Resilience 2050
Adapting to the Challenges of Tomorrow

White Papers
Issue 11 - February 2023

Overview of Climate Change & Resilience

We know that the climate in Maryland and across the globe has been changing and will continue to change, primarily due to an increase in the concentration of greenhouse gases in the atmosphere, which trap the sun's energy and increase global temperatures. Climate change threatens to upend many of the core assumptions about climate that agencies rely on to plan, design, and operate their infrastructure.

Over the past century, the climate has been changing in the Baltimore region. Trends considered in this white paper include:

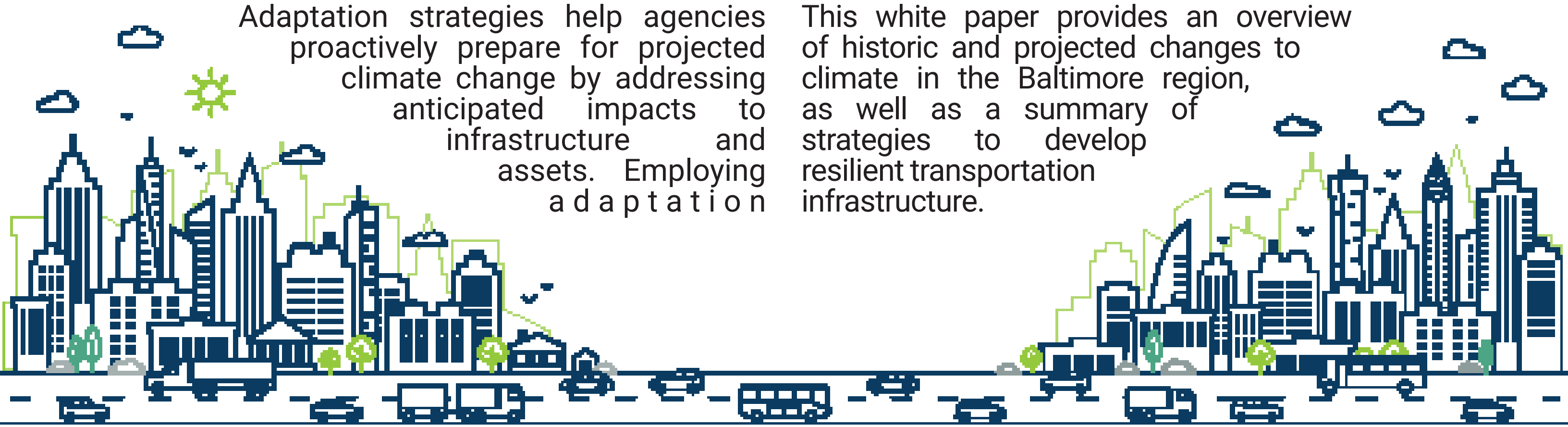
- **Temperatures are rising.** Annual temperature in the region has increased by 0.2°F per decade, a clear upward trend since 1895 that is expected to increase dramatically.
- **Annual precipitation rates are rising.** More precipitation is falling in intense storms. The Baltimore region will likely experience more extreme precipitation events over this century.
- **Sea levels are rising.** Relative sea level has risen by 1.22 feet from 1928 to 2020, a trend which will significantly impact the Baltimore region's shoreline. Nuisance flooding occurred in Annapolis fewer than 5 days per year in the 1950s, but now occurs more than 40 days per year. As sea levels rise and storms become more intense, the depth and extent of flooding from storm surges is also expected to be more severe.

Adaptation strategies help agencies proactively prepare for projected climate change by addressing anticipated impacts to infrastructure and assets. Employing adaptation strategies will help make communities more resilient. If not adapted to, these changes could lead to increases in flooding, changes in energy demand, reduced performance of materials and decreased safety for outdoor workers. To enhance resilience, agencies must adjust assumptions to consider climate projections and incorporate adaptation measures in their projects and plans.

Vulnerable populations, including people of color, those who are low-income, people with disabilities, children and the elderly, can feel climate impacts disproportionately. Climate hazards often present more severely in areas with higher concentrations of vulnerable populations, and communities that are largely low income or people of color may experience added impacts compared with populations that do not have these vulnerabilities. Agencies must keep this in mind when considering the impacts of climate change.

It is clear that the climate in the region has been changing, and that conditions will continue to change. This makes it imperative that the region adapt and become more resilient. The name of our *Resilience 2050* long-range transportation plan acknowledges the importance of resilience. Goals in the plan identify the need for improved accessibility, mobility, safety, security, infrastructure maintenance, economic opportunity and environmental responsibility. Climate change impacts threaten success in these goals, and it will become increasingly important to incorporate resilience strategies.

This white paper provides an overview of historic and projected changes to climate in the Baltimore region, as well as a summary of strategies to develop resilient transportation infrastructure.



Climate Change & Resilience

Introduction

We know that the climate in Maryland and across the globe has been changing and will continue to change. This changing climate is primarily due to an increase in the concentration of greenhouse gases in the atmosphere, which trap the sun's energy and increase global temperatures.[1] Climate change threatens to upend many of the core assumptions about climate that agencies rely on to plan, design and operate their infrastructure. As examples, potential changes in rainfall patterns could affect drainage needs and lead to increased flooding if not adapted to, and increases in temperatures can lead to changes in energy demand, materials performance and safety for outdoor workers.

Two ways to take action on climate change:

- ***Adaptation*: Measures to proactively adjust to a changing environment. Examples include ensuring sufficient building cooling systems given rising temperatures or siting assets outside future flood zones.**
- ***Mitigation*: Measures to reduce greenhouse gas emissions to slow or stop the impacts of climate change. Examples include transition to clean energy sources or electrification of building heating systems.**

To enhance resilience, agencies must adjust assumptions to consider climate projections and incorporate adaptation in projects and plans.

This white paper provides an overview of historic and projected changes to the climate as well as a summary of strategies to develop resilient transportation infrastructure.

Historical Climate Trends

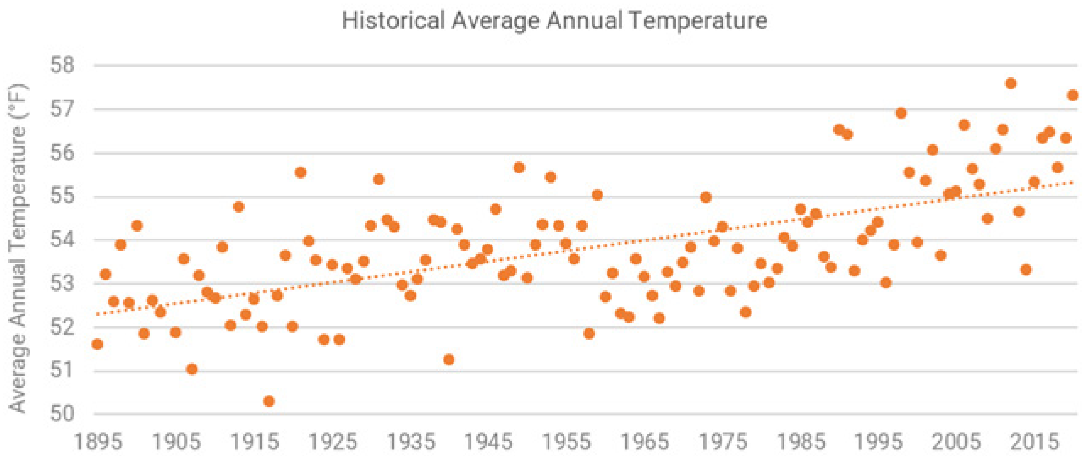
Over the past century, the climate has been changing in the Baltimore region.

- Annual temperature in the region has increased by 0.2°F per decade; there is a clear upward trend since 1895 (Figure 1).[2]
- Annual precipitation in the region has increased slightly over the past century (Figure 2), though more of this precipitation has been falling in intense storms.[3]
- Sea levels in the Chesapeake Bay and its tributaries have been rising due to slowly sinking land as well as warming oceans. Relative sea level, measured at the Annapolis tide gauge, has risen by 1.22 feet from 1928 to 2020.[4] Nuisance flooding (from high tides even during sunny days) occurred fewer than 5 days per year in Annapolis in the 1950s but now occurs more than 40 days per year (Figure 3).[5]

Let us know what you think about this paper!
publicinput.com/Resilience2050whitepapers

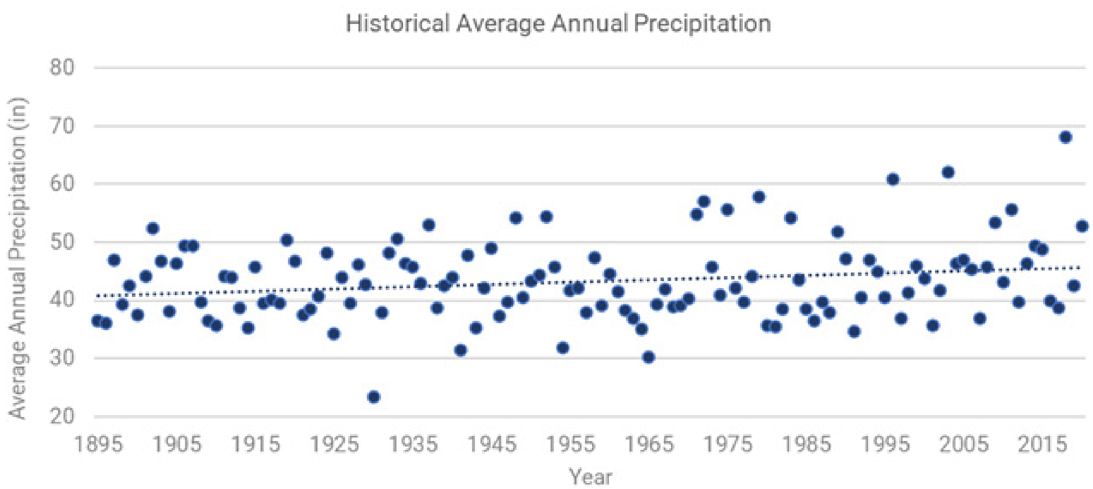
Resilience 2050
Adapting to the Challenges of Tomorrow

Figure 1 - Historical Average Annual Temperature



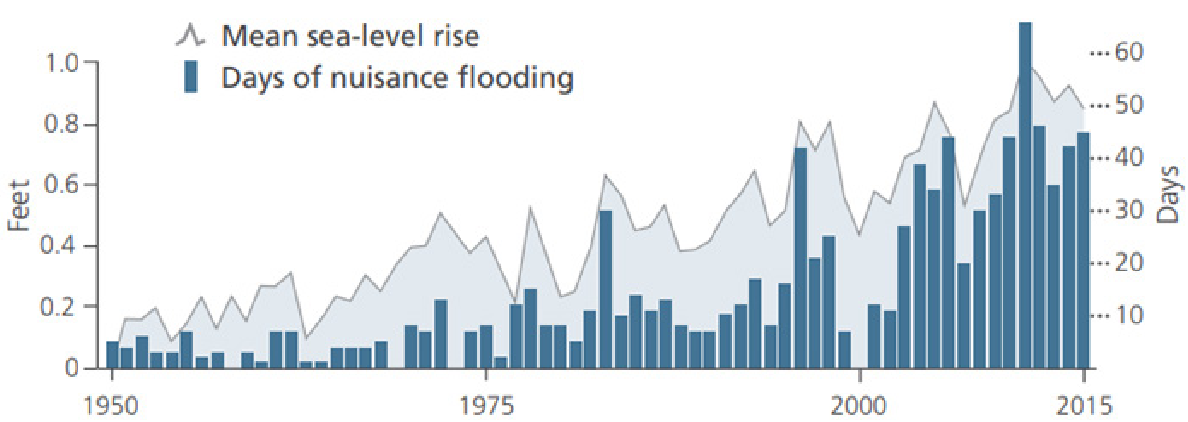
Averaged across the Baltimore region with data from National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information

Figure 2 - Historical Average Annual Precipitation



Averaged across the Baltimore region with data from National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information

Figure 3 - Historical Sea Level Rise and Nuisance Flooding in Annapolis



Source: University of Maryland's Center for Environmental Science, Sea-level Rise: Projections for Maryland 2018

Future Climate Trends

Climate projections for the region were developed as part of the work for the recently completed Climate Change Resource Guide. While there will be some inherent uncertainty in climate projections (e.g., we cannot exactly predict the amount of future emissions), it is certain that the climate is changing, so it is safest and most cost-effective to start planning for these changes now.

The projections for the climate variables are provided across three time horizons: near-term (centered around 2030), medium-term (centered around 2050) and long-term (to end of century). The planning horizon for the upcoming *Resilience 2050* long-range transportation plan extends through 2050, so projects included in *Resilience 2050* align with the near-term and medium-term future for these climate trends.

Changes in Temperature

Temperatures are projected to increase dramatically in the Baltimore region over the coming decades (refer to Figures 4, 5 and 6). Each jurisdiction within the region will experience similar projected changes, although areas near the Chesapeake Bay will continue to be warmer compared to the inland areas.

Figure 4 - Annual Temperature Across the Region

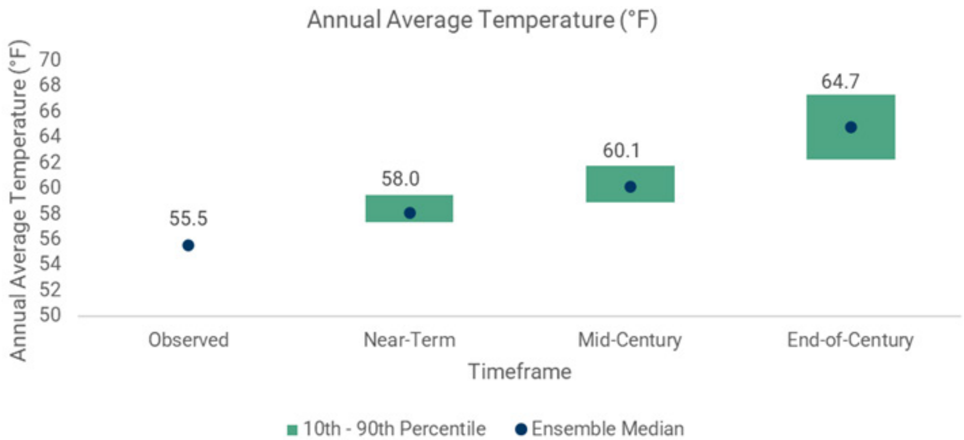
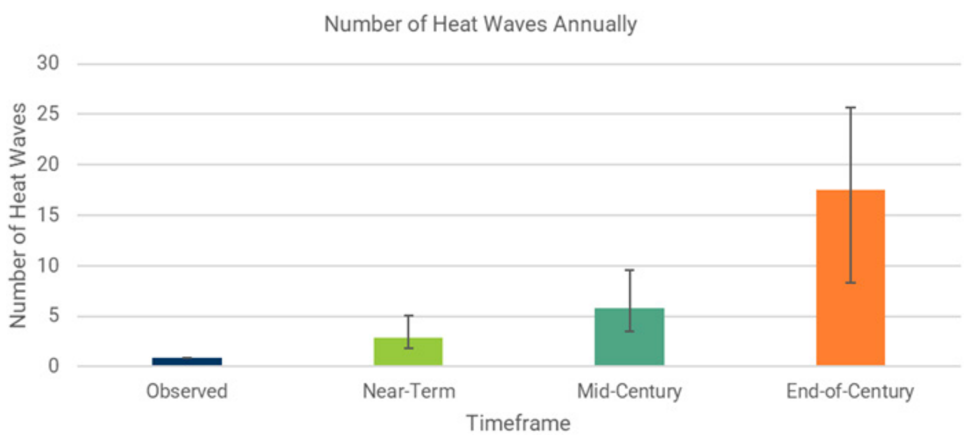


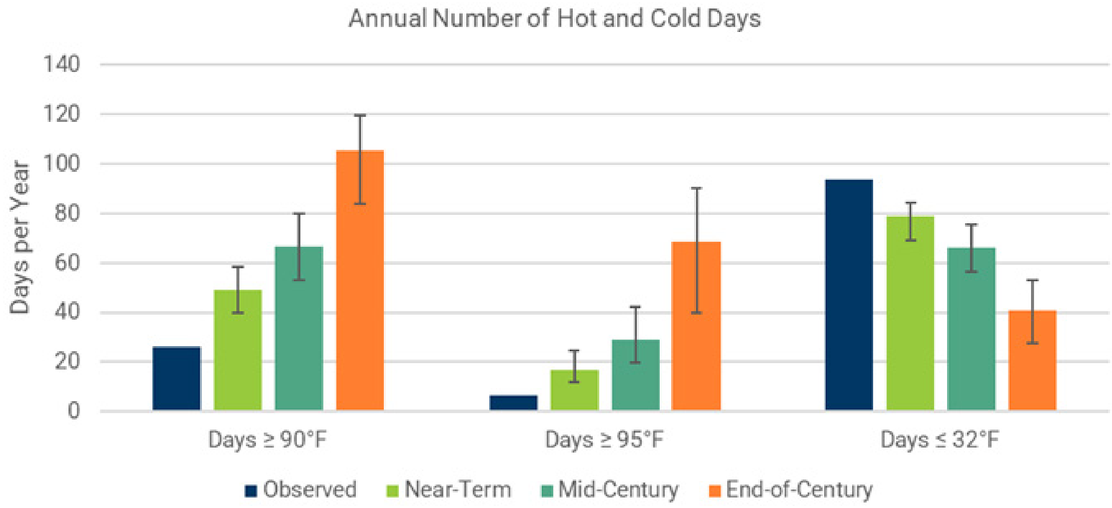
Figure 5 - Number of Heatwaves Annually



Error bars indicate 10th-90th percentile range across the 32-model ensemble. All projections are shown for representative concentration pathway (RCP) 8.5. Heatwaves defined as instances when there are 3 consecutive days above the observed 98th percentile.

Error bars indicate 10th-90th percentile range across the 32-model ensemble. All projections are shown for RCP 8.5. An RCP is a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change.

Figure 6 - Annual Number of Hot and Cold Days

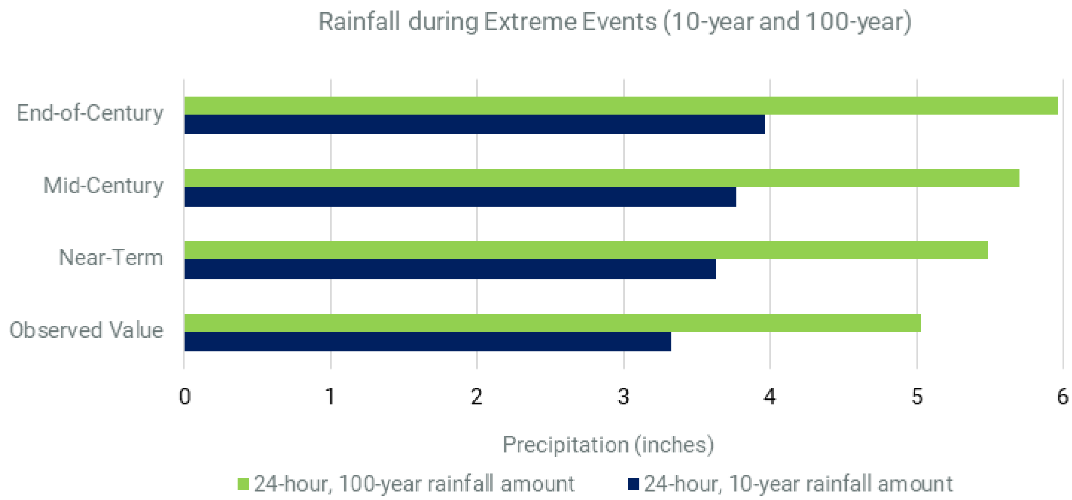


Changes in Precipitation

The Baltimore region will likely experience more extreme precipitation events over this century. Both the 24-hour, 10-year and 100-year rainfall events[6] are projected to be heavier, but overall average annual precipitation is not projected to increase notably. For example, annual precipitation is expected to increase by about 3 inches by mid-century. The projections indicate more precipitation falling in heavy events within a single day or consecutive days. The projected changes will be similar across each jurisdiction. The northern part of the region will continue to experience greater annual precipitation relative to the southern portion.

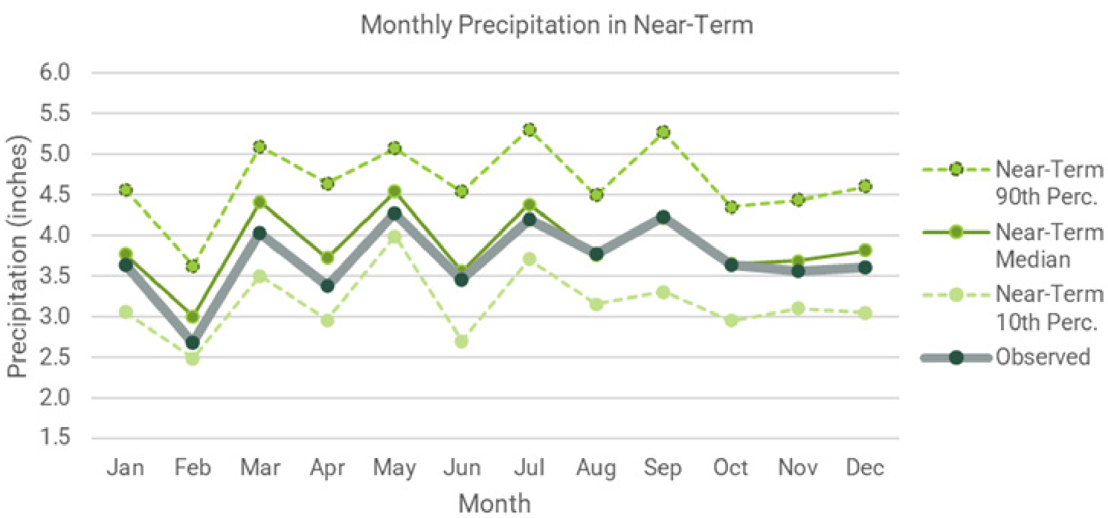
Precipitation increases are expected only during certain parts of the year. Precipitation is projected to increase in the winter and spring months, and stay relatively similar during summer and fall months. Figures 7 and 8 summarize the shifting precipitation patterns within the region.

Figure 7 - Rainfall During Extreme Events



All projections are shown for RCP 8.5. This is the climate modeling scenario used by the Federal Highway Administration.

Figure 8 - Near-Term Monthly Precipitation



Solid lines represent the 32-model ensemble median for RCP 8.5. Dashed lines represent the 10th and 90th percentile. Colors indicate the different time periods.

Figure 8 illustrates the following about monthly precipitation in the near-term. These trends are similar in mid-century and end-of-century.

- Average monthly precipitation is projected to increase slightly, though not substantially.
- Precipitation is likely to increase in the winter and spring months, with spring months exhibiting the highest projected total precipitation amounts.
  - » Although precipitation may increase in the winter, warming temperatures could result in less precipitation in the form of snow in the shoulder seasons.
  - » Increased winter precipitation combined with shifts in temperatures could result in changes in the number of freeze/thaw days, which can deteriorate infrastructure.

Sea Level Rise and Coastal Storm Surge

Sea level rise will significantly impact the Baltimore region shoreline, as summarized in Figure 9. Maryland's coastline will experience

Figure 9 - Projected Relative Sea Level Rise at Local Tide Guages

TIDE GAUGE	PROJECTED RELATIVE SEA LEVEL RISE (FEET)		
	NEAR-TERM (2030)	MID-CENTURY (2050)	END-OF-CENTURY (2080)
Baltimore	0.6 (0.4 - 0.9)	1.2 (0.8 - 1.6)	2.3 (1.6 - 3.1)
Annapolis	0.6	1.2	2.4

* Values shown are the state of Maryland's projected sea level rise values above 2000 levels. The projected value represents a central estimate, or the 50% probability that sea level rise is projected to meet or exceed. Values in parentheses indicate the likely range of projected sea level rise; sea level rise has a projected 67% probability of being between these values (not specified in the data source for the Annapolis tide gauge). The 2030 and 2050 projections for sea level rise are for RCP 4.5, though there is very little difference between RCP 4.5 and RCP 8.5 over the next 30 years. The 2080 projections are for RCP 8.5. Source: Sea-level rise: Projections for Maryland 2018.

minor differences in sea level rise across locations due to local differences in vertical land movements. Scientists determine relative sea level rise based on data from tide gauge stations in the Chesapeake Bay. Two of these stations are located in the Baltimore region.

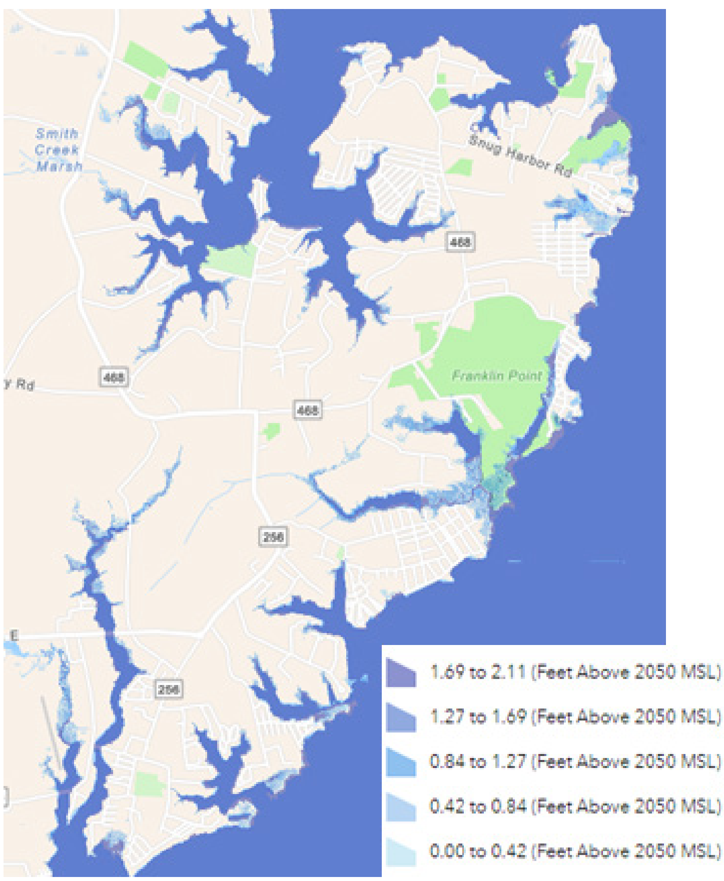
Figure 9 indicates it is likely that Anne Arundel and Queen Anne's counties will experience slightly greater increases in relative sea level compared to other coastal jurisdictions in the region (which should refer to the projections from the Baltimore tide gauge).

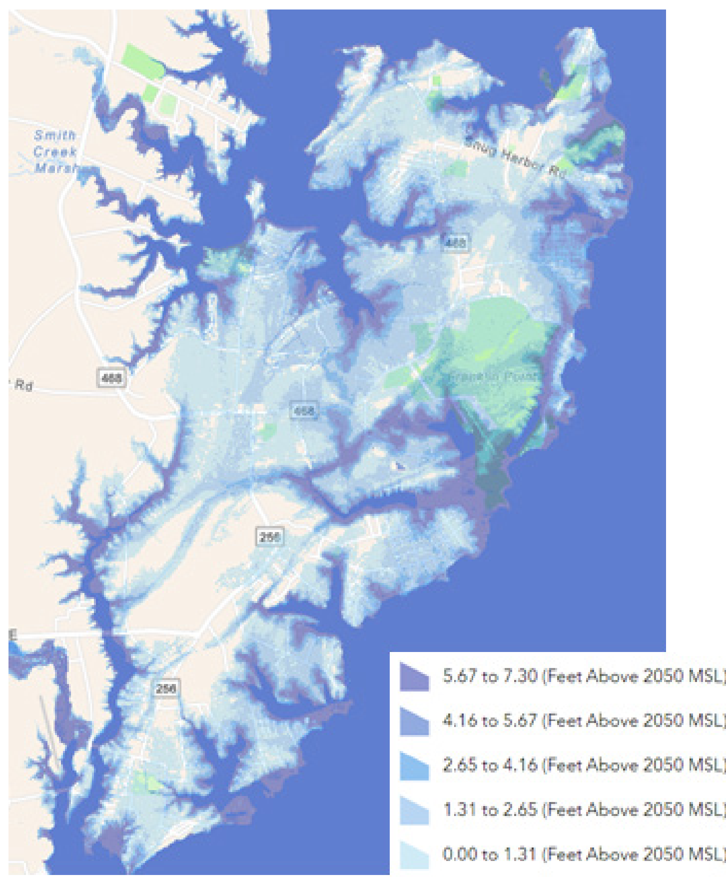
As sea levels rise and storms become more intense, the depth and extent of flooding from storm surges are also expected to become more severe.

Interactive maps for the entire Baltimore region showing inundation depth under different sea level and storm scenarios are available in the interactive [MDOT SHA Climate Change Vulnerability Viewer](). The viewer can be used for visualization of potential inundation from sea level rise and storms.

The illustrative static maps shown in Figure 10 from the Viewer show projected change in coastal flooding for a small portion of the region's coastline. The first map shows the projected inundation at high tide caused by sea level rise. The second map shows the increases in the level of storm surge during a 100-year flood with sea level rise.

Figure 10 - Sea Level Rise Inundation Depths by 2050 (left) and Flood Depths During a 100-Year Flood by 2050 (right)





Other Projected Changes in Extreme Weather

Overall, climate change will lead to an increase in both the frequency and intensity of extreme weather events in the Baltimore region. The changes in storms include an increase in the strength and volume of thunderstorms and derechos (i.e., windstorms) due to warmer atmospheric temperatures, which provide energy to storms. Similarly, scientists expect that there will be a greater number of strong hurricanes (i.e., Category 3 hurricanes or stronger) through mid-century.[7]

In addition, extreme cold snaps may continue to occur due to weakened “polar vortex” events, where cold Arctic air is released to the continental United States. These weak polar vortexes could be the result of climate change–induced Arctic warming and decreases in sea ice. The result could be more frequent cold weather outbreaks in the region.[8 9 10 11]

Current climate models do not provide quantitative estimates for the degree of these changes in extremes in the Baltimore region, but such shifts towards more extreme weather should nonetheless be on the radar and included in project planning and decision-making.

Climate Change Impacts Already Experienced by Local Agencies

Public works and transportation departments across the region are already seeing impacts from a changing climate, including increased maintenance, damage to infrastructure, operational impacts and rising costs. Climate impacts in the region arise from hazards including heavy precipitation and inland flooding, coastal flooding, extreme heat and other extreme weather.

Recent impacts in some jurisdictions may help illustrate how another jurisdiction may experience impacts in the future. Across the whole region, impacts are expected to be exacerbated given the future climate projections previously discussed.

In recent years, heavy rain has been perceived as the most impactful hazard. This finding is consistent with the Fourth National Climate Assessment, which indicates that at a regional scale, the Northeast region of the United States has experienced a greater recent increase in heavy precipitation than any other region in the contiguous United States.[12] As shown previously, both the 24-hour 10-year and 100-year rainfall events are projected to increase in the future. Aside from heavy precipitation, flooding in the Baltimore region is becoming more frequent and more widespread.

It is clear from the climate projections and recent observed impacts that climate change is exacerbating impacts across all hazards, including heavy precipitation and inland flooding, sea level rise and coastal flooding, extreme heat and other extreme weather.

Chapter 3 of the Climate Change Resource Guide has many examples of how climate change has impacted local infrastructure.

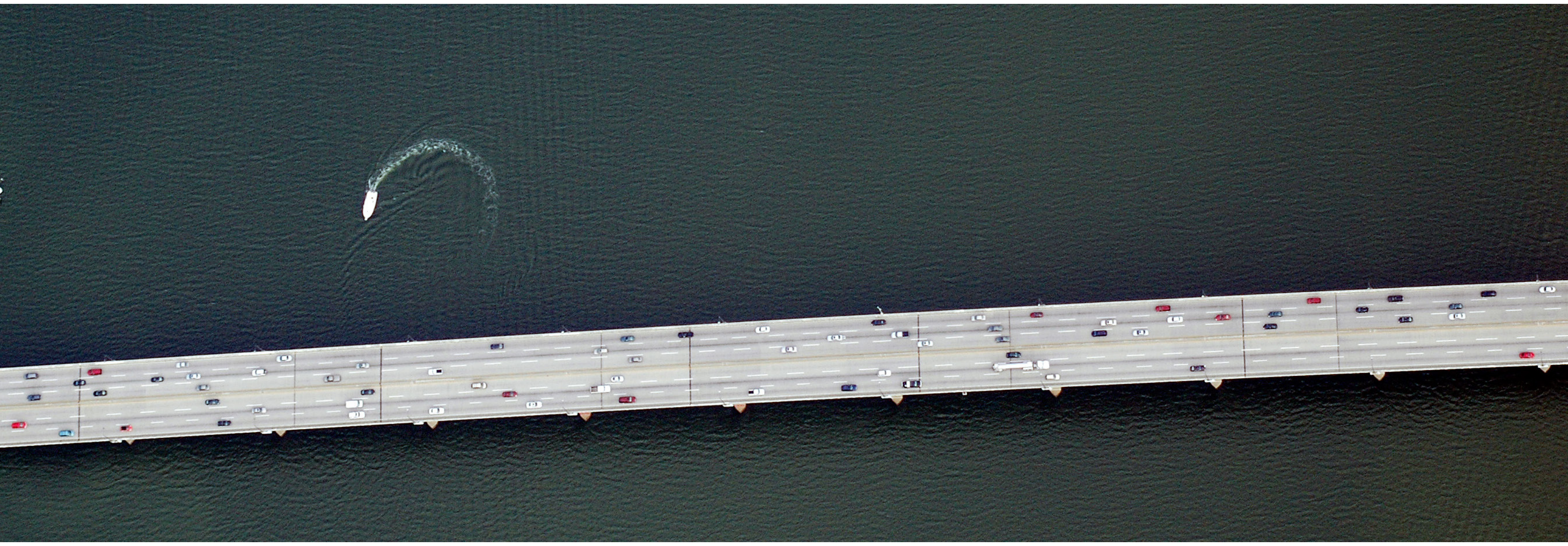
Climate Change Impacts and Social Equity

Climate change impacts can be felt disproportionately by vulnerable populations, including people of color, those who are low-income, those who have disabilities, children and the elderly. Vulnerable populations may have a difficult time stabilizing during and after extreme weather events and recovering from personal property damage. Climate hazards themselves often present more severely in areas with higher concentrations of vulnerable populations, with higher rates of impervious surfaces and higher temperatures in urban areas. Communities that are low income or predominantly people of color may experience added impacts compared with populations that do not have these vulnerabilities. Our Vulnerable Population Index map shows locations of vulnerable groups.

Climate Change Impacts on Budgets and Financing Sources

Supporting resilient transportation infrastructure includes the ability to fund operations, maintenance and adaptation strategies that increase due to climate impacts. Changes in climate conditions will increase costs associated with operations, maintenance and repair of infrastructure. Examples range from increased maintenance costs associated with clearing of debris from roadways following extreme storms to increased energy costs for facilities cooling during hot days. Changes in climate conditions will shorten the lifecycle of infrastructure and increase the need for rehabilitation and/or replacement of capital infrastructure sooner than anticipated.

Additionally, climate change is shaping the availability of financing sources. Public credit rating agencies, such as Moody's and Standard & Poor's, have recently integrated climate change into their evaluation of credit for governments. These new credit rating considerations are meant to reflect potential impacts of extreme weather and changing climate conditions on the financial health of governments and ability to repay.



Credit rating agencies are increasingly paying attention to the vulnerability of jurisdictions and states to climate change and their ability to manage climate impacts.

As such, climate adaptation efforts can help ensure that credit ratings are not downgraded, maintain or even improve bond ratings, save millions of dollars for taxpayers and boost availability of money for infrastructure projects.

Climate Adaptation Strategies

Adaptation strategies help agencies proactively prepare for projected climate change by addressing anticipated impacts to infrastructure and assets. Employing adaptation strategies will help make communities more resilient.

Adaptation measures help reduce vulnerabilities over the long-term that would otherwise result in a short-term emergency response. Climate change will increase the demand for emergency services and disaster management, though proactive climate adaptation measures will help to reduce mounting impacts under a changing climate.

Adaptation strategies can be incorporated at various stages of infrastructure lifecycle and across various functions, which include Planning, Design/Construction and Operations/Maintenance/Worker Safety.

Coordination across agencies and jurisdictions is a vital component of adaptation planning. Climate impacts, such as flooding, are not confined within jurisdictional boundaries and some adaptation strategies may be more cost-effective through joint solutions. Furthermore, one decision to positively impact resilience could have a negative impact on other priorities or decision-making. For example, installing green infrastructure is a strategy to manage stormwater, but road salt to address snow and ice in the winter could be harmful to vegetation and would require re-planting every year at a high cost.

There is a wide range of climate adaptation strategies for public infrastructure and many examples are provided in Chapter 5 of the Climate Change Resource Guide. Many of these strategies have been implemented in the region or state. Following are several case studies that illustrate how adaptation strategies can be used.

Crosscutting Strategy:
Resilience in Capital Improvement Programs

Ensure that municipal capital investments can continue to deliver infrastructure services in the face of climate change by identifying resilience design modifications for proposed capital projects.

Strategy Overview

Integrating resilience into Capital Improvement Programs (CIPs) entails asking project managers to:

1. Identify how a proposed capital investment might be impacted by future climate conditions.

2. Identify potential design modifications that could bolster the resilience of the project and appropriately budget for the selected resilience modification.

For example, the scope for an emergency generator capital project could be modified to include installation on an elevated platform to ensure that it remains operable during heavy storms and will not need to be replaced because of flooding. As another example, the scope for a mechanical equipment capital project could be modified to include shading to reduce overheating during very hot days.

This strategy can apply to all CIP projects, including maintenance for existing assets as well as construction of new assets.

- By considering how and when existing assets may be affected by climate change, local governments can plan for rehabilitation, relocation and/or replacement.

- New projects can be proactively designed for resilience, saving money and effort in the long run.

Example: City of Frederick, MD[13]

Frederick is developing a guide for project managers to integrate resilience into the CIP after the city issued a Climate Emergency Resolution that committed the city to consider all significant municipal actions through the lens of climate change. The guide lays out step-by-step instructions and resources to help project managers integrate resilience into CIP submissions by identifying and addressing climate change risks to a project (assessing sensitivity and exposure and then modifying project scope to address climate risks); identifying opportunities for adding climate resilience and greenhouse gas mitigation measures that would benefit the city as a whole; documenting the climate considerations in existing municipal project submission forms; and ensuring that resilience carries into project implementation (including sample RFP language). The goal of this Resource Guide is to help department staff comply with the Climate Emergency Resolution and proactively build the resilience of the city's investments.

Examples in the Baltimore region:

- *City of Baltimore*
- *Queen Anne's County*
- *City of Annapolis*

Crosscutting Strategy:
Climate Resilience Design Guidelines

Climate resilience design guidelines ensure that new infrastructure is designed and existing infrastructure is retrofitted, using data on future climate conditions.

Strategy Overview

Traditional infrastructure design guidelines rely on the idea of climate stationarity – meaning the climate conditions that the infrastructure will experience will be similar to historical climate conditions.

Climate change means that this assumption is no longer true and that we cannot rely on historical conditions to accurately predict the future. With this in mind, locally developed climate resilience design guidelines and standards can help ensure that infrastructure will be built to withstand future conditions, such as higher temperatures and more intense and/or frequent floods.

Although there is currently a lack of nationally adopted standards for resilient infrastructure, jurisdictions can develop standards and guidelines that are specific to each one's unique context and needs. For example, Maryland's Coast Smart Construction Program (described in Chapter 4 of the Climate Change Resource Guide) is an example of flood-related siting and design standards that takes into account future sea level rise above the Federal Emergency Management Agency's base flood elevation.

Example: New York City[14]

New York City developed Climate Resiliency Design Guidelines to provide step-by-step instructions on how to apply climate change data in the design of municipal facilities. The guidelines apply to all city capital projects to protect the city's public investments into the future. The guidelines provide:

» Climate projections to incorporate into design

» Instructions for determining the useful life of capital projects and the corresponding timeframe for the future climate projections

» Advice on managing uncertainty (e.g., through adaptable design that can be modified or augmented over time)

» Project-specific considerations (e.g., financing requirements, interdependencies between services or resources, existing hazard mitigation projects and risk studies, as well as operations and maintenance)

The Climate Resiliency Design Guidelines also provide detailed guidance on core resilience design elements for a number of climate hazards:

» Temperature—minimize contributions to the urban heat island effect; minimize impact to the asset from increasing temperatures

» Precipitation—consider precipitation design adjustments for on-site stormwater systems; incorporate climate change projections into the city's drainage planning

» Sea level rise—address risks in the current floodplain; address risks in the future floodplain given sea level rise

The guidelines also emphasize equity as part of the design process, because climate impacts are often felt most severely by vulnerable populations.

Case Study: Installing Green Infrastructure When Upgrading Road and Stormwater Infrastructure

Reduce stormwater runoff and temperatures while gaining other community co-benefits.

Green infrastructure can help to infiltrate and filter rainwater, minimize local flooding, reduce the urban heat island effect, improve air quality and create a more welcoming and greener neighborhood. Green infrastructure includes solutions such as bioswales, porous pavement, rain gardens, rain barrels and green roofs.

Green infrastructure is an important tool for handling stormwater runoff onsite rather than allowing the water to flow elsewhere, potentially causing flooding or sewer overflows. Some of the key locations where green infrastructure can be integrated are along the roadways through curb extensions and by planting strips that are designed as bioswales and rain gardens.

Example: Philadelphia, PA[15]

Philadelphia has been implementing green infrastructure along roadways since 2011 with its Green City, Clean Waters program. In the 10 years since the program began, Philadelphia has exceeded its goals, installing green infrastructure at 800 sites throughout the City and keeping more than 2.7 billion gallons of stormwater runoff out of the sewer system. Although initially started to reduce combined sewer overflows, the Philadelphia Water Department has integrated the program into its Climate Change Adaptation Program.

Source:
Philadelphia Water Department, Green City, Clean Waters

Let us know what you think about this paper!
publicinput.com/Resilience2050whitepapers

Local and State Resilience Efforts

Most jurisdictions in the region have identified a staff person to lead its jurisdictional resilience/sustainability efforts. Staff in these positions work closely across agencies to educate about the need for adaptation and resilience as well as provide support on the development and implementation of resilience/adaptation projects. Many jurisdictions have climate adaptation plans that provide a holistic approach to addressing climate impacts. Anne Arundel County and the City of Annapolis partnered to establish a Resilience Authority to finance and support the construction of resilient infrastructure. Maryland state government continues to be a leader in preparing for climate change, with resilience efforts throughout its agencies. Transportation infrastructure has been a focus of the local and state resilience work.

Importance of Regional Resilience Efforts

For many years, BRTB work has included reducing emissions and improving air quality. More recently, work has expanded to include adaptation, such as the Climate Change Resource Guide and follow up recommendations for its implementation and for enhanced interjurisdictional coordination on resilience. Regional resilience efforts related to transportation will continue to be closely linked to and supportive of local and state work.

With a renewed focus on climate change and resilience at the national level, there are various new programs and sources of funding, such as through the 2021 Infrastructure Investment and Jobs Act and other programs, that directly support enhanced resilience. We have been following these programs and will work with public and private partners to apply as appropriate.

It is clear that the climate in the region has been changing, and conditions are predicted to keep changing, including higher temperatures, longer heat waves, more frequent flooding, more frequent and more severe weather and rising sea levels. These conditions make it imperative that the region adapt and become more resilient. The importance of resilience is acknowledged in our long-range transportation plan, aptly named *Resilience 2050*. Goals in the plan identify the need for improved accessibility, mobility, safety, security, infrastructure maintenance, economic opportunity and environmental responsibility. Impacts from climate change threaten our meeting these goals, and it will become increasingly important to incorporate strategies to enhance resilience.

Resilience 2050
Adapting to the Challenges of Tomorrow

Notes

1. U.S. Global Change Research Program. Fourth National Climate Change Assessment: Chapter 2: Our Changing Climate. 2018. https://nca2018.globalchange.gov/chapter/2/

2. NOAA. National Centers for Environmental Information. www.ncdc.noaa.gov

3. NOAA. National Centers for Environmental Information. www.ncdc.noaa.gov

4. NOAA. Sea Level Trends. https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8575512

5. University of Maryland Center for Environmental Science. Sea-level Rise: Projections for Maryland 2018. 2018. https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/Sea-LevelRiseProjectionsMaryland2018.pdf

6. A 10-year rainfall event is defined as a rain storm with an amount of rain that is equaled or exceeded once every 10 years. A 100-year rainfall event is defined as a rain storm with an amount of rain that is equaled or exceeded once every 100 years. A 100-year rainfall event is more extreme than a 10-year event.

7. U.S. Global Change Research Program. Fourth National Climate Assessment: Volume II: Impacts, Risks, and Adaptation in the United States. 2018. https://nca2018.globalchange.gov/

8. Kretschmer M, et al. More-Persistent Weak Strotospheric Polar Vortex States Linked to Cold Extremes. 2018. https://doi.org/10.1175/BAMS-D-16-0259.1

9. Zhang P, et al. Prolonged Effect of the Stratospheric Pathway in Linking Barents-Kara Sea Sea Ice Variability to the Midlatitude Circulation in a Simplified Model. 2018. https://doi.org/10.1007/s00382-017-3624-y

10. Overland J, et al. The Melting Arctic and Midlatitude Weather Patterns: Are They Connected? 2015. https://doi.org/10.1175/JCLI-D-14-00822.1

11. Kim B, et al. Weakening of the Stratospheric Polar Vortex by Arctic Sea-ice Loss. 2014. https://doi.org/10.1038/ncomms5646

12. U.S. Global Change Research Program. Fourth National Climate Assessment. Chapter 18: Northeast. 2018. doi: 10.7930/NCA4.2018.CH18

13. For more details on this internal municipal resource, contact the City of Frederick's Sustainability Manager.

14. NYC Mayor's Office of Resiliency. Climate Resiliency Design Guidelines. Version 4. 2020. https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v4-0.pdf

15. Philadelphia Water Department. Green City, Clean Waters. https://water.phila.gov/green-city/