Technical Memorandum

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Cc:	Andrew Staples, PE (HDR)
Date:	3/3/2023
Subject:	Spokane Future Flows – Climate Assessment

1.0 Introduction

The City of Spokane (City) will be updating its Water System Plan (WSP) and developing its Link Spokane strategy for integrating transportation and utility infrastructure planning. As a foundational component of these long-range planning efforts, the City is updating its water demand and sewer flow forecasts.

This technical memorandum (TM) assesses the potential future impacts of climate change on water demand. This includes:

- Analysis of historic climate trends
- Evaluation of projected climate trends
- Correlation of climate factors to water demand

This effort is focused solely on the impacts of climate change upon water demand. It does not address questions related to potential impacts upon supply availability (e.g., impacts to groundwater recharge and subsequently to water availability). Supply-related impacts are being examined by the City through a separate, parallel effort to be conducted in 2023.

The results of the analyses presented in this TM will inform the range of water demand forecasts presented in subsequent deliverables of the Spokane Future Flows project, and may also be used in combination with the above-mentioned supply-related analysis to develop a more complete understanding of the range of potential impacts that climate change may impart upon the water utility.

2.0 Background

Cities, agencies, communities, businesses, and individuals are facing new and intensifying challenges from extreme weather events, increasing air temperatures, and increased precipitation variability as a result of climate change. The City of Spokane (City) has chosen to be proactive in response to these changes as part of their strategic planning. This step-by-step analysis utilizes historic climate trends to set the baseline for understanding projected future climate trends in air temperatures and precipitation so that the City's risk/vulnerabilities related to water demand can be correlated to those that are anticipated to change at future time scales due to climate change.

There is significant concern within the water management industry regarding changes in precipitation variability and intensity; however, it is very likely that increasing air temperatures are going to cause a greater impact to water resources than changes in precipitation. For example, a recent study (Udall, 2017) found that for every 1ºF increase in Colorado River Basin average annual air temperature, there was a four percent decrease in Colorado River flows. This statistic is, of course, tied just as much to water demand as it is to the parameters of evaporation and evapotranspiration. Whether it will be watering lawns, fields, gardens, or supplying drinking fountains, as the temperature increases so will the demand for water resources.

3.0 Climate Analysis Data Sources

Climate trend data sources are described below.

3.1 Historic Climate Trends

Historic climate trends are critical to setting a relationship between observed changes in the historical climate and projected changes in the future climate. They represent the current state of our changing climate and how that change has occurred over time in the observed record. This section investigates current climate trends, as well as their extrapolations into the future so that those extrapolations can be compared with future climate scenarios.

The National Climatic Data Center (NCDC) was the primary source for historic meteorological reporting data for this analysis. The weather reporting station at Spokane International Airport, identified in Figure 1, was the primary source for climatological data and presents a representation of the City as a whole. This station is located approximately four miles west southwest of the city center. It has a period-of-record (POR) that extends from August 1, 1889, to present. The POR of 1950-2021 was utilized for this analysis due to the availability of the most consistent dataset during this time period.

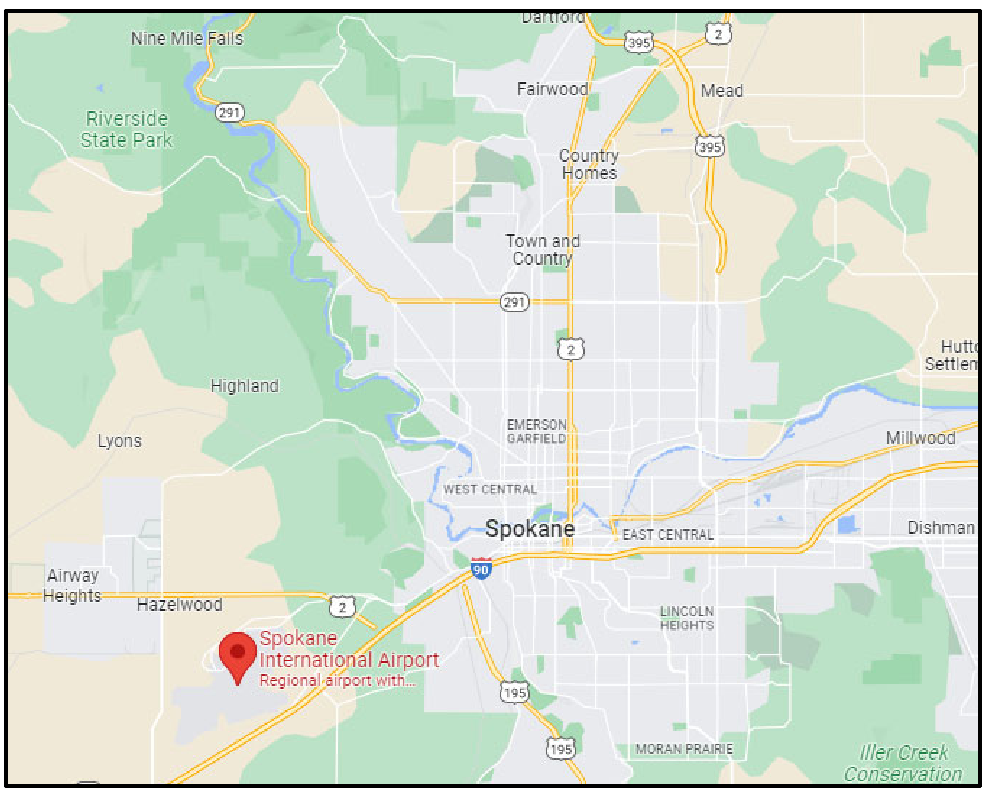

Figure 1. Map of meteorological reporting station used for the development of the historic climate data and climate trends.

3.2 Projected Climate Trends

Climate change projections are outputs from global climate models that utilize future climate scenarios (climate forcing) to quantify future changes in atmospheric parameters. Changes in air temperatures and precipitation may result in consequential changes in other water-related parameters such as evaporation and evapotranspiration. The emission of greenhouse gases (GHG) from human activity is expected to be largely responsible for the magnitude of climate change through the end of this century. To develop a range of potential climate change outcomes, this study utilized two future GHG emissions scenarios, or Representative Concentration Pathways (RCP), to provide a perspective on future change. RCP 4.5 represents a future where GHG emissions continue to increase until the year 2050, and then begin decreasing through the year 2100. In this scenario, it takes until the year 2070 before that decrease in emissions after 2050 begins to reverse the climate trend. RCP 8.5 represents a future where emissions continue to accelerate through the year 2100. RCP 4.5 is considered the middle-of-the-road case, while RCP 8.5 represents the highest level of future emissions.

The following sections provide analysis and projections of changes in atmospheric conditions that are expected to have an impact on water availability, as well as on water demand for the City. Climate modeling and regional downscaling at future time scales were developed as part of the work performed for the Coupled Model Intercomparison Project Phase 5 (CMIP5) and using the Localized Constructed Analogs method (LOCA; Pierce et al. 2014). These climate projections were based on the Intergovernmental Panel on Climate Change Assessment Report 5 (IPCC, 2014).

4.0 Air Temperature Trends

Increasing air temperatures are anticipated to be an outcome of climate change on a global scale, throughout the United States, and the City. These increasing air temperatures are expected to have an impact on water supply and demand.

4.1 Observed Air Temperature Trends

Figure 2 identifies the observed trend showing overall increases in average annual maximum temperature for the City (the average of every daily maximum temperature) while Figure 3 shows the change in average annual minimum temperatures for Spokane during the POR 1950-2021. This same pattern regularly shows up in the analysis of average annual air temperatures across North America. It is a trend that is usually particularly pronounced as it pertains to nighttime minimum temperatures.

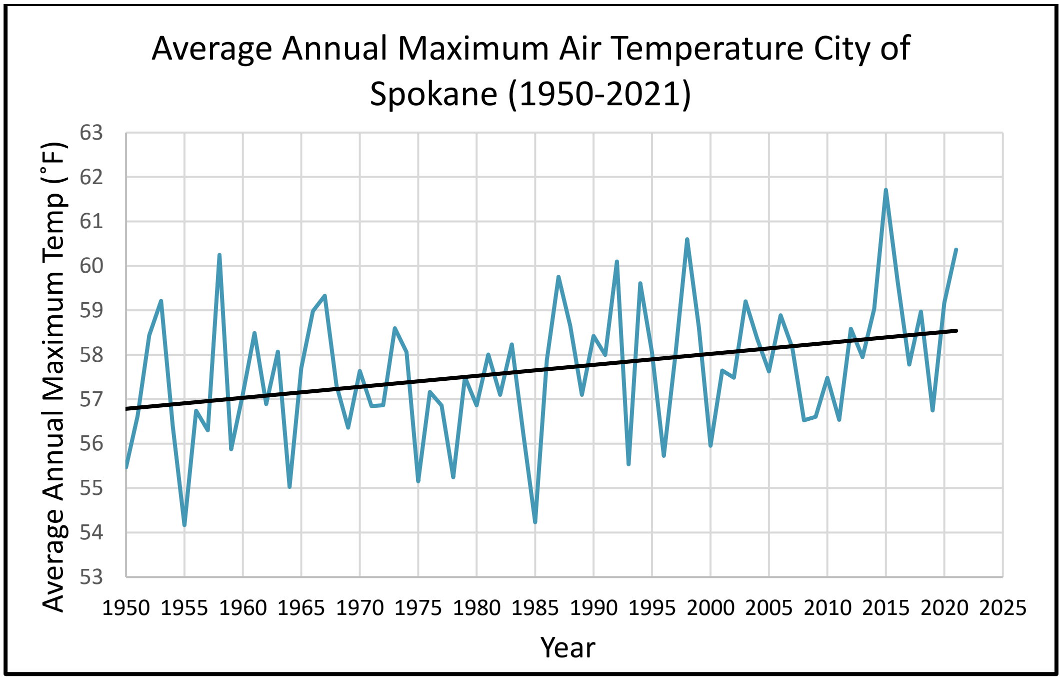

Figure 2. Observed average annual maximum air temperatures (ºF) for Spokane 1950-2021. Trendline in black. Source Data: National Climatic Data Center (NCDC)

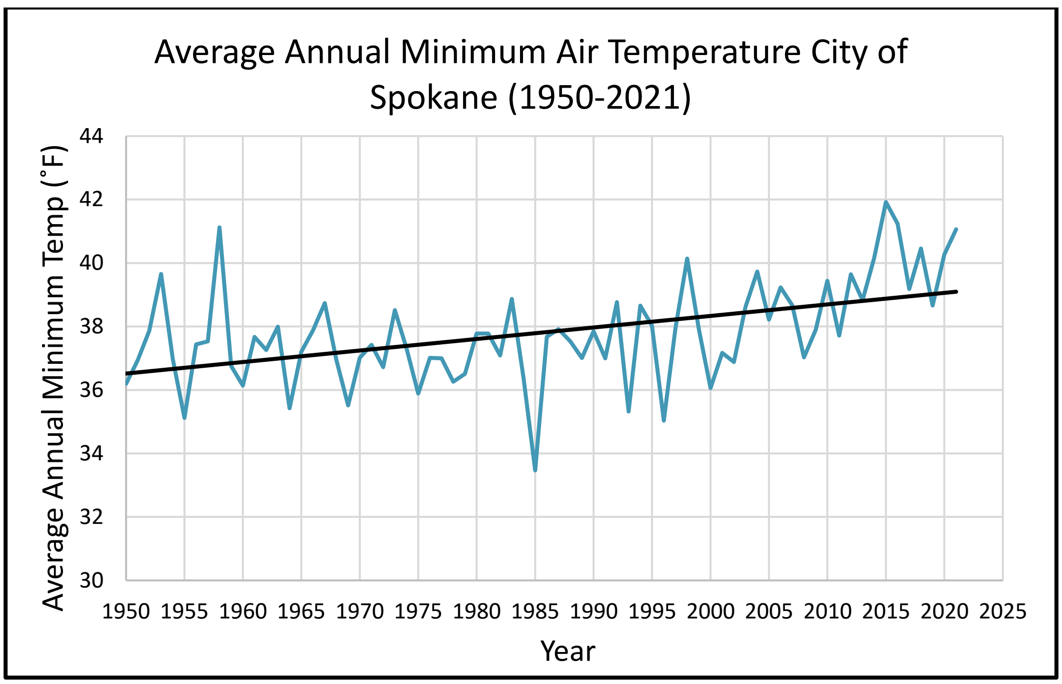

Figure 3. Observed annual mean minimum air temperatures (ºF) for Spokane 1950-2021. Trendline in black. Source Data: NCDC

Figure 2 and Figure 3 show increasing trends in annual average temperatures. These trends provide the opportunity to better understand the point and/or inflection in these graphs where the climate of the City began to warm at a higher rate. As seen elsewhere in North America and on a global scale, significantly higher rates of annual warming began around the year 1977.

Figure 4 and Figure 5 show extrapolations of maximum and minimum temperature trends out to 2050 based on these trendlines. An extrapolation of the observed maximum and minimum temperature trends beginning in the year 1950, indicated by the black trendline, forecast an average annual maximum temperature of 59.2ºF and an average annual minimum temperature of 40.2 ºF by the year 2050. Based only on the observed data from 1977-2021, these same extrapolations, indicated by the red trendline, forecast an average annual maximum temperature of 60.1ºF by 2050, and an average annual minimum temperature of 42.4ºF. While climate projections generally indicate a much greater potential for increased warming, these extrapolations of historical data provide a baseline for projected change that have a high likelihood of occurring.

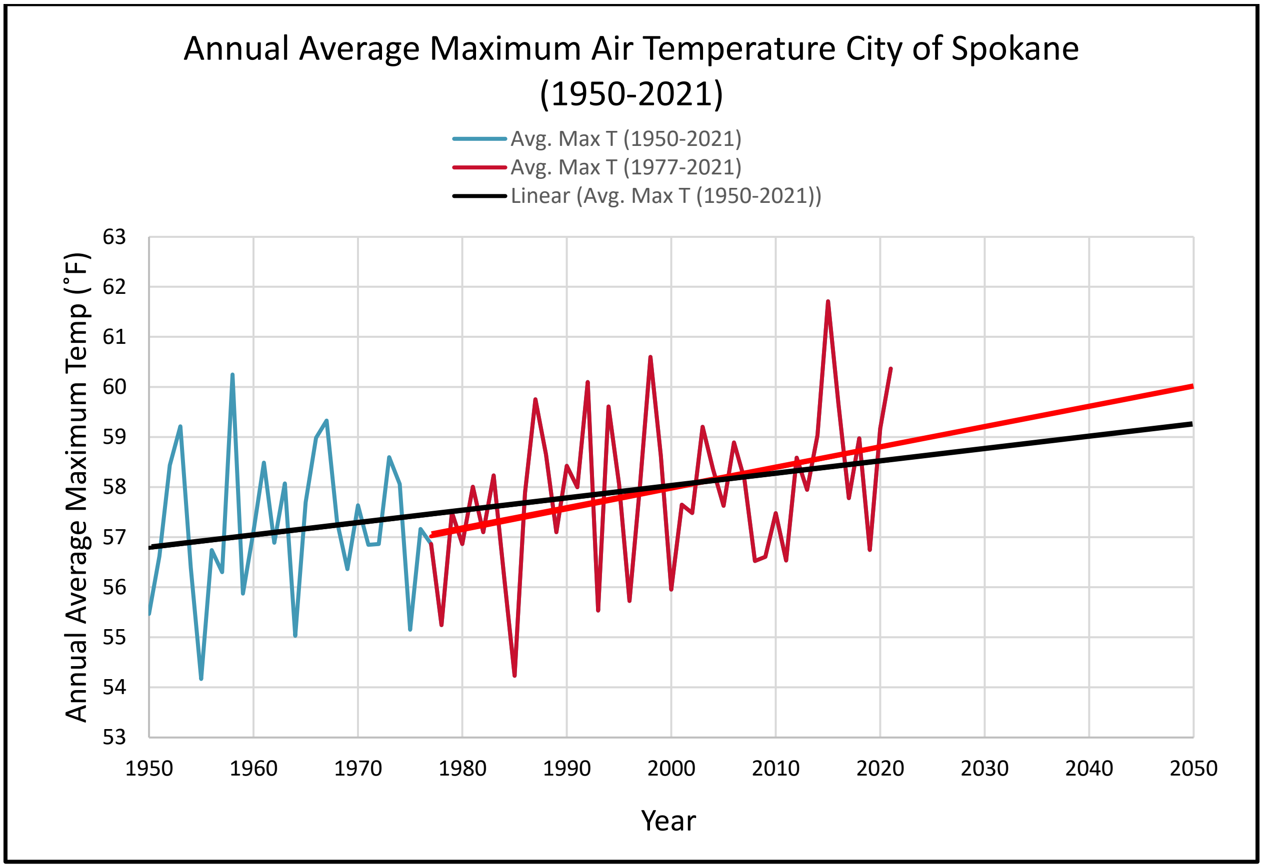

Figure 4. City of Spokane annual average maximum air temperature trends for 1950-2021 (black line) and 1977-2021 (red line), extrapolated to the year 2050. Source Data: NCDC

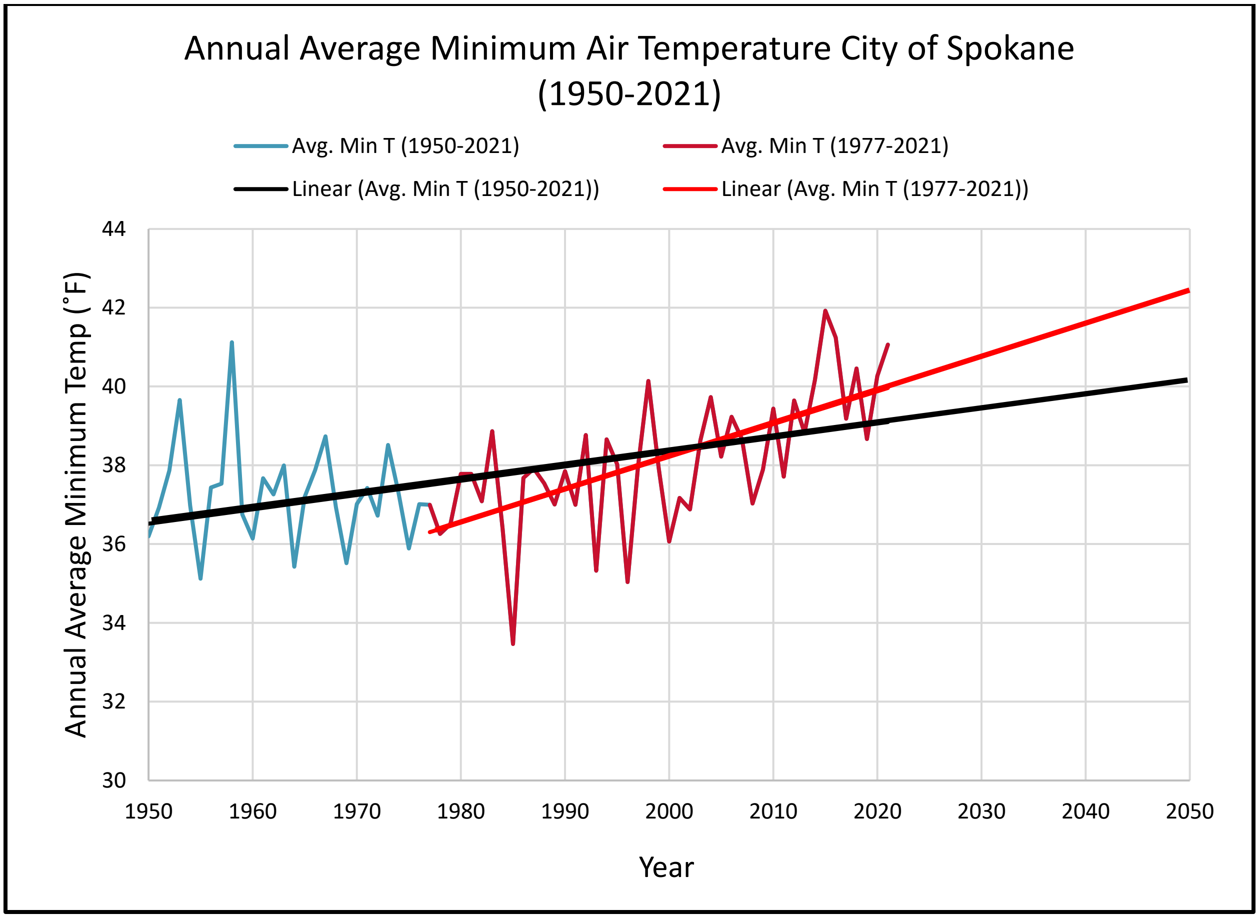

Figure 5. City of Spokane annual average minimum air temperature trends for 1950-2021 (black line) and 1977-2021 (red line) extrapolated to the year 2050. Source Data: NCDC

4.2 Projected Air Temperature Trends

The downscaled climate data provided by the CMIP5 data, specific to the City, were used to quantify expected changes in air temperatures at future time scales. The recent release of IPCC Assessment Report 6 (AR6) (IPCC, 2021) indicates that these projections may be less conservative than those reported in AR5, which used CMIP5 modeling results. However, IPCC AR6 data were unavailable at the time of this writing.

Figure 6 shows the projected average annual maximum air temperatures expected in the City for the years 2020-2099 based on the RCP 4.5 (blue) and RCP 8.5 (red) climate scenarios, based on the IPCC AR5 CMIP5 downscaled projections. Figure 6 shows a significant difference in the outcomes from the two climate scenarios past the year 2050. The projected air temperatures represented in Figure 6 are weighted mean values. A considerable range of possible outcomes exists above and below these mean values.

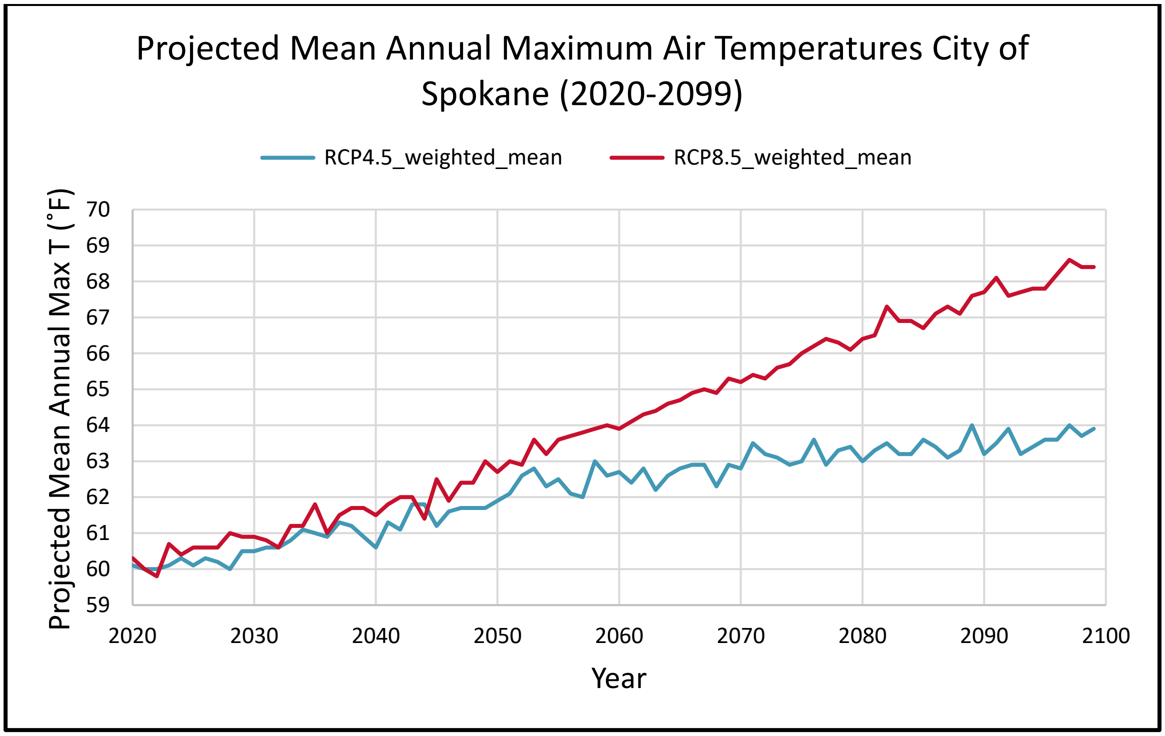

Figure 6. Projected mean annual maximum air temperatures for Spokane based on RCP 4.5 and RCP 8.5 climate scenarios. Source Data: CMIP5

4.3 Relationship of Maximum Air Temperatures to Water Pumping in Spokane

As noted in this Section 3.1, observed air temperature trends indicate that air temperatures in the City are increasing, particularly during the most recent 35 years. While there are many factors that contribute to increased pumping during a given month, such as amount of precipitation, cloud cover, increasing population conservation habits, and land use, this study examined the relationship between June-September daily average pumping per month and observed changes in monthly average maximum air temperatures during these months during the available POR 1994-2021 for pumping data (four months a year times 27 years equals 108 points of comparison).

Figure 7 shows the correlation between June-September monthly average maximum air temperatures and daily average pumping per month values for the City. While the correlation is not exacting (R^2=0.40), it does show a useable trend wherein months with higher average air temperatures generally indicate increased pumping. There are several outliers in June pumping (very high volume), which could be attributable to many causes, but have not been specifically identified at this time.

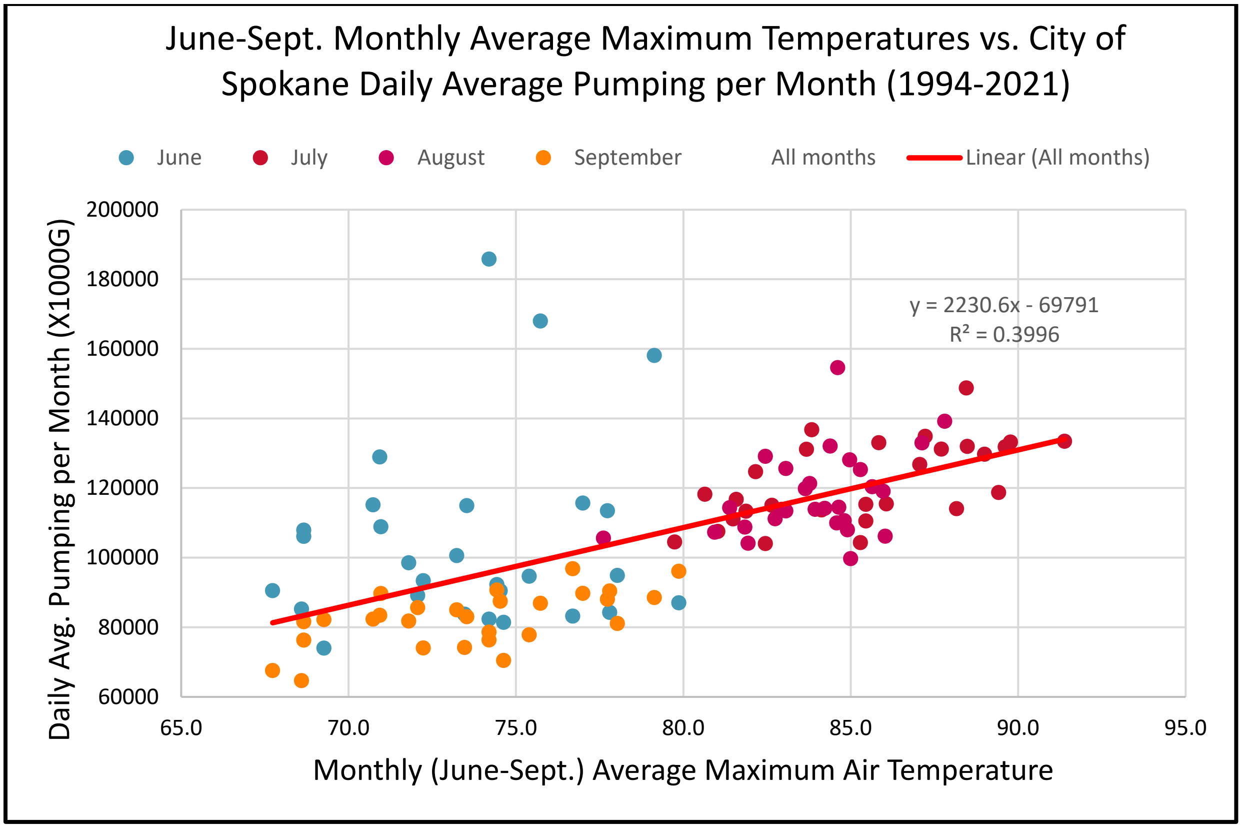

Figure 7. June-Sept. daily average pumping (thousands of gallons) per month as a function of monthly average maximum air temperature for the City of Spokane 1994-2021. Trendline shown in black.

Based on the historic correlation between monthly average maximum air temperatures (June-Sept.) and daily average pumping per month in Figure 7, and the percentage change between the current (2020) mean annual maximum temperature (60.1˚F) and projected mean annual maximum air temperatures projected in Figure 6, approximate percent changes in future pumping can be determined. Table 1 identifies the percent change in daily average pumping (June-Sept.) based on projected changes in annual maximum air temperatures.

Table 1. Relative percentage change in June-Sept. daily pumping based on changes in air temperatures at future time scales for two climate (emissions) scenarios.

	RCP 4.5			RCP 8.5		
Future Year	2050	2075	2100	2050	2075	2100
Increase in Mean Annual Max T (˚F)	1.8	2.9	3.8	2.4	5.7	8.1
Average Percent Pumping Change	3.00%	4.83%	6.32%	3.99%	9.45%	13.43%

5.0 Observed Annual Precipitation Trend

As the annual average air temperatures increase, as noted in the previous section, so does the atmosphere's ability to hold and release moisture. This is physically related to the Clausius-Clapeyron equation wherein as air temperatures increase, the atmosphere's ability to hold moisture increases approximately 3.5 percent per degree F of annual mean temperature.

5.1 Observed Precipitation Trends

Using Figure 4 and Figure 5, it was determined that the mean annual air temperature in the City has increased 2.16˚F between the years 1950-2021. Figure 8 shows the observed annual precipitation trend in the City during those same years. The precipitation trend in Figure 8 represents a 6.90 percent increase in annual precipitation during the years 1950-2021. Applying the Clausius-Clapeyron relationship to the 2.16˚F increase in mean annual air temperature indicates that a 7.56 percent increase would have been expected in annual precipitation.

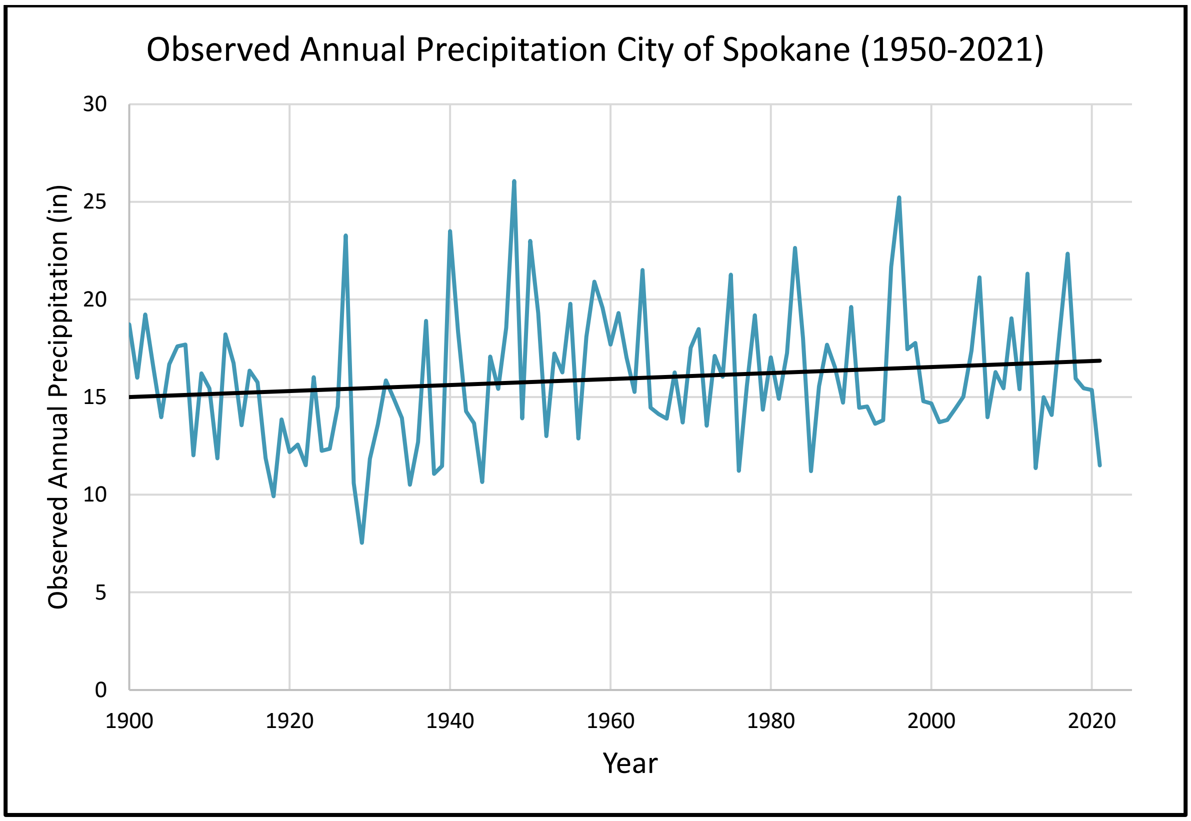

Figure 8. Observed annual total precipitation (1950-2021) for the City of Spokane. Trendline shown in black.

5.2 Projected Precipitation Trends

Projected trends in annual precipitation (Figure 9) for the City of Spokane are in-line with the observed trend in annual precipitation as seen in Figure 8. The projected trend in annual precipitation under both emission scenarios clearly indicate the impact of increasing air temperatures on anticipated increases in annual precipitation. While these projections of future annual precipitation resemble an extension of the long-term observed trend in annual precipitation, there is still significant year-over-year variability showing in these projections that should make for increasing demand in dry years and reduced demand in wet years.

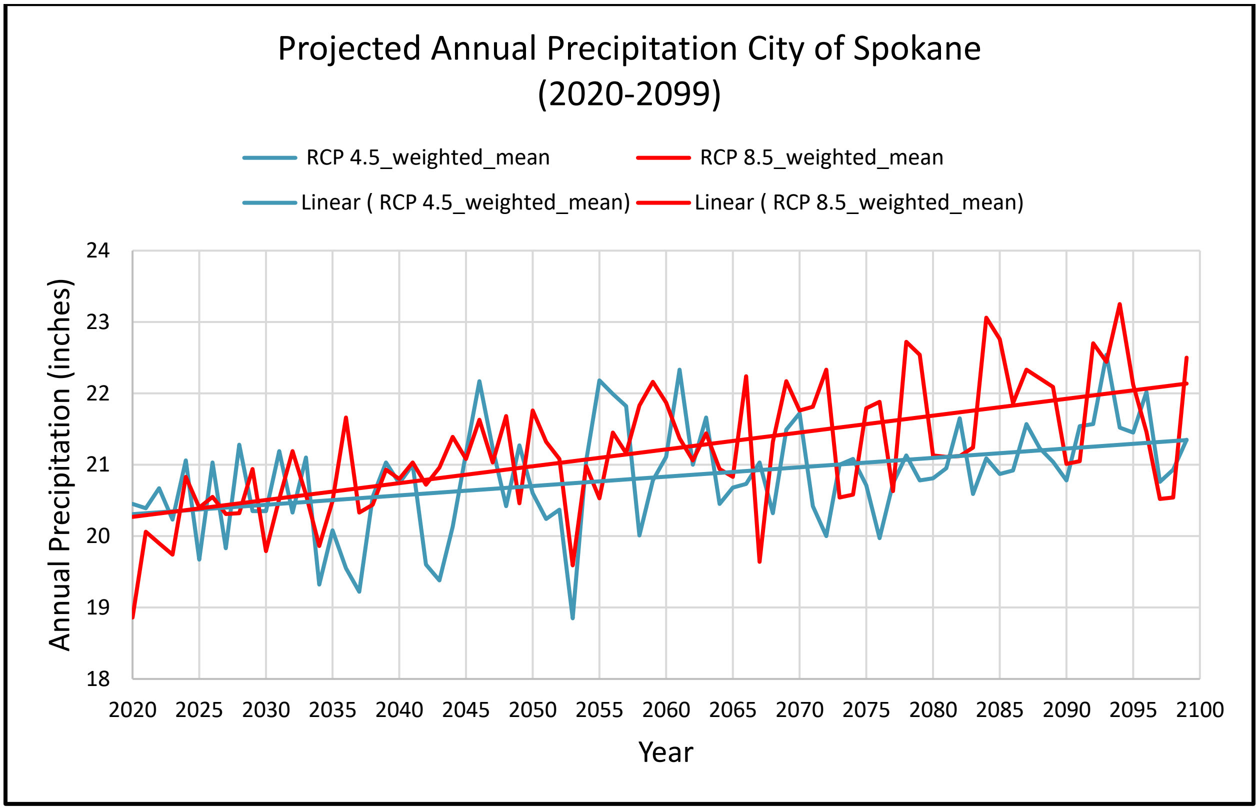

Figure 9. Projected annual precipitation based on RCP 4.5 and 8.5 scenarios. RCP 4.5 trendline shown in blue, RCP 8.5 trendline shown in red.

6.0 Conclusion

As has been found in many other climate studies in the western U.S., increasing air temperatures are expected to have a much greater impact on water supplies and water management than changes in year-over-year precipitation variability. The analysis performed within this study corroborates these findings. As air temperatures increase, demand will likely increase, and therefore pumping is expected to increase. Yet, as air temperatures increase, annual precipitation is also expected to increase. The largest unknown is whether the increase in precipitation and water availability in Spokane will be enough to counteract the impact of increased air temperatures on water demand. Using the year 2050 as an example, based on these study data, Spokane can expect a three to four percent increase in pumping between now and 2050, solely based on increasing air temperatures (see Table 1). During this same time period, annual precipitation is expected to increase two to three percent under the respective climate scenarios (RCP 4.5 and 8.5). Additionally, the seasonality of future precipitation in the region should play a big role in water management and water demand. This would be a consequence of warmer, drier summers and wetter winter/cool season precipitation, which is expected to be a result of climate change in the region. Such relationships could be used by the City in future examination of water supply availability.

For the current purpose of informing the City's future flows evaluation, the relationship between air temperature and water demand has been used to define future water usage scenarios that incorporate the influence of climate change. Moderate and more aggressive levels of climate change impact have been defined as imparting a three and four percent increase in water demand by 2050, respectively. These factors are taken into account along with other variables, such as various levels of water conservation implementation and demographic growth, to develop a range of future water demand projections. The results of that analysis will be presented in a subsequent document that will compile all of the related project elements into one reference.

7.0 References

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