APPENDIX D - CLIMATE ASSESSMENT OF THE LOWER MINNESOTA RIVER WATERSHED DISTRICT

Young Environmental Consulting Group, LLC

Technical Memorandum

To: Linda Loomis, Administrator
Lower Minnesota River Watershed District

From: Lan Tornes, Natural Resources Scientist
Katy Thompson, PE, CFM
Della Schall Young, CPESC, PMP

Date: April 28, 2020

Re: Climate Assessment for the Lower Minnesota River Watershed District

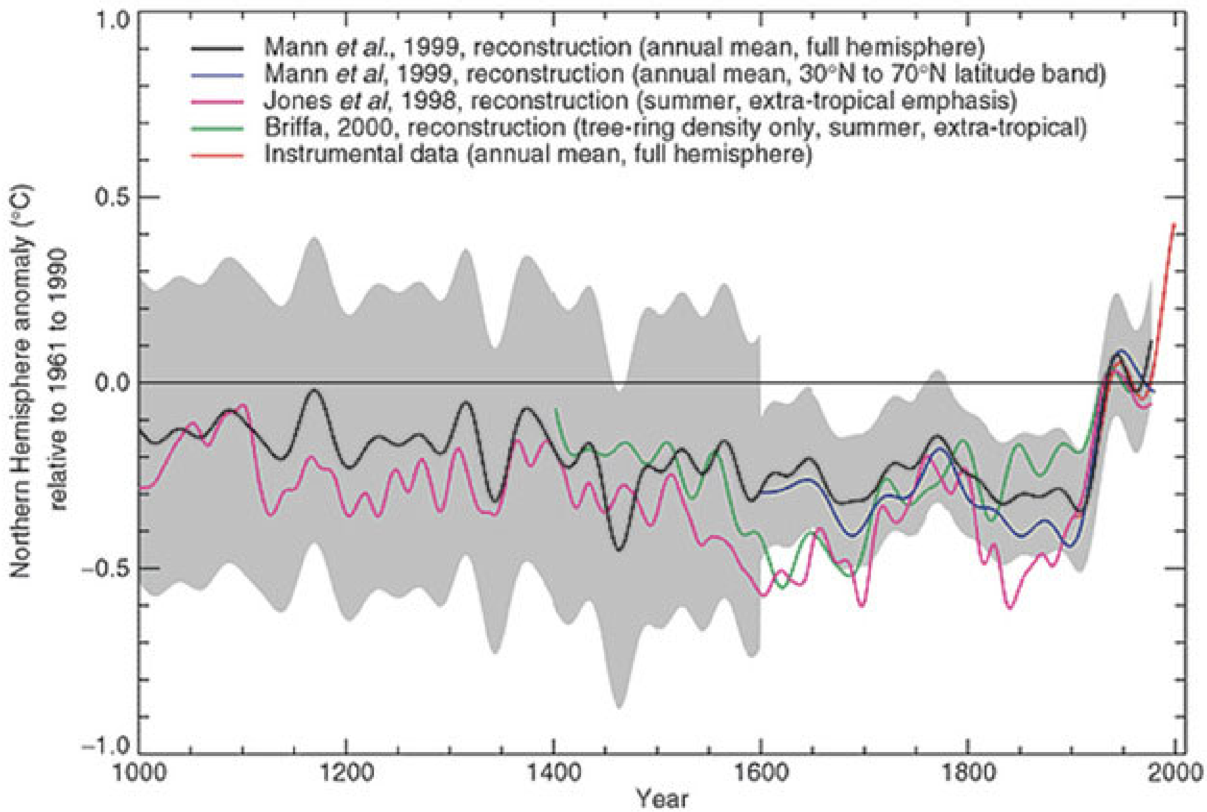
---

As part of the Lower Minnesota River Watershed District (LMRWD or District) 2020 Fens Sustainability Gaps Analysis, Young Environmental Consulting Group, LLC (Young Environmental) has reviewed the past, present, and projected climate trends in the District. To better manage the fens in the future, it is important to look to the past, compared with today's climate conditions, to establish the range of climatic conditions to which the fens of the lower Minnesota River Valley have been subjected. Considering the current health of the fens in light of future climate predictions will help the LMRWD adaptively manage them. This document is intended to simply establish the past, present, and projected climate conditions of the lower Minnesota River Valley, based on available data sources. For the specifics on how these conditions are expected to affect the fens, refer to the *LMRWD 2020 Fens Sustainability Gaps Analysis*.

Changing climate and its effect on natural resources continues to be an important discussion topic worldwide. There is disagreement about the specific cause of climate change, but scientific data show the earth is warming at an unprecedented rate (NASA 2020). **Figure 1**, published in the May 10, 2013, issue of *The Atlantic*, shows reconstructed temperatures over the last millennium, compared with recent instrument-based readings. The thirty-year temperature record from 1961 to 1990 is established as the normal period and is set as the zero value on the vertical axis. Temperatures before and after that normal period are categorized as "anomalous" because they deviate from that normal range. Reconstructed records from about the year 1000 CE showed temperatures consistently below normal, or negative, until the early 1900s. After that point, temperatures began increasing uniformly toward the established 30-year normal.

Data collected in recent years show that temperatures have displayed a rapid increase since about 1990 to values nearly 0.5 degrees above the established normal.

Figure 1. Global Temperature Anomalies Relative to 1961–1990: 30-Year Normal (Mooney 2013)



According to the Minnesota Department of Natural Resources (MNDNR), Minnesota has warmed by 2.9°F between 1895 and 2017, while becoming an average of 3.4 inches wetter. Although Minnesota has been getting warmer and wetter since 1895, the most dramatic changes have occurred in the past several decades, with each of the top 10 combined warmest and wettest years on record occurring between 1998 and 2017. Although climate conditions vary from year to year, these changes are expected to continue through the twenty-first century (MNDNR 2020a).

It will be important to understand how natural systems respond to a changing climate and how it might affect natural resources. Determining effects at a regional or local scale is more uncertain because most climate models are developed at a regional or global scale.

Study Methods

The information presented in this report came from many different publicly available sources, including federal, state, and local agencies. Researchers have reviewed past climate trends from the beginning of known meteorological records, present-day values based on 30-year averages, and projected future trends for the District.

Past Values

Information provided by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI 2020) is summarized in the Minnesota Climate Trends web map (MNDNR 2020b). This tool provides raw data as well as summaries of historical climate trends in temperature and precipitation going back to 1895. Data are compiled from established weather stations across the entire state as well as from groups of stations in major watersheds. The compiled data are spatially averaged to provide values of temperature and precipitation representative of watershed(s) chosen by the user. The area described as the Lower Minnesota River Watershed was chosen for summary in this report, which includes data compiled and averaged across that area from all the climate weather stations within the watershed.

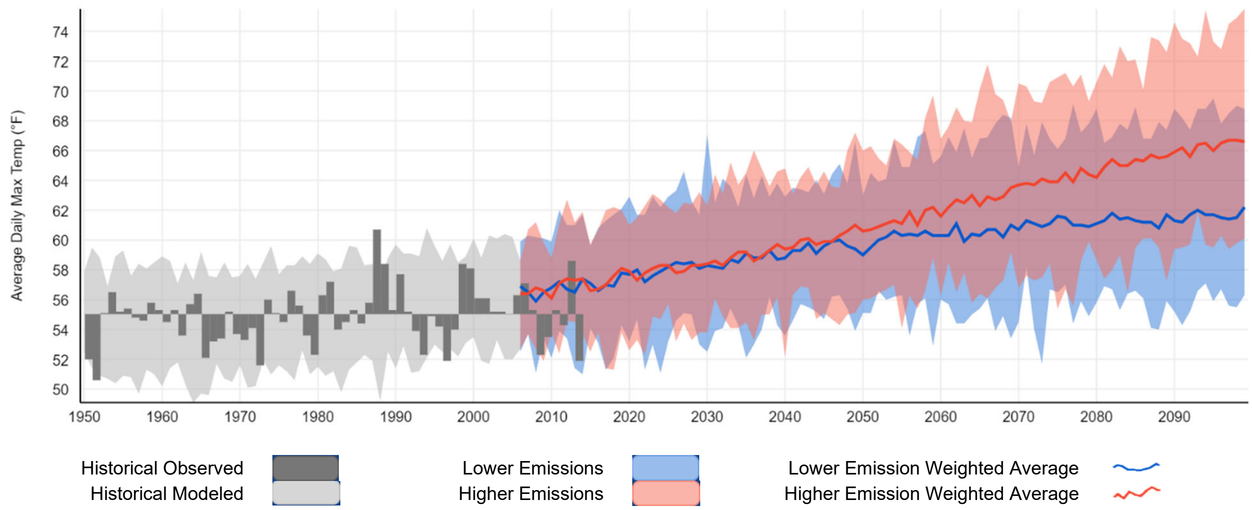
Present-Day Values

Present-day values, or normal values, for temperature and precipitation were obtained from the NOAA NCEI National Climatic Data Center (NCDC). The 1981–2010 Climate Normals are the NCDC's latest three-decade averages of climatological variables, including temperature and precipitation. This newer product replaces the 1971–2000 Climate Normals product. The NCDC data sets are updated every 10 years; the next cycle is expected to be available in early 2021. Data were available for several sites in the LMRWD. The data for the climate stations at Chaska, Chanhassen, and the Minneapolis-St. Paul International Airport (MSP) were selected for summarizing in this document; **Table 1** contains temperature data and **Table 2** contains precipitation data.

Projected Future Values

The projected future climate conditions within the LMRWD were obtained from NOAA's Climate Explorer. Climate Explorer is a tool used to project selected climate-related variables and estimate future conditions on a local scale in the coming decades, derived from global climate model projections (NOAA 2020b). Climate Explorer is supported by a consortium of federal agencies, including the US Global Change Research Program and NOAA. The City of Savage, in Scott County, as the center of the LMRWD watershed, was selected to generate local climate data projections. The projected conditions show values and ranges for scenarios with lower or higher global greenhouse gas emissions. **Figure 2** provides an example of the output generated from Climate Explorer. In the figure, the gray band represents the range of climate model output for the historical period from 1950 to 2006, which may also be called hindcasts or simulations. The blue band represents the lower global greenhouse gas emission scenarios for 2006 to 2100 and assumes that global emissions of heat-trapping gases peak around the year 2040 and then decline. The blue line shows the weighted mean of all blue-band projections at each one-year time step. The red band represents the high global greenhouse gas emission scenarios for 2006–2100, which assume that global emissions of heat-trapping gases continue to increase through the twenty-first century. The red line shows the weighted mean of all red-band projections at each one-year time step.

Figure 2. Example Graph from NOAA Climate Explorer



Temperature Trends

Past, present, and projected temperatures from identified sources were examined using the study methods described above. The results appear below.

<u>*Past Temperature Trends*</u>

In looking at past temperature trends, the following variables have been considered:

- **Average Annual Daily Low Temperature:** This metric is an annual average of the daily low temperatures from 1895 to 2015 and provides insight into the overnight or winter temperature trends.
- **Average Annual Daily Temperature:** This metric is an annual average of the daily high and low temperatures from 1895 to 2015 and provides insight into overall temperature trends.
- **Average Annual Maximum Temperature:** This metric is the annual average of the daily high temperatures from 1895 to 2015 and provides insight into daytime or summer temperature trends.
- **January Average Temperature:** This metric shows the average of the daily high

and low temperatures in the month of January from 1895 to 2015 and provides insight into ways in which winter temperatures are changing.

- **July Average Temperature:** This metric is the average of the daily high and low temperatures in the month of July from 1895 to 2015 and provides insight into the temperature trends in summer.

Figure 3 shows the calculated daily low temperature each year from 1895 to 2015, averaged from data from weather stations in the Lower Minnesota River watershed. Even with the variability in temperature data, the trend toward warming at a rate of nearly 0.3°F per decade is evident. During the 120 years of record, the average annual low temperature has increased from about 32°F to about 36°F. The annual average temperature shown in **Figure 4** has also increased during the last 120 years, with an average rate of less than 0.2°F per decade. The annual average maximum temperature, **Figure 5**, does not show a notable trend. The January average temperature, **Figure 6**, shows an increasing trend of about 0.26°F per decade. Although many temperature records suggest trends toward increasing temperatures, **Figure 7** suggests that the average of the July high temperatures may actually be decreasing.

Figure 3. Average Annual Daily Low Temperatures in the Lower Minnesota River Watershed (MNDNR 2020b)

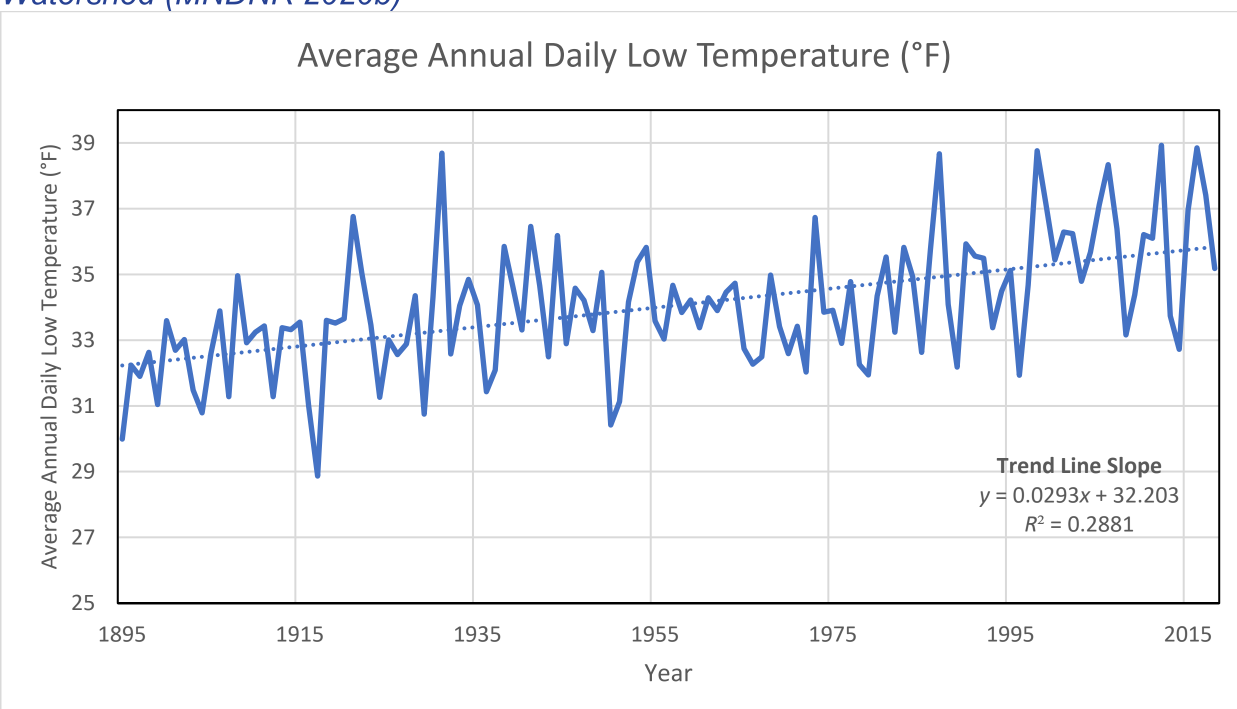


Figure 4. Annual Average Temperature in the Lower Minnesota River Watershed (MNDNR 2020b)

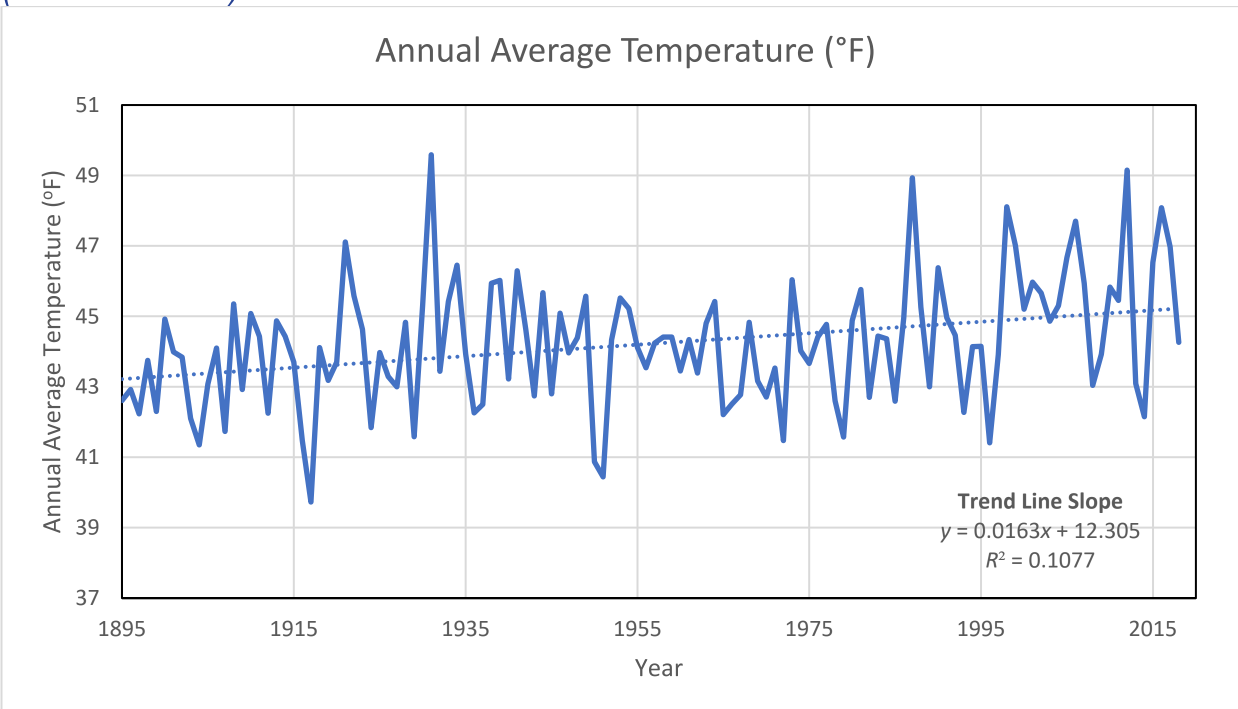


Figure 5. Average Annual Maximum Temperature in the Lower Minnesota River Watershed (MNDNR 2020b)

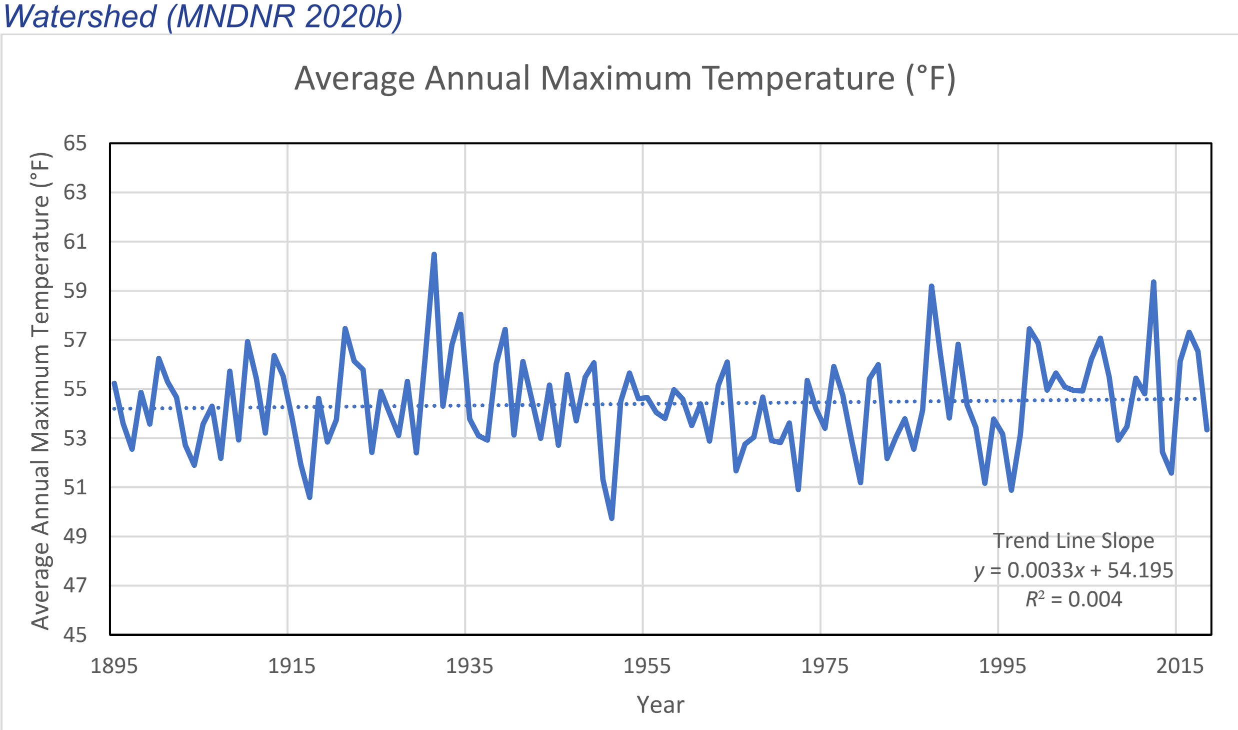


Figure 6. January Average Temperature in the Lower Minnesota River Watershed (MNDNR 2020b)

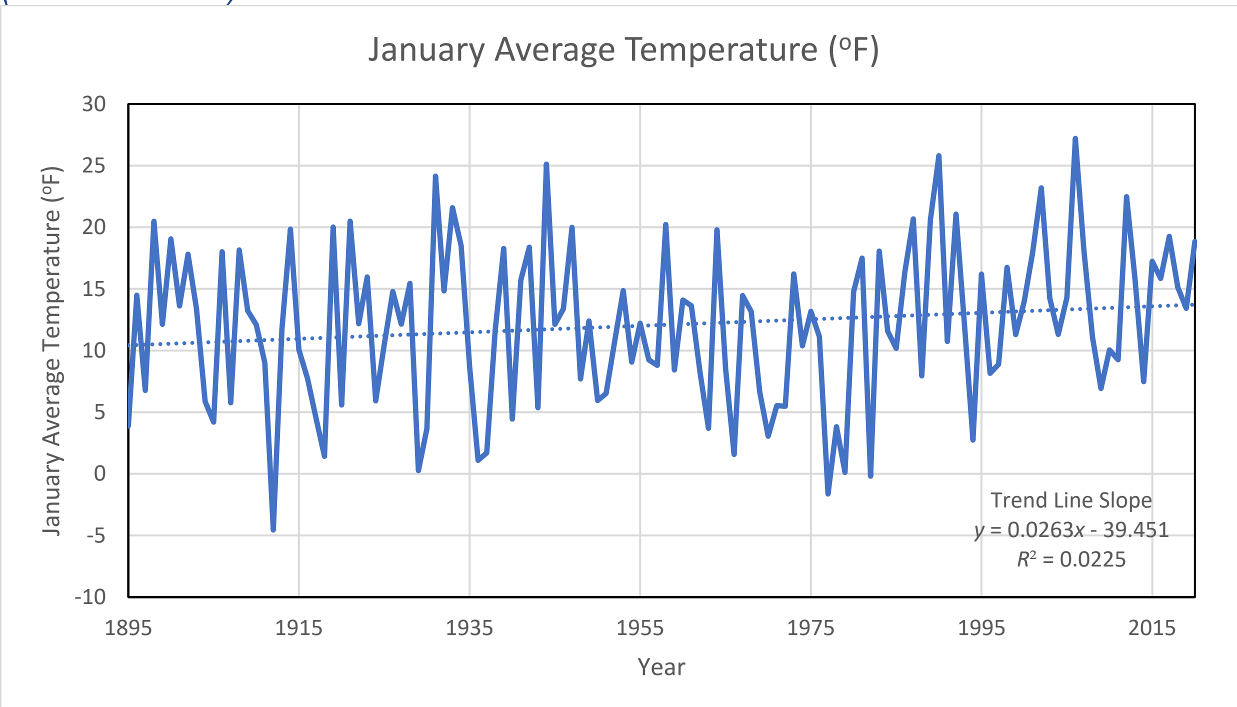
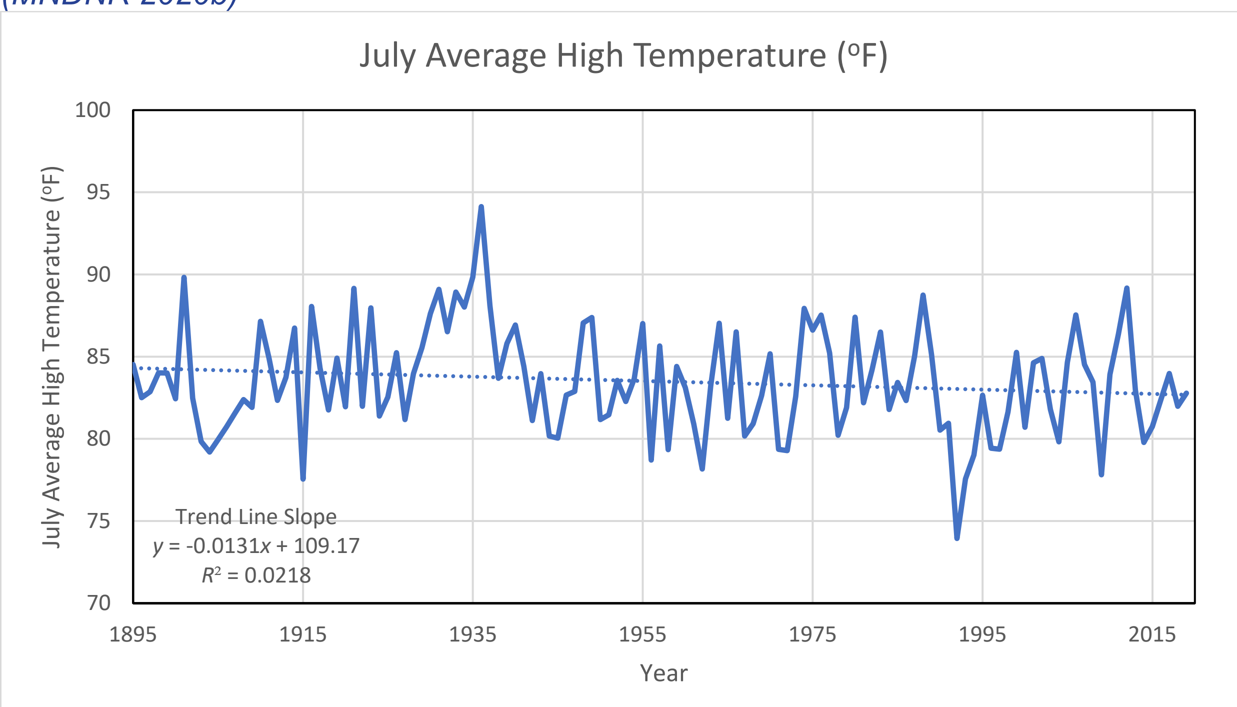


Figure 7. July Average High Temperature in the Lower Minnesota River Watershed (MNDNR 2020b)



The following data summarize the past temperature trends found in our analysis.

- The average low temperatures in the District have been increasing since 1895; both the daily low and January daily temperatures suggest that the watershed may be warming and losing extreme cold values.
- The average high temperatures have remained steady, although there is evidence to suggest that summer average daily high temperatures are decreasing.

These trends suggest that the historic range of temperatures in the LMRWD may be shrinking, reducing the overall variability of temperature swings.

Present-Day Temperature Trends

The most recent 30-year normal average temperatures from NOAA at the selected stations appear in **Table 1**. Temperatures vary seasonally at these stations, with January temperatures averaging in the teens above 0°F, and July temperatures averaging in the low 70s. The average annual temperature at Chanhassen is 45°F, with Chaska slightly below and the MSP slightly above that temperature.

Table 1. Monthly Normal Temperatures at Selected Locations in the LMRWD, 1981–2010

	Chaska			Chanhassen			Minneapolis-St. Paul Airport		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
January	2.6	12.7	22.8	5.6	14.3	23.1	7.5	15.6	23.7
February	8.3	18.4	28.4	10.4	19.1	27.9	12.8	20.8	28.9
March	19.8	30.0	40.2	22.4	31.3	40.1	24.3	32.8	41.3
April	34.2	45.8	57.3	35.9	46.5	57.1	37.2	47.5	57.8
May	45.9	57.7	69.5	47.5	58.0	68.6	48.9	59.1	69.4
June	56.1	67.3	78.5	57.4	67.6	77.8	58.8	68.8	78.8
July	60.7	71.8	82.8	61.9	72.0	82.1	64.1	73.8	83.4
August	58.0	69.3	80.6	60.2	69.9	79.7	61.8	71.2	80.5
September	48.7	60.2	71.7	50.8	60.7	70.6	52.4	62.0	71.7
October	36.4	47.5	58.6	38.0	47.8	57.7	39.7	48.9	58.0
November	23.3	32.3	41.2	25.0	32.7	40.3	26.2	33.7	41.2
December	8.5	17.5	26.4	10.4	18.1	25.8	12.3	19.7	27.1
Annual	33.7	44.3	55.0	35.6	45.0	54.3	37.3	46.3	55.3

Source: NOAA 2020a

Projected Future Temperature Trends

In looking at future temperature trends for the lower Minnesota River Valley, the following variables have been considered:

- **Average Daily Maximum Temperature:** From the NOAA Climate Explorer, this measurement represents a projected range of average daily high temperatures for high and low global emission scenarios.

- **Average Daily Minimum Temperature:** From the NOAA Climate Explorer, these values represent a projected range of average daily low temperatures for high and low global emission scenarios.

The following graphs were generated using the NOAA Climate Explorer tool. **Figure 8** shows the projection of the average daily temperatures for the lower and higher global emissions scenarios, shown in blue and red, respectively. The lower emission scenario, shown in blue, assumes heat-trapping gases will be stabilized by 2040 and will then dramatically reduce. The higher emission scenario, shown in red, assumes that global emissions of heat-trapping gases will continue increasing through 2100. The solid blue and red lines show the weighted average for all projections at each time step, whereas the area shows the range of all projections at each time step.

At the beginning of the climate projections in 2006, the weighted mean daily temperature for the blue, lower emission, scenario is 56.9°F and the red, higher emission, scenario is 56.4°F. Near the end of the projections in 2099, the weighted mean daily temperature for the blue line scenario is 62.2°F and for the higher emission scenario is 66.6°F, indicating an increase in the average daily temperatures for the District of 4.9°F by the end of this century.

Figure 8. Projected Average Daily Maximum Temperatures for the LMRWD (NOAA 2020b)

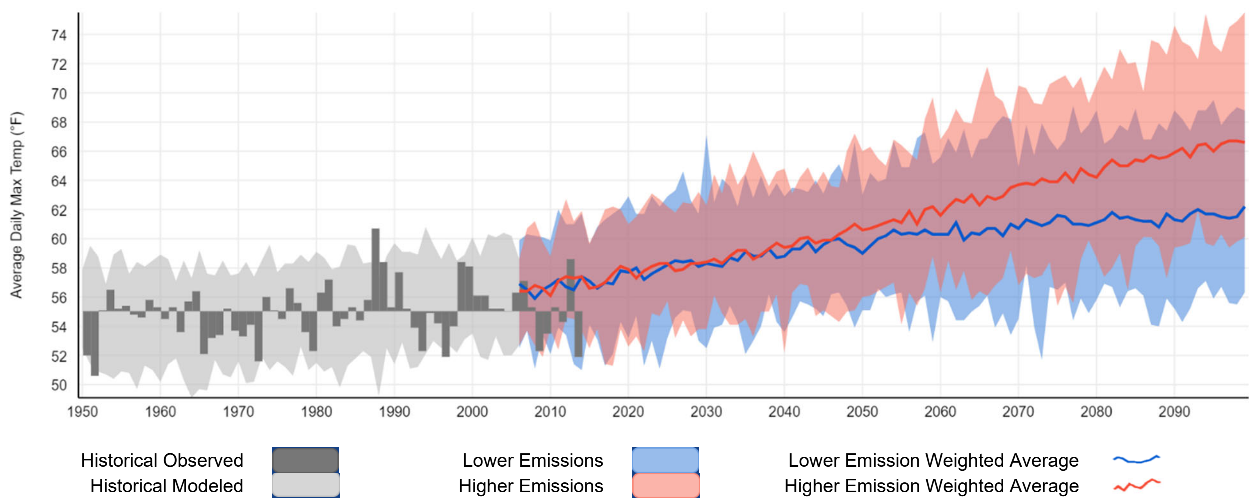
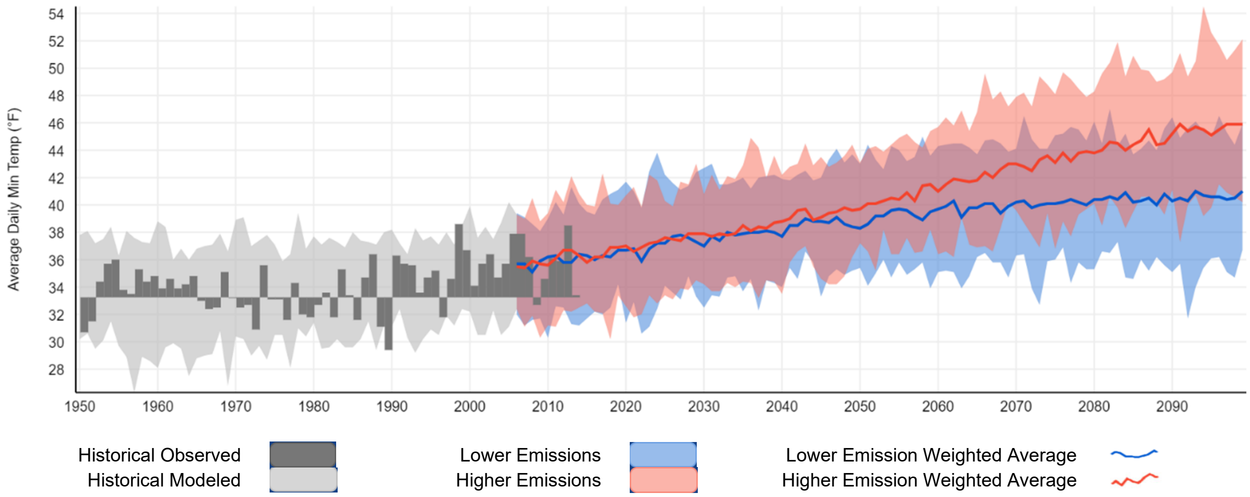


Figure 9 shows the projection of the average daily minimum temperature for the lower and higher emissions scenarios from Climate Explorer. At the beginning of the projections in 2006, the weighted mean daily temperature for the blue lower emission scenario is 35.7°F and the red, higher emission, scenario is 35.5°F, an overall difference of 0.2°F. Near the end of the projections in 2099, the weighted average daily temperature for the blue line (lower emission) scenario is 41.0°F and the red line (higher emission) scenario is 45.9°F, an overall difference of 4.9°F, representing an increase of

nearly 15 percent for the low emissions scenario and 29 percent for the high emissions scenario. This is consistent with MNDNR data that indicate nights in Minnesota have warmed 55 percent faster than days since 1970 (MNDNR 2020c). That would suggest that the daily minimum temperatures have already increased and are part of a larger trend that might continue.

Figure 9. Projected Average Daily Minimum Temperatures for the LMWRD (NOAA 2020b)



Growing Season

Another indicator of a climate and temperature changes is the length of the growing season. The US Environmental Protection Agency (USEPA) provides climate-change information on their website, and **Figure 10** is copied from that site (USEPA 2016).

A projection of the growing degree days in Savage, Minnesota, also was obtained from the NOAA Climate Explorer and is shown in **Figure 11**. Growing degree days are a measure of heat accumulation used to predict plant and animal development rates, such as when a crop is expected to mature and when an insect will emerge from dormancy. Higher numbers of growing degree days indicate longer and warmer growing conditions (NOAA 2020b). The Climate Explorer models suggest that the LMRWD could experience a 34 to 71 percent increase in the number of growing degree days from 2006 to the end of the century, indicating that the length of the summer growing season in the LMRWD will continue increasing under all scenarios.

Figure 10. Length of Growing Season for the Contiguous 48 United States, 1895–2005 (USEPA 2016)

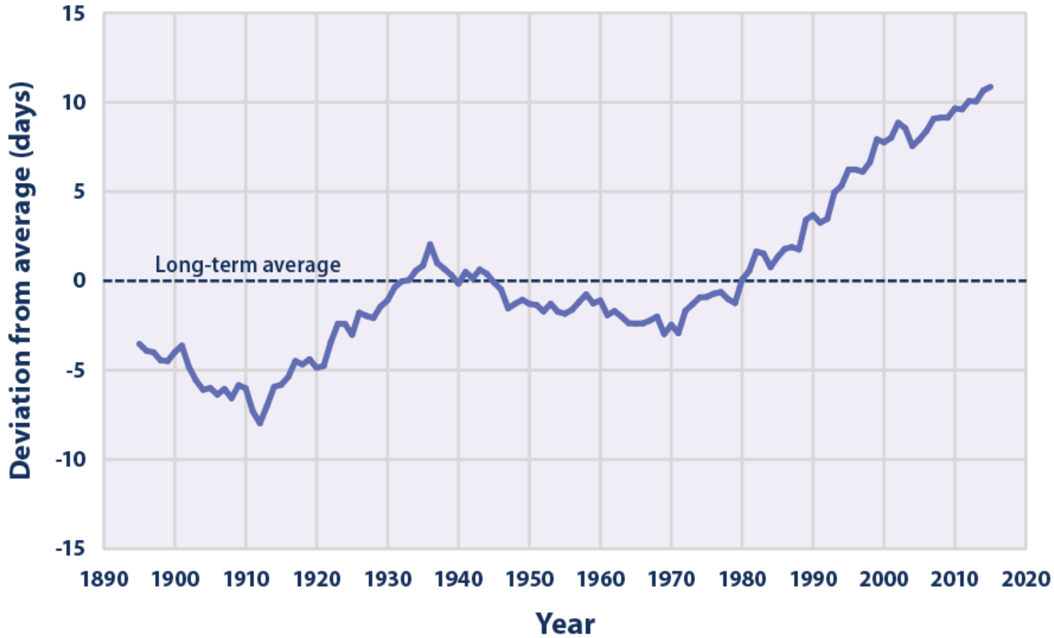
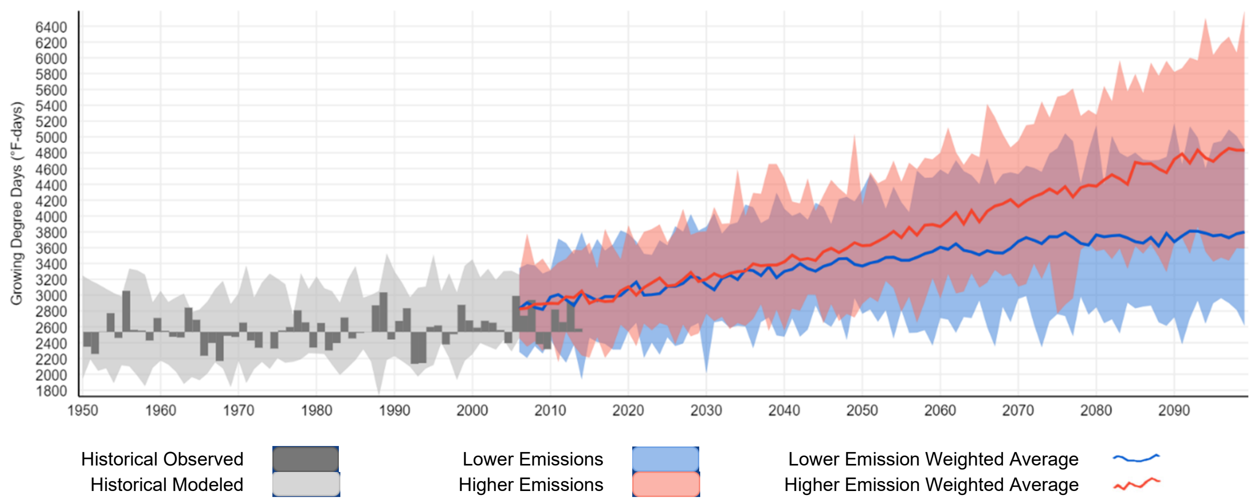


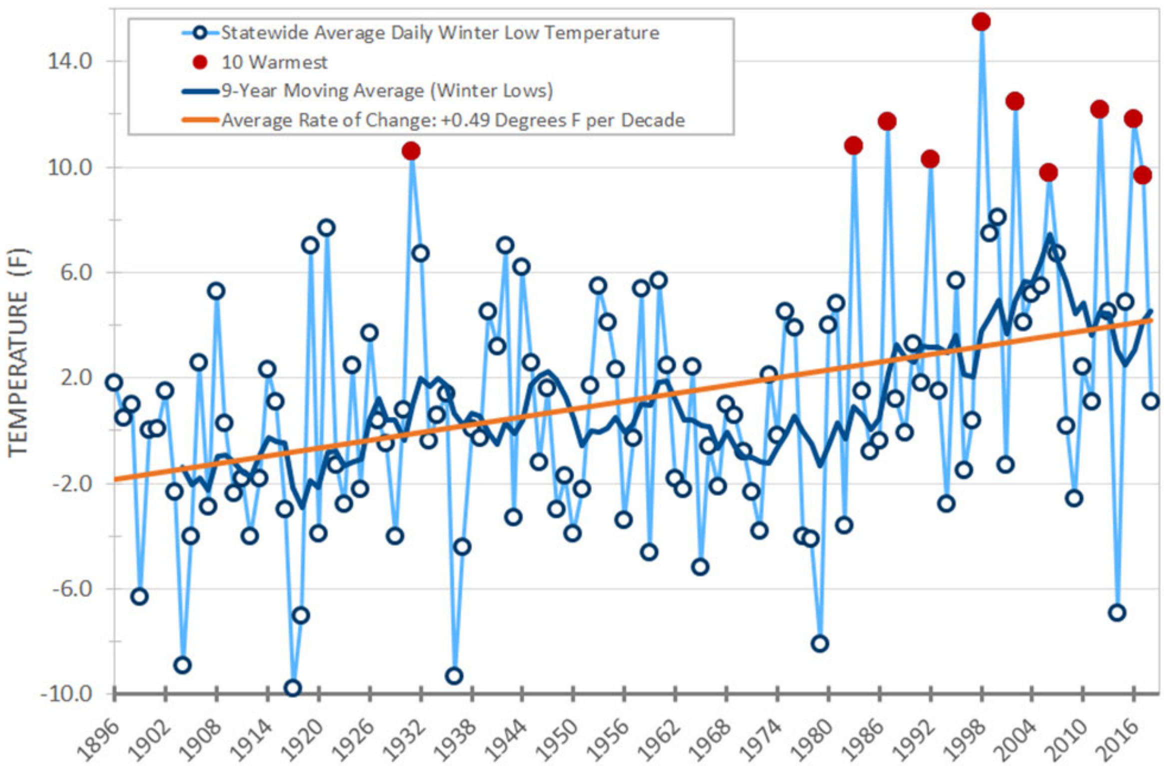
Figure 11. Modified Growing Degree Days in Savage, MN, in Degrees Fahrenheit Days per year (NOAA 2020b)



Temperature Trends Summary

According to the MNDNR, most of Minnesota's observed warming has been when it is coolest—namely, at night and during the winter. Since 1970, winter has warmed much faster than summer, and nights have warmed faster than days; the frequencies of -35°F readings in northern Minnesota and -25°F readings in the south have fallen by up to 90 percent. Although Minnesota will always see periodic severe cold spells, winters do not often get as cold as they once did, and the long-term decline in cold extremes is expected to continue. The 0.26°F per decade warming winter trend shown in **Figure 6** is validated by the MNDNR's Climate Trends website and **Figure 12** (MNDNR 2020a). **Figure 12** shows the average daily winter low temperature and highlights the warming trend observed, including the fact that nine of the top ten warmest winters have occurred since 1980.

Figure 12. Minnesota Average Daily Winter Low Temperatures December through February, 1896–2018 (MNDNR 2020a)



The general trend of warmer winters and warmer overall temperatures is also highlighted by the following graphs from Climate Explorer. The number of days the LMRWD experiences a daily high of less than 32°F is shown in **Figure 13,** and the number of days LMRWD experiences a daily high of more than 105°F is shown in **Figure 14**.

Figure 13. Number of Days per Year with Maximum Temperature below Freezing for Savage, MN, 2006–2099 (NOAA 2020b)

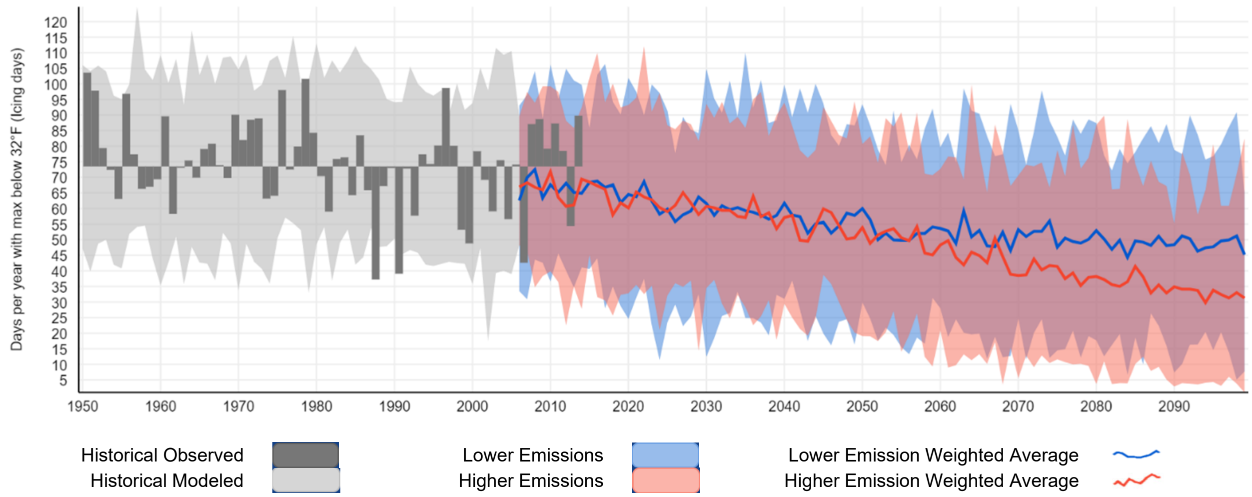
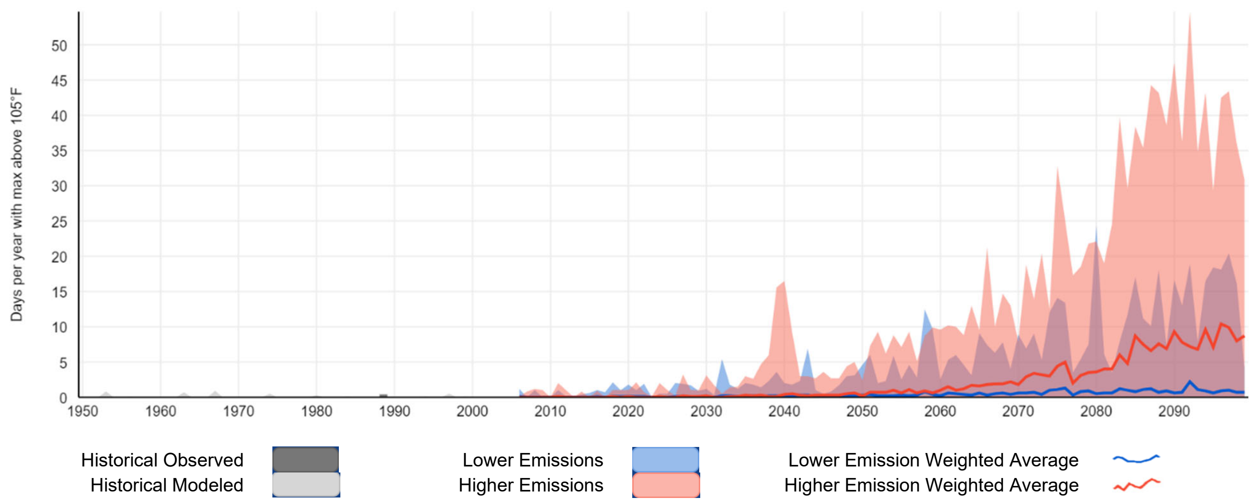


Figure 14. Number of Days per Year with Maximum Temperature above 105°F for Savage, MN, 2006–2099 (NOAA 2020b)



The data indicate that LMRWD can expect warmer winters and longer summers, with increases to more extreme summer temperatures under all global greenhouse gas emission scenarios in the future.

Precipitation Trends

Heavy rains now occur more frequently and more intensely in Minnesota than at any time on record. Dramatic increases in the occurrence of 1-inch and 3-inch rainfall events have been seen at long-term observation stations. The measurable depth of the largest rainfall each year has also become greater. Minnesota has also had a substantial increase in devastating, large-area extreme rainstorms since 2000 (MNDNR 2020e). Rains that historically would have been in the 98th percentile annually (the largest 2 percent) have become more common. Climate projections indicate these big rains will continue increasing into the future (MNDNR 2020a).

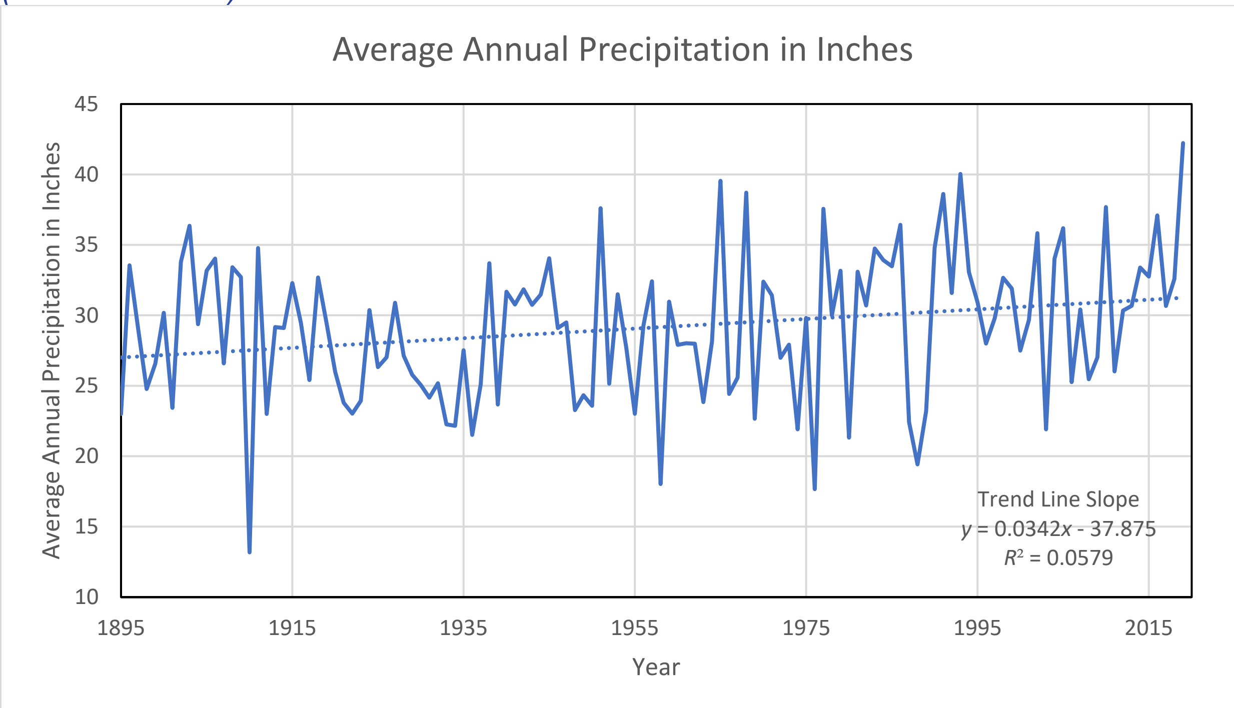
The U.S. Global Change Research Program states that excessively heavy precipitation has been trending upward across much of the United States and many other parts of the world over the past few decades (U.S. Global Change Research Program, 2017).

Past, normal, and projected precipitation data for the District were collected from identified sources using the methods described previously and appear below.

Past Precipitation Trends

To assess historical precipitation trends, we reviewed the average annual precipitation data from 1895 to 2015, using the MNDNR Minnesota Climate Trends tool. **Figure 15** shows the annual precipitation averaged from weather stations in the Lower Minnesota River watershed (MNDNR 2020b). An upward trend is indicated with annual precipitation of about 27 inches in the late 1800s, rising to over 31 inches in 2019, indicating an increase in the average annual precipitation in the LMRWD of 0.34 inches per decade.

Figure 15. Average Annual Precipitation for the Lower Minnesota River Watershed (MNDNR 2020b)



Present-Day Precipitation Trends

Table 2 shows the monthly normal and annual precipitation for the three selected stations from the 1981–2010 NOAA NCDC data set for weather stations in Chaska and Chanhassen and at the MSP. The majority of the precipitation falls during the warmer summer months (May through September), and less falls during the colder months (December through March). The stations all receive at least 31 inches of precipitation, with Chaska receiving nearly 33 inches a year. This amount is consistent with the historic annual precipitation trends noted in the previous section and in **Figure 15**. Although much of the winter precipitation falls as snow, data summarizing how much of the precipitation falls as liquid versus solid precipitation was not readily available.

Table 2. Monthly Normal Precipitation in Inches, 1981–2010.

	Chaska	Chanhassen	Minneapolis-St. Paul Airport
January	0.93	0.87	0.90
February	0.73	0.94	0.77
March	1.83	1.78	1.89
April	3.10	3.00	2.66
May	3.70	3.66	3.36
June	4.29	4.02	4.25

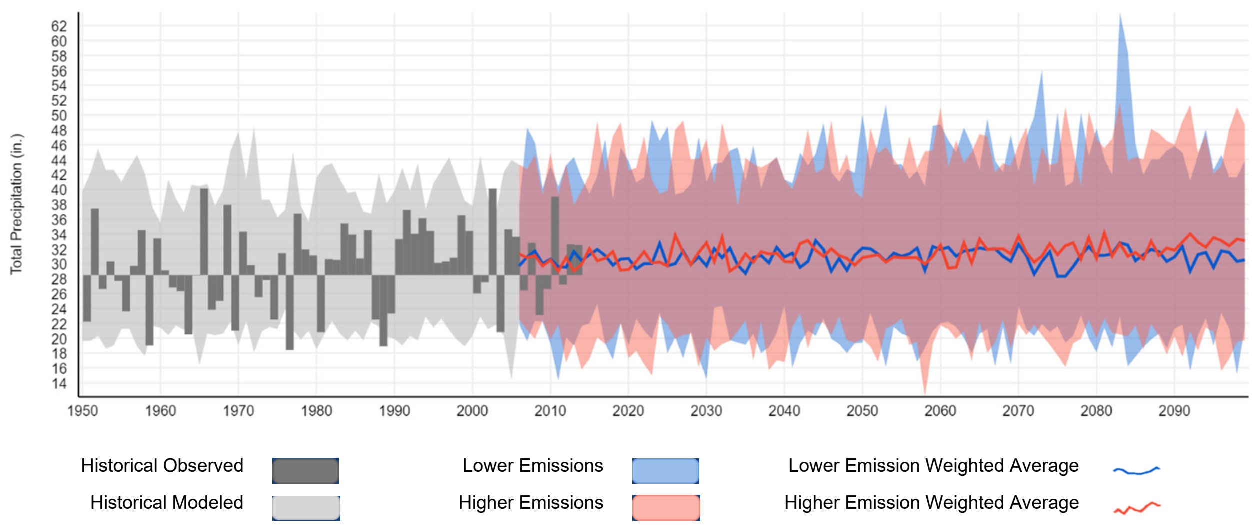
	Chaska	Chanhassen	Minneapolis-St. Paul Airport
July	3.95	3.59	4.04
August	5.16	4.14	4.30
September	3.53	3.43	3.08
October	2.59	2.51	2.43
November	1.74	1.97	1.77
December	1.18	1.25	1.16
Annual	32.73	31.16	31.61

Source: NOAA 2020a

Projected Future Precipitation Trends

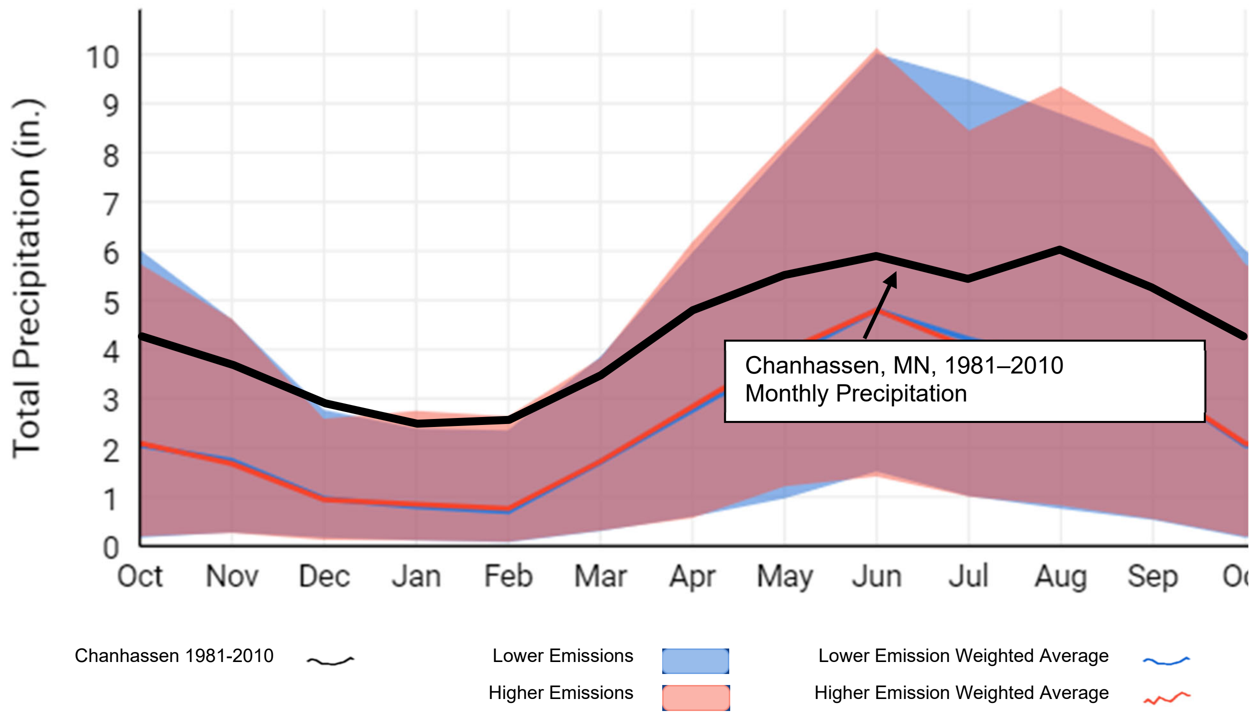
Figure 16 shows the NOAA Climate Explorer's (NOAA 2020b) projected annual precipitation for the Lower Minnesota River watershed under high and low global emission scenarios. The provided model results do not appear to suggest any upward or downward trend in precipitation in either the lower or higher emissions scenarios.

Figure 16. Projected Total Annual Precipitation for the Lower Minnesota River Watershed (NOAA 2020b)



The Climate Explorer model output provided in **Figure 17** below shows the projected monthly distribution of the annual precipitation, a graphic representation of the average annual precipitation distributed across an entire year. The data indicate that under both the high and low emissions scenarios, the overall distribution of rainfall is not predicted to change significantly, with the summer months continuing to receive the majority of the rainfall. The 1981–2010 monthly normal precipitation for Chanhassen, from **Table 2** and shown as the black line on **Figure 17**, confirms that the Climate Explorer model predictions do not project a substantial deviation from the historical annual distribution of precipitation.

Figure 17. Normal Monthly Precipitation at Chanhassen, MN (NOAA 2020b)



Frozen Precipitation

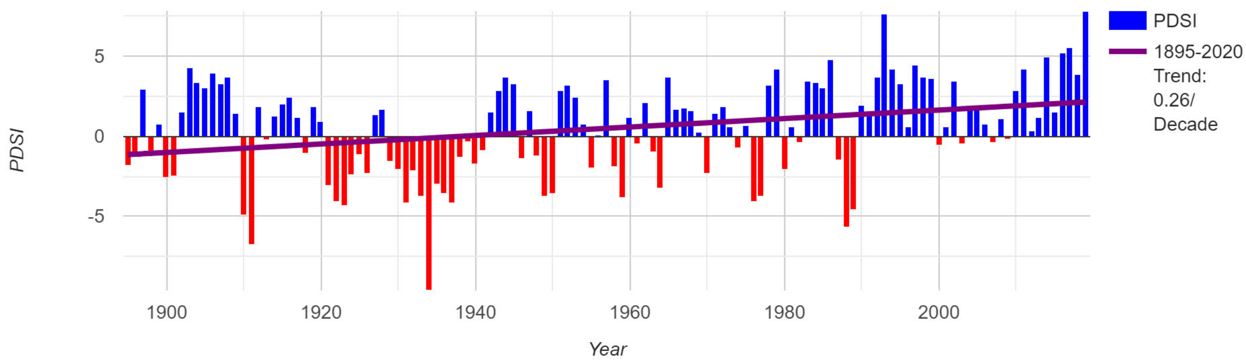
Snow cover is an important part of the Minnesota climate. In the winter, it reflects sunlight and keeps surface temperatures low. It protects and shelters small plants and animals. It insulates the soil, preventing heat loss, while also reducing the penetration of frost. The winter snowpack stores water that provides runoff in the spring. Definitive information about the changing snowpack characteristics in Minnesota near the LMRWD was not available.

According to Climate.gov, the timing of spring snow melt affects the length of the growing season, the timing and dynamics of spring river runoff, permafrost thawing, and wildlife populations. The Northern Hemisphere's land snow cover averaged 24.8 million square kilometers in 2019. This is 0.3 million square kilometers less than the 50-year average, making it the thirty-fourth most (or seventeenth least) extensive snow cover on record. The report goes on to state, “Despite occasional positive anomalies tied to natural variability in atmospheric circulation patterns, springtime Northern Hemisphere snow cover has declined” (Dahlman 2020). The effects on resources in the LMRWD are difficult to quantify but probably will be evident as the growing body of information is examined and interpreted.

Droughts

The MNDNR Minnesota Climate Trends website provides some simple metrics for determining drought conditions by looking at index values that correlate to moisture excess (positive) and deficit (negative) conditions within the Lower Minnesota River watershed for each month going back to 1895 (MnDNR 2020b). All months have a positive correlation in the data, indicating that the watershed may be less prone to droughts; see **Figure 18** for an example of the Palmer Drought Severity Index (PDSI) for August, the month with the greatest trend.

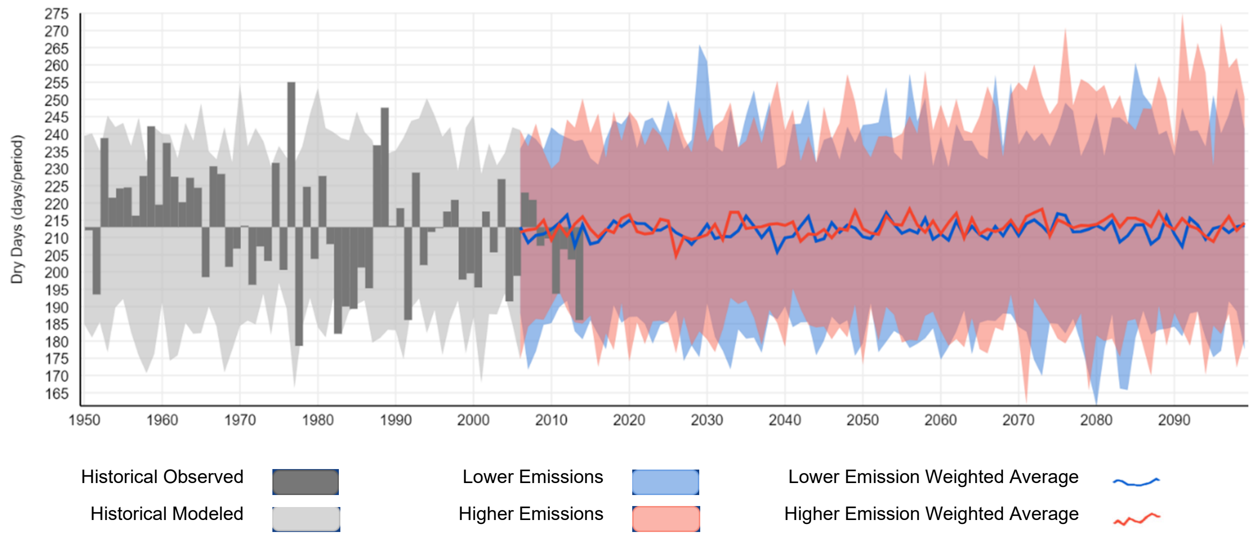
Figure 18. Palmer Drought Severity Index for August, Lower Minnesota River Watershed District (MNDNR 2020b)



The average trend for all months from 1895 to 2020 is +0.18°F, indicating movement away from severe droughts since 1990 for the LMRWD.

The NOAA Climate Explorer does not provide any directly comparable drought predictions for the lower and higher emission scenarios but does provide a data set that predicts the number of dry days that may occur each year with less than 0.01 inches of rainfall (**Figure 19**). These data show a similar trend with the average weighted projections, indicating movement toward a steady number of dry days in the LMWRD each year and less variability overall.

Figure 19. Annual Number of Days with Less than 0.01 Inches of Rainfall in Savage, MN, 2006–2099 (NOAA 2020b)



Precipitation Trends Summary

The MNDNR has predicted increasing variability in individual precipitation events across the state (MNDNR 2020c). That variability may not be evident in the Climate Explorer plots of projected annual precipitation shown in **Figure 16** because the extremes and variability would be hidden in the averages.

The MNDNR State Climatology Office continues to examine climate records by using various statistical and graphical techniques to understand and elucidate subtle changes in climate that could have major effects on natural, cultural, and economic resources in the future. One of their recent efforts produced the following graph (**Figure 20**) showing the increasing frequency of heavy precipitation events. The bars in the graph show the deviation in frequency of 1-inch rainfall events averaged from 40 rain gage stations in Minnesota and referenced to a long-term average between 1916 and 1960. The yellow/gold bars show the decades that experienced lower than average 1-inch rainfall events occurring between 1916 and 1935. All other decades have exceeded the 1916–1960 average for the number of small, 1-inch events, indicating a trend toward more frequent small events and intense larger rainfall events. This trend is also predicted by the NOAA Climate Explorer when looking at the predicted number of days with rainfall events greater than 3 inches (**Figure 21**). Both global greenhouse gas emission scenarios predict an increase in the number of days on which the LMWRD has large rainstorm events.

Figure 20. Changes in Heavy Precipitation Frequency and Intensity (CEAM 2017)

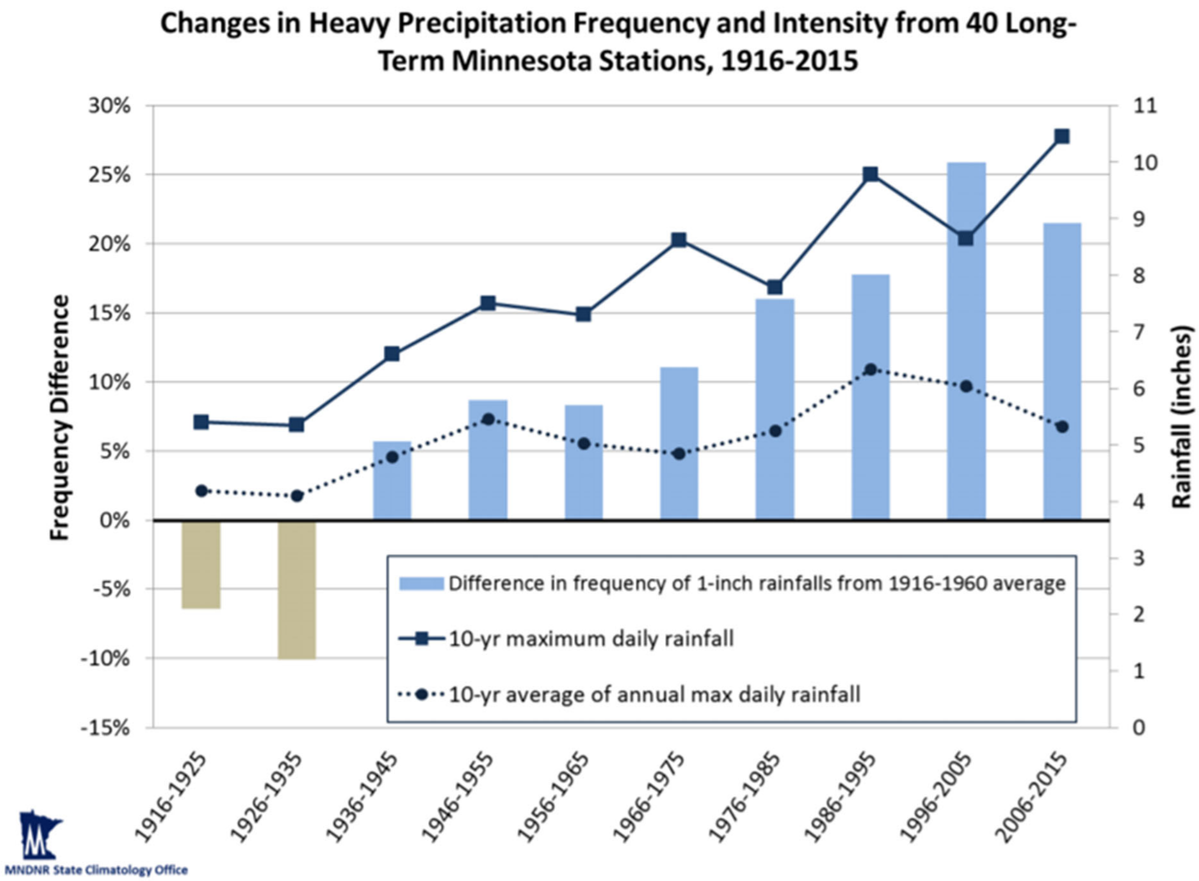
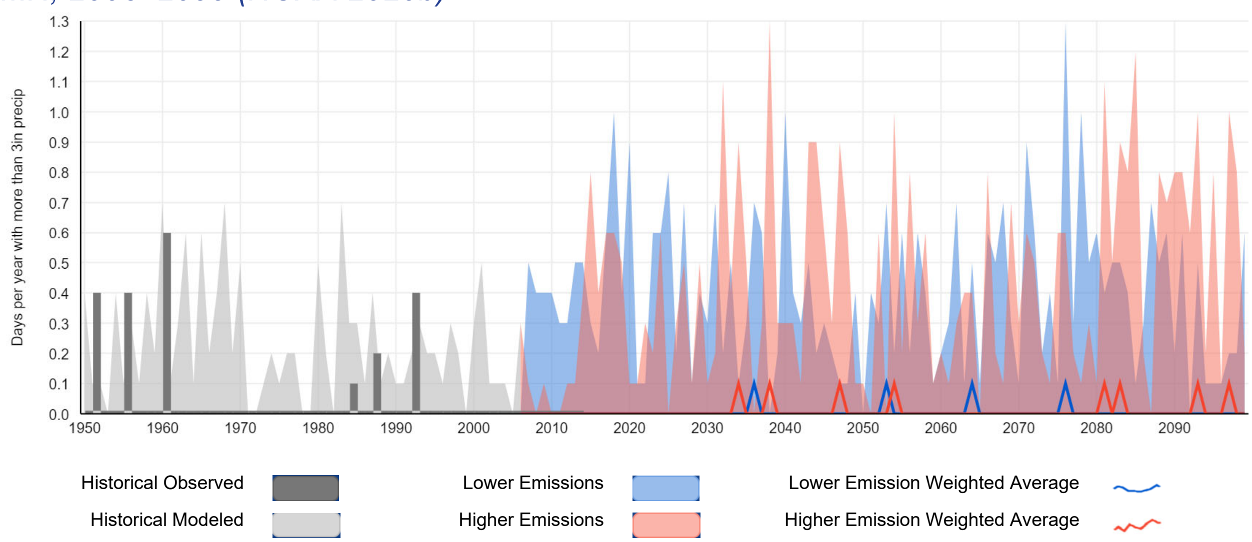


Figure 21. Predicted Number of Days with More than 3 Inches of Rainfall at Savage, MN, 2006–2099 (NOAA 2020b)



Conclusions

The climate of the Lower Minnesota River valley is changing, and the unique ecosystems and natural resources that have evolved within the LMRWD jurisdiction will face increased pressure to survive in a changed climate. One way to help protect native species and resources is to understand the conditions under which they evolved, consider their current status with present-day climate data, and look at future trends to develop management strategies that can aid in their survival. The purpose of this document is to lay out these trends—historic, present, and future—and identify those specific to the LMRWD so that they can be used for future management plans.

The scientific community is in agreement that the climate is evolving and that the past is no longer a metric that can reliably be used to manage natural resources. However, understanding the past can shed light on the optimal conditions for a specific ecosystem or species. Based on our review, the historic climate conditions in the LMRWD were on average colder, more extreme, and drier than today.

Specific metrics considered in this analysis related to temperature are provided in **Table 3** and summarized below.

- The average low temperatures in the District have been increasing since 1895; both the daily low and January daily temperatures suggest that the watershed may be warming and losing extreme cold values.
- The average high temperatures have remained relatively steady, although there is evidence to suggest that the summer average daily high temperatures are decreasing; long-term climate predictions point to hotter summers.
- These trends suggest that the historic range of temperatures in the LMRWD may be shrinking, reducing the overall variability of temperature swings. USEPA evidence of a long-term increase in the length of the growing season since 1970 and Climate Explorer models suggest that the LMRWD is highly likely to experience increasing lengths of the summer growing season under all scenarios.

Table 3. Temperature Trends Summary for the Lower Minnesota River Watershed District

	Historic Values			**Present Day**	**Future Prediction**	
Temperature Metrics	Min (°F)	Max (°F)	Trend (°F/Decade)	1981–2010	Low Emission	High Emission
Average Annual Minimum Temperature	28.87	38.93	+0.29	35.5	38.7	40.6
Average Annual Temperature	39.73	49.59	+0.16	45.2	-	-
Average Annual Maximum Temperature	49.74	60.49	+0.02	54.9	59.6	61.3
January Average Temperature	-4.55	27.21	+0.26	14.2	-	-
January Average Minimum Temperature	-13.34	21.43	+0.39	5.2	-	-
January Average Maximum Temperature	4.24	35.28	+0.13	23.2	-	-
July Average Temperature	64.82	79.76	+0.05	72.5	-	-
July Average Minimum Temperature	55.52	67.11	+0.22	62.2	-	-
July Average Maximum Temperature	73.94	94.13	-0.13	82.8	-	-

Specific metrics considered in this analysis related to precipitation and their trends are summarized below.

- Historic data suggest an increase in the average annual precipitation in the LMRWD of 0.34 inches per decade, whereas the NOAA Climate Explorer showed few trends in the total annual precipitation, indicating any trends may be obscured by the high and low extremes in the global climate modeling.
- Intense and heavy precipitation events are occurring more frequently in the LMRWD and are expected to increase in the future, based on climate projections. The more intense and heavy precipitation not only causes localized flooding but also increases erosion of streambanks and sediment and pollutant loading downstream.
- There is evidence to suggest that the risk of droughts in the LMRWD has been decreasing and LMRWD may not experience as many drought periods in the future.

All these trends in temperature and precipitation indicate that the local climate in the Minnesota River Valley is changing and that there is a need to manage the District's natural resources actively with changing climate in mind.

References

CEAM 2017. “How the Climate of Minnesota Is and Is Not Changing.” Available at http://www.ceam.org/vertical/Sites/%7BD96B0887-4D81-47D5-AA86-9D2FB8BC0796%7D/uploads/Adapting_to_Climate_Change-_What_Changes_Are_Expected_How_Will_it_Impact_My_City_and_How_Should_We_Prepare_(CEAM_2017).pdf. City Engineers of Minnesota. Accessed April 14, 2020.

Dahlman, LuAnn, and Rebecca Lindsey. February 14, 2020. “Climate Change: Spring Snow Cover.” National Oceanic and Atmospheric Administration. Available at https://www.climate.gov/news-features/understanding-climate/climate-change-spring-snow-cover. Accessed February 18, 2020.

MNDNR. 2020a. “Climate Trends.” Available at: https://www.dnr.state.mn.us/climate/climate_change_info/climate-trends.html. Accessed February 17, 2020.

MNDNR. 2020b. “Minnesota Climate Trends Tool.” Available at: https://arcgis.dnr.state.mn.us/ewr/climatetrends/#. Accessed February 14, 2020.

MNDNR. 2020c. “Minnesota’s Climate Is Already Changing.” Available at: https://files.dnr.state.mn.us/natural_resources/climate/change/climatechange-factsheet.pdf. Accessed February 18, 2020.

MNDNR 2020d. “Understanding Hydroclimatic Change in Minnesota.” Minnesota Department of Natural Resource, State Climatology Office. Available at: http://climateapps.dnr.state.mn.us/MN_Climate_2020.pptx. Accessed March 31, 2020.

MNDNR 2020e. “Historic Mega-Rain Events in Minnesota.” Available at: https://www.dnr.state.mn.us/climate/summaries_and_publications/mega_rain_events.html. Accessed April 14, 2020.

Mooney, Chris. May 10, 2013. “The Hockey Stick: The Most Controversial Chart in Science, Explained.” The Atlantic. Available at: https://www.theatlantic.com/technology/archive/2013/05/the-hockey-stick-the-most-controversial-chart-in-science-explained/275753/. Accessed February 17, 2020.

NASA 2020. “Global Climate Change: Vital Signs of the Planet.” Available at https://climate.nasa.gov/evidence/. Accessed March 24, 2020.

NOAA 2020a. “Data Tools: 1981–2010 Normals.” National Oceanic Atmospheric Administration, National Centers for Environmental Information. Available at: https://www.ncdc.noaa.gov/cdo-web/datatools/normals. Accessed February 3, 2020.

NOAA 2020b. “The Climate Explorer.” National Oceanic Atmospheric Administration. Available at: https://crt-climate-explorer.nemac.org/. Accessed February 24, 2020.

U.S. Environmental Protection Agency. August 2016. “Climate Change Indicators: Length of Growing Season.” Available at: https://www.epa.gov/climate-indicators/climate-change-indicators-length-growing-season. Accessed March 24, 2020.

U.S. Global Change Research Program, 2017. “The National Global Change Research Plan 2012–2021: A Triennial Update.” Washington, DC. Available at: https://www.globalchange.gov/browse/reports/national-global-change-research-plan-2012-2021-triennial-update. Accessed February 17, 2020.