Climate Change and Sea Level Rise Adaptation Report
Kent County, Maryland

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Project Partners

- Kent County Department of Planning, Housing, and Zoning
- Kent County Office of Emergency Services
- Maryland Department of Natural Resources, Chesapeake & Coastal Program, Coast Smart Communities Initiative
- Eastern Shore Land Conservancy, Coastal Resilience Program
- Maryland Sea Grant Extension
- North Carolina Sea Grant
- South Carolina Sea Grant Consortium
- Carolinas Integrated Sciences & Assessments

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Introduction

This study has three intended purposes: 1) to augment the Kent County Hazard Mitigation Plan by understanding how existing hazards and risks may evolve and intensify in the future due to climate change; 2) to inform the Kent County Comprehensive Plan and other planning processes by recommending strategies for mitigating risks, becoming resilient to extreme events, and adapting to changing conditions; and 3) to stimulate conversations and improve collaboration across governmental departments and with community stakeholders.

In 2004, Kent County developed its Hazard Mitigation Plan for the unincorporated areas of the County and its five municipalities: Betterton, Chestertown, Galena, Millington, and Rock Hall. The Plan was updated in 2014. The Plan satisfies the requirements of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), the Disaster Mitigation Act of 2000, and 44 CFR, Part 201.6 (Code of Federal Regulations). The hazard identification process for Kent County involved investigating various types of natural hazards faced by the County over the past several decades. Since it is assumed that hazards experienced by the County in the past may be experienced in the future, the hazard identification process includes a history and an examination of various hazards and their occurrences.

The following natural hazards have been documented in Kent County. They have been assessed as risks in the Hazard Mitigation Plan and ranked by the County Hazard Mitigation Planning Committee in order of importance based on past occurrences, damages, claims, etc. With the exception of earthquakes, all of these hazards are expected undergo changes in probability and/or intensity as a result of climate change.

1. Hurricanes
2. Riverine and Coastal Flooding
3. Winter Storm/Winter Weather
4. Other Severe Storms (thunderstorms, lightning, hail)
5. Drought
6. Soil Movement/Steep Slopes
7. Wildfire
8. Extreme Heat
9. Tornadoes
10. Earthquakes

The ongoing implementation of the Hazard Mitigation Plan represents the essential aspect of comprehensive disaster mitigation planning through evaluation and understanding of potential hazards, vulnerabilities, and risks.

While the Hazard Mitigation Plan augments the Kent County Comprehensive Plan in a number of ways, the results of this study will better inform applicable strategies in both planning documents and will assist the County in developing new strategies to ensure the resilience of its residents and its vulnerable environment. The twenty-one recommendations for improving resilience found in

Section 3 are based on input collected from over three dozen participants in the study as well as from community stakeholders. The recommendations fall into eight categories and, in the broadest terms, address ways to improve infrastructure, inform and protect residents, and allocate the County's resources in a cost-effective manner.

Section 1. Kent County Climate Change Vulnerability Assessment

Kent County is naturally vulnerable to elevated water levels and heavy rainstorms. Surrounded on three sides by water, the county has low-lying areas that are exposed to flooding during times of high water in the Chesapeake Bay and two of its tributaries, the Chester and Sassafras Rivers. Poor drainage due to flat terrain and clay soils make the county naturally susceptible to precipitation-driven flooding. As a community that relies heavily on agriculture as an economic engine, the county also has particular sensitivities to extremes of temperature and precipitation.

Climate change is exacerbating environmental conditions in Kent County and increasing the risk of certain natural hazards. This section examines how climate change is altering the likelihood of extreme conditions (heat, precipitation, and flooding) in Kent County today and in the future.

1.1 Perceived climate changes in Kent County

Informal observations by the three dozen participants in the Kent County Vulnerability Study provide on-the-ground indications that changes are occurring in seasonal patterns, extreme events, and flood frequency. While these local perceptions cannot be regarded as rigorous scientific data, they nonetheless tell an important story of Kent County's changing conditions and are largely corroborated by the findings of the National Climate Assessment and Maryland's climate assessments.

1.1.1 Seasonal shifts

Several participants noted changes in seasonal conditions or patterns. Winters were widely reported to be less severe with fewer extreme cold days and fewer hard freezes, though strong winter storms are still believed to be a very real threat. Springs were noted by several participants to be cooler and wetter.

- *"It doesn't freeze like it used to. There's no more skating on the ponds."*
- *"As a teen I remember being hired to work in dry fields during school vacation in March. Now we're not able to work in the fields until April because they stay wet longer."*

1.1.2 Precipitation

Many of the participants reported perceiving an increase in both the intensity and the frequency of heavy rainfall events. Some noted that the spring season is becoming wetter while others said that summer rainstorms are becoming more intense.

- *"The 2 to 4 inch rainstorms are more common."*
- *"It seems like all we have now is 100-year events."*
- *"The 100-year event is much more frequent and unrelated to growth or development."*

1.1.3 Flooding

Most participants reported perceiving an increase in tidal and precipitation driven flood events. Meteorologists from the National Weather Service's regional office in Mt Holly, New Jersey reported that for Kent County the frequency of nuisance flooding from tides and wind is increasing more rapidly than the increase in minor and moderate flooding events from rain and storm events. Tidal flooding, unrelated to storms or rain, is occurring several times per month along the Chestertown waterfront. Residents in Rock Hall are experiencing flooding of ditches and roads several times a year during spring tides and king tides or when wind conditions are right.

- *"The Chester River floods more frequently at high tide, particularly in the summer."*

Much of the county is flat so flooding can occur during heavy rains when water cannot drain quickly. In areas near the coast, high tides or storm surges can backup ditches and creeks, further impeding drainage from heavy rain and causing flooding.

1.1.4 Hurricanes, winter storms, and nor'easters

Nearly all participants listed storm events as the most significant natural threat to Kent County because of the combination of storm surge, flooding, rain or snow, and wind. Tropical Storm Isabel in 2003 and Tropical Storm Irene in 2011 were the events most frequently cited. Isabel's 7-9 foot storm surge caught many in the county by surprise. Waterfront homes in Chestertown reportedly had up to 4 feet of water in the houses. A storm tide estimated by participants at 9 feet caused major damage (greater than 50% of assessed value) to approximately one-third of the structures in Rock Hall. A few participants thought winter storms were also increasing in severity.

- *"Now every storm is a serious concern for life and property."*

1.2 Temperature

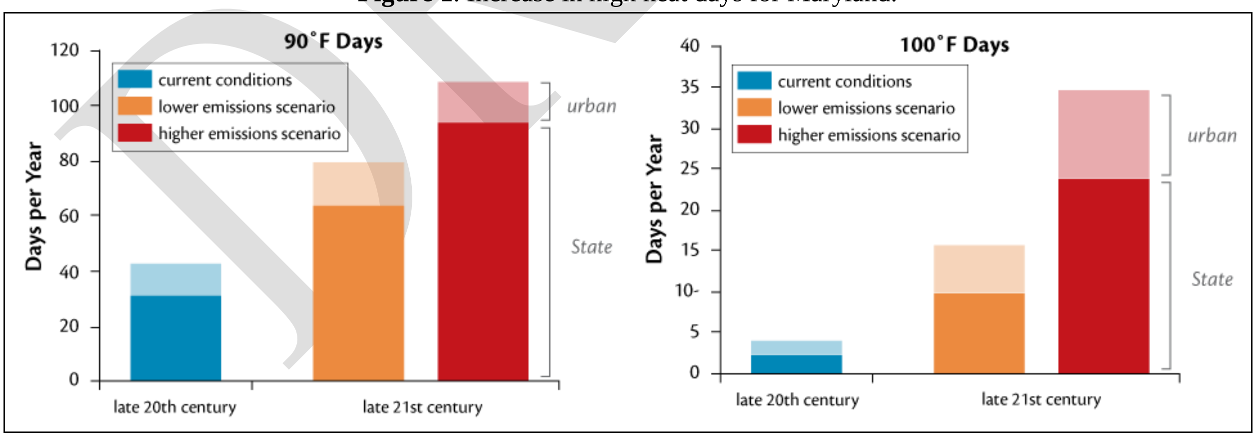
The most direct effect of climate change will be warmer temperatures for most places around the world, including Maryland and Kent County. In addition to having direct impacts on social and ecological systems, higher temperatures will affect other planetary systems such as the water cycle and the oceans.

1.2.1 Temperature observations and projections

The temperature projections presented here are subject to various sources of uncertainty. One of the largest sources of uncertainty is not scientific but political. The projections depend very strongly on the speed at which countries, states, and municipalities curb greenhouse gas emissions. Currently, global emissions are on a worst case scenario pathway, which will result in a warming of annual average surface temperatures by approximately 7.2°F in the year 2100. While recent international agreements give reason to hope that this worst case scenario can be avoided, the preponderance of evidence indicates that trends of greenhouse gas concentrations in the atmosphere are continuing on the worst case, business-as-usual pathway. If rapid greenhouse gas reduction measures are taken in the next two decades, the average global temperature increase could be limited to 1.8–3.6°F[1].

Compared to the first half of the 20th century, the average annual temperature in Kent County has increased by 1.5°F[2]. The Chesapeake region, which is expected to warm faster than the global average, could be up to 8°F warmer by the end of this century. Winters will be milder and summers will be hotter. Winters could be 4.5°F to 7.5°F warmer, while summers could be 4.5°F to 8.5°F warmer. In the summer, Maryland will experience longer stretches of consecutive high heat days. The number of days surpassing 90°F will double from 30 per year to 60, or even triple to 90 days under the worst case (Figure 1). Under this worst case, it will be a rare week in June, July, and August when daily high temperatures stay below 90°F. The number of 100°F days grows from 2-3 per year to 10-25 days per year.

Figure 1. Increase in high heat days for Maryland.



Source: Dr. Donald Boesch. Presentation to Kent County Vulnerability Workshop on February 23, 2016.

[1] Dr. Donald Boesch, University of Maryland Center for Environmental Science. Presentation to Kent County Vulnerability workshop on February 23, 2016.
[2] 2014 National Climate Assessment. http://nca2014.globalchange.gov/report/our-changing-climate/recent-us-temperature-trends

1.2.2 Temperature consequences

Extreme heat conditions for long periods will have public health impacts on many populations across the county. Outdoor labor will become more strenuous and less productive. County-employed work crews who are responsible for grounds maintenance and road work will be vulnerable. An often overlooked consequence of extended periods of hot weather is the public health concern of elevated nighttime temperatures. When nighttime temperatures stay elevated above 75°F or 80°F, residents without air conditioning are unable to cool their homes at night. The resulting high interior temperatures do not provide residents with relief from the outdoor heat. Under these extended high heat conditions, residents with poor health or mobility conditions are particularly vulnerable to heat related stress and emergencies. Residents who cannot afford air conditioning in their homes are also vulnerable.

Buildings and roads are two types of county infrastructure that are vulnerable to high heat. Approximately 70% of the roads in Kent County are tar-and-chip construction. On hot days, the tar becomes soft, exposing the road to deformation and damage when heavy vehicles or farm equipment drive on it. In extreme cases, vehicles can deform the roadbed so severely that they become stuck. Blacktop roads have a higher heat tolerance but can be two to ten times as costly to build.

Buildings are vulnerable to high heat when the HVAC systems cannot keep up with the cooling demand. In some buildings, the Detention Center in particular, the HVAC system was designed several decades ago. Those designs did not anticipate a warming climate, nor the heat-generating computer systems that have become ubiquitous since then. The capacity of the HVAC systems at the Detention Center, Courthouse, and Library are barely adequate for today's cooling demand. The systems overheat and "trip out" 3 or 4 times per year per building. Each time a system trips out, it weakens the equipment, causes stress for building occupants, and results in overtime costs when facilities staff are called out to cool and restart the equipment. Upgrades for the county's HVAC systems would cost $250,000–$300,000 according to a rough estimate by county staff.

Buildings that do not have HVAC systems or adequate ventilation could see increases in mold and mildew, creating health concerns for the county employees who work there. These buildings include the arena in Worton and some older Parks & Recreation storage facilities.

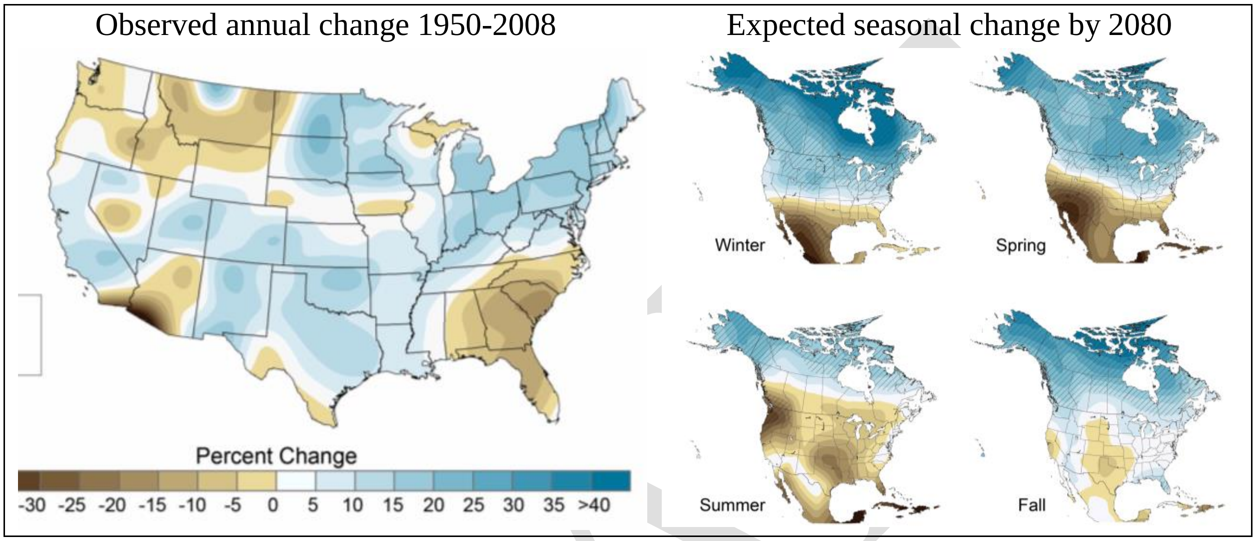
1.3 Precipitation

1.3.1 Precipitation observations and projections

The warmer air temperatures caused by climate change cause higher rates of evaporation and allow the atmosphere to hold more water. As result, precipitation will decrease in some parts of the United States and increase in others. Maryland straddles the border between the Northeast and

Southeast regions demarcated in the 2014 National Climate Assessment[3]. The Northeast region has experienced an 8% increase in amount annual precipitation (1991-2012 vs. 1901-1960). The Southeast region has a mix of areas that have seen more or less precipitation. For Kent County, the observed increase in precipitation is between 5% and 10% over the past six decades.

Figure 2. Observed and projected changes in precipitation



Source: Dr. Don Boesch, presentation to Kent County on February 23, 2016

Over the next 75 years, precipitation is projected to increase by 10-20% above the end of the 20th century. However, the increase in precipitation will not be uniform throughout the year. Winter and spring are expected to become wetter, while summer is expected to be drier. Precipitation is also expected to be concentrated in the form of heavier downpours. Since the middle of last century, the heaviest of downpours have become substantially heavier. The amount of water that now falls in the heaviest 1% of rain events has increased by 71% for the Northeast and 27% for the Southeast. For Kent County, heavy downpours exceeding today's 1-in-20-year event will become two to three times more likely by 2080-2100.

As rainfall becomes concentrated in heavier downpours, Kent County will also see longer dry periods between precipitation events. The annual maximum number of consecutive dry days is projected to increase by as much as 10% from the end of last century to the end of this century (i.e. if the longest dry spell in a given year was 20 days, it will become 22 days by the end of the century).

1.3.2 Precipitation consequences

Heavy precipitation events have two significant consequences in Kent County. The first is flooding that occurs when water cannot drain into creeks or infiltrate into the soil quickly (addressed below

[3] All precipitation data presented in this section are drawn from the 2014 National Climate Assessment (http://www.globalchange.gov)

in Section 1.5.2). The second consequence may occur when water is able to infiltrate into soils. Elevated groundwater levels which can cause water to seep into basements. The Kent County Detention Center is particularly vulnerable because it has a groundwater spring located nearby. A set of pumps keeps the water table at least 12 feet below the building's foundation. However, during wet or rainy periods the pumps cannot keep up and the basement floors get wet. This is a problem because the Emergency Operations Center and communications equipment is housed in the basement. The public works building at 709 Morgnec Road had groundwater come up through the floors due to the heavy rain during tropical storm Isabel in 2003, indicating that it too is vulnerable to extreme rain events.

Kent County relies on 17 major pump stations and nearly a thousand smaller, residential grinder pumps to move water through the stormwater system. These pumps will need the capacity to accommodate increasing flows during wetter wet seasons and heavier downpours.

Longer dry spells during the summer growing season will have consequences for farms and unirrigated crops. As more irrigation capacity is added to the regions farms, there will be an increased demand on groundwater and aquifers.

1.4 Sea level rise

Water levels around the globe vary naturally on daily, monthly, annual, and multiyear scales. Locally, water levels are rising for three reasons. (1) 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. (2) 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. Groundwater extraction for drinking water and agriculture has been shown accelerate subsidence in other parts of the world, though no such studies are known to exist for Kent County. (3) Changes in ocean dynamics, such as a weakening of the Gulf Stream Current, can cause ocean water rise along the U.S. Atlantic seaboard. Land subsidence accounts for approximately half of the observed sea level rise in Kent County over the past 100 years. However, climate change is expected to increase the relative effects of ice melt, thermal expansion of seawater, and ocean dynamics in coming years.

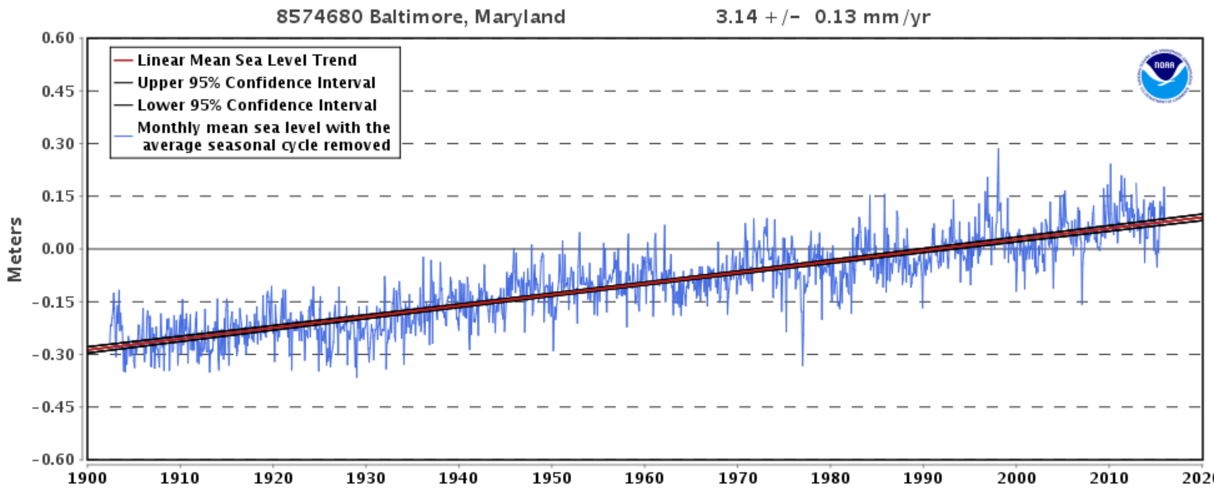
1.4.1 Relative sea level rise

A network of space-based satellites and land-based tide gauges monitor these changes in water levels. Satellites measure "absolute" sea level as the height of the water above the center of the Earth. Tide gauges measure "relative" sea level, the water level one observes from the shoreline. Both methods of measurement can be influenced by winds, storms, tides, and seasons. In order to accurately measure changes in sea level, measurements must be averaged over long periods of time to determine a clear trend. **Relative sea level rise**, then, is the cumulative effect over a period of years, centuries, and millennia of the three inputs described in the preceding paragraph.

1.4.2 Historical and observed sea level rise trends

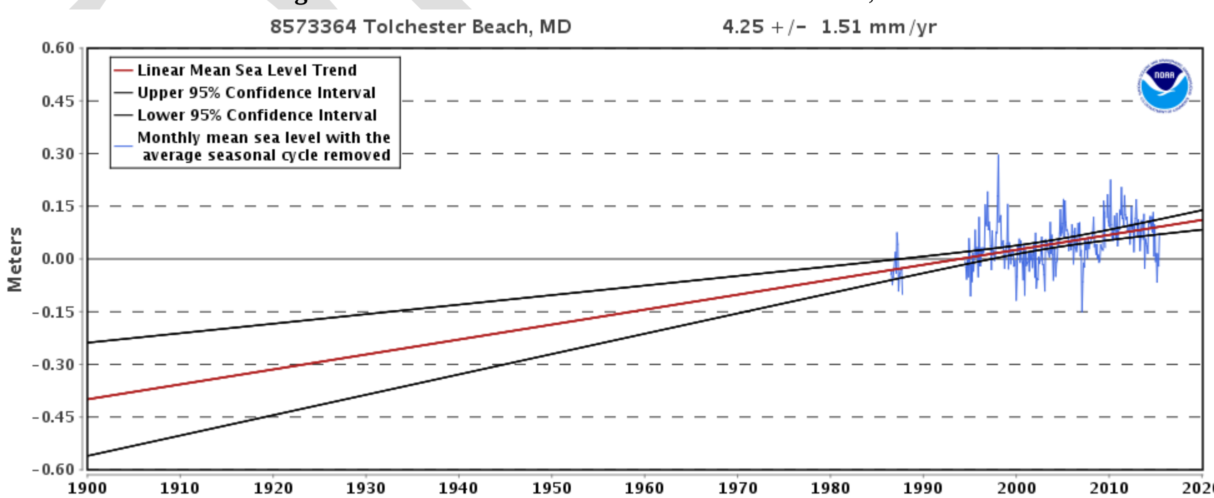
Globally, sea level has risen an average of half a foot in the past century. In the Chesapeake Bay region, relative sea level rise has been double the global average, due to the additional effect of land subsidence. Spanning more than 110 years, the NOAA tide gauge at Baltimore Harbor (Figure 3a) has 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.

Figure 3a. Mean Sea Level Trend for Baltimore, MD



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

Figure 3b. Mean Sea Level Trend for Tolchester Beach, MD



Source: NOAA. http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8573364

The NOAA tide gauge at Tolchester Beach in Kent County (Figure 3b) has recorded an average rise of 4.25mm per year (0.17 inches/year) based on data from 1986-2014[4]. This is equivalent to a rise of 16.7 inches in 100 years. Table 1 shows that the rate of relative sea level rise at Tolchester Beach exceeds that of the nearby gauges in the upper Chesapeake Bay. In fact, Tolchester Beach and Kent County are experiencing sea level rise rates among the fastest observed on the East Coast, exceeding many locations like Miami and Charleston that are frequently in the news for sea level rise challenges.

Table 1. Historical relative sea level rise rates for the upper Chesapeake Bay and selected East Coast Stations.

NOAA Tide Gauge Station	Historical Relative Sea Level Rise	Inches per 100 years Equivalent
Upper Chesapeake Bay		
Tolchester Beach, MD	**4.25 mm/year**	**16.7**
Chesapeake City, MD	3.92 mm/year	15.4
Cambridge, MD	3.72 mm/year	14.6
Annapolis, MD	3.53 mm/year	13.9
Baltimore, MD	3.14 mm/year	12.4
Other East Coast Stations		
Sewells Point, Norfolk, VA	4.60 mm/year	18.1
Charleston, SC	3.16 mm/year	12.4
Boston, MA	2.84 mm/year	11.2
The Battery, New York City, NY	2.84 mm/year	11.2
Miami Beach, FL	2.39 mm/year	9.4

Source: http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

1.4.3 Future projections of sea level rise

The University of Maryland Center for Environmental Science (UMCES) and the Scientific and Technical Working Group of the Maryland Climate Change Commission produced future sea level rise projections[5] for the state in 2013. The forecasts include the three contributing factors described above (ocean volume, land subsidence, and ocean dynamics) and are based on scientific

[4] The relatively short period of data collection for the Tolchester Beach gauge makes it less reliable than the Baltimore gauge for determining the magnitude of the rising sea level trend, as indicated by the large confidence interval of ±1.51 mm/year.

[5] Boesch, D.F., et al. 2013. Updating Maryland's Sea-level Rise Projections. Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission, 22 pp. University of Maryland Center for Environmental Science, Cambridge, MD. www.umces.edu/sea-level

approaches used by the National Research Council and the Intergovernmental Panel on Climate Change. The topline recommendation from the state's report is:

> "It is prudent to plan for **relative sea level rise of 2.1 feet by 2050**…on top of which storm surge would have to be factored in, to judge the risks to land-based facilities."
>
> \- Boesch, et al. 2013

The state's report issued "best estimate" and "high estimate" scenarios for sea level rise for the years 2050 and 2100. The high estimate assumes a business-as-usual scenario in which global carbon dioxide emissions are not meaningfully reduced. The best estimate assumes a moderate level of global carbon dioxide emissions reduction[6]. The best estimates of relative sea level rise for Maryland are 1.4 feet by 2050 and 3.7 feet for 2100 (Table 2). The high estimate is 2.1 feet by 2050 and 5.7 feet by 2100. It is important to remember that these are 'still-water' projections; storm surge and wave heights must be added onto these forecasts.

Table 2. Maryland and Global Sea Level Rise Scenarios

Date/Estimate	Maryland Relative Sea Level Rise (feet)	Global Mean Sea Level Rise (feet)
2050 Best	1.4	0.9
2050 High	2.1	1.6
2100 Best	3.7	2.7
2100 High	5.7	4.6

Source: Boesch et al, 2013.

The report's recommendation to plan for 2.1 feet of relative sea level rise in Kent County by 2050 is a "no regrets" strategy. Despite recent international agreements, current greenhouse gas emission trends are still indicating a trajectory towards the high estimate for sea level rise. Planning for the high estimate would prepare the County to meet currently expected conditions in 2050 with the benefit buying the county one or two additional decades of preparation if significant global greenhouse gas reductions are made. It is important to keep in mind that sea levels will continue to rise well beyond 2100, perhaps by many more feet.

6 In December 2015, 196 countries attending the UN Climate Change Conference of Parties agreed to goals limiting global warming to less than 2 degrees Celsius compared to pre-industrial levels and achieving zero net anthropogenic greenhouse gas emission in the second half of the 21st century. However, current emission trends are still on a business-as-usual trajectory that, if unchanged, potentially leads to the high estimate of sea level rise and global average temperatures.

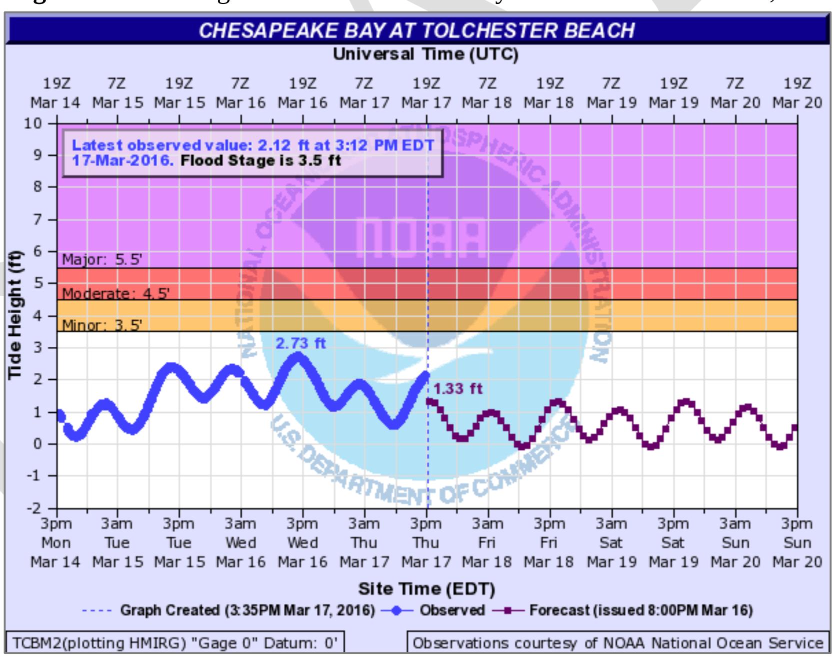
1.5 Flooding

Kent County experiences a semidiurnal tide – two high tides and two low tides every day. The two high tides differ from each other by 3-6 inches depending upon location in the county. The low tides also differ from each other in a similar manner. The 19-year average height of the higher of the two high tides is known as **Mean Higher High Water (MHHW)**.

The National Weather Service defines three flood stages for coasts and rivers. **Minor flooding** causes little or no property damage but may be a public hazard due to road inundation. **Moderate flooding** causes inundation to some structures and roads in coastal areas and along rivers. **Major flooding** cause widespread flooding of structures and roads. Flood stages are measured as water elevations above MHHW. For Kent County, the National Weather Service has determined the following flood stages for the Chesapeake Bay at Tolchester Beach:

- Minor flooding: 3.5 feet above MHHW
- Moderate flooding: 4.5 feet above MHHW
- Major flooding: 5.5 feet above MHHW

Figure 4. Flood stages and semidiurnal tide cycle for Tolchester Beach, MD



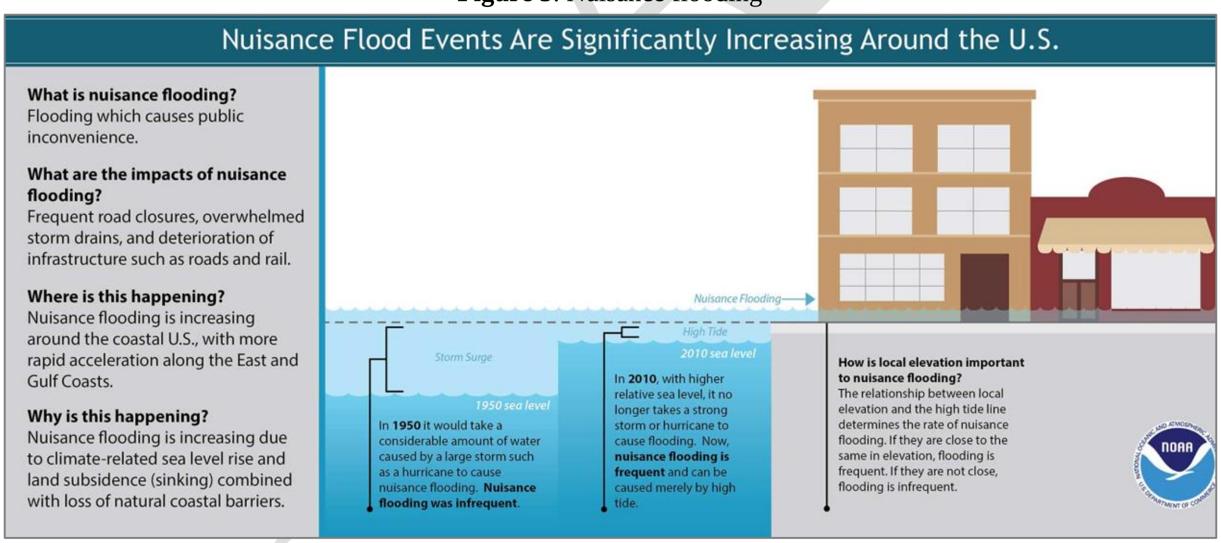
Source: NOAA. http://water.weather.gov/ahps2/hydrograph.php?wfo=phi&gage=tcbm2

1.5.1 Nuisance Flooding

The National Oceanic and Atmospheric Administration (NOAA) defines **nuisance flooding** at a threshold equivalent to the NWS minor flood stage. As with minor flooding, nuisance flooding causes temporary, minor disruptions mainly to roadways and drainage structures. The key difference between minor and nuisance flooding is what causes the flooding. Minor flooding (as well as moderate and major flooding) is caused by a specific event such as heavy rain, high wind event, or storm surge. Nuisance flooding, sometimes casually called “sunny day flooding”, is not attributable to any specific event. Rather, nuisance flooding occurs when tides, and occasionally wind, conspire to cause the ocean or a bay to overflow its usual boundaries causing a public inconvenience. Nuisance flooding typically occurs near the monthly spring tides and in the fall and spring when the lunar cycle and the Earth’s orbit around the sun cause strong tidal forces.

As water elevations rise due to relative sea level rise, the margin between daily high tides and the nuisance flood threshold shrinks. The result is an increasing frequency of nuisance flooding as high tides more often exceed the minor flooding threshold with no apparent weather event to cause it. In fact, the dramatic increase in frequency of nuisance flooding in the upper Chesapeake Bay is one of the most visible effects of climate change in the region (Figure 5). Since 1957, Annapolis and Baltimore have seen an increase of over 920% in the number of days per year with flooding[7]. Annapolis, the closest location to Kent County for which data exists, now sees nearly 40 days per year of flooding. Many participants in this study confirmed a similar trend in Kent County. They observe higher frequencies of nuisance flooding in Kent County in locations such as the Chestertown and Rock Hall waterfronts.

Figure 5. Nuisance flooding



Source: http://oceanservice.noaa.gov/facts/nuisance-flooding-large.jpg

Frequent nuisance flooding can degrade roadways, drainage infrastructure, and septic systems. Frequent nuisance flooding also disrupts the delivery of social services such as public safety and public transportation. Service vehicles that are frequently driven on flooded roads will have a shorter service life due to salt corrosion. Public health can be impacted when increasingly wet

[7] http://www.noaanews.noaa.gov/stories2014/20140728_nuisanceflooding.html

areas become breeding grounds for insects. When public access to the shoreline, marinas, and businesses are impaired on a regular basis, the public value of the shoreline is diminished.

1.5.2 Precipitation-driven Flooding

Precipitation-driven flooding occurs when water from rainstorms cannot quickly drain off the landscape or be absorbed by soils. Kent County's relatively flat topography and abundance of clay soils make it naturally susceptible to flooding. With downpours becoming more frequent and more intense, drainage and flooding become a larger issue for the county. The most commonly reported consequences from participants were road inundation, washouts, and wet basements in county buildings.

Precipitation-driven flooding is compounded when it occurs during high tides, nuisance flooding, or storm surge. In these periods, tidal water from the rivers or Bay can flow in reverse up ditches and creeks, slowing or backing up rainwater as it drains off the landscape. Structures and neighborhoods near creeks, rivers, and the Bay can experience inundation and isolation during these periods as roadways are made temporarily impassible.

1.5.3 Storm surge

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 can be dramatically higher in the narrow, upper tidal reaches of tributary rivers, including the Sassafras and Chester Rivers. For Kent County, the US Army Corps of Engineers' SLOSH model predicts the following storm surge water elevations[8]:

- Category 1 4-6 feet
- Category 2 7-10 feet
- Category 3 11-14 feet
- Category 4 14-18 feet

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.

[8] The SLOSH model simulates worst-case storm paths. Generally for Kent County, the worst case is a storm path that makes landfall on the Virginia or North Carolina coast and travels parallel to, but just west of the Chesapeake Bay. Isabel in 2003 and the 1933 hurricane both approximately followed this path.

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 7–9 feet of storm surge to Kent County. 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.

For this study, one sea-level-rise-plus-storm-surge scenario was modeled: a Category 1 hurricane occurring in the year 2050. Projecting a 5.5-foot Category 1 storm surge on top of a sea level rise of 2.1 feet (as recommended by the 2013 Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission) produces a storm tide that is at least 7.6 feet above today's MHHW. GIS modeling by the Eastern Shore Regional GIS Cooperative at Salisbury University was commissioned for this study. The analysis finds that 2,368 structures, approximately 10% of the structures in Kent County, would experience flooding under this scenario (Table 3 and Appendix A). Approximately 11,000 acres of land would be flooded in this event.[9]

It is important to note that FEMA's digital flood insurance rate maps (DFIRMs) do not anticipate sea level rise or the effect that climate change may have on precipitation rates or storm strength. The DFIRMs delineate areas of current risk of the 0.1% annual chance flood (the "100-year flood") and the 0.2% annual chance flood (the "500-year flood"). As sea level rises and precipitation rates increase, the probability rises that the 0.1% and 0.02% thresholds will be exceeded. Put another way, what would have been the 'flood of the century' during the 1900's, can be expected to recur in coming decades on timeframes shorter, and perhaps much shorter, than every 100 years.

1.5.4 Permanent inundation due to sea level rise

In addition to enhancing the extent and impact of storm surge, sea level rise will permanently inundate low-lying coastal areas. Permanent inundation will affect agricultural land, roads, homes,

[9] Surging Seas by Climate Central: Sea level rise analysis July, 2016. http://ssrf.climatecentral.org/#location=MD_County_24029&state=Maryland&level=7&folder=Land&geo=County&pt=t&target=&p=L&protection=tidelthresh

businesses, and infrastructure. For this study, two permanent inundation scenarios were modeled using GIS following the state guidance: 2.1 feet of permanent inundation in 2050 and 5.7 feet of inundation in 2100. Appendix A is a description of the methodology and results of the analysis. The GIS data and analysis will be housed at the Kent County Department of Planning.

Table 3 shows the number of structures and acres that are permanently inundated in each scenario. By 2050, the county can expect 186 currently existing structures and approximately 2,500 acres of land to become permanently inundated. By 2100, assuming current sea level rise trends, the county can expect 1,530 currently existing structures and approximately 8,000 acres of land to be permanently inundated. Future analysis could explore the types of structures (home, outhouse/shed, commercial, infrastructure, etc.) that are vulnerable and the potential effects of their loss in terms of vulnerable populations, county tax base, public safety, water and soil contamination, economic activity, agricultural production, community cohesion, and other areas of concern.

Table 3. Structures and approximate acreage impacted under sea level rise scenarios.

Scenario	Structures inundated	Acres inundated
2050 / 2.1 feet SLR	186	2,500
2100 / 5.7 feet SLR	1,530	8,000
2050 / 7.6 feet (SLR + Cat 1 Storm Surge)	2,368	11,000
Source: Structure data maintained by the Kent County Department of Planning; structure analysis by Eastern Shore Regional GIS Cooperative (Appendix A). Acreage estimated using the Surging Seas tool by ClimateCentral.org.		

In addition to the GIS analysis presented above and in Appendix A, this study also produced a GIS inventory of road segments, bridges, and stream crossings that are subject to flooding or may become prone to flooding as sea level rises. All GIS data will be maintained at the Kent County Department of Planning, Housing, and Zoning.

1.6 Hurricanes and Winter Storms

Hurricanes, winter storms, and nor'easters are Kent County's most disruptive common weather events because they bring multiple, sometimes compounding impacts. Flooding, high winds, and heavy precipitation are common to both hurricanes and winter storms. The question of whether climate change is increasing the frequency or intensity of these storms has not yet been answered conclusively by scientists. Some studies indicate that a warmer ocean may fuel more frequent hurricanes. Others studies counter that notion, citing changes in wind patterns over the ocean that will lower the probability of hurricane formation. In 2015, warmer ocean temperatures in both the Atlantic and Pacific Oceans did give rise to some of the strongest hurricanes and typhoons on record. Therefore, it is reasonable to anticipate and prepare for stronger hurricanes even if they do not become more frequent. There is no record of a Category 3 or stronger hurricane making landfall in the Chesapeake region and it has been rare that a storm maintains that intensity as far north as Maryland. However, climate change may be increasing the probability that strong storms can persist farther north. In 2015, Hurricane Joaquin, fueled by above average water temperatures, passed offshore of the Chesapeake region as Category 3 storm before turning out to sea.

It is known that certain climate change impacts will worsen the effects of these storms. Sea level rise, as discussed above, will increase the reach and impact of storm surge from hurricanes and tropical storms. Locations that historically have been safe from storm surge may become more exposed. Shoreline erosion during hurricanes and nor'easters will also be intensified by sea level rise as places that were once far enough inland or upland become exposed.

As the Atlantic Ocean warms off the eastern seaboard, it will become increasingly is capable of providing heat and moisture to coastal storms, fueling heavier precipitation. In 2016, sea surface temperatures in the Atlantic Ocean were as much as 5°F above average. As Hurricane Joaquin passed offshore of southeast states, it funneled a river of moisture towards land that resulted in the South Carolina's worst flooding in history. Heat and moisture from the ocean was also the engine that fueled Winter Storm Jonas, a blizzard that crippled the Chesapeake region with 15–30 inches of snow. So while warmer air temperatures may reduce the number of snow storms, the additional moisture available from a warmer ocean could make for heavier snowfalls and heavy winter rainstorms.

Section 2. A Participatory Process for Assessing Vulnerability

On March 10, 2015 the Kent County Commissioners approved a proposal by the Department of Planning, Housing, and Zoning to apply for a Coast Smart Communities Grant supporting an assessment of the county's vulnerability to climate change impacts, including sea level rise. The grant, funded by NOAA and administered by the Maryland Department of Natural Resources (DNR), was approved for $31,600 and covered the period from October 1, 2015 to September 30, 2016.

A "participatory" approach was adopted for the study. Contrasted with surveying, engineering, or modelling approaches to risk analysis, a participatory approach accesses the rich, on-the-ground knowledge about local hazards and conditions that can only come from local participants. This approach also promotes constructive dialogue between participants, which results in a deeper understanding of the issues by a broader group of people. Several of the county staff who participated in the study remarked that they had never before been engaged in this type of inter-departmental conversation.

2.1 Steering Committee

The Vulnerability Study was led by a steering committee consisting of Kent County staff, the Eastern Shore Land Conservancy's (ESLC) Coastal Resilience Program, Maryland DNR, the Maryland Sea Grant, and the Carolinas Integrated Sciences & Assessments (CISA) program. The Committee included:

- Amy Moredock — Kent County Department of Planning, Housing, & Zoning
- Virginia Gregg — Kent County Office of Emergency Services
- Brian Ambrette — Eastern Shore Land Conservancy, Coastal Resilience Program
- Kate Skaggs and Sasha Land — Maryland Department of Natural Resources, Coast Smart Communities Grant Program
- Virginia Carrasco — Maryland Sea Grant Extension
- Jessica Whitehead — Carolinas Integrated Sciences & Assessments (CISA), North Carolina Sea Grant
- Elizabeth Fly — Carolinas Integrated Sciences & Assessments (CISA), South Carolina Sea Grant Consortium

2.2 The VCAPS Process

The study was conducted using the Vulnerability, Consequences, and Adaptation Planning Scenarios ("VCAPS") process[10]. VCAPS is a method that helps communities integrate local experience and scientific knowledge. Participants develop a cause-and-effect chain of weather events, climate change risks, impacts on assets and resources, and consequences to the community. With this understanding, participants are then able to identify actions that can be taken to reduce vulnerability and prepare for the impacts of climate change.

2.2.1 Participants

More than three dozen participants contributed to the study through scoping interviews, VCAPS workshops, or both. Participants were selected by the steering committee based on their understanding of county government operations; role in county planning processes; or relevant involvement in environmental or community issues. The primary source of participants were the various departments of the Kent County government, including planning, emergency services, public works, and health. Participants were also drawn from outside the county government, including municipal representatives (mayors, managers, fire chiefs, and planners), environmental and community organizations, and farmers. Appendix B lists the interviewees and workshop participants.

2.2.2 Scoping Interviews (January and February, 2016)

The first step of the VCAPS process was an interview with each of the participants to learn their role in local government planning; to gather their knowledge of impacts of weather events on the

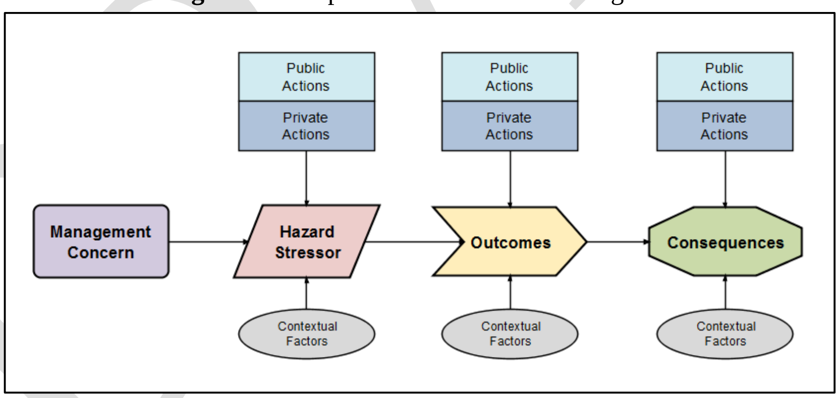
[10] SERI & CISA 2014. "VCAPS: Vulnerability, Consequences, and Adaptation Planning Scenarios." www.vcapsforplanning.org

county; and to understand local environmental and community concerns. All of the participants were interviewed individually or in pairs. The interviews painted a more detailed picture of how weather is changing in recent decades, how extreme weather events impact the county, and how local government and the community respond.

2.2.3 VCAPS Workshops (February 23-24, 2016)

Trained facilitators led participants in a two-day conversation about how specific infrastructure, communities, and other areas of concern are affected by climate change. Dr. Donald Boesch, Professor of Marine Science and President of the University of Maryland Center for Environmental Science (UMCES) gave participants an overview of climate science as well as the occurring and expected impacts of climate change in Maryland. The participants then worked through VCAPS diagramming exercises focusing on cause and effect relationships between climate stressors and local consequences. At the heart of VCAPS is a visual diagram that is co-created by participants based on their experiences and their understanding of climate science. Starting with a **climate hazard stressor** (heat, precipitation, flooding, etc.), participants created scenarios for many **management concerns** (infrastructure, public health, homes, community assets). The scenarios may contain several **outcomes** and **consequences** in a causal chain (Figure 6). At any step along the chain, there may be **public and private actions** that can mitigate the impact of the natural hazard. Three main diagrams emerged from the diagramming workshops, oriented around winter storms, extreme heat, and the several types of flooding encountered in Kent County (Appendix C).

Figure 6. Components of the VCAPS diagram.



Source: Carolinas Integrated Sciences and Assessments (CISA). www.vcapsforplanning.org

2.3 Public Information Session

[This section to be completed following the Public Information Session on August 24, 2016.]

Section 3. Preparedness and Resilience Actions

The following sections describe twenty-one adaption actions that were identified by study partners and participants through the VCAPS process. The actions have been organized into eight categories. Each entry presents the actions recommended by the VCAPS participants ("stakeholders") and recommended actions that the county may wish to consider.

3.1 Cooperation and Collaboration (CC)

Action CC-1: Interdepartmental Cooperation

Improve coordination and collaboration among county departments.

Many county departments have jurisdiction over, responsibility for, or an interest in community assets that will be affected by climate change and rising sea levels. Encouraging departments to communicate and coordinate their activities with respect to infrastructure, policies, and vulnerable communities can increase the county's ability to prepare for and respond to climate change hazards.

Concern

- "Siloed" decision making can overlook systemic vulnerabilities as well as opportunities for collaboration.

Recommended Action

- Continue inter-departmental conversations about managing climate risks to infrastructure and vulnerable communities.

Additional information

- Several participants in the study noted that the VCAPS diagramming workshop was one of the most collaborative and productive experiences they have had while working for the county government. There is an opportunity to continue this momentum, both in regards to reducing climate risks and in other areas of county operations.

Action CC-2: New Partnerships

Explore new partnerships to increase resilience.

This study brought together municipal, county, regional, and state partners as well as partners from outside Maryland. These and other new partnerships can be cost effective ways to alleviate gaps in technical expertise and staff capacity when addressing climate hazards.

Stakeholders' recommended actions

- Revive and strengthen partnerships with Red Cross and other aid organizations.
- Maintain mutual aid agreements and protocols with surrounding counties and towns to ensure continuity of fire, EMS, and public safety services during storms.

- Seek partnerships to review historic preservation ordinance for ways to increase resilience of historic structures (see also the Annapolis Coast Smart project).

3.2 Community Resilience (CR)

Action CR-1: Vulnerable Populations

Identify and assist vulnerable populations and communities.

Specific consideration of how to communicate with and provide services to Kent County's vulnerable communities can mitigate injury or loss of life during extreme weather events.

Concern

- Particular groups may have increased vulnerabilities to climate hazards due to their location, age, health, income, or primary language.

Stakeholders' recommended actions

- Continue efforts by the Department of Social Services and the Faith-Based Emergency Committee to identify and assist residents with special needs (e.g. medical, transportation, cooling/air conditioning/warming assistance) during extreme weather events.
- Increase residents' awareness about cooling locations and transportation assistance.

Additional information

- Several church groups in Kent County have detailed knowledge about residents who have special needs (e.g. require oxygen, need to be checked on during heat emergencies, etc.).

Action CR-2: Community Preparedness

Cultivate a culture of responsibility and contribution.

Participants noted residents' spirit of self-reliance and willingness to assist neighbors during emergencies. Encouraging this spirit and generosity can increase the community's resilience to extreme weather and allow the county to direct services to where they are needed most.

Stakeholders' recommended actions

- Encourage residents to know and manage their risks if they buy property in a low-lying area.
- Encourage property owners on private roads to consider upgrading to blacktop when road resurfacing is necessary.
- Encourage residents to remove snow or debris on sidewalks and around hydrants promptly following a storm.
- Encourage homeowners to clean, mow, and maintain swales and ditches on their property.

Additional recommended actions

- Support "riverwatcher" groups and encourage recordkeeping of water levels, king tides, and storm tides.

3.3 Education, Information, and Outreach (EO)

Action EO-1: Flood Risk Awareness

Inform residents and real estate sector of flood hazards.

When homeowners and potential homebuyers have information about flood hazards on their property, they are better equipped to make decisions about how to reduce their risk and plan for emergency situations. This can reduce the burden on emergency responders during a flood event, reduce damage and losses, and increase the county's ability to "bounce back" following an event.

Concern

- Residents, seasonal residents, and visitors may not fully understand flood risks or how to reduce their risk.

Stakeholders' recommended actions

- Improve flood risk awareness of homeowners and potential homebuyers.
- Improve flood risk awareness for realtors, surveyors, builders, and engineers.
- Improve flood risk outreach to vulnerable communities and hard-to-reach populations.
- Place high water signage on vulnerable bridges & roads.

Resources

- South Carolina Guide to Beachfront Property: http://www.scdhec.gov/library/CR-003559.pdf

Action EO-2: Property Maintenance

Educate and encourage residents to maintain common infrastructure on their property.

Community assets such as ditches, sidewalks, and fire hydrants are often located on private property. By maintaining access to these assets, residents can help preserve the assets' functionality, which reduces costs to the county and allows services to be directed where they are needed most.

Concerns

- Poorly maintained ditches can become clogged with vegetation and debris.
- Ice accumulates when snow is not removed in a timely manner from sidewalks and around fire hydrants.

Stakeholders recommended actions

- Improve visibility of hydrants and signage to encourage snow removal by property owners.
- Use social media and email reminders to clear snow from sidewalks.
- Encourage residents to maintain vegetation near power lines.
- Encourage residents to clear debris from around sump pumps and not to drain sump pumps to sewers.

- Encourage property owners to keep flood vents clear and to anchor buoyant structures and storage tanks.

Action EO-3: Shoreline Erosion

Educate and encourage shoreline property owners to stabilize erosion prone areas.

Practices that stabilize shoreline erosion can protect against property loss and improve water quality in the Chesapeake Bay and tributaries.

Concerns

- Land loss from erosion can expose structures to increased flood risk.
- Soil loss from erosion can decrease water quality in rivers and the Bay.

Stakeholders' recommended actions

- Develop a homeowner education program for shoreline stabilization and maintenance of Critical Area buffers.
- Encourage homeowners to adopt natural or nature-based shoreline erosion control practices (e.g. living shorelines, native plantings, and buffers).

3.4 Emergency Management (EM)

Action EM-1: Cooling Centers

Facilitate access to cooling centers for at-risk populations during heat emergencies.

Cooling centers are critical during high heat emergencies. By facilitating access and transportation to cooling centers, the number of heat illnesses may be reduced, which may also lower costs for emergency medical services.

Concerns

- For residents who do not have air conditioning, extended periods of high temperatures may not allow home interiors to cool down at night, increasing risk of heat illness.
- Vulnerable groups may not have access to transportation to cooling centers.

Stakeholders' recommended actions

- Increase public awareness of public buildings (community center, library, etc.) where residents can seek relief from heat.
- Expand and maintain a contact list of vulnerable groups to inform that cooling centers are open and to ensure special needs and concerns are met (e.g. summer camps, residents with health needs, seniors, and faith communities)
- Use email, Facebook, and other social media to notify public about heat alerts and emergency cooling center locations and hours.
- Encourage residents to check on neighbors during heat emergencies.

3.5 Infrastructure and Maintenance (IM)

Action IM-1: County Employees

Plan for a safe and productive work environment for outdoor and offsite employees during weather emergencies and high heat days.

By taking actions to improve communication and to protect employees during inclement and extreme weather events, the county can improve employee safety, productivity, and emergency response.

Concerns

- Outdoor employees are exposed to environmental working conditions (e.g. high heat, snow, rain, thunderstorms) that may be unsafe, reduce productivity, or degrade morale.
- Employees who travel offsite or out of the county may not be notified in a timely manner of unfolding emergencies (e.g. thunderstorms, flooding), which may put their safety at risk or, if they are critical operations personnel, may degrade emergency response.

Stakeholders' recommended actions

- For outdoor employees, start work earlier in the day and schedule tasks to avoid the hottest time of day.
- Consult week-long weather forecast when making weekly work plans (NOAA seasonal outlooks).
- Identify weather thresholds for when it is too dangerous to work outside.
- Provide fluids and shade to work crews.
- Encourage outdoor employees to wear lightweight clothing.

Additional recommended actions

- Generate and formalize extreme weather operations plans (for high heat, extreme cold, and storms) with input from county staff, health department, and emergency services.
- Develop and implement an emergency communication system to warn outdoor and out-of-county employees of impending weather emergencies (tornadoes, strong storms, etc.).

Action IM-2: Road and Bridges

Maintain structural safety and functional condition of roads and bridges.

With planning, upgrades, and maintenance that anticipates future conditions (temperatures, extreme precipitation, and water levels), transportation infrastructure can retain its function and safety for residents, visitors, and, most importantly, emergency access.

Concerns

- Tar-and-chip roadways may become unstable or damaged during extended periods of high heat, resulting in repair costs and impaired access by residents and emergency services.

- Washed out roadways, bridges, and culverts result in repair costs and impaired access by residents and emergency services.

Stakeholders recommended actions

- Upgrade roads with slurry seal or blacktop.
- Continue beaver dam control near vulnerable roads and infrastructure.

Additional recommended actions

- Coordinate scour and debris checks on bridges and infrastructure following storm events among responsible agencies.

Action IM-3: Electrical System

Protect the electrical transmission system from hazards.

Ensuring the continuity of electrical supply can minimize disruption to residents and reduce medical and fire emergencies.

Stakeholders' recommended actions

- Where possible, bury power lines that are in vulnerable areas.
- Maintain vegetation near power lines.

Additional recommended actions

- Encourage underground utilities in new subdivisions and new construction.

Action IM-4: Water Systems

Ensure functional operation of water system under heavier flows.

Ensuring that drinking water and wastewater systems can accommodate more frequent and higher flows may prevent system downtime, damage, contamination, or discharges, which can lower repair costs and fines, and minimize service disruptions for residents and visitors.

Concern

- Future 1% chance 1-hour precipitation rates may surpass today's design standards, exposing the water system to more frequent conditions that exceed its capacity.

Stakeholders' recommended actions

- Locate and disconnect remaining downspouts and sump pumps that feed to sewer pipes.

Additional recommended actions

- Periodically review (for example, every 5 years) the 1% chance 1-hour precipitation assumptions in water system design standards to ensure adequate capacity of the system and its components (pipes, pumps, plants) to handle changing precipitation expectations.

Additional information

- According to the 2009 International Building Code, the 1% chance ("100-year") 1-hour precipitation rate for Kent County is 3.25 inches per hour.[11] Current design standards in Kent County accommodate a maximum of 4 inches per hour. Future 1% chance 1-hour precipitation rates may become higher.
- An extreme rainfall event on July 30, 2016 in Ellicott City, Maryland dropped 4.56 inches of rain in 1 hour and 5.92 inches in 2 hours[12], exceeding the 0.1% chance ("1,000-year") storm event. Extensive flooding resulted in two deaths and substantial property damage.

3.6 Planning and Decision-making (PD)

Action PD-1: Data Integration

Incorporate state and federal data resources into county planning processes.
Ready access to the latest climate and vulnerability information can facilitate sound, data-based decision making.

Concern

- Information gaps may slow decision making processes or may lead to policies that fail to remedy the intended problem.

Stakeholders' recommended actions

- Incorporate the State Highway Administration's road & bridge inundation inventory into county data and plans (e.g. capital investment plan, comprehensive plan, hazard mitigation plan, floodplain ordinance, etc.).
- Incorporate the U.S. Army Corps of Engineers SLOSH model storm surge data and Maryland state sea level rise guidance into planning documents and processes (e.g. capital investment plan, Comprehensive Plan, Hazard Mitigation Plan, floodplain ordinance, etc.).

Additional recommended actions

- Identify data needs for upcoming planning processes and seek partnerships (e.g. with academic institutions or neighboring communities) to acquire the information more cost-effectively.

Action PD-2: Capital Investment

Develop a capital investment and maintenance plan that anticipates climate change impacts.
Accounting for the environmental conditions (heat, precipitation, water levels) that are expected during the lifetime of a capital project or equipment purchase can maximize the benefit of the taxpayers' investment by reducing downtime and avoiding future repair or early replacement costs.

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[11] http://publicecodes.cyberregs.com/icod/ibc/2009f2cc/icod_ibc_2009f2cc_16_par116.htm
[12] National Weather Service. https://nwschat.weather.gov/p.php?pid=201607311619-KLWX-NOUS41-PNSLWX

Concerns

- Some existing county infrastructure does not have adequate capacity to function properly under environmental conditions that are expected during its lifetime.
- By failing to consider conditions that are likely to arise during an asset's lifetime, new systems risk being under-designed for extreme weather conditions.

Stakeholders' recommended actions

- Develop a 5-year maintenance and upgrade plan (modeled after the county's water infrastructure maintenance plan) for major building systems (e.g. HVAC, groundwater elevation control) with additional capacity for higher outdoor temperatures, higher cooling loads from electronics, and increased precipitation rates.

Additional recommended actions

- Develop a capital investment plan ensuring that new facilities, equipment (building systems, emergency vehicles), and projects (road upgrades, water/wastewater infrastructure) are adequately designed for future conditions that are expected during the asset's lifetime. Protect taxpayers' investment by including climate projections in decisions about each asset's siting, design, capacity, and operations.

Action PD-3: Historical, Cultural, and Recreational Assets

Develop a process for determining which assets to protect, move, save, or abandon.

For some community assets and infrastructure, difficult decisions will need to be made about whether and how to preserve their function. A proactive and transparent decision making process can increase the likelihood that sound choices will be made

Concern

- After an extreme event, decisions about saving or restoring damaged community assets are often made in the face of time pressures, insufficient information, elevated emotions, and other stresses, which may result in choices that are regretted later on.

Stakeholders' recommended actions

- Develop a process for determining whether and how vulnerable infrastructural, historical, cultural, and recreational assets can be protected in place, moved, or abandoned.

Additional recommended actions

- Develop a post-disaster redevelopment plan (PDRP) to guide smart rebuilding following a storm event or other natural disasters.[13]

[13] Kent County has a local Recovery Plan that guides immediate, short, and long term recovery from a catastrophic event. Kent County also participates in the Upper Eastern Shore Regional Recovery Plan, a first in Maryland, with Caroline, Cecil, Queen Anne's, and Talbot counties, which coordinates mutual aid and other forms of support during and following a regional catastrophe. The PDRP recommended here might pick up where recovery planning leaves off by informing smarter ways to redevelop neighborhoods and commercial areas so that repetitive losses are avoided in the future.

- Enhance existing and develop additional Comprehensive Plan resilience strategies that are informed by the County's Hazard Mitigation Plan.

Resources

- Sarasota County, Florida Post-Disaster Redevelopment Plan: https://www.scgov.net/pdrp/Pages/default.aspx
- Florida Post-Disaster Redevelopment Guidebook for local jurisdictions: http://floridadisaster.org/Recovery/documents/Post%20Disaster%20Redevelopment%20Planning%20Guidebook%20Lo.pdf
- Florida PDRP Initiative: http://floridadisaster.org/Recovery/IndividualAssistance/pdredevelopmentplan/Index.htm
- Post-Disaster Redevelopment Planning Toolkit: http://www.floridajobs.org/community-planning-and-development/programs/community-planning-table-of-contents/post-disaster-redevelopment-planning/toolkit

3.7 Land Use and Land Management (LU)

Action LU-1: Shoreline Stabilization

Protect shoreline assets and prevent erosion.

Protecting erosion-prone shoreline areas can preserve valuable land area, mitigate flooding, and preserve options for property owners who face rising water levels.

Concerns

- Shoreline erosion degrades the protective, flood buffering area between the water and structures on land.
- Existing coastal infrastructure may be inadequate for higher tides, floods, and flood frequency that will result from sea level rise.

Stakeholders' recommended actions

- Encourage and prioritize natural and nature-based erosion control options like living shorelines and native plantings.
- Design with additional elevation when repairing or upgrading county bulkheads, retaining walls, jetties, riprap, and docks to preserve function with rising water levels.

Action LU-2: Building Codes

Reduce flood risk.

The county's existing flood mitigation requirements (anchoring, flood vents, 2-foot freeboard elevation or flood proofing) could be strengthened to ensure newly constructed and significantly improved buildings are adequately prepared for flood conditions that can be expected in their lifetimes.

Concern

- The county's existing floodplain regulations and building codes do not prepare residents and businesses for higher flood levels in the future due to sea level rise. Buildings that are constructed to today's standards may not be adequately prepared for flooding conditions that are expected during their lifetime.

Stakeholders' recommended actions

- Explore the feasibility of a 3-foot freeboard requirement for new construction and significant improvements in order to be consistent with federal guidance.

Additional recommended actions

- Adopt higher regulatory standards in floodplain. For example, the current floodplain requirements identify a flood protection elevation (FPE), or "freeboard", of two (2) feet above the flood elevation, which is less stringent than the federal guidance. In accordance with the inundation models, the County should consider a higher FPE standard. Additional examples of higher standards include requiring elevation certificates for all structures or Limit of Wave Action (LimWA) setbacks for new construction in the floodplain.
- For all real property transactions, require an elevation certificate and disclosure of flood risk, Critical Area buffers, steep slopes, and wetlands.

Resources

- Federal Flood Risk Management Standard: http://www.fema.gov/media-library-data/1422649643416-c0ff9e51d11442790ab18bae8dc5df4b/Federal_Flood_Risk_Management_Standard.pdf

Action LU-3: Floodplain Mapping

Identify, map, and mitigate areas of future flood risk.

Knowing and visualizing which locations will experience new or increasing flood risk in the future can help guide the county's decisions today about siting and constructing buildings that are safe for future occupants and can maintain function in future conditions.

Concern

- Areas that may be exposed to new flooding in the future are not currently mapped. Design, siting, and construction decisions for those areas are not adequately considering future expected flood risk.

Stakeholders' recommended actions

- Determine whether the cost of challenging FEMA's new flood maps is worthwhile.

Additional recommended actions

- Promote awareness of assets and resources located within the 0.2% chance ("500-year") floodplain that may become increasingly at risk due to sea level rise. Currently, properties located within the 0.2% chance floodplain are neither required to meet floodplain requirements nor carry flood insurance. A disclosure regarding such properties should be developed to better-inform residents of their vulnerability and protection options.

- Consider adopting an expanded floodplain (i.e. including the 0.2% chance "500-year" floodplain) or a "coastal resilience overlay zone" for greater protection from sea level rise and an increased margin of safety against errors in FEMA flood risk maps.
- Create a prioritized list of properties for land acquisition for flood mitigation, conservation, buffering, etc. (see Kent County Hazard Mitigation Plan).
- Implement the Prioritized List of Mitigation Projects (Crosswalk) identified in the Hazard Mitigation Plan.

3.8 Research and Data (RD)

Action RD-1: Road Upgrades

Assess alternative road construction methods and materials.

In order to make sound decisions about road surface upgrades, the county will need information on cost, durability, heat tolerance, and other factors for various road construction methods and materials.

Concerns

- Current tar-and-chip road construction may not be suitable for extended periods of high temperatures in the future.
- The cost of upgrading all of the county's road surfaces is high.

Stakeholders' recommended actions

- Conduct cost and lifetime analyses for different road materials. (Testing is planned this year for a new slurry-seal product.)
- Inventory, assess, and prioritize roads for upgrade to more heat tolerant construction and materials.

Action RD-2: Bridge and Road Inventory

Create an inventory of road segments and bridges that are vulnerable to flooding.

A prioritized inventory of vulnerable roads and bridges will help plan upgrades or relocations that prepare the county for future water levels and flood risks. The inventory will allow the county to budget funds and resources to upgrades over a long time horizon, rather than responding to multiple washouts after an emergency.

Concerns

- Roads and bridges that become impassable due to flooding are disruptive to residents, visitors, business, emergency response, and county services.
- Repeated and prolonged inundation can damage road beds and surfaces, resulting in high repair costs and community disruption.

Stakeholders' recommended actions

- Inventory bridges and roads that will be vulnerable under sea level rise and storm surge scenarios.
- Explore options for alleviating flooding on vulnerable roads (e.g. elevating, rerouting, or abandoning road segments).

Resources

- MD State Highway Administration and the Eastern Shore Regional GIS Cooperative at Salisbury University have partnered to produce an inventory of road inundation locations for several sea level rise scenarios for each county in the state. The inventory should be available in late 2016.

Action RD-3: Washout Impacts

Assess impacts of road and bridge washouts to emergency response.

Emergency response can be improved during storm events by identifying and upgrading critical choke points, particularly along single access routes.

Concerns

- Communities, residents, businesses, and property are, at best, inconvenienced or, at worst, much more vulnerable if washed out or inundated roads and bridges limit access or cause lengthy detours for emergency responders.
- One-road-in / one-road-out locations are at risk of being severed from emergency services.

Stakeholders' recommended actions

- Assess the impact of washouts on emergency response times and identify alternatives.

Appendix A. Sea Level Rise Impact GIS Analysis

ESRGC
Eastern Shore Regional GIS Cooperative
Salisbury University 1101 Camden Avenue Salisbury, Maryland 21801
410.677.5390 www.esrgc.org

Flood Mitigation Study for Kent County, Maryland
July 2016

The Eastern Shore Regional GIS Cooperative (ESRGC) undertook a sea level rise study for Kent County, Maryland to support the mitigation of damage to structures due to sea level change. Sea level change refers to the combined forces of land surface subsidence and rising sea levels. This study uses the projected stillwater surface of Mean Sea Level (MSL) for three identified scenarios in an attempt to aid in identifying structures vulnerable to sea level change. The scenarios defined by Kent County include the MSL in 2050 (2.1 feet), the MSL in 2100 (5.7 feet), and the MSL in 2050 during a Category 1 flood event (7.6 feet). Each product forecasts the areas of inundation and represents the new "zero elevation" for the future scenario.

Methodology:
The US Army Corps of Engineers (USACE) provided the sea level change (SLC) estimate. SLC was localized during water elevations collected from a qualifying National Oceanic and Atmospheric Administration (NOAA) tidal reference station. NOAA observations were transformed from tidal datum to North American Vertical Datum of 1988 (NAVD88). A final correction for glacial isostatic adjustment and land subsidence was applied to create an SLC value for the official project year, 2015. The 2015 LiDAR contributed to a county-wide digital elevation model (DEM). The LiDAR-derived DEM is the base from which the SLC value is applied.

A modified "bathtub" model was employed to determine the areas likely inundated by the three identified scenarios. All pixels in the DEM with an elevation value at or below the predicted SLC rate were reset to zero. To ensure the "local minima" were excluded, a county network model of stream flowlines was created from the National Hydrography Dataset (NHD). The connectivity of a predicted inundation area was tested against the network to ensure Chesapeake Bay influence.

Kent County provided the structure footprints used for this study. The structure footprints are a combined layer for addressable and non-addressable building layers from the 2006 delivery of E-911 data. Sporadic updates have been attempted but the layer remains largely current as of 2006, however, structures within the 500 year floodplain have been updated. Structures within the 500 year floodplain include the attribute "FLOOD" in the field named "Flood."

Structure Inundation:
Flood depths were classified into six inch intervals and a cascading intersection was used to identify impacted structures for each scenario. The cascading intersection process selects structures that intersect the shallower flood polygons first and increases to the deeper flood polygons, therefore shallower depths are overwritten as the maximum depth per structure is identified. Through this process a structure that intersects multiple flood depths is assigned the greatest depth. Each structure has a depth category for all three scenarios identified by Kent County. Images 1 – 6 show each scenario and identify a structure to highlight the greatest flood depth assignment to the structure.

A future update of the structures using recent imagery is recommended for the areas within the three depth polygons. While Kent County notes the structures within the 500 year floodplain have been updated more recently, a significant update to the structure layer would produce more accurate estimates of structures impacted by the three identified scenarios.

Image 1 – Scenario 1 Depth Categories

Although the structures below intersect several depths, each structure is assigned the greatest depth category to determine the maximum depth for each structure.

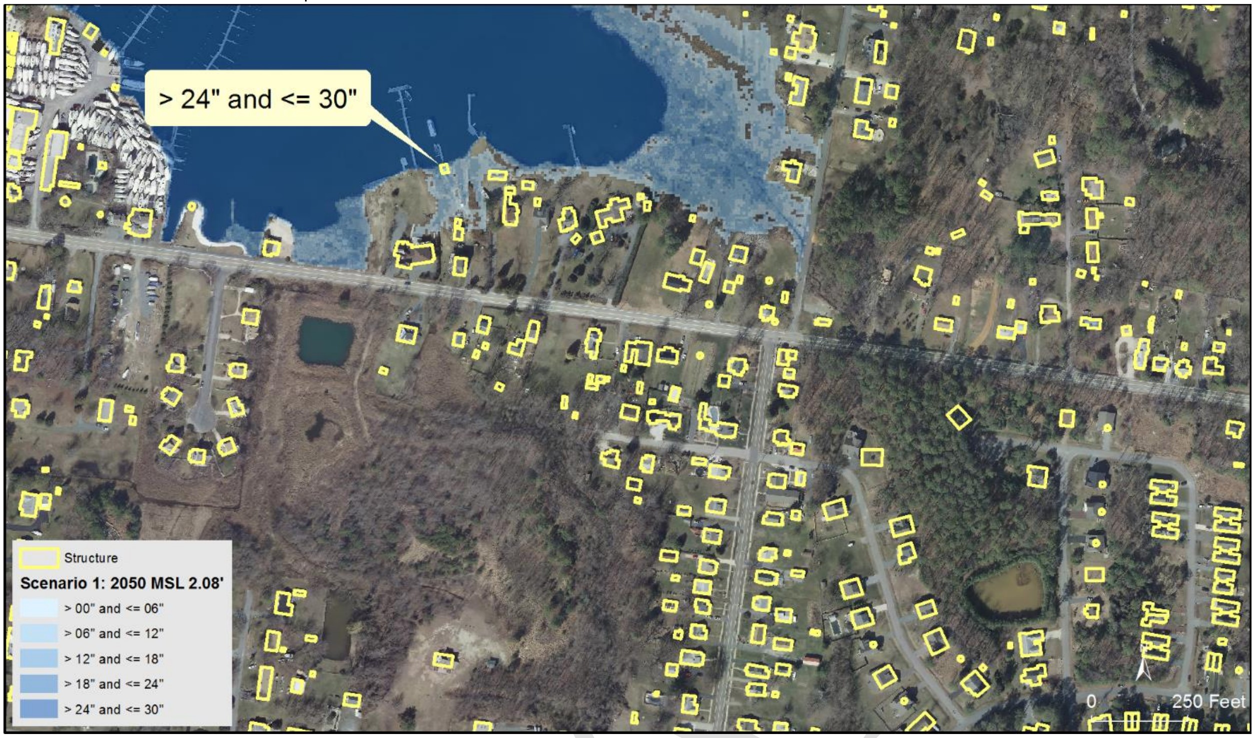


Image 2 – Scenario 1 Depth Categories (detailed)

This image shows multiple depth categories for the identified structure. The structure was assigned the greatest depth category to determine the maximum depth.

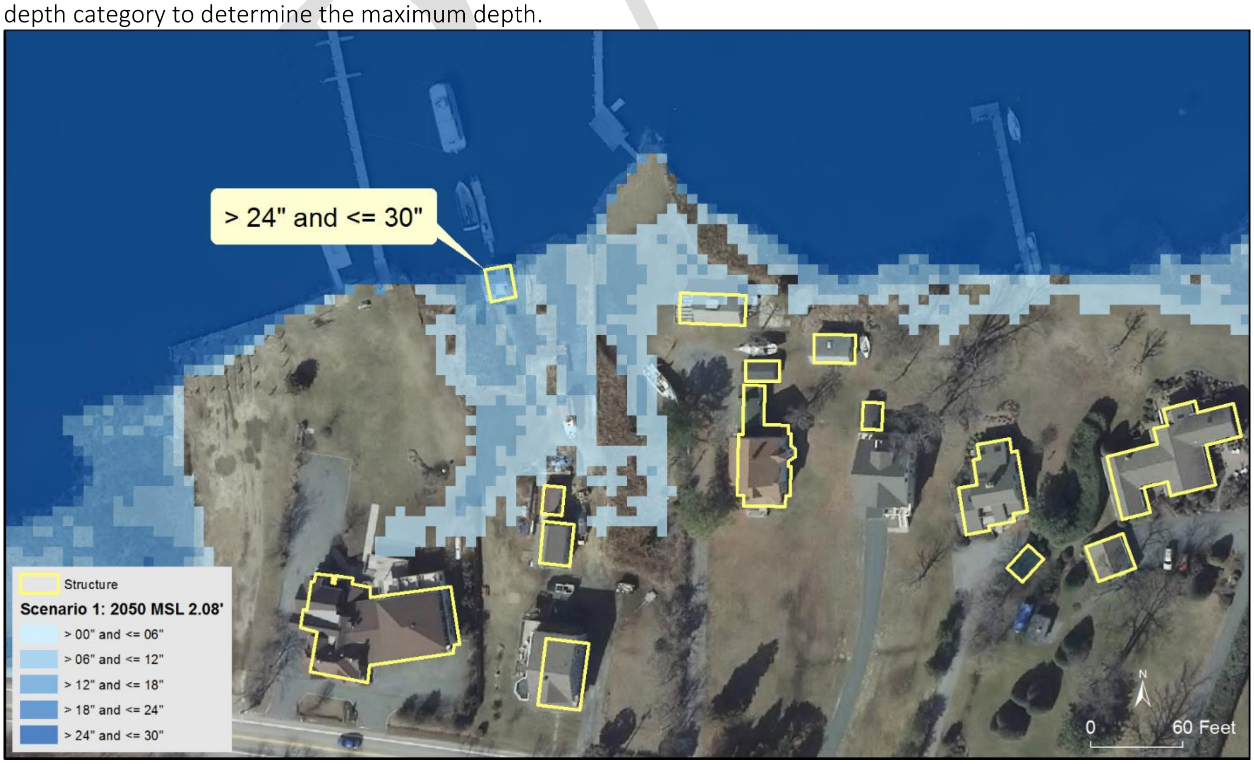


Image 3 – Scenario 2 Depth Categories

Although the structures below intersect several depths, each structure is assigned the greatest depth category to determine the maximum depth for each structure.

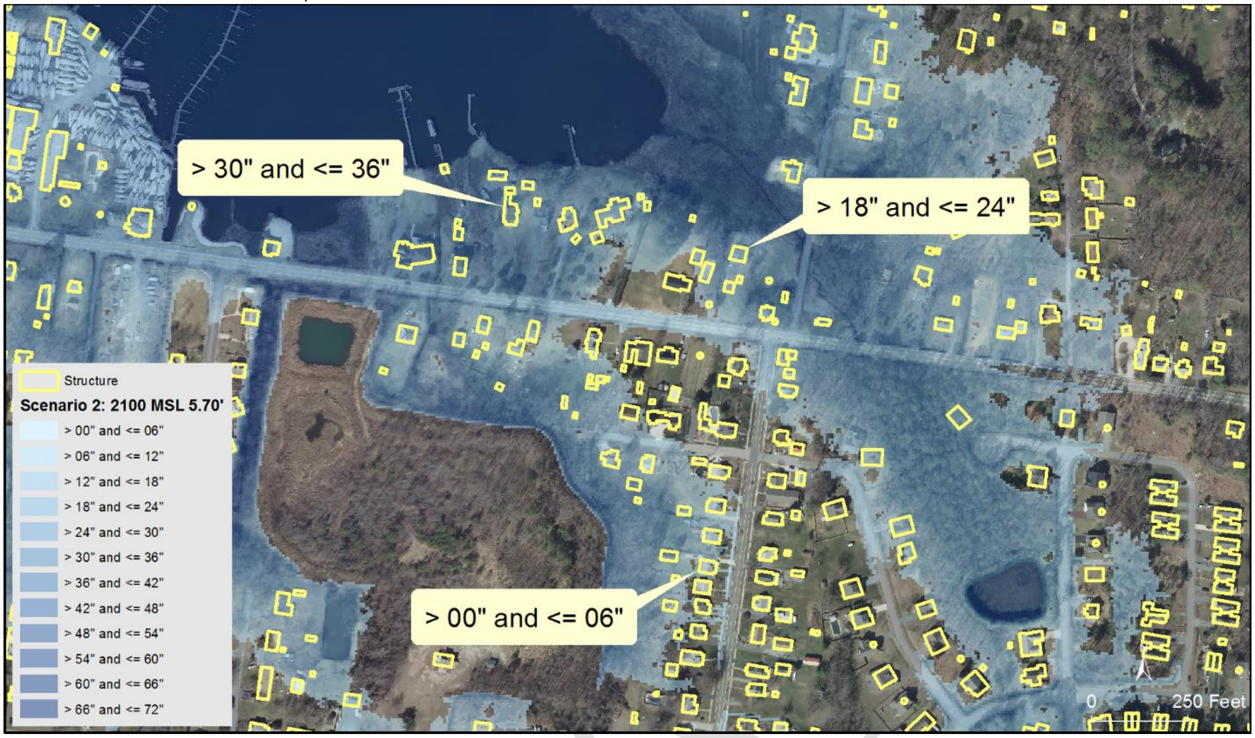


Image 4 – Scenario 2 Depth Categories (detailed)

This image shows multiple depth categories for the identified structure. The structure was assigned the greatest depth category to determine the maximum depth.

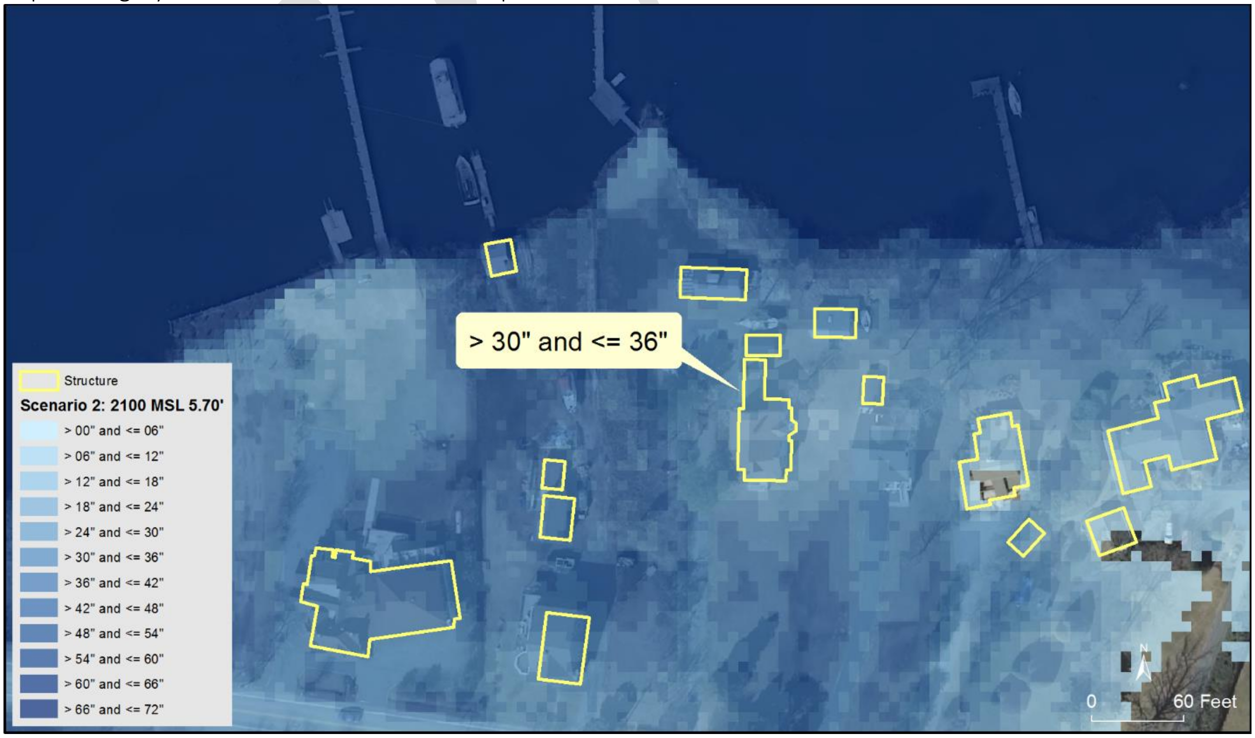


Image 5 – Scenario 3 Depth Categories

Although the structures below intersect several depths, each structure is assigned the greatest depth category to determine the maximum depth for each structure.

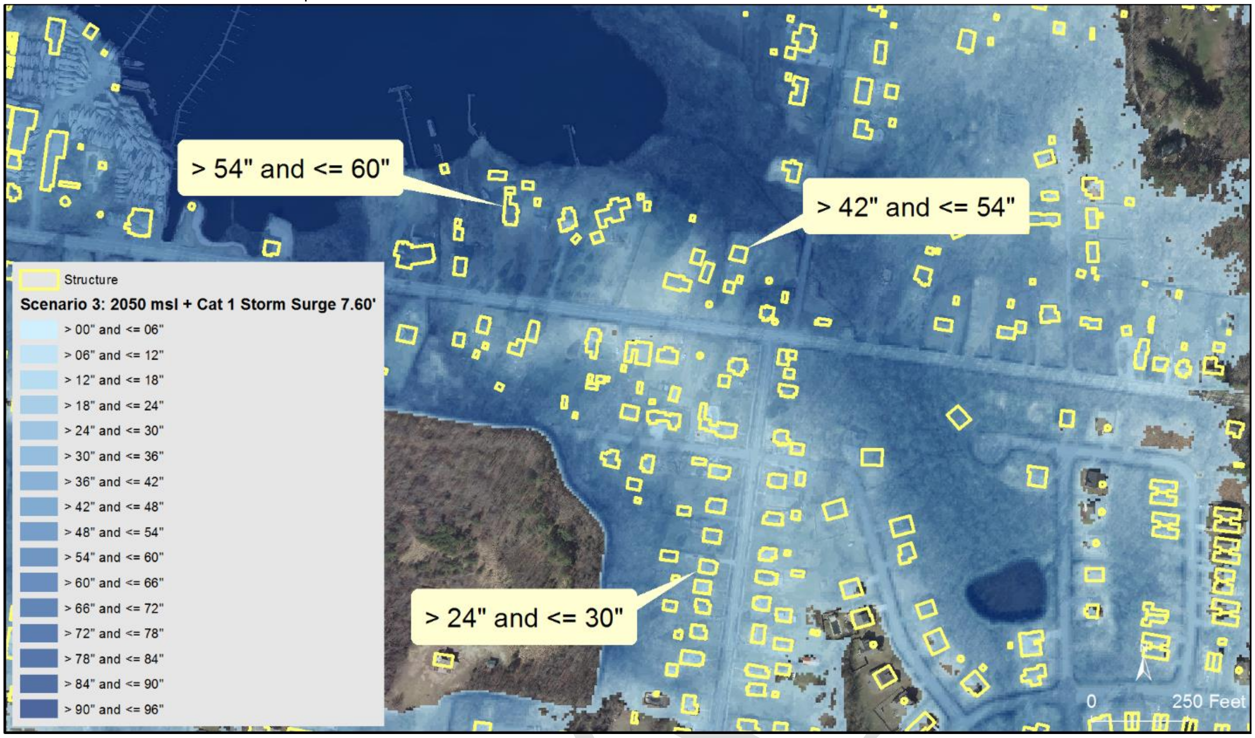


Image 6 – Scenario 3 Depth Categories (detailed)

This image shows multiple depth categories for the identified structure. The structure was assigned the greatest depth category to determine the maximum depth.

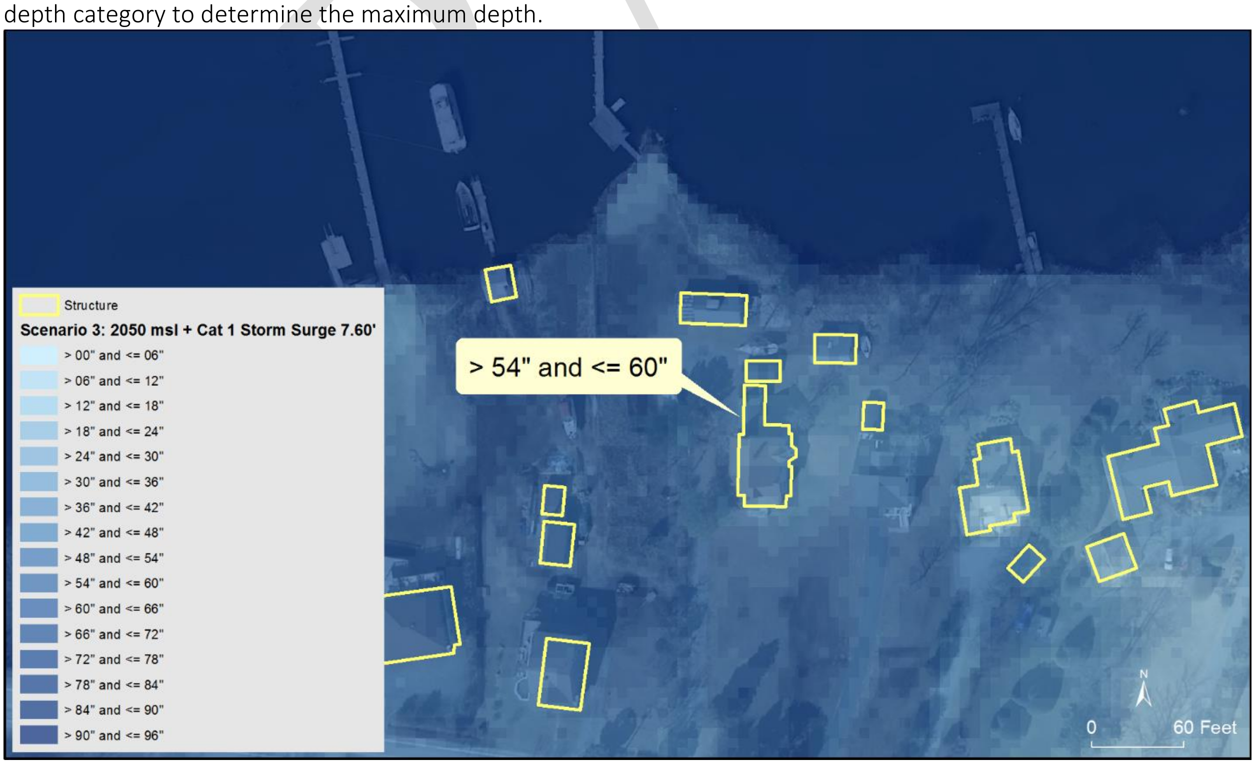


Table 1 – Scenario 1: 2050 Mean Sea Level

Six Inch Depth Classification	Description of Interval	Number of Structures Impacted
1	> 00" and <= 06"	29
2	> 06" and <= 12"	13
3	> 12" and <= 18"	9
4	> 18" and <= 24"	7
5	> 24" and <= 30"	128
Total Number of Structures Impacted		**186**

Number of structures not impacted: 25,218

Table 2 – Scenario 2: 2100 Mean Sea Level

Six Inch Depth Classification	Description of Interval	Number of Structures Impacted
1	> 00" and <= 06"	182
2	> 06" and <= 12"	226
3	> 12" and <= 18"	0
4	> 18" and <= 24"	425
5	> 24" and <= 30"	195
6	> 30" and <= 36"	154
7	> 36" and <= 42"	113
8	> 42" and <= 48"	64
9	> 48" and <= 54"	22
10	> 54" and <= 60"	12
11	> 60" and <= 66"	9
12	> 66" and <= 72"	128
Total Number of Structures Impacted		**1,530**

Number of structures not impacted: 23,874

Table 3 – Scenario 3: 2050 Mean Sea Level and Category 1 Flood Event

Six Inch Depth Classification	Description of Interval	Number of Structures Impacted
1	> 00" and <= 06"	175
2	> 06" and <= 12"	196
3	> 12" and <= 18"	225
4	> 18" and <= 24"	245
5	> 24" and <= 30"	219
6	> 30" and <= 36"	218
7	> 36" and <= 42"	235
8	> 42" and <= 48"	197
9	> 48" and <= 54"	182
10	> 54" and <= 60"	157
11	> 60" and <= 66"	99
12	> 66" and <= 72"	62
13	> 72" and <= 78"	12
14	> 78" and <= 84"	11
15	> 84" and <= 90"	7
16	> 90" and <= 96"	128
Total Number of Structures Impacted		**2,368**

Number of structures not impacted: 23,036

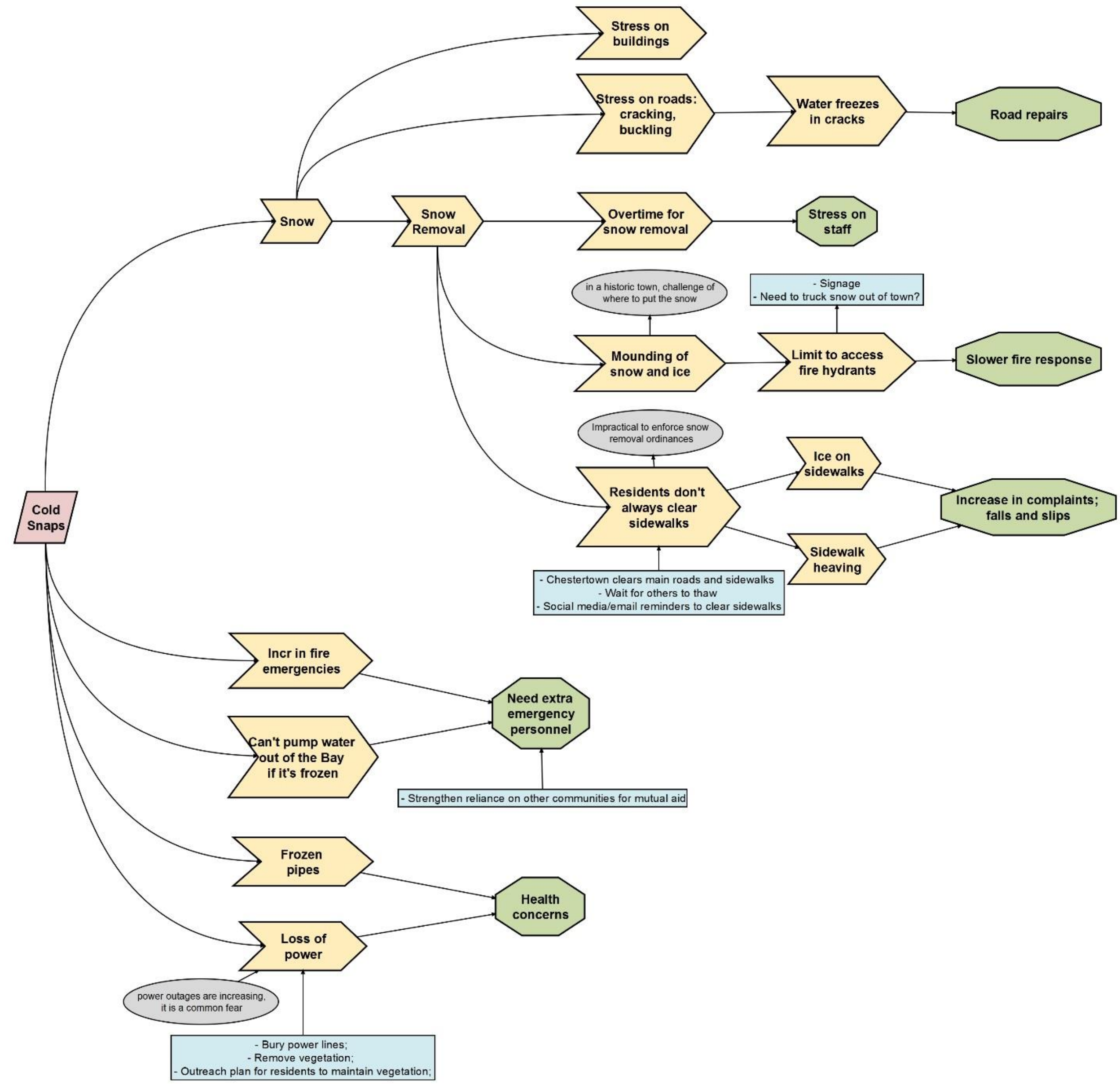
Appendix B. VCAPS Participants

Name	Title	Department/Organization
Amy Moredock	Director	Department of Planning, Housing and Zoning
Rick Myers	Chief Enforcement Officer / Floodplain Manager	Department of Planning, Housing and Zoning
Stephanie Jones	Environmental Planner	Department of Planning, Housing and Zoning
Ginger Gregg	Emergency Management Planner	Office of Emergency Services
Wayne Darrell	Director	Office of Emergency Services
James M. Wright	County Engineer	Department of Public Works
Daniel Voshell	Director	County Roads
Mike Wojton	Director	Department of Water & Wastewater Services
Bob Merritt	Building Maintenance Supervisor	Department of Public Works
Mark Dixon	Grounds Maintenance Supervisor	Department of Public Works
Marty Holden	Director	Environmental Operations Department
Charlene Perry	Director, Emergency Preparedness	Health Department
John Beskid	Director, Environmental Health Services	Health Department
Ronald Fithian	County Commissioner Town Manager	Kent County Board of Commissioners Rock Hall
Chris Cerino	Mayor	Chestertown
Donald Sutton	Mayor	Betterton
Claude "CJ" Morales	Mayor	Millington
Kees de Mooy	Zoning Administrator	Chestertown
Briggs Cunningham	Center for Environment & Society	Washington College

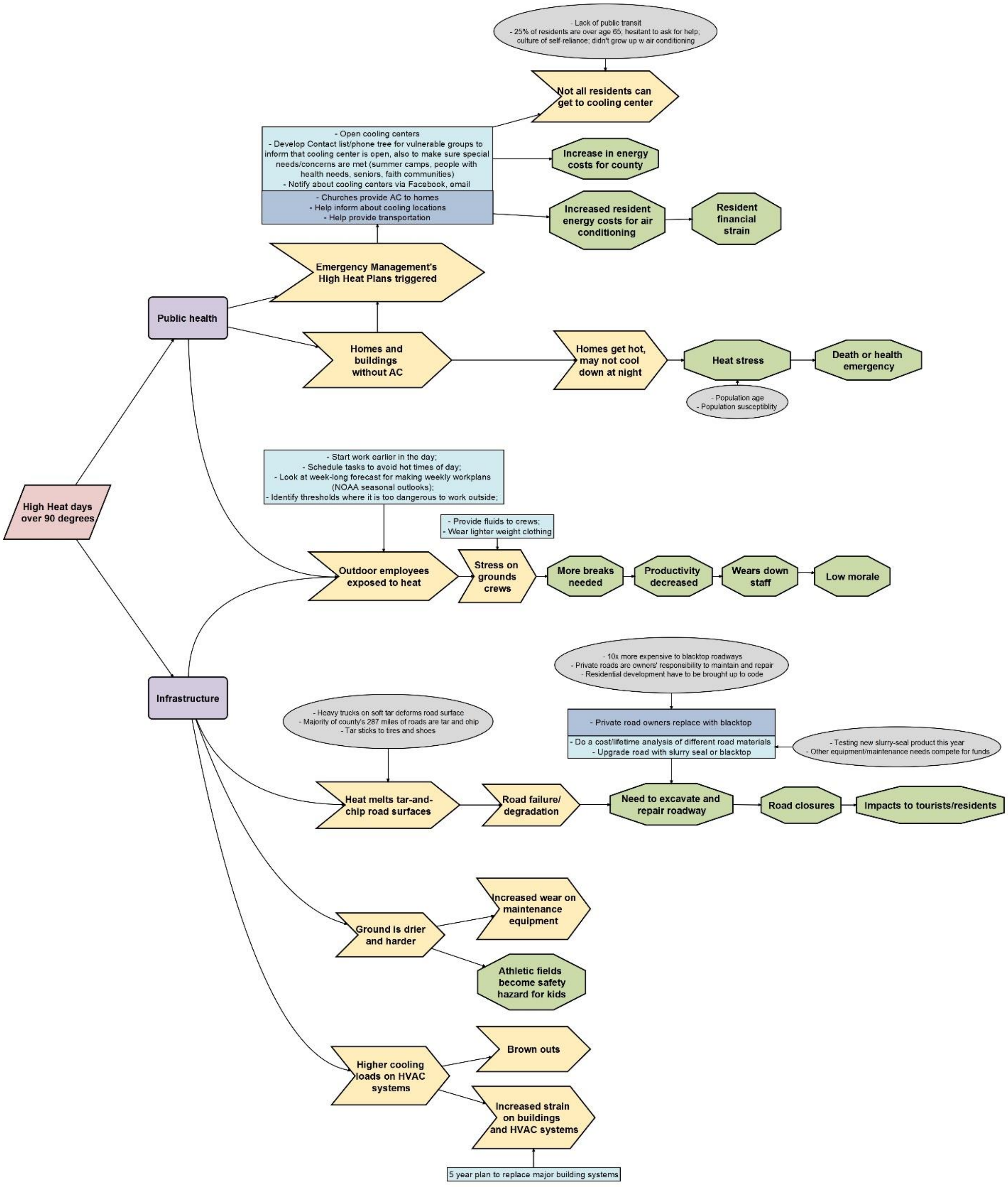
Richard Budden	Realtor	Chesapeake Bay Association of Realtors
Karen Miller	District Manager	Soil & Water Conservation District
Joe Blizzard	Sediment & Erosion Control	Soil & Water Conservation District
Isabel Junkin Hardesty	Riverkeeper	Chester River Association
Emmett Duke	Riverkeeper	Sassafras River Association
Trey Hill	Partner / Farmer	Harborview Farms
Chuckie White	President	Waterman's Association
Joe Hickman	Owner / Farm Manager	Francis J. Hickman Farm Management and Consultation
Joe Miketta, Dean Iovino, Mitchell Green	Meteorologists	National Weather Service, Mt Holly, New Jersey
Wayne Gilchrest	Program Director	Sassafras Environmental Education Center
Sean Jones	Owner / Manager	Jones Family Farm
Madeleine Russell	Assistant Local Government Outreach	University of Georgia Marine Extension & Georgia Sea Grant
Jennifer Dindinger	Watershed Restoration Specialist	University of Maryland Extension
Dr. Donald Boesch	President	University of Maryland Center for Environmental Science
Kate Skaggs	CoastSmart Communities Planner	Maryland Department of Natural Resources

Appendix C. VCAPS Diagrams

C.1 Winter Storms



C.2 Extreme Heat



C.3 Flooding from Sea Level Rise & Increased Precipitation