US Army Corps of Engineers ®
Wilmington District

PHILPOTT LAKE, VIRGINIA
WATER STORAGE REALLOCATION
INTEGRATED FEASIBILITY STUDY AND ENVIRONMENTAL ASSESSMENT

APPENDIX F: CONSIDERATION OF POTENTIAL IMPACTS OF CLIMATE CHANGE OF THE PHILPOTT LAKE REALLOCATION

Final Report
February 2023

ECB 2018-14 Climate Change Assessment

To effectively incorporate climate change adaptation and to increase resilience and decrease vulnerability of Philpott Lake Reallocation Project, the first step was to identify where vulnerability exists. The current USACE Screening-Level Climate Change Vulnerability Assessment (VA) Tool and other tools described in Engineering & Construction Bulletin (ECB) 2018-14 were used in this analysis, including the Timeseries Toolbox (TST)). This discussion will start with a literature review of climate observations and predictions before moving onto an analysis starting at the broad regional scale and finishing at the project level with the analysis.

1 Literature Review

The Smith River Basin and the Philpott Dam are in Water Resource Region number 03, the South Atlantic-Gulf Region. A January 2015 report conducted by the USACE Institute for Water Resources summarizes the available climate change literature for this region. The report covers both observed and predicted changes using data published through 2014. Figure 1 shows a summary matrix of the observed and projected trends used in the report.

Multiple studies focused on observed mean temperature, mean seasonal temperature and extreme temperatures. Generally, the studies concurred on increased average annual temperature (Carter et al, 2014, Patterson et al, 2012, Laseter et al, 2012). However, there are conflicting results on observed seasonal changes with some results showing warmer summers and colder winters (Wang et al, 2009) and others showing no observed seasonal changes (Westby et al, 2013). Analysis of global climate model (GCM) projections generally agree that over the next century mean annual temperatures will rise with the largest increases in summer months (Carter et al, 2014; Elguindi and Grundstein, 2013; Qi et al, 2009; Tebaldi, 2006). The 2018 Fourth National Climate Assessment found increasing temperatures and increasing extreme heat events along the Southeast and projects increasing temperatures to continue in the future. The 2022 NOAA State Climate Summary for Virginia show temperatures rising 1.5°F since the beginning of the 20th century and projects the increase in temperatures to continue in the future.

Precipitation trend analysis for the South Atlantic-Gulf region showed mixed results with low consensus for increasing trends in annual precipitation totals and precipitation intensity, and moderate consensus for increasing extreme high precipitation events (Wang and Zhang, 2008; McRoberts and Nielsen-Gammon, 2011; Pryor et al., 2009). Wang and Zhang (2008) found an increase in extreme precipitation event frequency and Pryor et al. (2009) found a statistically significant increase in the number of precipitation days per year. Wang, Killick, and Fu (2013) investigated high and low extreme precipitation in the South-Atlantic Gulf region and supported the findings of Wang and Zhang (2008) with an increase in high extreme precipitation events but found no statistically significant change in the low extreme precipitation events. Analysis of GCM projections are split on future precipitation with some models showing more annual precipitation and others showing less (Bastola et al, 2007; Jayakody et al, 2013; Qi et al, 2009). There is general consensus on more intense and frequent storm events (Gao et al 2012; Tebaldi 2006; Wang and Zhang 2008). The 2018 Fourth National Climate Assessment found increasing extreme rainfall events and projects this trend to continue in the future. The 2022 NOAA State Climate Summary for Virginia found a small upward trend in total annual precipitation and an upward trend in the annual number of extreme precipitation events. The annual precipitation in Virginia is projected to increase.

Studies of stream gages in the regions have shown mixed results but have a moderate consensus on decreasing streamflow. Xu et al (2013) showed no statistically significant trend in stream flows. Kalra et al (2008) found a negative statistically significant trend in annual and seasonal stream flows. Small et al (2006) found a statistically significant negative trend for annual low flows at several gages across the region. GCM projections coupled with macro-scale hydrologic models show no clear consensus on future stream flow trends (Bastola et al, 2007; Carter et al, 2014; Hagemann et al, 2013; Irizarry-Ortiz et al, 2013; Qi et al, 2009; Wang et al 2013a; Wang et al 2013b). The 2018 Fourth National Climate Assessment projects increases in the frequency and severity of droughts in the Southeast US. The 2022 NOAA State Climate Summary for Virginia also projects more intense droughts due to higher projected temperatures and increased rate of loss of soil moisture during dry spells.

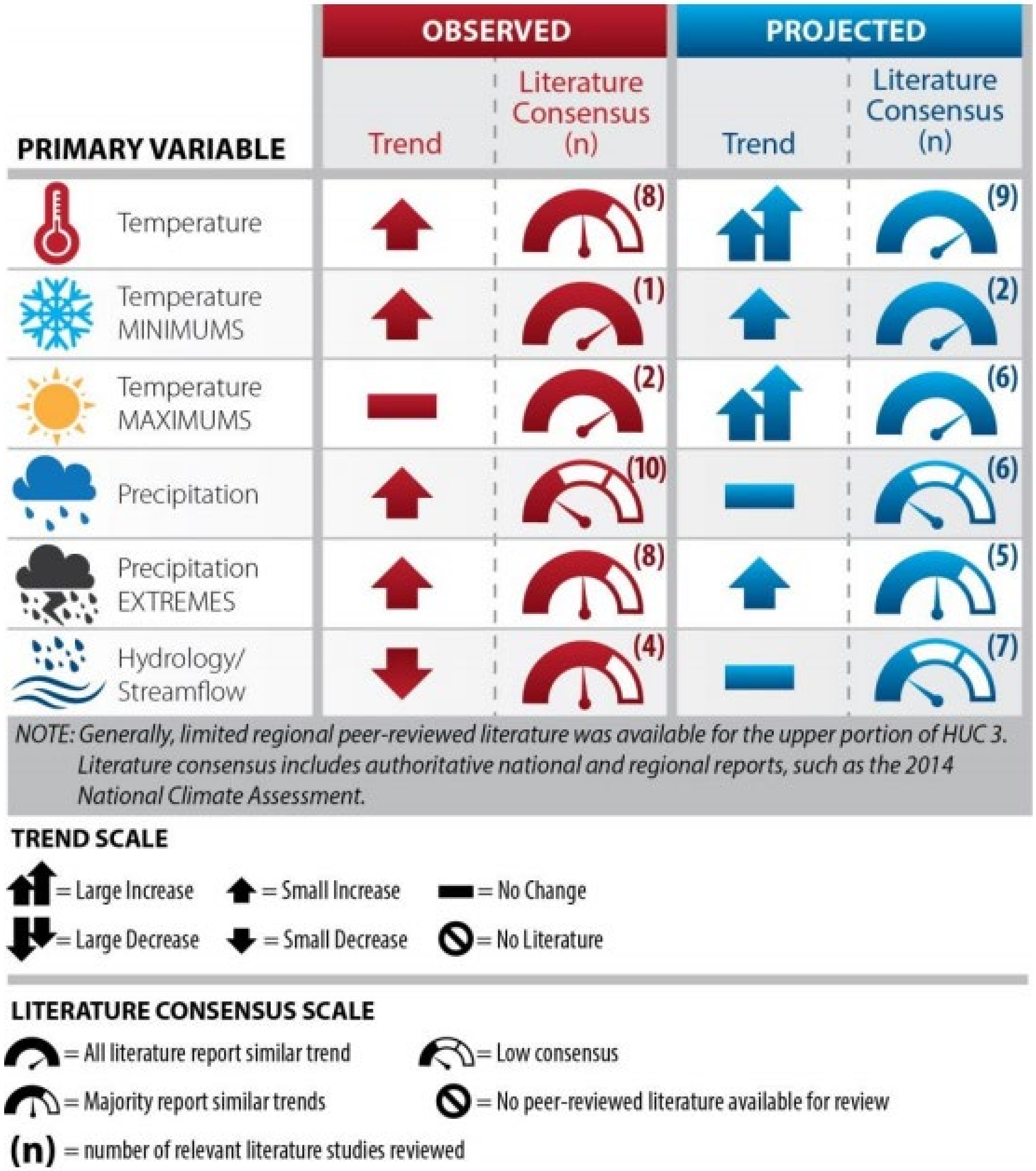


Figure 1. Summary matrix of observed and projected climate trends.

2 Vulnerability Assessment

With the knowledge that climate information and understanding is constantly evolving, USACE has developed the USACE Screening-Level Climate Vulnerability Assessment at the Watershed-Scale. The preliminary, screening-level nationwide analysis is built on existing, national-level tools and data that include indicators or processes to identify vulnerabilities in watersheds with respect to climate change. The USACE Watershed Climate Vulnerability Assessment (VA) Tool facilitates screening-level analysis of vulnerabilities of a given business line and HUC-4 watershed to the impacts of climate change, relative to the other continental United States HUC-4 watersheds. It uses the Coupled Model Intercomparison Project (CMIP5) GCM-BCSD-VIC dataset (2014) to define projected hydrometeorological inputs, combined with other data types, to define a series of indicator variables to define a vulnerability score. 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% of cumulative runoff projections). Data are available for three epochs, the current epoch (Base), and two future 30-year epochs (centered on 2050 and 2085).

The VA Tool was used to examine the future water supply-related vulnerability of the project area (Figure 2 and Figure 3). For the Chowan-Roanoke watershed (HUC 0301), this tool shows that the area is projected to be relatively less vulnerable compared to the entirety of the USACE portfolio with respect to water supply and hydropower business lines. While there is an increase in the WOWA scores between year 2050 and year 2085 for both the Dry and Wet scenarios (43.7 to 50.38 for Dry and 53.8 to 56.6 for Wet, respectively), the future increases still do not exceed the threshold for inclusion among the 20% most vulnerable HUC-4 watersheds represented by the water supply business line. For the hydropower business line, which also does not exceed the threshold for inclusion among the 20% most vulnerable HUC-4 watersheds, there is a decrease in the WOWA scores between 2050 and 2085 (62.552 and 61.869, respectively), but an increase in the WOWA scores between 2050 and 2085 for the Wet scenario (63.533 and 68.532, respectively).

The three largest indicators of vulnerability for the water supply business line are drought severity, sediment, and runoff precipitation. Drought severity is characterized by the most negative value calculated by subtracting potential evapotranspiration from precipitation over any 1-, 3-, 6- or 12-month period. Drought severity has the largest impact for the 2085 Dry scenario, with over 50% of the indicator contribution, and ranges from 1-10% for the other scenarios. The sediment indicator represents the ratio of the change in the sediment load in the future to the present load. The sediment indicator contribution is around 63% for both the 2050 and 2085 Wet scenario, around 53% for the 2050 Dry scenario, and 26% for the 2085 Dry scenario. The runoff precipitation indicator represents the median of the deviation of runoff from the monthly mean times the average monthly runoff divided by the deviation of the precipitation from the monthly mean times the average monthly precipitation. The runoff precip indicator contributes around 26% of the vulnerability for the 2050 Dry scenario, around 14% for the 2085 Dry scenario, around 22% for the 2050 Wet scenario, and around 20% for the 2085 Wet scenario.

The three largest indicators of vulnerability for the hydropower business line change between the different scenarios, but all include flood magnification, which is the change in flood runoff. For the 2050 Dry scenario the largest indicator contributions are from flood magnification (32.12%), runoff precip (23.36%), and low flow reduction (15.96%). For the 2085 Dry scenario the large indicator contributions are drought severity (32.71%), flood magnification (21.65%) ad runoff precip (16.05%). For the 2050 Wet scenario the largest indicator contribution comes from flood magnification (34.37%), runoff precip (22.50%), and sediment (15.75%). For the 2085 Wet scenario the largest indicator contributions are the flood magnification (34.12%), sediment (22.08%), and runoff precip (16.32%).

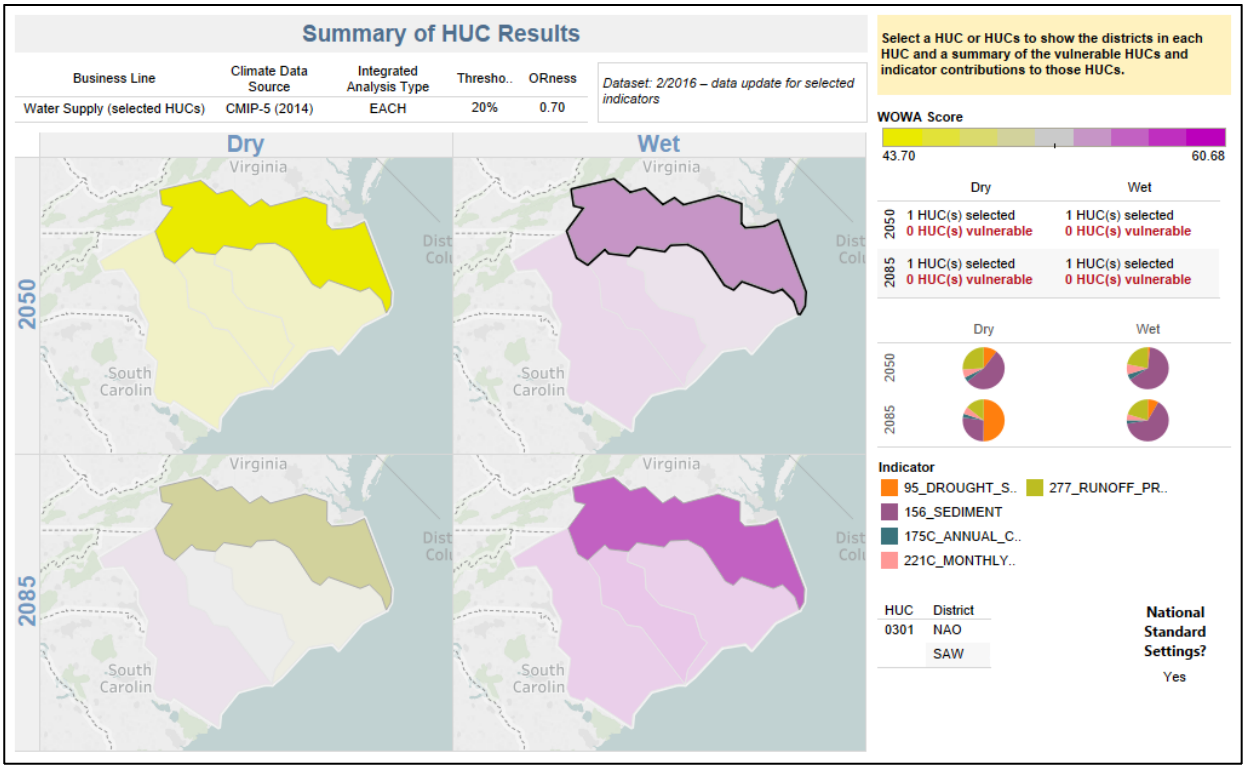


Figure 2. Projected Vulnerability for Chowan-Roanoke Watershed with respect to Water Supply.

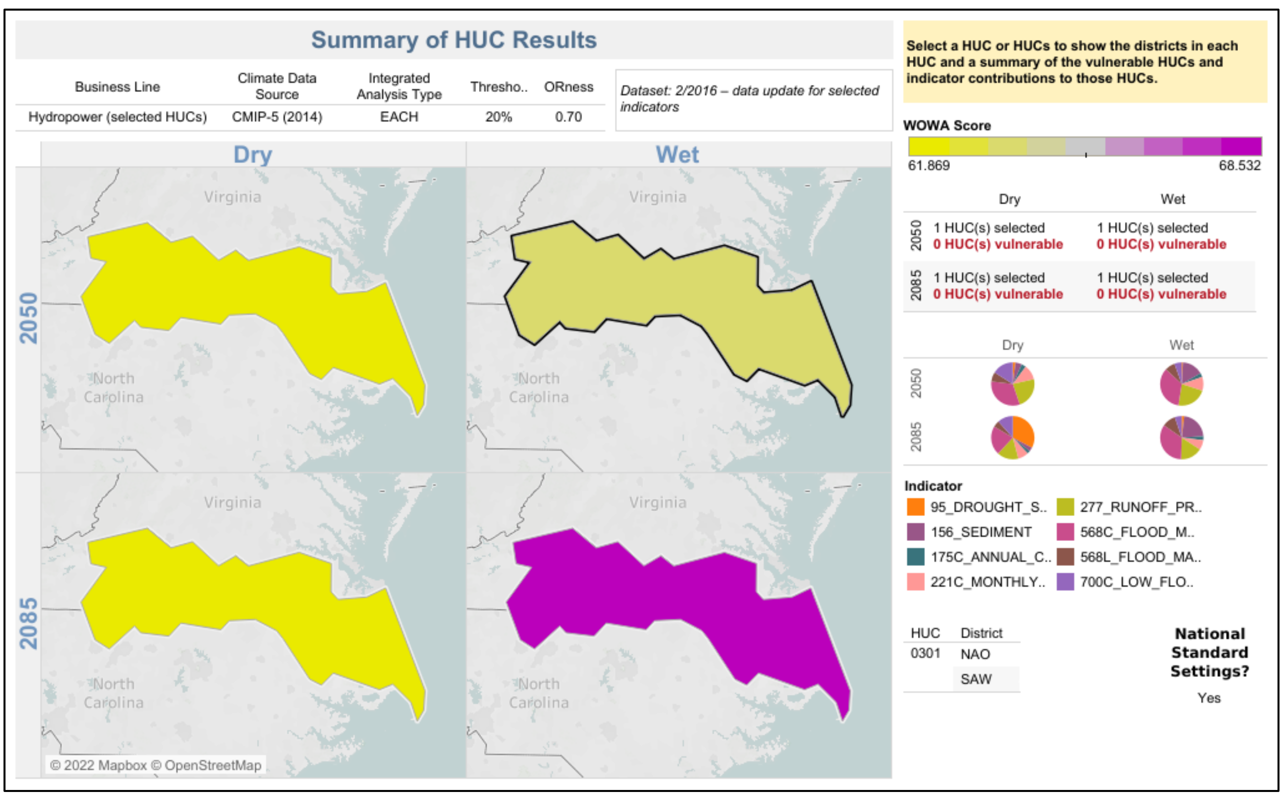


Figure 3. Projected Vulnerability for Chowan-Roanoke Watershed with respect to Hydropower.

While the VA tool identifies watersheds that may or may not be relatively vulnerable, it may not be appropriate to cascade those results to the project by default, because projects exist at finer spatial scales than the HUC-4 watersheds, evidenced by the fact that the watershed for Philpott Lake is such a relatively small portion of the overall Chowan-Roanoke watershed (212 square miles compared to over 18,000 square miles). To give a fuller picture of the potential vulnerabilities at this project, additional tools were employed to assess conditions by investigating other data and projections.

3 Climate Hydrology Assessment Tool

The USACE Climate Hydrology Assessment Tool (CHAT) was used to examine modeled, hindcast and projected trends in Upper Roanoke watershed hydrology to support the assessment, based on analysis of 32 general circulation models and 2 future emissions scenarios (representative concentration pathway) through the year 2099. The CHAT uses CMIP5-based simulations of hydrology and climatology, incorporating future projections of greenhouse gas emissions statistically downscaled using the Localized Constructed Analogs (LOCA) method. The CHAT compares a simulated hindcast period (1951-2005) to a simulated future period (2006-2099) of an unregulated basin condition using two different future emission scenarios (RCP 4.5 and RCP 8.5). The hindcast period simulation (1951-2005) assumes greenhouse gas emissions to be equivalent to a reconstruction of historically observed greenhouse gas emission levels. The RCP 4.5 scenario represents a rising radiative forcing pathway stabilizing at 4.5 W/m^2 before 2100 and the RCP 8.5 scenario represents a rising radiative forcing pathway leading to 8.5 W/m^2 before 2100. Radiative forcing expresses the change in energy in the atmosphere due to greenhouse gas emissions. For projected annual maximum monthly mean streamflows, the CHAT displays the results derived using two future RCP scenarios in one plot.

As expected for this type of analysis, there is considerable variability in the annual maximum monthly mean flows (Figure 4); however, there is an overall projected upward trend in mean annual maximum monthly flows over time for the Upper Roanoke watershed (Figure 5). The simulated hindcast period (1951-2005) has an increasing slope of 2.75 cfs/year; however, it was not statistically significant. The simulated future period (2006-2099) has a statistically significant ($p<0.05$) increasing slope of 7.83 cfs/year, indicating that the monthly maximum flow is projected to increase in the future.

Simulated annual accumulated precipitation (Figure 6) has a statistically significant increasing trend of 0.0195 in/year for the simulated hindcast period, a statically significant increasing trend of 0.0284 in/year for the simulated future period under the RCP 4.5 emissions scenario, and a statistically significant increasing trend of 0.0518 in/year for the simulated future period under the RCP 8.5 scenario.

Simulated annual mean temperature (Figure 7) for the watershed has a statistically significant increasing slope of 0.0321 degrees F/year for the simulated hindcast period, a statistically significant increasing slope of 0.0454 degrees F/year for the simulated future period under the RCP 4.5 scenario, and a statistically significant increasing slope of 0.0988 degrees F/year for the simulated future period under the RCP 8.5 scenario.

Simulated annual maximum temperature (Figure 8) for the watershed has a statistically significant increasing slope of 0.0393 degrees F/ year, a statistically significant increasing slope of 0.0561 degrees F/year for the simulated future period under the RCP 4.5 scenario, and a statistically significant increasing slope of 0.1292 degrees F/year for the simulated future period under the RCP 8.5 scenario.

Simulated drought indicator (Figure 9) for the watershed has a decreasing slope of 0.0035 days/year for the simulated hindcast period, but it was not statistically significant. For the simulated future period under the RCP 4.5 emissions scenario there is a statistically significant increasing slope of 0.0098 days/year, and under the RCP 8.5 emissions scenario there is a statistically significant increasing trend of 0.0194 days/year.

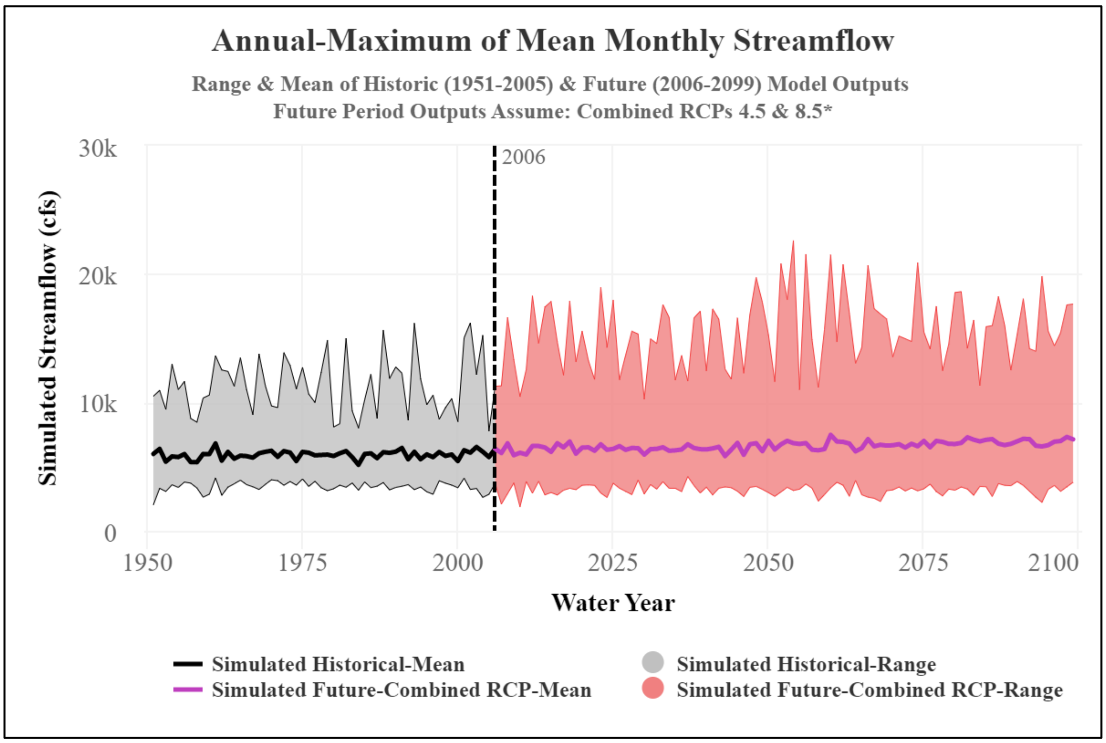


Figure 4. Range of Projected Annual Maximum Monthly Streamflow for the Upper Roanoke Watershed. Predicted Annual Maximum Monthly Flow is shown on the y-axis (cfs) with the range of predictions shaded in grey for the simulated historical period and shaded in red

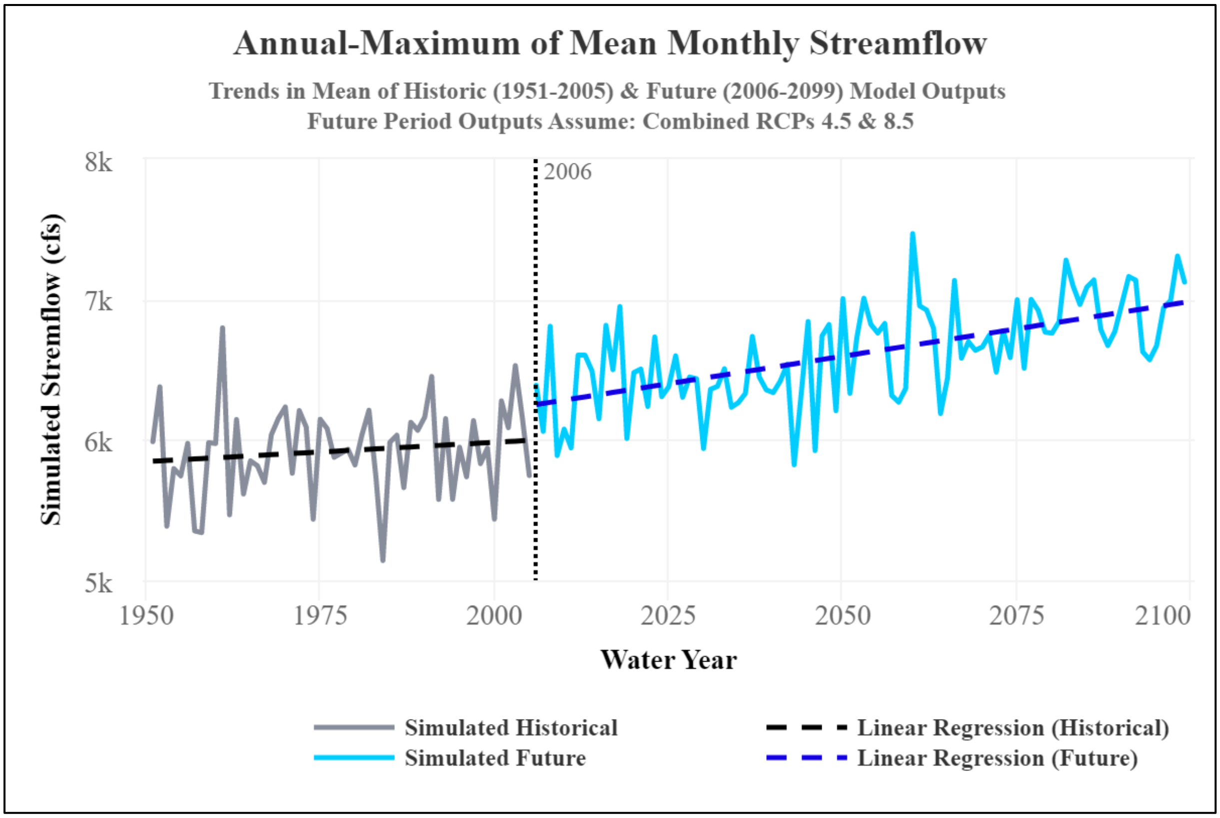


Figure 5. Trends in Mean Projected Annual Maximum Monthly Streamflow for the Upper Roanoke Watershed.

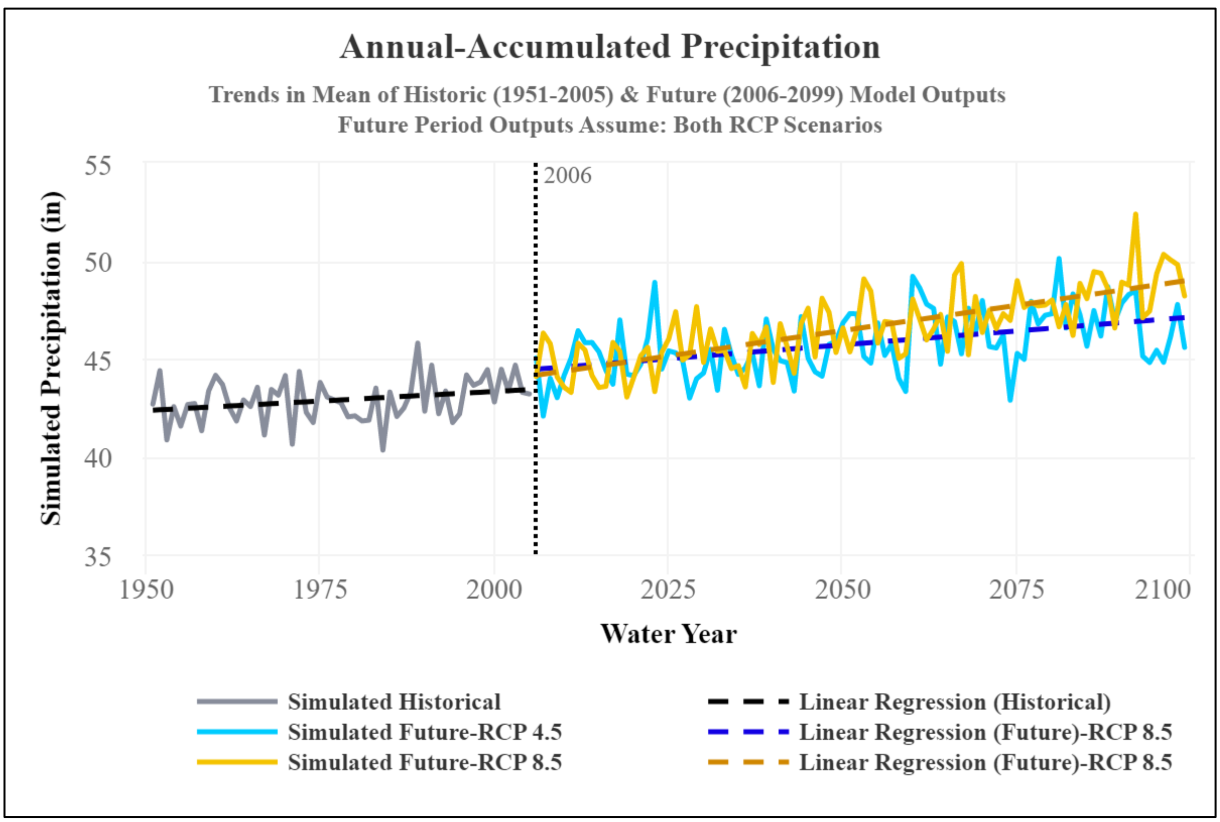


Figure 6. Trends in Projected Annual Accumulated Precipitation for the Upper Roanoke Watershed.

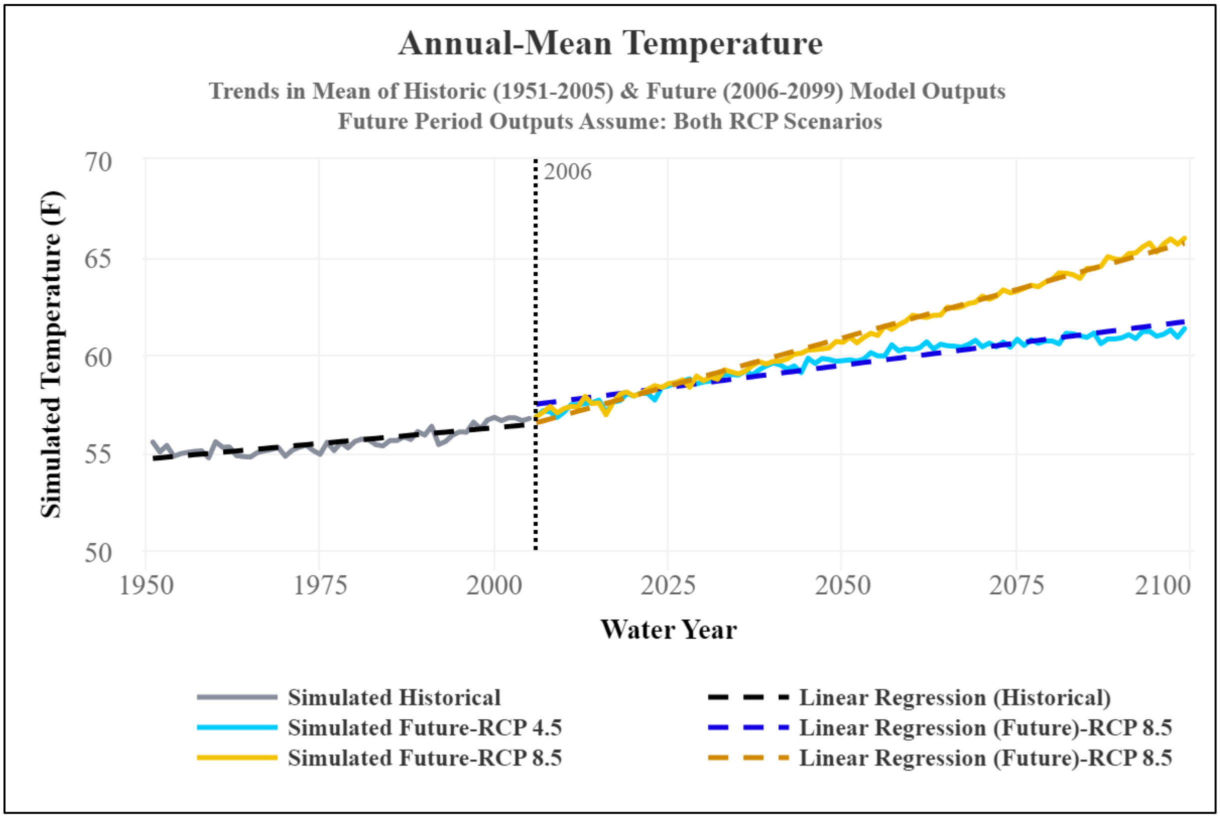


Figure 7. Trends in Projected Annual Mean Temperature for the Upper Roanoke Watershed.

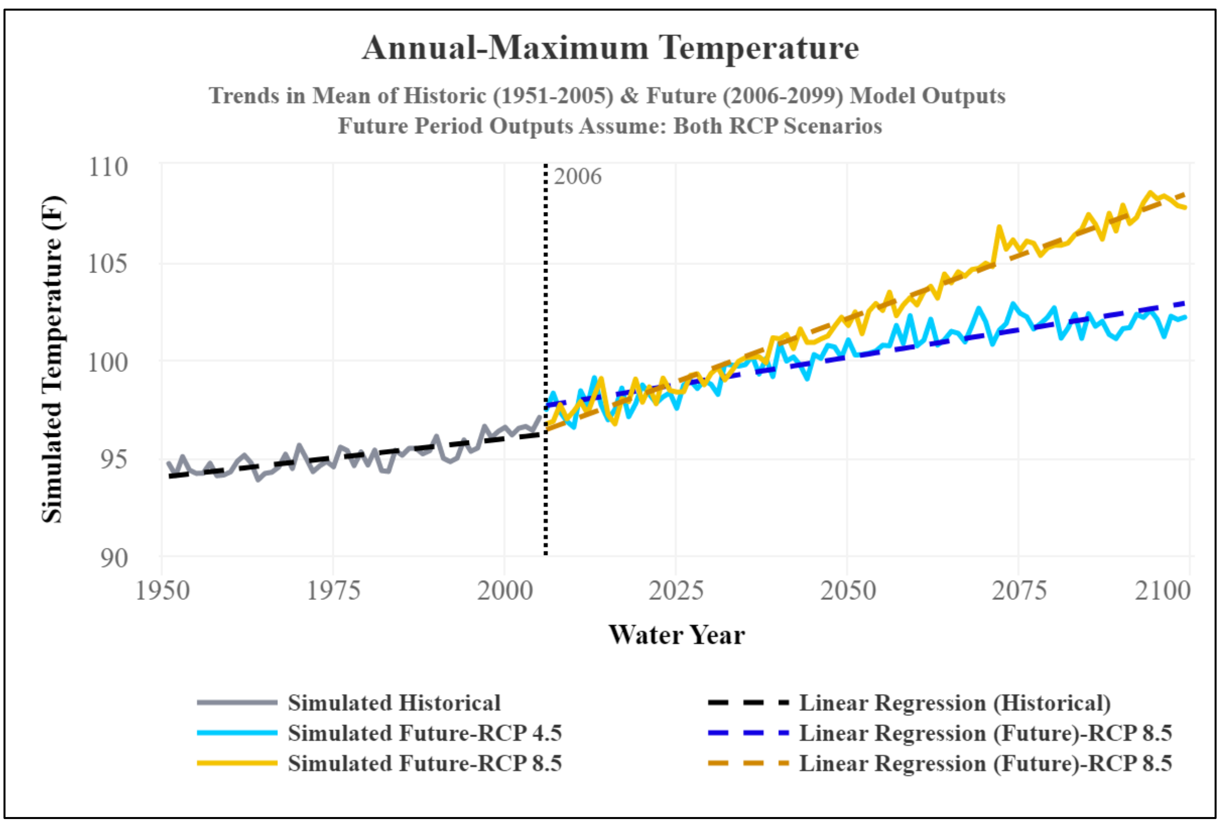


Figure 8. Trends in Projected Annual Maximum Temperature for the Upper Roanoke Watershed.

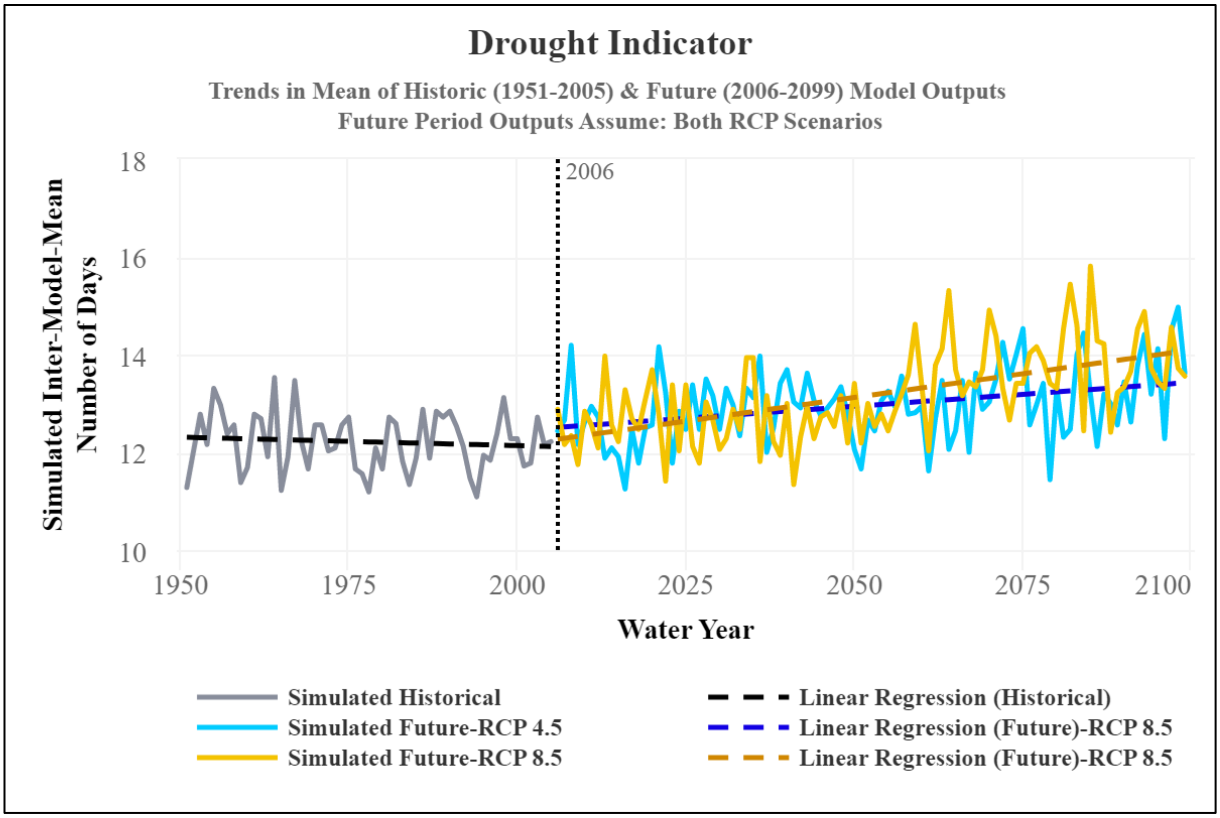


Figure 9. Trends in Projected Drought Indicator for the Upper Roanoke Watershed.

4 Time Series Toolbox

The Timeseries Toolbox (TST) was used to analyze historic timeseries data for trends. Available daily data were aggregated into monthly minimum and monthly average timeseries for analysis to examine trends at the average and lower end streamflow within the area that would have a larger impact to water supply. The t-test, Mann-Kendall, and Spearman Rank Order tests are applied to evaluate timeseries for monotonic trends. This analysis uses a statistical significance level of 0.05. A significant level of 0.05 translates to a 5% probability of encountering a false positive (Type I error) or identifying a significant trend when there is no significant trend. Two methods of determining the directionality of trends detected are used in this analysis, Traditional Slope (least Squares Regression and Sen's Slope. Traditional slope is calculated fitting a simple linear regression to the data, minimizing the sum of the squares of residuals. Sen's Slope determines the presence of a trend by taking the average of all the slopes between every two points in the series, and it can be more accurate than the traditional slope method for skewed and heteroskedastic data.

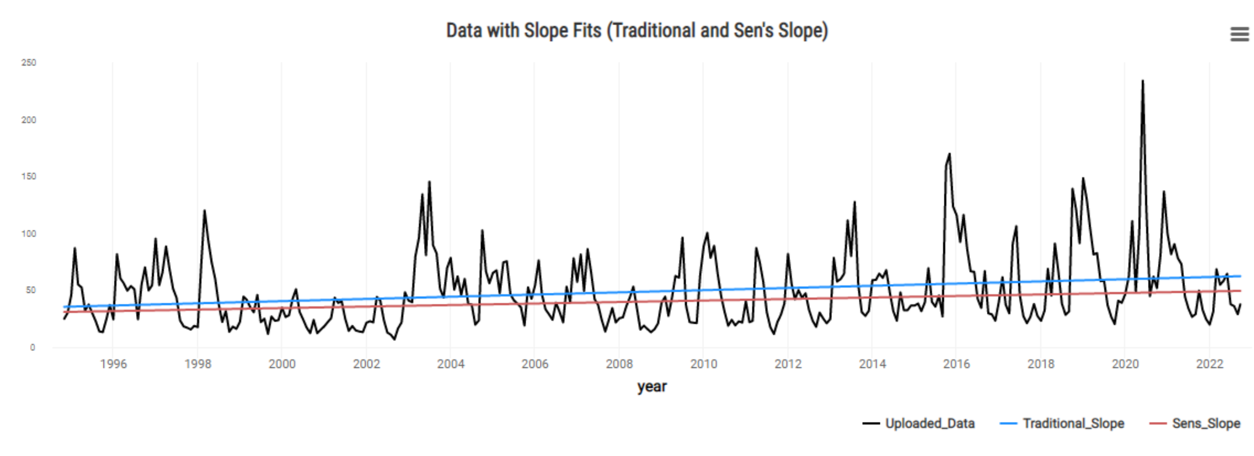
Historical USGS data were analyzed for one of the larger unregulated tributaries into Philpott Lake (USGS 02071530 Smith River at Smith River Church near Woolwine, VA) and three nearby unregulated gage stations (USGS 02069700 South Mayo River near Nettleridge, VA, USGS 02070000 North Mayo River near Spencer VA, and USGS 02056900 Blackwater River near Rocky Mount VA) (Figure 10). Table 1 shows the drainage area for each of the USGS gages and the period of data available for analysis. For Smith River at Smith River Church near Woolwine monthly average (Figure 11) and monthly minimum (Figure 12) flows have a small increasing trend that is statistically significant. South Mayo River near Nettle ridge monthly average (Figure

13) and monthly minimum (Figure 14) streamflows both have near zero slopes that are not statistically significant. North Mayo River near Spencer VA monthly average (Figure 15) streamflows show a small increasing trend that is not statistically significant while monthly minimum (Figure 16) shows a small increasing trend that is statistically significant. Blackwater River near Rocky Mount VA monthly average (Figure 17) shows a small increasing trend that is not statistically significant while monthly minimum streamflows (Figure 18) show a small increasing trend that is statistically significant. While the gage for Smith River at Bassett is shown (Figure 19 and Figure 20), it is important to note that Philpott Dam (located 6.2 miles upstream) began construction in 1948 and went into operation in 1950. This gage is used for monitoring of flows from Philpott Dam and as a control point for minimum flows on the Smith River. Monthly average flows show a statistically significant increasing trend while monthly minimum flows show a statistically significant small decreasing trend.

Table 1. USGS Gages in analysis

USGS Gage	Drainage Area	Period of Record	Trend	Significance
Smith River at Smith River Church near Woolwine VA	26.3 sq. mi.	10/1/1994-9/26/2022	Minimum: increasing	Yes
			Average: increasing	Yes
South Mayo River near Nettleridge VA	85.5 sq. mi.	10/1/1962-9/26/2022	Minimum: small decreasing	No
			Average: small increasing	No
North Mayo River Near Spencer VA	108 sq. mi.	10/1/1936-9/26/2022	Minimum: increasing	Yes
			Average: increasing	No
Blackwater River near Rocky Mount VA	115 sq. mi.	10/1/1976-9/26/2022	Minimum: increasing	Yes
			Average: increasing	No
Smith River at Bassett VA	259 sq. mi.	4/1/1939-9/26/2022	Minimum: decreasing	Yes
			Average: increasing	Yes

Figure 10. USGS gauge locations



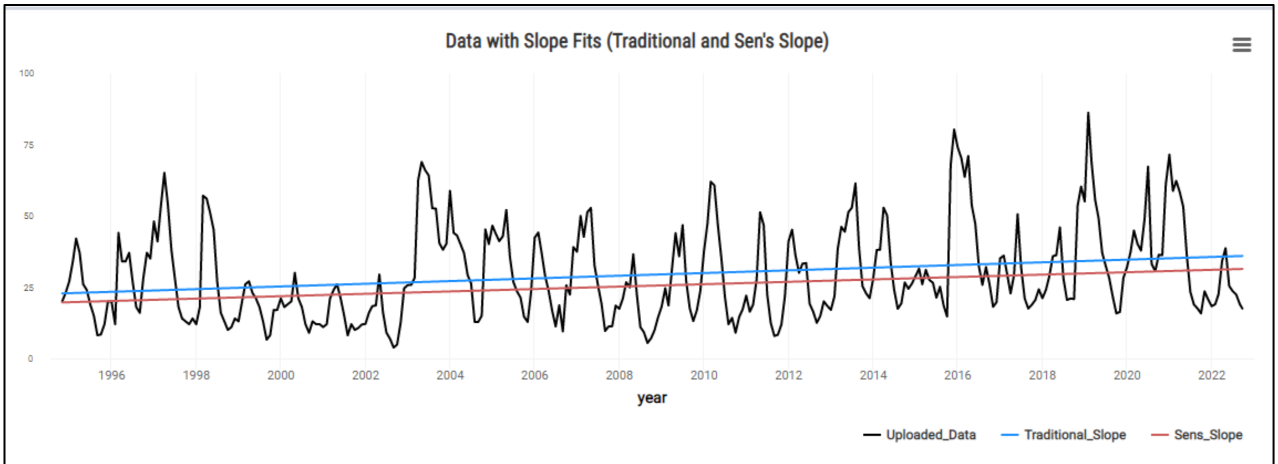
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.9623647258	-1884
Sen's Slope	Positive	0.6631578947	-1292

Trend Hypothesis Test

Test	P-Value
t-Test	0.0000039572
Mann-Kendall	0.000018835
Spearman Rank-Order	0.0000094207

Figure 11. Monthly Average Streamflow for Smith River at Smith River Church near Woolwine, VA.



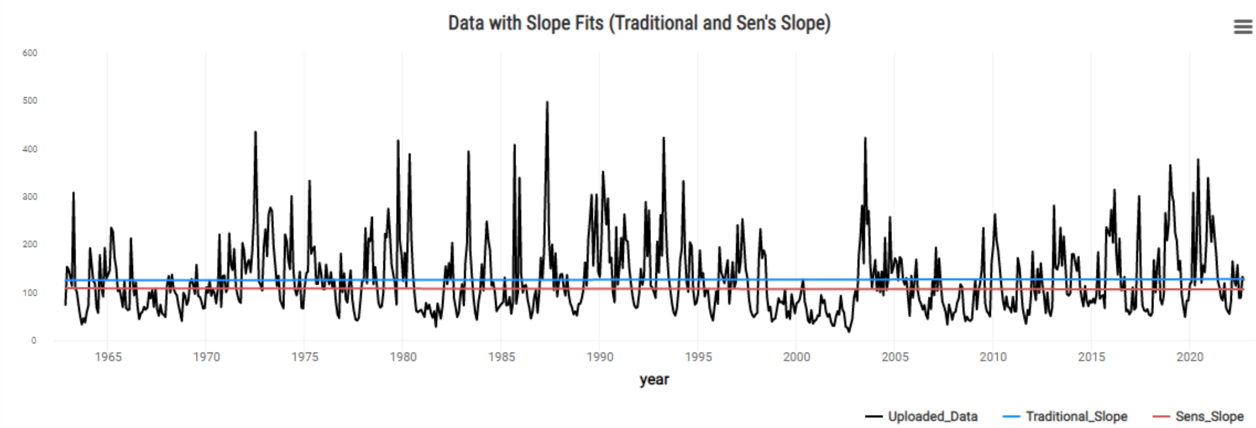
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.4697143237	-914
Sen's Slope	Positive	0.42	-818

Trend Hypothesis Test

Test	P-Value
t-Test	0.000012219
Mann-Kendall	0.0000070333
Spearman Rank-Order	0.0000030677

Figure 12. Monthly Minimum Streamflow for Smith River at Smith River Church near Woolwine, VA.



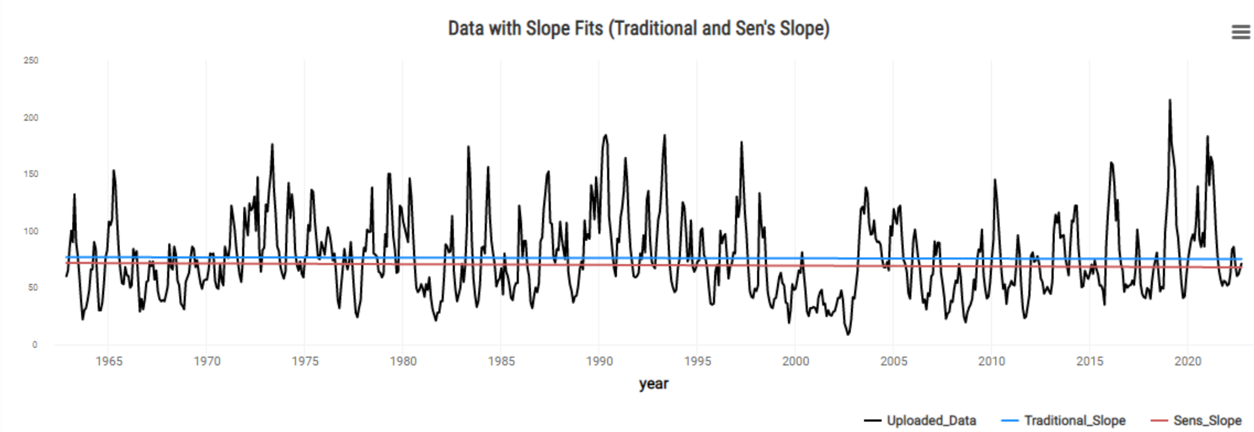
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.0380258295	50
Sen's Slope	Negative	-0.0357657552	178

Trend Hypothesis Test

Test	P-Value
t-Test	0.80886
Mann-Kendall	0.78103
Spearman Rank-Order	0.74922

Figure 13. Monthly Average Streamflow for South Mayo River near Nettleridge, VA.



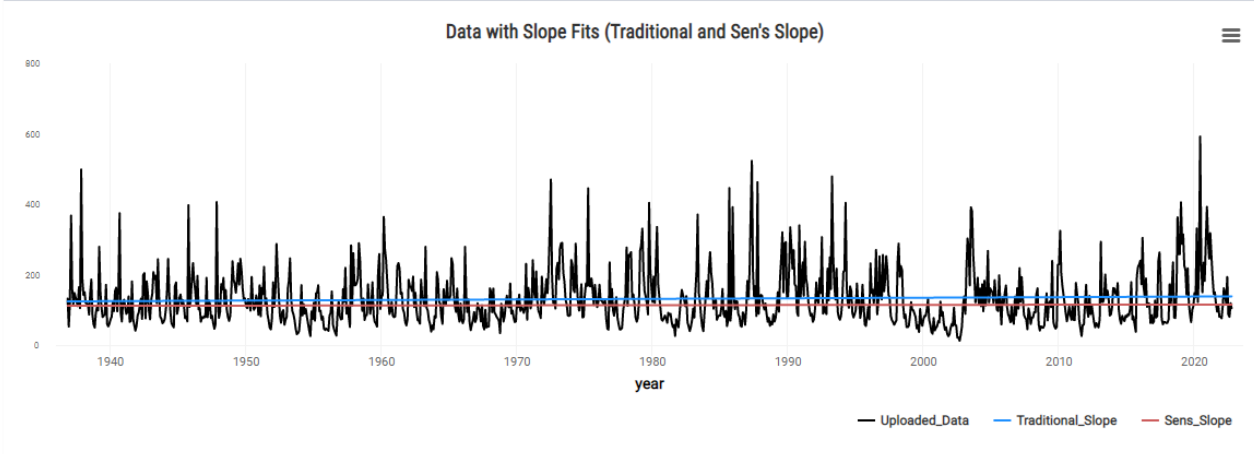
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Negative	-0.027679087	131
Sen's Slope	Negative	-0.0644339279	198

Trend Hypothesis Test

Test	P-Value
t-Test	0.7065
Mann-Kendall	0.31914
Spearman Rank-Order	0.26826

Figure 14. Monthly Minimum Streamflow for South Mayo River near Nettleridge, VA.



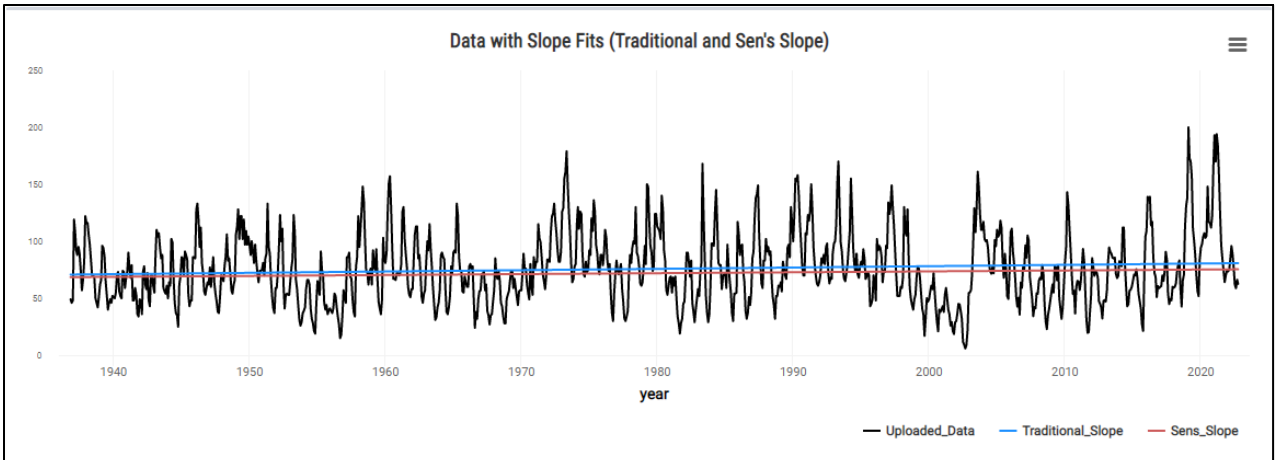
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.1634873111	-193
Sen's Slope	Positive	0.0425133389	29

Trend Hypothesis Test

Test	P-Value
t-Test	0.088982
Mann-Kendall	0.55088
Spearman Rank-Order	0.54712

Figure 15. Monthly Average Streamflow for North Mayo River near Spencer, VA.



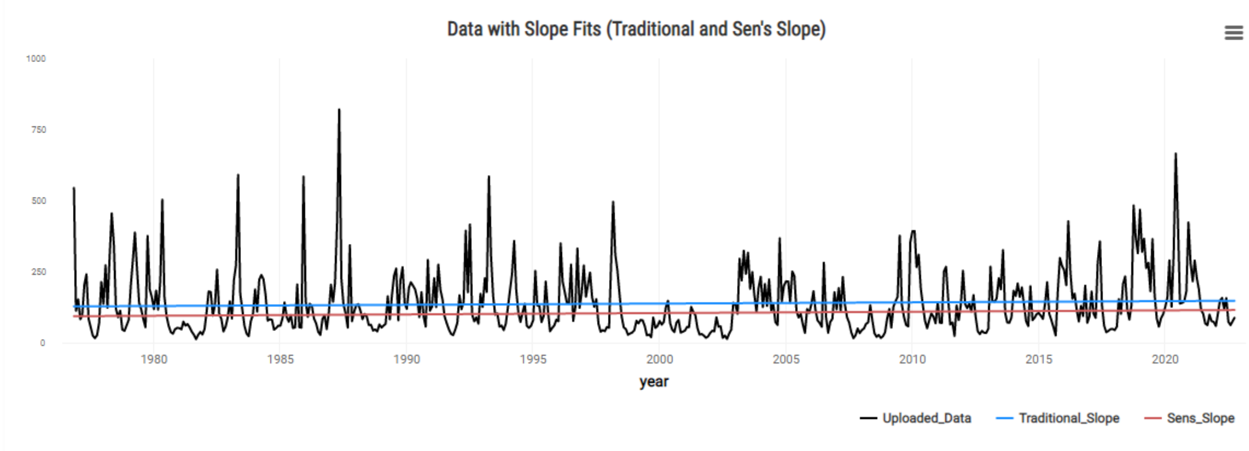
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.1166923944	-155
Sen's Slope	Positive	0.08011498	-87

Trend Hypothesis Test

Test	P-Value
t-Test	0.0024862
Mann-Kendall	0.026683
Spearman Rank-Order	0.027478

Figure 16. Monthly Minimum Streamflow for North Mayo River near Spencer, VA.



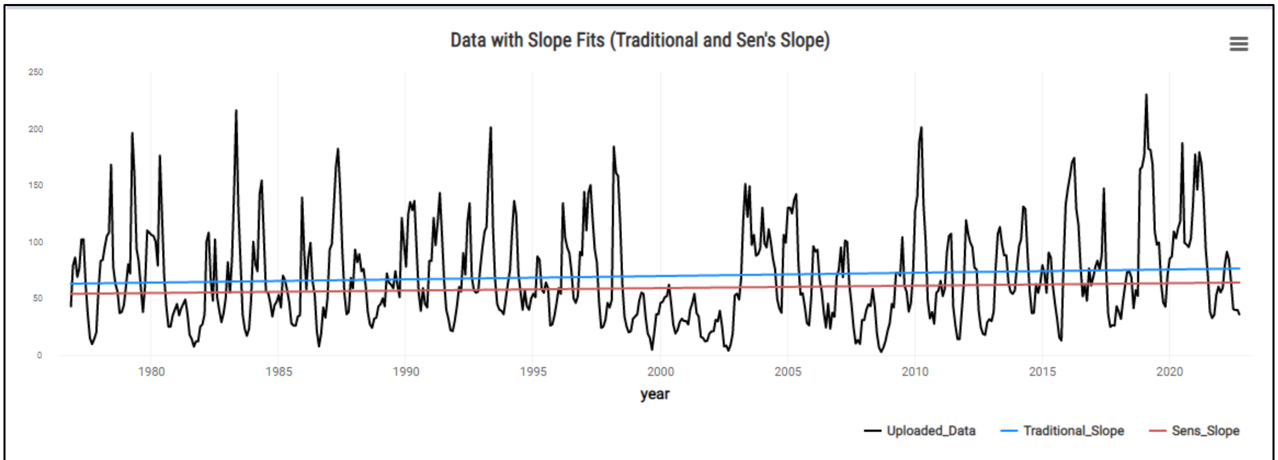
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.4290447476	-721
Sen's Slope	Positive	0.4748175778	-845

Trend Hypothesis Test

Test	P-Value
t-Test	0.21597
Mann-Kendall	0.044825
Spearman Rank-Order	0.041062

Figure 17. Monthly Average Streamflow for Blackwater River near Rocky Mount, VA.



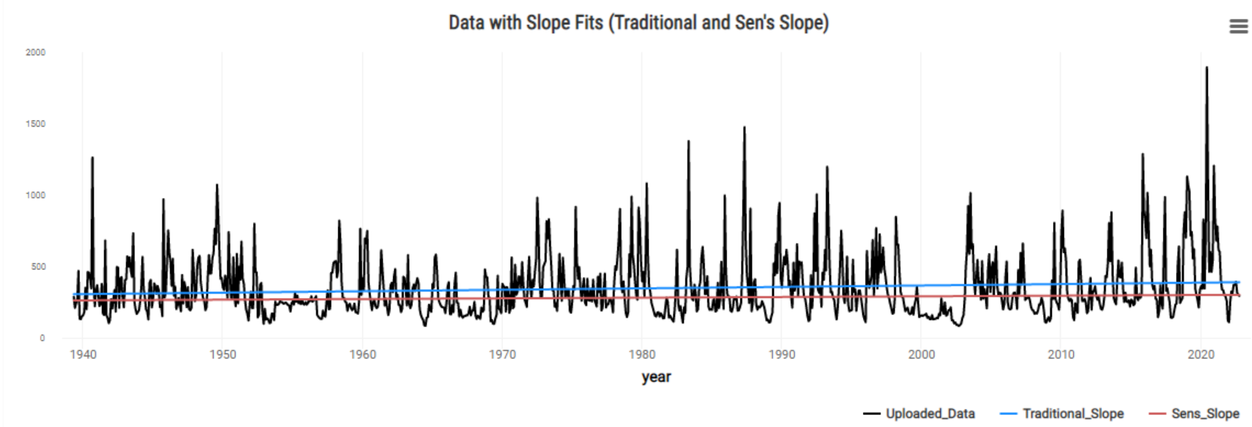
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	0.2903919483	-511
Sen's Slope	Positive	0.2164733136	-374

Trend Hypothesis Test

Test	P-Value
t-Test	0.032848
Mann-Kendall	0.080293
Spearman Rank-Order	0.064298

Figure 18. Monthly Minimum Streamflow for Blackwater River near Rocky Mount, VA.



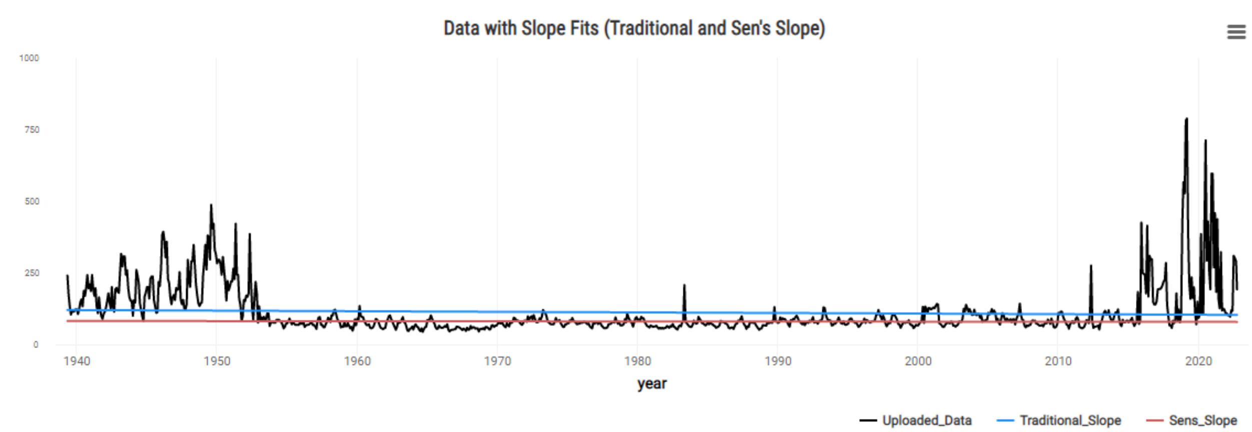
Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Positive	1	-1640
Sen's Slope	Positive	0.4715906563	-653

Trend Hypothesis Test

Test	P-Value
t-Test	0.0002454
Mann-Kendall	0.014373
Spearman Rank-Order	0.011107

Figure 19. Monthly Average Streamflow for Smith River near Bassett, VA.



Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Negative	-0.2033746792	514
Sen's Slope	Negative	-0.0392947103	158

Trend Hypothesis Test

Test	P-Value
t-Test	0.065994
Mann-Kendall	0.34013
Spearman Rank-Order	0.031084

Figure 20. Monthly Minimum Streamflow for Smith River near Bassett, VA.

5 Nonstationarity Detection

The Nonstationarity Detection analysis function within the Timeseries Toolbox is used to look at hydrologic time series data for stationarity, or the assumption that the statistical characteristics of hydrological time series data are constant through time. Stationarity in data enables the use of well-accepted statistical methods for water resources planning and design where future conditions are reliant on observed records (Friedman, et al. 2018).

The TST was used to examine the hydrologic time series of monthly average and monthly minimum streamflows at the same gages (Figure 21 and Figure 22 – South Mayo River near Nettleridge, VA; Figure 23 and Figure 24 - North Mayo River near Spencer VA; Figure 25 and Figure 26 – Blackwater River near Rocky Mount VA; and Figure 27 and Figure 28 - Smith River at Bassett VA) as were investigated as described above, except Smith River at Smith River Church near Woolwine VA which did not have minimum period of record needed for analysis. In addition, each dataset was examined using the Breakpoint Analysis tool within the TST, which looks for shifts in the slope of data trends.

For all of the unregulated time series analyzed, statistically significant nonstationarities were detected using multiple individual tests over the timeseries; however, there were no strong nonstationarities detected. A strong nonstationarity is one that demonstrates consensus, robustness, and a significant change in the sample mean and/or variance. While there are instances of consensus and robustness in some of the analyzed series, these were not accompanied by a significant change in the sample mean and/or variance. In addition, for the unregulated gages, no statistically significant breakpoints were found. The minimum flow dataset observed 6.2 miles below Philpott Dam on the Smith River at Bassett reflects evidence of a strong nonstationarity circa 1945 because of the dam's completion in 1950. The breakpoint analysis (Figure 29) detected two breakpoints in the monthly minimum flow, one in 1952 near the completion of the dam, and a second in 2010 which are due to several long-term generation outages that required extended periods of higher-than-normal minimum releases to manage flows and storage. Results of nonstationarity detection analysis are displayed in Table 2.

Table 2. USGS gages analyzed- Nonstationarity Detection Results

USGS Gage	Period of Record	Statistically Significant Trend	Nonstationarity Detection Results (year, Strong?, consensus/robustness, Magnitude)
South Mayo River near Nettleridge VA	10/1/1962-9/26/2022	Minimum: None	1981, 2003, but no consistent shift in magnitude
		Average: None	1982, 2013, but no consistent shift in magnitude
North Mayo River Near Spencer VA	10/1/1936-9/26/2022	Minimum: increasing	Early 40's, 1981, but no consistent shift in magnitude
		Average: None	None
Blackwater River near Rocky Mount VA	10/1/1976-9/26/2022	Minimum: increasing	None
		Average: None	1981, 1991, 2012, potential decrease in std. dev. Overtime, no consistent change in mean
Smith River at Bassett VA	4/1/1939-9/26/2022	Minimum: decreasing	Considerable evidence of nonstationarities tied to dam being constructed circa 1945
		Average: increasing	1964, 1979, 1994, but no consistent shift in magnitude

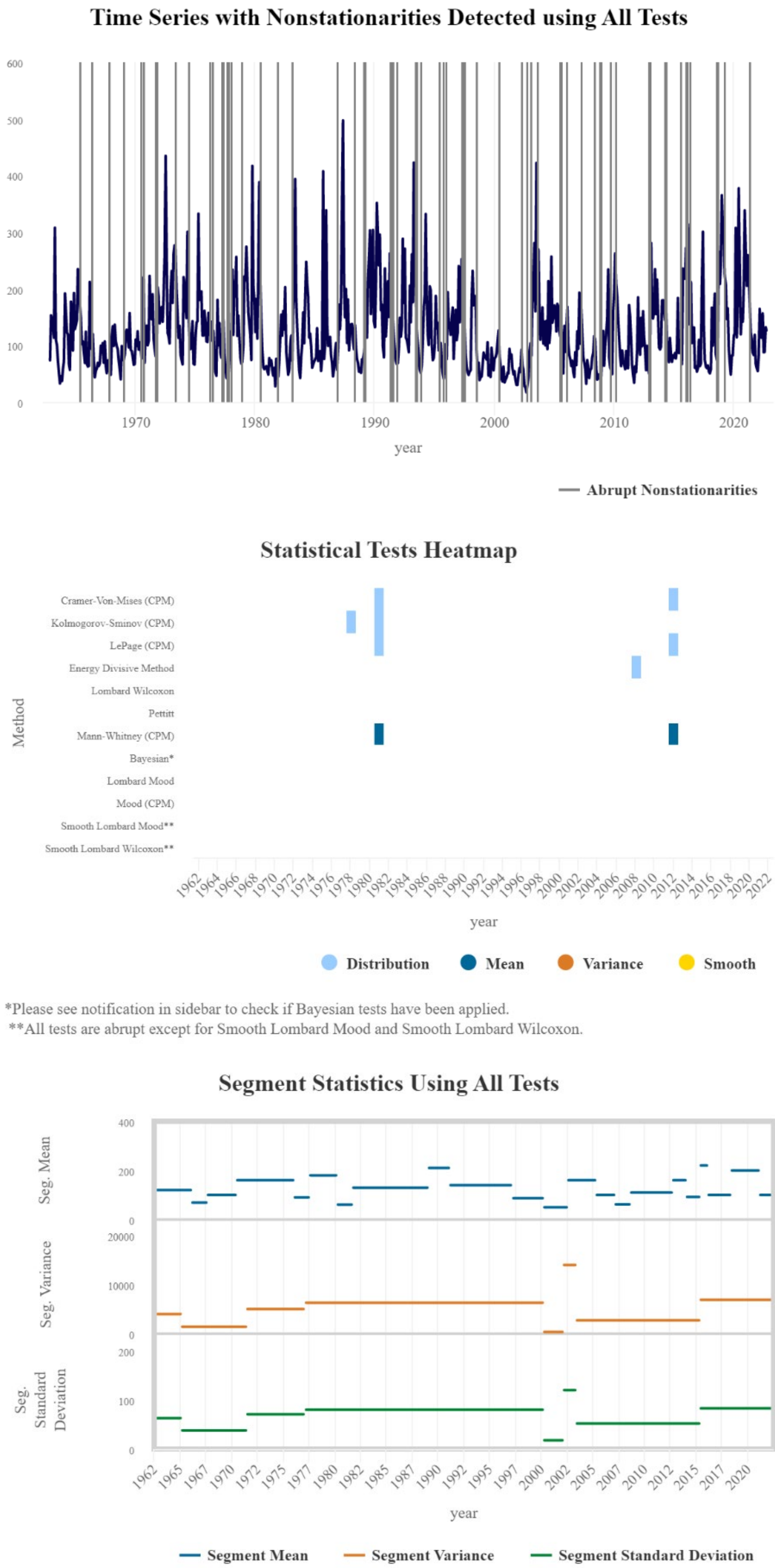
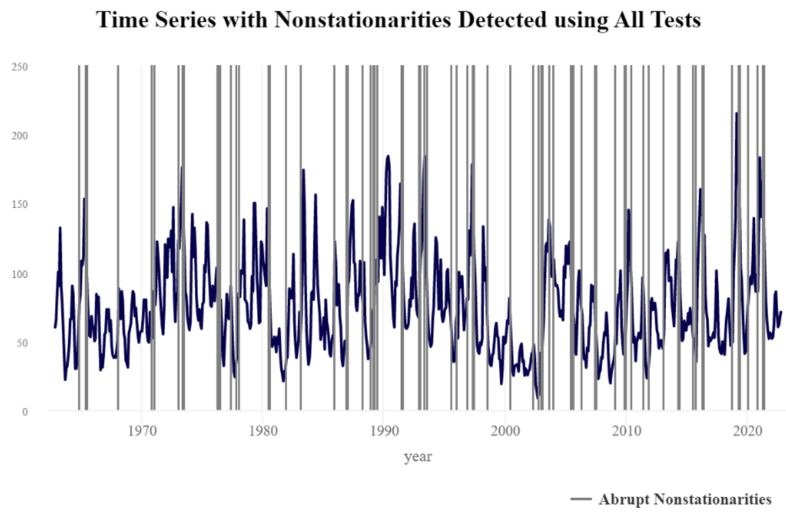
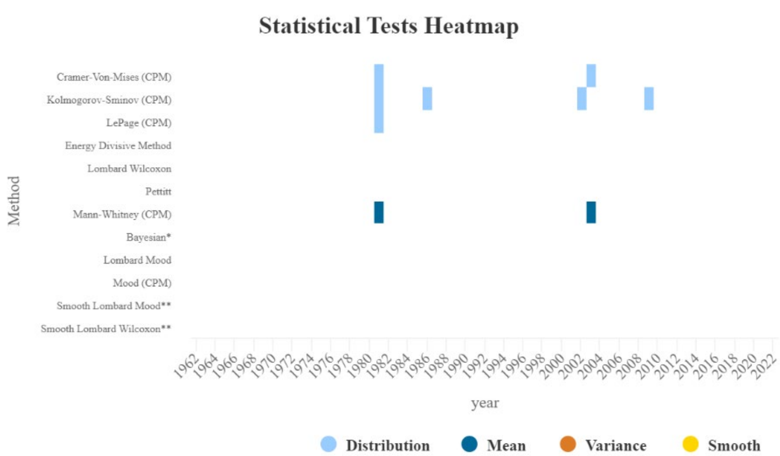


Figure 21. Nonstationarity Analysis for Average Monthly Flow for South Mayo River near Nettleridge VA





*Please see notification in sidebar to check if Bayesian tests have been applied.
**All tests are abrupt except for Smooth Lombard Mood and Smooth Lombard Wilcoxon.

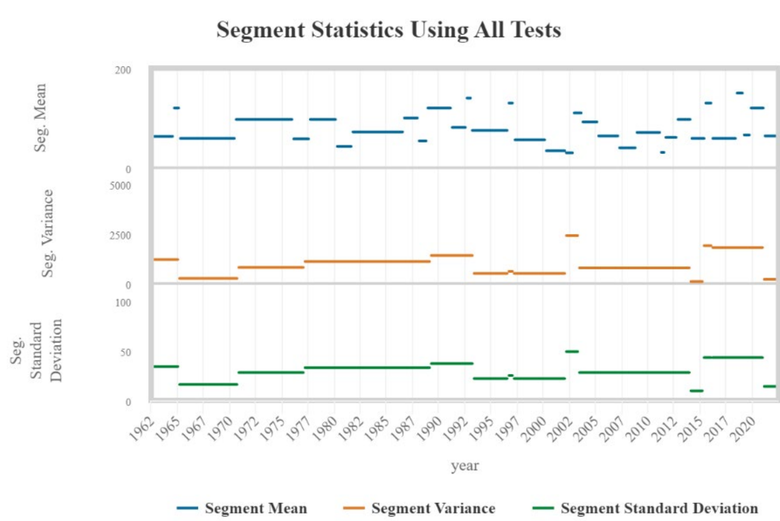
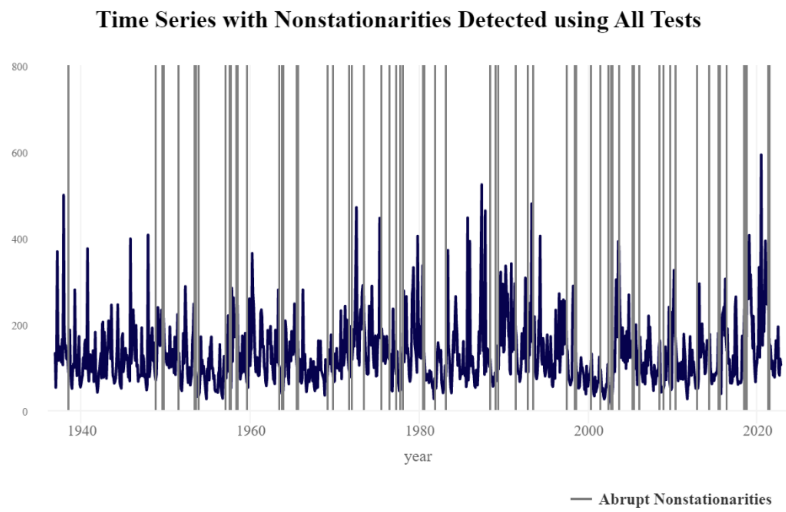
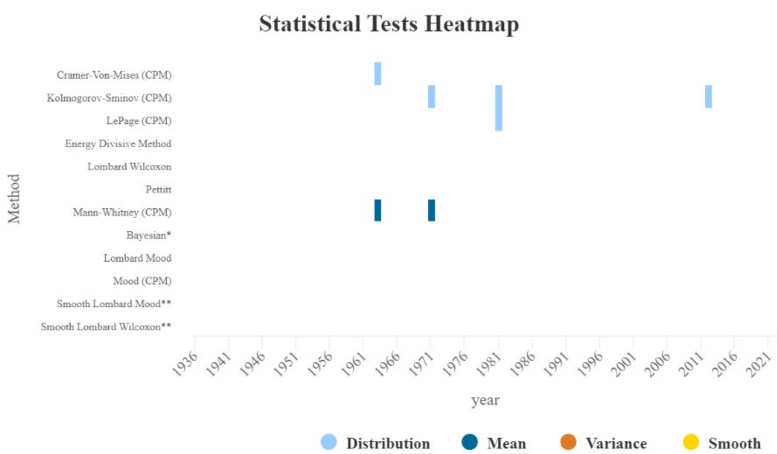


Figure 22. Nonstationarity Analysis on Monthly Minimum Flows for South Mayo River near Nettleridge, VA.





*Please see notification in sidebar to check if Bayesian tests have been applied.
**All tests are abrupt except for Smooth Lombard Mood and Smooth Lombard Wilcoxon.

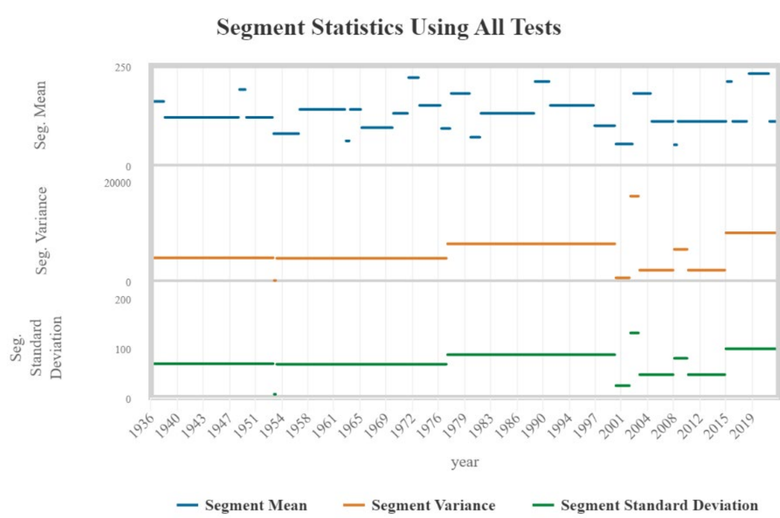
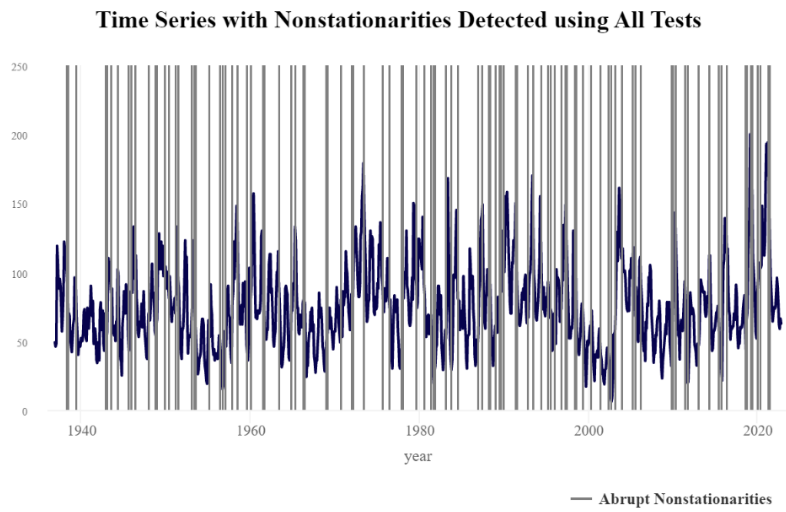
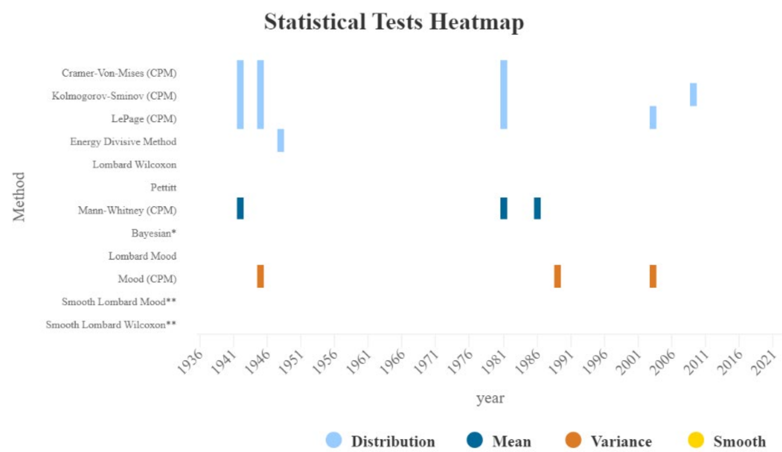


Figure 23. Nonstationarity Analysis on Monthly Average Flows for North Mayo River near Spencer, VA.





*Please see notification in sidebar to check if Bayesian tests have been applied.
**All tests are abrupt except for Smooth Lombard Mood and Smooth Lombard Wilcoxon.

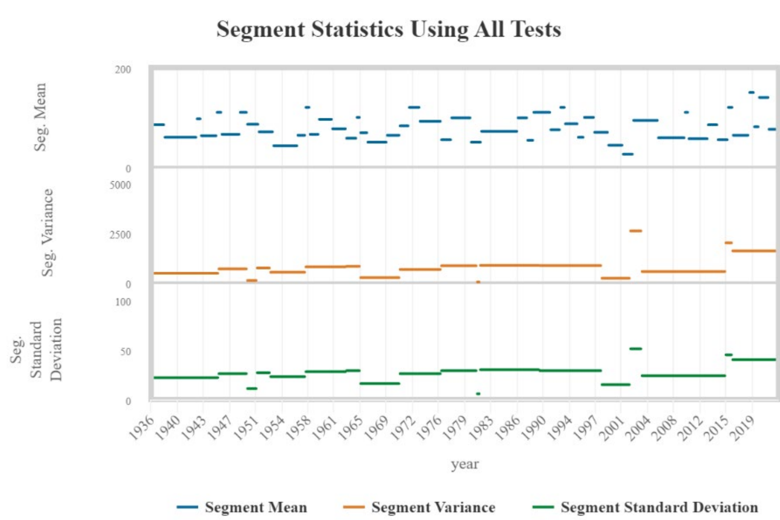
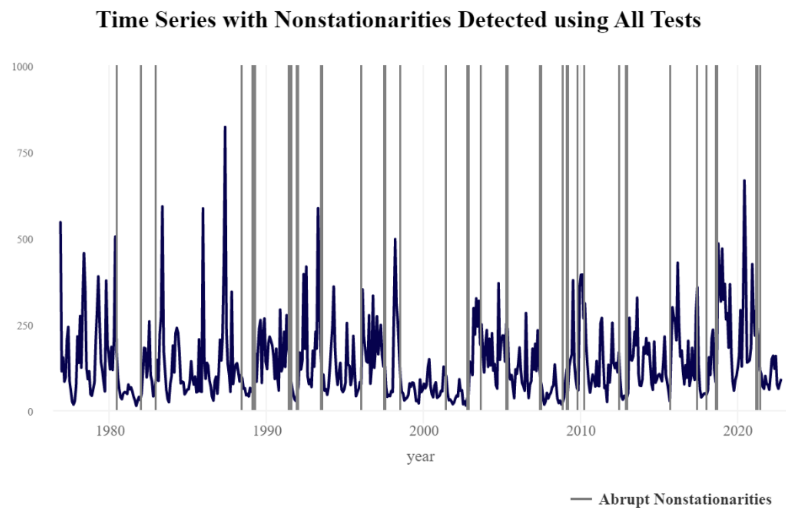
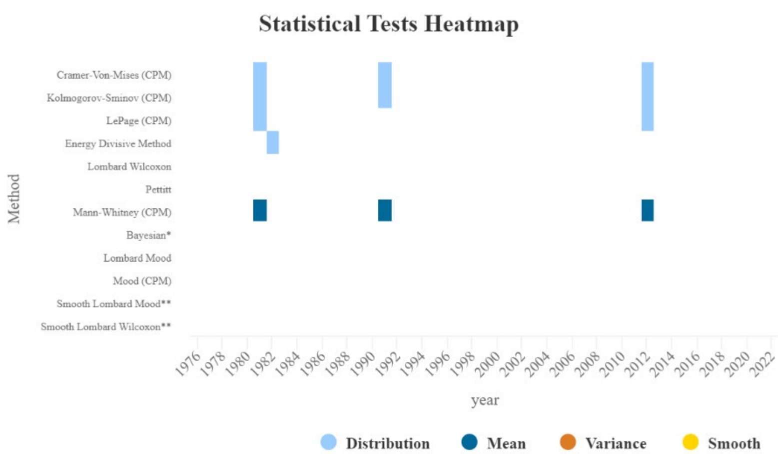


Figure 24. Nonstationarity Analysis for Monthly Minimum Flows for North Mayo River near Spencer, VA.





*Please see notification in sidebar to check if Bayesian tests have been applied.
**All tests are abrupt except for Smooth Lombard Mood and Smooth Lombard Wilcoxon.

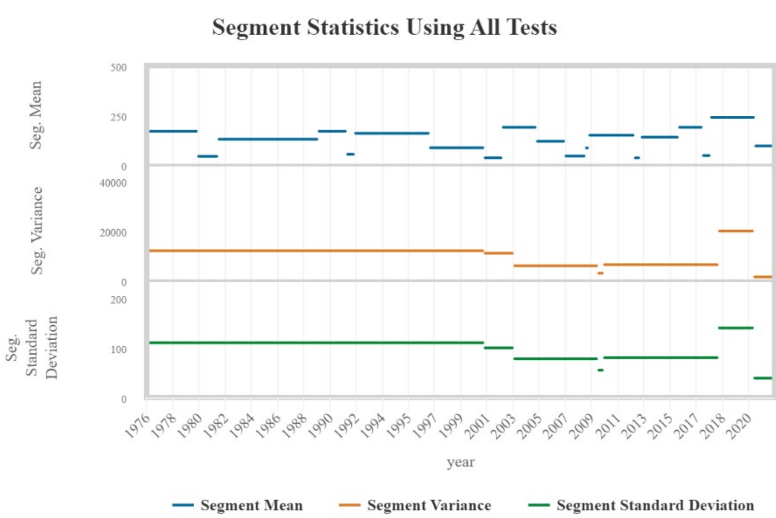


Figure 25. Nonstationarity Analysis for Monthly Average Flows for Blackwater River near Rocky Mount, VA.

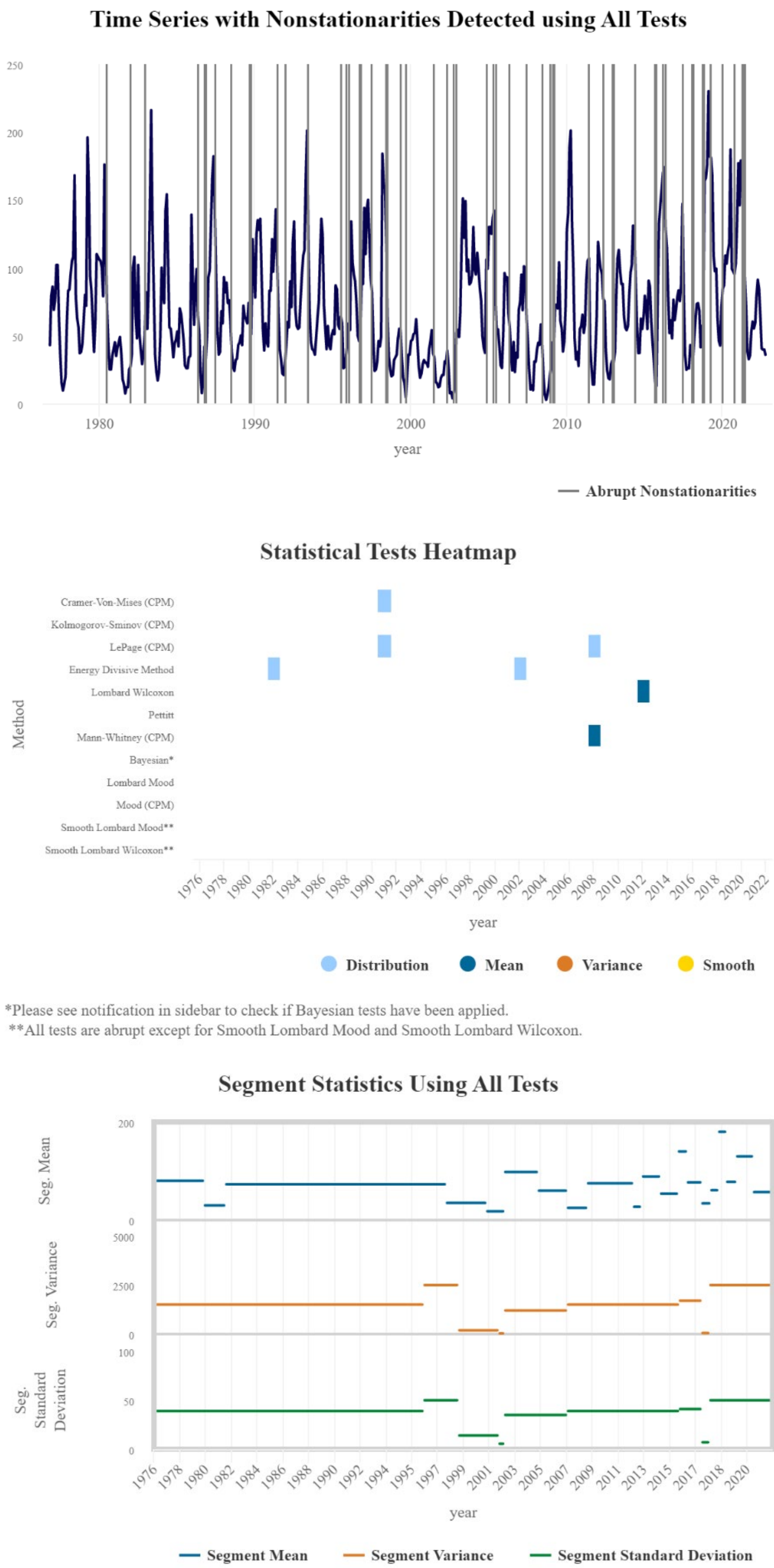
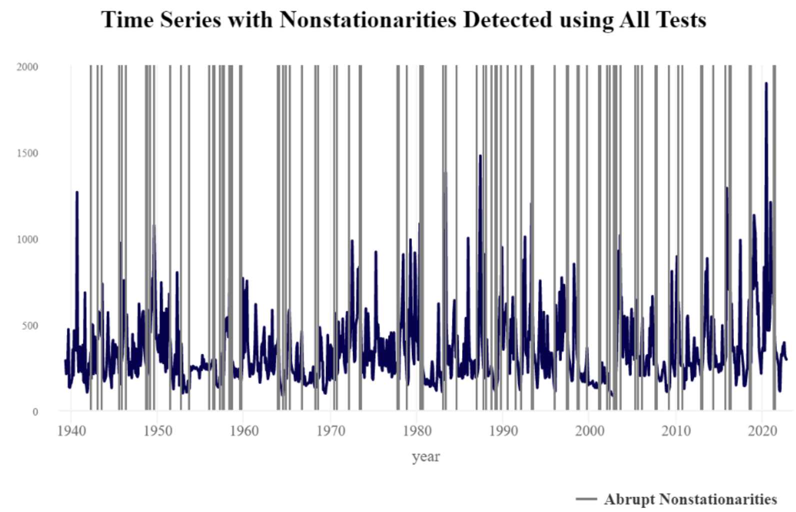
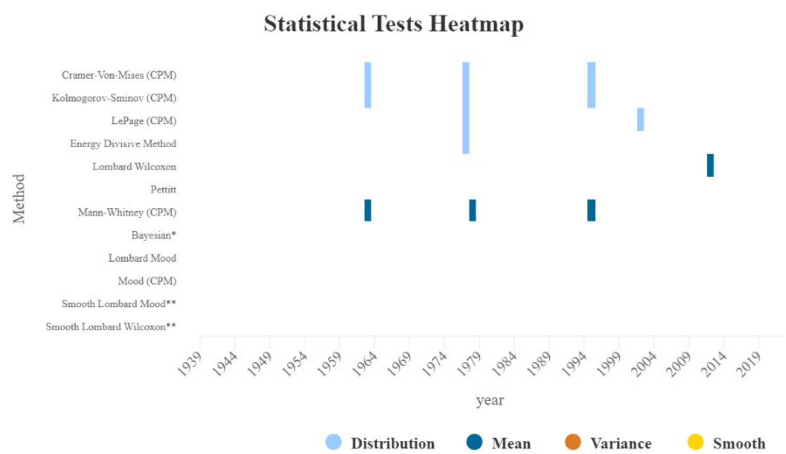


Figure 26. Nonstationarity Analysis for Monthly Minimum Flows for Blackwater River near Rocky Mount, VA.





*Please see notification in sidebar to check if Bayesian tests have been applied.
**All tests are abrupt except for Smooth Lombard Mood and Smooth Lombard Wilcoxon.

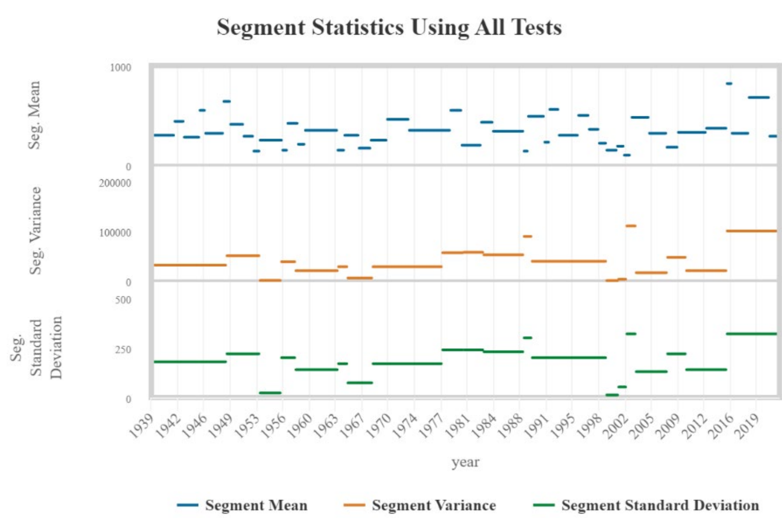
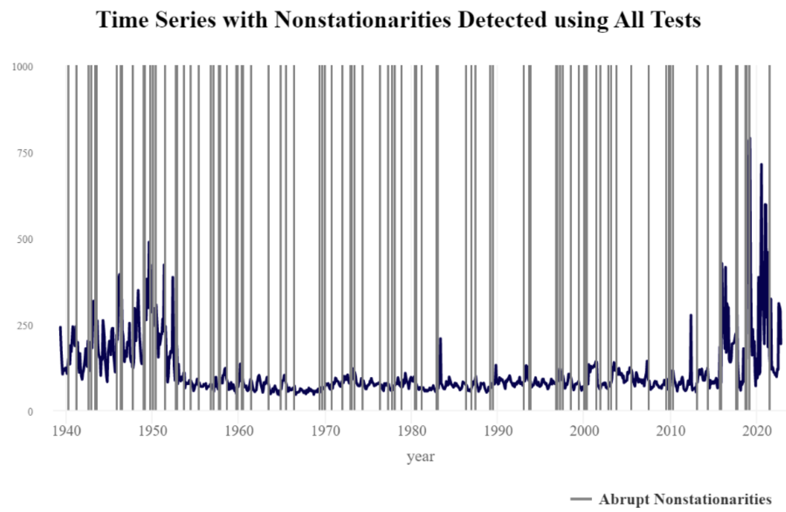
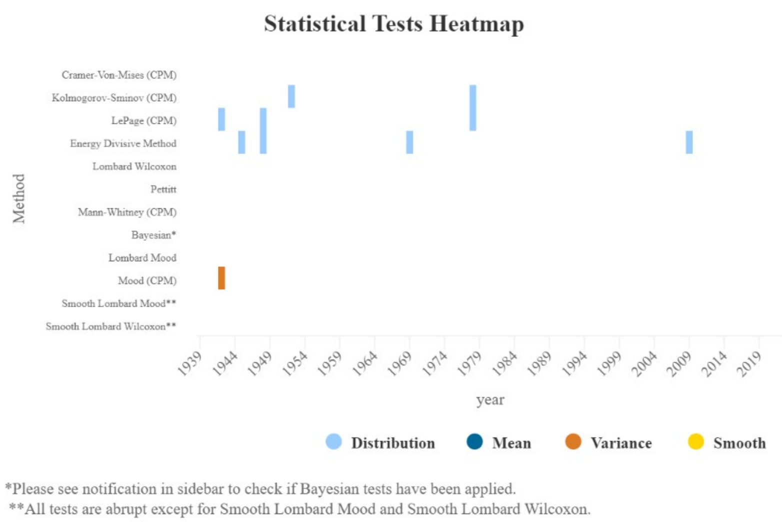


Figure 27. Nonstationarity Analysis for Monthly Average Flows for Smith River at Bassett, VA.





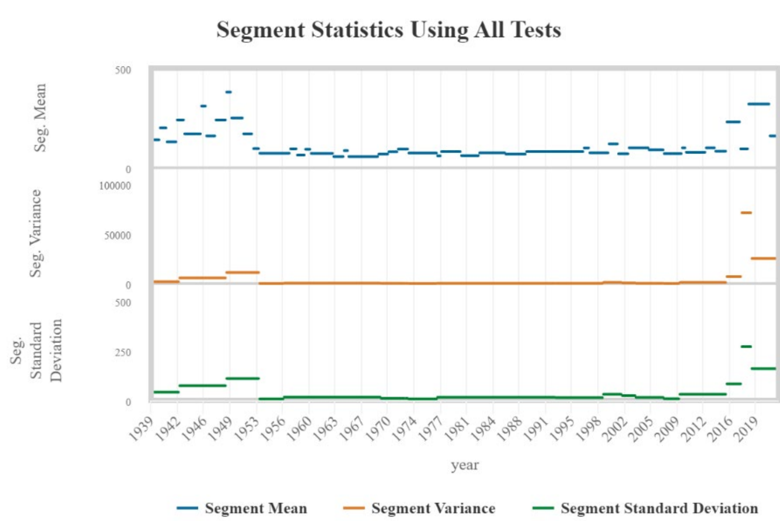
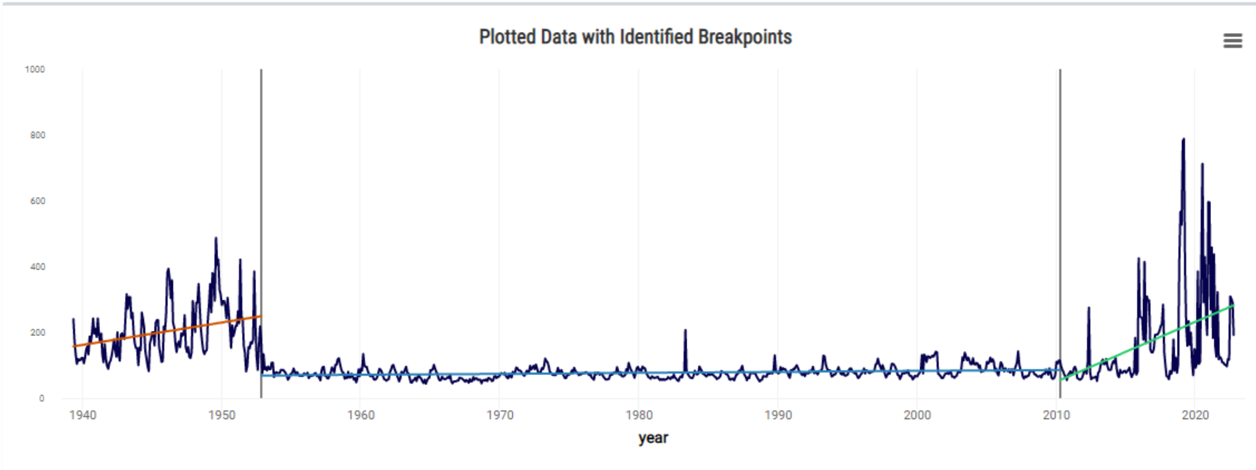


Figure 28. Nonstationarity Analysis for Monthly Minimum Flows for Smith River at Bassett, VA.



2
Number of Breakpoints

11303
Minimum BIC

67
Total RMSE

Breakpoint Segment Details

Date Range	Slope		P-Value (Trend)	Intercept	Directionality
1939-04-01 to 1952-10-31	0.567246	**	0.000015554	156.68825	Positive
1952-10-31 to 2010-03-31	0.024659	**	1.6602e-12	68.82588	Positive
2010-03-31 to 2022-09-26	1.517072	**	4.0601e-9	53.08003	Positive

Figure 29. Breakpoint analysis for Smith River at Bassett monthly minimum flows.

6 Conclusion

Currently, the conservation pool at Philpott Lake currently primarily serves as a hydropower pool and releases are sometimes made to augment low flows downstream. The pool is also operated to maintain Fish and Wildlife (F&W) habitat. Henry County is seeking reallocation of a portion of the conservation pool for water supply. The conservation pool currently has no water supply allocation.

In the literature reviewed, temperatures are forecasted to increase in the future with more extreme rain events; however, there is less consensus on future annual precipitation totals and streamflow. The changing climate is projected to lead to more extreme drought events.

Within the Upper Roanoke basin, the CHAT tool predicts increasing temperatures, annual precipitation, and drought indicators in the simulated future period for both emissions scenarios (RCP 4.5 and 8.5). Observed monthly minimum and monthly average streamflow data within the region do not indicate a widespread trend

An analysis of watershed climate vulnerability using the USACE VA Tool shows the area to be relatively less vulnerable for the water supply and hydropower business lines compared to the entire USACE portfolio. The variables used to compute the watershed vulnerability score for the water supply business line include increased drought severity, increased sedimentation, and decreased runoff from precipitation. The variables used to compute the watershed vulnerability for the hydropower business line include increased flood magnification, decreased runoff from precipitation, increased low flow reduction, increased drought severity, and increased sedimentation. No nonstationarities were detected in nearby stream gages from both monthly minimum and monthly average streamflows. This indicates that within the records for the gages, there hasn't been a change in the distribution of the streamflow means and/or variance.

Philpott Lake has an inactive pool which was designed to allow for sedimentation within the lake. Between the initial 1951 lake survey and the latest survey in 1997, the total sediment volume has only increased by 530 acre-feet, which results in less than a 1% decrease in inactive storage and has no effect on the conservation pool.

A reallocation from the conservation pool for water supply would increase the resilience of Henry County to deal with the potential of future increases in drought versus the No Action alternative. Because there is not resounding evidence indicating that either decreases in future water yield or increases in future sediment load will impact water availability in the conservation pool, the anticipated residual risk due to climate change to Philpott Lake's ability to continue to provide hydropower benefits, augment low flows downstream, and maintain fish and wildlife habitat is low.

Table 3- Climate Risks to Philpott Dam.

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood	Justification for Rating
Conservation Pool (Water Supply vs. Low Flow Augmentation/ Hydropower/F&W)	Increased sedimentation	Increased watershed erosion in warmer, drier future	Loss of storage in conservation pool	Low,	Sedimentation will likely occur in the inactive pool; sedimentation rates have historically been low at Philpott Lake
Conservation Pool (Water Supply vs. Low Flow Augmentation/ Hydropower/F&W)	Decreased Inflow	Decreased inflows leading to slower refilling to guide curve	Extended periods of drought with slower refilling	Low	USGS gages in area are not showing a decreasing trend in minimum streamflows

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