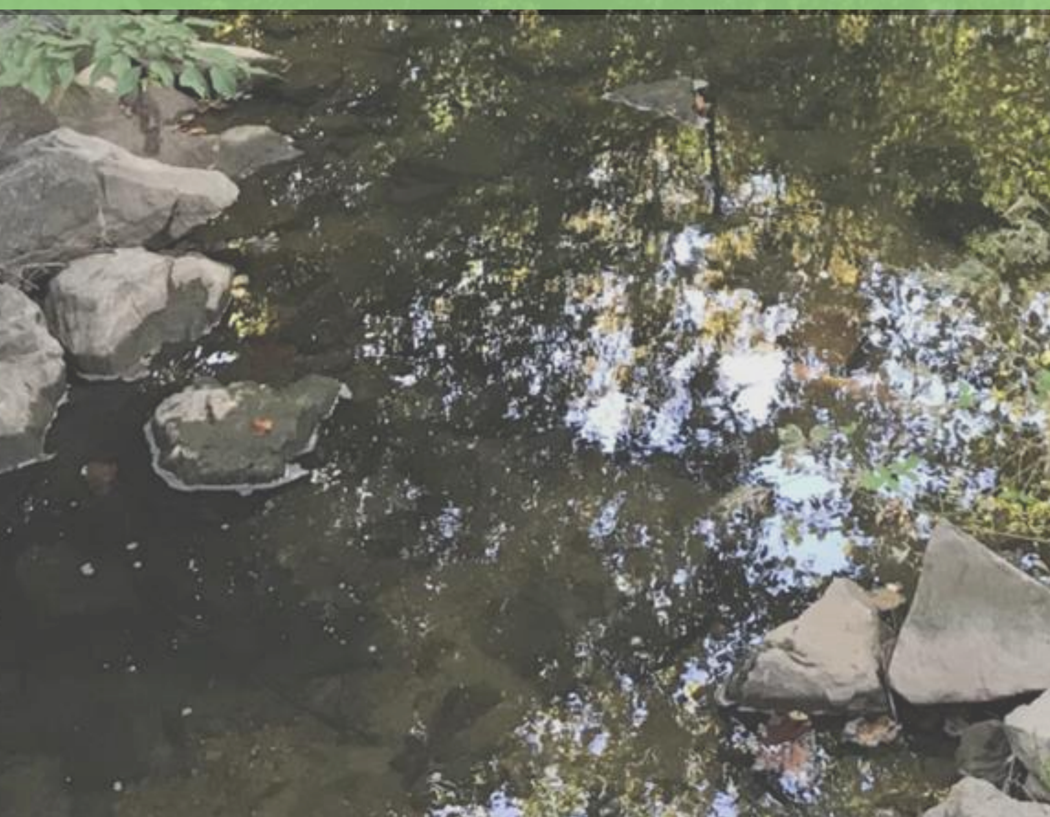
US Army Corps of Engineers

ANACOSTIA WATERSHED RESTORATION MONTGOMERY COUNTY, MARYLAND CONTINUING AUTHORITIES PROGRAM SECTION 206 AQUATIC ECOSYSTEM RESTORATION FEASIBILITY STUDY

DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX E: CLIMATE CHANGE ASSESSMENT



MARCH 2025

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Introduction

Engineering and Construction Bulletin (ECB) 2018-14 (rev2) requires that USACE studies provide a qualitative description of climate change impacts to inland hydrology and/or sea level change assessments as necessary. ECB 2018-14 stipulates that for project areas at elevations less than or equal to 50 feet NAVD88, a determination should be made as to whether sea level rise will affect the river stage by increasing (or decreasing) water surface elevation downstream of the project area. The entire project area is away from Chesapeake Bay coast and above 50 feet NAVD88. The lowest ground elevation is approximately 240ft NAVD88. Therefore, a sea level rise assessment is not necessary for this CAP 206 study.

This assessment is performed to highlight existing and future challenges facing the study area due to climate change and is conducted in accordance with United States Army Corps of Engineers' (USACE) Engineering Construction Bulletin (ECB) 2018-14, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects, revised 19 August 2022. In accordance with ECB 2018-14, this evaluation identifies potential climate change vulnerabilities for the project area within Anacostia River watershed in Montgomery County, Maryland.

The goal of this CAP 206 study is to provide a solution in the Anacostia River watershed in Montgomery County that will restore ecological function, structure, and health in selected stream reaches and riparian zones and those areas downstream affected by restoration actions. This assessment highlights existing and future climate change driven risks for the study area. Study background information can be found in the main report, and more general background information on climate change driven risk can be found in ECB 2018-14.

Study Background

The Montgomery County CAP 206 study is being completed under the CAP Section 206 authority, which allows USACE to develop aquatic ecosystem projects that improve the quality of the environment, are in the public interest, and are cost-effective solutions to the identified problems.

The Anacostia River watershed encompasses approximately 176 square miles, located entirely within the metropolitan area of Washington, D.C. The drainage within Montgomery County is approximately 61 square miles, accounting for about one-third of the total Anacostia River watershed. The Anacostia River flows through Maryland and then the District of Columbia into the Potomac River; the river ultimately drains to the Chesapeake Bay. Anacostia River sub-watersheds largely within Montgomery County include Sligo Creek, Northwest Branch, Paint Branch, and Little Paint Branch.

The Tentatively Selected Plan was identified in February 2023 and is composed of stream restoration at Lamberton Creek, Bel Pre Creek, and Sligo Creek (Figure 1). In coordination with the non-Federal sponsor for the feasibility study, Montgomery County Department of Environmental Protection (MCDEP), USACE modified the recommendation to include only Lamberton Creek and Bel Pre Creek in April 2024. MCDEP and Maryland National Capital Park and Planning Commission, Montgomery County Parks (M-NCPPC) have identified that they will be co-sponsors for the design and implementation phase of this project. Sligo Creek was removed from the recommended plan as stream restoration will be implemented by the M-NCPPC in coordination with the Washington Sanitary Sewer Commission (WSSC). through a separate effort from this study. The streams largely flow through forested parkland but are incised and have degraded instream habitat. The streams have reduced stream/floodplain connection from conditions several decades ago, causing loss of ecosystem function and floodplain wetlands habitats.

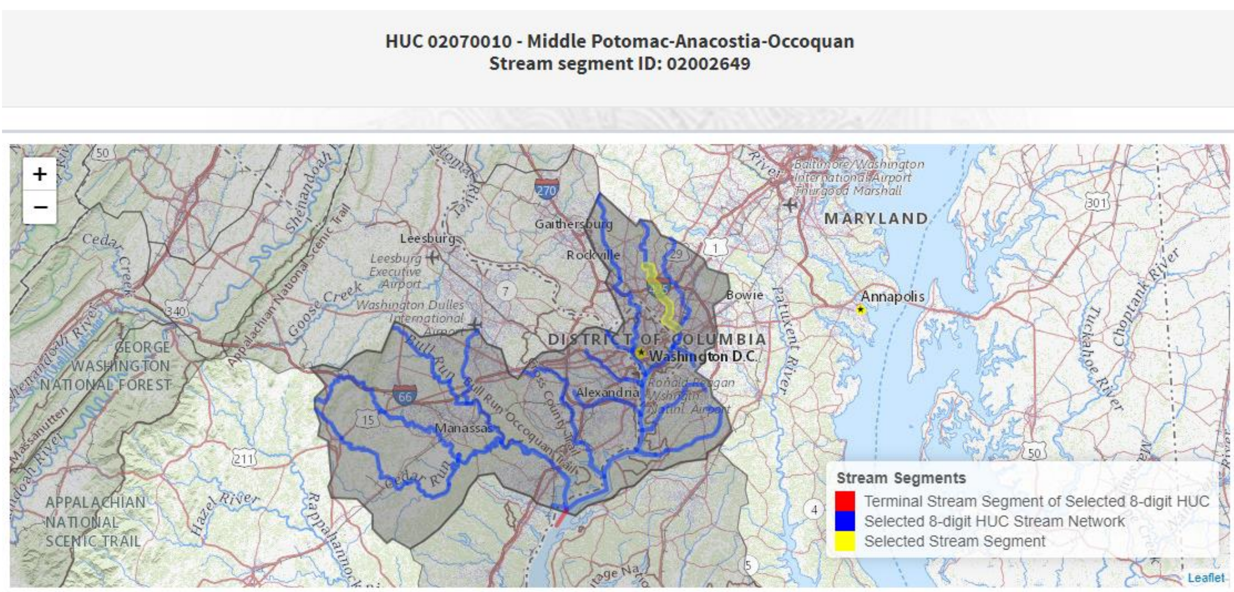

Figure 1 Study Area

This study is being completed to identify aquatic ecosystem restoration (AER) actions that would improve in-stream habitat and fish passage in degraded streams within the

Anacostia River watershed in Montgomery County. The Anacostia River watershed has been degraded by human alteration of the natural landscape and is characterized by significant urban development due to the growth of the metropolitan area of Washington D.C.

Future climate conditions may impact the aquatic ecosystem for the watershed; therefore, the Ecosystem Restoration business line is the focus of this analysis. The key climate-related variable relevant to the study is peak streamflow, representing the high flow regime. Variables like temperature and precipitation impact streamflow response and are thus also relevant to the study.

Literature Review

The Fourth National Climate Assessment (NCA4) and the USACE's Civil Works Technical Report CWTS-2015-09, as well as state-specific resources published by the National Oceanic and Atmospheric Administration (NOAA), the June 2016 Maryland Department of Transportation Climate Change Vulnerability Assessment are the basis for this literature review.

The NCA4 considers climate change research at both a national and regional scale (USGCRP 2018). Civil Works Technical Report CWTS-2015-09 was published by USACE in 2015 as part of a series of regional summary reports covering peer-reviewed climate literature. The 2015 USACE Technical Reports cover 2-digit, United States Geological Survey (USGS), hydrologic unit code (HUC) watersheds in the United States (U.S). The project area is located in 2-digit HUC 02, the Mid-Atlantic Region (USACE 2015) and in the NCA4 Northeast region.

These references summarize trends in historic and observed temperature, precipitation, and streamflow records, as well as provide an indication of future hydrometeorology based on the outputs from Global Climate Models (GCMs). In this assessment, background on observed and projected temperature and precipitation is provided as context for the impact they have on observed and projected streamflow. Temperature, precipitation, and streamflow measurements have been taken since the late 1800s and provide insight into how the climate has changed over the past century. GCMs are used in combination with different representative concentration pathways (RCPs) reflecting projected radiative forcings up to year 2100. Radiative forcings encompass the change in net radiative flux due to external drivers of climate change, such as changes in carbon dioxide or land use/land cover. GCMs are used to approximate future temperature and precipitation. Projected temperature and precipitation time series can be transformed to regional and local scales (a process called downscaling). Downscaled time series can then be applied as inputs to macro-scale hydrologic models (Graham, Andreasson, and Carlsson, 2007).

Uncertainty is inherent to climate change modeling due to the coarse spatial scale of the GCMs and the many inputs and assumptions required to create climate changed projections (USGCRP 2017). When applied, precipitation-runoff models introduce an additional layer of uncertainty. However, these methods represent the best available science to predict future hydrologic variables (e.g., precipitation, temperature, streamflow). It is best practice to use multiple GCMs when studying climate change impacts to understand how various model assumptions impact results (Gleckler et al. 2008).

According to the Fourth National Climate Assessment, climate change is expected to intensify current, observed trends in temperature and precipitation in the U.S., including the northeast region (Carter, et al., 2014). The study area is in Montgomery County, Maryland, approximately 40 miles northeast of Washington DC.

Temperature

Maryland’s climate is generally moist with a rather large seasonal range of temperatures. Due to Maryland’s mid-latitude location, the jet stream is often in the vicinity, particularly in the late fall, winter, and spring. In addition, Maryland’s location on the East Coast of the North American continent exposes it both to the cold winter and warm summer air masses of the continental interior and the moderate and moist air masses of the western Atlantic Ocean. In winter, the contrast between frigid air masses of the continental interior and the relatively warm Atlantic Ocean provides the energy for occasional intense storms commonly known as nor’easters. As a result of these varying influences, Maryland’s climate is characterized by moderately cold and occasionally snowy winters and warm, humid summer.

Temperatures in Maryland have risen about 2.5° Fahrenheit (F) since the beginning of the 20th century (Figure 2), and temperatures in this century have been warmer than in any other period. The warmest year on record was 2012, and 7 of the 10 warmest years have occurred since 2000. The second-warmest year was 2020, and July 2020 was the all-time hottest month for both Montgomery County and the state.

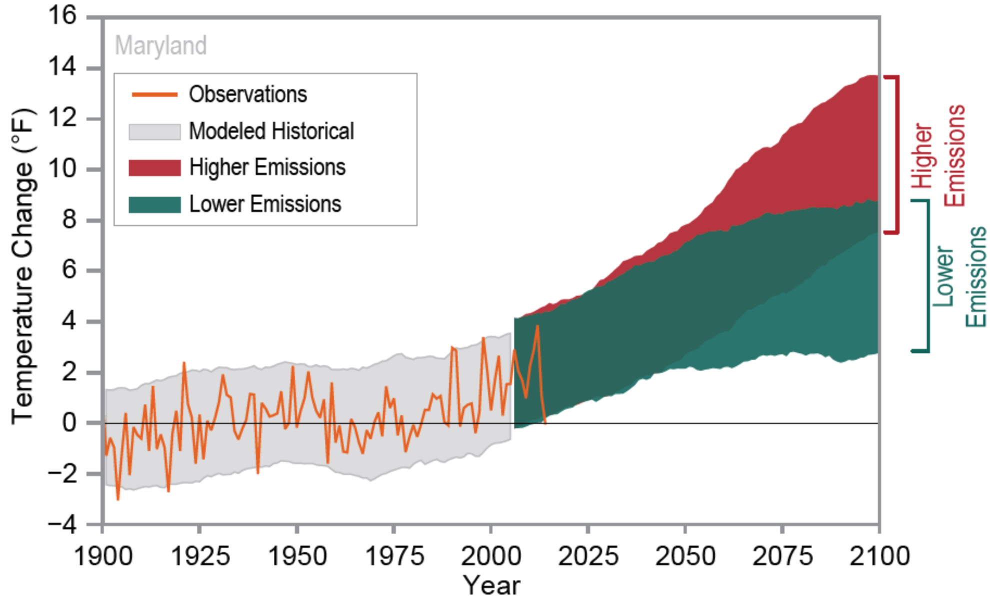

Figure 2 Observed and Projected Temperature Change for Maryland (Source: NOAA)

Maryland's "climate stripes" is shown in Figure 3. Each vertical bar represents the temperature of a year from 1895 – 2020. The colors represent the annual temperature relative to the average between 1951 – 1980 (blue is cooler than the average, orange/red is hotter). An interactive version of the plot shows the temperature for each year relative to the average: ***http://berkeleyearth.lbl.gov/regions/maryland***

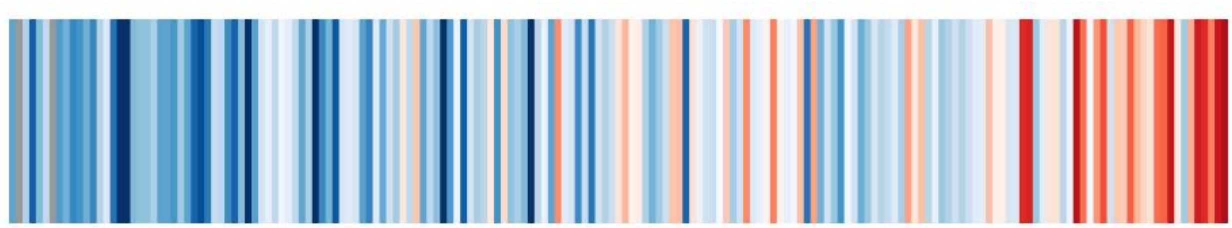

Figure 3 Maryland's Climate Stripes (Source: University of Maryland)

As per USACE CHAT tool, the following temperature trend is observed and projected for both RCP scenarios.

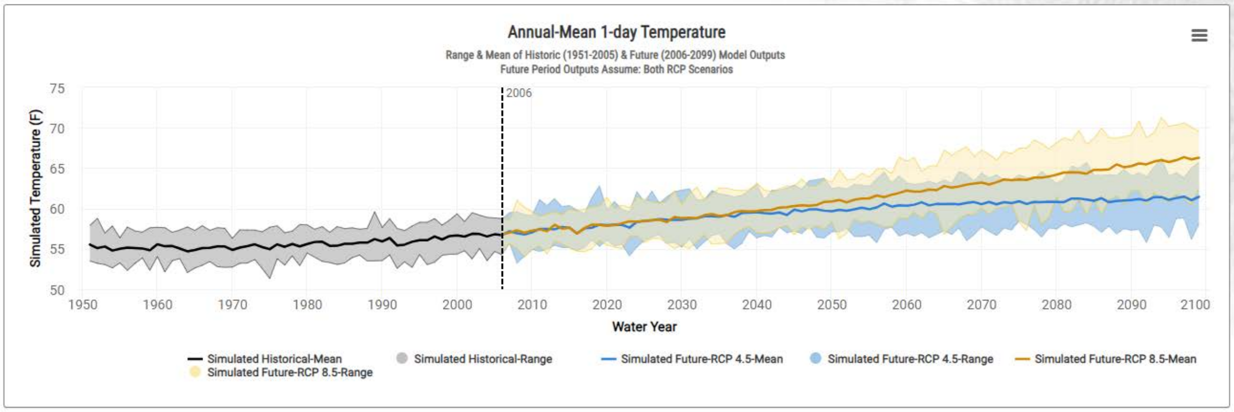

Figure 4 Annual Mean 1 day Temperature Changes

Precipitation

According to NOAA's Maryland State Summaries, average annual precipitation varies from around 50 inches in the extreme west to around 40 inches just to the east of the Appalachian Mountains. The wettest period was the 1970s, with the wettest 5-year period being 1971–1975, while the driest period was the 1960s, with the driest five-year period being 1962–1966. Annual mean precipitation has been above average for the last two decades. The annual number of extreme precipitation events (days with more than 2 inches) averaged 2.5 days per year during 2005–2014 compared to 1.8 days per year during 1950–2004.

Maryland is susceptible to several extreme weather types including tropical storms and hurricanes, severe thunderstorms, tornadoes, nor'easters, blizzards and ice storms, flooding, drought, and heat and cold waves. Hurricane Irene in 2011 caused considerable wind damage along the coast. Hurricane Sandy in 2012 caused damage from wind and a storm surge of 4–5 feet, which destroyed a large portion of Ocean City's fishing pier and caused widespread flooding in Crisfield and other low-lying areas of the lower Eastern Shore. On June 29, 2012, a derecho (a widespread, long-lived line of thunderstorms with very strong winds) moved through the Ohio Valley and the Mid-Atlantic states; Maryland and Washington, D.C. were two of the hardest hit areas. One-third of Maryland residents and one-quarter of D.C. residents were left without power after the storm, with some outages lasting longer than a week. Mountainous terrain in the narrow, western portion of the state, and the dense urbanized areas of the state are each highly vulnerable to flash flooding. During August 12–13, 2014, torrential rains of up to 6–10 inches occurred resulting in flooding along the coastal plain from Baltimore into New Jersey. This event resulted in the second highest calendar day precipitation total (6.3 inches on August 13) since 1933. Most recently, an extreme precipitation event occurred on July 30, 2016, impacting Ellicott City with 6 inches of rain in several hours and causing two fatalities.

Average annual precipitation is projected to increase in Maryland over the 21st century, particularly during winter and spring (Figure 4). This is part of a large-scale pattern of projected increases in precipitation over northern and central portions of North America. More frequent intense rainfall events are projected, potentially increasing flooding events in urban areas. The 100-year rain-storm event, as defined by historical data, is expected to occur every 20 to 50 years by the end of the century. Increasing and more intense extreme precipitation events will likely expand the flood hazard areas (areas that will be inundated by a flood event).

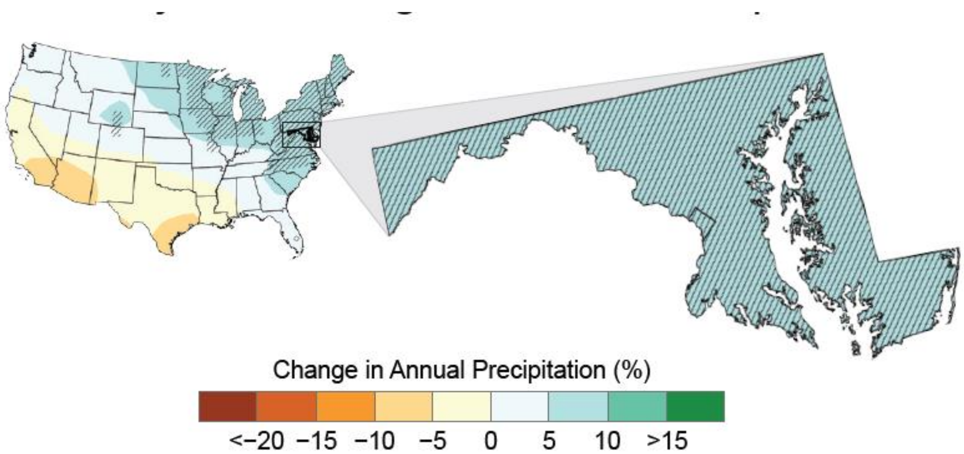

Figure 5 Projected Change in Annual Precipitation (Source: NOAA)

As per CHAT tool, the Annual maximum 1-day precipitation trend is shown below for both RCP scenarios:

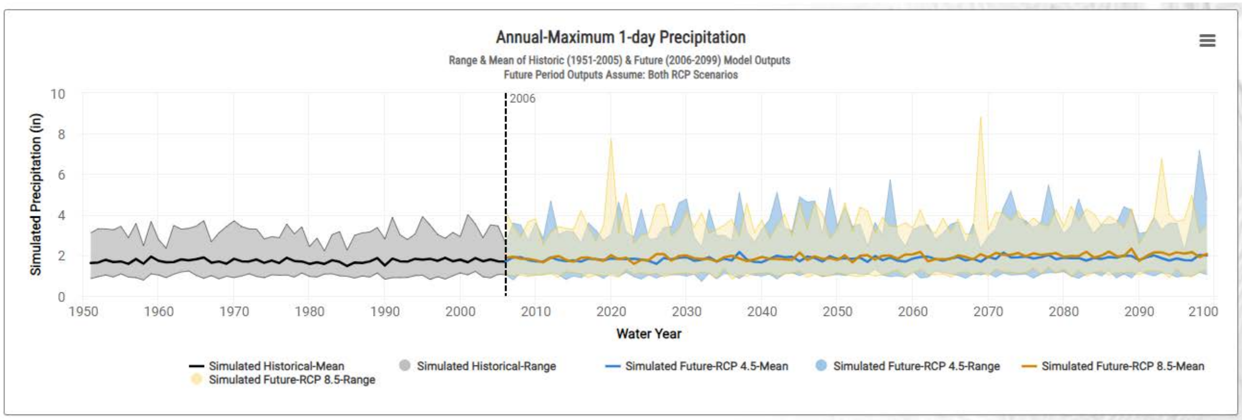

Figure 6 Annual Maximum 1-day Precipitation Trend

Streamflow

Observed streamflow trends are strongly influenced by precipitation, temperature, and other factors such as land use and land cover in a region, groundwater dynamics, drainage patterns, channel geomorphology, and regulation. Studies of trends and non-stationarity in streamflow data collected over the past century have been performed throughout the continental U.S., some of which include the MidAtlantic Region. Xu et al. (2013) investigated trends for multiple stream gages in the Mid-Atlantic Region. No statistically significant ($p < 0.05$) trends in either annual streamflow or baseflow were identified for any of the stations in the Mid-Atlantic Region. These results are supported by Kalra et al. (2008) who analyzed historical streamflow (1952 – 2001) for over 600 flow stations throughout the U.S., including a large number in the Mid-Atlantic Region.

As per CHAT tool, the Annual maximum of Mean Monthly Streamflow trend is shown below for both RCP scenarios:

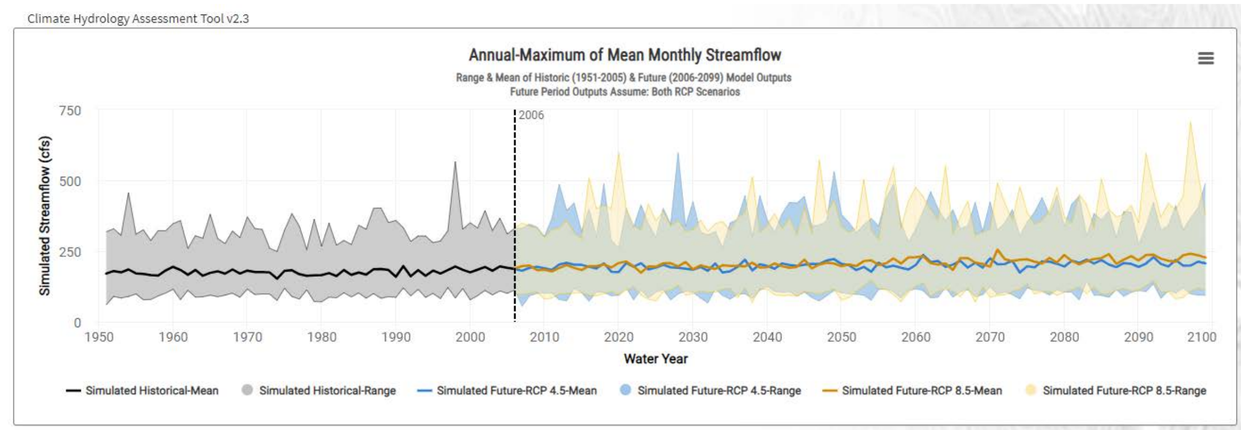

Figure 7 Annual Maximum of Mean Monthly Streamflow

As per Time Series Trend Analysis for the selected stream segment ID 02002649, the Annual-Maximum of Mean Monthly Streamflow trend is shown below:

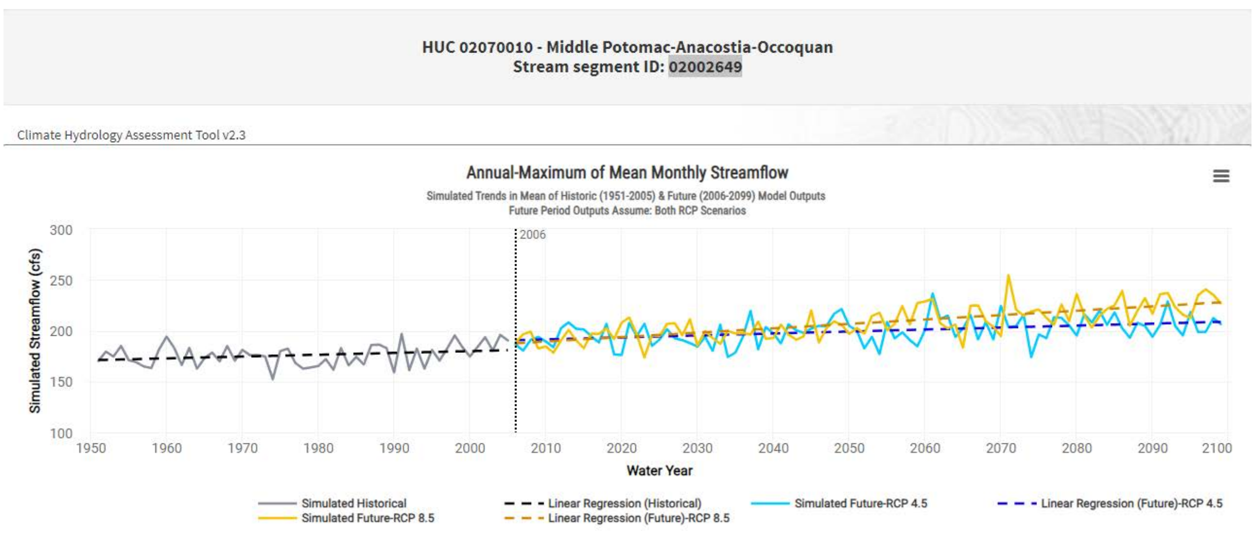

Figure 8 Simulated Stream Flow Trend Lines

The p-values displayed below in table 1 are reflective of the linear regression fit drawn above. A smaller p-value indicates greater statistical significance. The typically adopted threshold for statistical significance prescribed by most statistical references is 0.05 is associated with a 5% risk of a Type I error or false positive. This is the threshold of significance applied by the CHAT.

Table 1 Statistical Significance Test Results

Simulated Historical (1951 to 2005)	Simulated Future (2006 to 2099)	
0.1776 Traditional Slope	**0.1944** Traditional Slope-RCP 4.5	**0.4322** Traditional Slope-RCP 8.5

Statistical Significance Tests (Historical)

Test	p-value
t-Test	0.045**
Mann-Kendall	0.079
Spearman Rank-Order	0.0606

Statistical Significance Tests (Future)

Test	p-value RCP 4.5	p-value RCP 8.5
t-Test	2.66e-05**	< 2.2e-16**
Mann-Kendall	4.58e-05**	< 2.2e-16**
Spearman Rank-Order	1.32e-05**	< 2.2e-16**

** Indicates a statistically significant simulated trend (at the alpha = .05 level) was detected.

The CHAT tool shows statistically significant trend for increasing stream flow for future. However, other literature review shows no statistically significant ($p < 0.05$) trends in either annual streamflow or baseflow were identified for any of the stations in the Mid-Atlantic Region. There is little to no consensus in the literature regarding changes in projected, future streamflow in the mid-Atlantic Region.

Non-stationarity Detection Tool

The assumption that hydrologic datasets are stationary (their statistical characteristics are unchanging) in time underlies many types of hydrologic analysis. Statistical tests can be used to test this assumption using the techniques outlined in Engineering Technical Letter (ETL) 1100-2-3 Guidance for Detection of Non-stationarities (2017). The USACE Time Series Toolbox (TST) is a web-based tool that enables the user to perform the statistical tests outlined in ETL 1100-2-3. Both user uploaded time series data, as well as preloaded USGS annual peak discharge and stage datasets can be tested for non-stationarities and monotonic trends using the TST (USACE 2020c).

There is one USGS gage (01650800 Sligo Creek Near Takoma Park, Maryland) but it has records since 2009, not enough for record for Non-Stationarity Detection Tool. Sligo Creek is a tributary of Northwest Branch Anacostia River. For this evaluation, the TST is applied to annual peak streamflow data collected by USGS gage 01651000, Northwest Branch Anacostia River near Hyattsville, Maryland. The NSD Tool for the USGS gage site detected several non-stationarities starting around 1951, then in mid-1960’s and in 1969 as shown in Figure 9. Non-stationarities indicate that past conditions may not represent future conditions. The non-stationarities that occurred for the gage were investigated but it was not determined why they have occurred. Burnt Mills Dam was constructed in the 1930s for recreational purpose and has a drainage area of 29 square miles. Non stationarities mentioned above cannot be explained with the construction of the Burnt Mills Dam. There are no other dams/reservoirs within Montgomery County may have caused these non-stationarities.

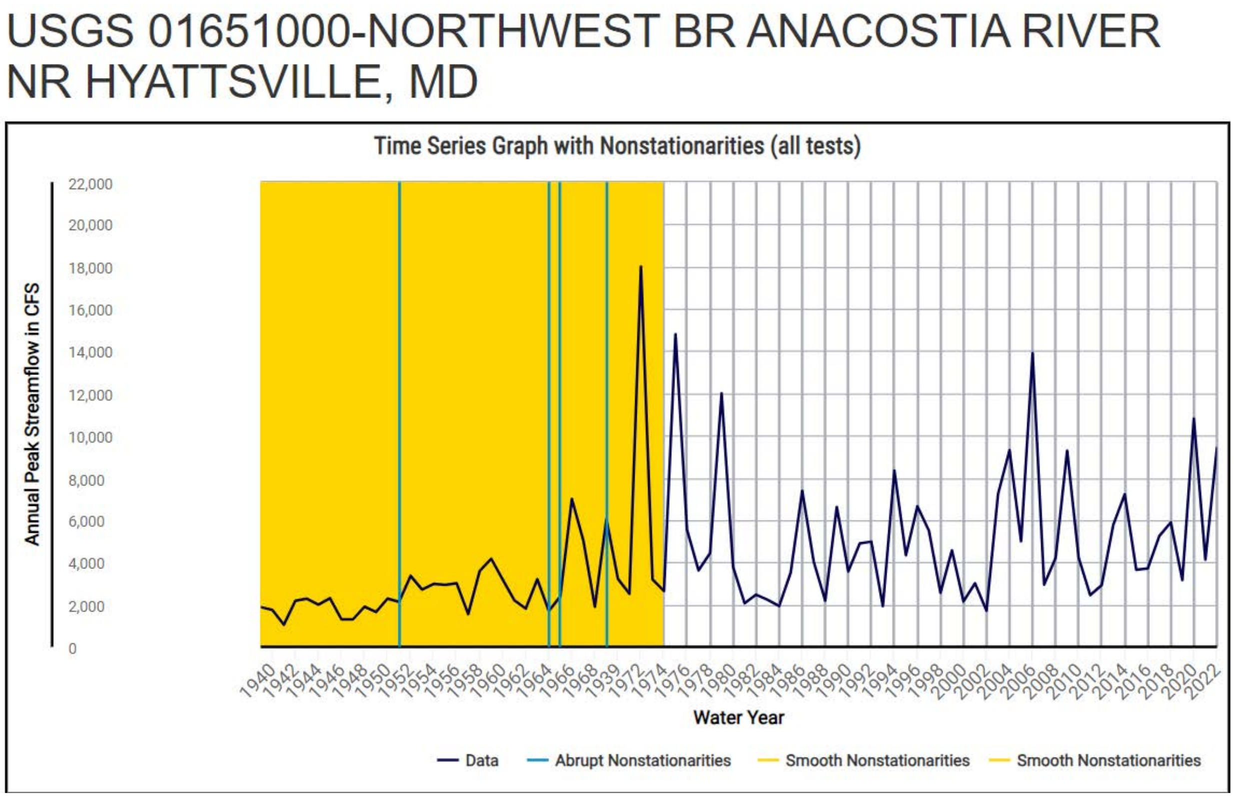

Figure 9 Non-Stationarities for Northwest Branch Anacostia River

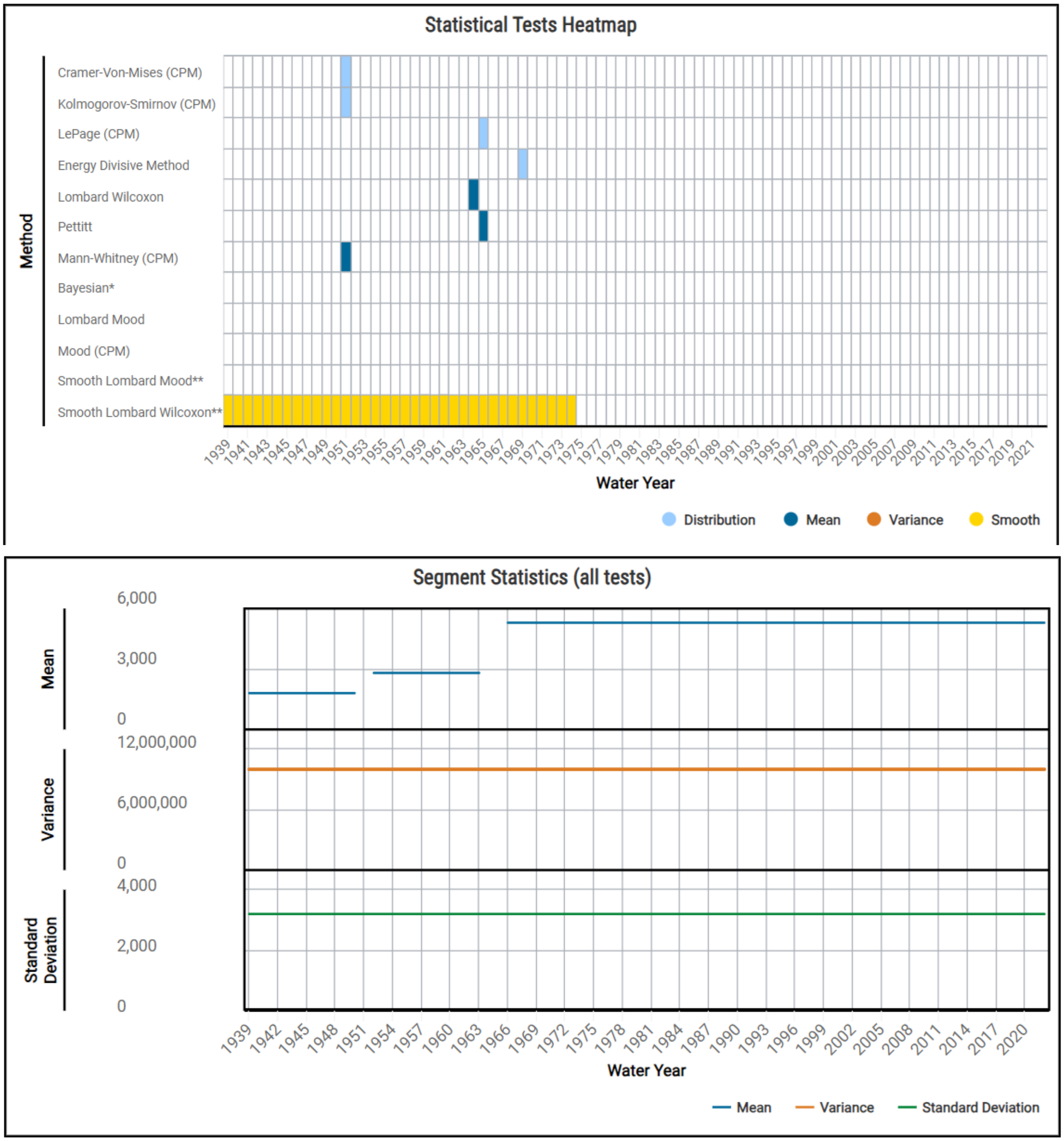

Figure 10 Statistical Tests for Non-Stationarities

USACE Vulnerability Assessment

The USACE Watershed Climate Change Vulnerability Assessment (VA) Tool facilitates a screening-level, comparative assessment of the vulnerability for a selected USACE business line and 4-digit HUC watershed to the impacts of climate change, relative to the other 4-digit HUC watersheds within the continental United States (CONUS). It uses the Coupled Model Intercomparison Project (CMIP5) GCM-BCSD (Bias Corrected, Spatially Disaggregated) -VIC dataset (2014) to define projected hydrologic and meteorologic inputs, combined with other data types, to define a series of indicator variables to define a vulnerability score (USACE 2020b).

Vulnerabilities are represented by a weighted-order, weighted-average (WOWA) score generated for two subsets of simulations (wet—top 50% of cumulative runoff projections; and dry—bottom 50% cumulative runoff projections). Data are available for three epochs. The epochs include the historic period (“Base” epoch) and two 30-year, future epochs (centered on 2050 and 2085). The Base epoch is not based on projections and so it is not split into different scenarios. For this application, the tool was applied using its default, National Standards Settings. In the context of the VA Tool, there is some uncertainty in all of the inputs to the vulnerability assessments. Some of this uncertainty is reflected by the differences in results for each of the subset-epoch combinations.

As shown in Figure 11, the Potomac (HUC 0207) watershed is considered not vulnerable to climate change impacts for the ecosystem restoration business line for none of four epoch-subset combinations. A watershed is considered relatively vulnerable to climate change impacts if it has a vulnerability score that falls within the top 20% of WOWA scores for a given business line in the CONUS.

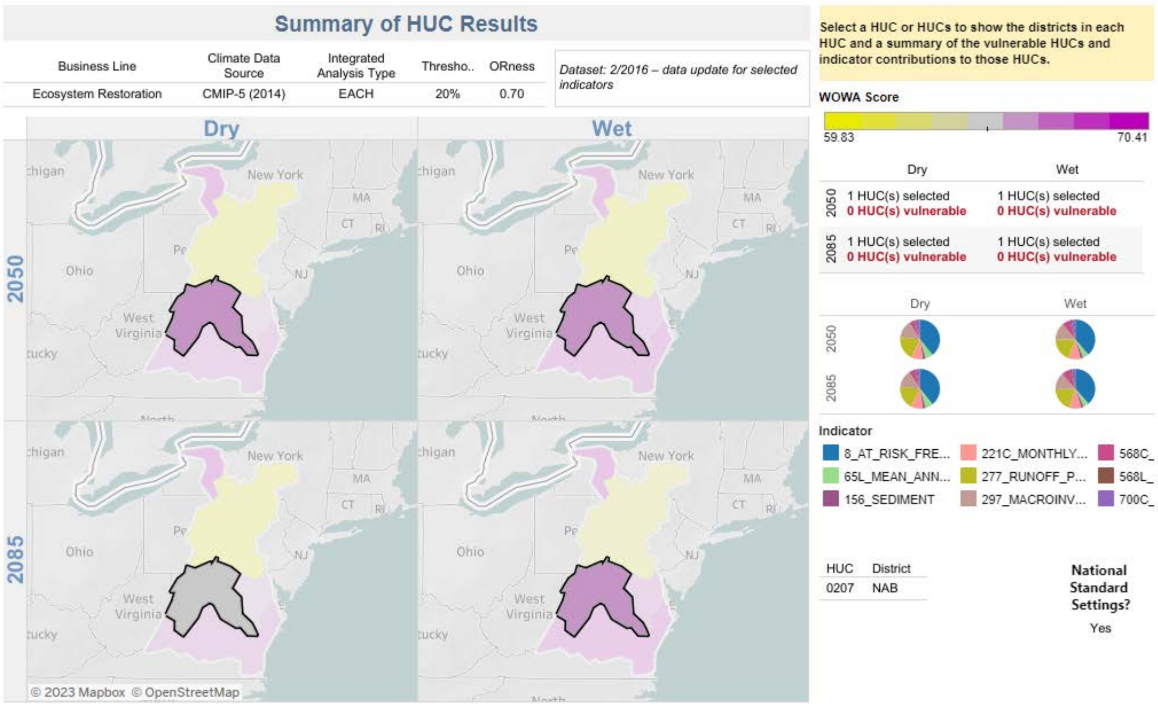

Figure 11 VA Tool 4-Digit HUC Summary: Potomac Watershed (HUC 0207)

Conclusions

The increase in observed temperature is the strongest evidence that climate change is evident in the basin. The literature review indicates that precipitation increased over the observed period of record and is projected to increase in the future as a result of climate change. More extreme events have occurred in recent years and the climate hydrology assessment tool predicts increases in projected annual maximum monthly flows during the next century.

The interaction between streamflow, precipitation, and temperature illustrates that there is some uncertainty with predicting future flood flows. While precipitation increased during the observed record and may continue to increase in the future, increases in temperature and evapotranspiration may potentially outweigh watershed runoff which could reduce flood risk.

The Potomac (HUC 0207) watershed is determined to be not vulnerable to climate change impacts for the ecosystem restoration business line in the four epoch-subset combinations examined in this report.

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