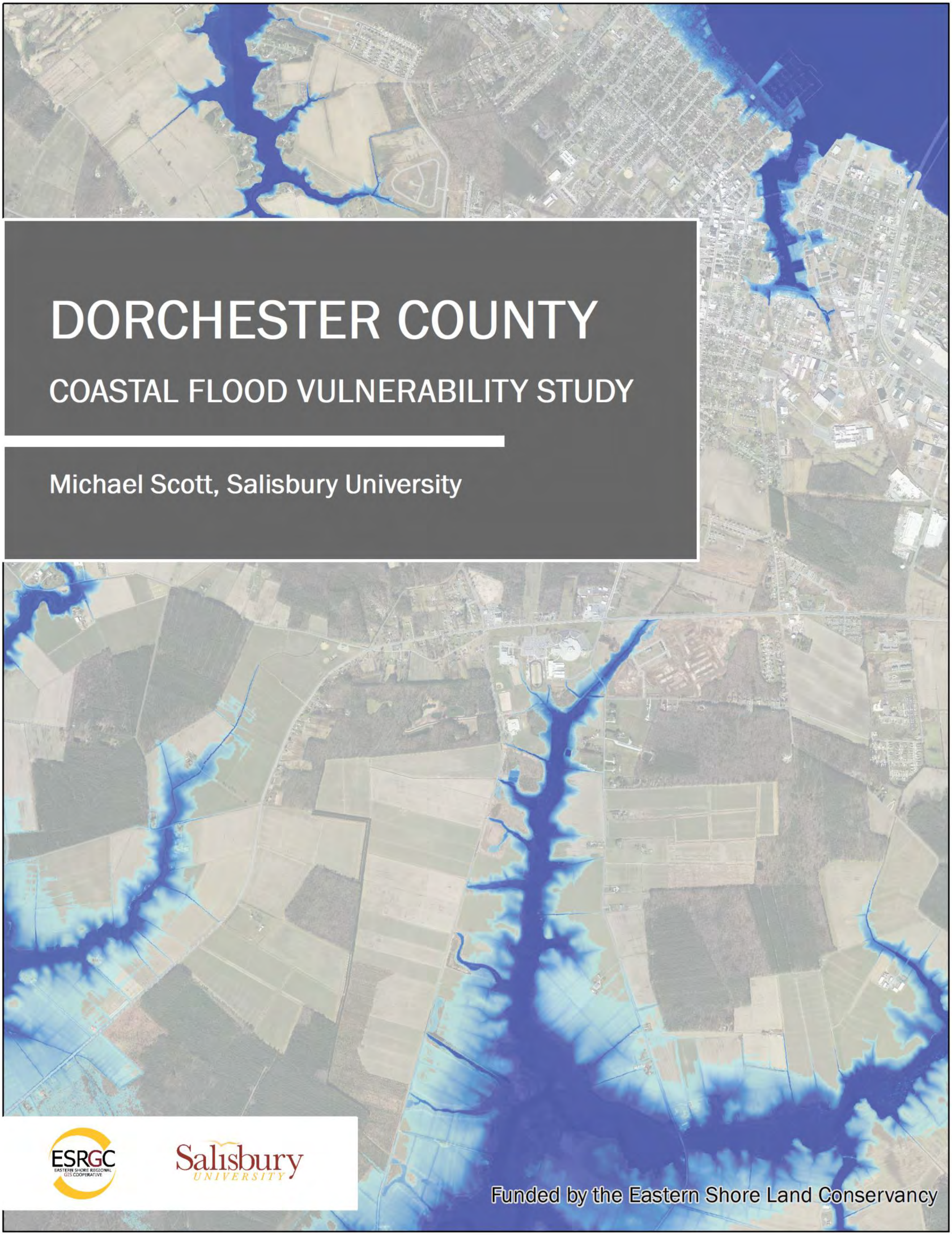
Conclusions

Several conclusions can be made regarding the question of coastal flooding vulnerability in Cecil County. First, given that Cecil County has several significant sources of flood threat and given that it contains more than 46,375 improved structures, the fact that only 709 (1.5%) are vulnerable to the 1% chance flood is probably a result of historical land use patterns (focused on road/railroad development between Philadelphia and Baltimore) as well as a fortuitous geomorphology. Second, given the potential for sea level rise in the coming decades, the time to redouble the County's efforts to protect its citizens from flooding is now. Having said that, this analysis shows that Cecil County has some time to adjust to the change in the flood threat. Third, even though the County as a whole is somewhat flood-resistant, there are certain areas that remain very vulnerable, such as Port Deposit, Charlestown, North East, Locust Point, and the Hollywood Beach area, for which there are no easy answers.

DORCHESTER COUNTY

COASTAL FLOOD VULNERABILITY STUDY

Michael Scott, Salisbury University



ESRGC EASTERN SHORE REGIONAL GIS COOPERATIVE

Salisbury UNIVERSITY

Funded by the Eastern Shore Land Conservancy

Executive Summary

Given the topography and historical development patterns of Maryland's Eastern Shore, the potential for damage from periodic flood events caused by coastal storms and extreme high tides is well-known. What is uncertain is the degree to which the vulnerability of Eastern Shore communities is increasing as sea levels change in the Chesapeake Bay and its tributaries. Therefore, the goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. The methods employed in this research are considered best practices, are accepted by FEMA and provide a consistent framework for assessing risk from floods. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the county and help make informed decisions about mitigation measures to reduce the potential impacts. Having said that, we recommend that the damage statistics in this report be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Results of the analysis predict that 2,713 buildings (worth $482.2 million in the structure and its contents combined) would feel the impacts of a 1%-chance flood in Dorchester County, with 631 of them experiencing more than 10% damage, for a total predicted damage of $11.2 million. Those moderately or severely damaged structures represent less than 25% of the total number of vulnerable buildings but they represent well over half of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits. The much more severe 0.2%-chance flood impacts 3,098 buildings in the county valued at $569.8 million with 1,195 damaged moderately with a total potential damage of $26.8 million. Given that about 93.4% of the potential damage from a 1% chance flood event comes from residential buildings, instigating mitigation actions that are targeted at Dorchester County homeowners might yield the best results.

In Dorchester County, the magnitude of predicted sea level rise for the remainder of this century is typical for the DelMarVa Peninsula. The US Army Corps of Engineers expects an estimated mean sea level increase in the county of 2.11 ft by 2050 and 5.78 ft by 2100. The sea level rise itself will impact a considerable number of buildings in 2050 – 790, worth $79.0 million in structure and contents. But by 2100, this balloons to 3,463 structures worth $659.4 million. The degree of potential damage from sea level rise inundation in 2100 is also concerning – only $66.4 million or $19,172 per building. Unfortunately a certain level of flood vulnerability seems to be built into Dorchester County, given its expanses of low-lying areas and wetlands.

However, when the 1% chance flood is combined with the predicted sea level rise, the vulnerability of the County's built environment is particularly highlighted. In 2050, the 1% chance flood is predicted to impact 3,619 buildings (a 75% increase over the same scenario today), worth $703.7 million (about 1.5x greater than present-day) and

potentially causing $77.3 million in flood damage (a 7x increase from 2015). The same flood in 2100 could impact 4,585 buildings (a 79% increase from 2050) worth $935.2 million in value (a 75% increase from 2050) and cost a potential $154.1 million in damage (about a 2x increase over the same estimate in 2050).

This coastal flood vulnerability analysis of Dorchester County yields several important conclusions. First, given that Dorchester County has several significant sources of flood threat and given that it contains more than 16,069 improved structures, the fact that 2,713 (16.9%) are already vulnerable to the 1%-chance flood is probably a result of historical land use patterns that are particularly water-oriented, the extreme lack of ground elevation in the southern half of the county, and the impact of sea level change since the 1660's. Second, given the potential for sea level rise in the coming decades, Dorchester County is uniquely vulnerable. By 2050, more than one-fifth of all of the structures in the county will feel the effects and by 2100, if the predictions hold, almost 30% of the county's buildings could be inundated by a 1% chance flood. Even with no flooding at all, mean sea level will bring water to the footprint of about 5% of all of the building stock in Dorchester County. Unfortunately, the impacts that other counties will experience in the future are happening now to the people of Dorchester. But all is not lost. One advantage of this situation is that there will be very little argument about the nature of the threat that Dorchester County faces. This will make consensus about potential mitigation measures much easier to achieve. There are many places around the world that have learned to live alongside a constant flood threat and thrived. It just means that the people of Dorchester County need to become vigilant about implementing in flood-proofing into every development and re-development project planned for the hazard zone. Doing so will enable them to avoid the worst of the negative impacts of flooding and preserve their way of life.

Introduction and Study Context

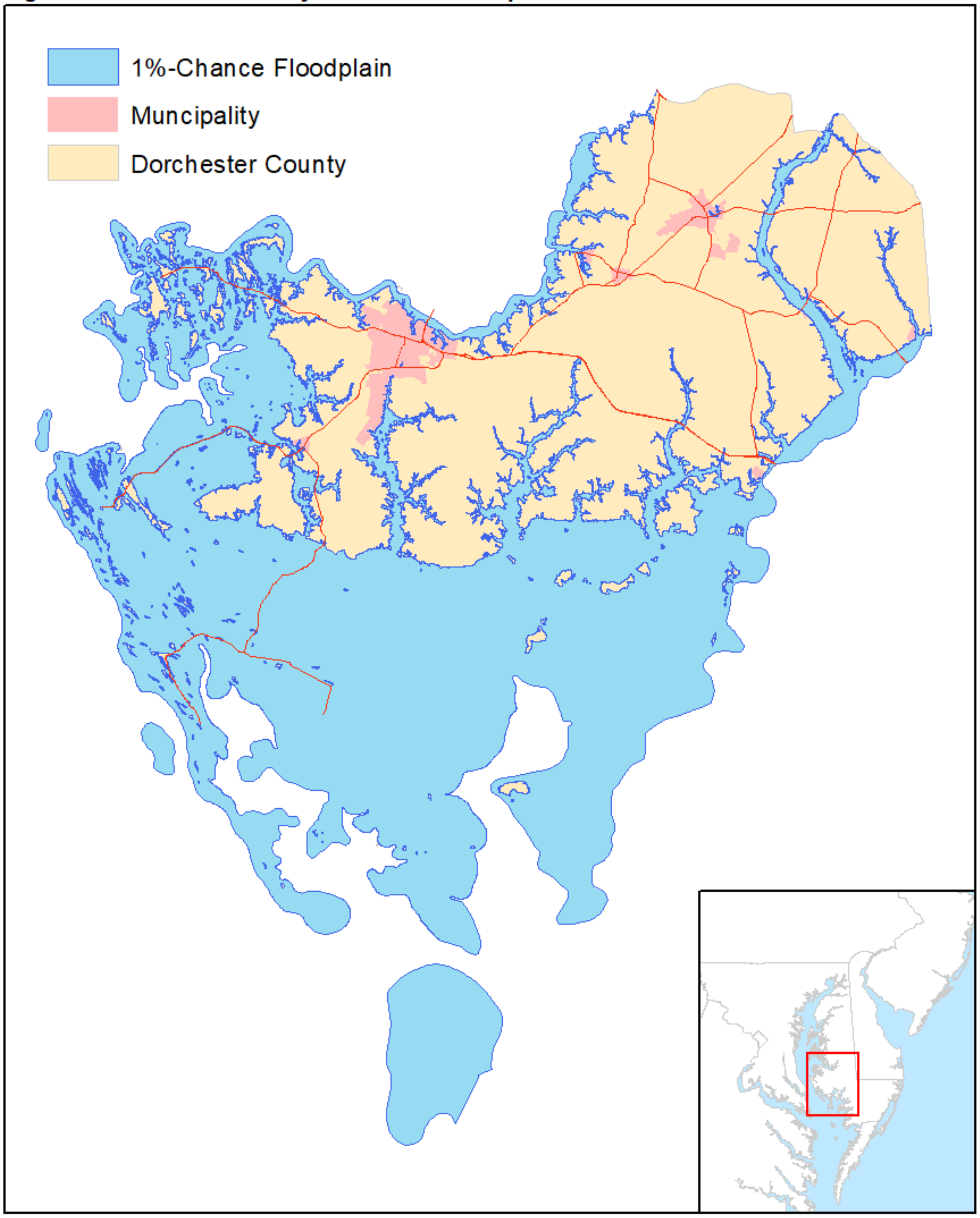
Flooding occurs when rivers, creeks, streams, ditches, or other water bodies receive more water that they can handle from rain, snowmelt, storm surge, or excessive high tides. The excess water flows over adjacent banks or beaches/marshes and into the adjacent floodplain. As many as 85 percent of the natural hazard disasters across the United States have been attributed to flooding.

This document presents the results of a coastal flood vulnerability study of Dorchester County, Maryland conducted by Dr. Michael Scott of Salisbury University at the request of the Eastern Shore Land Conservancy in Easton, Maryland. The goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. Specifically, using flood depth data calculated on behalf of the Maryland State Highway Administration, the flood scenarios of a 1% chance flood in 2015, a 0.2% chance flood in 2015, no periodic flooding in 2050, a 1% chance flood in 2050, no periodic flooding in 2100, and a 1% chance flood in 2100 were evaluated versus the location and value of buildings in Dorchester County. The results are an accounting of the potential damage from periodic flooding, exacerbated by future sea level change. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the count and help make informed decisions about mitigation measures to reduce the potential impacts.

Dorchester County’s Floodplain

The following map (Figure 1) depicts the 1% chance floodplains within Dorchester County, as designated by FEMA on the Flood Insurance Rate Maps or FIRMs. The 1% chance flood (formerly referred to as the 100-year flood) is a flood which has a 1 percent chance of being equaled or exceeded in any given year (MDE, *Maryland Floodplain Manager’s Handbook*). Dorchester County can experience riverine flooding as a result of excessive rainfall in a matter of hours, such as from a severe thunderstorm. Additionally, some soils can become saturated over a longer period of time and reduce their absorption potential. Riverine flooding can affect any of the rivers and streams in the County but primarily affects the non-tidal or brackish portions of the streams that feed Chesapeake Bay. Tidal flooding in Dorchester County usually occurs as a result of tropical storms (including hurricanes) as well as the combination of high astronomical tides with a landward wind. Dorchester County has 48.3% of its land area is in the 1% chance floodplain.

Figure 1 Dorchester County 1% chance floodplain from dFIRMs



While Dorchester County is clearly vulnerable to both riverine and coastal/tidal flooding, only tidal flooding is considered in this vulnerability study. It is entirely possible that those areas in the county beyond the tidal flooding extent will experience a change in their flooding occurrence if the consensus predictions of global climate change come to pass. Current research suggests that extreme rainstorms (as well as extreme droughts) will become more common (National Climate Assessment, 2014).

Flood Measurement

There are two US Geological Survey gauging stations within the County. Four National Weather Service Advanced Hydrologic Prediction Service hydrographs are within the County as well as and two National Oceanographic and Atmospheric Administration tide gauges (Table 1). Measurements of stream discharge, river stage, and tide height are critical to the prediction of flood events. At the CAMM2 hydrograph, flood stage is considered 3.5 ft above average tide and this hydrograph does offer flood level prediction. At the NOAA tide gauge in Bishops Head, the average range of the tide is 1.76 ft. The maximum water level ever recorded was 4.50 ft above mean lower low (MLLW) on March 7, 2018 during a nor'easter. That equals 3.48 ft above MSL, or less than the 1% chance flood height. The tide gauge at Bishops Head has only been recording since 2005. At the NOAA tide gauge in Cambridge, the average range of the tide is 1.62 ft. The maximum water level ever recorded was 6.18 ft above mean lower low (MLLW) on September 19, 2003 during Hurricane Isabel. That equals 5.16 ft above MSL, or just about than the 1% chance flood height. The tide gauge at Cambridge has been recording since 1980.

Table 1. River gauges, hydrographs and tide gauges in Dorchester County

Agency	ID Number	Station Name	Real-Time or Daily
USGS	01490000	Chicamacomico River near Salem	Real-time
USGS	01488110	Nanticoke River at Sharptown	Real-time
NWS	CAMM2	Chesapeake Bay at Cambridge	Real-time
NWS	BISM2	Chesapeake Bay at Bishops Head	Real-time
NWS	CMCM2	Chicamacomico River at Salem	Real-time
NWS	SRPM2	Nanticoke River at Sharptown	Real-time
NOAA	8571421	Bishops Head	Real-time
NOAA	8571892	Cambridge	Real-time

Flood Levels

Using the Flood Insurance Studies (FIS) of Dorchester County, published by FEMA effective March 16, 2015, the following table (Table 2) reports the flood elevations for the key flooding sources.

Table 2. Flood elevations for coastal event (Units are NAVD 1988 feet)

Flooding Source and Location	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY				
At Rioll Cove	3.1	3.7	3.9	4.3
At Charity Point	3.1	3.6	3.8	4.7
At Nancy's Point	3.2	3.7	3.8	4.6
CHOPTANK RIVER				
At Castle Haven Point	3.4	3.9	4.1	4.7
At Cambridge	3.5	4.1	4.3	5.0
LITTLE CHOPTANK RIVER				
At Casson Point	3.2	3.7	3.9	4.4
At Smith Cove	3.3	3.8	4.0	4.6
HONGA RIVER				
At Crab Point	3.2	3.8	4.0	4.8
FISHING BAY				
At Elliot's Island	3.9	4.6	4.8	5.3
HOOPER STRAIT				
At Hopkins Cove	3.4	3.9	4.2	4.7
NANTICOKE RIVER				
At Mulberry Point	4.0	4.8	5.0	5.8
At Upper Greens Cove	4.3	5.3	5.6	6.4

Hazards from Floods

Flooding causes $6 billion in average annual losses in the United States annually and account for an average of 140 casualties annually (USGS, "Flood Hazards – A National Threat," 2006). While most people's vision of the threat from flooding may include being swept away or buildings being structurally impacted, there are actually a number of hazards associated with flooding that occur both during and after an event.

During the Flood

While a flood event is underway, citizens will be faced with a number of threats. The hydraulic power of water is significant and walking through as little as 6 inches of moving water is dangerous because of the possibility of losing stable footing. Driving through flood water is the cause of many flood deaths each year. As little as one foot of water can float many cars and two feet of rushing water can carry away most vehicles including SUVs. That fact, combined with an inability for drivers to judge the depth of flood water, as well as the potential for flood waters to rise quickly without warning, making driving through flood water a very unwise action.

In addition to being swept away, flood water itself is to be avoided. Because of leaking industrial containers, household chemicals, and gas stations, it is not healthy to even touch the flood water without protective equipment and clothing. Downed power lines, flooded electric breaker panels, and other sources of electricity are a significant threat during a flood. One should also be prepared for the outbreak of fire. Electric sparks often cause fire to erupt and because of the inability of firefighting personnel to respond, a fire can quickly burn out of control.

After the Flood

Cleaning up after a flood can also expose citizens to a number of threats. For example, electrical circuits or electrical equipment could pose a danger, particularly if the ground is wet. Buildings that have been exposed to floodwater may exhibit structural instability of walkways, stairs, floors, and possibly roofs. Flood waters often dislodge and carry hazardous material containers such as tanks, pipes, and drums. They may be leaking or simply very heavy and unstable. The combination of chemical contamination and the likely release of untreated sewage (necessary when the sewage treatment plant is overwhelmed with flood-swelled effluent) mean that drinking water supplies can be unusable. Fire continues to be a very real threat after a flood. First-responders could be occupied with more pressing emergencies and traditional fire suppression equipment may be inoperable, but there may be mobility problems that keep fire-fighting equipment from reaching an outbreak. Finally, there is the mental toll of being involved in a disaster. Continued long hours of work, combined with emotional and physical exhaustion and losses from damaged homes and temporary job layoffs, can create a highly stressful situation for citizens. People exposed to these stressful conditions have an increased risk of injury and emotional crisis, and are more vulnerable to stress-induced illnesses and disease.

Impact to Buildings

Fortunately, the number of people killed or injured during floods each year is relatively small. The built environment within the floodplain, however, is likely to bear the brunt of a flood's impact. Whether the water is moving or standing, the exposure of buildings to flood water could cause a great deal of damage. If the water is moving, the differing hydraulic pressure inside the building vs. outside can cause the walls and foundation to buckle and fail. If the water is standing for any length of time, even materials above the flood height will become saturated with flood water as the flood water is absorbed (known as wicking). Certainly, most of the contents of flooded buildings that were located at or below the flood height will need to be discarded. This includes carpet, furniture, electronic equipment, and other household or commercial items. In most cases it is not simply the fact that the objects have become wet but since the flood water brings with it sediment and chemicals, it makes it nearly impossible to recover all but the most precious/heirloom items.

Flood Vulnerability Assessment

The goal of mitigation is to increase the flood resistance of a community, so that the residents and businesses will become less susceptible to future exposures to flooding, thereby resulting in fewer losses. A key component to reducing future losses is to first have a clear understanding of the current threats, the current probability that those threats would occur, and the potential for loss from those threats. The Vulnerability Assessment is a crucial first step in the process as it is an organized and coordinated process of assessing potential hazards, their risk of occurring, and the possible impact of an event.

Study Method

The Vulnerability Assessment was conducted using the method developed for HAZUS-MH, FEMA's loss estimation software, to assess the County's built environment to vulnerability to flooding. HAZUS-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide credible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards, including floods, hurricane winds and earthquakes. The methodology supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

The primary input to any vulnerability assessment is a "depth of flood" grid. This flood depth grid was created using an elevation grid derived from LiDAR measurements. By incorporating the polygons of the 1% chance floodplain from the FIRMs, the coastal flood elevations from the Flood Insurance Study as well as the current elevation grid, HAZUS-MH was able to create a flood depth grid with a reasonable precision for the 1% (Figure 2) and 0.2%-chance (Figure 3) coastal flood scenarios with Dorchester County's current mean sea level. In addition, areas predicted to be inundated by a higher mean sea level in 2050 (Figure 4) and 2100 (Figure 5) were also modeled. Finally, the depth of flood for the 1%-chance event was mapped using the 2050 (Figure 6) and 2100 (Figure 7) predicted sea levels. For the full detail of how these depth grids were created, please see "GIS Data Products to Support Climate Change Adaptation Planning: Dorchester County, Maryland" at http://www.esrgc.org/mapServices/.

Figure 2 Predicted flood depths for Dorchester County 1% chance floodplain at MSL in 2015

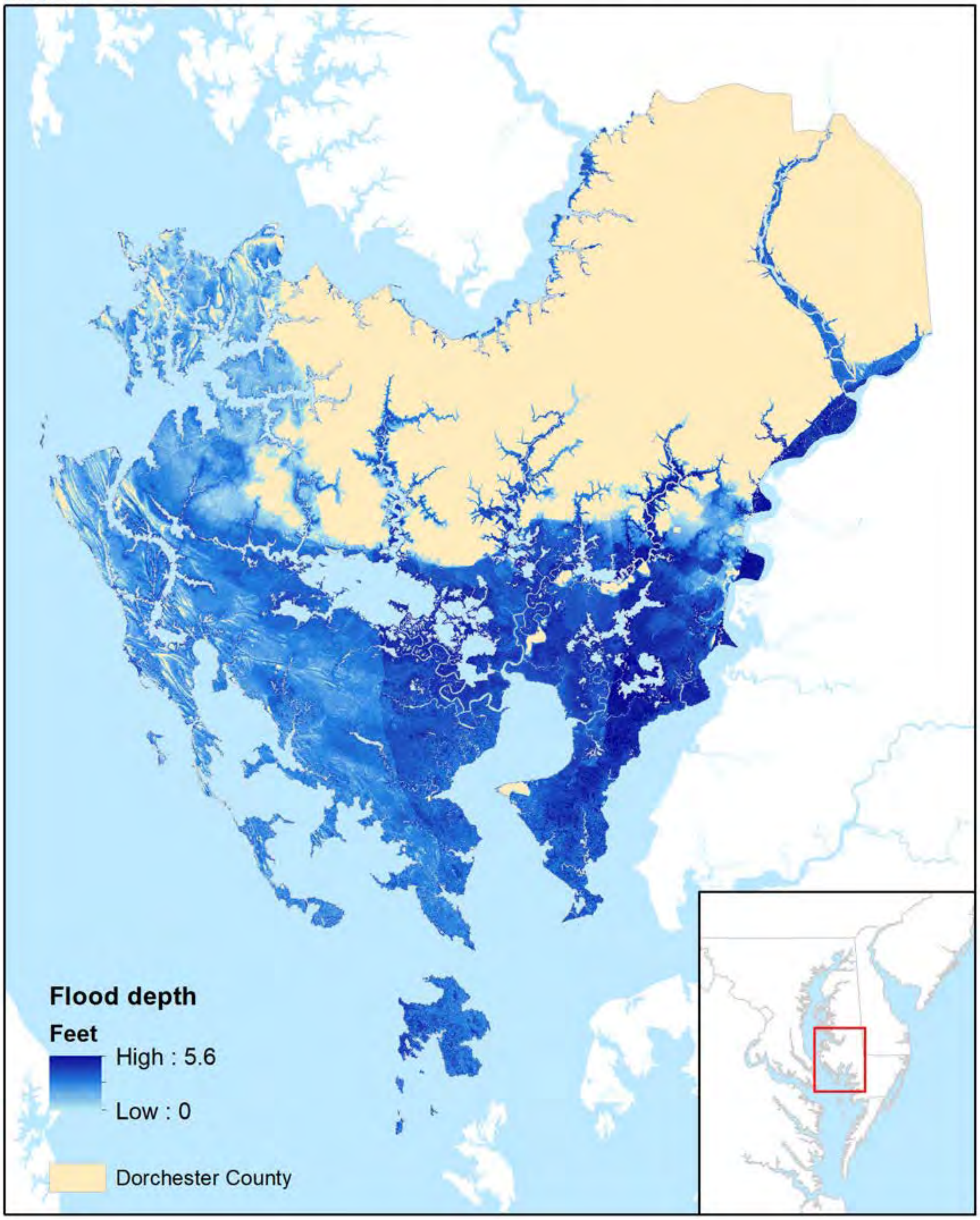


Figure 3 Predicted flood depths for Dorchester County 0.2% chance floodplain at MSL in 2015

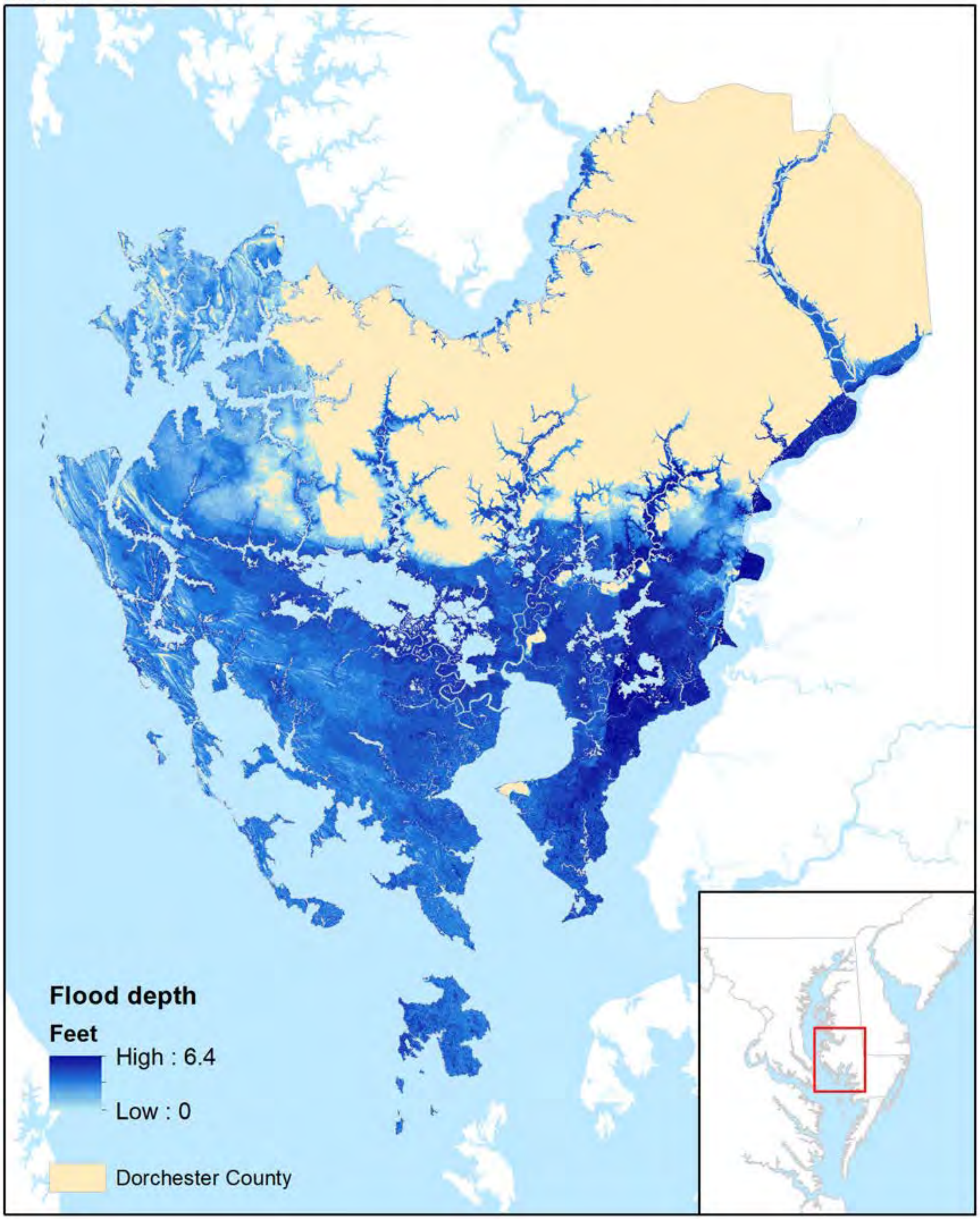


Figure 4 Predicted depth of MSL inundation in Dorchester County in 2050

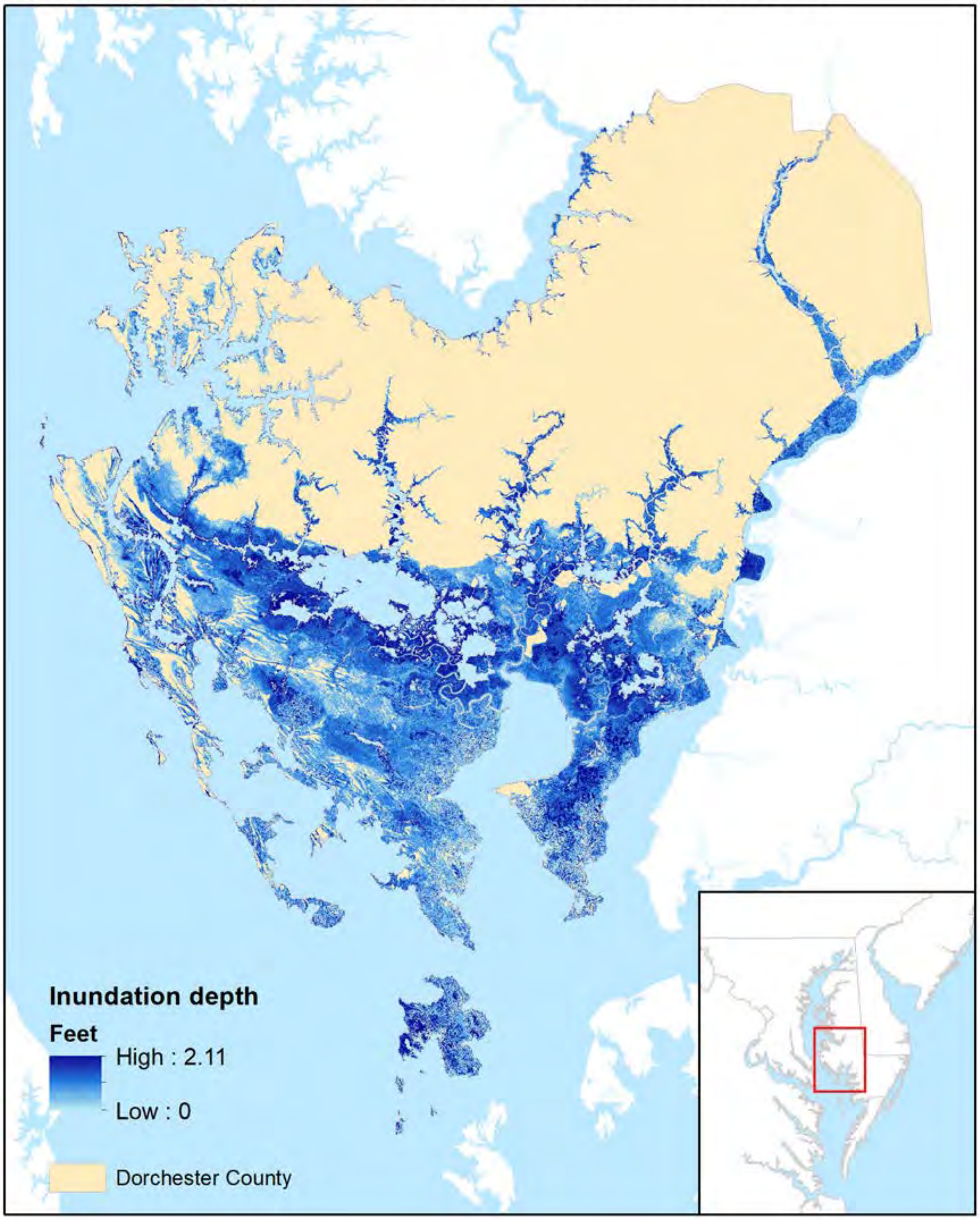


Figure 5 Predicted depth of MSL inundation in Dorchester County in 2100

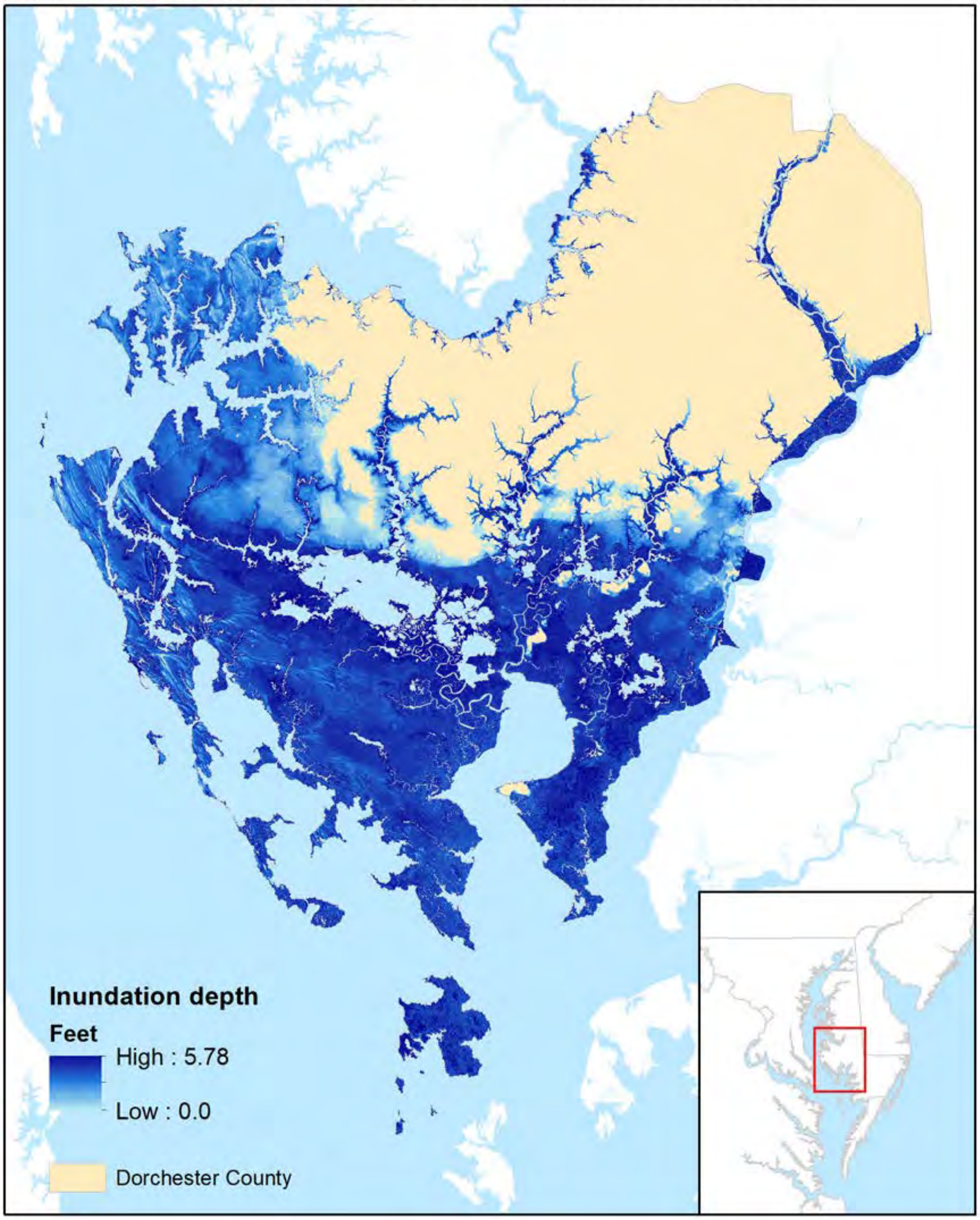


Figure 6 Predicted flood depths for Dorchester County 1% chance floodplain at MSL in 2050

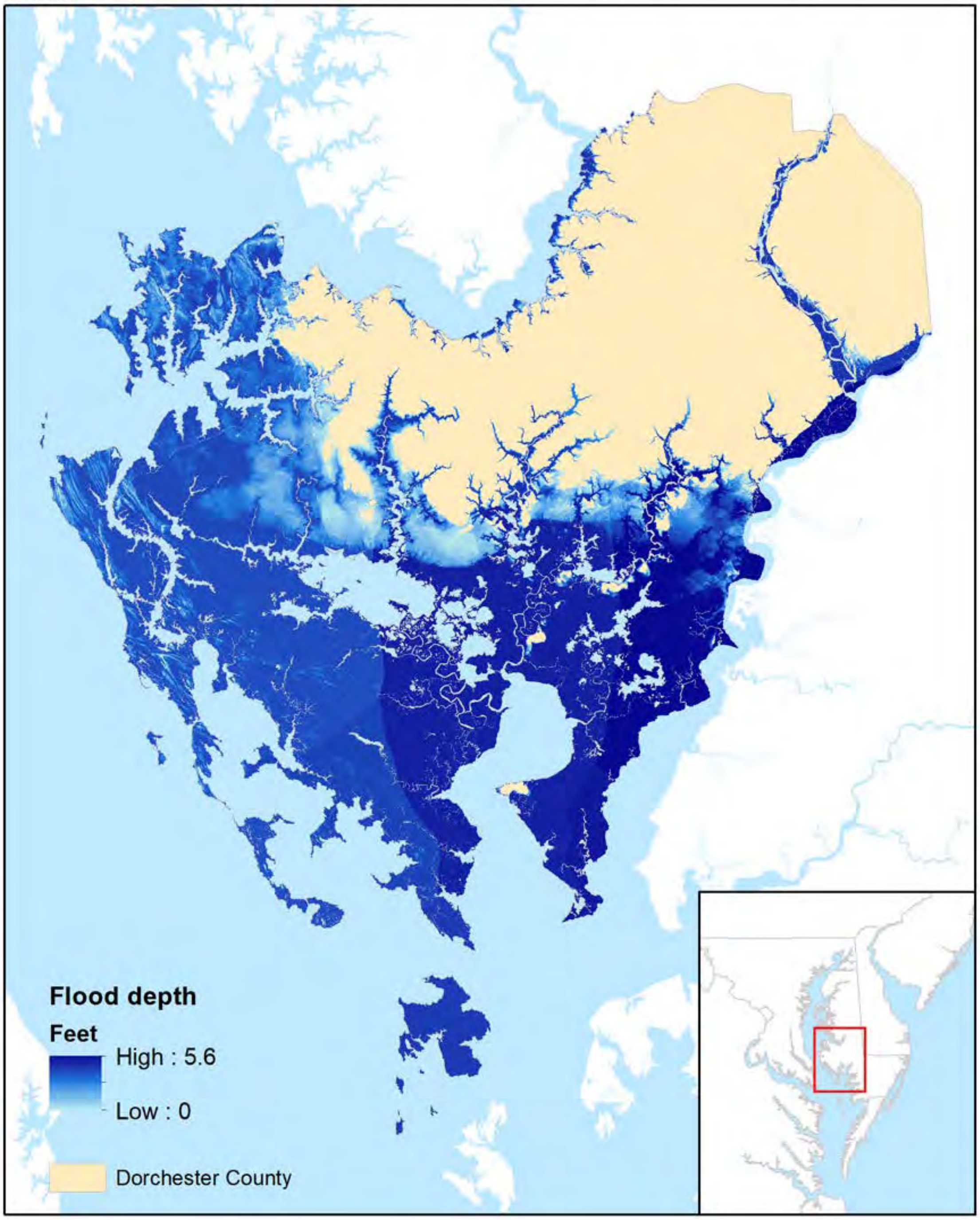
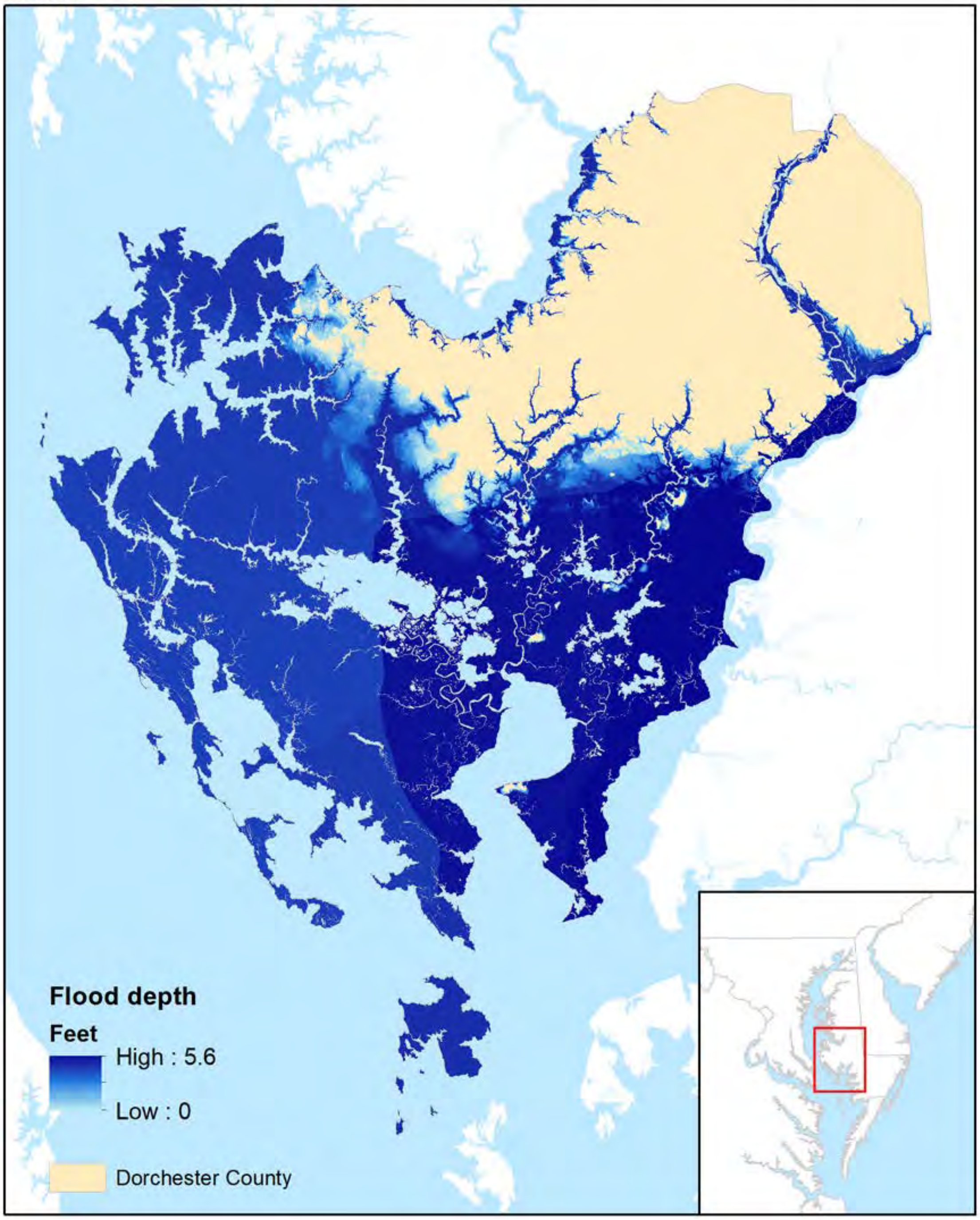


Figure 7 Predicted flood depths for Dorchester County 1% chance floodplain at MSL in 2100



Using these flood depth grids, those buildings that are vulnerable to flood water, and the degree to which they are vulnerable, were determined. Fortunately, Dorchester County maintains a set of “addressable” building footprint polygons, separate from any outbuildings. Next, the average depth of flood water for each modeling scenario was calculated for each building by converting the depth grids to depth points and intersecting the building footprints and the depth points. Dorchester County’s 2015 tax parcels were then digitally overlaid, thus assigning attributes such as total assessed value of the improvements, the land use of the parcel (residential, commercial, etc), and the structure style (1 story, 2 story, apartments, etc) to the building footprint. Because the foundation heights are unknown, an assumption of a 24” foundation was made. Using that assumed foundation height, the flood depth above the first finished floor was calculated. The total value of the building and its contents was found, using industry-standard estimates of the contents value based on the use of the building (i.e. residential contents are 50% of the building value, while commercial contents are 100% of the building value). Finally, using the depth-damage curves provided by FEMA via the HAZUS-MH software, the potential damage percentage, and therefore the potential damage to both the building and its contents in 2015 dollars, for each building for each flood scenario was estimated.

It is important to note when viewing the following results that the numbers generated carry with them a degree of uncertainty. Nearly every component (the ground elevations, the flood heights, the foundation heights, the assessed value, etc.) has confidence constraints of various magnitudes. The HAZUS-MH model itself is a simplified version of the complex engineering models used to create the flood insurance rate maps. Having said that, considerable research has been conducted to review HAZUS-MH analysis results after an event and have found that the software does a reasonably good job of both predicting the depth of flood as well as the insured losses. But was with any simulation analysis, we recommend that these damage statistics be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Flood Results for Present-Day (2015)

The results of the analysis indicate that there are 2,713 buildings predicted to be impacted by a 1% chance flood in Dorchester County (Table 3). A majority of them (1,468) would only experience minor nuisance flooding in this scenario; Nearly a quarter of them (631 or 23.3%) would experience greater than 10% damage. Thus, the overall predicted damage percentage from this flood level is 2.3% of the total value of the structures and contents ($11.2 million of damage from $482.2 million in value). When standardized per building, those buildings that are predicted to incur incidental damage are also the most valuable (an average of $234,130 per building vs $74,869 per building that are damaged 10% or greater). This is not surprising given that many of these more expensive structures are found in Cambridge and the other more densely populated areas – areas that by their nature are well-known to be susceptible to occasional flooding. It is also worth noting that a significant mitigation opportunity exists. There are 126 buildings predicted to be damaged between 20 and 60% in the 1% chance event that represent less than 5% of the total number of vulnerable buildings. However, they represent over 12% of the potential damage. Working to make those structures less vulnerable to flooding should yield worthwhile financial benefits. Unfortunately, nearly all the half of the potential damage comes from 505 buildings damaged between 10 and 20%. That is a large number of property owners to reach in a short time period.

The spatial distribution of the structures vulnerable to the 1%-chance flood event follows a predictable pattern (Figure 8). Large concentrations of vulnerable buildings are found in the Neck District (between the Choptank River, the Little Choptank River, and the Chesapeake Bay), the Church Creek area, Taylor's Island, Hooper's Island, and the southern peninsula headed for Crocheron. One can see the road network in the south of the county highlighted as that is where the development has taken place. Other areas impacted, but less so, are along the Little Blackwater River, the Nanticoke River, the Chicamacomico River, and Marshyhope Creek.

Table 3. Potential damage to structures/contents from a 1% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,468	54.1%	$343,703,305	$234,130	$88,313	$60	0.8%
1 - 10%	614	22.6%	$91,281,677	$148,667	$4,217,805	$6,869	37.6%
10 - 20%	505	18.6%	$41,625,330	$82,426	$5,512,769	$10,916	49.1%
20 - 30%	112	4.1%	$5,167,598	$46,139	$1,227,945	$10,964	10.9%
30 - 40%	8	0.3%	$337,354	$42,169	$119,230	$14,904	1.1%
40 – 50%	4	0.1%	$87,450	$21,862	$39,863	$9,966	0.4%
50% or more	2	0.1%	$24,450	$12,225	$12,872	$6,436	0.1%
Total	2,713	100.0%	$482,226,894	$177,747	$11,218,796	$4,135	100.0%

Note: All dollar values are from 2015 tax assessments.

The very severe 0.2% chance flood event represents a current worst-case scenario for Dorchester County (Table 4). In such an event, 3.098 buildings would be impacted with 1,184 impacted moderately (10 – 50%) and 9 impacted severely (50% or greater). The total value of the structures and their contents that are vulnerable to flooding expands to $569.8 million and the potential damage is calculated to be $26.8 million, or more than double that of the 1% chance event. The number of buildings that are minimally effected (1,147) drops by more than 17% as a percentage of the total vulnerable buildings (54.1% in 1%-chance scenario vs. 37.0% in the 0.2%-chance). This indicates that in such a severe flood, the water is not reaching many more structures than previously impacted, only 385. Unfortunately, the potential damage that could be sustained to those buildings subjected to the flood will be higher.

Figure 8 Spatial distribution of vulnerable structures in Dorchester County 1% chance flood at MSL in 2015 (n=2,713)

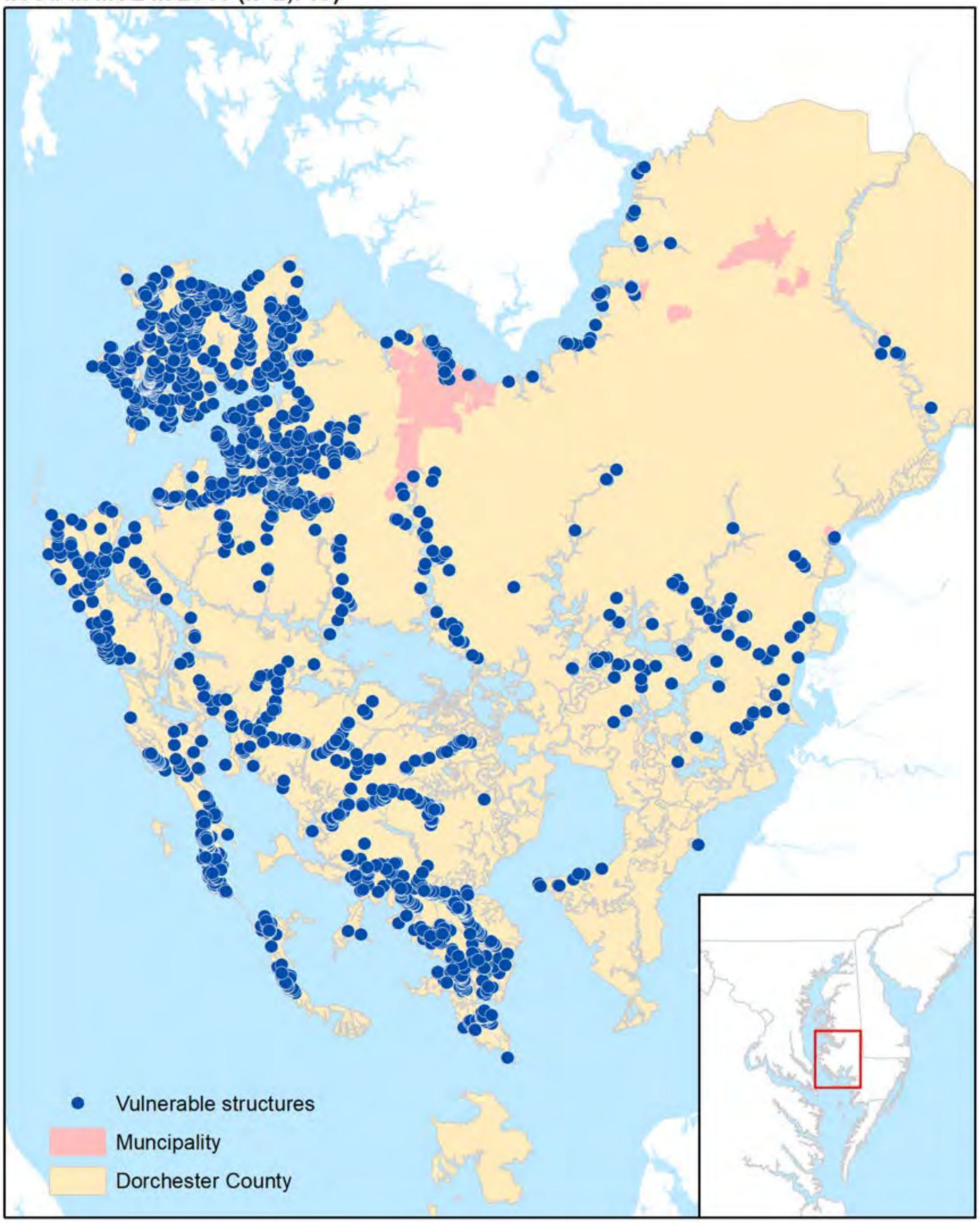


Table 4. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,147	37.0%	$289,544,515	$252,436	$102,732	$90	0.4%
1 - 10%	756	24.4%	$159,791,863	$211,365	$8,269,028	$10,938	30.8%
10 - 20%	853	27.5%	$98,618,509	$115,614	$13,234,030	$15,515	49.3%
20 - 30%	299	9.7%	$20,200,873	$67,561	$4,596,321	$15,372	17.1%
30 - 40%	24	0.8%	$1,072,912	$44,705	$365,372	$15,265	1.4%
40 – 50%	10	0.3%	$292,502	$29,250	$132,447	$13,245	0.5%
50% or more	9	0.3%	$259,200	$28,800	$141,277	$15,697	0.5%
Total	3,098	100.0%	$569,780,374	$183,919	$26,841,208	$8,664	100.0%

Note: All dollar values are from 2015 tax assessments.

When the potential damage was also examined with respect to land use, it was found that no matter the scenario, the vast majority all of buildings vulnerable to flooding in Dorchester County were residential, ranging from 92.8% in the 1% chance scenario (Table 5) to 93.0% in the 0.2% chance scenario (Table 6). The second largest category was agricultural buildings, 1.9% in both the 1% chance scenario and the 0.2% chance scenario. In the 1% chance scenario, the majority of the damage (93.4%) comes from residential buildings, which is to be expected given the number of residential buildings affected. However, given that (relatively) few industrial buildings are predicted to be impacted (21 or 0.8%), it is concerning that they account for 2.8% of the predicted damage. But still, the vast majority of mitigation actions need to be targeted at Dorchester County homeowners as that will yield the best results.

Table 5. Potential damage to structures/contents from a 1% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	2,518	92.8%	$445,000,845	$10,480,245	2.4%	93.4%
Commercial	50	1.8%	$14,275,613	$265,008	1.9%	2.3%
Government	42	1.5%	$13,446,811	$13,102	0.1%	0.1%
Industry	21	0.8%	$5,565,754	$313,749	5.6%	2.8%
Religious	30	1.1%	$3,598,650	$144,113	4.0%	1.3%
Agricultural	52	1.9%	$339,220	$2,579	0.8%	0.0%
Total	2,713	100.0%	$482,226,894	$11,218,796	2.3%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 6. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	2,880	93.0%	$523,423,336	$24,272,748	4.6%	90.4%
Commercial	57	1.8%	$21,371,215	$994,891	4.7%	3.7%
Government	45	1.5%	$14,305,814	$686,814	4.8%	2.6%
Industry	21	0.7%	$5,565,754	$640,450	11.5%	2.4%
Religious	36	1.2%	$4,422,827	$238,653	5.4%	0.9%
Agricultural	59	1.9%	$691,428	$7,652	1.1%	0.0%
Total	3,098	100.0%	$569,780,374	$26,841,208	4.7%	100.0%

Note: All dollar values are from 2015 tax assessments.

One final way to break down the countywide vulnerability results is to examine them by property value. The following tables explore the vulnerability of the buildings based on the values of the structure and its contents (Tables 7 & 8). Each flooding scenario presents remarkably consistent results and thus there are some overall conclusions that can be made. First, in both flood scenarios, the least valuable properties suffer the most damage, relative to their value. Given that the owners of these properties are historically the least likely to have flood insurance, this situation could be debilitating for those property owners. Second, nearly 2/3 of the total damage from the 1% chance event is generated by relatively inexpensive properties (both a structure and contents value between $50,000 and $300,000). This is a concern as not only does it represent nearly 1,600 separate properties but these homeowners (nearly all are residential) are unlikely to have the resources necessary to make significant changes themselves. Finally, with the increase in flood depths in the 0.2% chance scenario, the damage percentages begin to spread out among the range of property values. This suggests that the 0.2%-chance flood is severe enough to damage many different areas and are felt by working-class, middle-class, and upper-class neighborhoods alike.

Table 7. Potential damage to structures/contents from a 1% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	648	23.9%	$11,887,727	$1,095,883	9.2%	9.8%
$50 - $100	520	19.2%	$38,664,175	$2,446,942	6.3%	21.8%
$100 - $200	691	25.5%	$100,812,975	$3,261,330	3.2%	29.1%
$200 - $300	388	14.3%	$93,828,765	$1,477,059	1.6%	13.2%
$300 - $400	220	8.1%	$74,936,192	$781,806	1.0%	7.0%
$400 - $500	100	3.7%	$44,216,950	$407,149	0.9%	3.6%
$500 - $1,000	130	4.8%	$86,160,610	$637,539	0.7%	5.7%
$1,000 - $2,000	11	0.4%	$14,347,500	$270,504	1.9%	2.4%
$2,000 - $3,000	1	0.0%	$2,832,200	$0	0.0%	0.0%
More than $3,000	4	0.1%	$14,539,800	$840,584	5.8%	7.5%
Total	2,713	100.0%	$482,226,894	$11,218,796	2.3%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 8. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	711	23.0%	$13,211,357	$1,669,277	12.6%	6.2%
$50 - $100	581	18.8%	$43,275,025	$4,331,658	10.0%	16.1%
$100 - $200	783	25.3%	$114,119,075	$7,660,639	6.7%	28.5%
$200 - $300	470	15.2%	$113,914,840	$4,905,126	1.6%	18.3%
$300 - $400	258	8.3%	$88,158,342	$2,574,715	2.9%	9.6%
$400 - $500	117	3.8%	$51,740,725	$1,549,323	3.0%	5.8%
$500 - $1,000	156	5.0%	$104,201,160	$2,059,465	2.0%	7.7%
$1,000 - $2,000	15	0.5%	$19,515,450	$1,114,205	5.7%	4.1%
$2,000 - $3,000	3	0.1%	$7,104,600	$0	0.0%	0.0%
More than $3,000	4	0.1%	$14,539,800	$976,799	6.7%	3.6%
Total	3,098	100.0%	$569,780,374	$26,841,208	4.7%	100.0%

Note: All dollar values are from 2015 tax assessments

Sea level Rise Inundation in 2050 and 2100

Unfortunately, we know that the water levels in the Chesapeake Bay that feed this periodic tidal flooding are not static – they are quite dynamic. Scientists at the USGS estimate that mean sea level in the Bay was about 2 feet lower when Captain John Smith first mapped it in 1608 (Larsen, 1998; https://pubs.usgs.gov/fs/fs102-98/). The Mid-Atlantic region is predicted to be one of the most affected by sea level change going forward because of the presence of the combination of eustatic sea level rise, thermal expansion of sea water as the earth warms, the slowdown of the North Atlantic gyre, and the subsidence of the land surface from the glacial isostatic rebound. The current sea level trend, measured from 1937 to 2015 at the Solomons Island tide gauge is 3.74 mm/year or 1.23 ft in 100 years.

However, scientists do not think that a linear trend will continue. The rate is expected to increase. The models used in this flood mitigation plan follow the same method used by the Maryland State Highway Administration to document the potential flood vulnerability of the road infrastructure from periodic flooding in 2050 and 2100. For that method, the "high" estimates of sea level change from the US Army Corps of Engineers was chosen as the appropriate planning scenario. For Dorchester County, this means the USACE expects an estimated mean sea level increase of 2.11 ft by 2050 and 5.78 ft by 2100 (Figures 4 & 5).

Using these amounts of change in mean sea level, additional analysis of the vulnerability of the built environment from the inundation expected from mean sea level (but no flooding) in 2050 and 2100. However, it should be noted that these damage estimates are not particularly appropriate for non-periodic flooding. They are included here primarily for comparison's sake. If the buildings predicted to be inundated constantly by a rise in mean sea level were not elevated beyond the reach of the water, the damage done to them would be a great deal more severe.

As the 2050 mean sea level inundation results show (Table 9), Dorchester County is uniquely vulnerable on Maryland's Eastern Shore. There are 790 buildings are predicted to experience water in the footprint of their structure. Thankfully, nearly all (98.4%) are not damaged to any quantifiable degree. These are building footprints intersecting with less than 6" of water. The remaining thirteen properties in the county that may be impacted by sea level inundation are worth about $2.1 million. The spatial distribution of the properties shows the majority in the southern portion of the county below the Blackwater River: Toddville, Crapo, Wingate, Bishops Head, and Crocheron are examples. There are small clusters of buildings in Tilghman's Island, Church Creek, and Brooks Creek (Figure 9). By 2100, the situation will have changed dramatically – the number of buildings at risk from inundation increased 4.4x, from 790 in 2050 to 3,463 in 2100 (Table 10). Those 3,463 buildings represent $659.4 million in structure and content value. Again, the prediction of damage in the scenario is very uncertain as the processes that cause inundation damage are quite different than periodic flood damage. However, an overall damage rate of 10.1% is very concerning and is more than 6x the rate that we expect from a 1% chance flood event in 2015. With regard to the spatial distribution of the structures predicted to be inundated in 2100 (Figure 10), it is difficult to discern any specific pattern besides the widespread impacts across all of peninsular Dorchester County.

Table 9. Potential damage to structures/contents from mean sea level inundation in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	777	98.4%	$76,950,218	$99,035	$848	$1	0.4%
1 - 10%	9	1.1%	$282,862	$31,429	$14,455	$1,606	6.4%
10 - 20%	4	0.1%	$1,806,125	$451,531	$211,074	$52,768	93.2%
20 - 30%	0	0.0%	$0	$0	$0	$0	0.0%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	790	100.0%	$79,039,205	$100,050	$226,377	$337	100.0%

Note: All dollar values are from 2015 tax assessments

Table 10. Potential damage to structures/contents from mean sea level inundation in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	598	17.3%	$162,108,798	$271,085	$69,588	$116	0.1%
1 - 10%	566	16.3%	$137,635,936	$243,173	$7,746,354	$13,686	11.7%
10 - 20%	1,392	40.2%	$262,212,848	$188,371	$34,358,077	$24,683	51.8%
20 - 30%	783	22.6%	$92,753,727	$118,459	$22,252,730	$28,420	33.5%
30 - 40%	62	1.8%	$2,150,214	$34,681	$726,440	$11,717	1.1%
40 – 50%	30	0.1%	$1,521,150	$50,705	$681,435	$22,714	1.0%
50% or more	32	0.1%	$995,325	$31,104	$556,845	$17,401	0.8%
Total	3,463	100.0%	$659,377,999	$190,407	$66,391,470	$19,172	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 9 Spatial distribution of vulnerable structures in Dorchester County, no flood at MSL in 2050 (n=790)

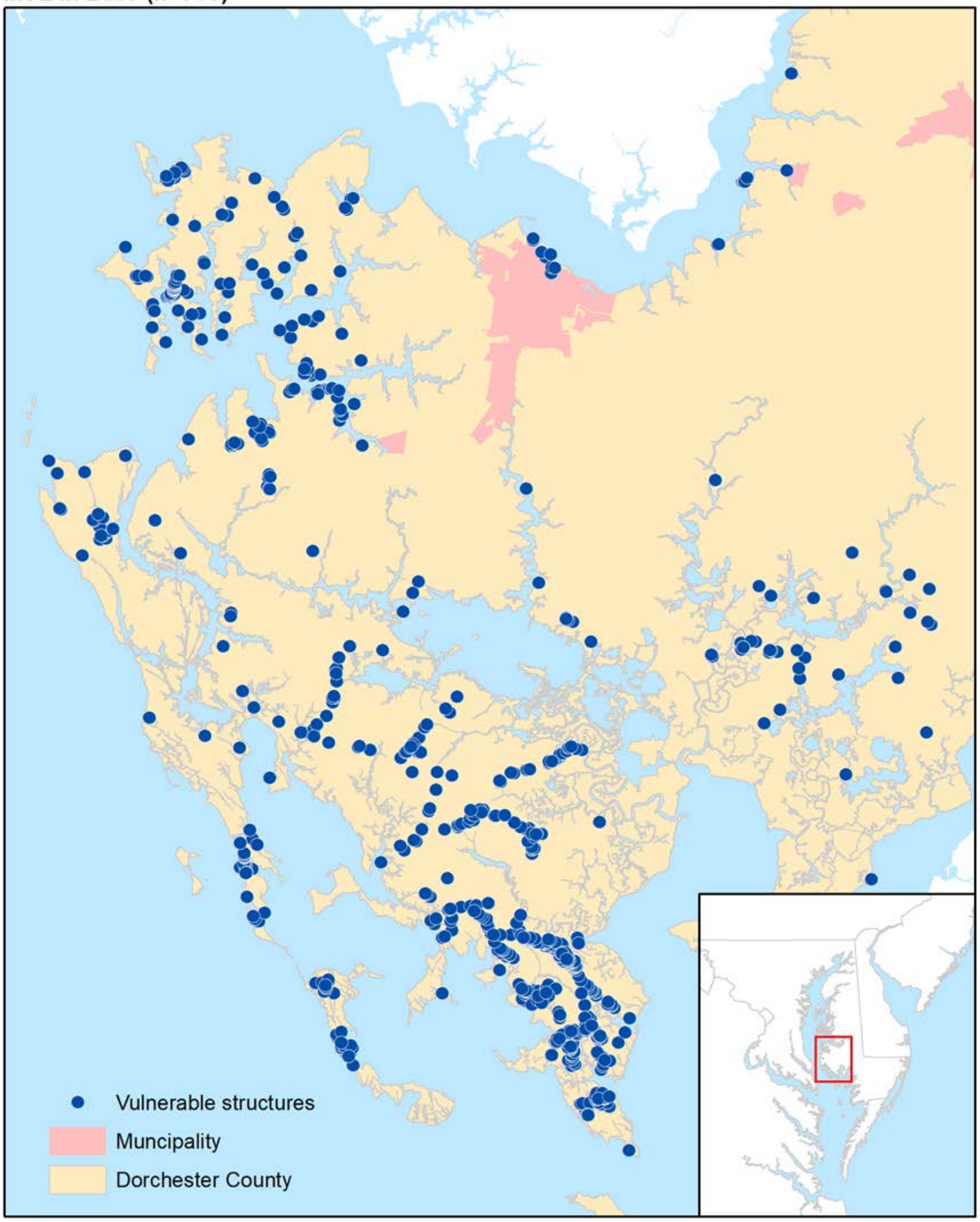
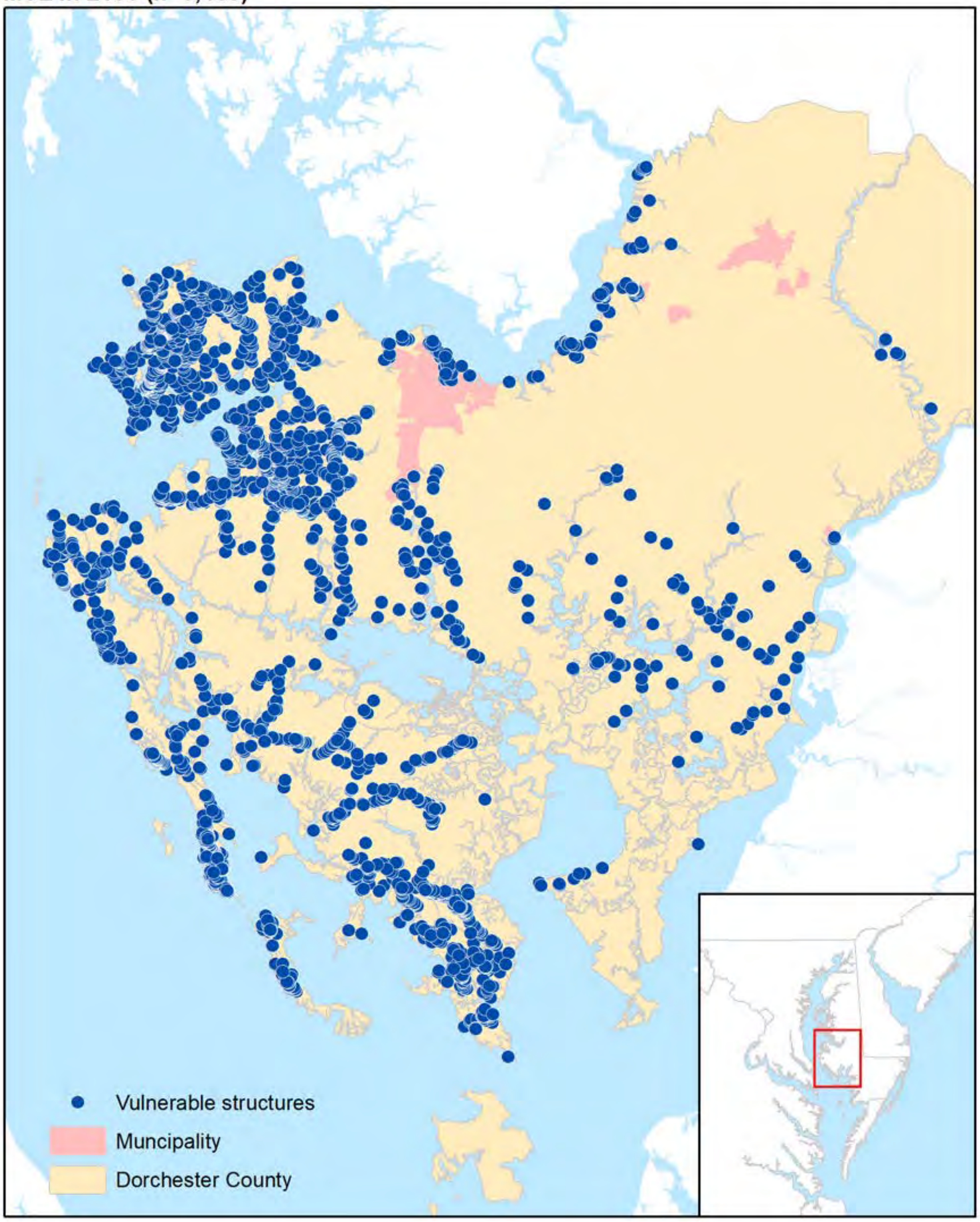


Figure 10 Spatial distribution of vulnerable structures in Dorchester County, no flood at MSL in 2100 (n=3,463)



With regard to inundation with respect to land use, the impact from sea level change in 2050 will be overwhelmingly (89.9%) residential (Table 11). However, nearly all of the potential damage comes from industrial buildings. In Dorchester County, these buildings are mostly infrastructure related (like power transfer stations). By 2100 however, it becomes clear that sea level change in Dorchester County will be disproportionately felt by residents, with 93.0% of all of structures being inundated as residential, and that sector suffering 91.4% of the potential damage (Table 12).

Table 11. Potential damage to structures/contents from mean sea level inundation in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	710	89.9%	$66,757,657	$20,394	0.0%	9.0%
Commercial	23	2.9%	$4,926,333	$0	0.0%	91.0%
Government	12	1.5%	$2,689,606	$0	0.0%	0.0%
Industry	12	1.5%	$3,483,502	$205,980	5.9%	0.0%
Religious	13	1.6%	$1,130,475	$0	0.0%	0.0%
Agricultural	20	2.5%	$51,632	$0	0.0%	0.0%
Total	790	100.0%	$79,039,205	$226,377	0.3%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 12. Potential damage to structures/contents from mean sea level inundation in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	3,220	93.0%	$606,237,280	$60,677,982	10.0%	91.4%
Commercial	67	1.9%	$26,475,090	$2,006,300	7.8%	3.0%
Government	47	1.4%	$14,519,814	$2,002,474	13.8%	3.0%
Industry	22	0.6%	$6,265,129	$1,073,869	17.1%	1.6%
Religious	42	1.2%	$5,137,204	$606,244	11.8%	0.9%
Agricultural	65	1.9%	$743,482	$24,601	3.3%	0.0%
Total	3,463	100.0%	$659,377,999	$66,391,470	10.0%	100.0%

Note: All dollar values are from 2015 tax assessments.

When examining the vulnerability of Dorchester County's structure by the property value, the results in 2050 show plurality of properties in the less than $50,000 range (Table 13). This result is particularly concerning – the owners of these properties will likely not have the financial resources to mitigate against the threat. In fact, it is possible that the modest values of the properties may be a result of the flood potential that is only going to worsen with sea level change. In 2100 however (Table 14), the results are distributed across the value spectrum with a peak in the modest $100,000 to $200,000 range. It is difficult to imagine that the owners of these properties will be able to make the changes necessary to warn off the impact of 5.78 ft of sea level rise.

Table 13. Potential damage to structures/contents from mean sea level inundation in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	378	47.8%	$7,162,882	$12,552	1.7%	5.5%
$50 - $100	186	23.5%	$13,381,000	$7,814	0.1%	3.5%
$100 - $200	140	17.7%	$19,331,725	$11,858	0.1%	5.2%
$200 - $300	46	5.8%	$10,600,350	$24,177	0.2%	10.7%
$300 - $400	17	2.2%	$5,680,608	$0	0.0%	0.0%
$400 - $500	7	15.4%	$3,118,300	$0	0.0%	0.0%
$500 - $1,000	10	1.3%	$6,825,240	$0	0.0%	0.0%
$1,000 - $2,000	4	0.5%	$5,596,300	$169,975	3.0%	75.1%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	2	0.3%	$7,342,800	$0	0.0%	0.0%
Total	790	100.0%	$79,039,205	$226,377	0.3%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 14. Potential damage to structures/contents from mean sea level inundation in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	758	21.9%	$13,996,634	$2,427,464	17.3%	3.7%
$50 - $100	632	18.2%	$47,085,900	$7,215,907	15.3%	10.9%
$100 - $200	894	25.8%	$130,504,950	$16,887,529	12.9%	25.4%
$200 - $300	536	15.5%	$130,081,005	$13,542,359	10.4%	20.4%
$300 - $400	295	8.5%	$101,046,200	$9,146,396	9.1%	13.8%
$400 - $500	135	3.9%	$60,069,475	$4,994,714	8.3%	7.5%
$500 - $1,000	185	5.3%	$124,497,585	$8,596,136	6.9%	12.9%
$1,000 - $2,000	19	0.5%	$25,458,150	$1,878,626	7.4%	2.8%
$2,000 - $3,000	5	0.1%	$12,098,300	$553,598	4.6%	0.8%
More than $3,000	4	0.1%	$14,539,800	$1,148,740	7.9%	1.7%
Total	3,463	100.0%	$659,377,999	$66,391,470	10.0%	100.0%

Note: All dollar values are from 2015 tax assessments

In the event that the USACE's predictions come to pass, the 2.11 ft rise in MSL will significantly impact the flood vulnerability of Dorchester County (Table 15). In the 1%-chance flood scenario, the number of buildings impacted will increase by 75% (from 2,713 to 3,619). Additionally, the number of buildings with greater than minimal damage (greater than 10%) quadrupled, rising from 631 to 2,558 and from a value of $47.2 million to nearly $417.5 million. In 2050, 51 structures are predicted to be severely damaged (greater than 50%), up from just 2. The total amount of building and contents value vulnerable to flooding will not quite double from $482.2 million to $703.7 billion and the amount of potential damage will increase 7x from $11.2 million to $77.6 million. The spatial distribution of these vulnerable structures show that there are very few structures in the west or southern quadrants of the county that are not affected.

Of course, the prediction for the year 2100 (5.78 ft increase in MSL) must be considered highly uncertain. However, as of this writing, there is a growing consensus in the scientific community that the SLC estimates are more than likely too conservative, rather than too aggressive. Until that consensus solidifies, the current USACE estimate is still reasonable for planning purposes. Obviously, sea level being 5.78 ft higher in Dorchester County 82 years from now will significantly impact much of the vulnerable coastal development (Table 16). The number of vulnerable buildings will increase by 169% (from 2,713 in 2015 to 4,585 in 2100), with most (84%) of those buildings damaged 10% or more. The number predicted to be severely damaged will go from 2 in 2015 to 51 in 2050 to 149 in 2100. While the amount of building and contents value vulnerable to flooding will more than double, from $482.2 million to $935.2 billion, the amount of potential damage will explode more than 13.8x from $11.2 million to $154.1 million. The spatial distribution shows flood waters reaching a large number of properties south of US 50 and expanding into communities on the tributaries of the Choptank River that were previously spared damaging flood waters. Paradoxically, the number of buildings and the total amount of value of vulnerable property does not increase an outrageous amount in the sea level change scenarios – because so many properties in Dorchester County are already at risk of flooding. Where the impact is mostly felt is in the potential damage amount, due to the increases the depth of flooding for those structures that are already vulnerable now (Figure 12).

Table 15. Potential damage to structures/contents from a 1% chance flood event in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	573	15.8%	$160,586,917	$280,256	$73,409	$128	0.4%
1 - 10%	488	13.5%	$125,683,152	$257,547	$7,139,543	$14,630	25.2%
10 - 20%	1,510	41.7%	$293,193,795	$194,168	$38,495,164	$25,493	52.1%
20 - 30%	846	23.4%	$113,908,381	$134,643	$27,682,731	$32,722	19.2%
30 - 40%	125	3.5%	$6,790,800	$54,326	$2,135,043	$17,080	2.8%
40 – 50%	26	0.7%	$1,679,279	$64,588	$731,902	$28,150	0.0%
50% or more	51	1.4%	$1,881,675	$36,896	$1,104,748	$21,662	0.2%
Total	3,619	100.0%	$703,723,999	$194,453	$77,362,541	$21,377	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 11 Spatial distribution of vulnerable structures in Dorchester County, 1% chance at MSL in 2050 (n=3,619)

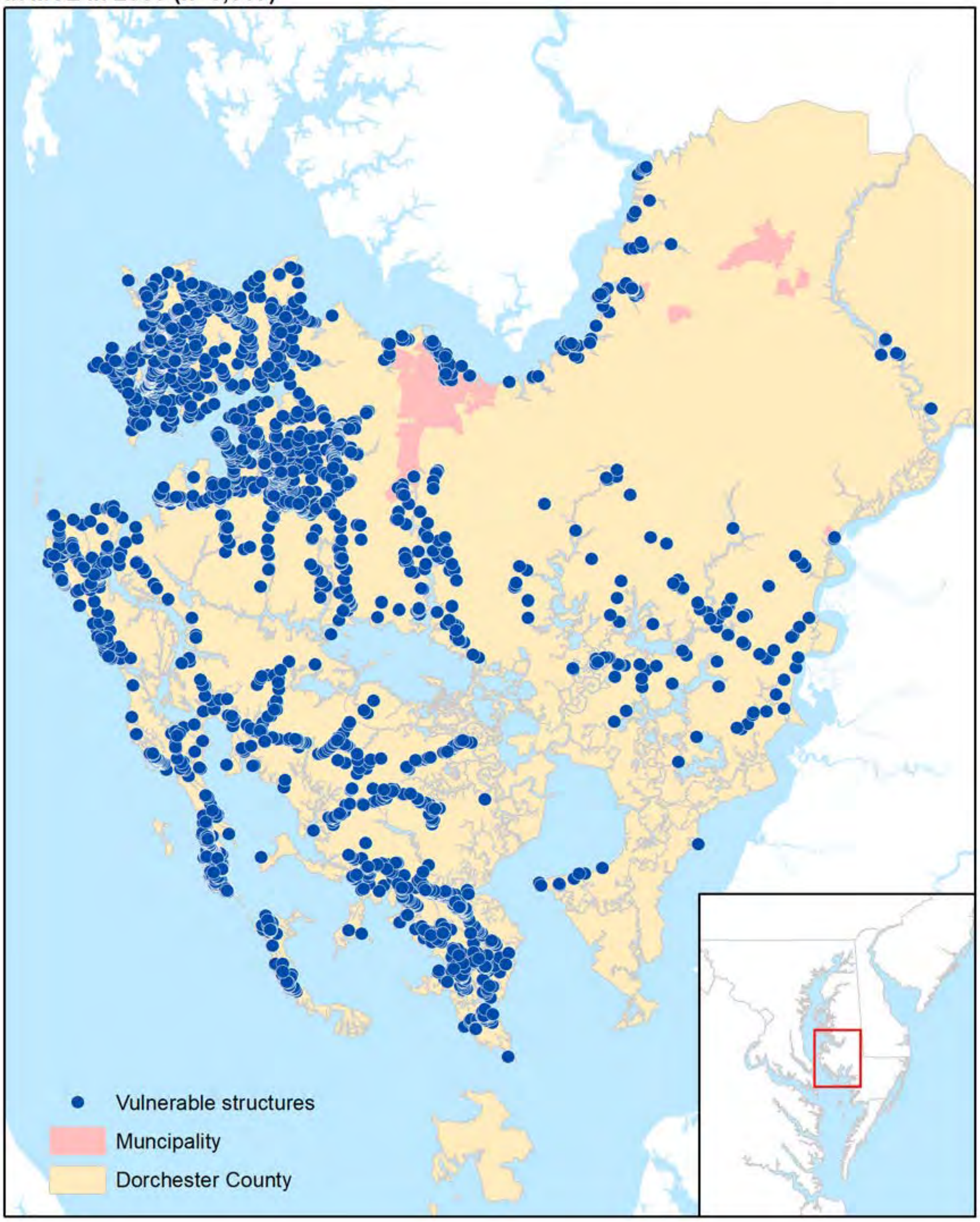


Table 16. Potential damage to structures/contents from a 1% chance flood event in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	527	11.5%	$162,038,692	$307,474	$23,460	$45	0.0%
1 - 10%	199	4.3%	$31,554,916	$158,567	$1,605,589	$8,068	1.0%
10 - 20%	1,942	42.4%	$448,343,743	$230,867	$68,126,359	$35,081	44.2%
20 - 30%	1,524	33.2%	$253,753,390	$166,505	$69,126,390	$45,359	44.9%
30 - 40%	238	5.2%	$29,615,372	$124,434	$9,538,449	$40,078	6.2%
40 – 50%	6	0.1%	$542,954	$90,492	$229,420	$38,237	0.1%
50% or more	149	3.2%	$9,325,050	$62,584	$5,423,927	$36,402	3.5%
Total	4,585	100.0%	$935,174,117	$203,964	$154,073,594	$33,604	100.0%

Note: All dollar values are from 2015 tax assessments

As for the spatial distribution of the flood threat in the two sea level change scenarios, it is a reasonable generalization to say that one can simply expect existing flood prone areas to flood more often, can expect deeper flood water when it does flood, and that areas adjacent to currently threatened areas are most likely to be newly-inundated. Maps of the 1% chance flood in 2050 and 2100 on along Water Street in Cambridge have been included as an example of what most areas in Dorchester County could expect (Figures 8 & 9). In the comparison of 2015 and 2050, the predicted 1% chance flood includes more buildings as vulnerable that are adjacent to the current flood area. But primarily, the 1% flood in 2050 will be more severe than today, thus yielding many more buildings in higher predicted damage categories. By contrast, the comparison of 2015 and 2100 shows not only a significantly more severe 1% chance flood, but a significant expansion of the vulnerable zone. This pattern is very similar across the peninsulas and necks of Dorchester County. The data from this analysis will be delivered to County officials so that they can map any area of the county this way, but Cambridge's patterns are very typical of what many areas of the county can expect.

Figure 12 Spatial distribution of vulnerable structures in Dorchester County, 1% chance at MSL in 2100 (n=4,585)

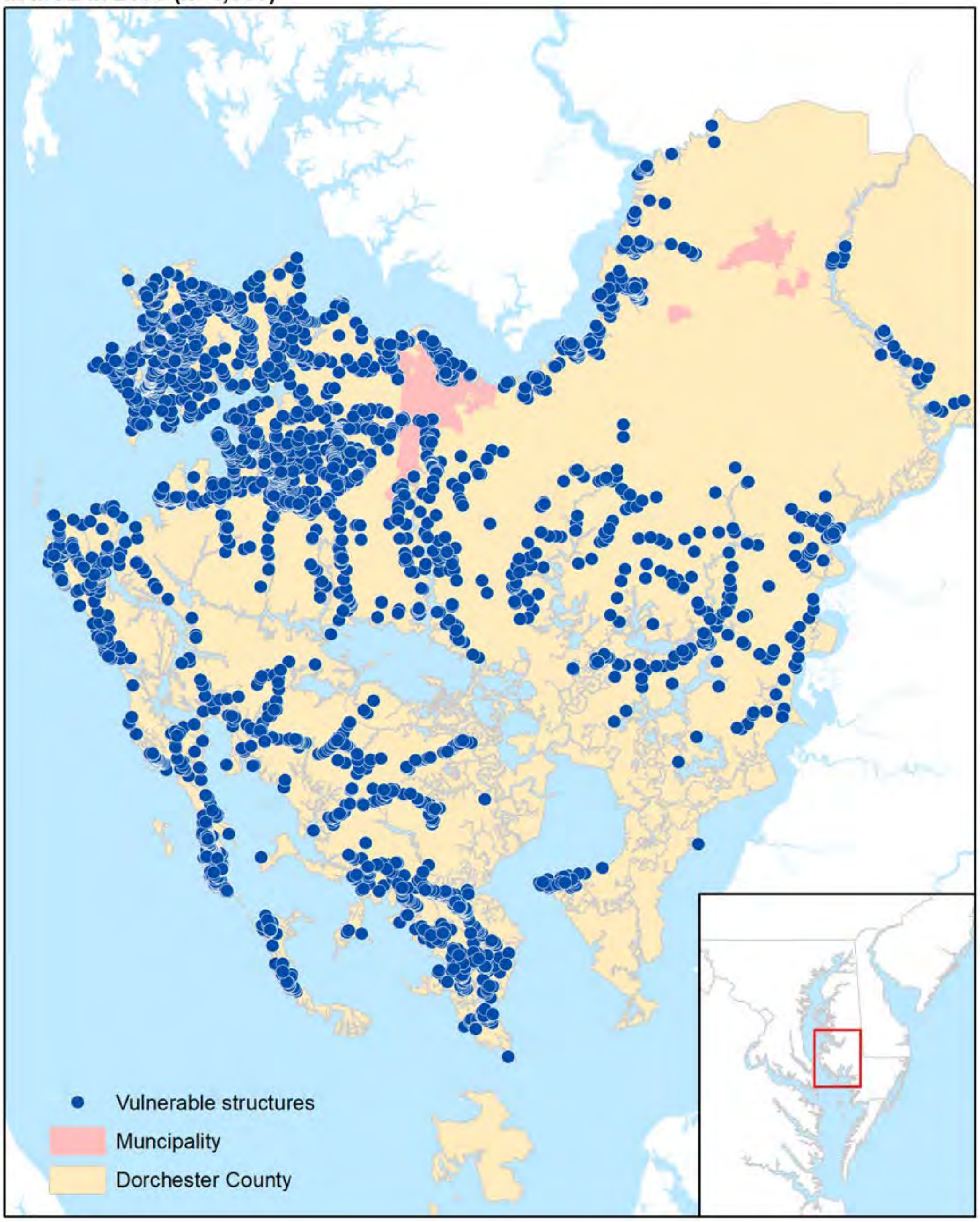


Figure 13 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2050, Cambridge, Maryland

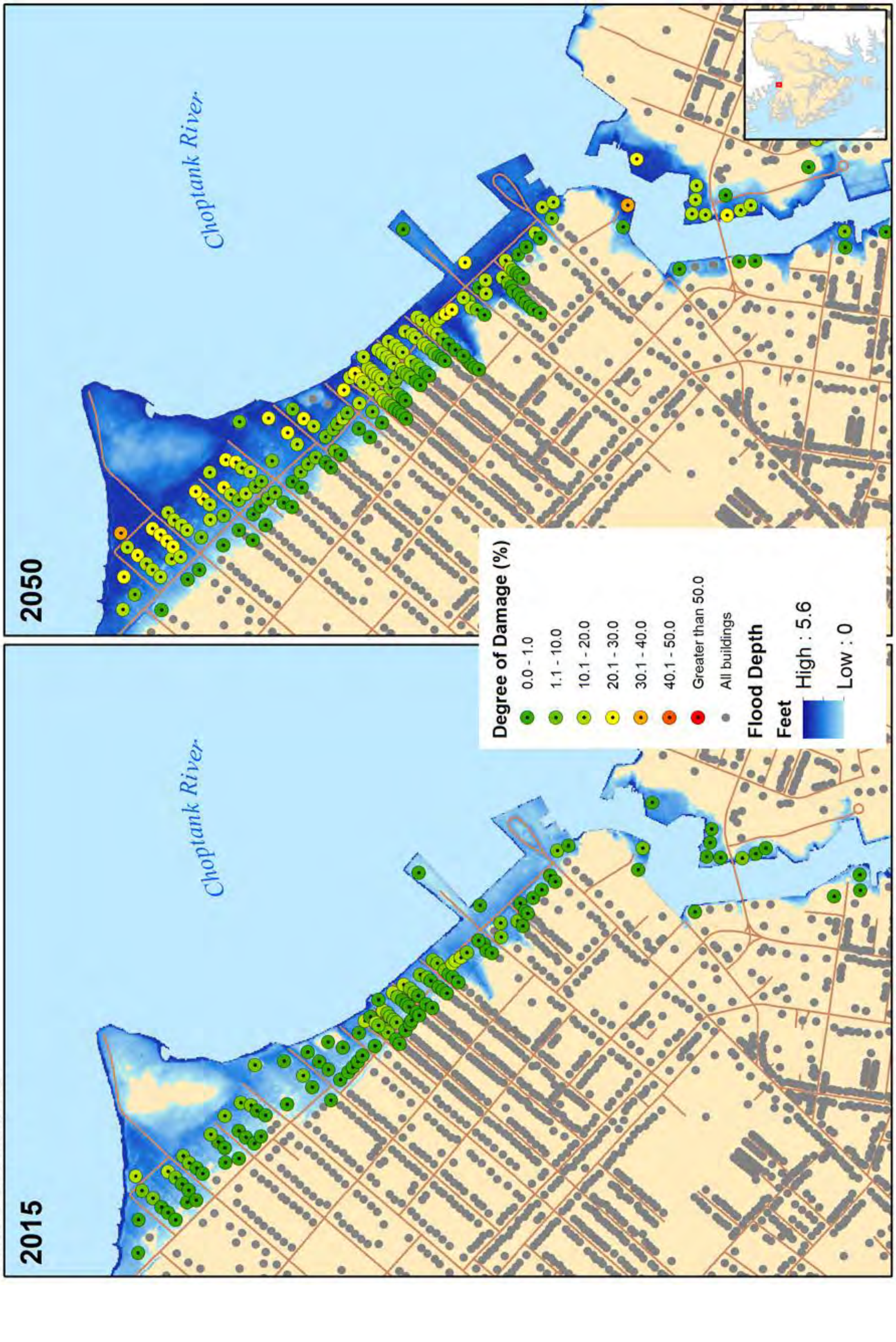
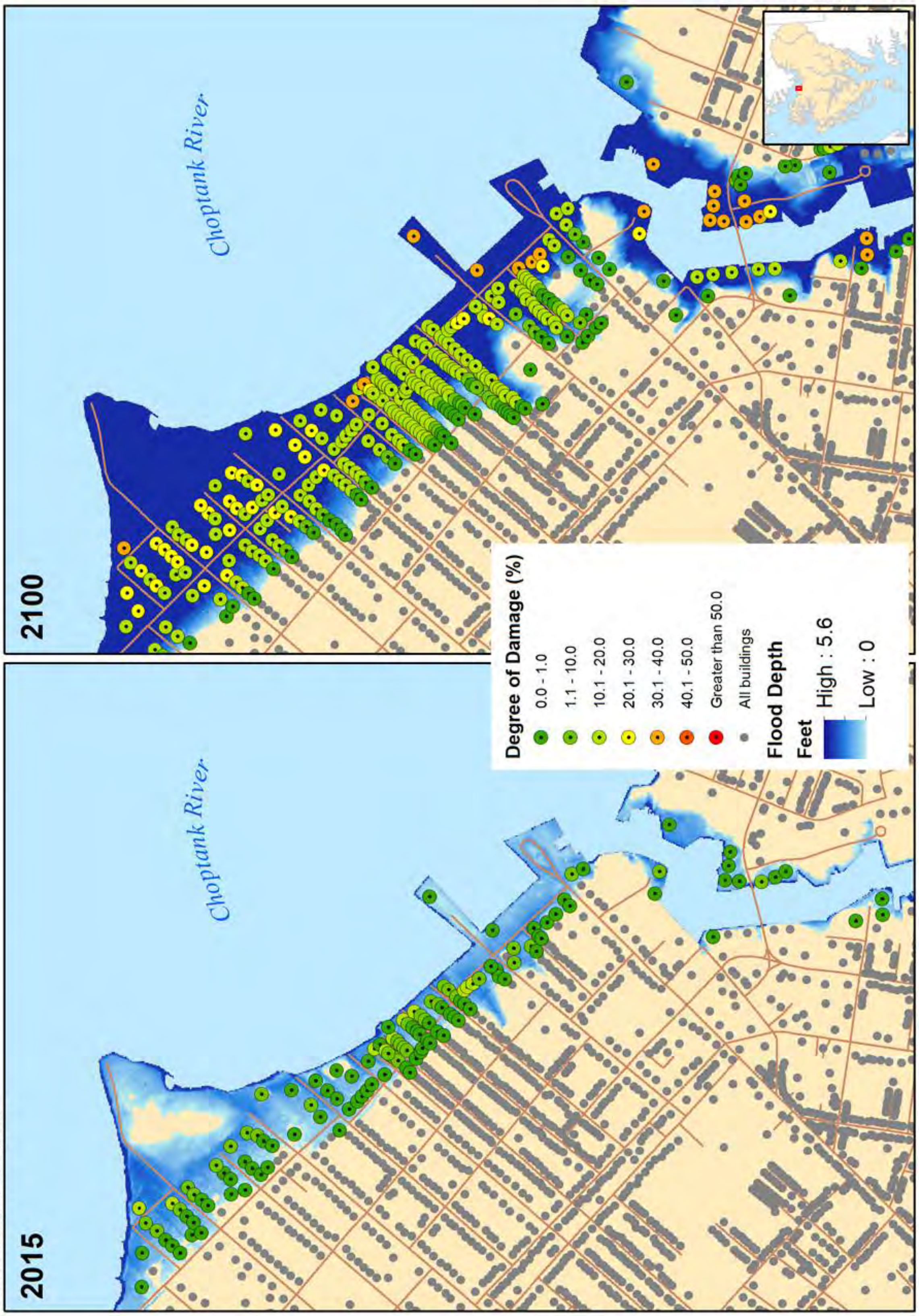


Figure 14 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2100, Cambridge, Maryland



The patterns of damage from flooding in the future when considering the use of the property are extremely similar to the results in 2015 (Table 17 and 18). The percentage distribution between the occupancy types is virtually identical between 2015 and 2050. Other than a slight rise in the percentage of commercial properties, the other key takeaway is that over 90% of the flood damage in 2050 will be residential. By 2100, there continues to be a very slight growth in the number and percentage of commercial properties affected, increasing from a total value in $78.2 million from $14.3 million in 2015.

Table 17. Potential damage to structures/contents from a 1% chance flood event in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	3.363	92.9%	$634,149,901	$70,873,166	11.2%	91.6%
Commercial	72	2.0%	$32,252,790	$2,377,438	7.4%	3.1%
Government	48	1.3%	$17,377,814	$2,311,425	13.3%	3.0%
Industry	24	0.7%	$13,770,754	$1,041,676	7.6%	1.3%
Religious	45	1.2%	$5,429,254	$722,859	13.3%	0.9%
Agricultural	67	1.9%	$743,486	$35,978	4.8%	0.0%
Total	3,619	100.0%	$703,723,999	$77,362,541	11.0%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 18. Potential damage to structures/contents from a 1% chance flood event in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	4,256	92.8%	$779,335,022	$135,834,711	17.4%	88.3%
Commercial	107	2.3%	$78,216,016	$9,696,250	12.4%	6.3%
Government	64	1.4%	$53,777,624	$4,149,129	4.4%	2.7%
Industry	24	0.5%	$13,770,754	$2,451,749	7.7%	1.6%
Religious	56	1.2%	$9,150,454	$1,768,874	19.3%	1.1%
Agricultural	78	1.7%	$924,248	$172,880	18.7%	0.1%
Total	4,585	100.0%	$935,174,117	$154,073,594	16.4%	100.0%

Note: All dollar values are from 2015 tax assessments.

In general, the distribution of vulnerability by property value does not change considerably once sea level change is added in 2050 (Table 19). There is a small percentage shift to the more valuable properties in this scenario. For example, 4.8% of all of the properties valued between $500,000 and $1 million are impacted by the 1% chance flood in 2015 but that percentage grows to 5.5% in 2050. This lack of significant change is not unexpected. Dorchester County does not have any significant enclaves of very wealthy property owners, nor is there spatial clustering of more impoverished areas, except perhaps some entrenched neighborhoods in Cambridge. The other reason there is no significant change to the distribution of properties values affected is that there is not a large expansion of vulnerable properties. Most of these properties are affected in both scenarios, but the damage is much greater in the sea level change scenarios. By 2100, this pattern is much the same (Table 20). It is also important to note that these are 2015 property values. If the rate of inflation for the next 85 years is the same as the last 85 ($1 in 1930 is worth $13.96 in 2015, according to the Consumer Price Index), the total property value at risk from flooding would be over $13 billion.

Table 19. Potential damage to structures/contents from a 1% chance flood event in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	780	21.6%	$14,443,494	$2,677,930	18.5%	0.5%
$50 - $100	660	18.2%	$49,288,575	$8,052,016	16.3%	3.3%
$100 - $200	940	26.0%	$136,919,075	$19,181,614	14.0%	17.3%
$200 - $300	564	15.6%	$136,960,980	$15,857,520	11.6%	17.0%
$300 - $400	306	8.4%	$104,741,300	$10,961,226	10.5%	17.3%
$400 - $500	139	3.8%	$61,773,375	$5,898,279	9.5%	13.8%
$500 - $1,000	198	5.5%	$133,136,800	$10,148,785	7.6%	22.9%
$1,000 - $2,000	20	0.6%	$26,657,150	$2,198,067	8.2%	7.9%
$2,000 - $3,000	6	0.2%	$14,956,300	$694,257	4.6%	0.0%
More than $3,000	6	0.2%	$24,846,650	$1,692,846	6.8%	0.0%
Total	3,619	100.0%	$703,723,999	$77,362,541	11.0%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 20. Potential damage to structures/contents from a 1% chance flood event in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	938	20.5%	$17,697,768	$3,744,873	21.2%	2.4%
$50 - $100	854	18.6%	$64,163,950	$12,397,369	19.3%	8.0%
$100 - $200	1,280	27.9%	$186,264,250	$35,145,518	18.9%	22.8%
$200 - $300	704	15.4%	$171,010,800	$31,752,390	18.6%	20.6%
$300 - $400	372	8.1%	$127,633,900	$21,789,928	17.1%	14.1%
$400 - $500	169	3.7%	$75,048,450	$11,564,457	15.4%	7.5%
$500 - $1,000	224	4.9%	$150,050,300	$23,886,573	15.9%	15.5%
$1,000 - $2,000	23	0.5%	$30,165,050	$5,126,339	17.0%	3.3%
$2,000 - $3,000	8	0.2%	$19,200,100	$2,849,207	14.8%	1.8%
More than $3,000	13	0.3%	$93,940,449	$4,816,839	5.1%	3.1%
Total	4,585	100.0%	$935,174,117	$154,073,594	16.4%	100.0%

Note: All dollar values are from 2015 tax assessments

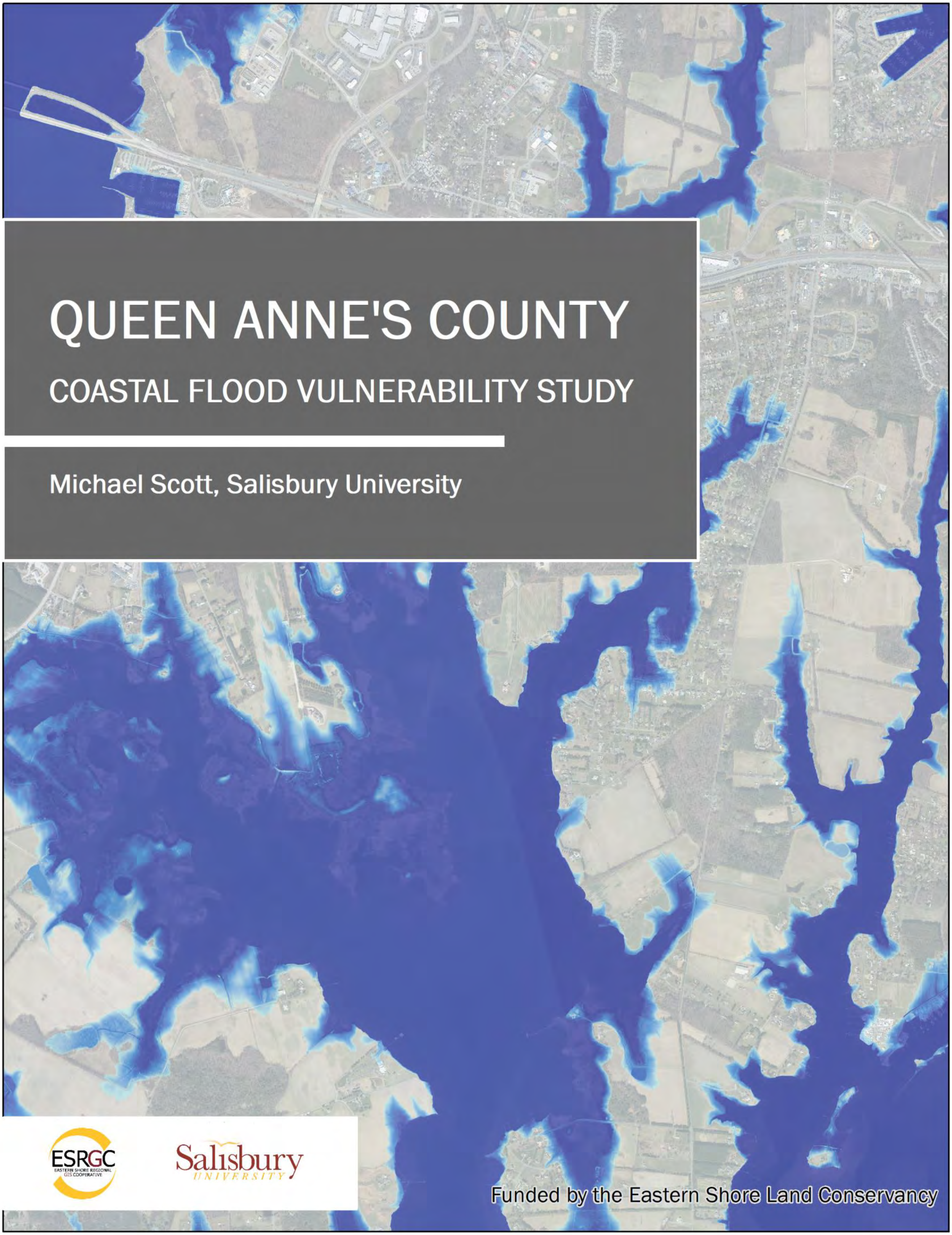
Study Caveats

It should not go without mentioning that the prediction of the flood threat with a future sea level change has more than the normal level of uncertainty. Not only are the estimates of sea level change not a foregone conclusion, but the nature of the flood threat itself is likely to change. For example, in a world with oceans that are 2 (or 5) feet higher, the controlling forces (subtropical high pressure systems, ocean upwelling, thermal heat transfer, etc.) of tropical storms are likely to be different. Thus, the periodicity of certain magnitudes of storm events could change. Similarly, this analysis uses statistical/stochastic models, not a dynamic simulations. Therefore, it does not take into account either individual storm parameters or geographic parameters such as land cover or the shape of the near-shore bottom, both of which will impact the flood predication and both are likely to change in a rising sea level scenario.

With regard to vulnerability estimates, there are also a number of important caveats to remember. First, this analysis assumes that all of the built infrastructure would be exactly as one found it in 2015. That is almost certainly not going to be the case, both with new structures being built and older structures being made more flood-resistant as the waters rise. Second, as mentioned above, the potential damage is being evaluated as if property values will not change by 2050 or 2100 – also not the case. Finally, this vulnerability analysis deliberately examined only damage to structural/contents because the relationship between building damage and depth of water is best understood. There are still many other sources of potential vulnerability: infrastructure damage/loss (both to rebuild and its impact on restarting the economy after a disaster), loss of productivity with businesses closed, debris removal, other consumer losses (cars, boats, sheds/garages), and of course, the potential loss of life.

Conclusions

Several conclusions can be made regarding the question of coastal flooding vulnerability in Dorchester County. First, given that Dorchester County has several significant sources of flood threat and given that it contains more than 16,069 improved structures, the fact that 2,713 (16.9%) are already vulnerable to the 1%-chance flood is probably a result of historical land use patterns that are particularly water-oriented, the extreme lack of ground elevation in the southern half of the county, and the impact of sea level change since the 1660's. Second, given the potential for sea level rise in the coming decades, Dorchester County is uniquely vulnerable. By 2050, more than one-fifth of all of the structures in the county will feel the effects and by 2100, if the predictions hold, almost 30% of the county's buildings could be inundated by a 1% chance flood. Even with no flooding at all, mean sea level will bring water to the footprint of about 5% of all of the building stock in Dorchester County. Unfortunately, the impacts that other county's will experience in the future are happening now to the people of Dorchester. But all is not lost. One advantage of this situation is that there will be very little argument about the nature of the threat that Dorchester County faces. This will make consensus about potential mitigation measures much easier to achieve. There are many places around the world that have learned to live alongside a constant flood threat and thrived. It just means that the people of Dorchester County need to become vigilant about implementing in flood-proofing into every development and re-development project planned for the hazard zone. Doing so will enable them to avoid the worst of the negative impacts of flooding and preserve their way of life.



QUEEN ANNE'S COUNTY

COASTAL FLOOD VULNERABILITY STUDY

Michael Scott, Salisbury University

ESRGC Eastern Shore Regional GIS Cooperative

Salisbury University

Funded by the Eastern Shore Land Conservancy

Executive Summary

Given the topography and historical development patterns of Maryland's Eastern Shore, the potential for damage from periodic flood events caused by coastal storms and extreme high tides is well-known. What is uncertain is the degree to which the vulnerability of Eastern Shore communities is increasing as sea levels change in the Chesapeake Bay and its tributaries. Therefore, the goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. The methods employed in this research are considered best practices, are accepted by FEMA and provide a consistent framework for assessing risk from floods. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the county and help make informed decisions about mitigation measures to reduce the potential impacts. Having said that, we recommend that the damage statistics in this report be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Results of the analysis predict that 751 buildings (worth $230.6 million in the structure and its contents combined) would feel the impacts of a 1%-chance flood in Queen Anne's County, with 25 of them experiencing more than 10% damage, for a total predicted damage of $2.0 million. Those 25 moderately or severely damaged structures represent less than 5% of the total number of vulnerable buildings but they represent nearly over half of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits. The much more severe 0.2%-chance flood impacts 1,423 buildings in the county valued at $420.4 million with 146 damaged moderately with a total potential damage of $11.2 million. Given that greater than 40% of the potential damage from a 1% chance flood event comes from commercial buildings, instigating mitigation actions that are targeted at Queen Anne's County business owners might yield the best results.

In Queen Anne's County, the magnitude of predicted sea level rise for the remainder of this century is typical for the DelMarVa Peninsula. The US Army Corps of Engineers expects an estimated mean sea level increase in the county of 2.08 ft by 2050 and 5.7 ft by 2100. Thankfully, the sea level rise itself will impact very few buildings in 2050 – only 2 (worth $1.7 million in structure and contents). But by 2100, this balloons to 1,388 structures worth $401.3 million. On the other hand, the degree of potential damage from sea level rise inundation in 2100 is modest – only $9.1 million or $6,949 per building. This indicates a certain level of flood-resistance built into Queen Anne's County, likely from both historical settlements patterns and hard-won knowledge of historically vulnerable locations.

However, when the 1% chance flood is combined with the predicted sea level rise, the vulnerability of the County's built environment is highlighted. In 2050, the 1% chance flood is predicted to impact 2,133 buildings (a 284% increase over the same scenario

today), worth $660.2 million (a 286% increase from today) and potentially causing $30.1 million in flood damage (a 15x increase from 2015). The same flood in 2100 could impact 4,723 buildings (a 221% increase from 2050) worth $1.6 billion in value (a 242% increase from 2050) and cost a potential $184.6 million in damage (a greater than 6x increase over the same estimate in 2050).

This coastal flood vulnerability analysis of Queen Anne's County yields several important conclusions. First, given that Queen Anne's County has several significant sources of flood threat and given that it contains more than 20,758 improved structures, the fact that 751 (3.6%) are vulnerable to the 1% chance coastal flood is probably a result of historical land use patterns, focused on agricultural development in the high-quality farmland found in the uplands as well as awareness of the flood threat given the long history of working the Chesapeake Bay. Second, given the potential for sea level rise in the coming decades, the time to redouble the County's efforts to protect its citizens from flooding is now. If no changes are made, more than 10% of the county's current structures will be impacted by flooding in 2050 and greater than one-fifth of the Queen Anne's building stock may need flood protection by 2100. Being able to avoid a 90-fold increase in flood damage over the next 80 years by taking immediate actions such as strengthening building codes, de-incentivizing flood plain development, and requiring more freeboard (the building height above the flood elevation) should provide a significant return on a property owner's investments. Third, given the demand for coastal development in a county that is included in the Baltimore metropolitan area, the County can harness market forces to help drive flood-resistant construction. Finally, this analysis shows that Queen Anne's County has some time to adjust to the change in the flood threat. This is positive not only because any adjustments can be implemented gradually and without disruption but also because Queen Anne's County has time for the redevelopment cycle of the next several decades to be guided by flood-smart principles.

Introduction and Study Context

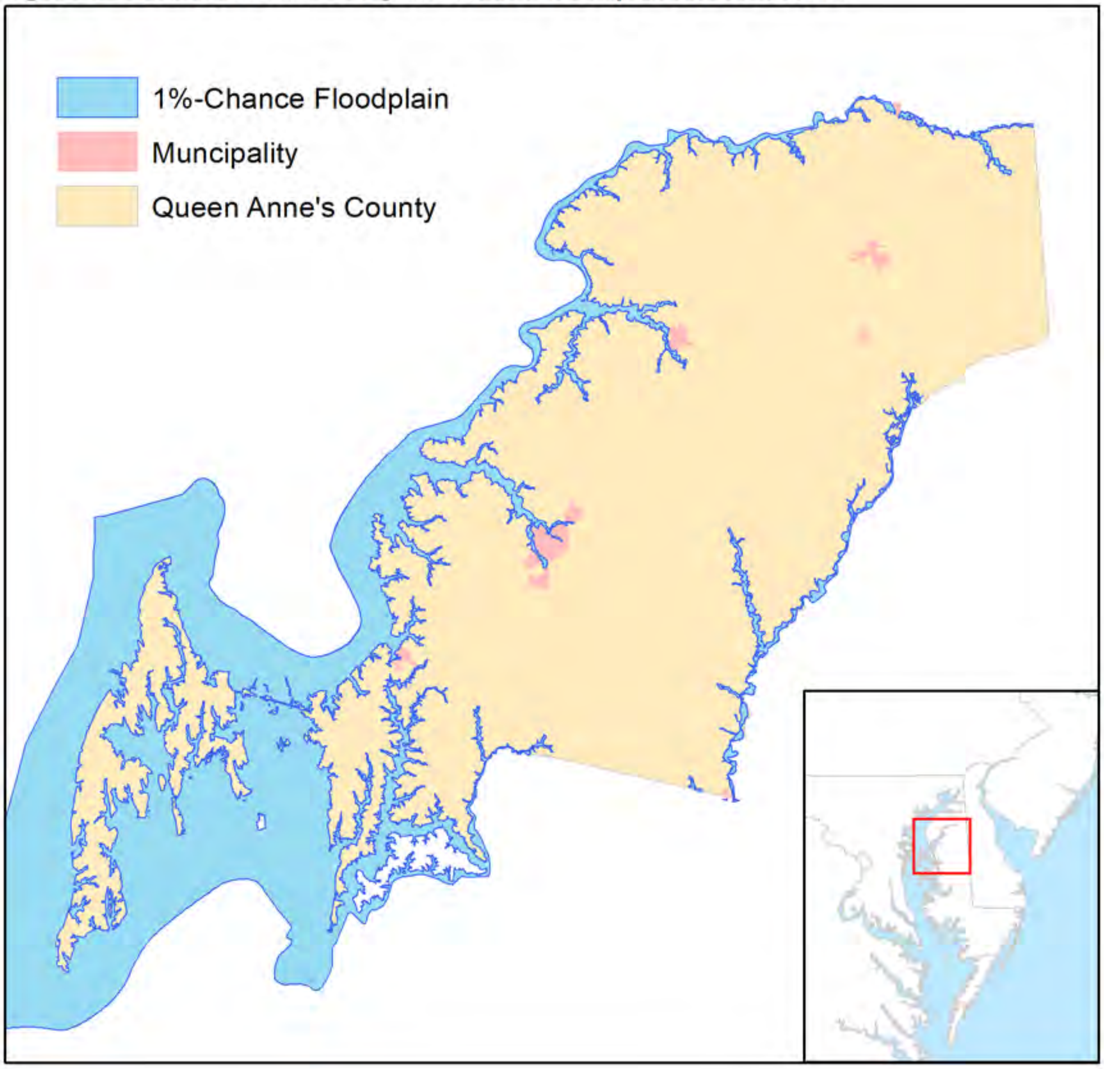
Flooding occurs when rivers, creeks, streams, ditches, or other water bodies receive more water that they can handle from rain, snowmelt, storm surge, or excessive high tides. The excess water flows over adjacent banks or beaches/marshes and into the adjacent floodplain. As many as 85 percent of the natural hazard disasters across the United States have been attributed to flooding.

This document presents the results of a coastal flood vulnerability study of Queen Anne's County, Maryland conducted by Dr. Michael Scott of Salisbury University at the request of the Eastern Shore Land Conservancy in Easton, Maryland. The goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. Specifically, using flood depth data calculated on behalf of the Maryland State Highway Administration, the flood scenarios of a 1% chance flood in 2015, a 0.2% chance flood in 2015, no periodic flooding in 2050, a 1% chance flood in 2050, no periodic flooding in 2100, and a 1% chance flood in 2100 were evaluated versus the location and value of buildings in Queen Anne's County. The results are an accounting of the potential damage from periodic flooding, exacerbated by future sea level change. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the count and help make informed decisions about mitigation measures to reduce the potential impacts.

Queen Anne's County's Floodplain

The following map (Figure 1) depicts the 1% chance floodplains within Queen Anne's County, as designated by FEMA on the Flood Insurance Rate Maps or FIRMs. The 1% chance flood (formerly referred to as the 100-year flood) is a flood which has a 1 percent chance of being equaled or exceeded in any given year (MDE, *Maryland Floodplain Manager's Handbook*). Queen Anne's County can experience riverine flooding as a result of excessive rainfall in a matter of hours, such as from a severe thunderstorm. Additionally, some soils can become saturated over a longer period of time and reduce their absorption potential. Riverine flooding can affect any of the rivers and streams in the County but primarily affects the non-tidal or brackish portions of the streams that feed Chesapeake Bay. Tidal flooding in Queen Anne's County usually occurs as a result of tropical storms (including hurricanes) as well as the combination of high astronomical tides with a landward wind. Queen Anne's County has 5.6% of its land area is in the 1% chance floodplain.

Figure 1 Queen Anne's County 1% chance floodplain from dFIRMs



While Queen Anne's County is clearly vulnerable to both riverine and coastal/tidal flooding, only tidal flooding is considered in this vulnerability study. It is entirely possible that those areas in the county beyond the tidal flooding extent will experience a change in their flooding occurrence if the consensus predictions of global climate change come to pass. Current research suggests that extreme rainstorms (as well as extreme droughts) will become more common (National Climate Assessment, 2014).

Flood Measurement

There are three US Geological Survey gauging stations within the County and several others close by. Only one National Weather Service Advanced Hydrologic Prediction Service hydrograph and no National Oceanographic and Atmospheric Administration tide gauges exists in the County (Table 1). Measurements of stream discharge, river stage, and tide height are critical to the prediction of flood events. While recording the water level, the MLTM2 hydrograph does not offer flood level prediction.

Table 1. River gauges, hydrographs and tide gauges in Queen Anne's County

Agency	ID Number	Station Name	Real-Time or Daily
USGS	01491500	Tuckahoe Creek near Ruthsburg	Real-time
USGS	01492500	Sallie Harris Creek near Carmichael	Real-time
USGS	01493000	Unicorn Branch near Millington	Real-time
NWS	MLTM2	Unicorn Branch near Millington	Real-time

Flood Levels

Using the Flood Insurance Studies (FIS) of Queen Anne's County, published by FEMA effective November 5, 2014, the following table (Table 2) reports the flood elevations for the key flooding sources.

Table 2. Flood elevations for coastal event (Units are NAVD 1988 feet)

Flooding Source and Location	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESTER RIVER				
Crumptown to Kingstown	3.0-4.7	5.3-5.6	6.0-6.6	7.0-8.5
Kingstown to mouth of the Corsica River	4.2-4.7	4.9-5.6	5.1-6.0	6.3-7.1
Mouth of the Corsica River to Kent Narrows	3.8-4.2	4.4-4.9	4.6-5.1	5.5-6.2
CHESAPEAKE BAY				
Kent Narrow to the Bay Bridge	3.7-3.9	4.2-4.5	4.4-4.7	5.4-5.7
Bay Bridge to the mouth of Eastern Bay	3.5-3.7	4.0-4.2	4.3-4.4	5.1-5.4
CRAB ALLEY BAY				
Entire shoreline	3.7-3.9	4.2-4.4	4.4-4.6	5.6-6.0
EASTERN BAY				
Mouth to mouth of Crab Alley Bay	3.5-3.9	4.1-4.2	4.4-4.6	5.6-6.0
Mouth of Prospect Bay to Bennett Point	3.7-3.8	4.2-4.3	4.4-4.5	5.4-5.8
PROSPECT BAY				
Entire shoreline	3.8-3.9	4.3-4.5	4.5-4.8	5.5-6.4
WYE RIVER				
Mouth to confluence with Wye East River	3.6-3.8	4.2-4.5	4.4-4.8	5.4-6.1
WYE EAST RIVER				
From the mouth	3.8-4.0	4.5-4.6	4.8-4.9	6.1-6.5

Hazards from Floods

Flooding causes $6 billion in average annual losses in the United States annually and account for an average of 140 casualties annually (USGS, "Flood Hazards – A National Threat," 2006). While most people's vision of the threat from flooding may include being swept away or buildings being structurally impacted, there are actually a number of hazards associated with flooding that occur both during and after an event.

During the Flood

While a flood event is underway, citizens will be faced with a number of threats. The hydraulic power of water is significant and walking through as little as 6 inches of moving water is dangerous because of the possibility of losing stable footing. Driving through flood water is the cause of many flood deaths each year. As little as one foot of water can float many cars and two feet of rushing water can carry away most vehicles including SUVs. That fact, combined with an inability for drivers to judge the depth of flood water, as well as the potential for flood waters to rise quickly without warning, making driving through flood water a very unwise action.

In addition to being swept away, flood water itself is to be avoided. Because of leaking industrial containers, household chemicals, and gas stations, it is not healthy to even touch the flood water without protective equipment and clothing. Downed power lines, flooded electric breaker panels, and other sources of electricity are a significant threat during a flood. One should also be prepared for the outbreak of fire. Electric sparks often cause fire to erupt and because of the inability of firefighting personnel to respond, a fire can quickly burn out of control.

After the Flood

Cleaning up after a flood can also expose citizens to a number of threats. For example, electrical circuits or electrical equipment could pose a danger, particularly if the ground is wet. Buildings that have been exposed to floodwater may exhibit structural instability of walkways, stairs, floors, and possibly roofs. Flood waters often dislodge and carry hazardous material containers such as tanks, pipes, and drums. They may be leaking or simply very heavy and unstable. The combination of chemical contamination and the likely release of untreated sewage (necessary when the sewage treatment plant is overwhelmed with flood-swelled effluent) mean that drinking water supplies can be unusable. Fire continues to be a very real threat after a flood. First-responders could be occupied with more pressing emergencies and traditional fire suppression equipment may be inoperable, but there may be mobility problems that keep fire-fighting equipment to reach an outbreak. Finally, there is the mental toll of being involved in a disaster. Continued long hours of work, combined with emotional and physical exhaustion and losses from damaged homes and temporary job layoffs, can create a highly stressful situation for citizens. People exposed to these stressful conditions have an increased risk of injury and emotional crisis, and are more vulnerable to stress-induced illnesses and disease.

Impact to Buildings

Fortunately, the number of people killed or injured during floods each year is relatively small. The built environment within the floodplain, however, is likely to bear the brunt of a flood's impact. Whether the water is moving or standing, the exposure of buildings to flood water could cause a great deal of damage. If the water is moving, the differing hydraulic pressure inside the building vs. outside can cause the walls and foundation to buckle and fail. If the water is standing for any length of time, even materials above the flood height will become saturated with flood water as the flood water is absorbed (known as wicking). Certainly, most of the contents of flooded buildings that were located at or below the flood height will need to be discarded. This includes carpet, furniture, electronic equipment, and other household or commercial items. In most cases it is not simply the fact that the objects have become wet but since the flood water brings with it sediment and chemicals, it makes it nearly impossible to recover all but the most precious/heirloom items.

Flood Vulnerability Assessment

The goal of mitigation is to increase the flood resistance of a community, so that the residents and businesses will become less susceptible to future exposures to flooding, thereby resulting in fewer losses. A key component to reducing future losses is to first have a clear understanding of the current threats, the current probability that those threats would occur, and the potential for loss from those threats. The Vulnerability Assessment is a crucial first step in the process as it is an organized and coordinated process of assessing potential hazards, their risk of occurring, and the possible impact of an event.

Study Method

The Vulnerability Assessment was conducted using the method developed for HAZUS-MH, FEMA's loss estimation software, to assess the County's built environment to vulnerability to flooding. HAZUS-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide credible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards, including floods, hurricane winds and earthquakes. The methodology supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

The primary input to any vulnerability assessment is a "depth of flood" grid. This flood depth grid was created using an elevation grid derived from LiDAR measurements. By incorporating the polygons of the 1% chance floodplain from the FIRMs, the coastal flood elevations from the Flood Insurance Study as well as the current elevation grid, HAZUS-MH was able to create a flood depth grid with a reasonable precision for the 1% (Figure 2) and 0.2%-chance (Figure 3) coastal flood scenarios with Queen Anne's County's current mean sea level. In addition, areas predicted to be inundated by a higher mean sea level in 2050 (Figure 4) and 2100 (Figure 5) were also modeled. Finally, the depth of flood for the 1%-chance event was mapped using the 2050 (Figure 6) and 2100 (Figure 7) predicted sea-levels. For the full detail of how these depth grids were created, please see "GIS Data Products to Support Climate Change Adaptation Planning: Queen Anne's County, Maryland" at http://www.esrgc.org/mapServices/.

Figure 2 Predicted flood depths for Queen Anne's County 1% chance flood at MSL in 2015

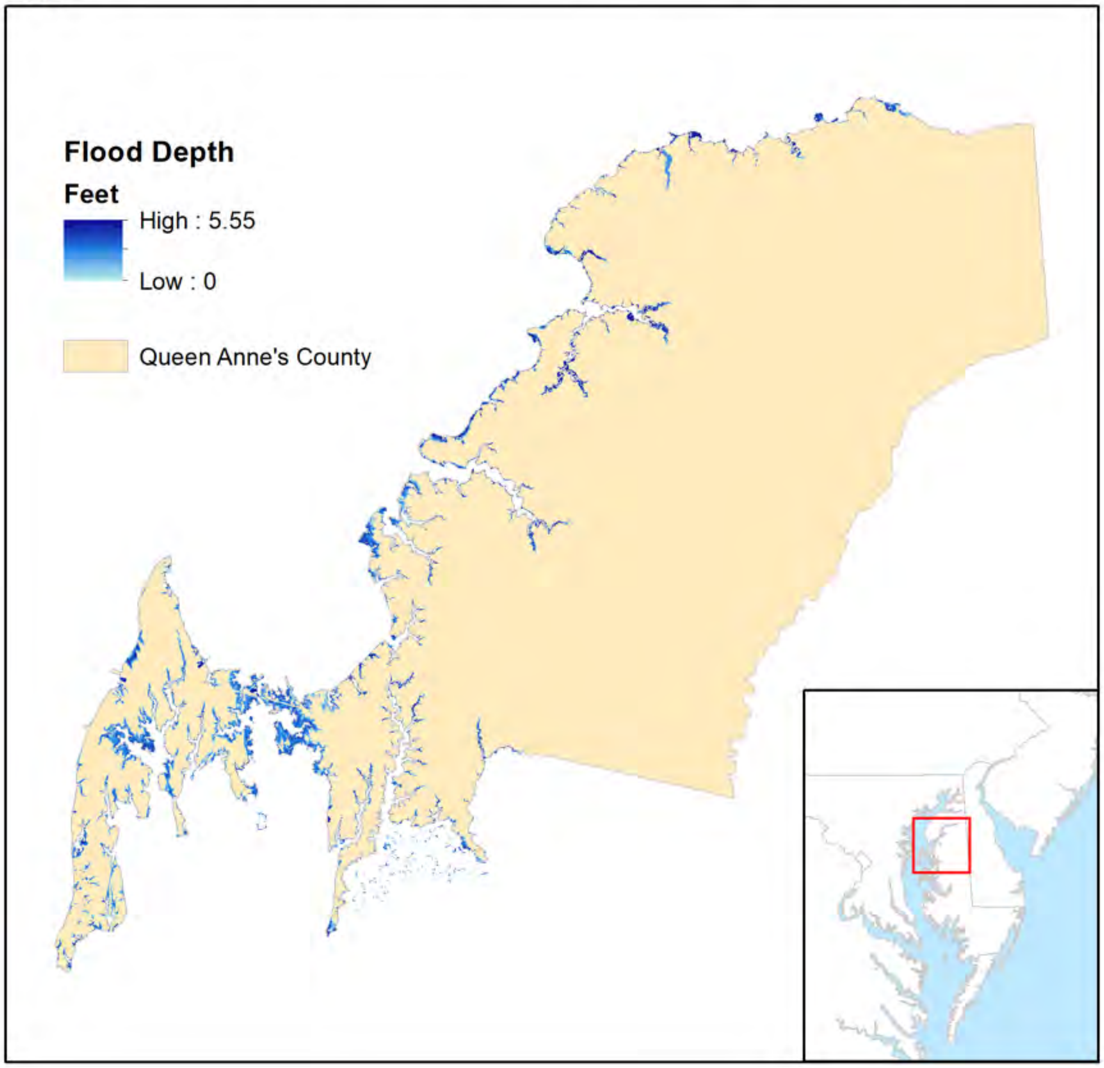


Figure 3 Predicted flood depths for Queen Anne's County 0.2% chance flood at MSL in 2015

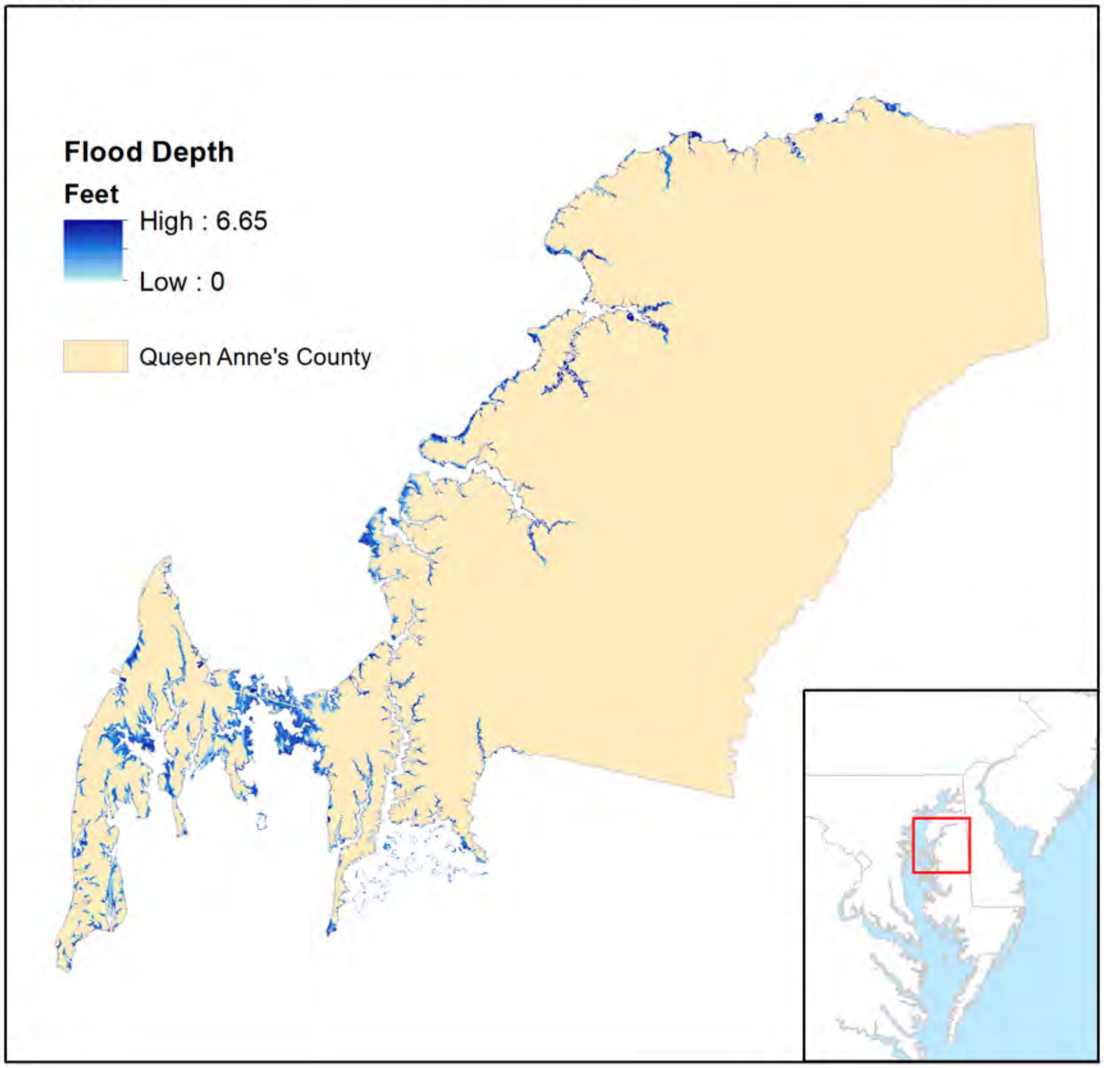


Figure 4 Predicted depth of MSL inundation in Queen Anne's County in 2050

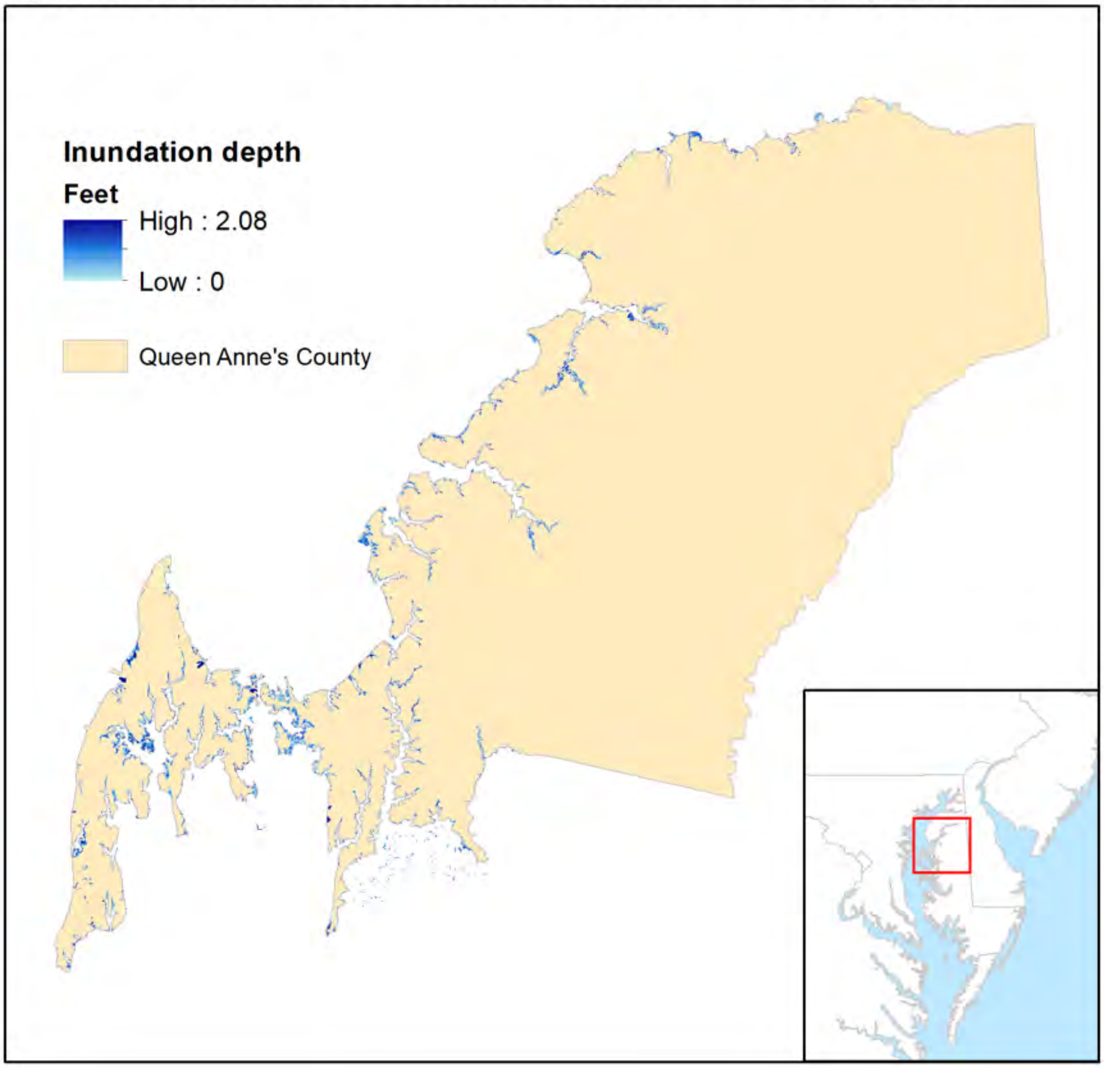


Figure 5 Predicted depth of MSL inundation in Queen Anne's County in 2100

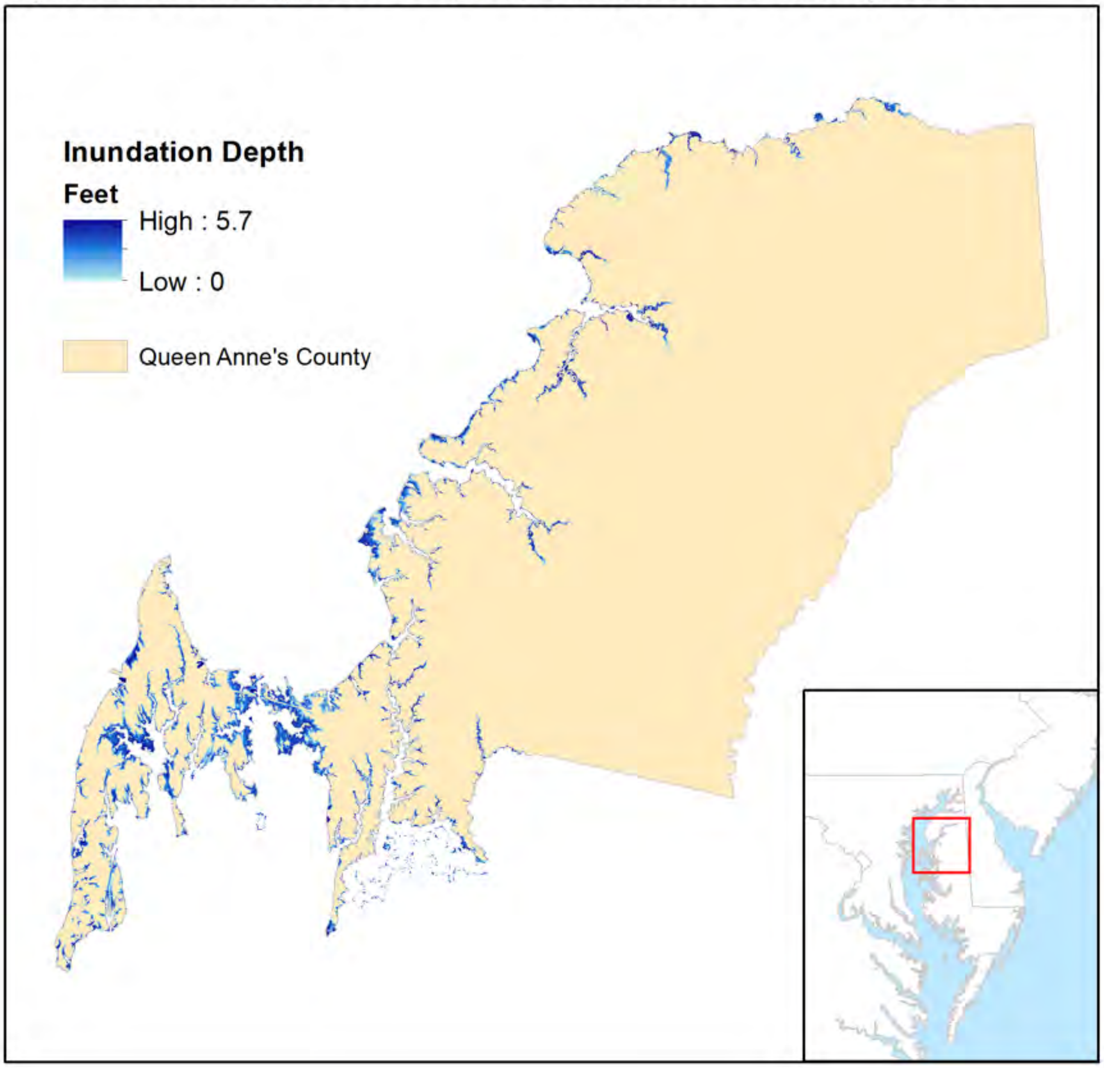


Figure 6 Predicted flood depths for Queen Anne's County 1% chance flood at MSL in 2050

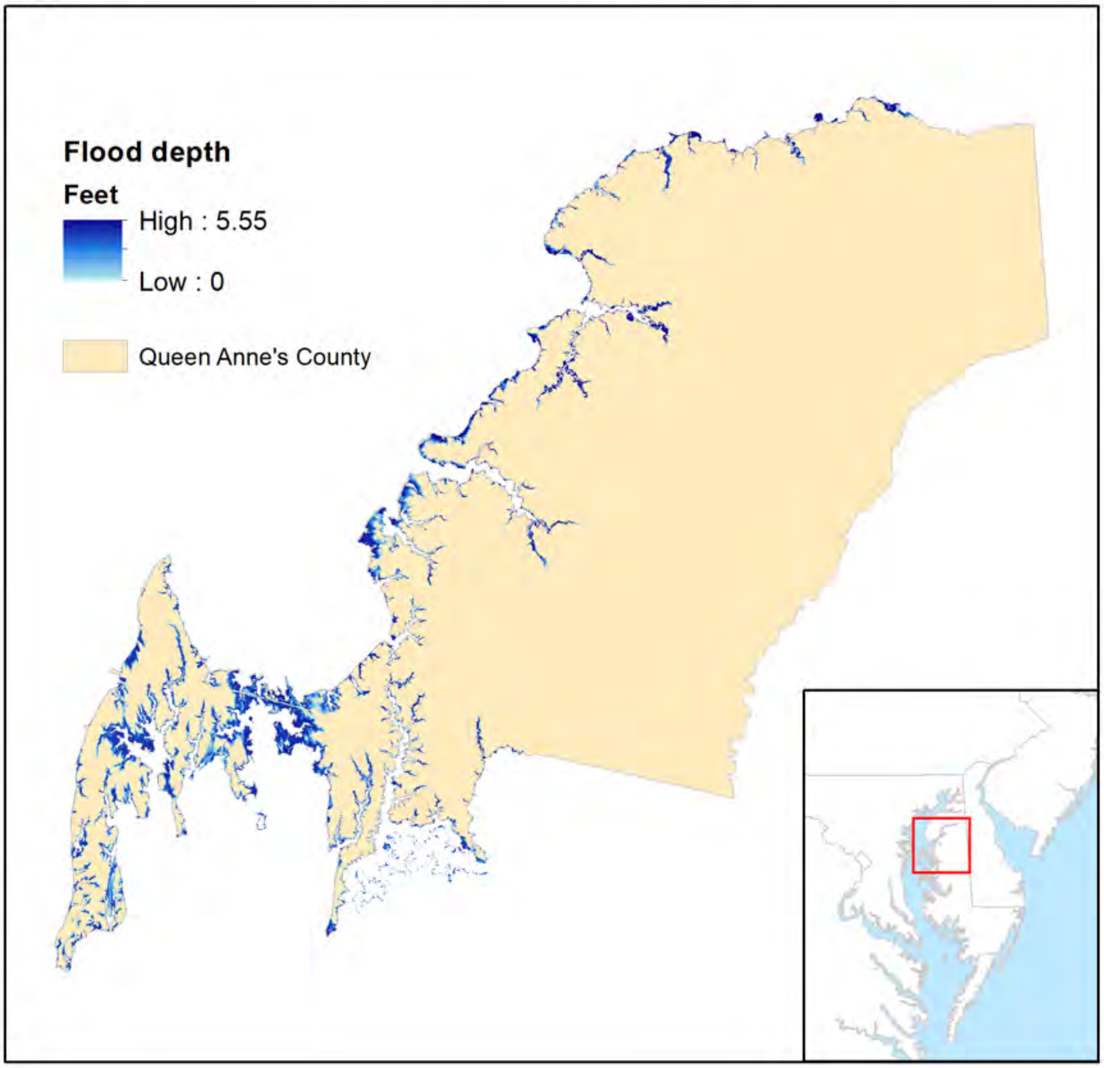
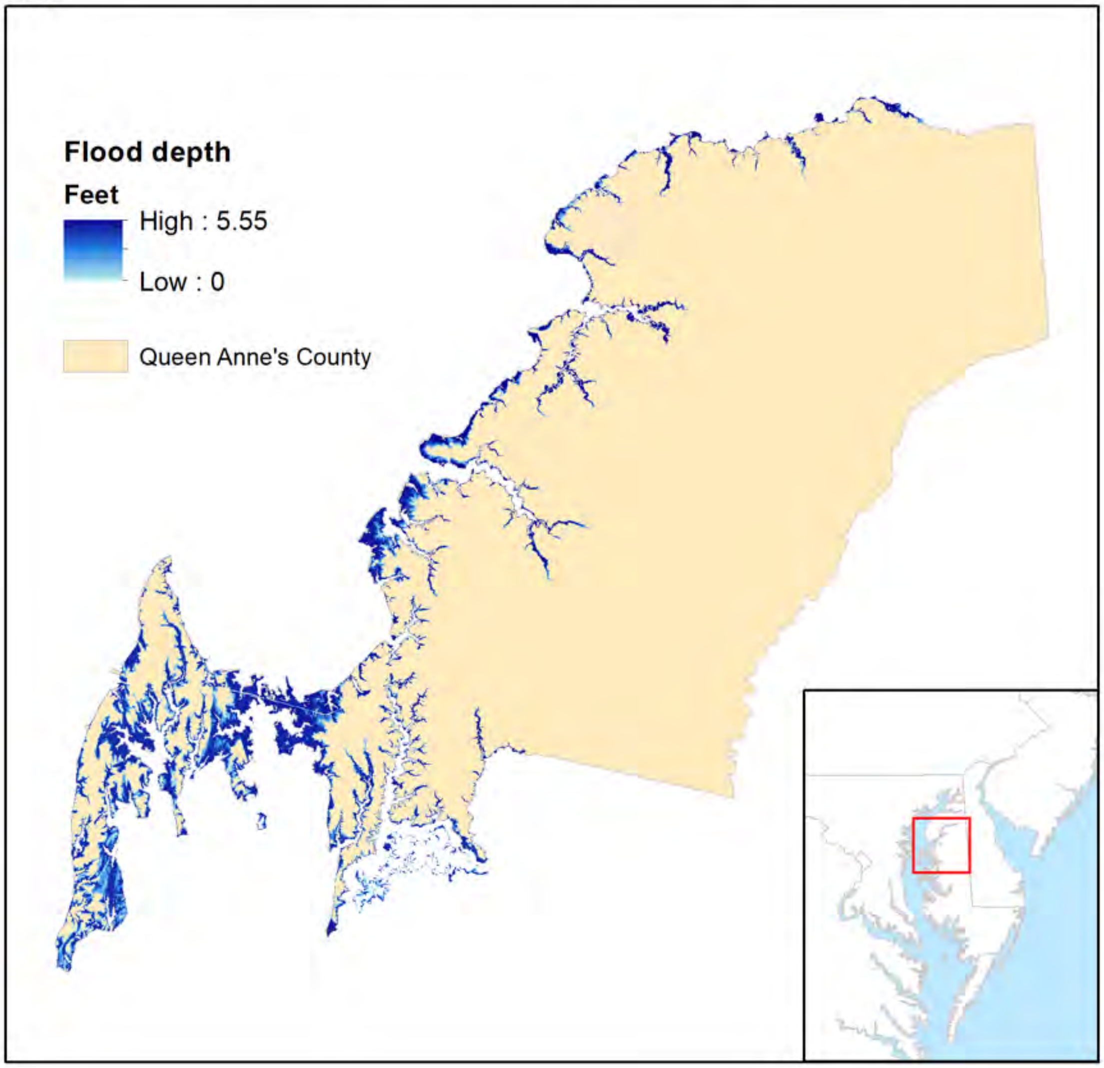


Figure 7 Predicted flood depths for Queen Anne's County 1% chance flood at MSL in 2100



Using these flood depth grids, those buildings that are vulnerable to flood water, and the degree to which they are vulnerable, were determined. Fortunately, Queen Anne's County maintains a set of "addressable" building footprint polygons, separate from any outbuildings. Next, the average depth of flood water for each modeling scenario was calculated for each building by converting the depth grids to depth points and intersecting the building footprints and the depth points. Queen Anne's County's 2015 tax parcels were then digitally overlaid, thus assigning attributes such as total assessed value of the improvements, the land use of the parcel (residential, commercial, etc), and the structure style (1 story, 2 story, apartments, etc) to the building footprint. Because the foundation heights are unknown, an assumption of a 24" foundation was made. Using that assumed foundation height, the flood depth above the first finished floor was calculated. The total value of the building and its contents was found, using industry-standard estimates of the contents value based on the use of the building (i.e. residential contents are 50% of the building value, while commercial contents are 100% of the building value). Finally, using the depth-damage curves provided by FEMA via the HAZUS-MH software, the potential damage percentage, and therefore the potential damage to both the building and its contents in 2015 dollars, for each building for each flood scenario was estimated.

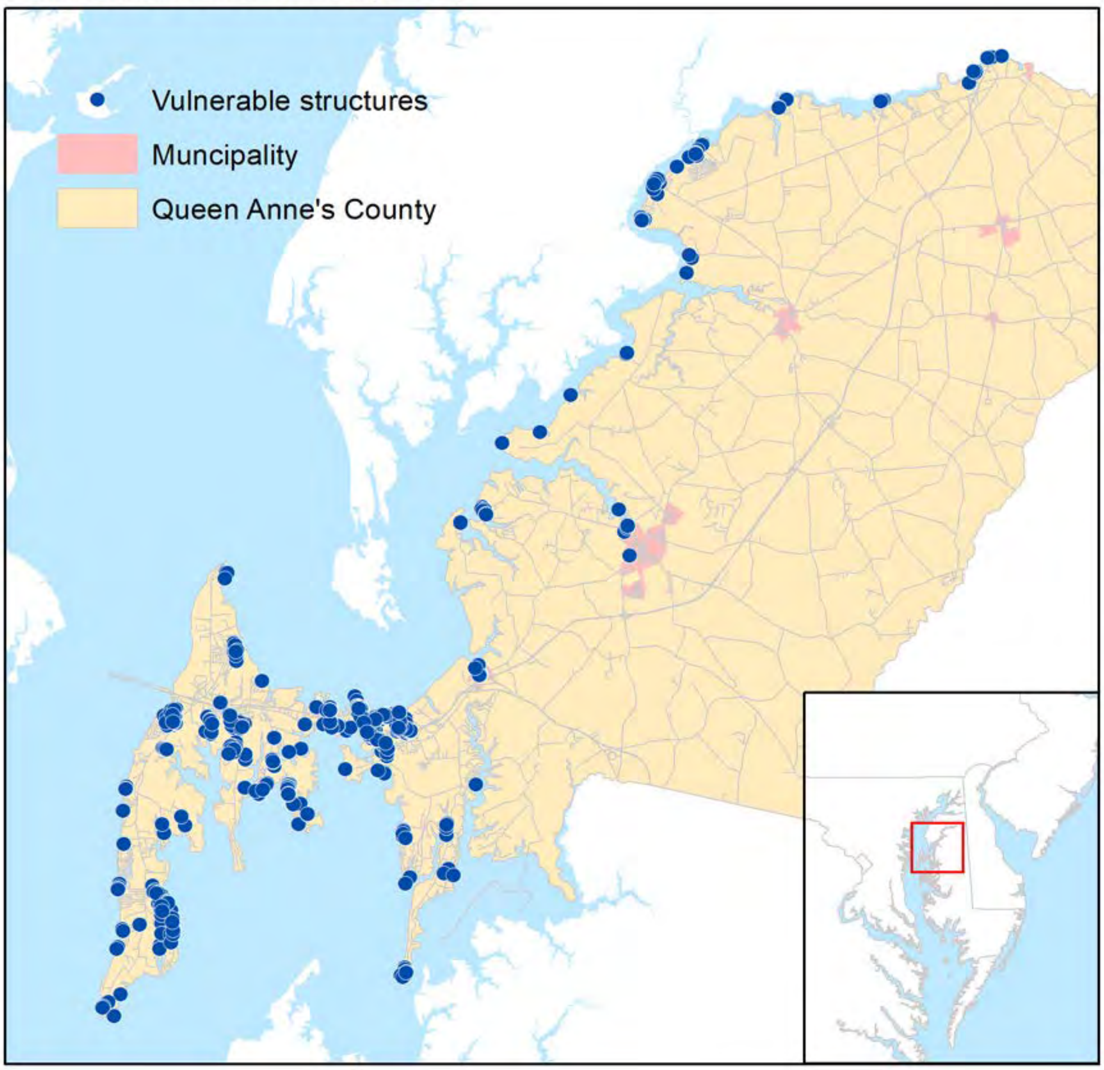
It is important to note when viewing the following results that the numbers generated carry with them a degree of uncertainty. Nearly every component (the ground elevations, the flood heights, the foundation heights, the assessed value, etc.) has confidence constraints of various magnitudes. The HAZUS-MH model itself is a simplified version of the complex engineering models used to create the flood insurance rate maps. Having said that, considerable research has been conducted to review HAZUS-MH analysis results after an event and have found that the software does a reasonably good job of both predicting the depth of flood as well as the insured losses. But was with any simulation analysis, we recommend that these damage statistics be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Flood Results for Present-Day (2015)

The results of the analysis indicate that there are 751 buildings predicted to be impacted by a 1% chance flood in Queen Anne's County (Table 3). However, a super-majority of them (646) would only experience minor nuisance flooding in this scenario; only 25 (3.3%) would experience greater than 10% damage. Thus, the overall predicted damage percentage from this flood level is 0.9% of the total value of the structures and contents ($2.0 million of damage from $230.5 million in value). When standardized per building, those buildings that are predicted to incur incidental damage are also the most valuable (an average of $312,828 per building vs $293,128 per building that are damaged 10% or greater). This is not surprising given that many of these more expensive structures are in the developed areas around Kent Island – an area that by its peninsular nature is well-known to be susceptible to occasional flooding. It is also worth noting that a significant mitigation opportunity exists. There are only 25 buildings predicted to be damaged between 10 and 40% in the 1% chance event. That represents less than 5% of the total number of vulnerable buildings but they represent over 50% of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits.

The spatial distribution of the structures vulnerable to the 1%-chance flood event follows a predictable pattern (Figure 8). While there are a few in Centreville and along Chester River, the majority are found in and around Kent Narrows and on Kent Island itself, particularly around Cox Creek and Eastern Bay. Other water-orientated development around Crab Alley Bay and Prospect Bay will also see their fair share of flood water in the 1% chance event

Figure 8 Spatial distribution of vulnerable structures in Queen Anne's County 1% chance flood at MSL in 2015 (n=751)



The very severe 0.2% chance flood event represents a current worst-case scenario for Queen Anne's County (Table 4). In such an event, 1,423 buildings would be impacted with 146 impacted moderately (10 – 50%). The total value of the structures and their contents that are vulnerable to flooding expands to $420.4 million and the potential damage is calculated to be $11.2 million, or 5.5x that of the 1% chance event. The number of buildings that are minimally effected (996) drops by more than 16% as a percentage of the total vulnerable buildings (86.0% in 1%-chance scenario vs. 69.8% in the 0.2%-chance). This indicates that in such a severe flood, the water is reaching many structures not previously impacted. These people tend to be less prepared for flooding because in less severe flood magnitudes, water does not reach them.

Table 3. Potential damage to structures/contents from a 1% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	646	86.0%	$202,086,571	$312,828	$30,497	$47	1.5%
1 - 10%	80	10.7%	$21,162,775	$264,535	$921,240	$11,515	45.6%
10 - 20%	22	2.9%	$6,880,143	$312,734	$968,426	$44,019	48.0%
20 - 30%	2	0.3%	$405,867	$202,843	$83,254	$41,627	4.1%
30 - 40%	1	0.1%	$42,200	$42,200	$15,551	$15,551	0.8%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	751	100.0%	$230,577,555	$307,027	$2,018,969	$2,688	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 4. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	993	69.8%	$304,347,765	$306,493	$34,492	$35	0.3%
1 - 10%	224	15.7%	$65,700,427	$293,305	$3,238,407	$14,457	28.9%
10 - 20%	117	8.2%	$43,747,017	$373,906	$6,362,270	$54,378	56.7%
20 - 30%	27	1.9%	$6,518,969	$241,443	$1,530,520	$56,686	13.7%
30 - 40%	1	0.0%	$67,200	$67,200	$22,270	$22,270	0.2%
40 – 50%	1	0.0%	$42,200	$42,200	$18,505	$18,505	0.2%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	1,423	100.0%	$420,423,578	$295,449	$11,211,463	$7,879	100.0%

Note: All dollar values are from 2015 tax assessments.

When the potential damage was also examined with respect to land use, it was found that no matter the scenario, the vast majority all of buildings vulnerable to flooding in Queen Anne's County were residential, ranging from 89.1% in the 1% chance scenario (Table 5) to 93.0% in the 0.2% chance scenario (Table 6). The second largest category was commercial buildings, ranging from 9.2% in the 1% chance scenario to 5.7% in the 0.2% chance scenario. In the 1% chance scenario, the majority of the damage (58.5%) comes from residential buildings, which is to be expected given the number of residential buildings affected. However, given that (relatively) few commercial buildings are predicted to be impacted, it is concerning that they account for 40.6% of the predicted damage. This suggests that suggesting mitigation actions that are targeted at Queen Anne's County business owners might yield the best results.

Table 5. Potential damage to structures/contents from a 1% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	669	89.1%	$180,063,631	$1,181,556	0.7%	58.5%
Commercial	69	9.2%	$47,177,341	$819,909	1.7%	40.6%
Government	8	1.1%	$2,394,806	$15,551	0.0%	0.8%
Industry	1	0.1%	$914,625	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	4	0.5%	$27,152	$1,954	7.2%	0.1%
Total	751	100.0%	$230,577,555	$2,018,969	0.9%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 6. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1,324	93.0%	$362,620,410	$8,178,604	2.3%	72.9%
Commercial	81	5.7%	$52,198,910	$3,010,971	5.8%	26.9%
Government	11	0.8%	$3,495,606	$18,505	0.5%	0.2%
Industry	3	0.2%	$2,081,500	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	4	0.3%	$27,152	$3,383	12.5%	0.0%
Total	1,423	100.0%	$420,423,578	$11,211,463	2.7%	100.0%

Note: All dollar values are from 2015 tax assessments.

One final way to break down the countywide vulnerability results is to examine them by property value. The following tables explore the vulnerability of the buildings based on the values of the structure and its contents (Tables 7 & 8). Each flooding scenario presents remarkably consistent results and thus there are some overall conclusions that can be made. First, in both flood scenarios, the least valuable properties suffer the most damage, relative to their value. Given that the owners of these properties are historically the least likely to have flood insurance, this situation could be debilitating for those property owners. Second, a majority of the total damage from the 1% chance event is generated by expensive properties (both a structure and contents value between $500,000 and $2 million). This is an opportunity as very few properties are contributing to the overall vulnerability of the county and could be addressed proactively. Finally, with the increase in flood depths in the 0.2% chance scenario, the damage percentages begin to spread out among the range of property values. This suggests that the 0.2%-chance flood is severe enough to damage many different areas and are felt by working-class, middle-class, and upper-class neighborhoods alike.

Table 7. Potential damage to structures/contents from a 1% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	42	5.6%	$684,772	$29,179	4.3%	1.4%
$50 - $100	54	7.2%	$4,507,825	$74,225	1.6%	3.7%
$100 - $200	234	31.2%	$35,807,775	$364,471	1.0%	18.1%
$200 - $300	190	25.3%	$45,893,483	$439,631	1.0%	21.8%
$300 - $400	98	13.0%	$34,279,575	$97,252	0.3%	4.8%
$400 - $500	45	6.0%	$20,073,150	$3,486	0.0%	0.1%
$500 - $1,000	71	9.5%	$47,114,775	$274,045	0.6%	13.6%
$1,000 - $2,000	12	1.6%	$17,123,800	$736,680	4.3%	36.5%
$2,000 - $3,000	4	0.5%	$8,923,200	$0	0.0%	0.0%
More than $3,000	1	0.1%	$16,169,200	$0	0.0%	0.0%
Total	751	100.0%	$230,577,555	$2,018,969	0.9%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 8. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	51	3.6%	$854,428	$68,926	8.1%	0.6%
$50 - $100	92	6.5%	$7,582,000	$406,738	5.4%	3.6%
$100 - $200	468	32.9%	$69,721,400	$2,223,521	3.2%	19.8%
$200 - $300	378	25.6%	$91,573,100	$2,602,938	2.8%	23.2%
$300 - $400	186	13.1%	$64,971,475	$1,252,139	1.9%	11.2%
$400 - $500	83	5.8%	$37,133,150	$690,680	1.9%	6.2%
$500 - $1,000	137	9.6%	$89,564,125	$2,254,175	2.5%	20.1%
$1,000 - $2,000	22	1.5%	$30,089,850	$1,712,346	5.7%	15.3%
$2,000 - $3,000	4	0.3%	$8,923,200	$0	0.0%	0.0%
More than $3,000	2	0.1%	$20,010,850	$0	0.0%	0.0%
Total	1,423	100.0%	$420,423,578	$11,211,463	2.7%	100.0%

Note: All dollar values are from 2015 tax assessments

Sea level Rise Inundation in 2050 and 2100

Unfortunately, we know that the water levels in the Chesapeake Bay that feed this periodic tidal flooding are not static – they are quite dynamic. Scientists at the USGS estimate that mean sea level in the Bay was about 2 feet lower when Captain John Smith first mapped it in 1608 (Larsen, 1998; https://pubs.usgs.gov/fs/fs102-98/). The Mid-Atlantic region is predicted to be one of the most affected by sea level change going forward because of the presence of the combination of eustatic sea level rise, thermal expansion of sea water as the earth warms, the slowdown of the North Atlantic gyre, and the subsidence of the land surface from the glacial isostatic rebound. The current sea level trend, measured from 1937 to 2015 at the Solomons Island tide gauge is 3.74 mm/year or 1.23 ft in 100 years.

However, scientists do not think that a linear trend will continue. The rate is expected to increase. The models used in this flood mitigation plan follow the same method used by the Maryland State Highway Administration to document the potential flood vulnerability of the road infrastructure from periodic flooding in 2050 and 2100. For that method, the "high" estimates of sea level change from the US Army Corps of Engineers was chosen as the appropriate planning scenario. For Queen Anne's County, this means the USACE expects an estimated mean sea level increase of 2.08 ft by 2050 and 5.7 ft by 2100 (Figures 4 & 5).

Using these elevated mean sea levels of 2050 and 2100, additional analyses were conducted of the vulnerability of the built environment from only inundation without any periodic flooding. It should be noted that these inundation damage estimates are not particularly appropriate for non-periodic flooding. They are included here primarily for comparison's sake. If the buildings predicted to be inundated constantly by a rise in mean sea level were not elevated beyond the reach of the water, the damage done to them would be a great deal more severe.

As the 2050 mean sea level inundation results show (Table 9), Queen Anne's County is largely protected. Only 2 buildings are predicted to experience water in the footprint of their structure although both of them will be damaged to some degree. The spatial distribution of the properties shows one near Castle Harbor Marina in Kent Island and one on Deep Point along the Chester River (Figure 9). By 2100, the situation has changed dramatically – the number of buildings at risk from inundation increased 694x, from 2 in 2050 to 1,388 in 2100 (Table 10). Those 1,388 buildings represent $401.3 million in structure and content value. Again, the prediction of damage in the scenario is very uncertain as the processes that cause inundation damage are quite different than periodic flood damage. However, an overall damage rate of 2.3% is very concerning and is more than double the rate that we expect from a 1% chance flood event in 2015. With regard to the spatial distribution of the structures predicted to be inundated in 2100 (Figure 10), the pattern is remarkably consistent with those areas subject to the 0.2%-chance flood in 2015.

Table 9. Potential damage to structures/contents from mean sea level inundation in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	0	0.0%	$0	$0	$0	$0	0.0%
1 - 10%	1	50.0%	$1,662,750	$1,662,750	$75,906	$75,906	90.2%
10 - 20%	1	50.0%	$42,200	$42,200	$8,254	$8,254	9.8%
20 - 30%	0	0.0%	$0	$0	$0	$0	0.0%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	2	100.0%	$1,704,950	$852,475	$84,160	$42,080	100.0%

Note: All dollar values are from 2015 tax assessments

Table 10. Potential damage to structures/contents from mean sea level inundation in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	990	71.3%	$294,654,291	$297,631	$40,645	$41	0.4%
1 - 10%	235	16.9%	$66,500,277	$282,980	$3,048,331	$12,972	33.5%
10 - 20%	140	10.1%	$34,653,756	$247,527	$4,767,750	$34,055	52.3%
20 - 30%	22	1.6%	$5,454,554	$247,934	$1,236,006	$56,182	13.6%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	1	0.1%	$42,200	$42,200	$18,948	$18,948	0.2%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	1,388	100.0%	$401,305,078	$289,125	$9,111,680	$6,949	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 9 Spatial distribution of vulnerable structures in Queen Anne's County, no flood event at MSL in 2050 (n=2)

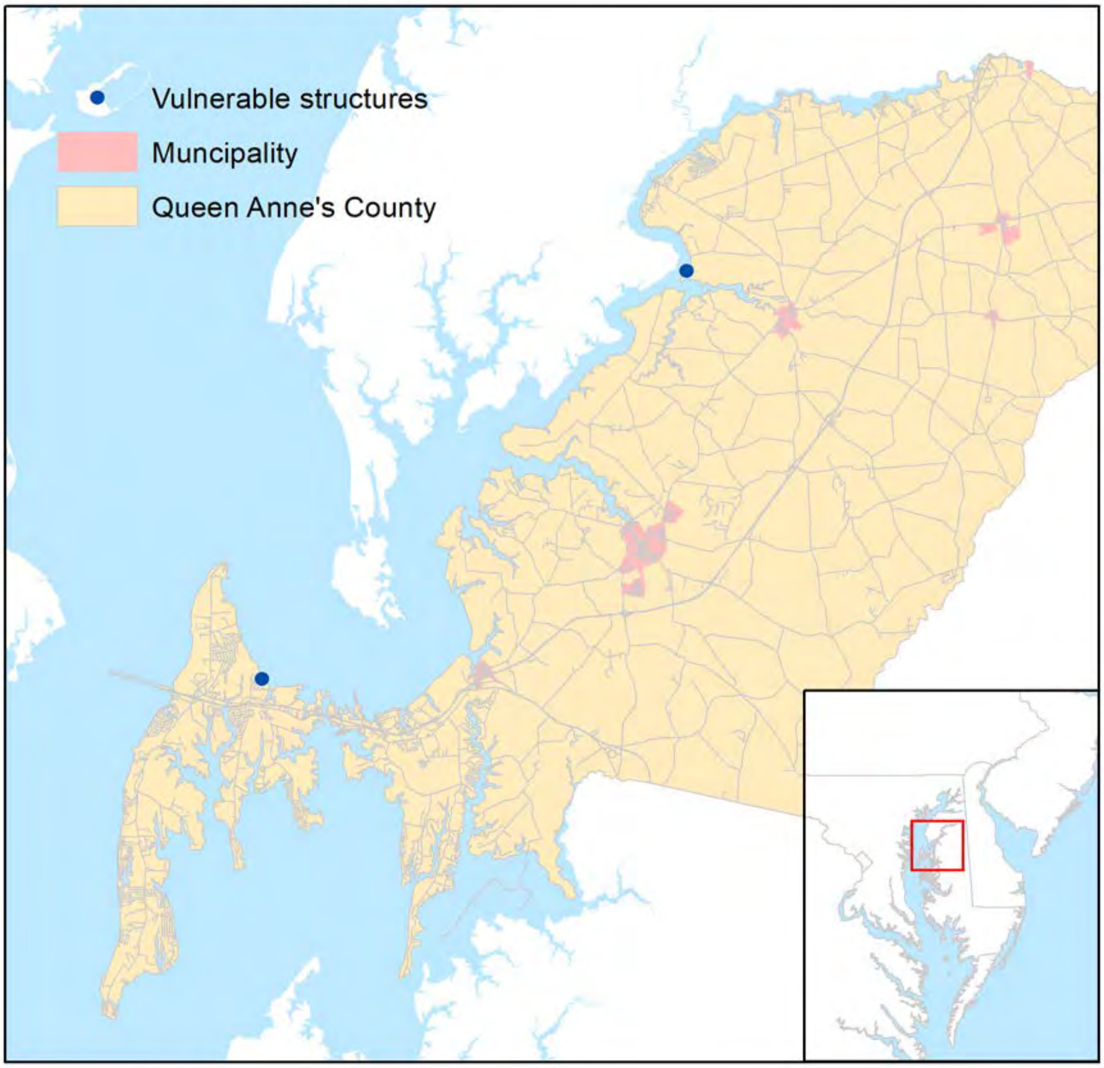
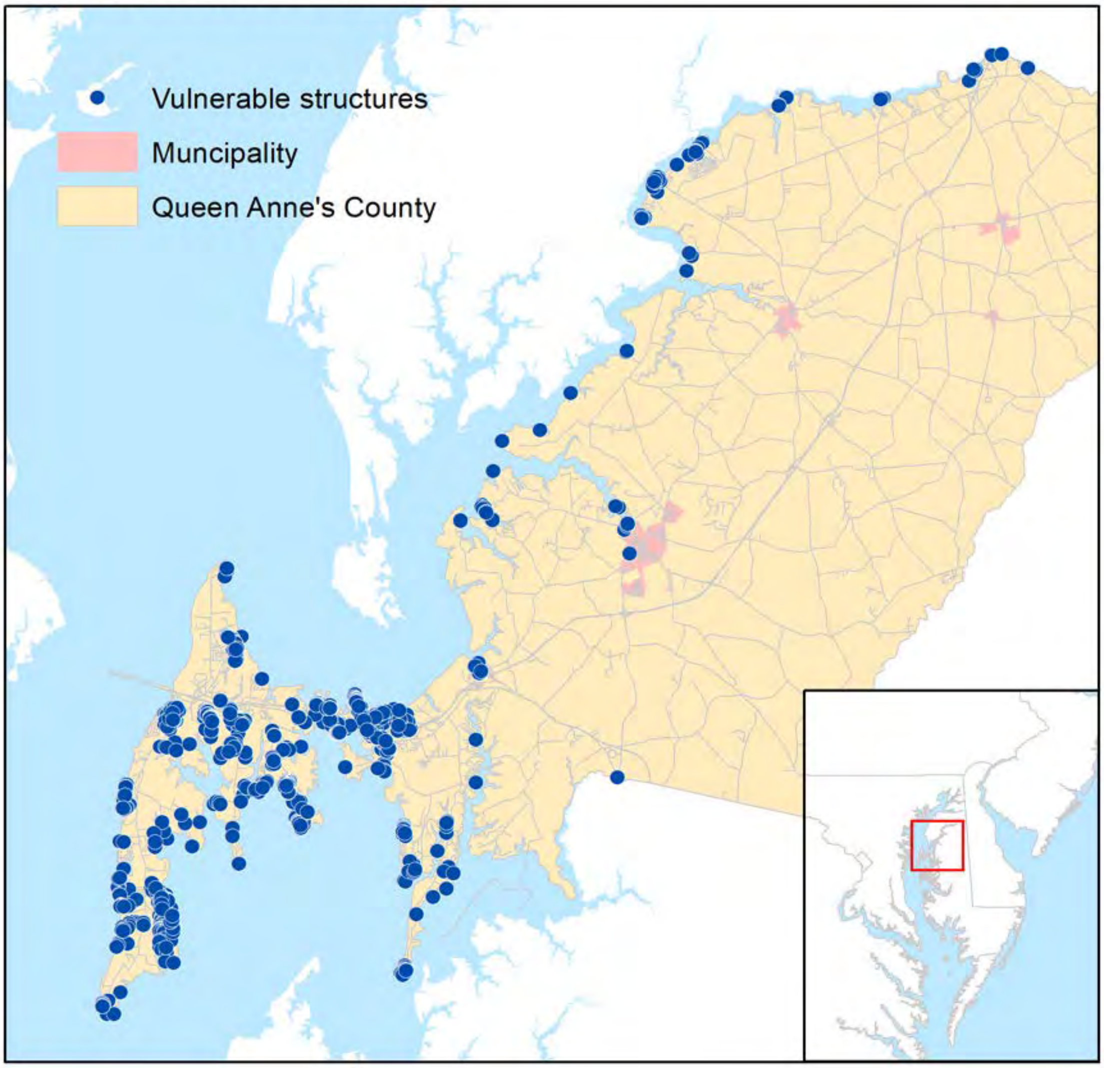


Figure 10 Spatial distribution of vulnerable structures in Queen Anne's County, no flood event at MSL in 2100 (n=1,388)



With regard to inundation with respect to land use, the impact from sea level change in 2050 was 50% residential and 50% commercial (Table 11). Of course, with such a small number of buildings, this division should be viewed with skepticism. By 2100 however, it becomes clear that sea level change in Queen Anne's County will be disproportionately felt by residents, with 93% of all of structures being inundated as residential (Table 12). And just as in the periodic flood scenarios of 2015, the commercial properties of Queen Anne's County bear a disproportionate damage burden, given their (relatively) small exposure

Table 11. Potential damage to structures/contents from mean sea level inundation in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1	50.0%	$1,662,750	$75,906	4.6%	90.2%
Commercial	0	0.0%	$0	$0	0.0%	0.0%
Government	1	50.0%	$42,200	$8,254	19.6%	9.8%
Industry	0	0.0%	$0	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	2	100.0%	$1,704,950	$84,160	4.9%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 12. Potential damage to structures/contents from mean sea level inundation in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1,291	93.0%	$342,486,612	$6,665,274	1.9%	73.2%
Commercial	80	5.8%	$53,297,208	$2,425,515	4.6%	26.6%
Government	10	0.7%	$3,412,606	$18,948	0.6%	0.2%
Industry	3	0.2%	$2,081,500	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	4	0.3%	$27,152	$1,943	7.2%	0.0%
Total	1,388	100.0%	$401,305,078	$9,111,680	2.9%	100.0%

Note: All dollar values are from 2015 tax assessments.

When examining the vulnerability of Queen Anne's County's structure by the property value, the results in 2050 show no significant pattern (Table 13). In 2100 however (Table 14), the results are more dire. Nearly three-quarters the structures (74.0%) predicted to be impacted by sea level inundation have a structure plus contents value of between $100,000 and $400,000. These are relative modest homes that are unlikely to have the financial resources to mitigate the potential threat.

Table 13. Potential damage to structures/contents from mean sea level inundation in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	1	50.0%	$42,200	$8,254	19.6%	9.8%
$50 - $100	0	0.0%	$0	$0	0.0%	0.0%
$100 - $200	0	0.0%	$0	$0	0.0%	0.0%
$200 - $300	0	0.0%	$0	$0	0.0%	0.0%
$300 - $400	0	0.0%	$0	$0	0.0%	0.0%
$400 - $500	0	0.0%	$0	$0	0.0%	0.0%
$500 - $1,000	0	0.0%	$0	$0	0.0%	0.0%
$1,000 - $2,000	1	50.0%	$1,662,750	$75,905	4.6%	90.2%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	2	100.0%	$1,704,950	$84,160	4.9%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 14. Potential damage to structures/contents from mean sea level inundation in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	47	3.4%	$767,228	$58,145	7.6%	0.6%
$50 - $100	91	6.6%	$7,573,775	$365,945	4.8%	4.0%
$100 - $200	479	34.5%	$71,502,500	$1,980,244	2.8%	21.7%
$200 - $300	373	26.9%	$90,257,450	$2,146,086	2.4%	23.6%
$300 - $400	173	12.6%	$60,539,825	$1,011,591	1.7%	11.1%
$400 - $500	80	5.8%	$35,829,500	$388,771	1.1%	4.3%
$500 - $1,000	118	8.5%	$77,035,600	$1,710,293	2.2%	18.8%
$1,000 - $2,000	21	1.5%	$28,865,150	$1,450,604	5.0%	15.9%
$2,000 - $3,000	4	0.3%	$8,923,200	$0	0.0%	0.0%
More than $3,000	2	0.1%	$20,010,850	$0	0.0%	0.0%
Total	1,388	100.0%	$401,305,078	$9,111,680	2.9%	100.0%

Note: All dollar values are from 2015 tax assessments

In the event that the USACE's predictions come to pass, the 2.08 ft rise in MSL will significantly impact the flood vulnerability of Queen Anne's County (Table 15). In the 1%-chance flood scenario, the number of buildings impacted will increase by over 284% (from 751 to 2,133). Additionally, the number of buildings with moderate-severe damage (between 30 – 50%), spiked by 15x, rising from 1 to 15 and from a total value of $42,200 to nearly $5.6 million. Thankfully, only 1 is predicted to be severely damaged (greater than 50%). The total amount of building and contents value vulnerable to flooding will nearly triple from $230.5 million to $660.2 million and the amount of potential damage will increase 15x from $2.0 million to $30.1 million. The spatial distribution of these vulnerable structures show the encroachment of much of the County along the Chesapeake Bay, particularly around Kent Narrows and Kent Island but also picking up vulnerable structures in the Corsica and Chester Rivers.

Of course, the prediction for the year 2100 (5.7 ft increase in MSL) must be considered highly uncertain. However, as of this writing, there is a growing consensus in the scientific community that the SLC estimates are more than likely too conservative, rather than too aggressive. Until that consensus solidifies, the current USACE estimate is still reasonable for planning purposes. Obviously, sea level being 5.7 ft higher in Queen Anne's County 82 years from now will significantly impact much of the vulnerable coastal development (Table 16). The number of vulnerable buildings will increase by 629% (from 751 in 2015 to 4,723 in 2100), with about one-tenth of those buildings damaged greater than 30%. The number predicted to be severely damaged will go from 0 in 2015 to 1 in 2050 to 16 in 2100. While the amount of building and contents value vulnerable to flooding will increase 6.9x, from $230.5 million to $1.6 billion, the amount of potential damage will more than 91.4x from $2.0 million to $184.6 million. The spatial distribution shows no appreciable change from the areas that are currently vulnerable – it is just that the flood waters both reach further inland increases in the number of structures potentially impacted in Queen Anne's County but also increases the depth of flooding for those structures that are vulnerable now, increasing their potential damage (Figure 12).

Table 15. Potential damage to structures/contents from a 1% chance flood event in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,193	55.9%	$403,231,179	$337,998	$80,908	$68	0.3%
1 - 10%	392	18.4%	$114,728,156	$292,674	$6,409,303	$16,350	21.3%
10 - 20%	379	17.8%	$100,864,831	$266,134	$13,137,390	$34,663	43.7%
20 - 30%	154	7.2%	$35,813,490	$232,555	$8,654,814	$56,200	28.8%
30 - 40%	12	0.5%	$5,358,235	$446,520	$1,674,082	$139,507	5.6%
40 – 50%	2	0.1%	$188,250	$94,125	$88,595	$44,297	0.3%
50% or more	1	0.0%	$67,200	$67,200	$33,917	$33,917	0.1%
Total	2,133	100.0%	$660,251,340	$309,541	$30,079,007	$14,101	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 11 Spatial distribution of vulnerable structures in Queen Anne's County, 1% chance flood at MSL in 2050 (n=2,133)

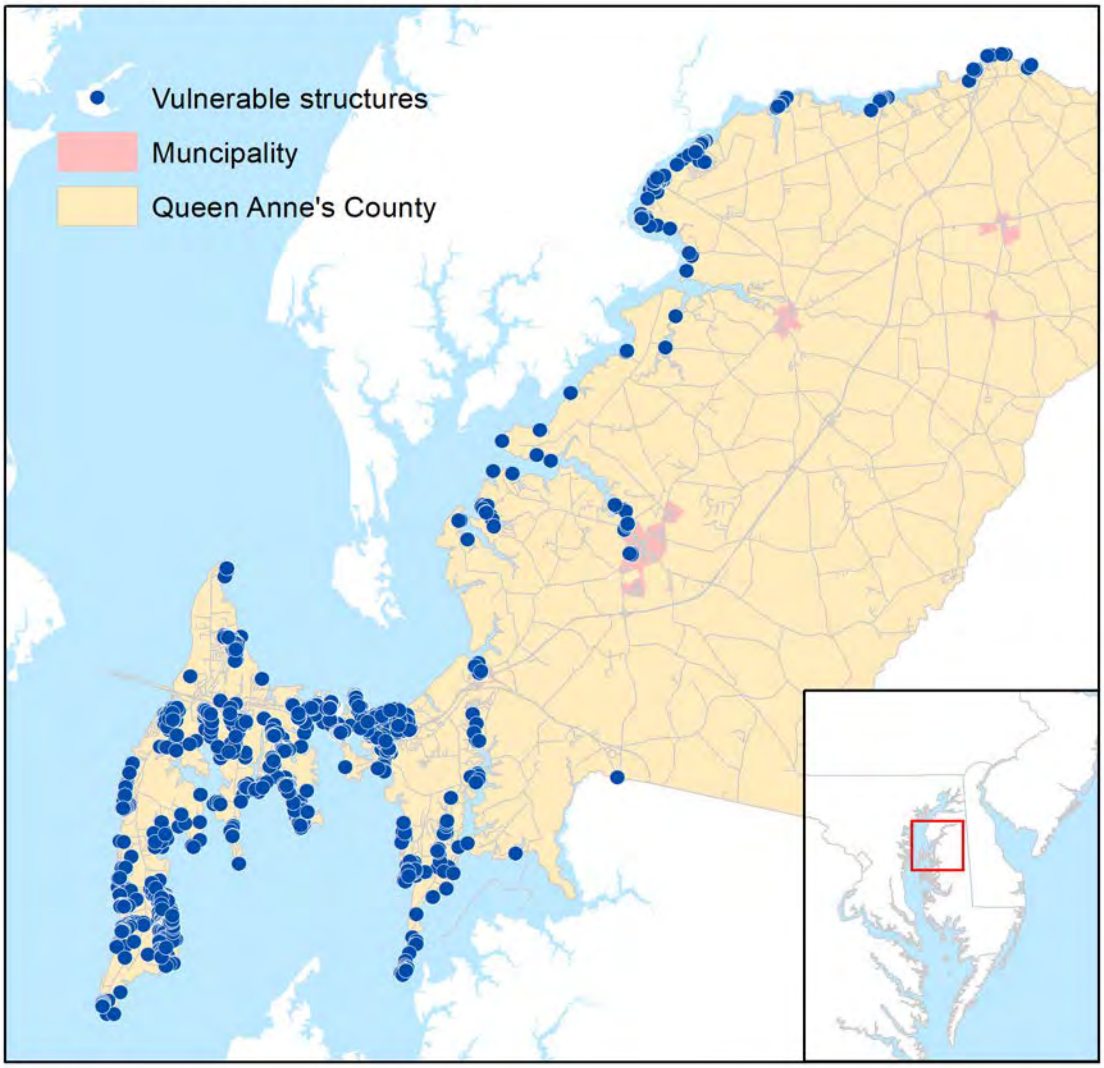


Table 16. Potential damage to structures/contents from a 1% chance flood event in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,306	27.7%	$570,707,218	$436,989	$192,655	$148	0.1%
1 - 10%	547	11.6%	$197,528,780	$361,113	$10,624,814	$19,424	5.8%
10 - 20%	1,437	30.4%	$481,832,157	$335,304	$72,805,577	$50,665	39.4%
20 - 30%	951	20.1%	$238,104,856	$250,373	$62,073,962	$65,272	33.6%
30 - 40%	409	8.7%	$94,577,281	$231,240	$31,722,988	$77,562	17.2%
40 – 50%	57	1.2%	$9,682,285	$169,865	$3,983,864	$69,892	2.1%
50% or more	16	0.3%	$4,741,550	$296,347	$3.206,821	$200,426	1.7%
Total	4,723	100.0%	$1,597,174,128	$338,169	$184,610,682	$39,087	100.0%

Note: All dollar values are from 2015 tax assessments

As for the spatial distribution of the flood threat in the two sea level change scenarios, it is a reasonable generalization to say that one can simply expect existing flood prone areas to flood more often, can expect deeper flood water when it does flood, and that areas adjacent to currently threatened areas are most likely to be newly-inundated. Maps of the 1% chance flood in 2050 and 2100 in the Romancoke area on Eastern Bay have been included as an example of what most areas in Queen Anne's County could expect (Figures 8 & 9). In the comparison of 2015 and 2050, the predicted 1% chance flood includes more buildings as vulnerable that are adjacent to the current flood area. But primarily, the 1% flood in 2050 will be more severe than today, thus yielding many more buildings in higher predicted damage categories. By contrast, the comparison of 2015 and 2100 shows not only a significantly more severe 1% chance flood, but a significant expansion of the vulnerable zone. This pattern is different from what one can expect in the upper part of the county. The lack of expansive wetlands and low-lying areas along the Chester River and its tributaries means that the spread of the flood zone in those areas is more constrained than in the Kent Island area. The data from this analysis will be delivered to County officials so that they can map any area of the county this way, but Romancoke's patterns are very typical of the lower areas in the county.

Figure 12 Spatial distribution of vulnerable structures in Queen Anne's County, 1% chance flood at MSL in 2100 (n=4,723)

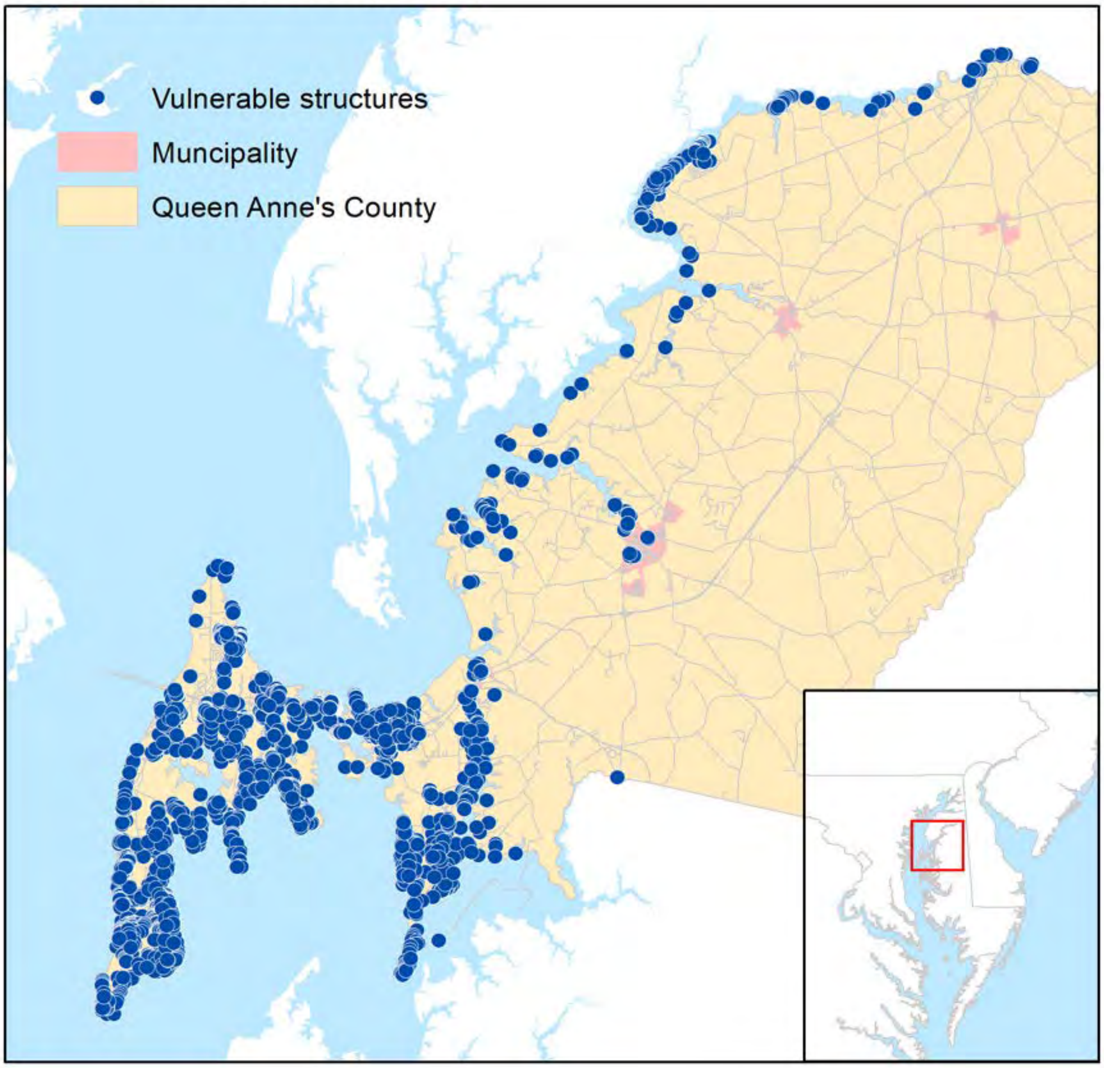


Figure 13 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2050, Romancoke, Maryland

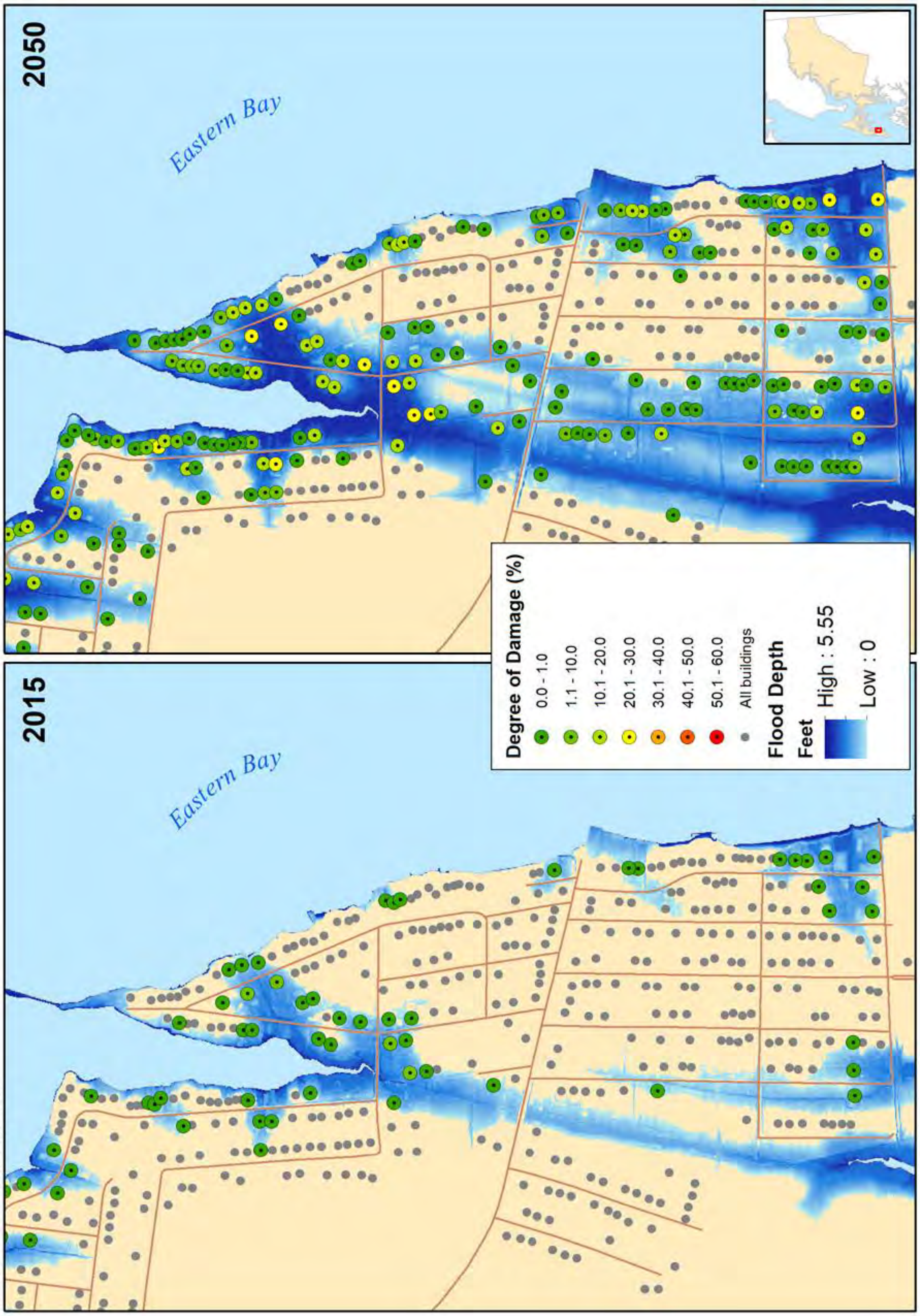
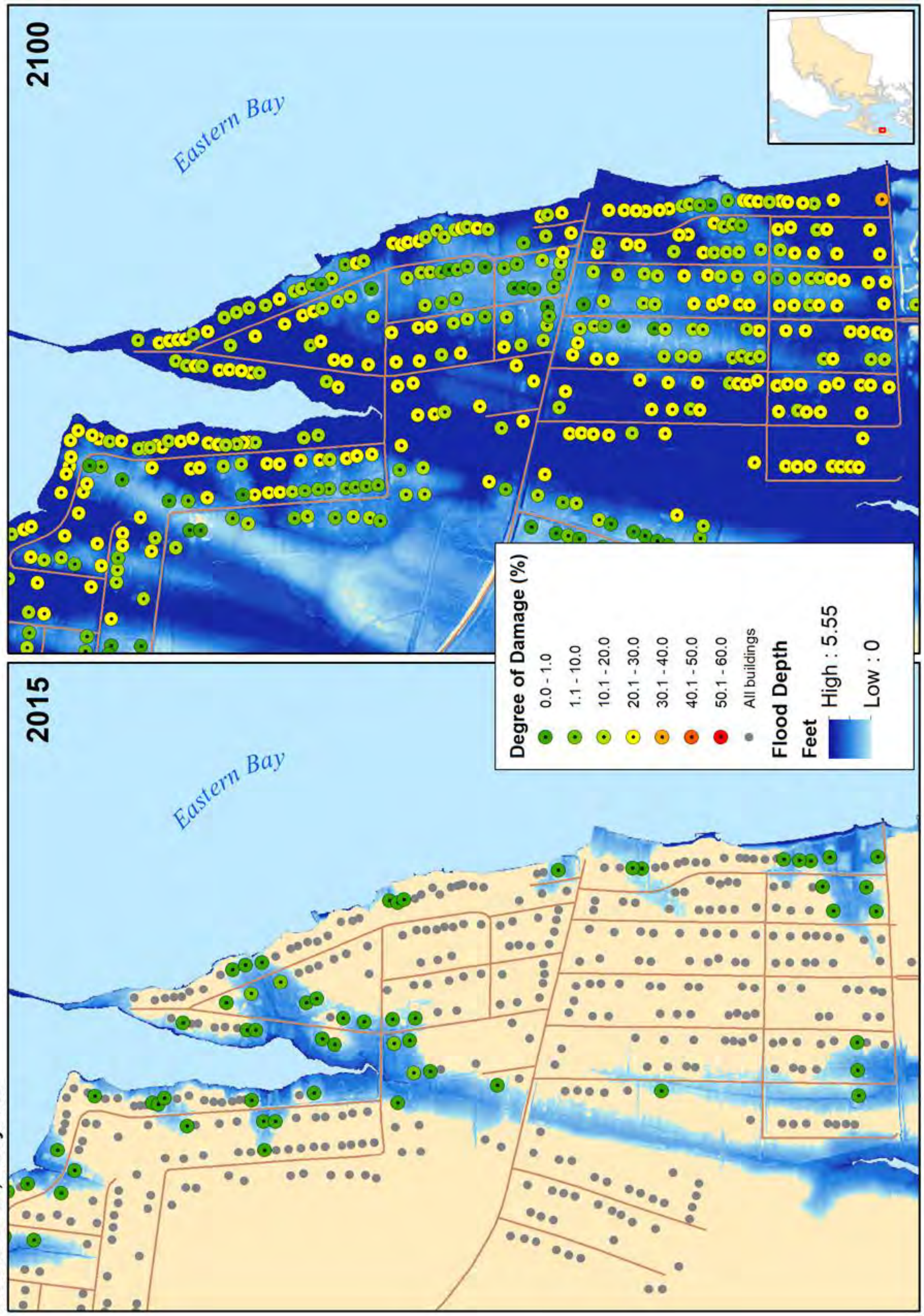


Figure 14 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2100, Romancoke, Maryland



The patterns of damage from flooding in the future when considering the use of the property are very similar to the results in 2015 with a few exceptions (Table 17 and 18). Besides the inclusion of three additional industrial sites worth almost $10 million in structure and contents value, the other key takeaway is that nearly 80% of the flood damage in 2050 will be residential, rather than a large commercial impact in 2015. That shift of burden away from commercial, governmental, and industrial land uses toward residential strengthens by 2100, with 94% of all of the structures impacted and 85% of all of the damage is coming from the residential sector.

Table 17. Potential damage to structures/contents from a 1% chance flood event in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	2,000	93.8%	$575,831,464	$24,006,759	4.2%	79.8%
Commercial	109	5.1%	$69,683,814	$5,557,271	8.0%	18.4%
Government	16	0.8%	$4,444,410	$509,602	11.6%	1.7%
Industry	4	0.2%	$10,264,500	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	4	0.2%	$27,152	$5,375	19.8%	0.0%
Total	2,133	100.0%	$660,251,340	$30,079,007	4.6%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 18. Potential damage to structures/contents from a 1% chance flood event in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	4,438	94.0%	$1,394,923,686	$156,870,575	11.2%	85.0%
Commercial	238	5.0%	$164,069,928	$24,326,420	14.8%	13.2%
Government	30	0.6%	$24,304,410	$2,675,174	11.0%	1.4%
Industry	6	0.1%	$10,811,750	$568,025	5.3%	0.3%
Religious	4	0.1%	$2,700,600	$148,800	5.5%	0.1%
Agricultural	7	0.1%	$363,754	$21,687	6.0%	0.0%
Total	4,723	100.0%	$1,597,174,128	$184,610,682	11.6%	100.0%

Note: All dollar values are from 2015 tax assessments.

In general, the distribution of vulnerability by property value does not change considerably once sea level change is added in 2050 (Table 19). Of course, the raw numbers of structures increases but the proportion of them that fall into the separate categories are remarkably similar. A divergence happens, however, when looking at the distribution of damage. In a 1%-chance flood scenario in 2050, the damage predicted for the more valuable buildings ($1 million to $2 million) decreased from 36.5% of the total damage in 2015 to only 11% in 2050. This result is not unexpected. Because more of the damage in 2015 is borne by commercial buildings, those properties tend to be worth more. As sea level rises, the flooding begins to reach relatively modest residential neighborhoods. By 2100, this pattern continues to deepen (Table 20). Nearly one-half of the predicted damage from a 1% chance event in 2100 will be borne by properties worth between $100,000 and $400,000. It is also important to note that these are 2015 property values. If the rate of inflation for the next 85 years is the same as the last 85 ($1 in 1930 is worth $13.96 in 2015, according to the Consumer Price Index), the total property value at risk from flooding would be over $22 billion.

Table 19. Potential damage to structures/contents from a 1% chance flood event in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	81	3.8%	$1,304,865	$145,616	11.1%	0.5%
$50 - $100	122	5.7%	$10,063,150	$857,722	8.5%	2.9%
$100 - $200	675	31.6%	$100,682,125	$5,950,760	5.9%	19.8%
$200 - $300	574	26.9%	$139,368,400	$6,905,023	5.0%	23.0%
$300 - $400	281	13.2%	$97,107,925	$4,375,948	4.5%	14.5%
$400 - $500	110	5.2%	$49,237,100	$2,353,889	4.8%	7.8%
$500 - $1,000	244	11.4%	$162,901,000	$5,407,925	3.3%	17.8%
$1,000 - $2,000	34	1.6%	$46,018,525	$3,316,473	7.2%	11.0%
$2,000 - $3,000	7	0.3%	$15,977,400	$479,226	3.0%	1.6%
More than $3,000	5	0.2%	$38,590,850	$286,425	0.7%	0.1%
Total	2,133	100.0%	$660,251,340	$30,079,007	4.6%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 20. Potential damage to structures/contents from a 1% chance flood event in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	132	2.8%	$2,309,114	$512,005	22.2%	0.3%
$50 - $100	285	6.0%	$23,306,250	$4,102,919	17.6%	2.2%
$100 - $200	1,470	31.1%	$219,715,200	$35,190,841	16.0%	19.1%
$200 - $300	1,153	24.4%	$281,552,900	$43,441,077	15.2%	15.4%
$300 - $400	632	13.4%	$216,957,450	$26,953,179	12.4%	14.6%
$400 - $500	300	6.4%	$133,952,250	$12,999,383	9.7%	7.0%
$500 - $1,000	589	12.5%	$392,619,015	$34,052,241	8.7%	18.4%
$1,000 - $2,000	113	2.4%	$148,841,600	$11,904,541	8.0%	6.4%
$2,000 - $3,000	27	0.6%	$63,786,600	$5,291,805	8.3%	2.9%
More than $3,000	22	0.5%	$114,133,749	$10,162,690	8.9%	5.5%
Total	4,723	100.0%	$1,597,174,128	$184,610,682	11.6%	100.0%

Note: All dollar values are from 2015 tax assessments

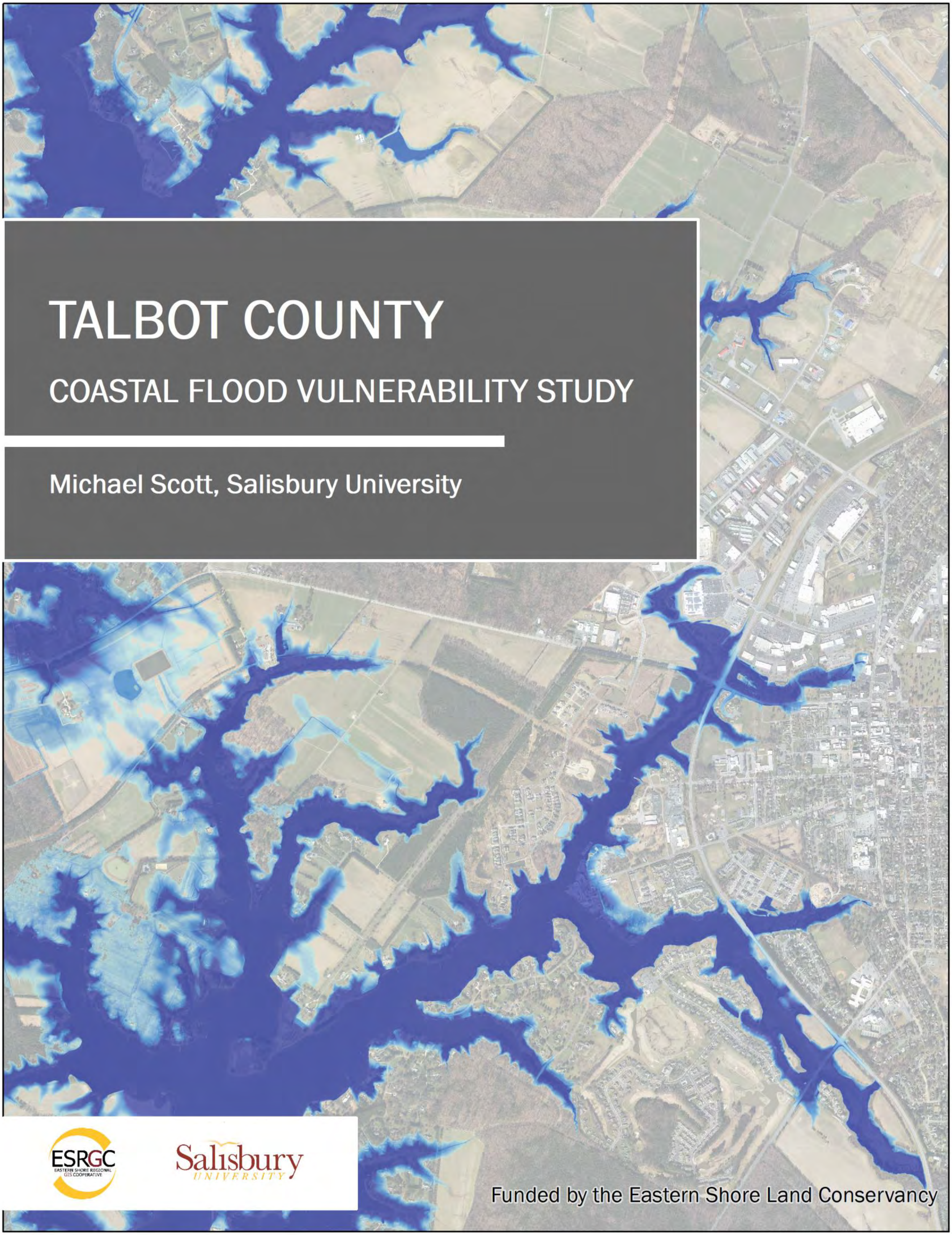
Study Caveats

It should not go without mentioning that the prediction of the flood threat with a future sea level change has more than the normal level of uncertainty. Not only are the estimates of sea level change not a foregone conclusion, but the nature of the flood threat itself is likely to change. For example, in a world with oceans that are 2 (or 5) feet higher, the controlling forces (subtropical high pressure systems, ocean upwelling, thermal heat transfer, etc.) of tropical storms are likely to be different. Thus, the periodicity of certain magnitudes of storm events could change. Similarly, this analysis uses statistical/stochastic models, not a dynamic simulations. Therefore, it does not take into account either individual storm parameters or geographic parameters such as land cover or the shape of the near-shore bottom, both of which will impact the flood predication and both are likely to change in a rising sea level scenario.

With regard to vulnerability estimates, there are also a number of important caveats to remember. First, this analysis assumes that all of the built infrastructure would be exactly as one found it in 2015. That is almost certainly not going to be the case, both with new structures being built and older structures being made more flood-resistant as the waters rise. Second, as mentioned above, the potential damage is being evaluated as if property values will not change by 2050 or 2100 – also not the case. Finally, this vulnerability analysis deliberately examined only damage to structural/contents because the relationship between building damage and depth of water is best understood. There are still many other sources of potential vulnerability: infrastructure damage/loss (both to rebuild and its impact on restarting the economy after a disaster), loss of productivity with businesses closed, debris removal, other consumer losses (cars, boats, sheds/garages), and of course, the potential loss of life.

Conclusions

Several conclusions can be made regarding the question of coastal flooding vulnerability in Queen Anne's County. First, given that Queen Anne's County has several significant sources of flood threat and given that it contains more than 20,758 improved structures, the fact that only 751 (3.6%) are vulnerable to the 1%-chance flood is probably a result of historical land use patterns, focused on agricultural development in the high-quality farmland found in the uplands as well as awareness of the flood threat given the long history of working the Chesapeake Bay. Second, given the potential for sea level rise in the coming decades, the time to redouble the County's efforts to protect its citizens from flooding is now. If no changes are made, more than 10% of the county's current structures will be impacted by flooding in 2050 and greater than one-fifth of the Queen Anne's building stock may need flood protection by 2100. Having said that, this analysis shows that Queen Anne's County has some time to adjust to the change in the flood threat. That so few buildings are predicted to be impacted by sea level change alone by 2050 is both an opportunity to mitigate the threat and a concern that a lack of action may not yield negative consequences before it is too late. Finally, even though the County as a whole is somewhat flood-prone, there are certain areas that are particularly vulnerable, such as Kingstown, Grasonville, Kent Narrows, Cloverfields, the Kent Point peninsula, Romancoke, and the Prospect Bay area, for which there are no easy answers.



TALBOT COUNTY

COASTAL FLOOD VULNERABILITY STUDY

Michael Scott, Salisbury University

ESRGC
EASTERN SHORE REGIONAL GIS COOPERATIVE

Salisbury
UNIVERSITY

Funded by the Eastern Shore Land Conservancy

Executive Summary

Given the topography and historical development patterns of Maryland's Eastern Shore, the potential for damage from periodic flood events caused by coastal storms and extreme high tides is well-known. What is uncertain is the degree to which the vulnerability of Eastern Shore communities is increasing as sea levels change in the Chesapeake Bay and its tributaries. Therefore, the goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. The methods employed in this research are considered best practices, are accepted by FEMA and provide a consistent framework for assessing risk from floods. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the county and help make informed decisions about mitigation measures to reduce the potential impacts. Having said that, we recommend that the damage statistics in this report be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Results of the analysis predict that 888 buildings (worth $288.6 million in the structure and its contents combined) would feel the impacts of a 1%-chance flood in Talbot County, with 41 of them experiencing more than 10% damage, for a total predicted damage of $2.4 million. Those moderately or severely damaged structures represent less than 5% of the total number of vulnerable buildings but they represent over half of the potential damage in the county from the 1% chance flood. Working to make those structures less vulnerable to flooding should yield considerable financial benefits. The much more severe 0.2%-chance flood impacts 1,511 buildings in the county valued at $535.2 million with 195 damaged moderately with a total potential damage of $9.7 million. Given that about 35% of the potential damage from a 1% chance flood event comes from commercial buildings, instigating mitigation actions that are targeted at Talbot County business owners might yield the best results.

In Talbot County, the magnitude of predicted sea level rise for the remainder of this century is typical for the DelMarVa Peninsula. The US Army Corps of Engineers expects an estimated mean sea level increase in the county of 2.11 ft by 2050 and 5.78 ft by 2100. Thankfully, the sea level rise itself will impact very few buildings in 2050 – only 39 (worth $12.8 million in structure and contents). But by 2100, this balloons to 1,846 structures worth $705.3 million. On the other hand, the degree of potential damage from sea level rise inundation in 2100 is modest – only $15.9 million or $8,624 per building. This indicates a certain level of flood-resistance built into Talbot County, likely from both historical settlements patterns and hard-won knowledge of historically vulnerable locations.

However, when the 1% chance flood is combined with the predicted sea level rise, the vulnerability of the County's built environment is highlighted. In 2050, the 1% chance flood is predicted to impact 2,496 buildings (a 281% increase over the same scenario

today), worth $1.0 billion (more than 3x than present-day) and potentially causing $31.3 million in flood damage (a 13x increase from 2015). The same flood in 2100 could impact 6,152 buildings (a 246% increase from 2050) worth $2.5 billion in value (a 250% increase from 2050) and cost a potential $262.2 million in damage (a greater than 8x increase over the same estimate in 2050).

This coastal flood vulnerability analysis of Talbot County yields several important conclusions. First, given that Talbot County has several significant sources of flood threat and given that it contains more than 20,805 improved structures, the fact that only 751 (4.3%) are vulnerable to the 1%-chance flood is probably a result of historical land use patterns (with the growth of Easton being driven by land-based, rather than water-based transportation), smart flood plain management regulations, and the increasing value of waterfront property in the past several decades. Second, given the potential for sea level rise in the coming decades, the time to redouble the County's efforts to protect its citizens from flooding is now. If no changes are made, almost 12% of the county's current structures will be impacted by flooding in 2050 and nearly one-third of the Talbot building stock may need flood protection by 2100. It seems that Talbot County has an important and hard-won margin of safety from coastal flooding. But once that margin of safety is pierced (with a 2 ft rise in sea level) then the results of hundreds of individual development decisions of the past century will begin to intersect the expanded hazard zone. Finally, this analysis shows that Talbot County has some time to adjust to the change in the flood threat. This is positive not only because any adjustments can be implemented gradually and without disruption but also because Talbot County has time for the redevelopment cycle of the next several decades to be guided by flood-smart principles.

Introduction and Study Context

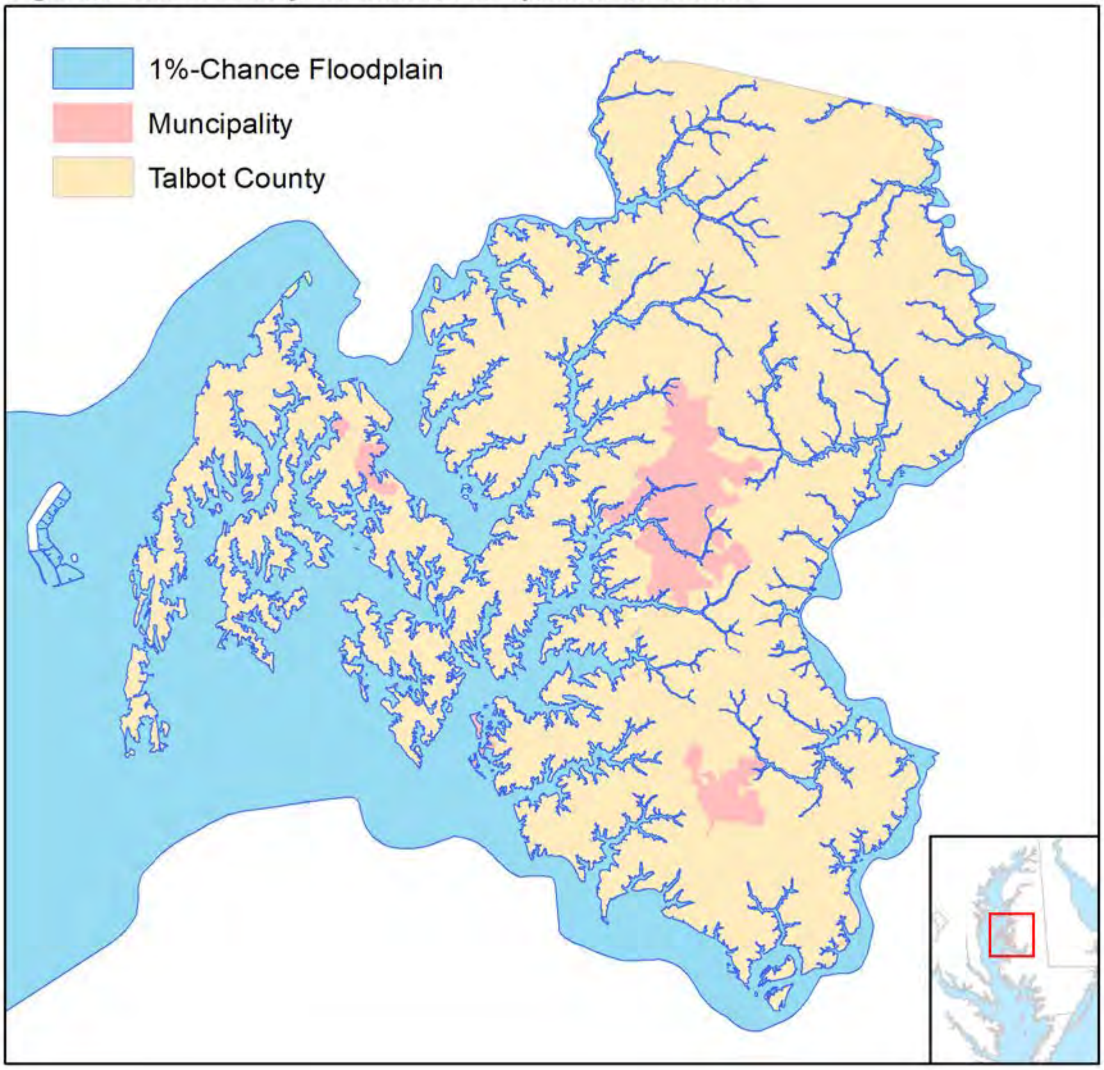
Flooding occurs when rivers, creeks, streams, ditches, or other water bodies receive more water that they can handle from rain, snowmelt, storm surge, or excessive high tides. The excess water flows over adjacent banks or beaches/marshes and into the adjacent floodplain. As many as 85 percent of the natural hazard disasters across the United States have been attributed to flooding.

This document presents the results of a coastal flood vulnerability study of Talbot County, Maryland conducted by Dr. Michael Scott of Salisbury University at the request of the Eastern Shore Land Conservancy in Easton, Maryland. The goal of the study was to model the potential damage to buildings and their contents from severe periodic coastal flooding events, both today and in the future using a value for predicted sea level change. Specifically, using flood depth data calculated on behalf of the Maryland State Highway Administration, the flood scenarios of a 1% chance flood in 2015, a 0.2% chance flood in 2015, no periodic flooding in 2050, a 1% chance flood in 2050, no periodic flooding in 2100, and a 1% chance flood in 2100 were evaluated versus the location and value of buildings in Talbot County. The results are an accounting of the potential damage from periodic flooding, exacerbated by future sea level change. This information should help the residents, business owners, and government officials be aware of particularly vulnerable areas of the count and help make informed decisions about mitigation measures to reduce the potential impacts.

Talbot County's Floodplain

The following map (Figure 1) depicts the 1% chance floodplains within Talbot County, as designated by FEMA on the Flood Insurance Rate Maps or FIRMs. The 1% chance flood (formerly referred to as the 100-year flood) is a flood which has a 1 percent chance of being equaled or exceeded in any given year (MDE, *Maryland Floodplain Manager's Handbook*). Talbot County can experience riverine flooding as a result of excessive rainfall in a matter of hours, such as from a severe thunderstorm. Additionally, some soils can become saturated over a longer period of time and reduce their absorption potential. Riverine flooding can affect any of the rivers and streams in the County but primarily affects the non-tidal or brackish portions of the streams that feed Chesapeake Bay. Tidal flooding in Talbot County usually occurs as a result of tropical storms (including hurricanes) as well as the combination of high astronomical tides with a landward wind. Talbot County has 12.2% of its land area is in the 1% chance floodplain.

Figure 1 Talbot County 1% chance floodplain from dFIRMs



While Talbot County is clearly vulnerable to both riverine and coastal/tidal flooding, only tidal flooding is considered in this vulnerability study. It is entirely possible that those areas in the county beyond the tidal flooding extent will experience a change in their flooding occurrence if the consensus predictions of global climate change come to pass. Current research suggests that extreme rainstorms (as well as extreme droughts) will become more common (National Climate Assessment, 2014).

Flood Measurement

There is one US Geological Survey gauging stations within the County. Only one National Weather Service Advanced Hydrologic Prediction Service hydrograph is near the County and one National Oceanographic and Atmospheric Administration tide gauges is located just outside the County (Table 1). Measurements of stream discharge, river stage, and tide height are critical to the prediction of flood events. At the CAMM2 hydrograph, flood stage is considered 3.5 ft above average tide and this hydrograph does offer flood level prediction. At the NOAA tide gauge, the average range of the tide is 1.62 ft. The maximum water level ever recorded was 4.14 ft above mean higher high water (MHHW) on September 19, 2003 during Hurricane Isabel. That equals 7.48 ft above MSL, or greater than the approximate equivalent of the 0.2% chance flood.

Table 1. River gauges, hydrographs and tide gauges in Talbot County

Agency	ID Number	Station Name	Real-Time or Daily
USGS	01492600	Eastern Bay at Claiborne	Real-time
NWS	CAMM2	Chesapeake Bay at Cambridge	Real-time
NOAA	8571892	Cambridge	Real-time

Flood Levels

Using the Flood Insurance Studies (FIS) of Talbot County, published by FEMA effective July 20, 2016, the following table (Table 2) reports the flood elevations for the key flooding sources.

Table 2. Flood elevations for coastal event (Units are NAVD 1988 feet)

Flooding Source and Location	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CHESAPEAKE BAY				
At Tilghman Island	3.4	4.0	4.1	4.8
At Clairborne	3.5	4.1	4.2	5.1
EASTERN BAY	3.6	4.1	4.2	5.3
CHOPTANK RIVER				
At Bow Knee Point	3.9	4.8	5.0	5.9
At Cambridge	3.5	4.1	4.3	5.0
TRED AVON RIVER				
At Oxford	3.5	4.1	4.3	5.1
At southern end of Baileys Neck	3.6	4.2	4.4	5.5
WYE EAST RIVER				
At Bruffs Island	3.7	4.2	4.4	5.5
MILES RIVER				
At St. Michaels	3.5	4.1	4.3	5.2
HARRIS CREEK				
At Indian Point	3.6	4.2	4.9	5.8
BROAD CREEK				
At Mulberry Point	3.6	4.1	4.5	5.7

Hazards from Floods

Flooding causes $6 billion in average annual losses in the United States annually and account for an average of 140 casualties annually (USGS, “Flood Hazards – A National Threat,” 2006). While most people’s vision of the threat from flooding may include being swept away or buildings being structurally impacted, there are actually a number of hazards associated with flooding that occur both during and after an event.

During the Flood

While a flood event is underway, citizens will be faced with a number of threats. The hydraulic power of water is significant and walking through as little as 6 inches of moving water is dangerous because of the possibility of losing stable footing. Driving through flood water is the cause of many flood deaths each year. As little as one foot of water can float many cars and two feet of rushing water can carry away most vehicles including SUVs. That fact, combined with an inability for drivers to judge the depth of flood water, as well as the potential for flood waters to rise quickly without warning, making driving through flood water a very unwise action.

In addition to being swept away, flood water itself is to be avoided. Because of leaking industrial containers, household chemicals, and gas stations, it is not healthy to even touch the flood water without protective equipment and clothing. Downed power lines, flooded electric breaker panels, and other sources of electricity are a significant threat during a flood. One should also be prepared for the outbreak of fire. Electric sparks often cause fire to erupt and because of the inability of firefighting personnel to respond, a fire can quickly burn out of control.

After the Flood

Cleaning up after a flood can also expose citizens to a number of threats. For example, electrical circuits or electrical equipment could pose a danger, particularly if the ground is wet. Buildings that have been exposed to floodwater may exhibit structural instability of walkways, stairs, floors, and possibly roofs. Flood waters often dislodge and carry hazardous material containers such as tanks, pipes, and drums. They may be leaking or simply very heavy and unstable. The combination of chemical contamination and the likely release of untreated sewage (necessary when the sewage treatment plant is overwhelmed with flood-swelled effluent) mean that drinking water supplies can be unusable. Fire continues to be a very real threat after a flood. First-responders could be occupied with more pressing emergencies and traditional fire suppression equipment may be inoperable, but there may be mobility problems that keep fire-fighting equipment to reach an outbreak. Finally, there is the mental toll of being involved in a disaster. Continued long hours of work, combined with emotional and physical exhaustion and losses from damaged homes and temporary job layoffs, can create a highly stressful situation for citizens. People exposed to these stressful conditions have an increased risk of injury and emotional crisis, and are more vulnerable to stress-induced illnesses and disease.

Impact to Buildings

Fortunately, the number of people killed or injured during floods each year is relatively small. The built environment within the floodplain, however, is likely to bear the brunt of a flood's impact. Whether the water is moving or standing, the exposure of buildings to flood water could cause a great deal of damage. If the water is moving, the differing hydraulic pressure inside the building vs. outside can cause the walls and foundation to buckle and fail. If the water is standing for any length of time, even materials above the flood height will become saturated with flood water as the flood water is absorbed (known as wicking). Certainly, most of the contents of flooded buildings that were located at or below the flood height will need to be discarded. This includes carpet, furniture, electronic equipment, and other household or commercial items. In most cases it is not simply the fact that the objects have become wet but since the flood water brings with it sediment and chemicals, it makes it nearly impossible to recover all but the most precious/heirloom items.

Flood Vulnerability Assessment

The goal of mitigation is to increase the flood resistance of a community, so that the residents and businesses will become less susceptible to future exposures to flooding, thereby resulting in fewer losses. A key component to reducing future losses is to first have a clear understanding of the current threats, the current probability that those threats would occur, and the potential for loss from those threats. The Vulnerability Assessment is a crucial first step in the process as it is an organized and coordinated process of assessing potential hazards, their risk of occurring, and the possible impact of an event.

Study Method

The Vulnerability Assessment was conducted using the method developed for HAZUS-MH, FEMA's loss estimation software, to assess the County's built environment to vulnerability to flooding. HAZUS-MH is a Geographic Information System (GIS)-based software tool that applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide credible damage and loss estimates. These methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards, including floods, hurricane winds and earthquakes. The methodology supports the evaluation of hazards and assessment of inventory and loss estimates for these hazards.

The primary input to any vulnerability assessment is a "depth of flood" grid. This flood depth grid was created using an elevation grid derived from LiDAR measurements. By incorporating the polygons of the 1% chance floodplain from the FIRMs, the coastal flood elevations from the Flood Insurance Study as well as the current elevation grid, HAZUS-MH was able to create a flood depth grid with a reasonable precision for the 1% (Figure 2) and 0.2%-chance (Figure 3) coastal flood scenarios with Talbot County's current mean sea level. In addition, areas predicted to be inundated by a higher mean sea level in 2050 (Figure 4) and 2100 (Figure 5) were also modeled. Finally, the depth of flood for the 1%-chance event was mapped using the 2050 (Figure 6) and 2100 (Figure 7) predicted sea-levels. For the full detail of how these depth grids were created, please see "GIS Data Products to Support Climate Change Adaptation Planning: Talbot County, Maryland" at http://www.esrgc.org/mapServices/.

Figure 2 Predicted flood depths for Talbot County 1% chance flood at MSL in 2015

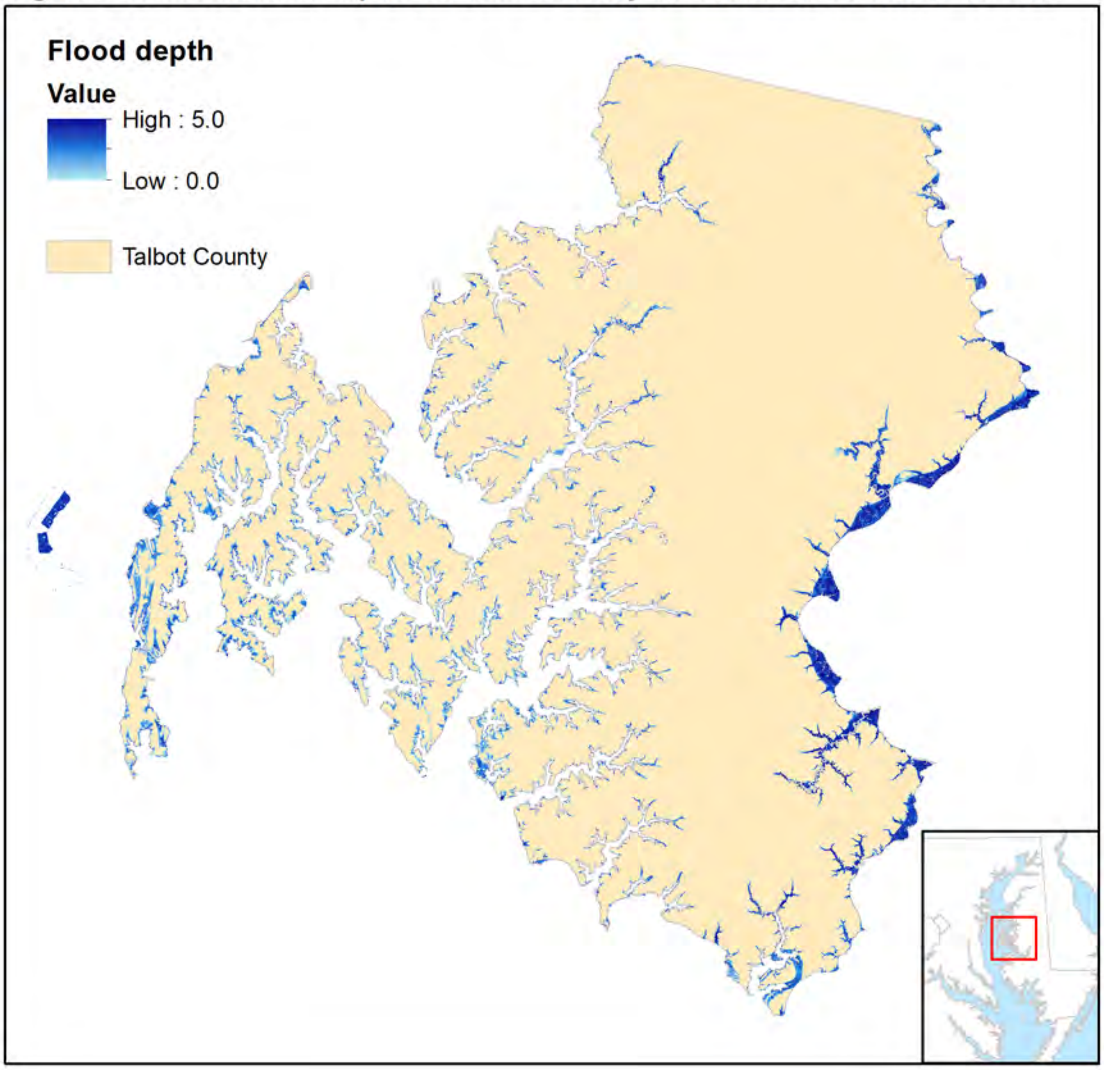


Figure 3 Predicted flood depths for Talbot County 0.2% chance flood at MSL in 2015

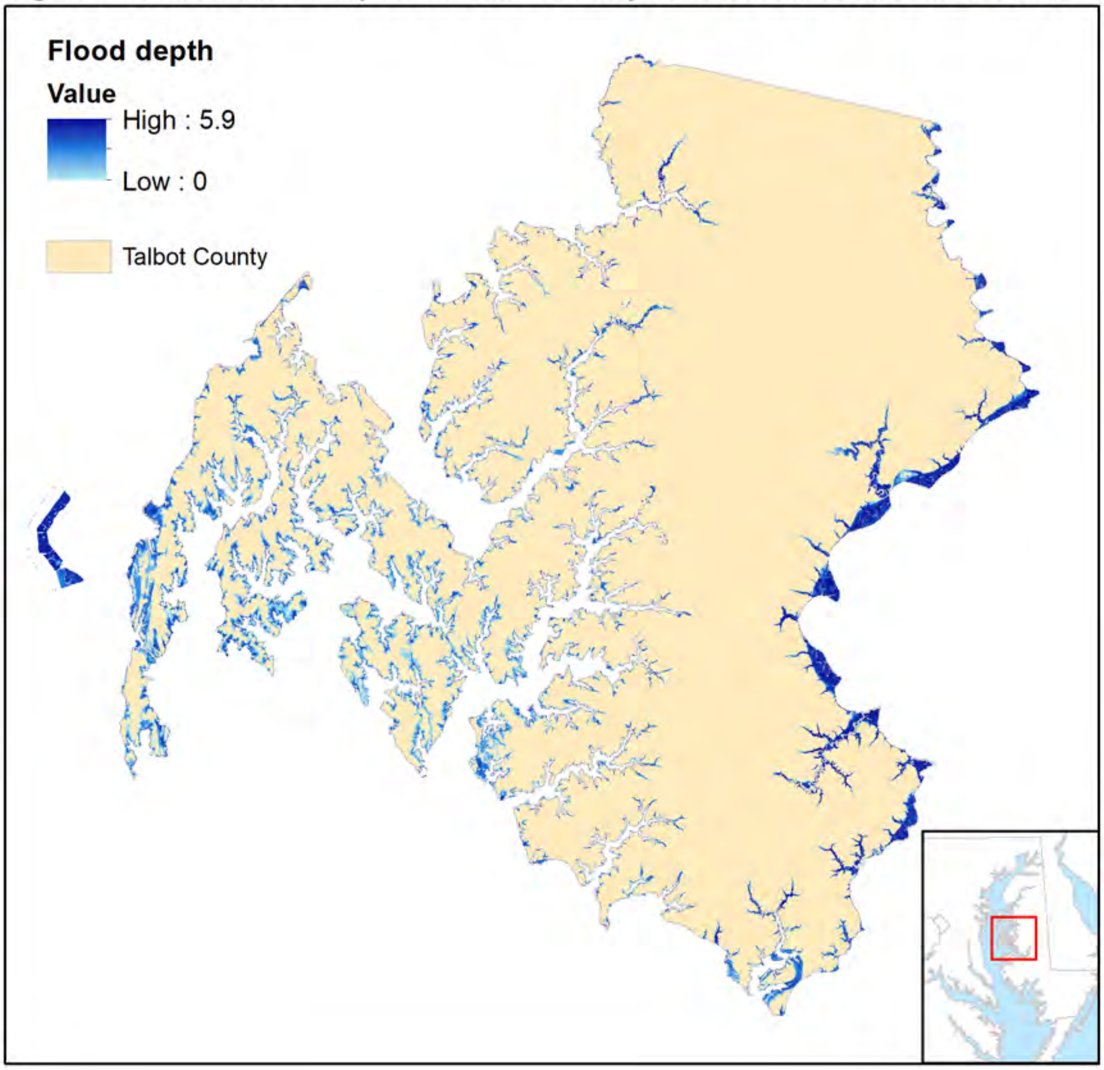


Figure 4 Predicted depth of MSL inundation in Talbot County in 2050

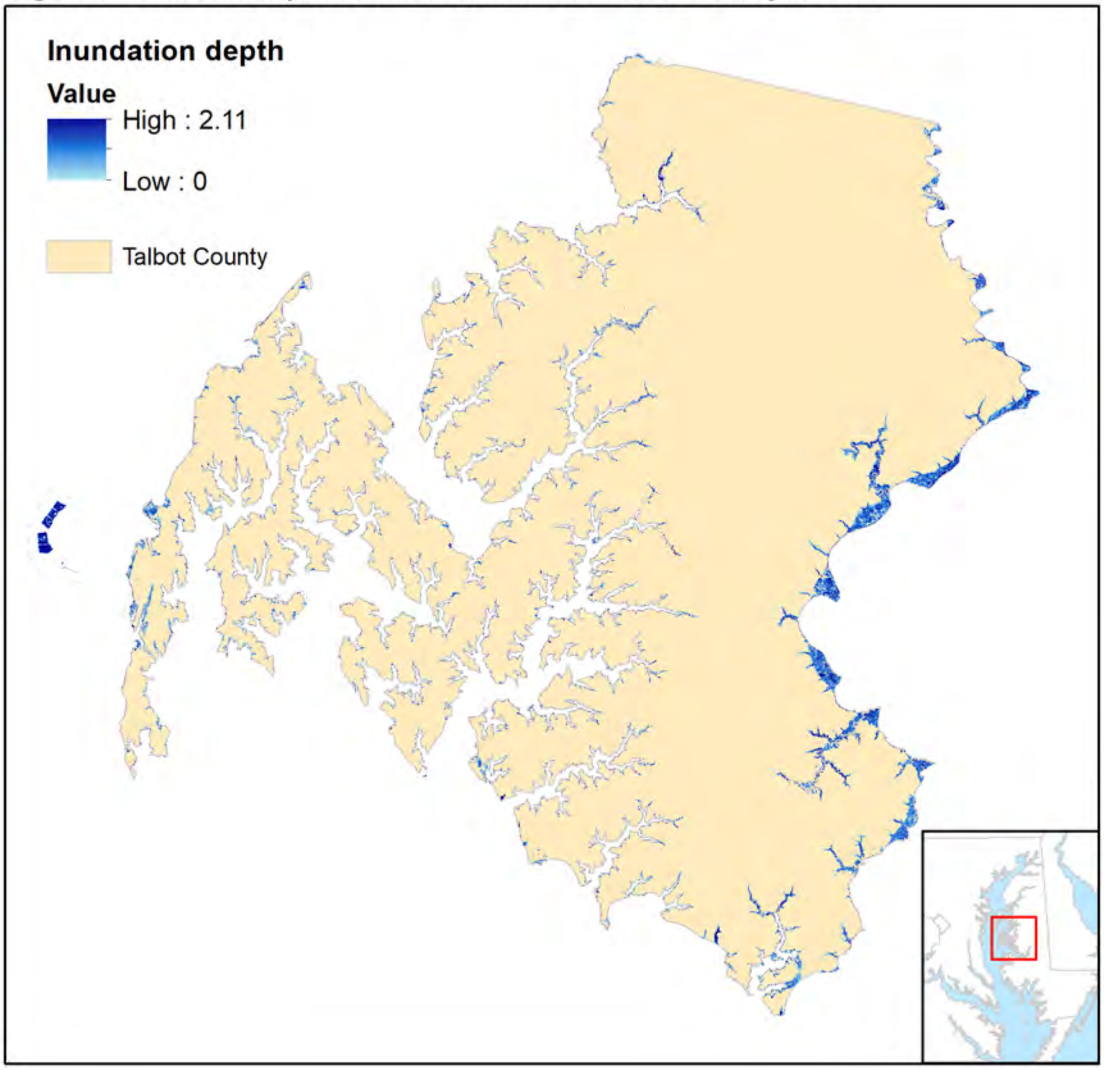


Figure 5 Predicted depth of MSL inundation in Talbot County in 2100

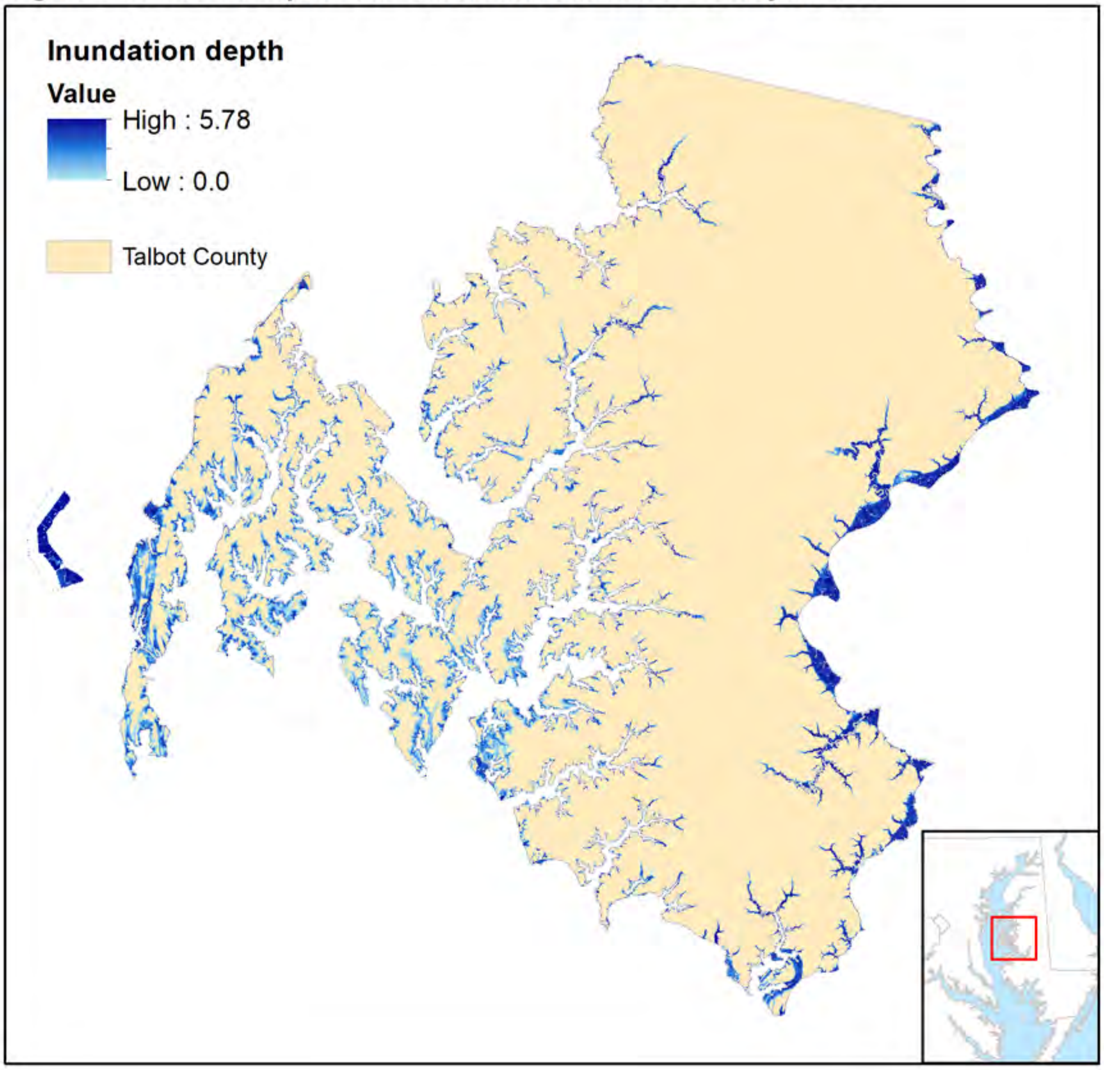


Figure 6 Predicted flood depths for Talbot County 1% chance flood at MSL in 2050

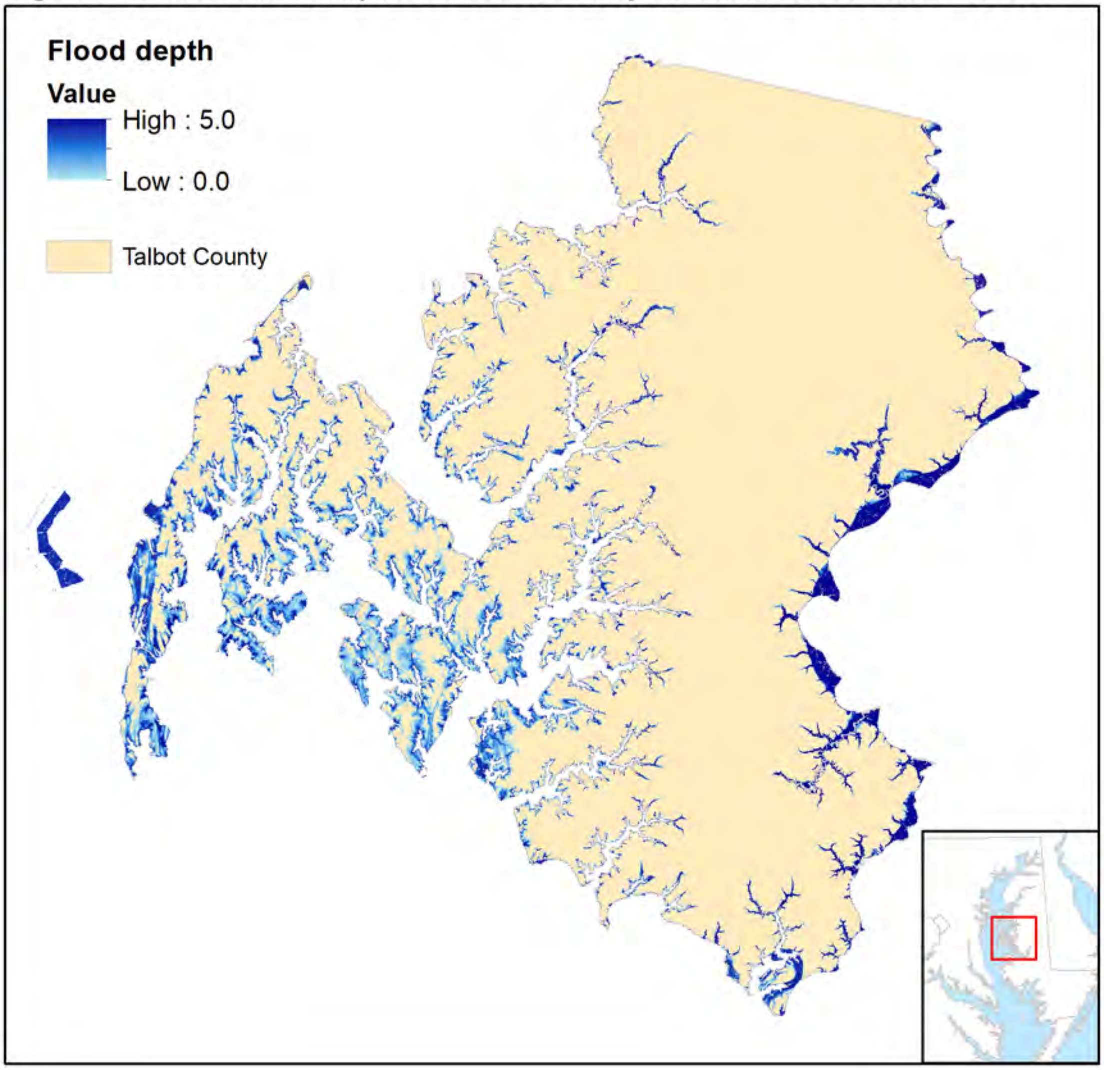
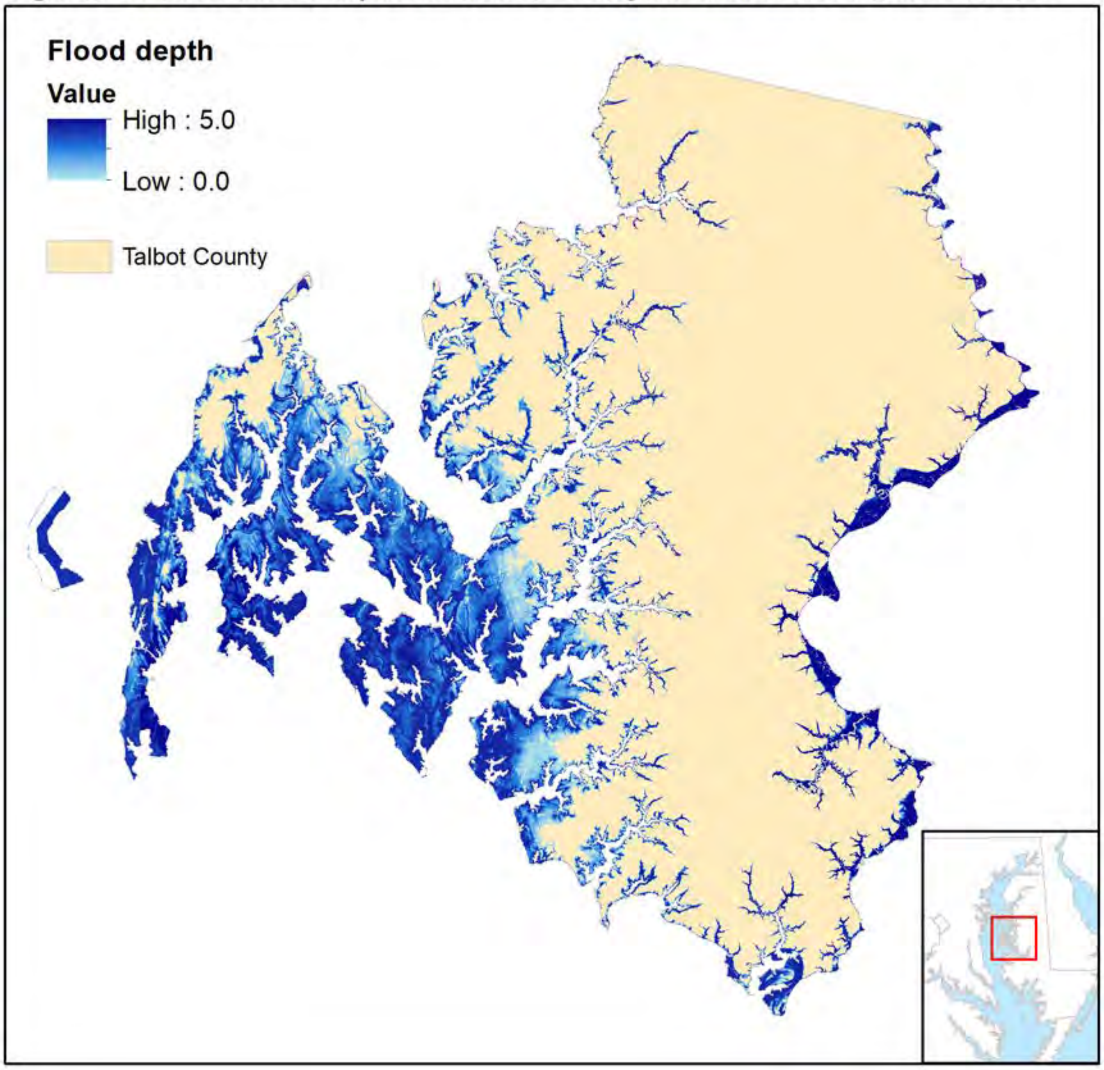


Figure 7 Predicted flood depths for Talbot County 1% chance flood at MSL in 2100



Using these flood depth grids, those buildings that are vulnerable to flood water, and the degree to which they are vulnerable, were determined. Fortunately, Talbot County maintains a set of "addressable" building footprint polygons, separate from any outbuildings. Next, the average depth of flood water for each modeling scenario was calculated for each building by converting the depth grids to depth points and intersecting the building footprints and the depth points. Talbot County's 2015 tax parcels were then digitally overlaid, thus assigning attributes such as total assessed value of the improvements, the land use of the parcel (residential, commercial, etc), and the structure style (1 story, 2 story, apartments, etc) to the building footprint. Because the foundation heights are unknown, an assumption of a 24" foundation was made. Using that assumed foundation height, the flood depth above the first finished floor was calculated. The total value of the building and its contents was found, using industry-standard estimates of the contents value based on the use of the building (i.e. residential contents are 50% of the building value, while commercial contents are 100% of the building value). Finally, using the depth-damage curves provided by FEMA via the HAZUS-MH software, the potential damage percentage, and therefore the potential damage to both the building and its contents in 2015 dollars, for each building for each flood scenario was estimated.

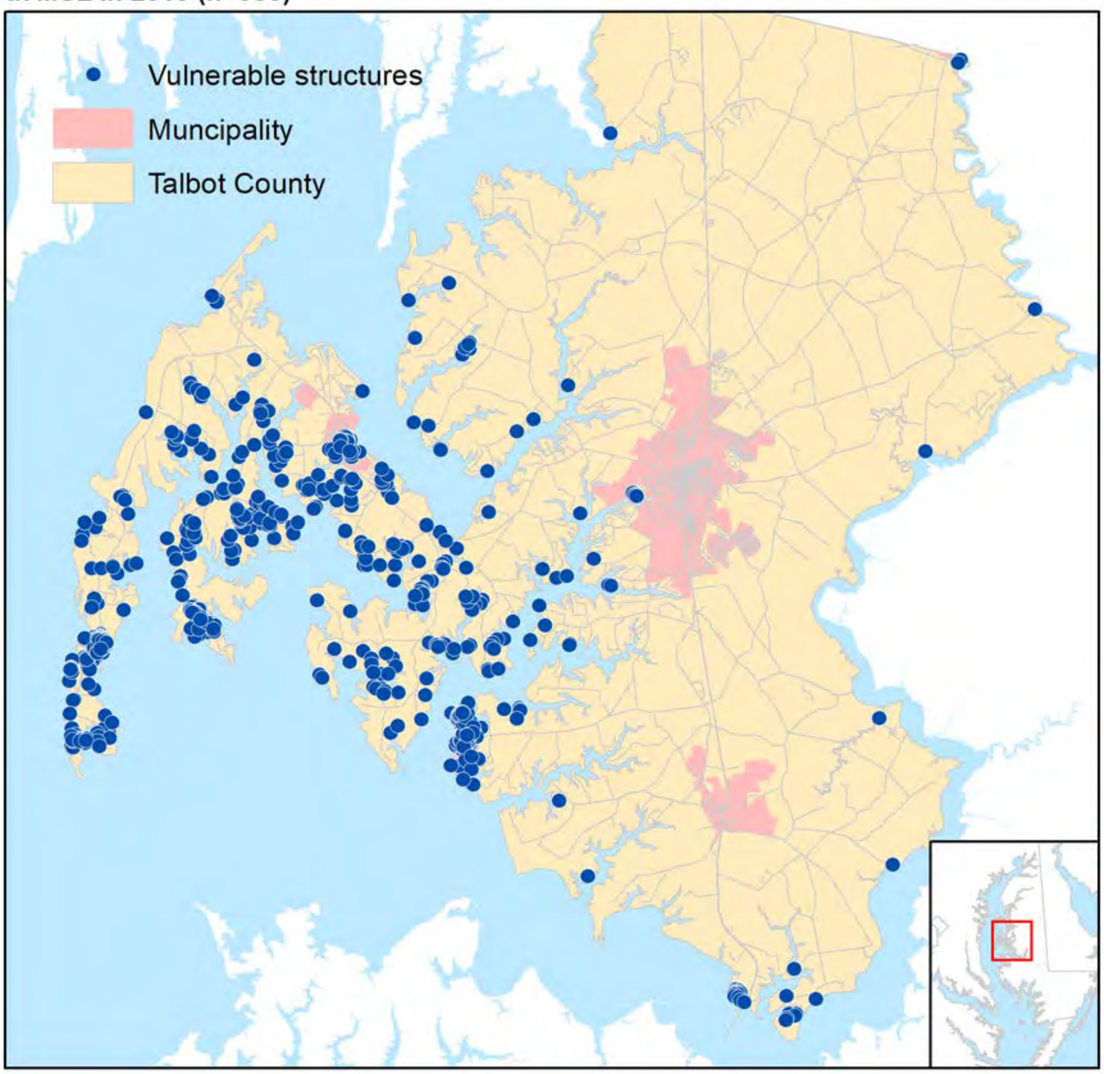
It is important to note when viewing the following results that the numbers generated carry with them a degree of uncertainty. Nearly every component (the ground elevations, the flood heights, the foundation heights, the assessed value, etc.) has confidence constraints of various magnitudes. The HAZUS-MH model itself is a simplified version of the complex engineering models used to create the flood insurance rate maps. Having said that, considerable research has been conducted to review HAZUS-MH analysis results after an event and have found that the software does a reasonably good job of both predicting the depth of flood as well as the insured losses. But was with any simulation analysis, we recommend that these damage statistics be viewed as merely an indicator of the potential degree of damage and not as a final and absolute number.

Flood Results for Present-Day (2015)

The results of the analysis indicate that there are 888 buildings predicted to be impacted by a 1% chance flood in Talbot County (Table 3). However, a super-majority of them (736) would only experience minor nuisance flooding in this scenario; only 41 (4.6%) would experience greater than 10% damage. Thus, the overall predicted damage percentage from this flood level is 0.8% of the total value of the structures and contents ($2.4 million of damage from $288.6 million in value). When standardized per building, those buildings that are predicted to incur incidental damage are also the most valuable (an average of $347,508 per building vs $195,760 per building that are damaged 10% or greater). This is not surprising given that many of these more expensive structures are found in the Bay Hundred and around St. Michael's and Oxford – areas that by their peninsular nature are well-known to be susceptible to occasional flooding. It is also worth noting that a significant mitigation opportunity exists. These 41 buildings predicted to be damaged between 10 and 40% in the 1% chance event represent less than 5% of the total number of vulnerable buildings. However, they represent over 50% of the potential damage. Working to make those structures less vulnerable to flooding should yield considerable financial benefits.

The spatial distribution of the structures vulnerable to the 1%-chance flood event follows a predictable pattern (Figure 8). While there are a few clustered at the head of Leeds Creek and at the Gateway Marina on the Choptank, the majority are found in and around St. Michael's, Bozman, Neavitt, areas along Broad Creek, Irish Creek, and the town of Oxford. Other water-orientated development in the Miles River and the Tred Avon River will also see their fair share of flood water in the 1% chance event

Figure 8 Spatial distribution of vulnerable structures in Talbot County 1% chance flood at MSL in 2015 (n=888)



The very severe 0.2% chance flood event represents a current worst-case scenario for Talbot County (Table 4). In such an event, 1,511 buildings would be impacted with 195 impacted moderately (10 – 50%). The total value of the structures and their contents that are vulnerable to flooding expands to $535.2 million and the potential damage is calculated to be $9.7 million, or 4x that of the 1% chance event. The number of buildings that are minimally effected (1,081) drops by more than 11% as a percentage of the total vulnerable buildings (82.9% in 1%-chance scenario vs. 71.5% in the 0.2%-chance). This indicates that in such a severe flood, the water is reaching many structures not previously impacted. These people tend to be less prepared for flooding because in less severe flood magnitudes, water does not reach them.

Table 3. Potential damage to structures/contents from a 1% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	736	82.9%	$255,766,200	$347,508	$36,511	$50	1.5%
1 - 10%	111	12.5%	$24,796,300	$223,390	$1,011,367	$9,111	42.0%
10 - 20%	33	3.7%	$5,219,965	$158,181	$662,002	$20,061	27.5%
20 - 30%	5	0.6%	$2,179,200	$435,840	$501,111	$100,222	20.8%
30 - 40%	3	0.3%	$627,000	$209,000	$198,409	$66,136	8.2%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	888	100.0%	$288,588,666	$324,987	$2,409,400	$2,713	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 4. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,081	71.5%	$421,928,397	$390,313	$47,964	$44	0.5%
1 - 10%	235	15.6%	$71,686,795	$305,050	$3,532,297	$10,776	36.3%
10 - 20%	165	10.9%	$35,724,985	$216,515	$4,530,309	$27,456	46.6%
20 - 30%	24	1.6%	$3,437,061	$143,211	$798,271	$33,261	8.2%
30 - 40%	5	0.3%	$2,319,600	$463,920	$767,783	$153,557	8.0%
40 – 50%	1	0.1%	$108,600	$108,600	$43,590	$43,590	0.4%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	1,511	100.0%	$535,205,439	$354,206	$9,720,215	$6,433	100.0%

Note: All dollar values are from 2015 tax assessments.

When the potential damage was also examined with respect to land use, it was found that no matter the scenario, the vast majority all of buildings vulnerable to flooding in Talbot County were residential, ranging from 93.1% in the 1% chance scenario (Table 5) to 94.1% in the 0.2% chance scenario (Table 6). The second largest category was commercial buildings, ranging from 6.3% in the 1% chance scenario to 5.2% in the 0.2% chance scenario. In the 1% chance scenario, the majority of the damage (65.5%) comes from residential buildings, which is to be expected given the number of residential buildings affected. However, given that (relatively) few commercial buildings are predicted to be impacted, it is concerning that they account for 34.6% of the predicted damage. This suggests that suggesting mitigation actions that are targeted at Talbot County business owners might yield the best results.

Table 5. Potential damage to structures/contents from a 1% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	827	93.1%	$259,212,690	$1,481,936	0.6%	65.5%
Commercial	56	6.3%	$24,235,000	$834,147	3.4%	34.6%
Government	3	0.3%	$4,825,600	$93,317	1.9%	3.9%
Industry	0	0.0%	$0	$0	0.0%	0.0%
Religious	2	0.2%	$315,375	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	888	100.0%	$288,588,666	$2,409,400	0.8%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 6. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1,422	94.1%	$493,686,590	$7,816,774	1.6%	80.4%
Commercial	78	5.2%	$33,843,420	$1,773,579	5.2%	18.2%
Government	6	0.4%	$7,308,602	$129,862	1.8%	1.3%
Industry	1	0.1%	$2	$0	0.0%	0.0%
Religious	2	0.1%	$315,375	$0	0.0%	0.0%
Agricultural	2	0.1%	$51,450	$0	0.0%	0.0%
Total	1,511	100.0%	$535,205,439	$9,720,215	1.8%	100.0%

Note: All dollar values are from 2015 tax assessments.

One final way to break down the countywide vulnerability results is to examine them by property value. The following tables explore the vulnerability of the buildings based on the values of the structure and its contents (Tables 7 & 8). Each flooding scenario presents remarkably consistent results and thus there are some overall conclusions that can be made. First, in both flood scenarios, the least valuable properties suffer the most damage, relative to their value. Given that the owners of these properties are historically the least likely to have flood insurance, this situation could be debilitating for those property owners. Second, nearly a majority of the total damage from the 1% chance event is generated by relatively inexpensive properties (both a structure and contents value between $100,000 and $300,000). This is a concern as not only does it represent nearly 400 separate properties but these homeowners (nearly all are residential) are unlikely to have the resources necessary to make significant changes themselves. Finally, with the increase in flood depths in the 0.2% chance scenario, the damage percentages begin to spread out among the range of property values. This suggests that the 0.2%-chance flood is severe enough to damage many different areas and are felt by working-class, middle-class, and upper-class neighborhoods alike.

Table 7. Potential damage to structures/contents from a 1% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	35	3.9%	$784,381	$27,843	3.5%	1.2%
$50 - $100	74	8.3%	$5,635,313	$112,787	2.0%	4.7%
$100 - $200	237	26.7%	$35,451,757	$560,933	1.6%	23.3%
$200 - $300	162	18.2%	$39,722,757	$538,262	1.4%	22.3%
$300 - $400	138	15.5%	$46,935,125	$328,871	0.7%	13.6%
$400 - $500	94	10.6%	$42,582,371	$377,187	0.8%	15.7%
$500 - $1,000	120	13.5%	$79,535,847	$448,160	0.6%	18.6%
$1,000 - $2,000	27	3.0%	$35,405,312	$15,356	0.0%	0.6%
$2,000 - $3,000	1	0.1%	$2,536,800	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	888	100.0%	$288,588,666	$2,409,400	0.8%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 8. Potential damage to structures/contents from a 0.2% chance flood event in 2015 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	54	3.6%	$1,158,585	$73,767	6.4%	0.8%
$50 - $100	109	7.2%	$8,298,344	$381,459	4.6%	3.9%
$100 - $200	357	23.6%	$53,266,298	$2,053,968	3.9%	21.1%
$200 - $300	290	19.2%	$71,544,807	$1,830,759	2.6%	18.8%
$300 - $400	239	15.8%	$81,935,106	$1,933,561	2.6%	19.9%
$400 - $500	149	9.9%	$67,146,121	$1,447,292	2.2%	14.9%
$500 - $1,000	250	16.5%	$169,903,590	$1,580,052	0.1%	16.3%
$1,000 - $2,000	60	4.0%	$74,585,637	$419,358	0.6%	4.3%
$2,000 - $3,000	3	0.2%	$7,366,950	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	1,511	100.0%	$535,205,439	$9,720,215	1.8%	100.0%

Note: All dollar values are from 2015 tax assessments

Sea level Rise Inundation in 2050 and 2100

Unfortunately, we know that the water levels in the Chesapeake Bay that feed this periodic tidal flooding are not static – they are quite dynamic. Scientists at the USGS estimate that mean sea level in the Bay was about 2 feet lower when Captain John Smith first mapped it in 1608 (Larsen, 1998; https://pubs.usgs.gov/fs/fs102-98/). The Mid-Atlantic region is predicted to be one of the most affected by sea level change going forward because of the presence of the combination of eustatic sea level rise, thermal expansion of sea water as the earth warms, the slowdown of the North Atlantic gyre, and the subsidence of the land surface from the glacial isostatic rebound. The current sea level trend, measured from 1937 to 2015 at the Solomons Island tide gauge is 3.74 mm/year or 1.23 ft in 100 years.

However, scientists do not think that a linear trend will continue. The rate is expected to increase. The models used in this flood mitigation plan follow the same method used by the Maryland State Highway Administration to document the potential flood vulnerability of the road infrastructure from periodic flooding in 2050 and 2100. For that method, the “high” estimates of sea level change from the US Army Corps of Engineers was chosen as the appropriate planning scenario. For Talbot County, this means the USACE expects an estimated mean sea level increase of 2.11 ft by 2050 and 5.78 ft by 2100 (Figures 4 & 5).

Using these elevated mean sea levels of 2050 and 2100, additional analyses were conducted of the vulnerability of the built environment from only inundation without any periodic flooding. It should be noted that these inundation damage estimates are not particularly appropriate for non-periodic flooding. They are included here primarily for comparison’s sake. If the buildings predicted to be inundated constantly by a rise in mean sea level were not elevated beyond the reach of the water, the damage done to them would be a great deal more severe.

As the 2050 mean sea level inundation results show (Table 9), Talbot County is largely protected. Only 39 buildings are predicted to experience water in the footprint of their structure and 82.1% of those are not damaged to any quantifiable degree. These are building footprints intersecting with less than 6” of water. The remaining seven properties in the county that may be impacted by sea level inundation are worth about $2.4 million. The spatial distribution of the properties shows the majority in St. Michael’s, Oxford, Tilghman Island, and Neavitt with others distributed around the county (Figure 9). By 2100, the situation will have changed dramatically – the number of buildings at risk from inundation increased 47x, from 39 in 2050 to 1,846 in 2100 (Table 10). Those 1,846 buildings represent $705.4 million in structure and content value. Again, the prediction of damage in the scenario is very uncertain as the processes that cause inundation damage are quite different than periodic flood damage. However, an overall damage rate of 2.3% is very concerning and is more than 6x the rate that we expect from a 1% chance flood event in 2015. With regard to the spatial distribution of the structures predicted to be inundated in 2100 (Figure 10), it is difficult to discern any specific pattern besides the widespread impacts across all of peninsular Talbot County.

Table 9. Potential damage to structures/contents from mean sea level inundation in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	32	82.1%	$10,403,990	$325,125	$0	$0	0.0%
1 - 10%	7	17.9%	$2,417,191	$345,313	$145,798	$20,828	100.0%
10 - 20%	0	0.0%	$0	$0	$0	$0	0.0%
20 - 30%	0	0.0%	$0	$0	$0	$0	0.0%
30 - 40%	0	0.0%	$0	$0	$0	$0	0.0%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	39	100.0%	$12,821,181	$328,748	$145,798	$20,828	100.0%

Note: All dollar values are from 2015 tax assessments

Table 10. Potential damage to structures/contents from mean sea level inundation in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,224	66.3%	$526,423,593	$430,436	$76,441	$63	0.4%
1 - 10%	325	17.6%	$108,256,133	$333,096	$5,265,091	$16,200	33.5%
10 - 20%	241	13.1%	$59,893,372	$248,520	$7,696,331	$31,935	52.3%
20 - 30%	49	2.7%	$7,904,100	$161,308	$1,821,742	$37,178	13.6%
30 - 40%	4	0.2%	$2,275,800	$568,950	$792,857	$198,214	0.0%
40 – 50%	3	0.2%	$627,000	$42,200	$266,709	$88,903	0.2%
50% or more	0	0.0%	$0	$0	$0	$0	0.0%
Total	1,846	100.0%	$705,380,000	$382,113	$15,919,170	$8,624	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 9 Spatial distribution of vulnerable structures in Talbot County, no flood event at MSL in 2050 (n=39)

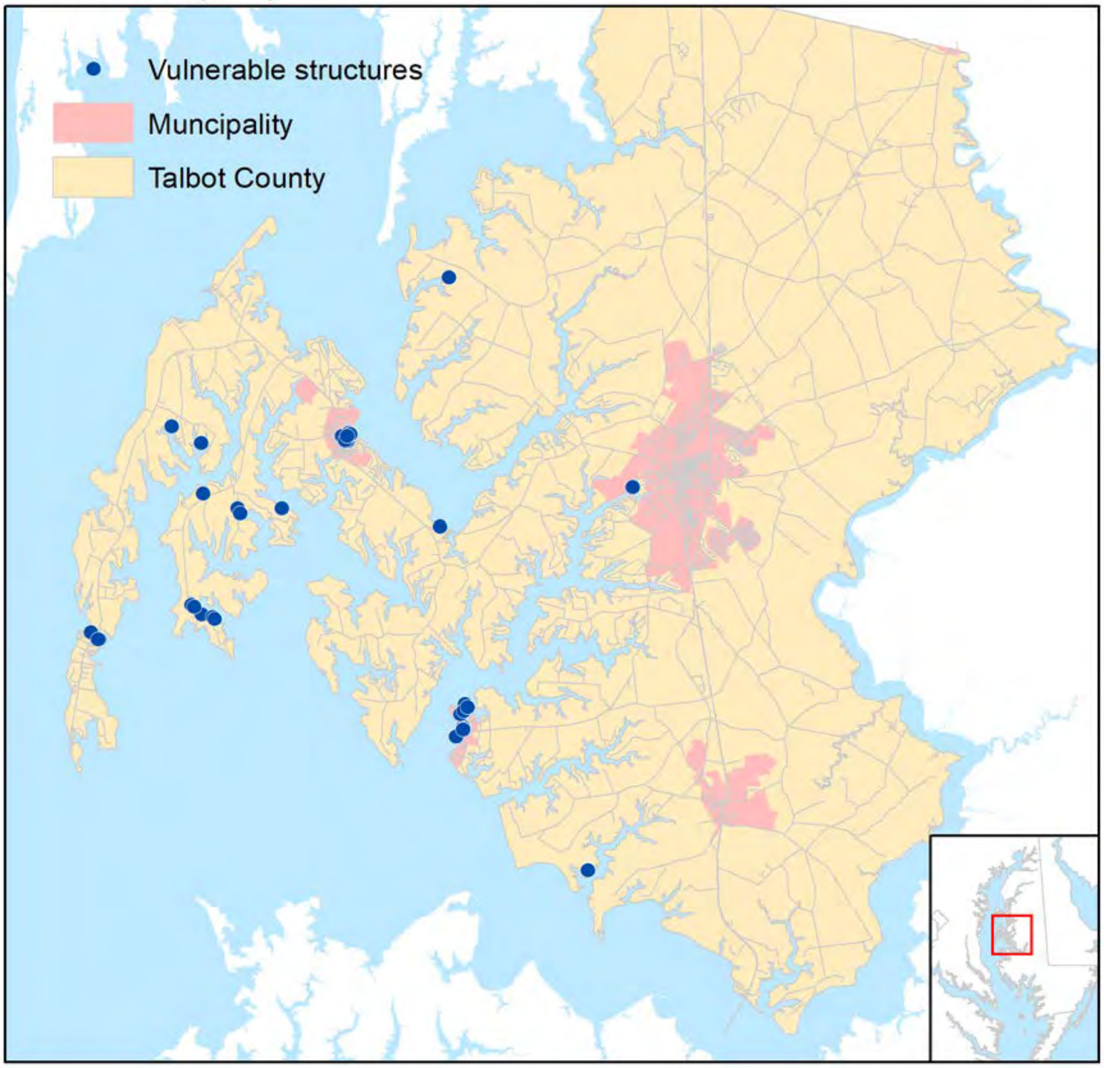
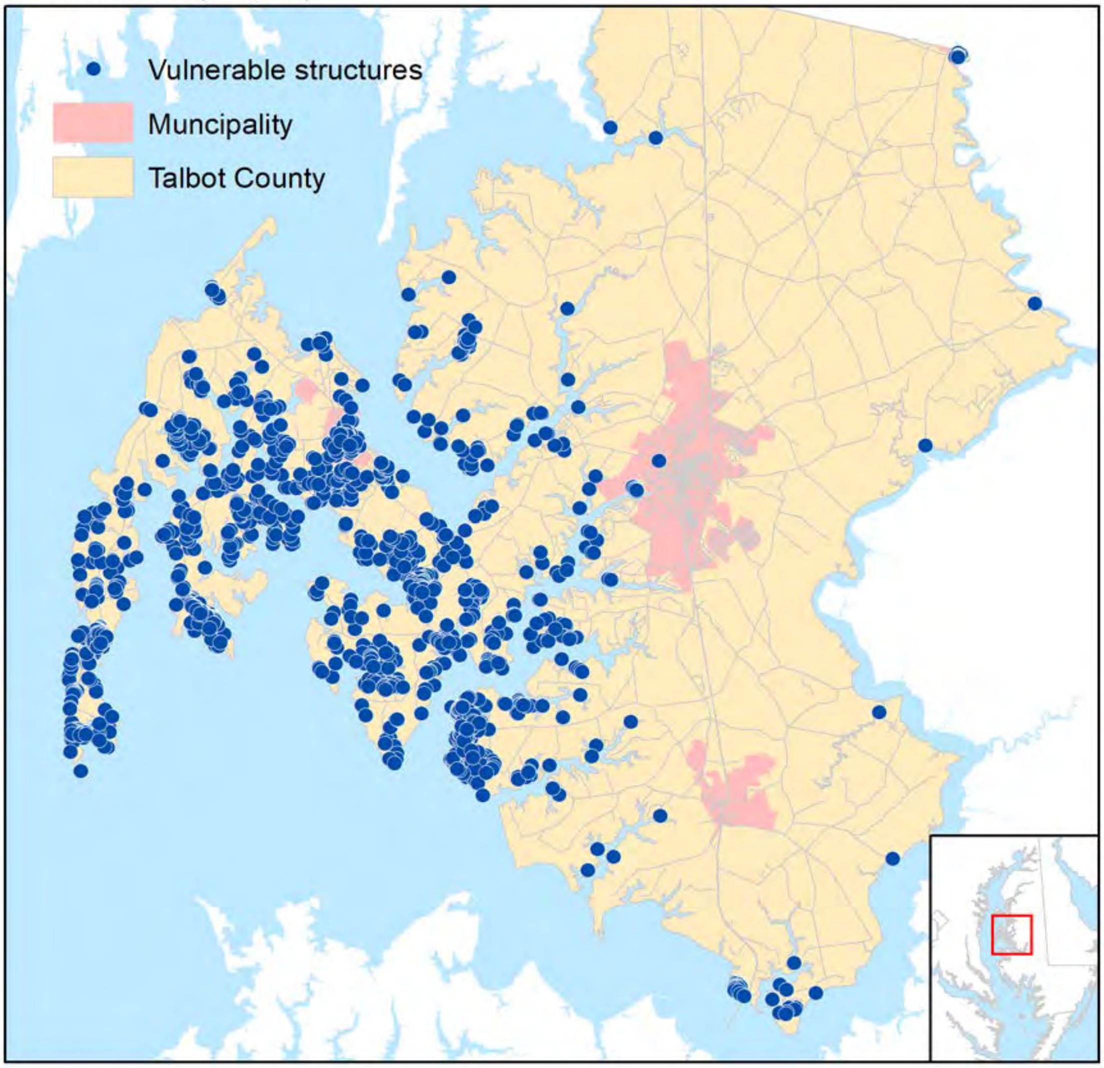


Figure 10 Spatial distribution of vulnerable structures in Talbot County, no flood event at MSL in 2100 (n=1,846)



With regard to inundation with respect to land use, the impact from sea level change in 2050 was almost 50% residential and 50% commercial – there is one government building affected (Table 11). The overrepresentation of commercial structures is not surprising as these are mostly marinas, restaurants, and boat storage facilities that by their nature have to be very close to the water's edge. By 2100 however, it becomes clear that sea level change in Talbot County will be disproportionately felt by residents, with 93.6% of all of structures being inundated as residential (Table 12). And just as in the periodic flood scenarios of 2015, the commercial properties of Talbot County bear a disproportionate damage burden, given their (relatively) small exposure

Table 11. Potential damage to structures/contents from mean sea level inundation in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	17	43.6%	$4,702,624	$66,784	1.4%	45.8%
Commercial	21	53.8%	$7,643,957	$79,014	1.0%	54.2%
Government	1	2.6%	$474,600	$0	0.0%	0.0%
Industry	0	0.0%	$0	$0	0.0%	0.0%
Religious	0	0.0%	$0	$0	0.0%	0.0%
Agricultural	0	0.0%	$0	$0	0.0%	0.0%
Total	39	100.0%	$12,821,181	$145,798	1.1%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 12. Potential damage to structures/contents from mean sea level inundation in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	1,728	93.6%	$641,915,613	$12,784,600	2.0%	80.3%
Commercial	101	5.5%	$53,561,202	$2,989,390	5.6%	18.8%
Government	10	0.5%	$7,349,106	$145,180	2.0%	0.9%
Industry	2	0.1%	$2,187,252	$0	0.0%	0.0%
Religious	2	0.1%	$315,375	$0	0.0%	0.0%
Agricultural	3	0.2%	$51,452	$0	0.0%	0.0%
Total	1,846	100.0%	$705,380,000	$15,919,170	2.3%	100.0%

Note: All dollar values are from 2015 tax assessments.

When examining the vulnerability of Talbot County's structure by the property value, the results in 2050 show preponderance of properties in the $200,000 - $300,000 range with all of the damage (minimal as it is) concentrated in properties valued at $200,000 to $500,000 (Table 13). In 2100 however (Table 14), the results are distributed across the value spectrum with a peak in the modest $100,000 to $300,000 range. These are relative modest homes that are unlikely to have the financial resources to mitigate the potential threat.

Table 13. Potential damage to structures/contents from mean sea level inundation in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	4	10.3%	$95,443	$0	0.0%	0.0%
$50 - $100	2	5.1%	$165,000	$0	0.0%	0.0%
$100 - $200	4	10.3%	$551,227	$0	0.0%	0.0%
$200 - $300	13	33.3%	$3,098,867	$68,455	2.2%	47.0%
$300 - $400	5	12.8%	$1,700,308	$32,980	1.9%	22.6%
$400 - $500	6	15.4%	$2,715,611	$44,363	1.6%	30.4%
$500 - $1,000	4	10.3%	$2,632,725	$0	0.0%	0.0%
$1,000 - $2,000	1	2.6%	$1,862,000	$0	0.0%	0.0%
$2,000 - $3,000	0	0.0%	$0	$0	0.0%	0.0%
More than $3,000	0	0.0%	$0	$0	0.0%	0.0%
Total	39	100.0%	$12,821,181	$145,798	1.1%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 14. Potential damage to structures/contents from mean sea level inundation in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	70	3.8%	$1,386,180	$92,884	6.7%	0.6%
$50 - $100	123	6.7%	$9,263,185	$531,122	5.7%	3,3%
$100 - $200	417	22.6%	$62,185,187	$3,049,155	4.9%	19.2%
$200 - $300	341	18.5%	$84,039,182	$2,896,959	3.4%	18.2%
$300 - $400	279	15.1%	$96,114,373	$2,899,331	3.0%	18.2%
$400 - $500	200	10.8%	$90,153,525	$2,227,679	2.5%	14.0%
$500 - $1,000	323	17.5%	$219,661,445	$3,270,825	1.5%	20.5%
$1,000 - $2,000	83	4.5%	$106,622,637	$952,216	0.9%	6.0%
$2,000 - $3,000	7	0.4%	$17,262,550	$0	0.0%	0.0%
More than $3,000	3	0.2%	$18,691,733	$0	0.0%	0.0%
Total	1,846	100.0%	$705,380,000	$15,919,170	2.3%	100.0%

Note: All dollar values are from 2015 tax assessments

In the event that the USACE's predictions come to pass, the 2.11 ft rise in MSL will significantly impact the flood vulnerability of Talbot County (Table 15). In the 1%-chance flood scenario, the number of buildings impacted will increase by over 281% (from 888 to 2,496). Additionally, the number of buildings with greater than minimal damage (greater than 10%), spiked by 14x, rising from 41 to 588 and from a value of $8.0 million to nearly $157.1 million. Thankfully, only 2 structures are predicted to be severely damaged (greater than 50%). The total amount of building and contents value vulnerable to flooding will more than triple from $288.6 million to $1.0 billion and the amount of potential damage will increase 13x from $2.4 million to $31.3 million. The spatial distribution of these vulnerable structures show the encroachment of much of the County along the Chesapeake Bay, particularly around Broad Creek (including the "back side" of St. Michael's) and Edge Creek.

Of course, the prediction for the year 2100 (5.7 ft increase in MSL) must be considered highly uncertain. However, as of this writing, there is a growing consensus in the scientific community that the SLC estimates are more than likely too conservative, rather than too aggressive. Until that consensus solidifies, the current USACE estimate is still reasonable for planning purposes. Obviously, sea level being 5.78 ft higher in Talbot County 82 years from now will significantly impact much of the vulnerable coastal development (Table 16). The number of vulnerable buildings will increase by 693% (from 888 in 2015 to 6,152 in 2100), with less than 5% of those buildings damaged greater than 30%. The number predicted to be severely damaged will go from 0 in 2015 to 2 in 2050 to 5 in 2100. While the amount of building and contents value vulnerable to flooding will increase 8.7x, from $288.6 million to $2.5 billion, the amount of potential damage will explode more than 109.3x from $2.4 million to $262.2 million. The spatial distribution shows no appreciable change from the areas that are currently vulnerable – it is just that the flood waters both reach further inland increases in the number of structures potentially impacted in Talbot County but also increases the depth of flooding for those structures that are vulnerable now, increasing their potential damage (Figure 12).

Table 15. Potential damage to structures/contents from a 1% chance flood event in 2050 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,487	59.6%	$692,769,323	$465,849	$135,900	$91	0.4%
1 - 10%	421	16.9%	$152,899,309	$363,181	$7,891,407	$18,744	25.2%
10 - 20%	444	17.8%	$129,126,664	$290,826	$16,325,883	$36,770	52.1%
20 - 30%	132	5.3%	$25,010,800	$189,476	$6,004,917	$45,492	19.2%
30 - 40%	10	0.4%	$2,899,137	$289,914	$890,160	$89,016	2.8%
40 – 50%	0	0.0%	$0	$0	$0	$0	0.0%
50% or more	2	0.1%	$102,450	$51,225	$57,425	$28,713	0.2%
Total	2,496	100.0%	$1,002,807,683	$401,766	$31,305,692	$12,542	100.0%

Note: All dollar values are from 2015 tax assessments

Figure 11 Spatial distribution of vulnerable structures in Talbot County, 1% chance flood at MSL in 2050 (n=2,496)

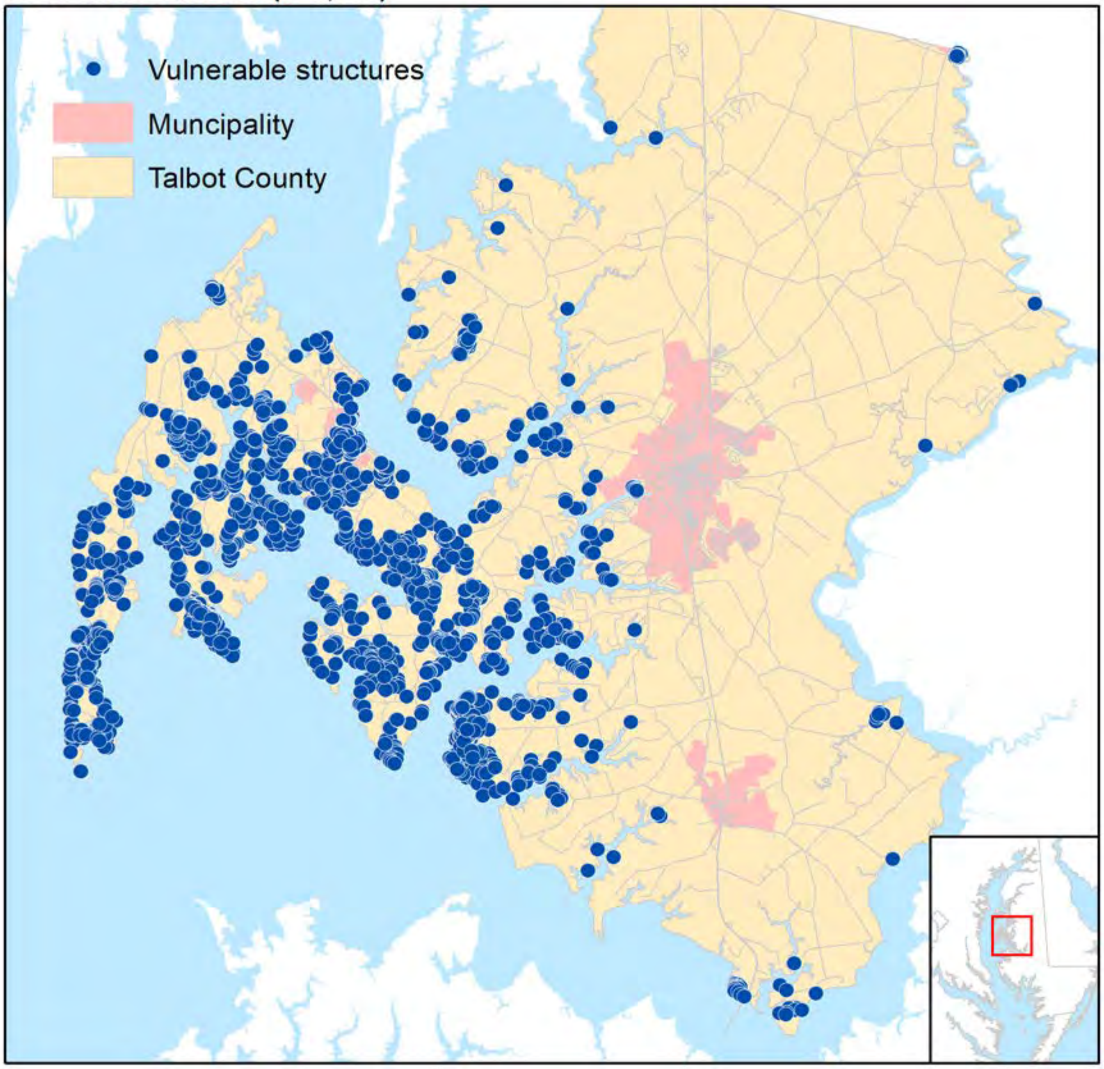


Table 16. Potential damage to structures/contents from a 1% chance flood event in 2100 by degree of damage category

Degree of Damage	Building Count	% of Total Count	Value of Structure and Contents	Value per Building	Total Potential Damage	Damage per Building	% of Total Damage
Less than 1%	1,522	24.7%	$768,885,307	$505,181	$202,331	$133	0.1%
1 - 10%	883	14.4%	$357,892,533	$405,314	$19,715,034	$22,327	7.5%
10 - 20%	2,570	41.8%	$1,049,295,013	$408,286	$149,249,769	$58,074	56.9%
20 - 30%	946	15.4%	$266,195,132	$281,390	$70,418,542	$74,438	26.9%
30 - 40%	225	3.7%	$69,962,750	$310,946	$22,361,024	$99,382	8.5%
40 – 50%	1	0.0%	$115,500	$115,500	$46,246	$46,246	0.0%
50% or more	5	0.1%	$249,000	$49,800	$162,345	$32,469	0.1%
Total	6,152	100.0%	$2,512,595,236	$408,419	$262,155,290	$42,613	100.0%

Note: All dollar values are from 2015 tax assessments

As for the spatial distribution of the flood threat in the two sea level change scenarios, it is a reasonable generalization to say that one can simply expect existing flood prone areas to flood more often, can expect deeper flood water when it does flood, and that areas adjacent to currently threatened areas are most likely to be newly-inundated. Maps of the 1% chance flood in 2050 and 2100 on the Tilghman Island around Knapp's Narrows connecting the Chesapeake Bay and Harris Creek have been included as an example of what most areas in Talbot County could expect (Figures 8 & 9). In the comparison of 2015 and 2050, the predicted 1% chance flood includes more buildings as vulnerable that are adjacent to the current flood area. But primarily, the 1% flood in 2050 will be more severe than today, thus yielding many more buildings in higher predicted damage categories. By contrast, the comparison of 2015 and 2100 shows not only a significantly more severe 1% chance flood, but a significant expansion of the vulnerable zone. This pattern is very similar across the peninsulas and necks of Talbot County. The data from this analysis will be delivered to County officials so that they can map any area of the county this way, but Tilghman Island's patterns are very typical of what many areas of the county can expect.

Figure 12 Spatial distribution of vulnerable structures in Talbot County, 1% chance flood at MSL in 2100 (n=6,152)

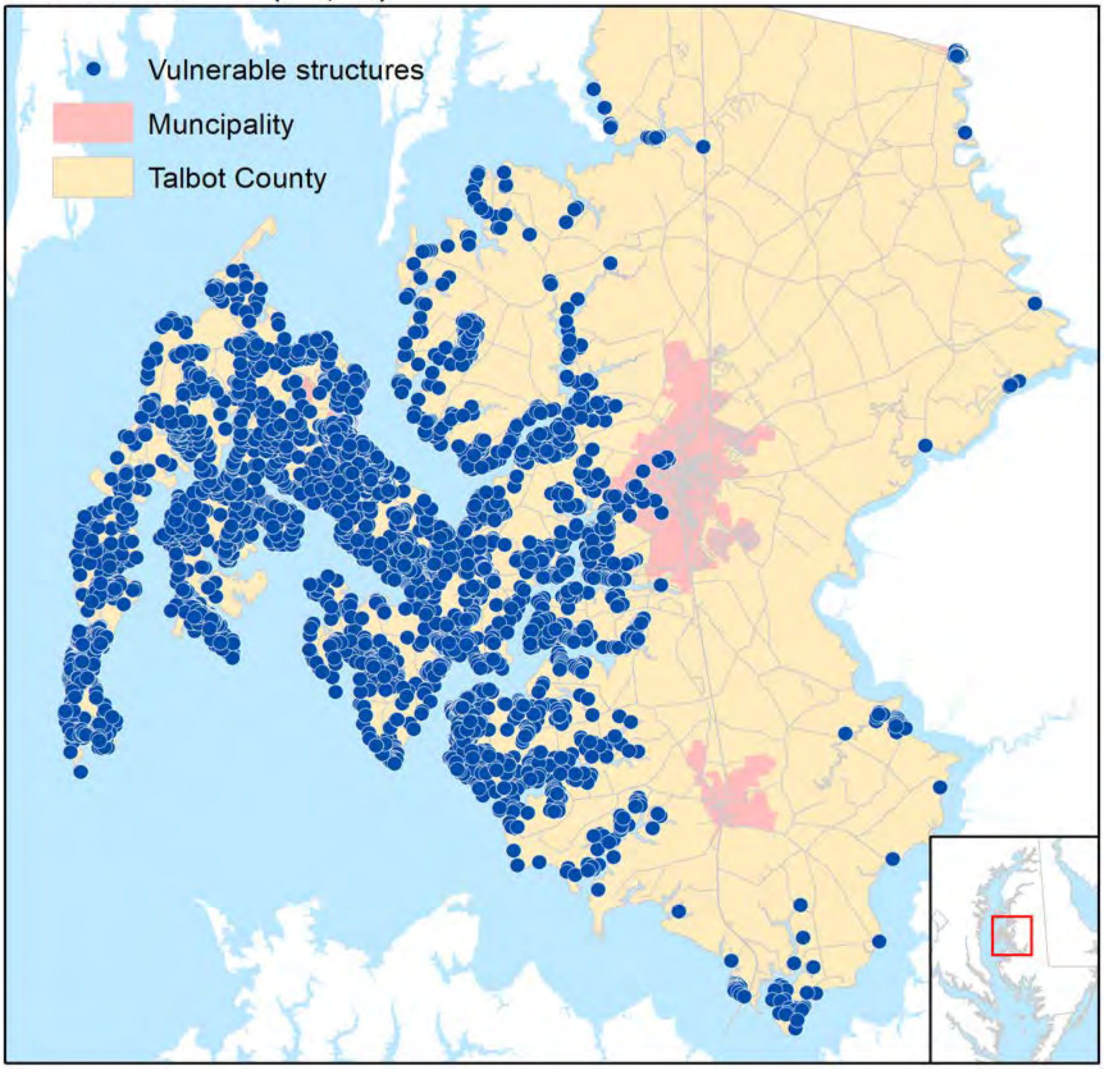


Figure 13 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2050, Tilghman Island, Maryland

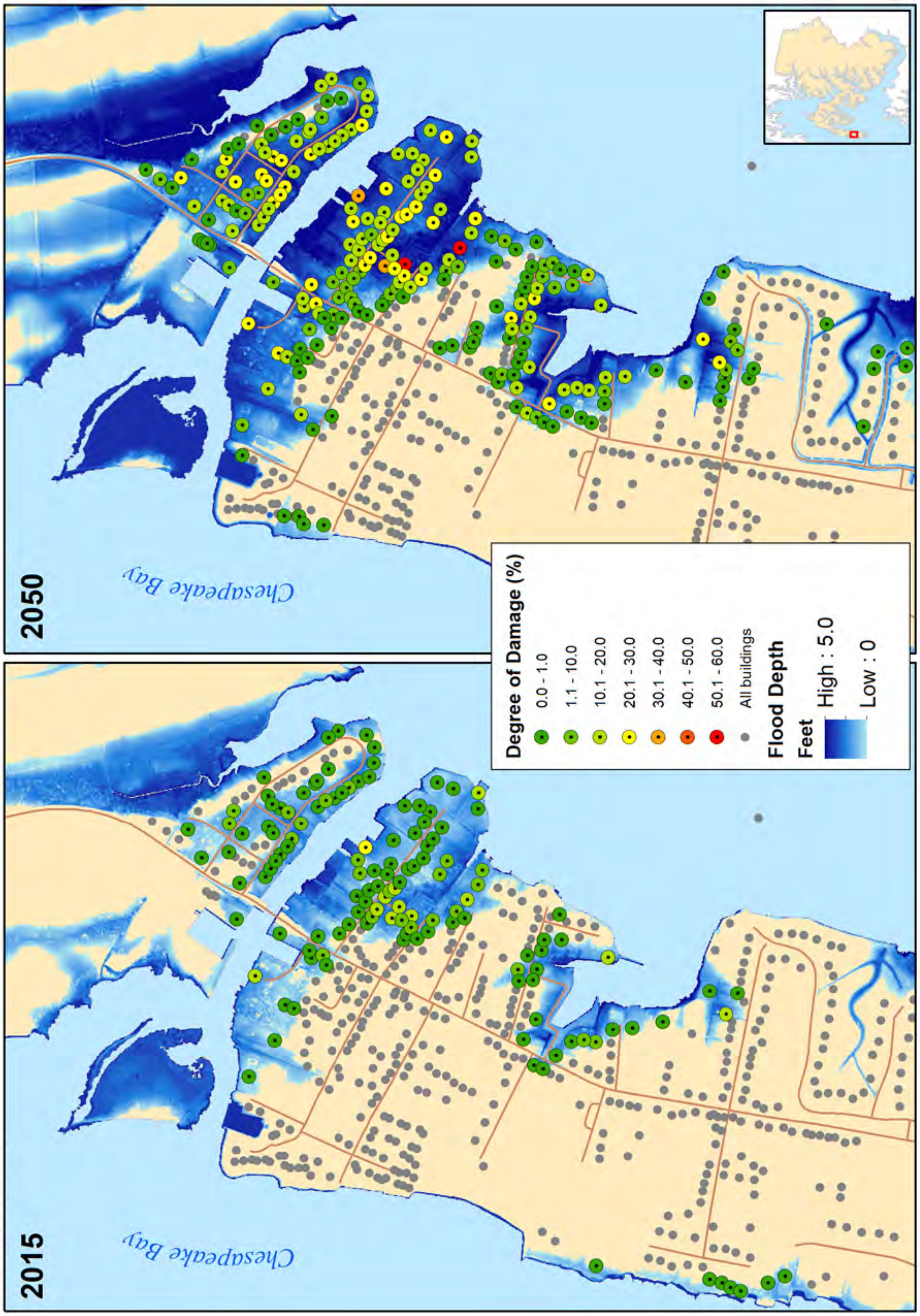
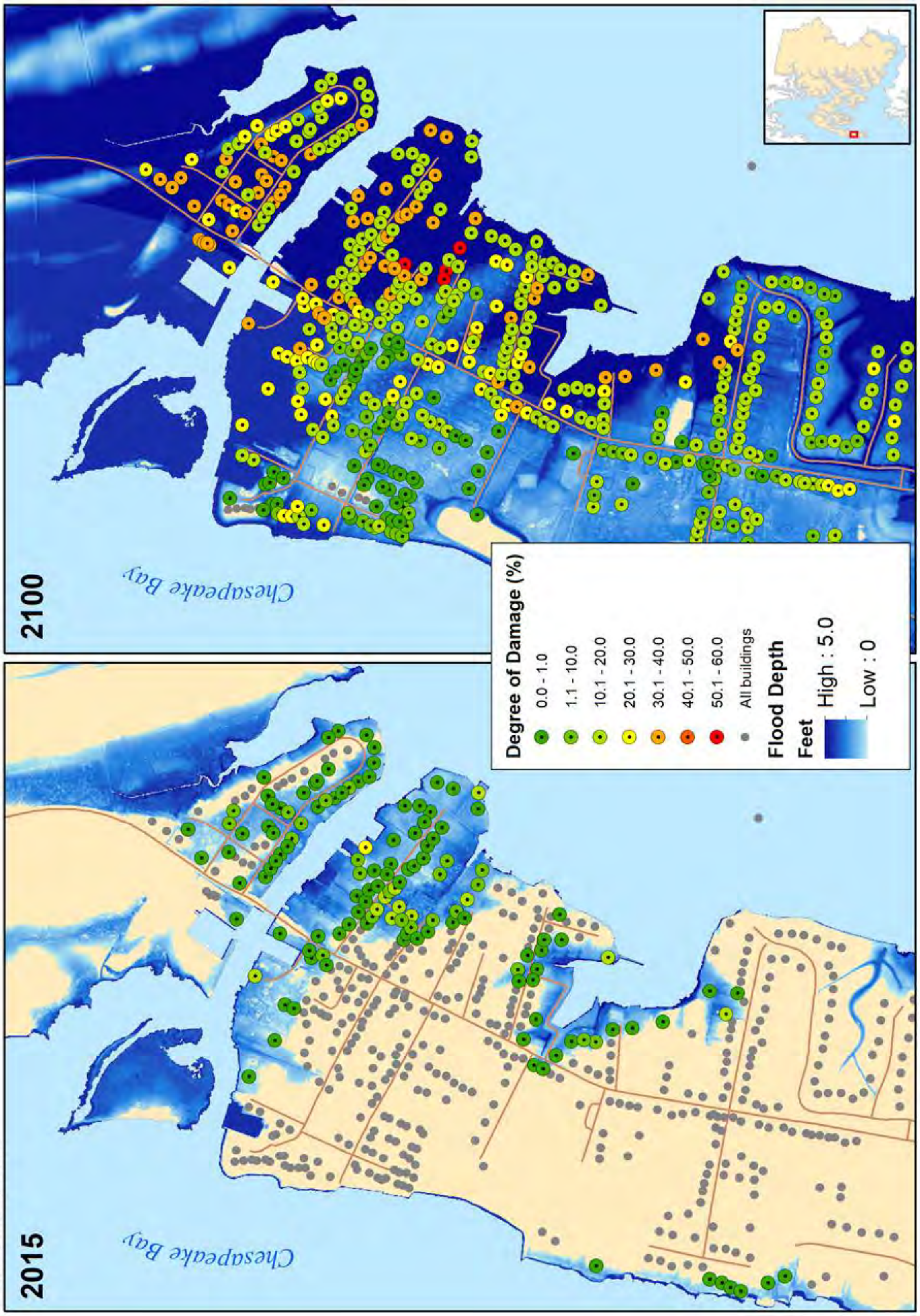


Figure 14 Comparison of flood depth extents and predicted damage for the 1% chance flood at MSL in 2015 vs. 2100, Tilghman Island, Maryland



The patterns of damage from flooding in the future when considering the use of the property are very similar to the results in 2015 with a few exceptions (Table 17 and 18). Besides the inclusion of three additional industrial sites worth over $2.3 million in structure and contents value and 4 agricultural buildings, the other key takeaway is that nearly 90% of the flood damage in 2050 will be residential, rather than a large commercial impact in 2015. That shift of burden away from commercial, governmental, and industrial land uses toward residential strengthens by 2100, with 94% of all of the structures impacted and over 90% of all of the damage is coming from the residential sector.

Table 17. Potential damage to structures/contents from a 1% chance flood event in 2050 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	2,349	94.2%	$924,003,642	$27,720,420	3.0%	88.5%
Commercial	121	4.9%	$64,126,778	$3,378,604	5.3%	10.8%
Government	14	0.6%	$10,504,608	$148,987	1.4%	0.5%
Industry	3	0.1%	$2,304,252	$0	0.0%	0.0%
Religious	5	0.2%	$1,484,400	$57,681	3.9%	0.2%
Agricultural	4	0.1%	$384,002	$0	0.0%	0.0%
Total	2,496	100.0%	$1,002,807,683	$31,305,692	3.1%	100.0%

Note: All dollar values are from 2015 tax assessments.

Table 18. Potential damage to structures/contents from a 1% chance flood event in 2100 by general occupancy type

General Occupancy Type	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Residential	5,780	94.0%	$2,239,079,635	$237,550,587	10.6%	90.6%
Commercial	290	4.7%	$171,392,413	$19,235,086	11.2%	7.3%
Government	42	0.7%	$87,607,224	$3,889,918	4.4%	1.5%
Industry	9	0.1%	$7,351,502	$924,579	12.6%	0.4%
Religious	17	0.3%	$6,721,650	$496,198	7.4%	0.2%
Agricultural	14	0.2%	$442,812	$58,922	13.3%	0.0%
Total	6,152	100.0%	$2,512,595,236	$262,155,290	10.4%	100.0%

Note: All dollar values are from 2015 tax assessments.

In general, the distribution of vulnerability by property value does not change considerably once sea level change is added in 2050 (Table 19). There is a small percentage shift to the more valuable properties in this scenario. For example, 13.5% of all of the properties valued between $500,000 and $1 million are impacted by the 1% chance flood in 2015 but that percentage grows to 19.5% in 2050. This result is not unexpected. The area of Talbot County west of US 50 is perforated into a multitude of peninsulas and necks. Because of the relative lack of land access to these peninsulas as well as large-lot zoning regulations and Talbot County's relative location to Washington, DC, the water-dominated western part of the county is home to many wealthy citizens and their estates. While these developments have been wisely placed away from flood prone areas as of 2015, the topography and exposure of these areas make them vulnerable once sea level is higher. By 2100, this pattern continues to deepen (Table 20). In 2015, only 3.1% of all of the impacted building were valued at over $1 million. By 2050, the proportion had grown to 6.0% and by 2100, 6.3% of the 6,152 structures threatened by a 1% chance storm are valued at more than $1 million in their structure and contents. It is also important to note that these are 2015 property values. If the rate of inflation for the next 85 years is the same as the last 85 ($1 in 1930 is worth $13.96 in 2015, according to the Consumer Price Index), the total property value at risk from flooding would be over $35 billion.

Table 19. Potential damage to structures/contents from a 1% chance flood event in 2050 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	85	3.4%	$1,789,313	$148,503	8.3%	0.5%
$50 - $100	165	6.6%	$12,664,192	$1,028,529	8.1%	3.3%
$100 - $200	531	21.3%	$79,258,100	$5,409,933	6.8%	17.3%
$200 - $300	454	18.2%	$112,183,520	$5,323,097	4.7%	17.0%
$300 - $400	361	14.5%	$124,271,357	$5,423,622	4.4%	17.3%
$400 - $500	264	10.6%	$118,829,100	$4,311,283	3.6%	13.8%
$500 - $1,000	486	19.5%	$331,143,330	$7,174,409	2.2%	22.9%
$1,000 - $2,000	135	5.4%	$174,406,937	$2,486,317	1.4%	7.9%
$2,000 - $3,000	12	0.5%	$29,570,100	$0	0.0%	0.0%
More than $3,000	3	0.1%	$18,691,733	$0	0.0%	0.0%
Total	2,496	100.0%	$1,002,807,683	$31,305,692	3.1%	100.0%

Note: All dollar values are from 2015 tax assessments

Table 20. Potential damage to structures/contents from a 1% chance flood event in 2100 by property value

Property Value (000s)	Building Count	% of Total	Value of Structure and Contents	Total Damage	% of Value	% of Total
Less than $50	323	5.3%	$6,816,962	$850,861	12.5%	0.3%
$50 - $100	475	7.7%	$36,554,950	$4,580,709	12.5%	1.7%
$100 - $200	1,343	21.8%	$199,642,750	$27,629,444	13.8%	10.5%
$200 - $300	1,171	19.0%	$288,953,350	$10,948,741	3.8%	4.2%
$300 - $400	822	13.4%	$284,795,775	$35,237,451	12.4%	13.4%
$400 - $500	541	8.8%	$242,295,025	$30,495,794	12.6%	11.6%
$500 - $1,000	1,095	17.8%	$744,068,875	$79,698,271	10.7%	30.4%
$1,000 - $2,000	324	5.3%	$424,088,500	$38,458,705	9.1%	14.7%
$2,000 - $3,000	30	0.5%	$71,873,750	$7,315,092	10.2%	2.8%
More than $3,000	28	0.5%	$213,505,299	$3,568,088	1.7%	1.4%
Total	6,152	100.0%	$2,512,595,236	$262,155,290	10.4%	100.0%

Note: All dollar values are from 2015 tax assessments

Study Caveats

It should not go without mentioning that the prediction of the flood threat with a future sea level change has more than the normal level of uncertainty. Not only are the estimates of sea level change not a foregone conclusion, but the nature of the flood threat itself is likely to change. For example, in a world with oceans that are 2 (or 5) feet higher, the controlling forces (subtropical high pressure systems, ocean upwelling, thermal heat transfer, etc.) of tropical storms are likely to be different. Thus, the periodicity of certain magnitudes of storm events could change. Similarly, this analysis uses statistical/stochastic models, not a dynamic simulations. Therefore, it does not take into account either individual storm parameters or geographic parameters such as land cover or the shape of the near-shore bottom, both of which will impact the flood predication and both are likely to change in a rising sea level scenario.

With regard to vulnerability estimates, there are also a number of important caveats to remember. First, this analysis assumes that all of the built infrastructure would be exactly as one found it in 2015. That is almost certainly not going to be the case, both with new structures being built and older structures being made more flood-resistant as the waters rise. Second, as mentioned above, the potential damage is being evaluated as if property values will not change by 2050 or 2100 – also not the case. Finally, this vulnerability analysis deliberately examined only damage to structural/contents because the relationship between building damage and depth of water is best understood. There are still many other sources of potential vulnerability: infrastructure damage/loss (both to rebuild and its impact on restarting the economy after a disaster), loss of productivity with businesses closed, debris removal, other consumer losses (cars, boats, sheds/garages), and of course, the potential loss of life.

Conclusions

Several conclusions can be made regarding the question of coastal flooding vulnerability in Talbot County. First, given that Talbot County has several significant sources of flood threat and given that it contains more than 20,805 improved structures, the fact that only 751 (4.3%) are vulnerable to the 1%-chance flood is probably a result of historical land use patterns (with the growth of Easton being driven by land-based, rather than water-based transportation), smart flood plain management regulations, and the increasing value of waterfront property in the past several decades. Second, given the potential for sea level rise in the coming decades, the time to redouble the County's efforts to protect its citizens from flooding is now. If no changes are made, almost 12% of the county's current structures will be impacted by flooding in 2050 and nearly one-third of the Talbot building stock may need flood protection by 2100. It seems that Talbot County has an important and hard-won margin of safety from coastal flooding. But once that margin of safety is pierced (with a 2 ft rise in sea level) then the results of hundreds of individual development decisions of the past century will begin to intersect the expanded hazard zone. Having said that, this analysis shows that Talbot County has some time to adjust to the change in the flood threat. That so few buildings are predicted to be impacted by sea level change alone by 2050 is both an opportunity to mitigate the threat and a concern that a lack of action may not yield negative consequences before it is too late. Finally, even though the County as a whole is somewhat flood-prone, there are certain areas that are particularly vulnerable, such as Bar Neck, Bellevue, Bozman, Copperville, Claiborne, Fairbank, Neavitt, Newcomb, Oxford, Royal Oak, Sherwood, St. Michael's, Tilghman, and Wittman, for which there are no easy answers.