**UPPER MISSISSIPPI RIVER RESTORATION**
**FEASIBILITY REPORT**
**WITH INTEGRATED ENVIRONMENTAL ASSESSMENT**

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**GILEAD SLOUGH**
**HABITAT REHABILITATION AND ENHANCEMENT PROJECT**

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**POOL 25, UPPER MISSISSIPPI RIVER MILES 246-251**
**CALHOUN COUNTY, IL**

# Appendix H: Resiliency Assessment

US Army Corps of Engineers®
St. Louis District

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Upper Mississippi River Restoration
Leading·Innovating·Partnering

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# 1 ECB 2018-14 Analysis of Potential Vulnerabilities

This assessment is performed in accordance with the United States Army Corps of Engineers' (USACE) Engineering Construction Bulletin (ECB) 2018-14, revised August 19th, 2022. In accordance with ECB 2018-14, this evaluation identifies potential vulnerabilities to changing hydrometeorological variables for the Upper Mississippi River Restoration (UMRR) Gilead Slough Habitat Rehabilitation and Enhancement Project. Study background information can be found in the main report, and more general background information on the identified risks can be found in ECB 2018-14.

# 2 Study Background

The project area is located between Mississippi River miles 256 and 252 on the left descending bank in the southern portion of Lock & Dam (L&D) 25's pool near Gilead, Illinois. The Gilead Slough HREP Project objectives include restoring backwater channel connectivity, flow diversity and bathymetric depth to benefit native riverine fish and wildlife; improving backwater channel habitat, including substrate stability, to benefit native freshwater mussels; and enhancing aquatic floodplain vegetation diversity through moist soil vegetation and floodplain forestry.

The river ecosystem within Pool 25 has been significantly affected by impoundment of the pool and the permanently higher water tables maintained by L&D 25. Geomorphic features, such as sandbar accretion and backwater deposition, are forming in the project area as sediment from the river deposits. Side channels and backwaters are important aquatic habitat for many native species including Upper Mississippi River (UMR) riverine fishes and freshwater mussels. Historically, the study area had freshwater mussel beds, but these beds have been impacted through time due to degraded backwater channel conditions (e.g., increased siltation, sediment homogenization). Sediment deposition and high turbidity degrade the backwaters adjacent to these channels. Restoring side channels and backwater areas to promote freshwater mussel habitats and riverine fisheries has been identified as a resource need within the Lower Impounded Reach of the Mississippi River. Ecosystem restoration is the focus of this analysis because the proposed project seeks to restore diverse habitats within Gilead Slough. Future changes in hydrometeorological variables may impact the effectiveness of project features. Hydrologic indicator variables most relevant to the ecological health of a watershed are defined as annual discharge (maximum, mean, and minimum), duration of high discharges (exceeding the 20% annual exceedance probability (AEP) discharge), and monthly mean discharge (USGS, 2022). To analyze ecosystem restoration features for this study, the annual average streamflow records were evaluated since they are representative of flows impacting project features throughout the year.

# 3 Literature Review

The *Fifth National Climate Assessment* (NCA5), the USACE *Civil Works Technical Report CWTS-2015-13,* as well as state and watershed specific resources published by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS) are the basis for this literature review. These references summarize trends in historic and observed temperature, precipitation, and streamflow records, as well providing an indication of future hydrology based on the outputs from Coupled Model Intercomparison Project Phase 5 (CMIP5) meteorological models. For this assessment, background on observed and projected temperature and precipitation is provided as context for the impact that they have on observed and projected streamflow. The 2015 USACE Technical Reports cover 2-digit, United States Geological Survey (USGS), hydrologic unit code (HUC) watersheds in the United States (U.S).

Gilead Slough is in 2-digit HUC 07, the Upper Mississippi Region (USACE, 2015) and in the NCA5 Midwest region.

In many areas, temperature, precipitation, and streamflow have been measured since the late 1800s and provide insight into how the hydrology in the study area has changed over the past century. CMIP5s are used in combination with different representative concentration pathways (RCPs) reflecting projected radiative forcings up to year 2100 to model future meteorological conditions. Radiative forcings encompass the change in net radiative flux due to external drivers, such as changes in carbon dioxide or land use/land cover. Projected temperature and precipitation results can be transformed to regional and local scales (downscaling) for use as inputs in precipitation-runoff models (Graham, Andreasson, and Carlsson, 2007). Uncertainty is inherent to projections of temperature and precipitation due to the CMIP5s, RCPs, downscaling methods, and many assumptions needed to create projections (USGCRP, 2023). When applied, precipitation-runoff models introduce an additional layer of uncertainty. However, these methods represent the best available science to predict changes in future hydrologic variables.

The following subsections discuss relevant hydrometeorological variables to this project with support from existing literature. Figure 1 shows a summary of the observed and projected changes in hydrometeorological factors summarized by the USACE (USACE, 2015). Within the literature, there is evidence temperature, precipitation, and streamflow have increased within the Upper Mississippi Watershed. Projections show strong consensus on increases in future temperature, and moderate consensus on increases in future precipitation. There is little to no consensus related to trends in future streamflow.

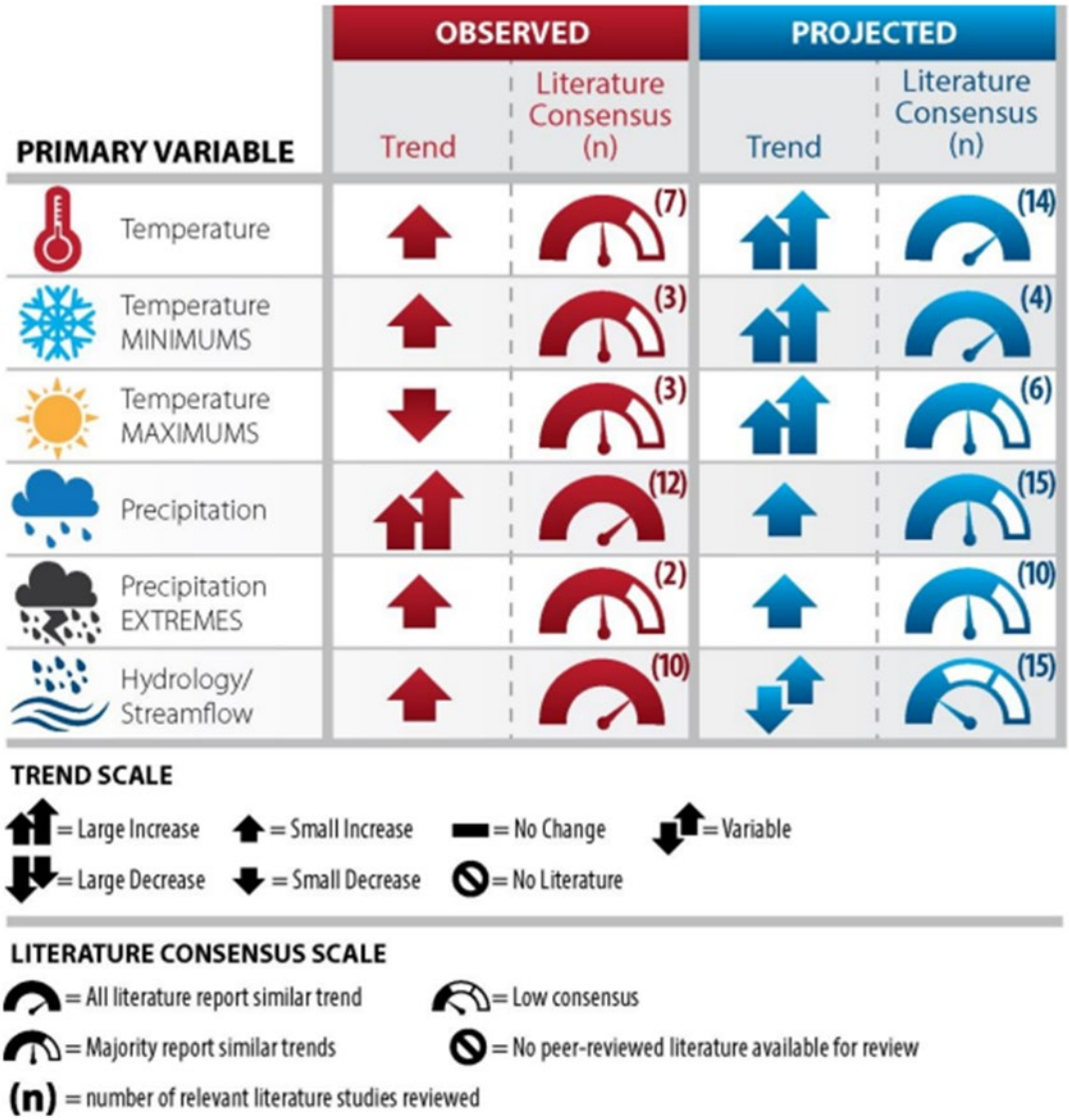



*Figure 1. Summary matrix of observed/projected trends and literary consensus of hydrometeorological factors (USACE, 2015)*

## 3.1 Temperature

The average annual temperature in the Midwest has increased by about 2°F since the first half of the 20th century (USGCRP, 2023). Increasing temperatures can accelerate snowmelt and lengthen the frost-free season (Carelton & Hsiang, 2019) (Liu, Goodrick, & Stanturf, 2013) (Woodward, Perkins, & Brown, 2010). Many studies indicate a change in seasonality in the region, marked by increasing winter temperatures and early spring melt (Schwartz, Ault, & Betancourt, 2013) (Wang, et al., 2009) (Westby, Lee, & Black, 2013). CMIP5 based projections of temperature for the Midwest show a statistically significant increase in both annual average temperature and the number of extreme heat days over the next century (Vavrus & Behnke, 2014).

Temperatures in Illinois have risen ~1.5°F since the beginning of the 20th century – temperatures in the 2000s have been higher than in any other historical period, save for the Dust Bowl in the 1930s (Frankson, et al., 2022). Illinois's location in the interior of North America and the lack of mountains expose the state to incursions of bitterly cold air masses from the Arctic in the winter and warm, humid

air masses from the Gulf in the summer. Annual average temperature varies widely across the state, with a range of about 10°F from north to south (Frankson, et al., 2022). In northeastern Illinois, Lake Michigan moderates temperatures, causing cooler summers and warmer winters.

Annual average temperatures are projected to increase beyond historical levels by the mid-century, and the intensity of cold waves is projected to decrease (Frankson, et al., 2022).

## 3.2 Precipitation

Average annual precipitation from 2002-2021 was 5-15% higher than the average from 1901-1960 in the central United States (USGCRP, 2023). Due to higher temperatures, more of this precipitation is falling as rain than snow, which contributes to reductions in snowpack and maximum annual snow equivalent (USGCRP, 2023). The number of extreme precipitation days (defined as the top 1% of heavy precipitation events) has increased in the Midwest by 45% since the 1950s, along with increases of more than 10% in the annual and 5-year maximum amounts (USGCRP, 2023).

In Illinois, precipitation in the spring and summer months has been above average since the mid-1990s (Frankson, et al., 2022). Illinois has also experienced an increase in the number of 2-inch extreme precipitation events, and storms in Illinois can occur in all seasons (Frankson, et al., 2022).

Precipitation is projected to increase in Illinois for the winter and spring months 15% or greater from late-20$^{th}$-century levels (Frankson, et al., 2022). The frequency and intensity of extreme precipitation events is also projected to increase. The intensity of future droughts is projected to increase too, as rising temperatures increase evaporation rates and the rate of soil moisture loss (Frankson, et al., 2022).

## 3.3 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. Annual water yield, annual maximum daily water yield, and annual maximum 7-day water yield are increasing throughout the Upper Mississippi River Basin (Simon, Artita, & Simon, 2020). Water yield represents discharge per unit of watershed area. For the 2020 USGS study, water yield was normalized by total annual precipitation to differentiate between the influence of altered precipitation versus other drivers of change in hydrologic response. Evaluations of precipitation-normalized water yield indicate that changes to water management and land use/cover in the Upper Mississippi River Basin are exacerbating increases in water yield (Simon, Artita, & Simon, 2020). The annual average streamflow has increased over time as well, along with increases in annual 7-day minimum low flows in the fall (Small, Islam, & Vogel, 2006).

There is little to no consensus in literature regarding projected future streamflow trends in the Upper Mississippi River Region.

## 3.4 Ecosystem Health

The following variables are critical to ecosystem health and have changed over time: annual discharge (maximum, mean, and minimum), duration of high discharges (exceeding the 20% AEP discharge), and monthly mean discharge (USGS, 2022). Results from the 2022 USGS report indicate that mean and minimum annual discharges are increasing at the USGS gages at Winona, Minnesota (05378500) and Keokuk, Iowa (05474500). The duration of high discharges has also increased from 1940 to 2019 for all gages analyzed. Significant increases in annual maximum discharges were detected for the Keokuk, Iowa

(05474500) and Valley City, Illinois (05586100) USGS gages. Based on an analysis of monthly, mean discharges, large increases in May mean discharges were identified for all three Mississippi River gages analyzed. There is some evidence that the maximum in monthly, mean discharge for a given year has shifted from occurring in April to either May or June.

Water quality analysis presented in the 2022 USGS report indicates that total suspended sediment (TSS) concentrations associated with mean discharges have decreased long-term in many reaches and tributaries of the Upper Mississippi River. The most significant changes have been observed in L&D pools 4 and 8. Phosphorus loads in all the L&D pools analyzed (pools 4, 8, 13, and 26) on the Upper Mississippi River have also decreased long-term. Although there are no long-term, significant trends in dissolved oxygen (DO) for the portions of the Upper Mississippi River assessed, low DO in backwater areas has been observed more frequently in the summer than in winter.

The concentration of submersed aquatic vegetation (SAV) is considered the primary indicator of aquatic vegetative health in the Upper Mississippi River. High prevalence of SAV (generally >50-percent) indicates quality habitat for waterfowl. Aquatic vegetation analysis identified trends in SAV in L&D pools 4, 8, and 13 (USGS, 2022). The prevalence of SAV in L&D pools 4 and 8 increased by 30% from 2002 to 2010. Since 2010, SAV concentrations at these two locations have plateaued. The prevalence of SAV in L&D 13 ‘s pool increased from 1998 to 2008. Since 2009, SAV concentrations have been decreasing in L&D 13’s pool. Additionally, since 2000, increases in aquatic plant species diversity have been observed in L&D pools 4 and 8. In the L&D 8 and 13’s pools, a positive trend in emergent vegetation has been recorded. Emergent vegetation provides habitat for aquatic species. No trends in aquatic vegetation were found within the lower portion of the Upper Mississippi River (L&D Pool 26).

# 4 Nonstationarity Detection and Trend Analysis

The assumption that hydrologic timeseries are stationary (their statistical characteristics are unchanging) in time underlies many traditional hydrologic analyses. Statistical tests can be used to test this assumption using the techniques outlined in USACE Engineering Technical Letter (ETL) 1100-2-3, Guidance for Detection of Nonstationarities (USACE, 2017). The USACE Time Series Toolbox (TST) tool is a web-based tool that performs the statistical tests described in the guidance (Olson, et al., 2025). Average, annual streamflow is analyzed for the Gilead Slough HREP Project because project features are vulnerable to damage from flows during the first few years of establishing habitat. Long-term, project features need to be designed to withstand future conditions.

Observed, average, annual discharge for the L&D 24 tailwater (TW) is aggregated from the mean daily flow values computed by USACE from observed, mean daily, stage measurements. Because the streamflow record analyzed has been generated based on a flow-stage rating curve, the quality of the data was verified using observed, USACE streamflow records recorded at locations upstream and downstream between L&D 24 tailwater and L&D 25 upper pool. If unverified, changes in the flow-stage rating curve applied can introduce a source of nonstationarity and/or uncertainty into the streamflow record. This should be taken into consideration when interpreting the results of trend and nonstationarity analysis. Based on this evaluation no discrepancies were found the L&D 24 tailwater streamflow record.

The USACE L&D 24 gage captures 140,700 square miles of drainage area and is influenced by regulation from the L&D 25 on the Mississippi River. The L&Ds were constructed and placed into operation in 1940.

The general objective of the L&Ds 24 and 25 is to maintain the authorized, nine-foot, navigation channel. The L&Ds maintain the minimum storage of water required for navigation and any additional water volume is outflowed. Consequently, operation of the L&Ds does not have a significant impact on annual, average streamflow. The TST tool was applied to detect nonstationarities and trends for the period of record from 1960 to 2023.

As shown in Figure 3, the average flow record observed at L&D 24 has little evidence of a nonstationarity. A strong nonstationarity demonstrates a degree of consensus, robustness and a significant increase or decrease in the sample mean and/or variance. While a small change in distribution, mean, and variance can be observed in the data, the data does not change significantly over time. There was no potential breakpoint identified, and the p-values for a change in distribution/mean/variance do not meet significance requirements for consideration.

Linear and monotonic trends are evaluated using the t-test, Mann-Kendall and Spearman Rank Order tests. The significance of trends is evaluated using a 0.05 level of significance threshold (p-value<0.05 is considered statistically significant). Trend analysis indicates no statistically significant, positive trend for the 1960-2023 period of record by the t-Test (p-value= 0.082396), Mann-Kendall test(p-value=0.1247), or Spearman Rank-Order (p-value=0.10953) test, see trendline in Figure 2.

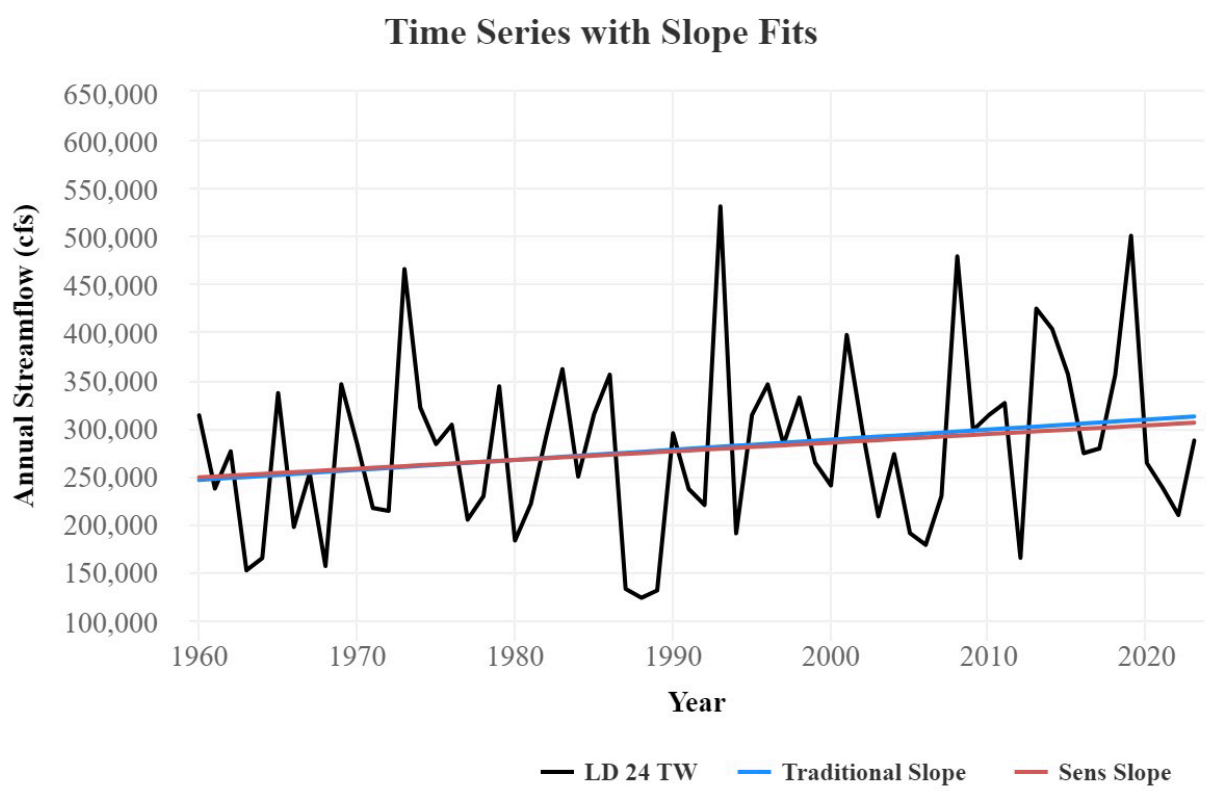
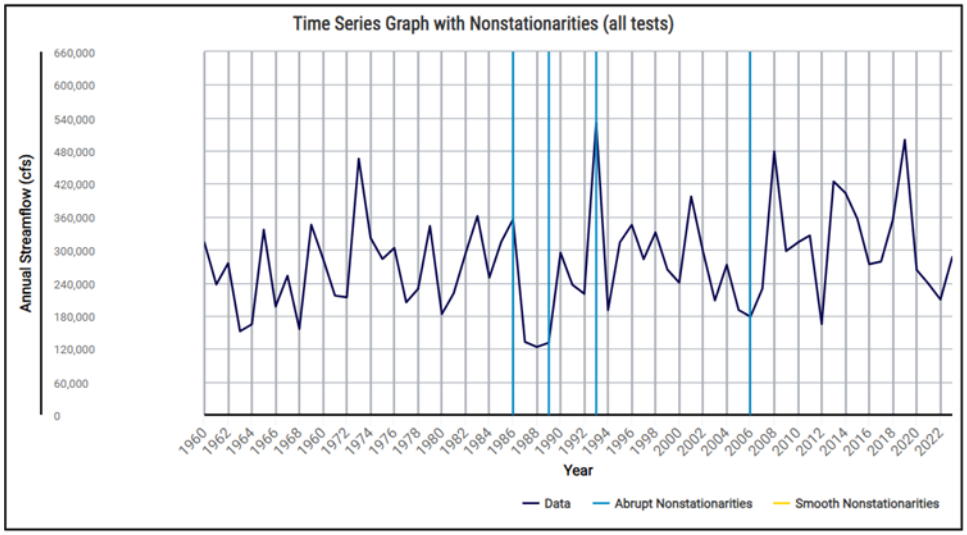
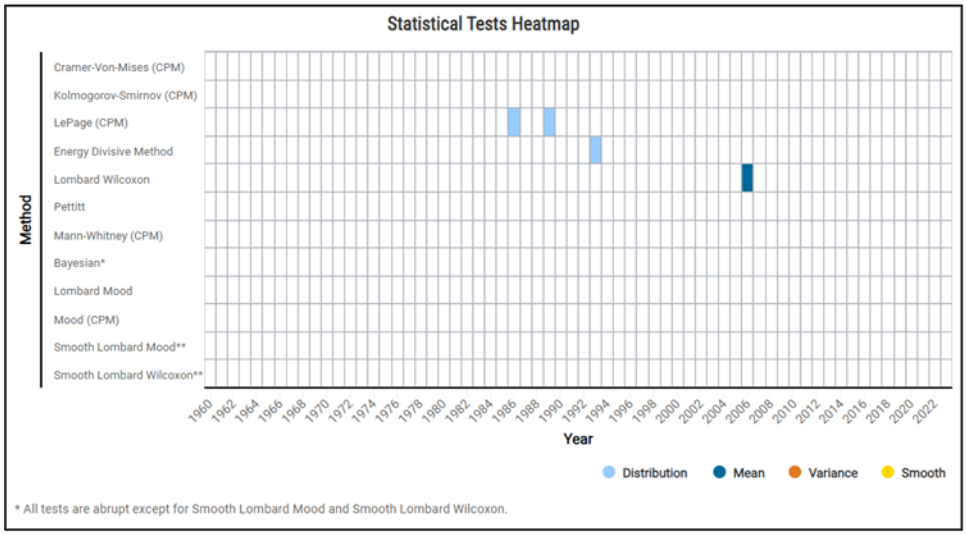



*Figure 2. Trend Analysis TST Output for Annual Streamflow at L&D 24 TW*



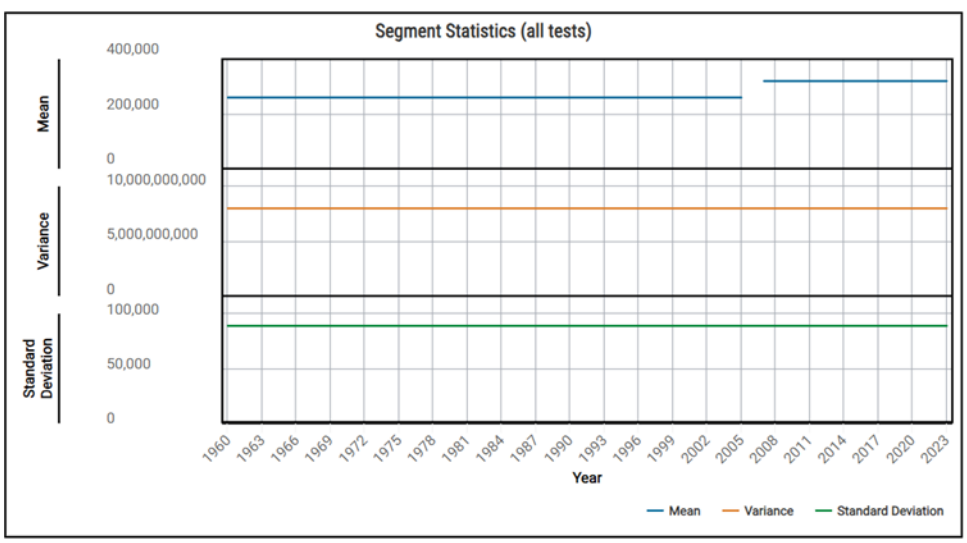




*Figure 3. TST Output for Annual Streamflow at L&D 24 TW*

# 5 Comprehensive Hydrology Assessment Tool

The USACE Comprehensive Hydrology Assessment Tool (CHAT) displays various simulated, historic and future streamflow, temperature, and precipitation outputs (Patel, et al., 2025). The CHAT uses Coupled Model Intercomparison Project Phase 5 (CMIP5) meteorological data outputs that have been statistically downscaled using the Localized Constructed Analogs (LOCA) method. The models used by the CHAT rely on scenarios representing different representative concentration pathways (RCPs). RCPs describe the change in radiative forcing at the end of this century, as compared with pre-industrial conditions. Projected hydrometeorological data in the CHAT for 2006 to 2099 are produced using two future scenarios: RCP 4.5 and 8.5. Simulated output representing the historic period of 1951 to 2005 is generated using a reconstitution of historic data.

To analyze runoff, LOCA-downscaled model outputs are used to force an unregulated, Variable Infiltration Capacity (VIC) hydrologic model. Areal runoff from VIC is then routed through a stream network using MizuRoute. Outputs represent the daily in-channel, routed streamflow for each stream segment – valid at the stream segment endpoint. Since the runoff is routed, the streamflow value associated with each stream segment is a representation of the cumulative flow, including all upstream runoff, as well as the local runoff contributions to that specific segment. Within the CHAT, streamflow output can be selected by stream segment and precipitation/temperature output can be selected for a given 8-digit Hydrologic Unit Code (HUC) watershed.

Gilead Slough HREP is in the 4-digit HUC 0711 (Upper Mississippi-Salt). The 8-digit HUC of interest specific to the study area is The Sny watershed (HUC07110004). Mississippi River stream segment 07000604 transects the study area. The annual-mean 1-day streamflow is analyzed for this assessment to investigate if and how potential, future streamflow conditions will change. Annual-maximum 1-day temperature is analyzed for this assessment as a proxy for water temperature. Warmer water holds less dissolved oxygen (DO) which affects the survival of aquatic life (USGS, 2022). The range of data is indicative of the uncertainty associated with projected streamflow and temperature.

## 5.1 CHAT Streamflow

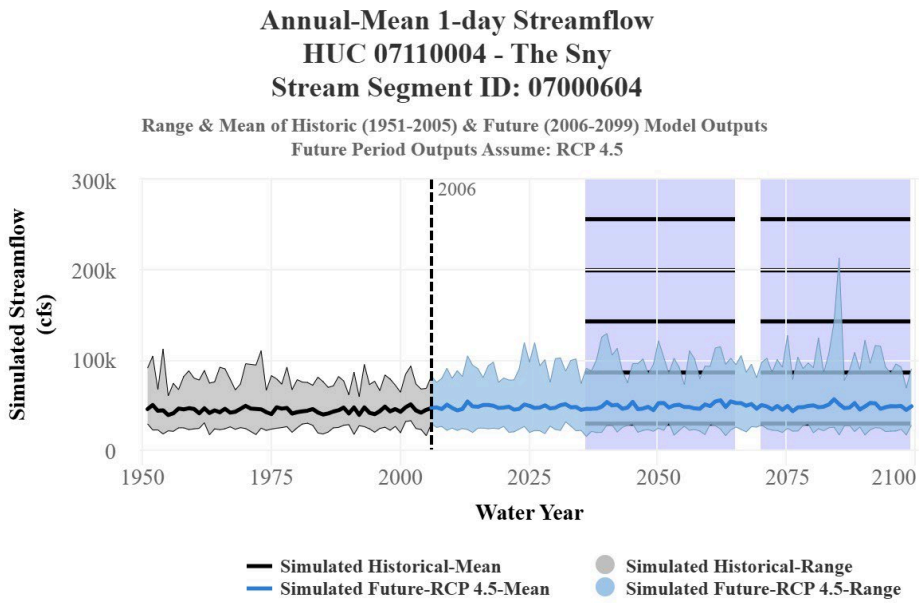
Annual-mean 1-day streamflow trends were evaluated using the t-Test, Mann-Kendall and Spearman Rank-Order tests. All three statistical tests are applied using a 0.05 level of significance. The direction and magnitude of change in statistically significant trends in annual-mean streamflow are evaluated using the slope of the fitted linear regression relationship (Figure 4). The results of the trend analysis are presented in Table 1.

The mean of the projections of simulated, annual-mean streamflow for the future period (2006-2099) shows a statistically significant, positive trend for the Sny watershed (HUC07110004) Stream Segment-07000604 when RCP 8.5 is assumed (Figure 4). The trendline has a slope of 79.8 cfs a year, which equates to a 3,990 cfs change in the average annual- mean streamflow over a 50-year period. There is no statistically significant trend in simulated, historic flows (1951-2005) or annual-mean streamflow for the future period (2006-2099) when RCP 4.5 is assumed. Additionally, the robustness metrics indicate no signal for either the 2035-2064 (mid-century) or the 2075-2099 (end of century) projections of annual-mean streamflow. The robustness metrics indicate a robust positive signal for the end of century projection of annual-mean streamflow when RCP 8.5 is assumed; however, the robustness metrics indicate no signal when for the mid-century projection when RCP 8.5 is assumed.

The CHAT was also used to evaluate the change in epoch-mean of simulated annual- and monthly-mean streamflow (Figure 5). Outputs are analyzed comparatively by describing simulated changes between different epochs (time periods). Monthly output is analyzed by determining the mean of the monthly value for the variable of interest for three epochs: 1950-2005 (baseline), mid-century, and end of century. The difference between epoch means is determined for both the baseline vs. mid-century and baseline vs. end of century epochs and results are presented as boxplots. These boxplots provide insight into both the range of results and the seasonality of changes overtime.

For the annual-mean streamflow using RCP 8.5, it was found that the median change from the base Epoch (1950-2005) to the mid-century epoch (2035-2064) is 11%. By the end-century epoch (2070-2099) the change relative to the base period is 16%. For RCP 4.5, the median change from the base epoch to both the mid-century and end-century epochs is 10%.

Changes in epoch-mean of simulated monthly-mean streamflow are presented in the bottom plot of Figure 5. For the stream segment of the Mississippi River analyzed, it appears that for both the mid-century and end-century epochs November through May mean flows are increasing. Greater increases are observed during December through May for the end of the century epoch. August-September flows appear to be decreasing regardless of what RCP is assumed for both epochs and RCPs analyzed.



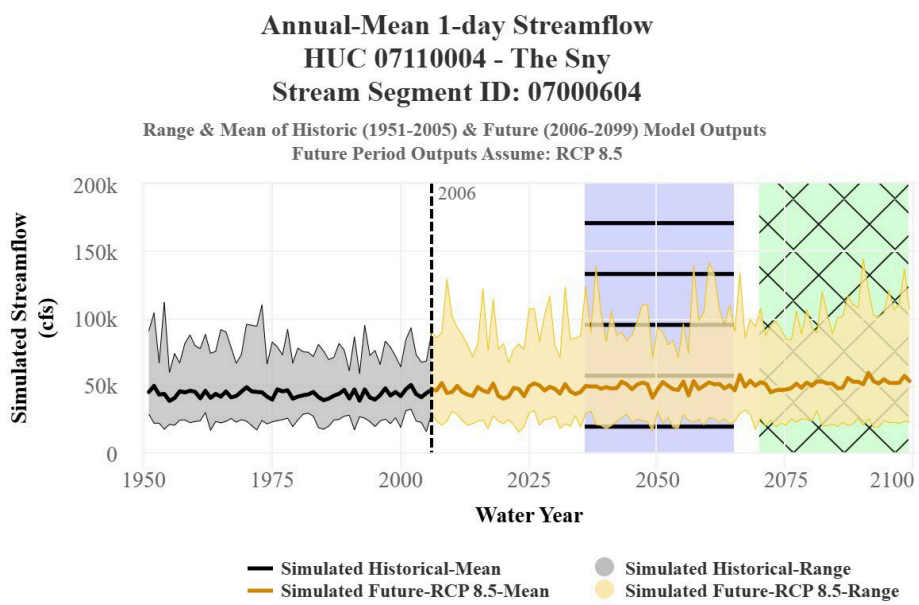



*Figure 4. CHAT Model Output for Annual-Mean 1-Day Streamflow*

*Table 1. Statistics of Trend Analysis CHAT Model Output for Annual-Mean 1-Day Streamflow*

| Trend Analysis | Historic (1951-2005) | Future (2006-2099) | | Historic (1951-2005) | | | Future (2006-2099) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RCP 4.5 | RCP 8.5 | | | | RCP 4.5 | | | RCP 8.5 | | |
| | p-values | | | Statistically Significant? (<0.05) | Slope (cfs/year) | Direction | Statistically Significant? (<0.05) | Slope (cfs/year) | Direction | Statistically Significant? (<0.05) | Slope (cfs/year) | Direction |
| t-Test | 0.853 | 0.183 | <0.001 | No | -4.5975 | ↓ | No | 13.691 | ↑ | Yes | 79.791 | ↑ |
| Mann-Kendall | 0.919 | 0.170 | <0.001 | No | | | No | | | Yes | | |
| Spearman Rank Order | 0.812 | 0.156 | <0.001 | No | | | No | | | Yes | | |

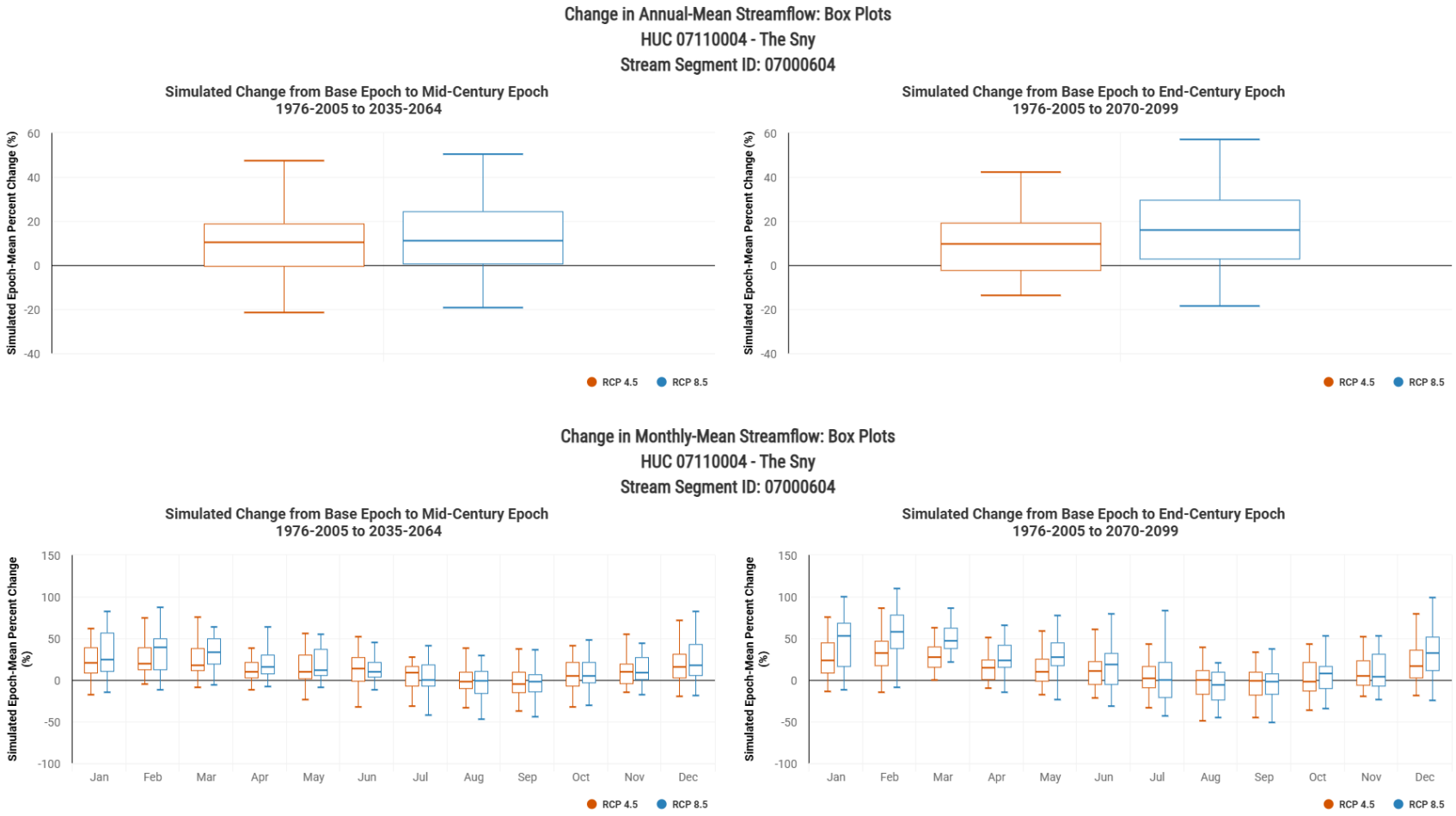



*Figure 5. CHAT Model Output for Epoch-Mean Change in Annual- and Monthly-Mean Streamflow*

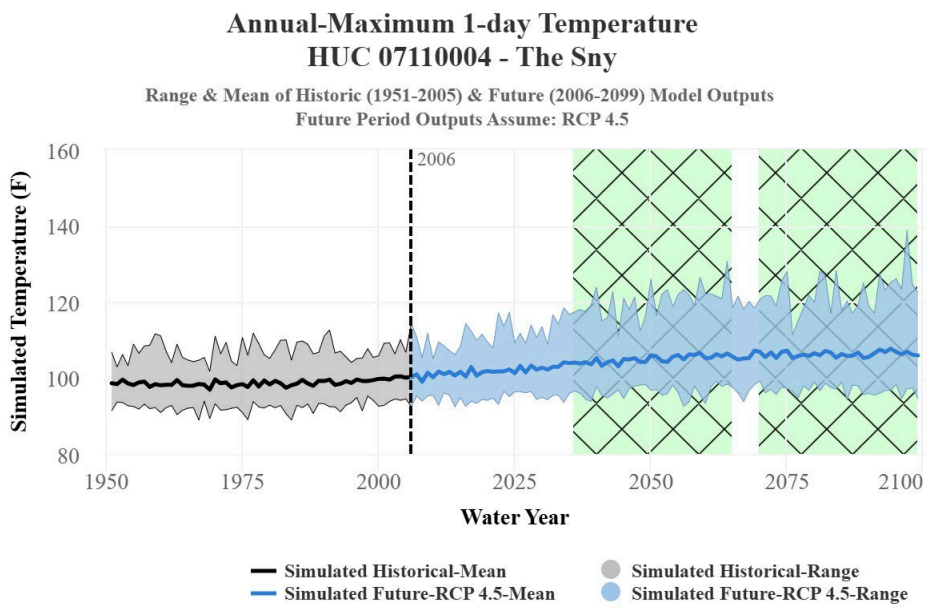
## 5.2 CHAT Temperature

Trends in annual-maximum 1-day temperature from the CHAT were analyzed using the same methodologies as described for streamflow. The results of the three statistical tests and the slopes associated with statistically significant trends are presented in Table 2 and Figure 6.

The mean of the simulated, annual-maximum temperature projections (future period: 2006-2099) shows a statistically significant, positive trend for The Sny watershed under both RCP scenarios. Both outputs project a significant magnitude of change in temperature over the next fifty years. The CHAT computes a trendline slope of 0.07°F per year for the RCP 4.5 scenario, which would be a 3.5°F increase in maximum temperature over a 50-year period. The CHAT computes a trendline slope of 0.13°F per year for the RCP 8.5 emission scenario, which would be a 6.8°F increase in maximum temperature over a 50-year period. There is also a statistically significant increasing trend in simulated, historic temperatures between 1951 and 2005 (slope of 0.02°F per year). Additionally, the robustness metrics indicate a robust positive signal for the mid-century and the end of century projections of annual-maximum 1-day temperature under all tested emissions scenarios (RCP 4.5 and RCP 8.5).

The CHAT was also used to evaluate the change in epoch-mean of simulated annual-maximum temperature (Figure 7). The median change from the base Epoch (1950-2005) to the mid-century epoch (2035-2064) is 5.3°F for RCP 4.5, and 6.5°F for RCP 8.5. By the end-century epoch (2070-2099) the change relative to the base period is 6.1°F for RCP 4.5, and 11.1°F for RCP 8.5.

Simulated monthly-maximum temperatures for both the mid-century epoch (2035-2064) and the end-century epoch (2070-2099) are increasing relative to historic temperature simulations (1950-2005) for all months and both RCPs (Figure 7). For the mid-century comparisons, 3.9°F increases or greater in temperature are projected under RCP 8.5 for all months. Larger changes in temperature are projected by the end of century. As compared to the temperature changes projected by mid-century, for the 2070-2099 epoch, there are larger differences in results where RCP 8.5 was assumed versus RCP 4.5. When RCP 8.5 is assumed, over 10°F of warming is projected from June through October. All RCP 8.5 comparisons show greater than 5°F of warming. When RCP 4.5 is assumed, between 5 to 10°F of warming is projected for all months except March, April, May, and November. Increases in maximum air temperature, particularly in the summer (June-August) will increase water surface temperatures. This can adversely impact water quality by decreasing DO in backwater areas within the study area.



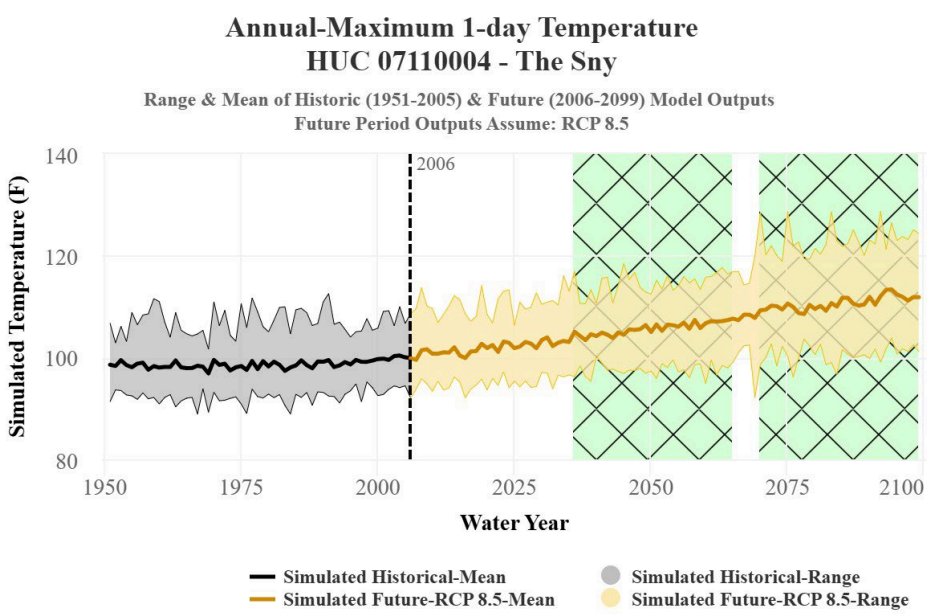



*Figure 6. CHAT Model Output for Annual-Maximum 1-Day Temperature*

*Table 2. Statistics of Trend Analysis CHAT Model Output for Annual-Maximum 1-Day Temperature*

| Trend Analysis | Historic (1951-2005) | Future (2006-2099) | | Historic (1951-2005) | | | Future (2006-2099) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RCP 4.5 | RCP 8.5 | | | | RCP 4.5 | | | RCP 8.5 | | |
| | p-values | | | Statistically Significant? (<0.05) | Slope (°F/year) | Direction | Statistically Significant? (<0.05) | Slope (°F/year) | Direction | Statistically Significant? (<0.05) | Slope (°F/year) | Direction |
| t-Test | <0.001 | <0.001 | <0.001 | Yes | 0.0249 | ↑ | Yes | 0.0699 | ↑ | Yes | 0.1357 | ↑ |
| Mann-Kendall | <0.001 | <0.001 | <0.001 | Yes | | | Yes | | | Yes | | |
| Spearman Rank Order | <0.001 | <0.001 | <0.001 | Yes | | | Yes | | | Yes | | |

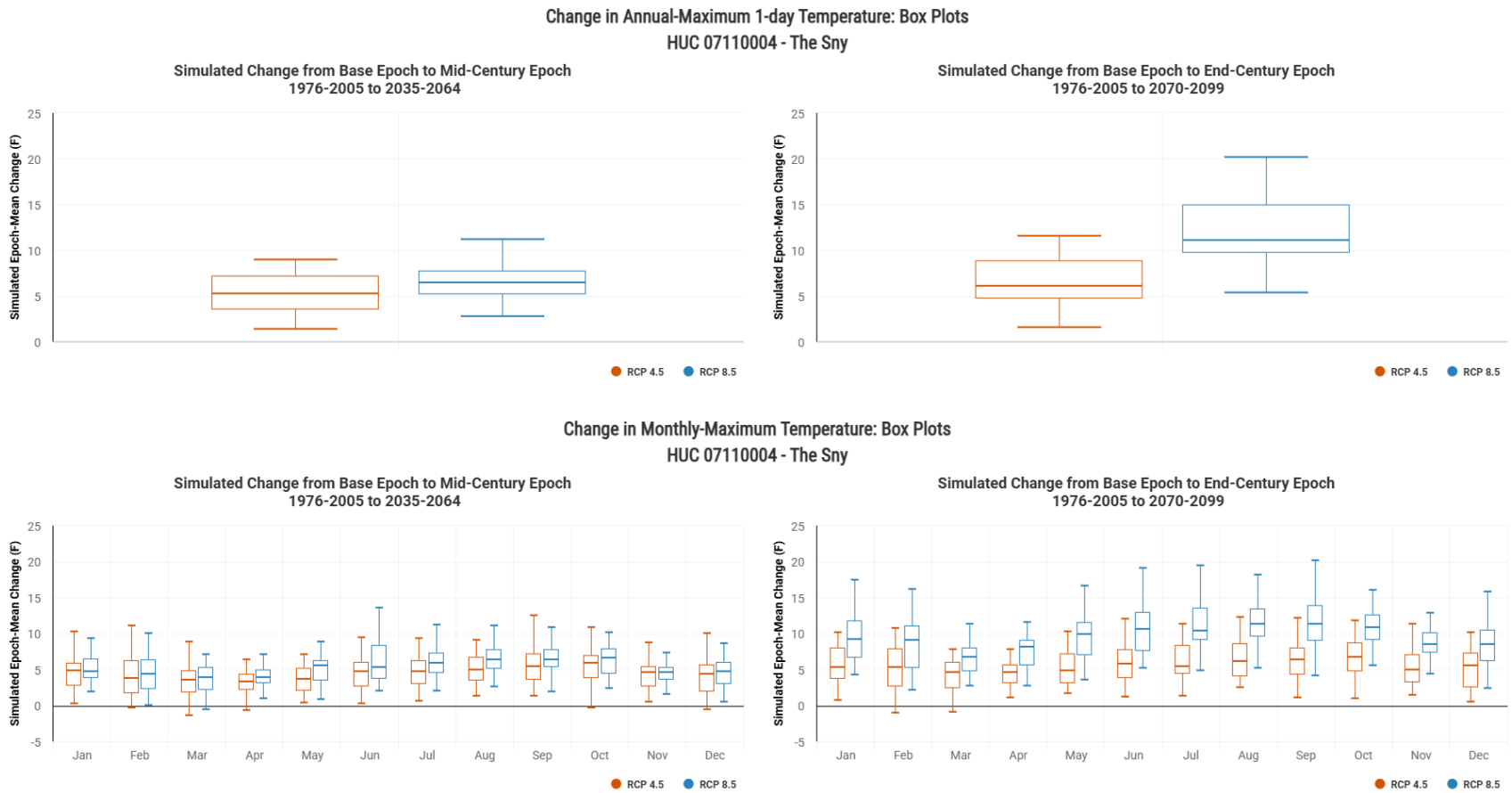



*Figure 7. CHAT Model Output for Epoch-Mean Change in Annual- and Monthly-Mean Temperature*

# 6 Civil Works Vulnerability Assessment Tool

The Civil Works Vulnerability Assessment Tool (CWVAT) is a screening-level tool that analyzes vulnerability for the entire United States at the watershed level. The tool uses maps, visualizations, and tables to help identify the hazard to which sites and regions are most exposed, and how that exposure is anticipated to change over time. Building resiliency into a project requires addressing the potential physical harm, security impacts, and degradation in readiness that may affect the project. The CWVAT uses several terms with specific contextual definitions for analysis (USACE, 2025):

**Vulnerability** is the degree to which infrastructure, systems, people, organizations, missions, operations, or activities are exposed, sensitive, and able to adapt to adverse impacts of natural hazards.

**Exposure** is the geographic proximity of infrastructure, systems, people, organizations, missions, operations, or activities to a hazard.

**Sensitivity** is the degree to which a hazard beneficially or adversely affects the intended function of infrastructure, systems, people, organizations, missions, operations, or activities.

The exposure scores, hazard scores, and normalized indicator values presented in the project area analysis are calculated using a z-score methodology. Z-score values are calculated using the median of all HUC-8 watershed values in the base epoch, with the standard deviation calculated across all epoch-scenarios (USACE, 2025). The sign of the normalized value indicates whether a site is either more (positive values) or less (negative values) exposed than the median (or “typical”) watershed and the magnitude indicates by how much.

## 6.1 Hazard Exposure

The CWVAT evaluates a watershed's or project area's total exposure to eight hazards: Wildfire, Drought, Coastal Flooding, Riverine Flooding, Extreme Temperature, Energy Demand, Land Degradation, and Historic Extreme Conditions. Note, the Historic Extreme Conditions hazard consists of static indicators which measure historic extremes. Figure 8 shows the hazard exposure scores across the five evaluated epoch-scenarios for all eight hazards.

For Base epoch-scenario, the watershed or project area is most exposed to Historical Extreme Conditions.

For 2050 Low, 2050 High, and 2085 Low epoch-scenarios, the watershed or project area is most exposed to Riverine Flooding.

For 2085 High epoch-scenario, the watershed or project area is most exposed to Extreme Temperature.

Note that while multiple hazards may appear to have the same score in visualizations and tables, this is a result of rounding and does not indicate identical underlying values.

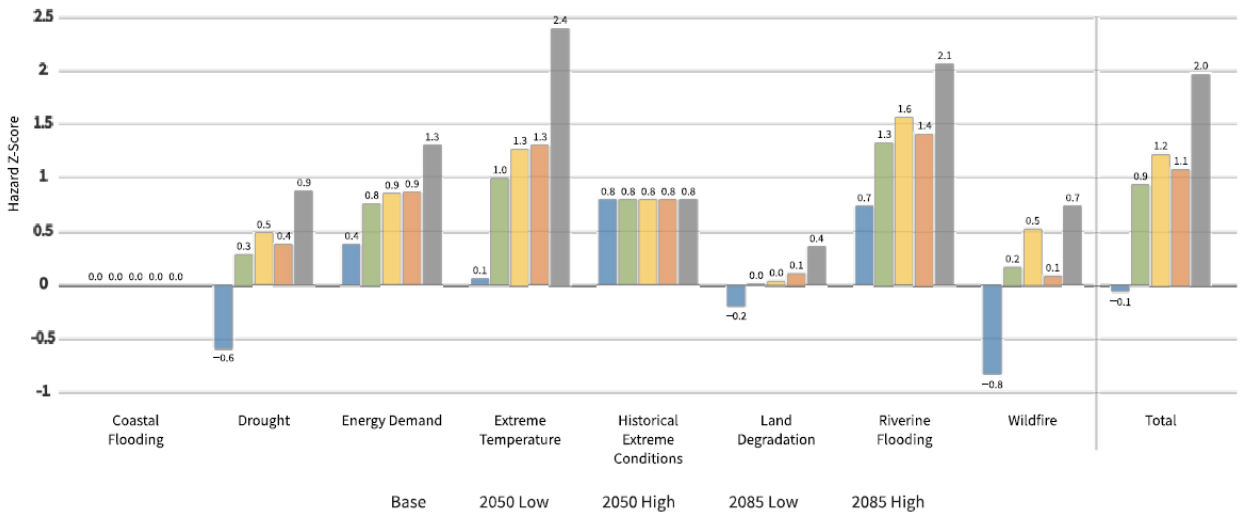



*Figure 8. Hazard Exposure Z-Scores*

## 6.2 Indicator Scores

For the Base epoch-scenario, Riverine Flood Extent is the indicator with the highest normalized indicator score. The Riverine Flood Extent is the area in acres within the watershed that may be inundated during the 1% annual exceedance probability (AEP) riverine flood event as determined by FEMA's National Flood Hazard Layer (NFHL). Note the NFHL does not include studies for every location in the US. As such the area inundated for some watersheds may be underrepresented.

For the 2050 Low, 2050 High and 2085 Low epoch-scenarios, Flash Drought Frequency is the indicator with the highest normalized indicator score. Flash Drought Frequency is the average number of times per year in which rapid-onset drought occurs, characterized by a sharp drop in precipitation over a 3-month period. Flash Drought Frequency indicates how often rapid onset ("flash") droughts occur.

For the 2085 High epoch-scenario, High Heat Days is the indicator with the highest normalized indicator score. High Heat Days is the average number of days in which temperatures exceed the 99th percentile temperature in the historic baseline period and indicates how often future temperatures exceed that of the most extreme historical high temperature for a given location.

Table 3 shows the top ten indicators for all hazards across the five epoch-scenarios.

*Table 3. Top 10 Indicators Contributing to Overall Exposure Ranked by Epoch-Scenario*

| Rank | Base | Z-score | 2050 Low | Z-score | 2050 High | Z-score | 2085 Low | Z-score | 2085 High | Z-score |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Riverine Flood Extent | 1.64 | Flash Drought Frequency | 1.70 | Flash Drought Frequency | 2.14 | Flash Drought Frequency | 1.65 | High Heat Days | 2.79 |
| 2 | Ice Storms Occurrence | 1.53 | Riverine Flood Extent | 1.64 | Riverine Flood Extent | 1.64 | Riverine Flood Extent | 1.64 | Flash Drought Frequency | 2.17 |
| 3 | Tornado Frequency | 1.39 | Ice Storms Occurrence | 1.53 | Ice Storms Occurrence | 1.53 | Ice Storms Occurrence | 1.53 | Drought Year Frequency | 2.13 |
| 4 | Ice Jam Occurrence | 1.37 | Tornado Frequency | 1.39 | High Heat Index Days | 1.42 | High Heat Index Days | 1.47 | Extreme Precipitation Days | 2.09 |
| 5 | Wildland Urban Interface | 0.66 | Ice Jam Occurrence | 1.37 | Tornado Frequency | 1.39 | Tornado Frequency | 1.39 | High Heat Index Days | 1.95 |
| 6 | Tropical Cyclone Maximum Precipitation | 0.65 | High Heat Index Days | 1.29 | Ice Jam Occurrence | 1.37 | Ice Jam Occurrence | 1.37 | Days Above 95°F | 1.93 |
| 7 | High Heat Index Days | 0.52 | Cooling Degree Days | 0.97 | Extreme Precipitation Days | 1.34 | High Heat Days | 1.26 | Cooling Degree Days | 1.70 |
| 8 | Cooling Degree Days | 0.41 | Extreme Precipitation Days | 0.90 | High Heat Days | 1.22 | Extreme Precipitation Days | 1.15 | Riverine Flood Extent | 1.64 |
| 9 | Tropical Cyclone Frequency | 0.35 | 5-Day Maximum Temperature | 0.87 | Cooling Degree Days | 1.10 | Cooling Degree Days | 1.12 | 5-Day Maximum Temperature | 1.55 |
| 10 | Maximum 1-Day Precipitation | 0.34 | High Heat Days | 0.86 | Drought Year Frequency | 1.09 | Drought Year Frequency | 1.12 | Ice Storms Occurrence | 1.53 |

# 7 Conclusion

The purpose of the Gilead Slough HREP project is to restore and enhance topographic and bathymetric diversity, substrate diversity and interior connectivity of aquatic habitat throughout study area to benefit native riverine fish and wildlife; improve side channel and slough area habitat, including substrate stability, to benefit native freshwater mussels and create aquatic habitat; and improve native vegetation composition, diversity and structural complexity throughout study area (wetlands, forests, etc.); and enhance water management capability throughout the study area.

Proposed project features include the following:

- Shoreline Protection with Gradual Slope Revetment (GSR)
- Excavation At Varying Depths
- Moist Soil Unit Creation with Pump (Active Management)
- Moist Soil Unit Creation with Overflow (Passive Management)
- Scour Structures
- Hard Points
- Backwater Excavation (Environmental Pool Management; EPM)
- River Connection Starting at Gilead
- Island Creation
- Barbs
- Sediment Deflection Dike
- Bank Protection
- Substrate Diversity

Output based on historic, observed, and projected hydrometeorological data was reviewed to support qualitative statements about how to incorporate resilience into the design of project features.

Increases in precipitation are projected for Illinois, most likely during the winter and spring. The frequency and intensity of extreme precipitation events are also projected to increase, potentially increasing the frequency and intensity of floods.

The intensity of future droughts is projected to increase even if precipitation increases. Rising temperatures will increase evaporation rates and the rate of soil moisture loss. Thus, future summer droughts are likely to be more intense.

Based on the weight of evidence presented in this assessment, changes in hydrometeorological variables are expected to occur within the project's 50-year life cycle. There are statistically significant increasing trends in projected flow data analyzed specific to this study area. As flow increases, floodplain forest habitat may be inundated more often. There is also evidence that temperatures are increasing in the study area which may negatively affect water quality and aquatic habitat. Table 4 indicates potential residual risks for this project, along with a qualitative rating of how likely those residual risks are to materialize and undermine project features resulting in harm to the study area.

Within the Upper Mississippi River Region, changes in hydrometeorological variables pose a potential risk to ecosystems due to the likelihood of the region experiencing shifts in the flow regime and increases in temperature in the future. Projects, like the Gilead Slough HREP project will serve to offset some of this risk by improving water quality and diversifying habitat. The standard practices used to design and construct USACE, ecosystem restoration projects include a degree of resilience because

features are typically designed to accommodate a wide range of flow conditions. Thus, it is unlikely that increases in flow will undermine project features. It is likely that increasing temperatures will place added stress on the ecosystem in the future. Ecosystem restoration standard design practices have been generated based on lessons learned from successful projects constructed between 1981 and 2015. These standards are listed in the 2012 *Upper Mississippi River Restoration (UMRR) Design Handbook* (USACE, 2012).

Even though USACE ecosystem restoration projects can already be considered inherently resilient, it would be worthwhile to consult with experts in floodplain habitat creation and maintenance to see if there are any additional opportunities to incorporate additional innovative, resilient features into the final design without incurring a significant change in cost. Added resilience should be targeted at ensuring project features can withstand higher flows (and higher water surface elevations) and greater periods of inundation. Additionally, opportunities to reduce potential future water quality impacts from rising water temperatures should be identified. A potential mechanism by which to accomplish this is to explore the development of an adaptive management plan, whereby if conditions are observed to be changing in the future, certain project features can be designed and/or flagged to accommodate the flexibility to be modified in response to changing future conditions.

*Table 4. Residual Risk*

| Project Feature | Trigger | Hazard | Harm | Qualitative Likelihood | Justification of Likelihood Rating |
|---|---|---|---|---|---|
| Backwater Habitat-Dredging, Excavation, Connection | Decreased discharge and WSE | Future droughts may increase sedimentation rates. | Increased sedimentation may decrease available habitat area in backwaters. | Unlikely | Proposed design will ensure necessary depth for overwintering habitat and provide connections for backwater habitat. It is unlikely that increased droughts will increase the severity of sediment deposition. |
| Shoreline Protection with Gradual Slope Revetment | Increased discharge and WSE | Future flood velocities and elevations may be higher. | Increased discharge and velocity will increase the shear stress on shoreline projection features and may overtop protected features. | Very Unlikely | Riprap is sized and graded to ensure a robust design, reduce project feature damage, and provide habitats. |
| Moist Soil Unit | Decreased discharge and WSE | Water volumes and depth may be lower than at present. | Lower WSE within moist soil unit has the potential to dry out moist soil unit features | Very Unlikely | Water control structures with overflows will be constructed within moist soil unit to provide water level management. Berms will be above ordinary high water, be compacted, include additional topsoil, and vegetated to slow the rate of erosion. |
| Substrate Diversity - Rock-Gravel Substrate | Increased discharge and WSE | Future flood volumes may be greater than at present. | Higher flows may cause erosion of substrate placed within the backwater channels. | Very Unlikely | Proposed design would ensure quality habitat for mussels and fisheries. |
| River Training Structure – Barbs, Hard Points, Scour Structures | Increased discharge and WSE | Future flood velocities and elevations may be higher. | Flow may overtop rock structures more frequently causing erosion of the backwater channels. | Very Unlikely | Riprap is sized and graded to ensure a robust design and reduce project feature damage. Orientation of rock structures are designed to withstand high flows. |
| Island/Sandbar Creation | Increased discharge and WSE | Future flood volumes may be greater than at present. | This will extend the duration and extent of island inundation resulting in habitat degradation and erosion. | Unlikely | The island design height would be set at an elevation slightly above normal pool that would be conducive to establishment of desired floodplain plant communities |
| Improved Existing Roads & Berms | Increased discharge and WSE | Water volumes and depth may be higher than at present. | Higher WSEL has the potential to overtop and/or erode levee and berm features. | Unlikely | Berms will have continuous riprap around shorelines to minimize high stage impacts and include additional topsoil to slow the rate of erosion. |

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