TRENDS IN TEMPERATURE, PRECIPITATION AND STREAM RUNOFF IN THE SAN JUAN MOUNTAINS: 2000 – 2021

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and

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Dedication

This paper is dedicated to the memory of John Porter: friend, mentor and father-in-law.

From the time John took over as General Manager of the Dolores Water Conservancy District in 1980, he was on the cutting edge of access to, and analysis of, emerging snow and stream measurement technologies.

John's rigorous use of all available data sources as a water manager was extended to his service as a leader on multiple governing boards including the Southwest Water Conservation Board, Colorado Water Congress, Colorado Water Resources and Power Development Authority, Colorado Water Trust, Southwest Basin Roundtable, Colorado River Water Users Association, Empire Electric Coop and Water Education Colorado; many of which John Chaired.

What made John such a strong leader was a combination of his remarkable interpersonal skills and his disciplined approach to organizing data and facts to help him and his associates make good decisions. People trusted John as a person, and they trusted the depth of his factual knowledge.

John received many awards including the Wayne Aspinall Water Leader of the Year Award from Water Congress in 2000 and the Diane Hoppe Leadership Award from Water Education Colorado in 2021, to mention a few.

John would have embraced this paper, added value to it, interpreted it and shared it with the water leaders that looked to him to provide a factual foundation to the complex water and watershed issues that we continue to face.

Can It Really Be This Dry?

This paper was inspired by an excursion to the alpine tundra of the Animas River watershed during a protracted heat wave in mid-June 2021. At an elevation of nearly 13,000 feet, there was very little snow, parched soils and dry vegetation. These conditions are not "typical" for the San Juan Mountains in June or really any other month. However, they have become more and more commonplace over the past 20+ years.

As I stood there overlooking the Needle Mountains contemplating the dryness that surrounded me, I tried to recall the San Juans of the 1980's and 1990's. The San Juans of my younger years were known for their lushness. A time when summer rains were so abundant, they were almost annoying. Good luck getting the campfire going. Or winters with snow of such depth that the structural integrity of any building was at risk. Shovel the roof and then go to work. Autumns of cool, crisp days with golden aspens framing a clear blue sky and snow white mountain peaks. And of course, there was the spring runoff that pretty much delivered other than the periodic dry year.

As the heat of the day came on, it was difficult for me to conjure these memories. I knew that circumstances were different. In fact, very different. But I didn't know how other than it is much drier. So, with a combination of curiosity and concern, I began to contemplate how these changes might be measured. The following paper is a summary of the resulting research which was undertaken in an attempt to gain a greater understanding of the changes in temperature, precipitation and stream runoff that have occurred in the San Juans during the 21st century. Michael Preston and I have prepared this paper as a contribution to general knowledge in the spirit of "citizen science".

John Norton
Retired Land and Water Appraiser

San Juan Mountains: Temperature, Precipitation and Stream Runoff

"Just the Facts"

The following paper is an important fact-based contribution to understanding the impacts that the drought period beginning in 2000 has had on the river basins that flow out of the San Juan Mountains. During my 12 years as Manager of the Dolores Water Conservancy District (DWCD), beginning in 2007, we pieced together historic SNOTEL, stream gage and temperature data in an attempt interpret present conditions and prepare for the future. As Chairman of the Southwest Basin Roundtable, during the same period, I saw other Roundtable members grappling with similar analytical challenges, in their home basins from a variety of perspectives including water management, forest health, water related ecology and water-based recreation.

As we were all trying to organize and analyze hydrologic facts in our home basins, we began to collectively realize that significant trends were developing that were affecting all river basins emanating from the San Juan Mountains. Recent studies have concluded that the period from 2000 to 2021 is the driest period in the Colorado River Basin in 1200 years. We saw dramatic local instances of the onset of this period including record low precipitation in 2002 and the resulting Missionary Ridge Fire which burned over four drainages, damaging water infrastructure and triggering mudslides, during runoff and rain events, for years to come. We all hoped that these events were anomalies, but we now know that the pattern of drought and wildfire intensified over the next 20 years in the river basins of the San Juan Mountains.

One question that many of us have been pondering, as the drought has continued to deepen is: How much have the variables of temperature, precipitation and stream flow changed, since the onset of the current drought beginning in 2000? We have "stories" about painful drought related events in our home basins, and a desire to relate these stories to hard facts in order to understand and deal with the challenges that are currently unfolding in the river basins of San Juan Mountains.

When John Norton shared with me his factual analysis of the hydrologic changes since 2000 and invited me to add my perspective as a water manager and forest health advocate, I embraced the opportunity to be part of this paper.

The focus of the paper is on the historic facts concerning changes in temperature, precipitation, and stream runoff from 2000 to 2021 in the San Juan Mountains. Primary data sources are 23 SNOTEL sites and 18 stream gages addressing the San Juan, Dolores, Gunnison and Rio Grande river basins.

This paper is intended as a tool to address basin level trends while providing easy access to facts that will help us analyze past episodes of the drought saga in our home basins in order to shape the unfolding of current and future episodes. This paper and its appendices use the period from 1990 to 1999 to establish baseline averages to measure the changes from 2000 forward.

In the hydrologic cycle that characterizes the San Juan Mountains, timing matters. This paper and appendices look at the variables of temperature and precipitation across the entire period from 2000-2021 annually, monthly and by season. Stream flow data is presented by year to demonstrate annual hydrologic yields that resulted from the variables of temperature, precipitation and timing in any given year.

Water managers get questions throughout the winter about current snowpack conditions and the prospects for a good water supply when the snowpack melts and runs off. During my tenure as Manager of DWCD my consistent answer was: “If we are going to have a good water year, we need good snow-pack by Christmas and the early part of January just to get by. If we get significant precipitation in late-January, February or March, an adequate water year will become a good water year.” My gut feel, as a water manager is validated in Appendix B which shows an increase of precipitation in December of +45% between 2000 and 2021, against the 1990s baseline, while January and February each decreased by -6%, March decreased by -28% and April decreased by -52%.

This is one of many examples of how I applied the data in this paper to check my experienced-based assumptions and the utility of John’s analytical approach. The data in this paper is organized to provide easy access to temperature, precipitation, and river flow data, so others can fact check their assumptions about the past episodes and frame their strategic assessments concerning current and future conditions on a macro or river basin level.

This paper does not interpret or model any of the data. All the data comes from the SNOTELs and river gauges in use for the entire 10-year 1990s baseline and the drought period from 2000 to 2021. The analysis uses familiar metrics such as degrees Fahrenheit, water inches of precipitation and acre feet of stream run-off. All forms of interpretation and modeling are up to the users of the data in this paper.

In this era of collaboration, inclusion and transparency, the purpose of this paper is to provide a common, reliable set of facts that can be easily accessed, analyzed and organized to meet the needs of the institutions, collaborative groups and individuals that will help shape our water and watershed future.

Michael Preston
Retired General Manager, Dolores Water Conservancy District
Former Chair, Southwest Basin Roundtable

Currently:
Ute Mountain Ute Tribe: Water Consultant; President, Weenuch-u’ Development Corp. Board
Coordinating Committee, Dolores Watershed Resilient Forests (DWRF) Collaborative
Steering Committee, SW Rocky Mountain Restoration Initiative (RMRI)

Summary

- During the time period 2000 thru 2021, average annual temperature in the San Juan Mountains has increased by +3.6 ºF while average annual precipitation has decreased by -7.0 inches or -19.0%.

- The fall season has experienced the greatest average annual temperature increase (+4.1 ºF) while the winter season exhibited the least (+3.2 ºF). Average annual precipitation increased during the winter season by +0.7 inches or +7.5% while decreasing significantly during the spring, summer and fall seasons with declines ranging from -1.9 to -3.1 inches or -24.7% to -30.1%.

- Combined annual stream runoff from 18 principal rivers/creeks emanating from the San Juan Mountains has decreased from 4,031,185 to 2,946,123 acre feet; a decline of -1,085,063 acre feet or -26.9%. The magnitude of this decrease varies by river basin: San Juan (-34.1%); Dolores (-29.2%); Gunnison (-14.5%); Rio Grande (-20.6%).

- Stream runoff relative to precipitation has a degree of variability when compared on an annual basis. A given amount of precipitation does not always generate the anticipated quantity of stream runoff. However, when viewed over a longer time frame, the variability in stream runoff relative to precipitation is reduced significantly.

Introduction

Beginning in the year 2000, the Colorado River Basin, as well as much of the Western United States, entered into an extended period of reduced precipitation combined with a long term rise in temperature; a trend that has continued through the past year. The San Juan Mountains, located in Southwest Colorado and Northern New Mexico, have experienced the same trends in temperature and precipitation. Given that these mountains provide the source of stream runoff for the San Juan, Dolores, Gunnison and Rio Grande river basins, an understanding of what changes have occurred to temperature, precipitation and stream runoff is important.

The purpose of this paper is to document changes to temperature, precipitation and stream runoff in the San Juan Mountains that have occurred for the years 2000 thru 2021. To accomplish this task, a ten year baseline from 1990 thru 1999 was established against which all changes have been measured. This decade was selected as it is the last full 10 year period prior to the decline in precipitation for the broader region that began in the year 2000. However, precipitation records indicate that for the San Juan Mountains the cycle of relative dryness began as early as 1998. A fixed baseline will provide the basis to measure changes that have already occurred in the 21st century as well as future increases and/or decreases.

This paper presents a simple statistical analysis of historical trends in temperature, precipitation and stream runoff in the San Juan Mountains relative to the 1990-99 baseline period. It is not a sophisticated hydrologic or climate model that attempts to explain the causal reasons for these trends. Nor does it attempt to make projections or predictions about future trends. Rather, its purpose is to hopefully facilitate a clearer understanding of what has occurred in the San Juan Mountains during the 21st century in terms of changes in temperature, precipitation and stream runoff. To this end, it relies on basic summation, average, moving average and regression statistical analysis.

The analysis utilizes temperature and precipitation information recorded by the Natural Resource Conservation Service's (NRCS) Snowpack Telemetry (SNOTEL) system. There are presently 34 SNOTEL climate sites in the San Juan Mountains. As of January 1, 1990, 23 of these sites had been constructed and were collecting both temperature and precipitation data. Climate data from these same 23 sites have been used throughout this analysis. The other 11 sites were constructed after January 1, 1990 with climate information collected after that time. As such, data from these 11 sites has not been incorporated into this research.

The analysis also relies on stream runoff information maintained by the Colorado Water Conservation Board (CWCB) and Colorado Division of Water Resources (DWR). Data from a total of 18 stream gauges are used in the analysis. These gauges are operated either by the U.S. Geological Survey (USGS) or the DWR with 16 gauges located in Colorado and two in New Mexico.

This paper quantifies annual temperature, precipitation and stream runoff on a calendar year basis. The 1990-99 baseline is a ten year fixed average. A running ten year average begins with the 1991-00 period and ascends accordingly for a total of 22 separate ten year periods. References to current or present conditions are referring to the most recent 2012-21 period. Seasons described in the paper are based on meteorological seasons. Temperature is measured in degrees Fahrenheit (ºF), precipitation in inches and elevation in feet. Both temperature and precipitation averages/totals are rounded to the nearest tenth as are percentages. Annual stream runoff is expressed in acre feet rounded to the nearest acre foot.

Temperature

Since the 1990-99 baseline period, average annual temperature in the San Juan Mountains, as recorded by the NRCS SNOTEL network of climate sites, has increased from 35.7 ºF to 39.2 ºF equating to a +3.6 ºF overall increase. All 23 SNOTEL sites registered temperature increases for this time period ranging from +2.4 ºF to +5.5 ºF. Similarly, all 12 months experienced temperature increases with the greatest occurring in June (+5.5 ºF) and November (+5.3 ºF) while the least was February (+1.7 ºF). See **Appendix A, B & F**.

Precipitation

Average annual precipitation in the San Juan Mountains has decreased since the 1990-99 baseline period from 36.9 to 29.9 inches which is a decline in average annual precipitation of -7.0 inches or -19.0%. All 23 SNOTEL sites recorded average annual precipitation declines. These declines range from -2.3 to -12.8 inches or -8.9% to -29.8%. Three of the 12 months experienced increases in average annual precipitation with December displaying by far the greatest change with an increase of +1.1 inches or +45.4%. The remaining nine months all registered declines in average annual precipitation. While precipitation declines were significant in March, June, August, September, October and November, the month of April demonstrated the largest decline in precipitation of -2.0 inches or -52.4%. See **Appendix A, B & F**.

Seasons

Relative to the 1990-99 baseline period, all four seasons experienced increases in average temperature. While the winter season benefited from an increase in precipitation, the spring, summer and fall seasons all had significant declines. The result is that the winter season increased proportionately from 25.6% to 33.9% of total annual precipitation while the combined spring, summer and fall seasons declined from 74.5% to 66.0% of total annual precipitation. See **Appendix C**.

Winter: The combined months of December, January and February had an increase in average temperature of +3.2 ºF. Average precipitation increased by +0.7 inches or +7.5%. This increase was due entirely to the month of December which increased by +1.1 inches versus declines in January and February of -0.2 inches respectively.

Spring: Average temperature in combined March, April and May increased by +3.3 ºF while average precipitation declined by -3.1 inches or -30.1%. The decline in precipitation was concentrated in March (-1.1 inches or -27.9%) and April (-2.0 inches or -52.4%). May experienced essentially no change in precipitation.

Summer: Combined June, July and August had a +3.8 ºF average temperature increase. This temperature increase was greatest in the month of June (+5.5 ºF). Average precipitation decreased by -1.9 inches or -24.7%. While July demonstrated a small increase in precipitation (+0.2 inches or +6.6%), declines occurred in June (-0.6 inches or -43.4%) and August (-1.4 inches or -39.0%).

Fall: With an average temperature increase of +4.1 ºF, the combined fall months of September, October and November have the greatest increase in temperature of all four seasons. November stands out with an increase of +5.3 ºF. Average precipitation declined by -2.7 inches or -28.6%. Precipitation declines were displayed in all three months: September (-0.5 inches or -16.0%), October (-1.2 inches or -39.3%) and November (-1.1 inches or -29.2%)

Stream Runoff

Stream runoff has been measured via gauges on 18 principal rivers/creeks emanating from the San Juan Mountains. These streams flow into one of four river basins: San Juan, Dolores, Gunnison and Rio Grande. No attempt has been made to correct for reservoir storage or depletions upstream of the gauges and therefore the amounts reported are not "natural flows". See **Appendix D**.

As compared to the 1990-99 baseline period, all 18 gauges recorded declines in stream runoff. Overall, the combined stream runoff from the San Juan Mountains has decreased from 4,031,185 to 2,946,123 acre feet; a decline -1,085,063 acre feet or -26.9%. All four river basins have experienced reductions. However, these reductions have not been uniform with the San Juan decreasing by -34.1%, the Dolores by -29.2%, the Gunnison by -14.5% and the Rio Grande by -20.6%. The greatest decreases in stream flow are concentrated along the south-southwest front of the San Juan Mountains with the north-northeast front experiencing declines of less severity.

Stream Runoff vs Precipitation

In the San Juan Mountains, the amount of stream runoff relative to precipitation has a degree of variability when viewed on a yearly basis. An individual year of substantial precipitation does not necessarily correlate to a year of substantial stream runoff. Multiple factors are involved including the timing of precipitation during the year, i.e., does it accumulate as snow or rain, temperature, soil moisture, the amount of precipitation during the previous Oct, Nov, Dec (start of the water year), wind, and dust on snow conditions to name a representative few. Exceedingly low precipitation years such as 2002, 2012, 2018 and 2020 appear to have uniformly resulted in reduced stream runoff. See **Appendix E**.

However, when viewed through a longer time frame, the variability in stream runoff relative to precipitation is significantly reduced. Comparing the 1990-99 baseline period to ten year moving averages for both stream runoff and precipitation, it becomes apparent that there is a fairly direct relationship between the two. Whether by the visual comparison of the ten year moving averages for stream runoff and precipitation or by plotting an independent variable (precipitation) against a dependent variable (stream runoff) in a simple regression analysis, it appears that over the long run there is a relatively close correlation between stream runoff and precipitation.

Data & Method

This study utilizes temperature, precipitation and stream runoff information for the 32 years from 1990 thru 2021. Temperature and precipitation is based on both monthly and annual statistics while stream runoff utilizes annual statistics only. There are 9,467 data points for temperature with 101 data points missing from the record; about 1% of total possible.

Precipitation is based on 9,568 data points with none missing. Annual stream runoff utilizes 576 data points also with none missing.

Microsoft Excel is the software used for data retention and statistical analysis. The 19,611 data points were downloaded from their source, retained, distributed across 189 separate spreadsheets and then analyzed to derive the reported results. This paper represents a summary of the total analysis.

Sources

Applied Climate Information System (SC-ACIS), National Oceanic and Atmospheric Administration (NOAA) Regional Climate Centers, Climate Data, available at http://scacis.rcc-acis.org/, last accessed March 1, 2022.

Colorado's Decision Support Systems (CDSS), Colorado Water Conservation Board and Colorado Division of Water Resources, Stations – Current and Historical, available at https://dwr.state.co.us/Tools/Stations?Stations=All, last accessed March 1, 2022.

Authors

John Norton is a retired land and water appraiser who specialized in the valuation of complex properties. For most of his 36 year appraisal career, of which 27 years were in Southwest Colorado, he focused on the appraisal of conservation easements protecting agricultural, wildlife and other open lands. His experience included appraisals in the San Juan, Dolores, Gunnison and Rio Grande river basins which provided a particularly relevant background in the water rights, water supply and groundwater issues of all four basins.

John was a Colorado Certified General Real Estate Appraiser and an MAI Member of the Appraisal Institute. In 2017, he received the Conservation Hero Award from the La Plata Open Space Conservancy and the Cranmer Award from Colorado Open Lands; both recognizing his conservation easement appraisal contributions to private land and water preservation.

A 1985 graduate of Fort Lewis college with a Bachelor of Arts degree in Business Administration, John has enjoyed and been in awe of the San Juan Mountains for his entire adult life. He has significant interest in the climate and water resources of the Southwestern United States.

John can be contacted at johnnorton.southwest@gmail.com.

Michael Preston received a B.A. in Religious Studies from the University of California at Santa Barbara, and an M.A. in Urban and Regional Planning at the University of Colorado at Denver.

During 27 years with Fort Lewis College (1980-2007), Preston worked with the Ute Mountain Ute Tribe on the negotiating team for the Colorado Indian Water Rights Settlement and as development coordinator for the 7,600 acre Tribal Farm and Ranch Enterprise that resulted from the Settlement. He also worked on collaborative forest restoration efforts involving Montezuma County, timber industry, conservation groups, and US/State Forest Service from 1995 until 2007.

Preston served as the General Manager of the Dolores Water Conservancy District, From 2007 to 2019 and as Chairman of the Southwest Basin Roundtable from 2008 to 2020.

Preston is President of Weenuch-u' Development Corp, which oversees Ute Mountain Ute Tribal Enterprises. He also serves on the Tribal Water Resources Committee. He continues his forest health involvement as the water representative on the Rocky Mountain Restoration Initiative (RMRI) Steering Committee and the Dolores Watershed Resilient Forests (DWRF) Collaborative Coordinating Committee.

In 2021 Preston received the Diane Hoppe Leadership Award from Water Education Colorado on the same evening that his friend, mentor and long-time associate John Porter received the same award posthumously.

Mike can be contacted at mpreston833@outlook.com.

APPENDIX A

SNOTEL Temperature & Precipitation Change From 1990-99 Baseline Average

	SNOTEL	Elevation *	Temp Change **	Precip Change ***	Precip % Change
1	Bateman	9,300	4.7	-4.9	-18.1%
2	Beartown	11,600	2.4	-6.3	-15.1%
3	Cascade	8,880	4.5	-7.0	-19.4%
4	Chamita	8,400	3.9	-8.0	-29.8%
5	Cumbres Trestle	10,040	3.2	-8.2	-19.2%
6	El Diente Peak	10,000	2.6	-4.8	-13.5%
7	Hopewell	10,000	4.9	-8.1	-24.3%
8	Idarado	9,800	3.2	-3.6	-10.8%
9	Lily Pond	11,000	5.0	-7.9	-22.9%
10	Lizard Head Pass	10,200	5.5	-5.8	-17.8%
11	Lone Cone	9,600	3.7	-5.0	-14.7%
12	Middle Creek	11,250	3.6	-11.0	-25.9%
13	Mineral Creek	10,440	2.9	-5.9	-17.9%
14	Molas Lake	10,500	2.7	-4.6	-12.9%
15	Red Mountain	11,200	2.4	-5.7	-12.8%
16	Scotch Creek	9,100	5.1	-5.8	-18.2%
17	Slumgullion	11,560	3.8	-2.3	-8.9%
18	Spud Mountain	10,660	3.5	-9.4	-19.0%
19	Stump Lakes	11,200	3.5	-10.1	-24.9%
20	Upper Rio Grande	9,400	4.1	-4.6	-20.7%
21	Upper San Juan	10,200	3.3	-10.5	-19.2%
22	Vallecito	10,880	3.2	-9.3	-25.4%
23	Wolf Creek Summit	11,000	5.0	-12.8	-23.5%

* Feet Above Sea Level
** Degrees Farenheit
*** Inches

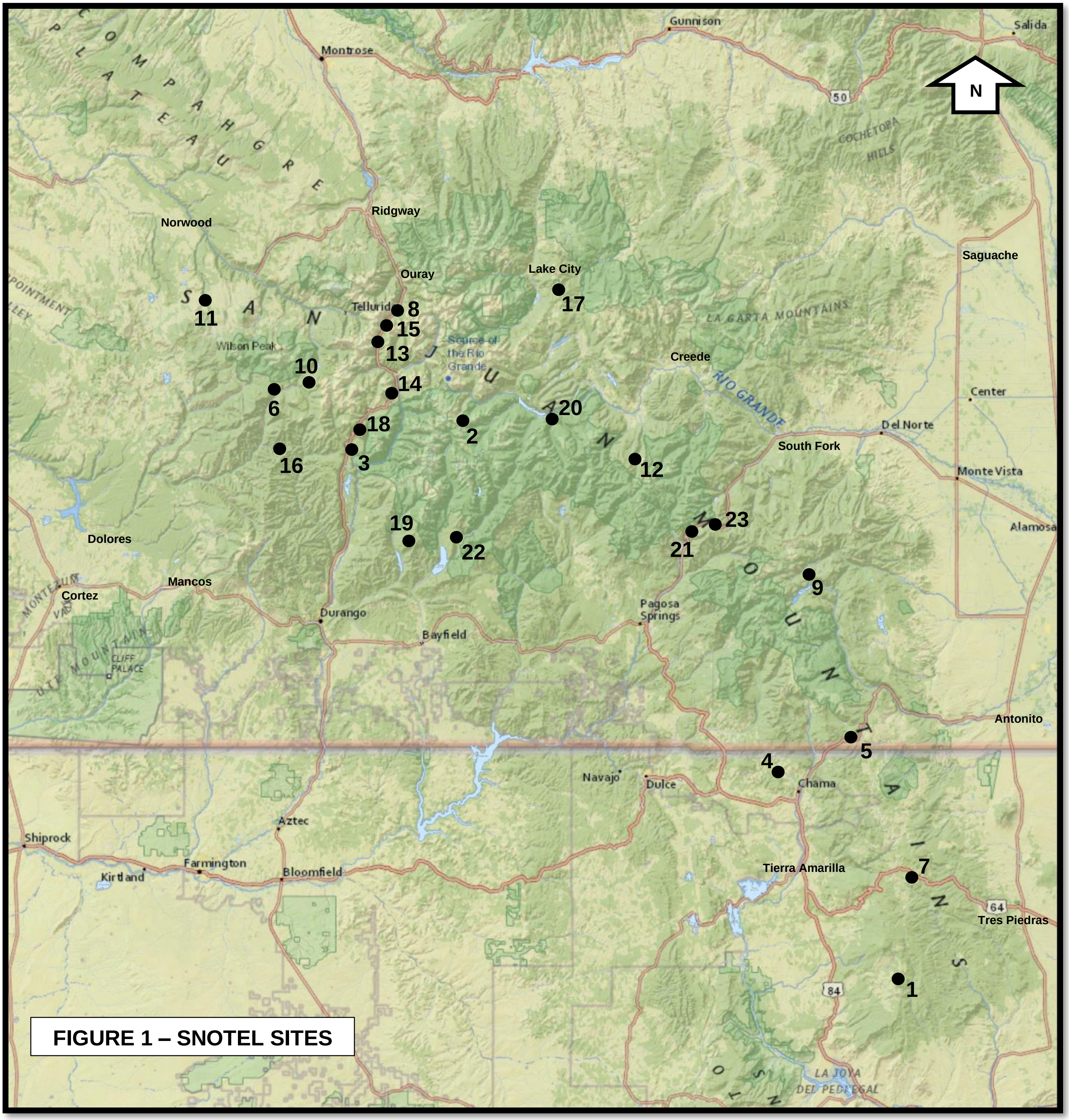


FIGURE 1 – SNOTEL SITES

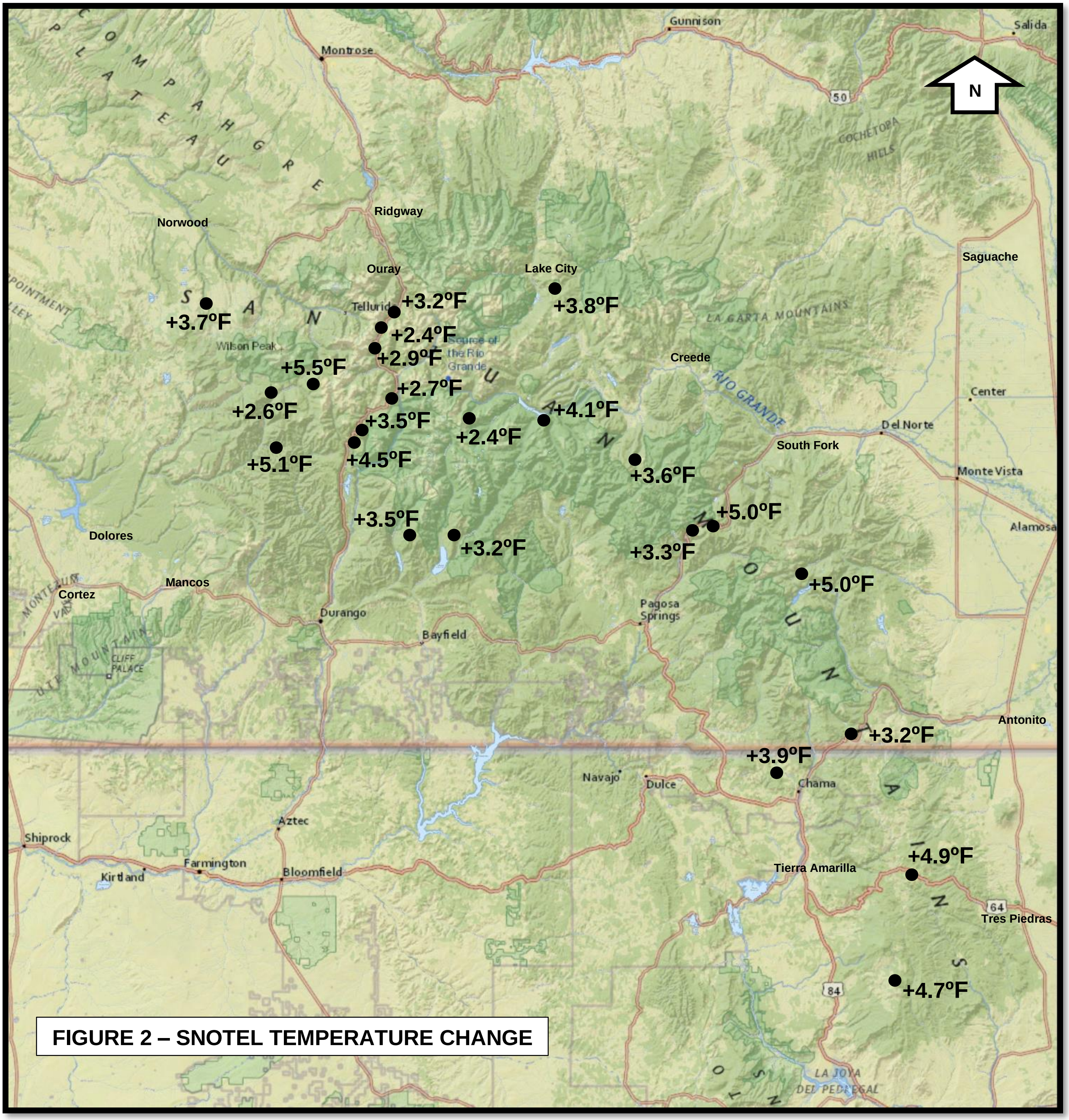


FIGURE 2 – SNOTEL TEMPERATURE CHANGE

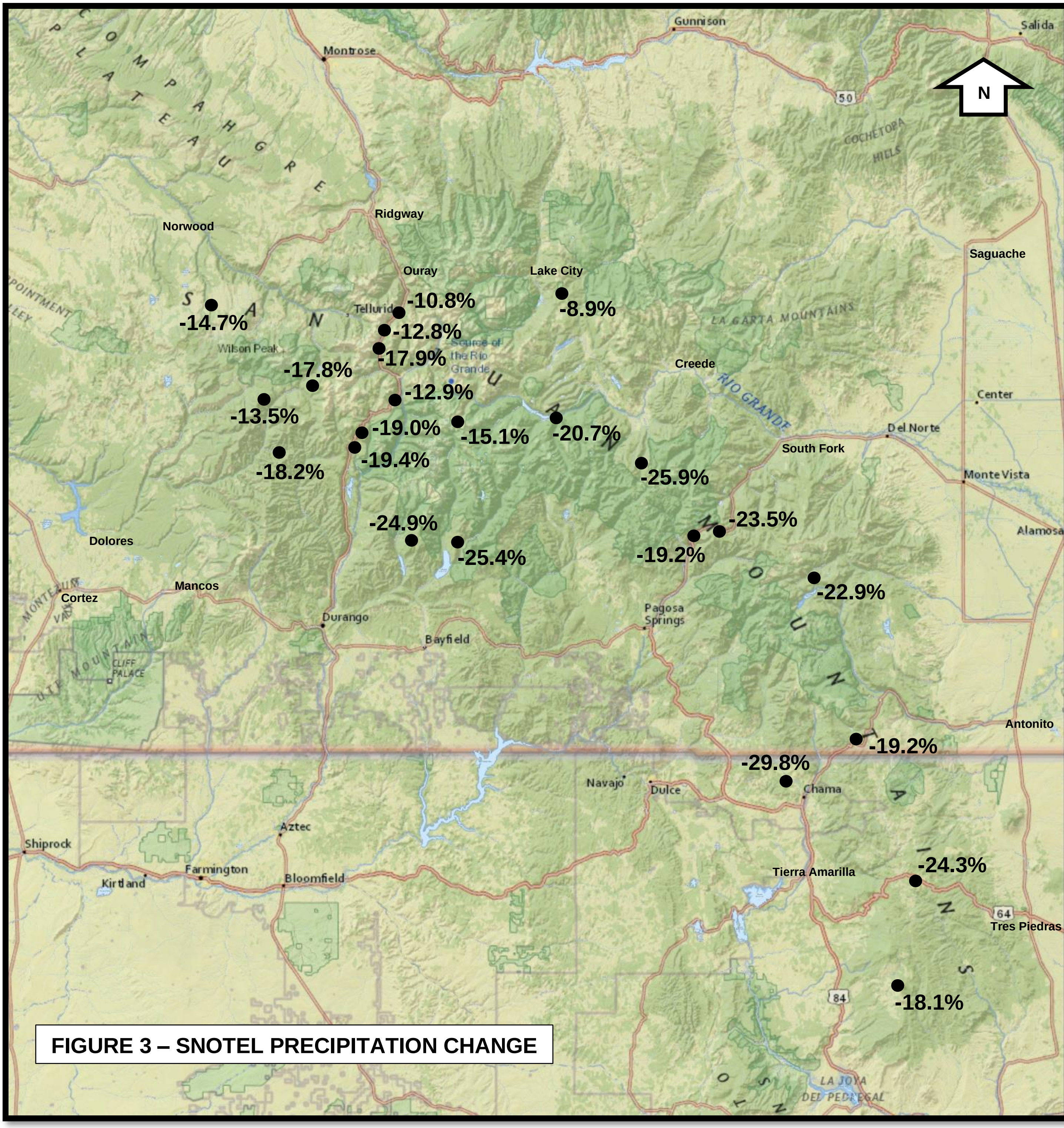


FIGURE 3 – SNOTEL PRECIPITATION CHANGE

Molas Lake SNOTEL Climate Site - March 2, 2022

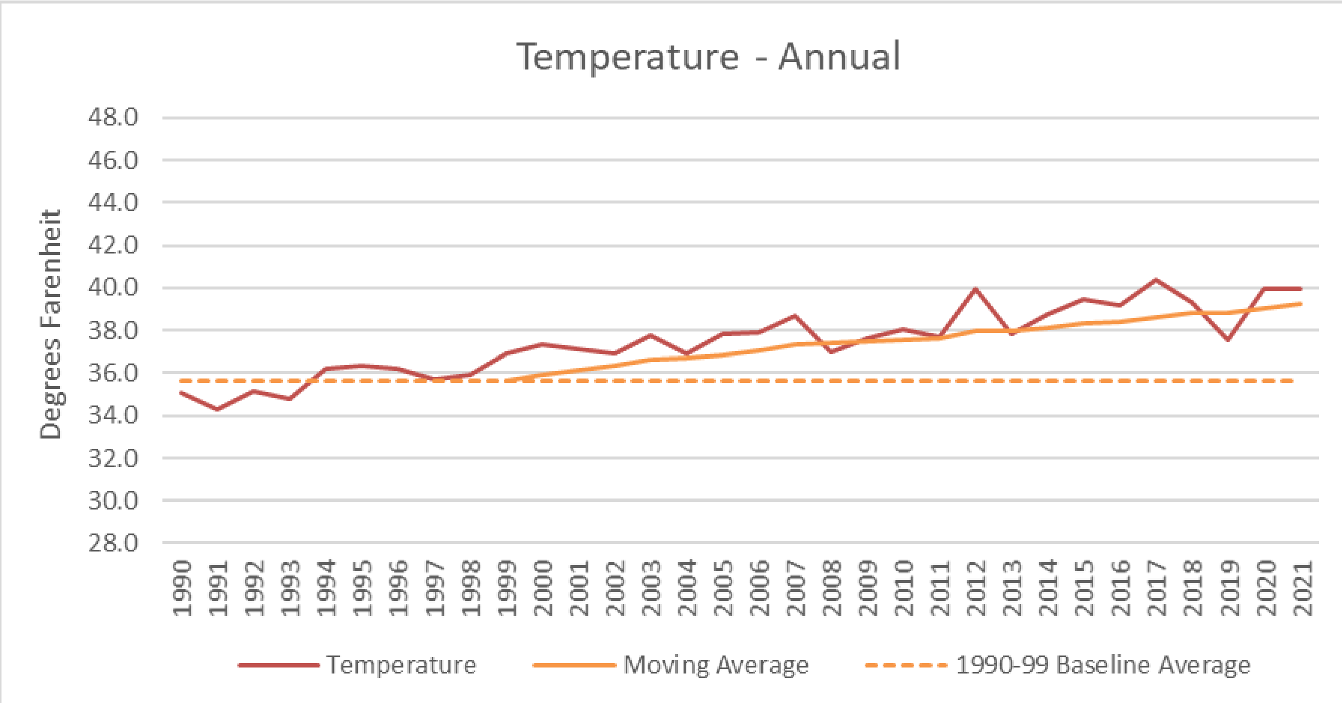
APPENDIX B

Annual Temperature & Precipitation Change From 1990-99 Baseline Average

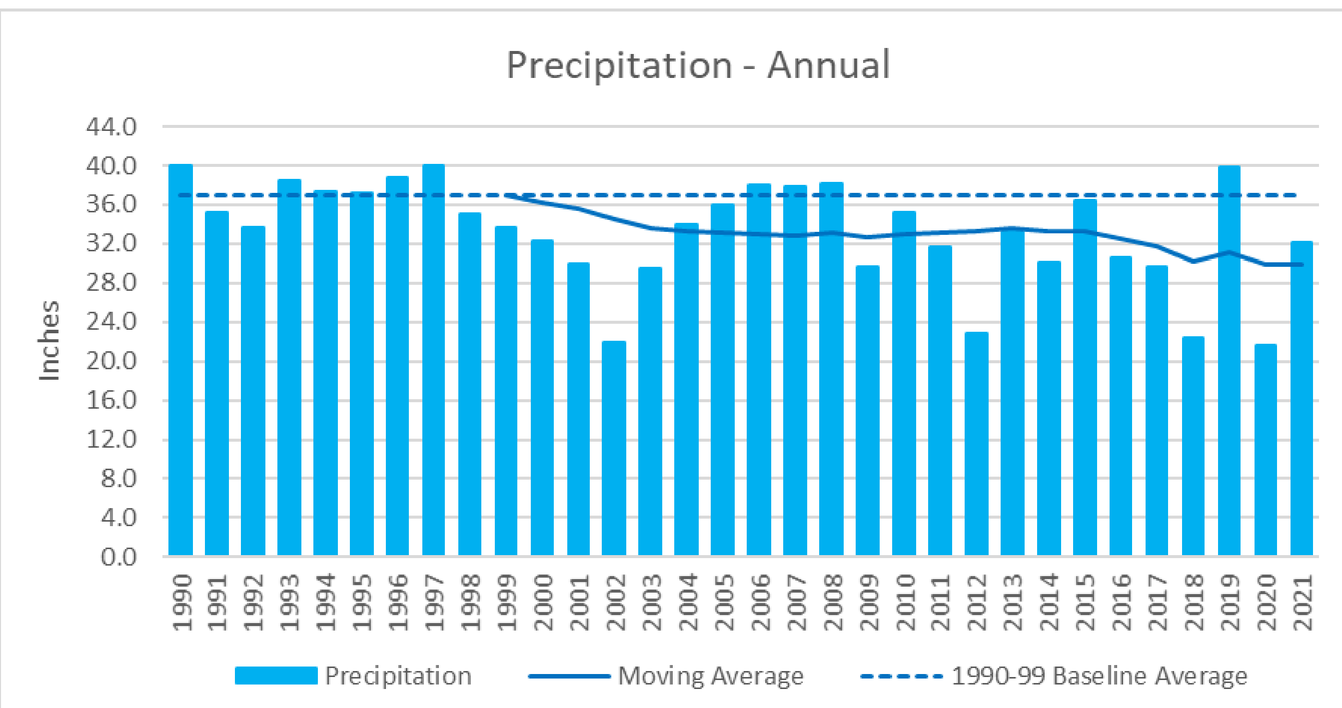
Period	Average Temp *	Average Temp Change *	Average Precip **	Average Precip Change **	Average Precip % Change
1990-99	35.7	-	36.9	-	-
1991-00	35.9	0.2	36.2	-0.8	-2.1%
1992-01	36.2	0.5	35.6	-1.3	-3.5%
1993-02	36.3	0.7	34.5	-2.5	-6.7%
1994-03	36.6	1.0	33.6	-3.4	-9.1%
1995-04	36.7	1.0	33.2	-3.7	-10.0%
1996-05	36.9	1.2	33.1	-3.8	-10.4%
1997-06	37.0	1.4	33.0	-3.9	-10.6%
1998-07	37.3	1.7	32.8	-4.1	-11.2%
1999-08	37.4	1.8	33.1	-3.8	-10.3%
2000-09	37.5	1.8	32.7	-4.2	-11.4%
2001-10	37.6	1.9	33.0	-3.9	-10.6%
2002-11	37.6	2.0	33.2	-3.8	-10.2%
2003-12	37.9	2.3	33.3	-3.7	-9.9%
2004-13	37.9	2.3	33.6	-3.3	-8.9%
2005-14	38.1	2.5	33.3	-3.7	-10.0%
2006-15	38.3	2.6	33.3	-3.6	-9.8%
2007-16	38.4	2.8	32.6	-4.4	-11.8%
2008-17	38.6	2.9	31.8	-5.2	-14.0%
2009-18	38.8	3.2	30.2	-6.7	-18.3%
2010-19	38.8	3.2	31.2	-5.7	-15.5%
2011-20	39.0	3.4	29.8	-7.1	-19.2%
2012-21	39.2	3.6	29.9	-7.0	-19.0%

* Degrees Farenheit

** Inches



Temperature - Annual
Degrees Farenheit
48.0
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

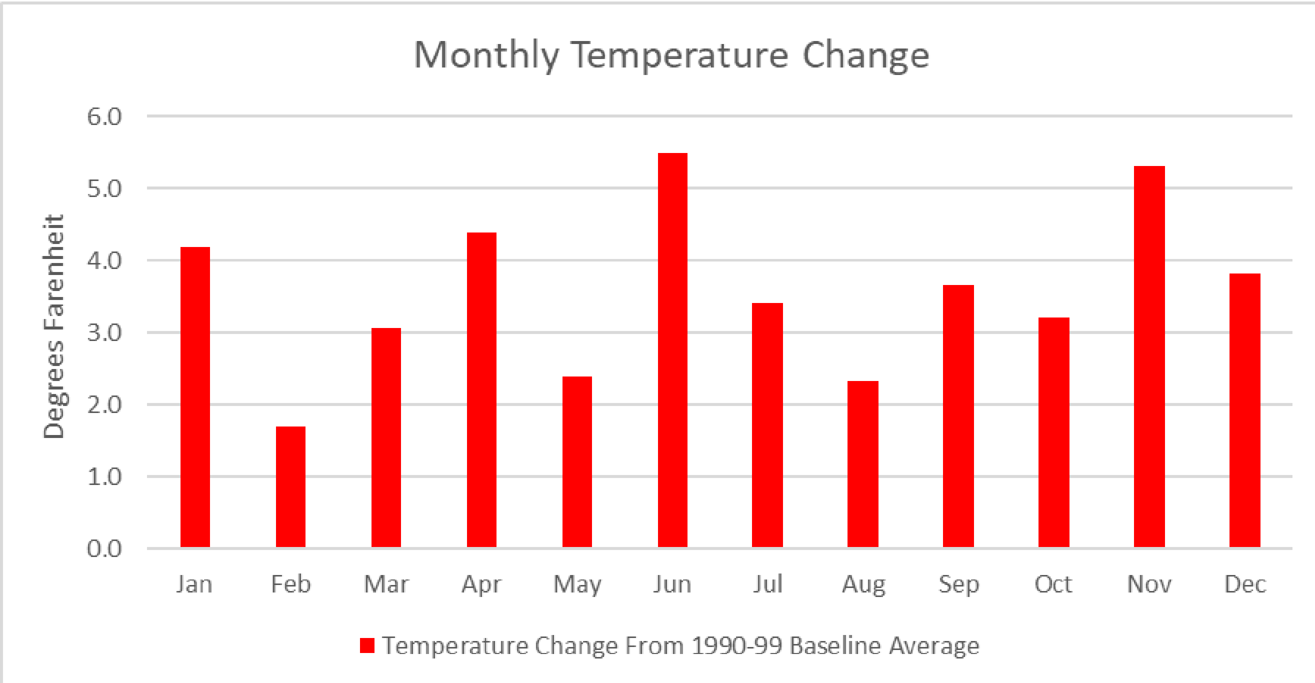


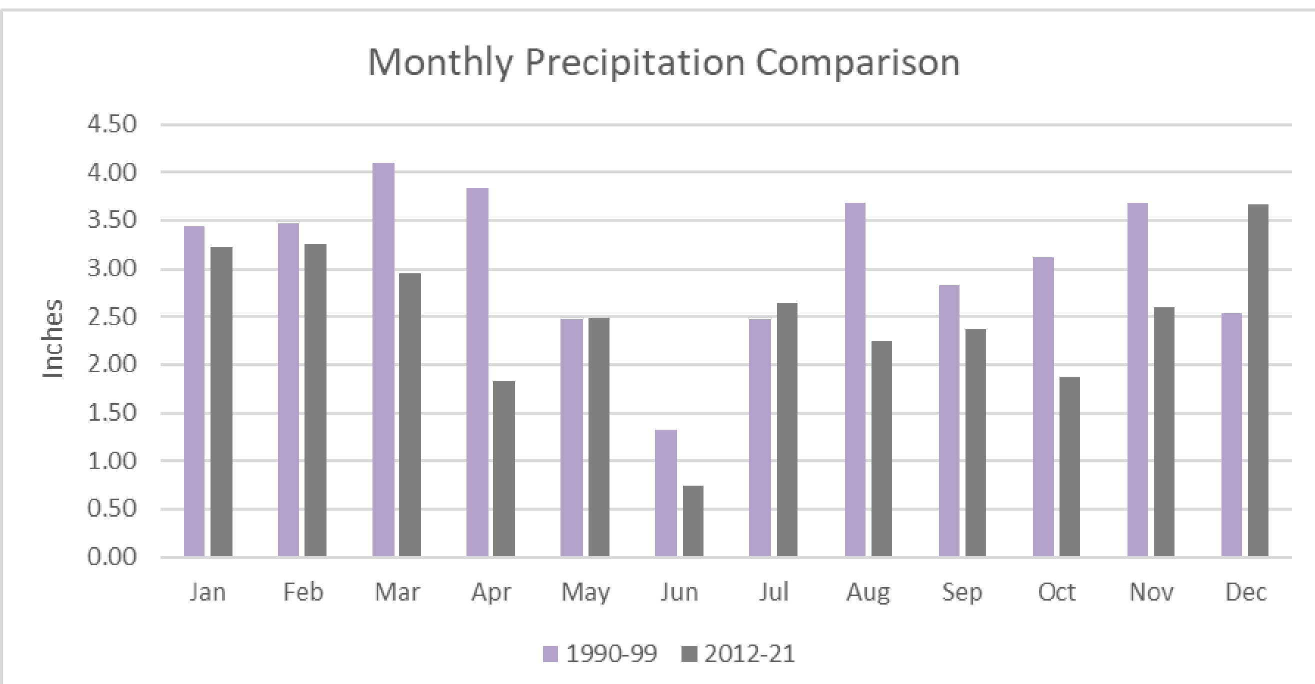
Precipitation - Annual
Inches
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

Monthly Temperature & Precipitation Change*

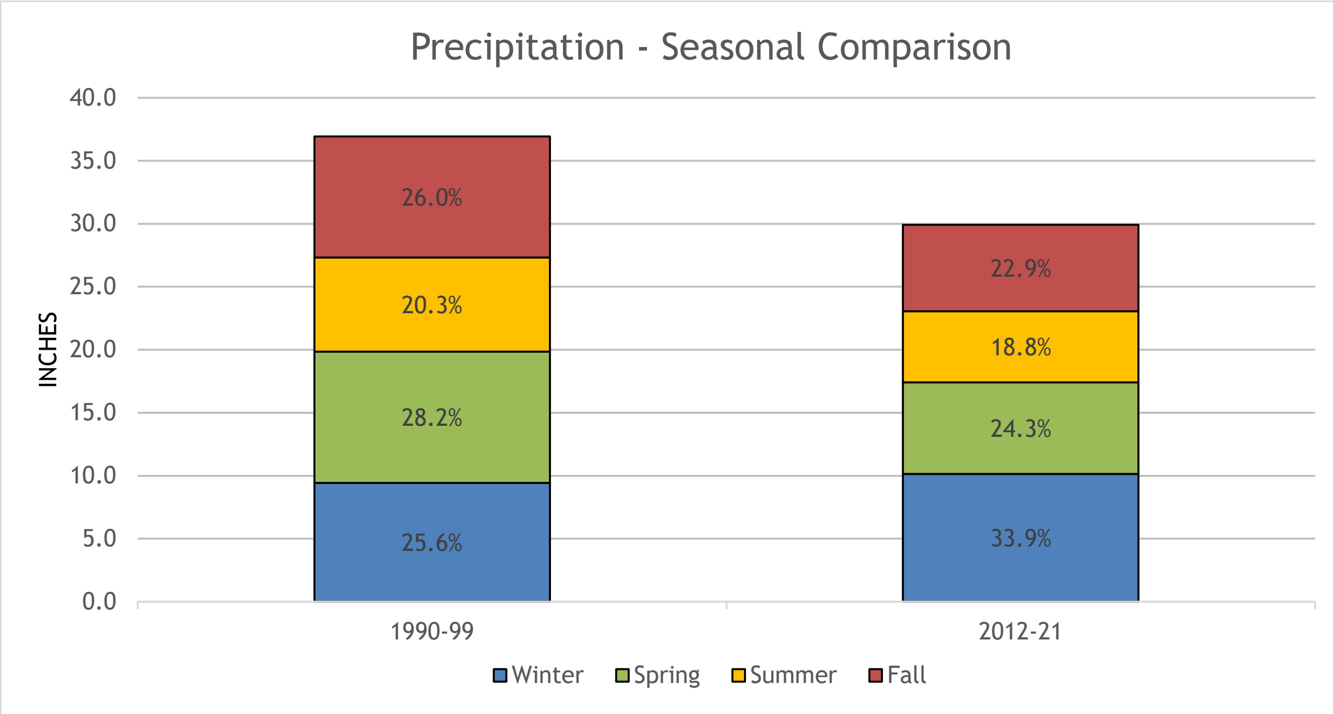
Month	Temp Change **	Precip Change ***	Precip % Change
Jan	4.2	-0.2	-6.4%
Feb	1.7	-0.2	-6.5%
Mar	3.1	-1.1	-27.9%
Apr	4.4	-2.0	-52.4%
May	2.4	0.0	0.6%
Jun	5.5	-0.6	-43.4%
Jul	3.4	0.2	6.6%
Aug	2.3	-1.4	-39.0%
Sep	3.7	-0.5	-16.0%
Oct	3.2	-1.2	-39.3%
Nov	5.3	-1.1	-29.2%
Dec	3.8	1.1	45.4%
Annual	3.6	-7.0	-19.0%

* 2012-21 Average relative to 1990-99 Baseline Average
** Degrees Farenheit
*** Inches


Monthly Temperature Change
Degrees Farenheit
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Temperature Change From 1990-99 Baseline Average


Monthly Precipitation Comparison
Inches
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1990-99
2012-21

APPENDIX C



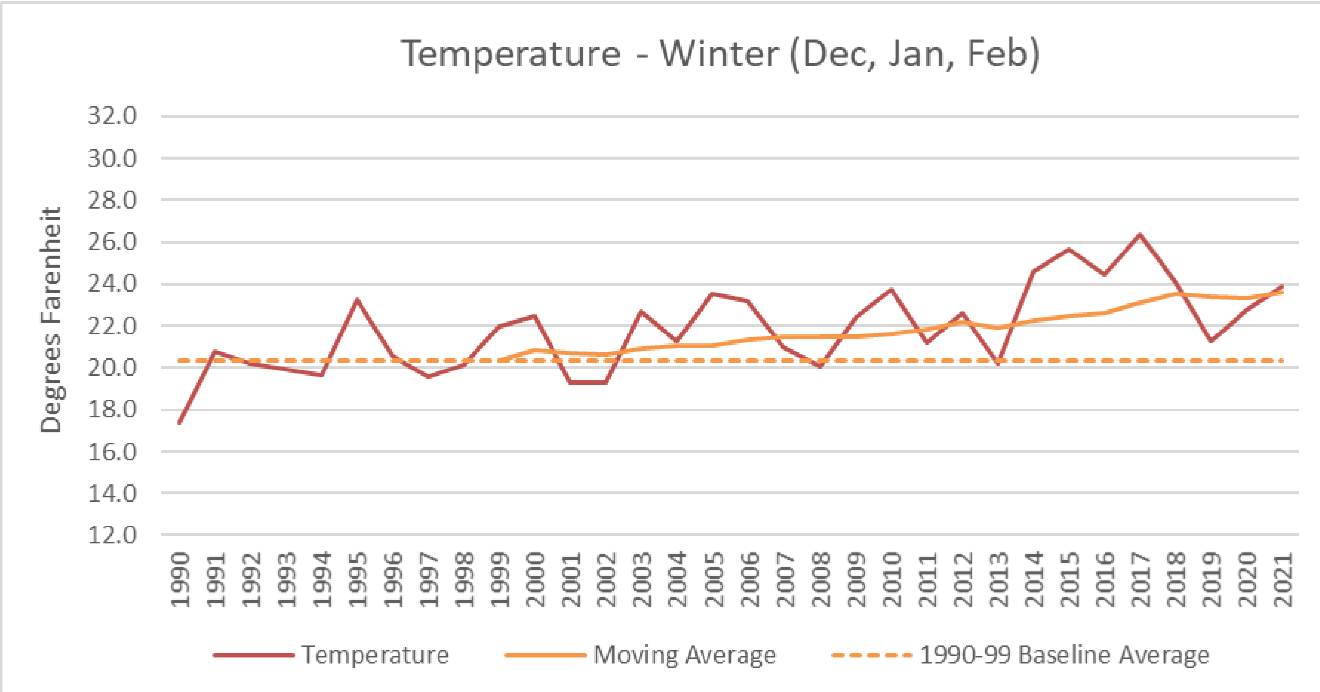
Seasonal Temperature & Precipitation Change*

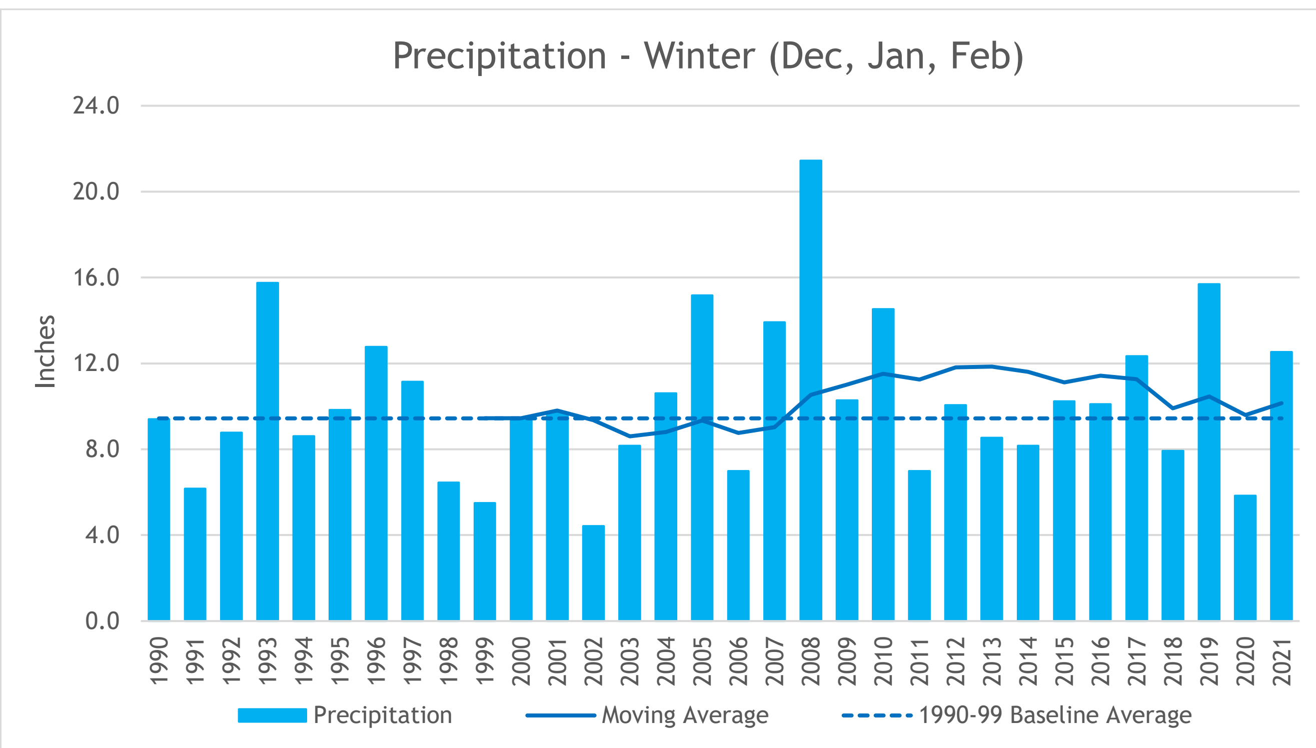
Season	Temp Change **	Precip Change ***	Precip % Change
Winter (Dec-Feb)	3.2	0.7	7.5%
Spring (Mar-May)	3.3	-3.1	-30.1%
Summer (Jun-Aug)	3.8	-1.9	-24.7%
Fall (Sep-Nov)	4.1	-2.7	-28.6%
Annual	3.6	-7.0	-19.0%

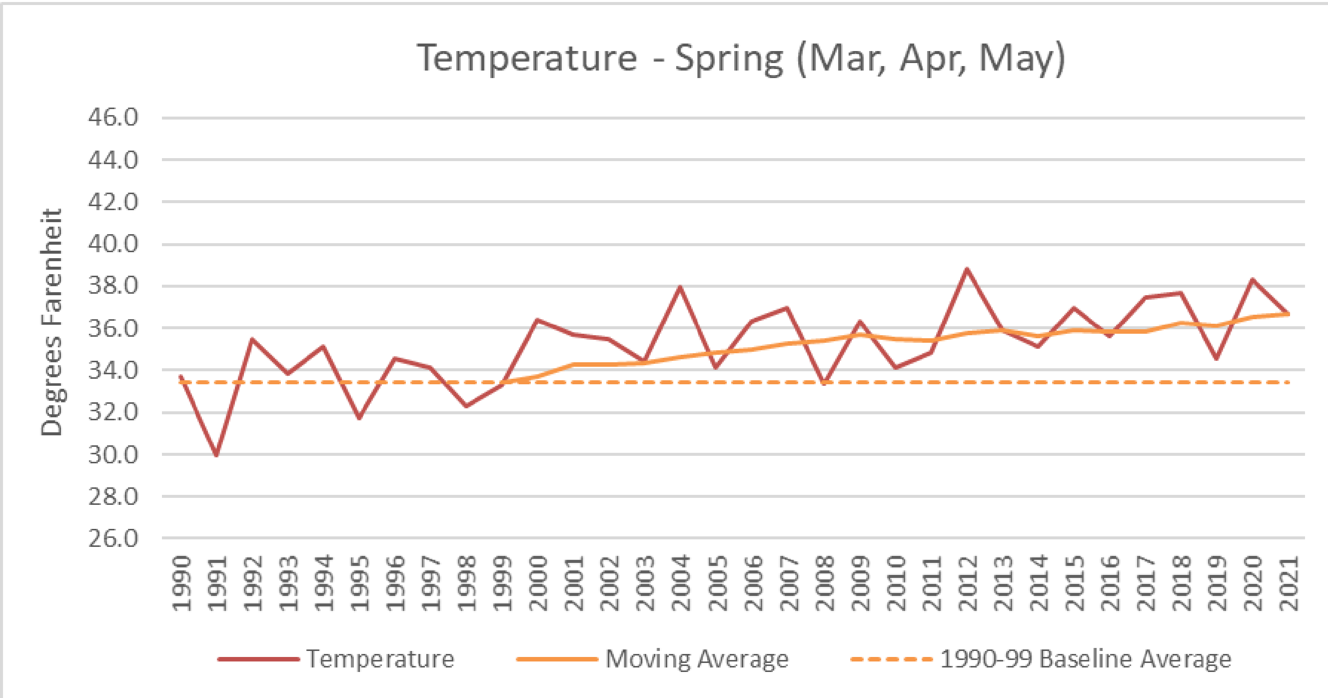
* 2012-21 Average relative to 1990-99 Baseline Average

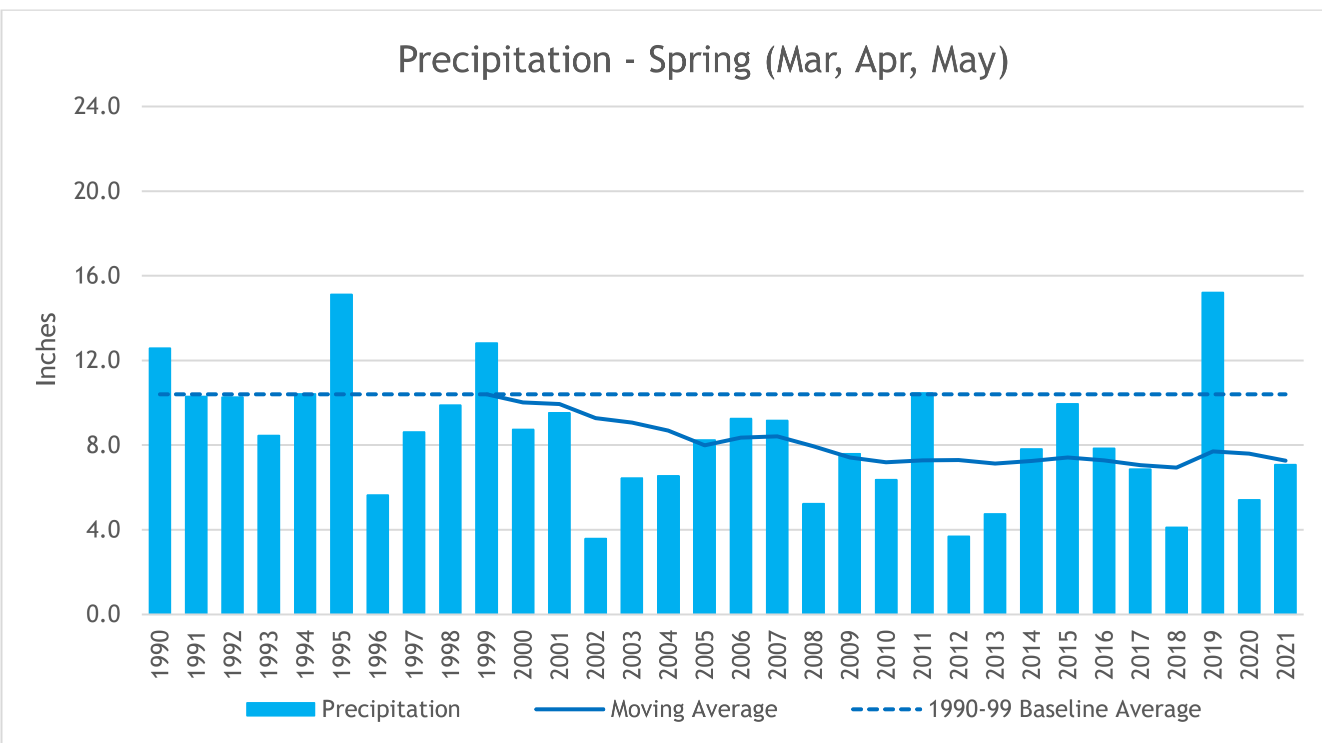
** Degrees Farenheit

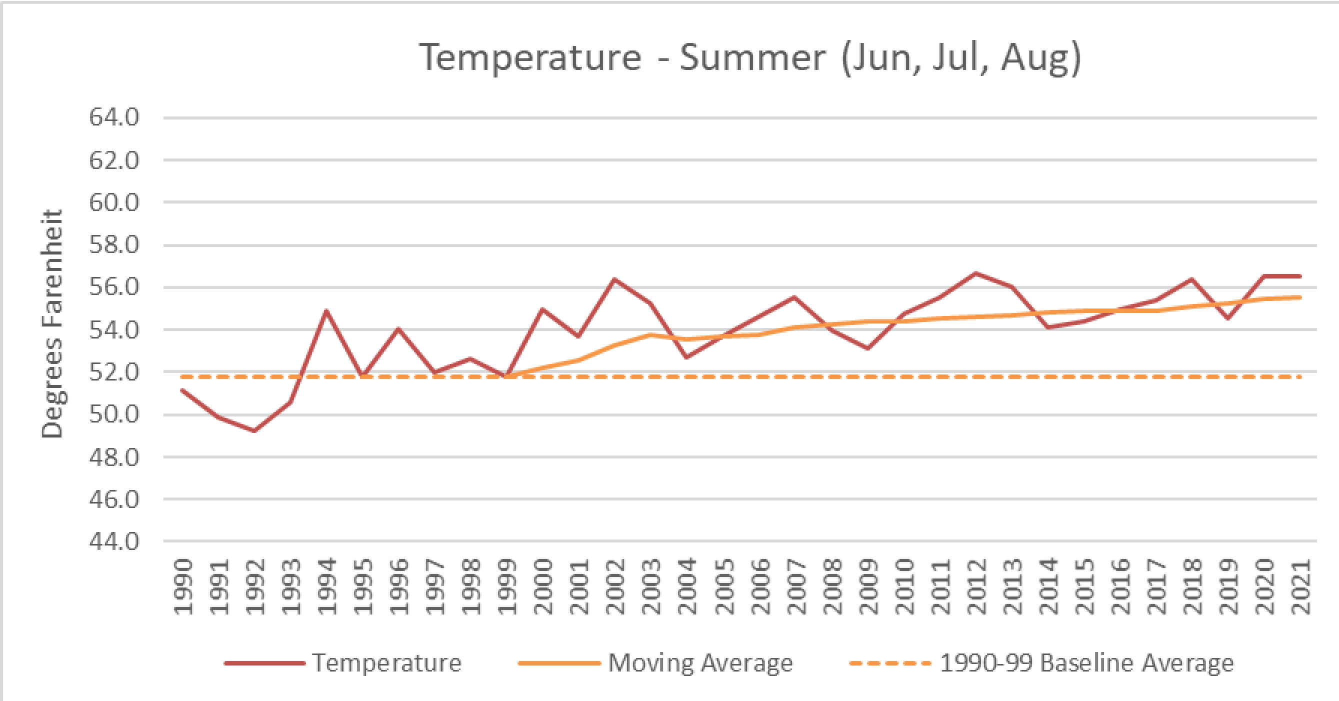
*** Inches

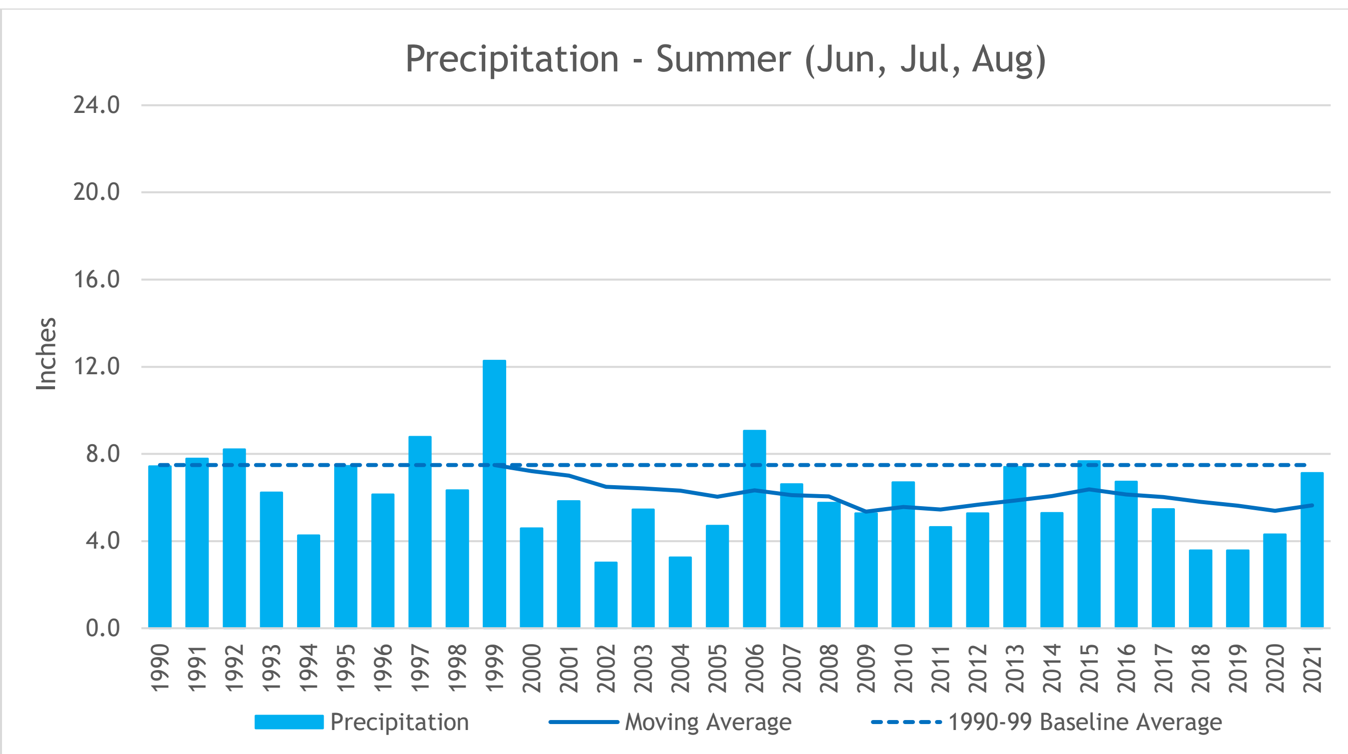

Temperature - Winter (Dec, Jan, Feb)
Degrees Farenheit
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

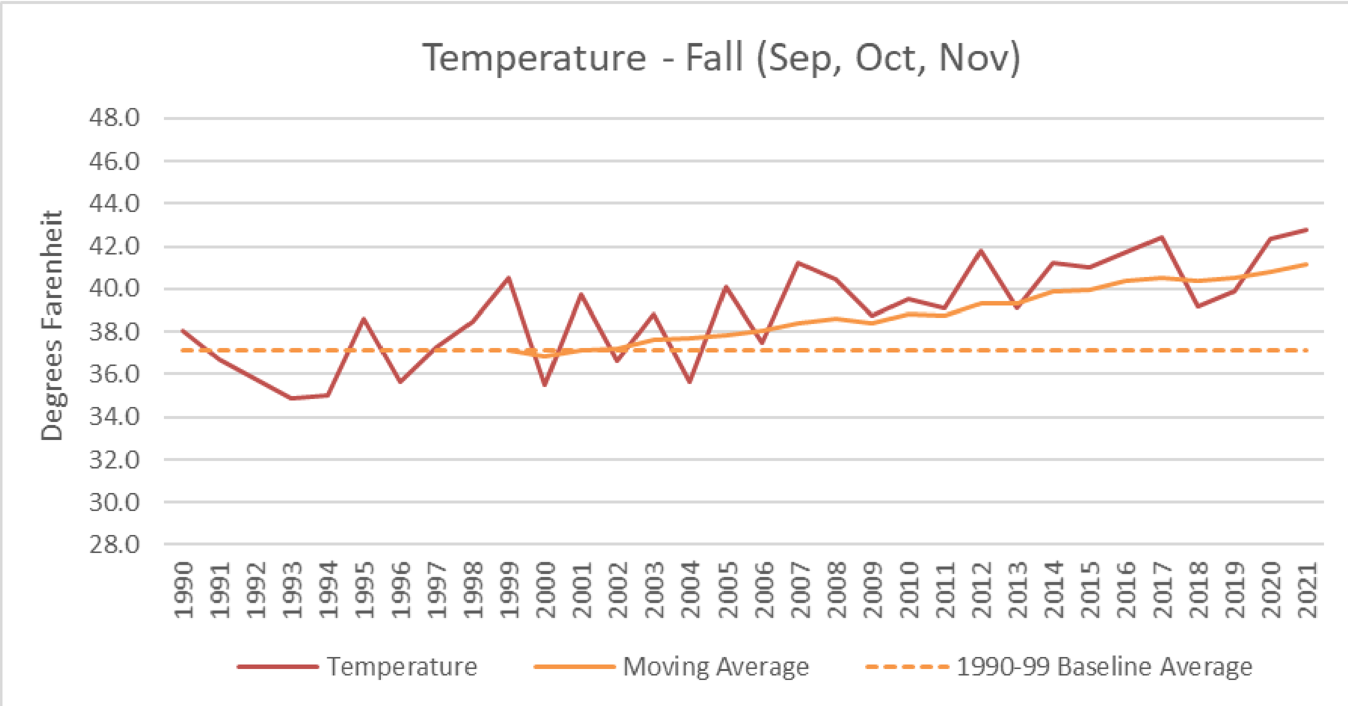

Precipitation - Winter (Dec, Jan, Feb)
Inches
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

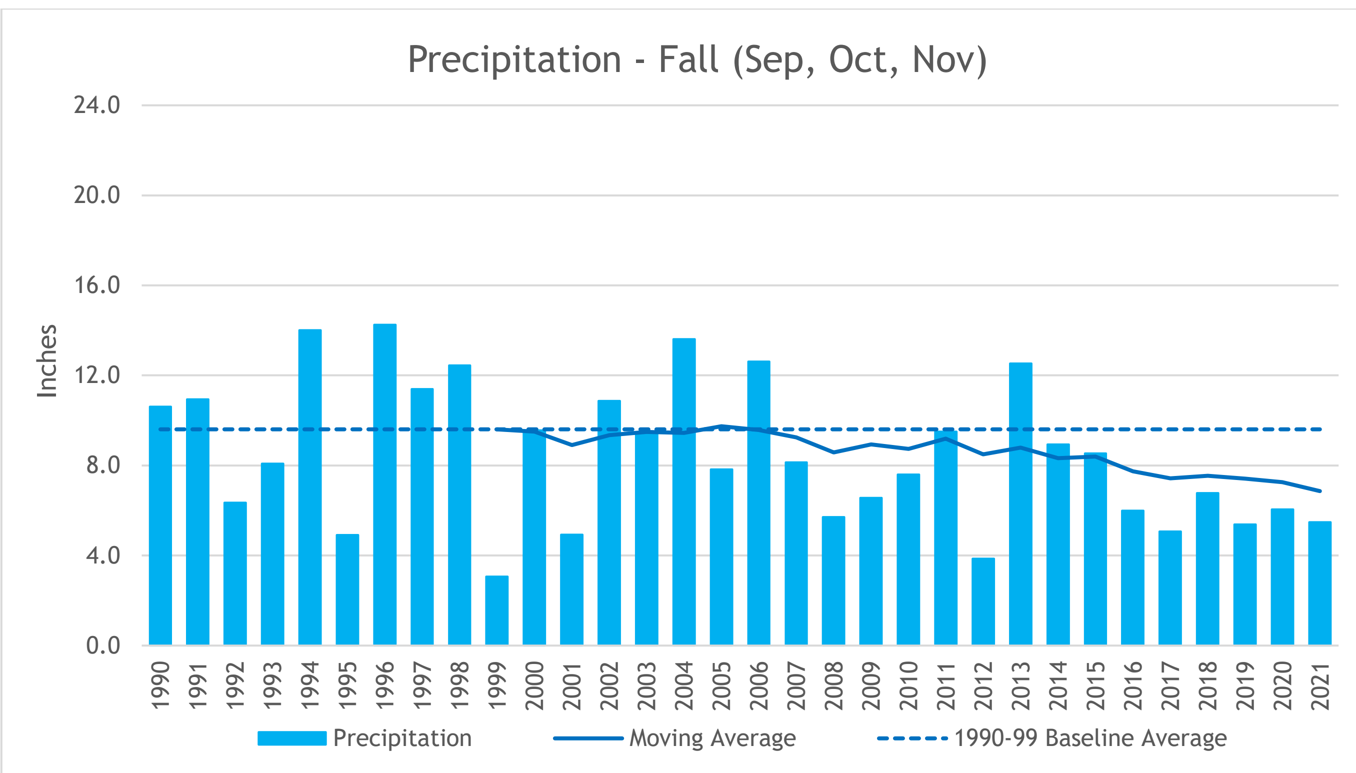

Temperature - Spring (Mar, Apr, May)
Degrees Farenheit
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average


Precipitation - Spring (Mar, Apr, May)
Inches
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - Summer (Jun, Jul, Aug)
Degrees Farenheit
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average


Precipitation - Summer (Jun, Jul, Aug)
Inches
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - Fall (Sep, Oct, Nov)
48.0
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
Degrees Farenheit
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average


Precipitation - Fall (Sep, Oct, Nov)
24.0
20.0
16.0
12.0
8.0
4.0
0.0
Inches
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

APPENDIX D

Annual Stream Runoff Change From 1990-99 Baseline Average

	Gauging Station	River Basin	1990-99 Average Annual Runoff *	2012-21 Average Annual Runoff *	Average Annual Runoff Change*	Average Annual Runoff % Change
A	San Juan River Near Carracas	San Juan	470,209	296,575	-173,634	-36.9%
B	Piedra River Near Arboles	San Juan	310,906	211,707	-99,199	-31.9%
C	Los Pinos River At La Boca	San Juan	188,418	110,129	-78,289	-41.6%
D	Animas River Near Cedar Hill	San Juan	717,908	493,388	-224,520	-31.3%
E	La Plata River At Hesperus	San Juan	31,305	20,563	-10,742	-34.3%
F	Mancos River Near Mancos	San Juan	25,199	16,101	-9,099	-36.1%
		Total San Juan	1,743,945	1,148,463	-595,482	-34.1%
G	Dolores River At Dolores	Dolores	319,297	218,816	-100,481	-31.5%
H	San Miguel River Near Placerville	Dolores	186,194	139,296	-46,898	-25.2%
		Total Dolores	505,491	358,112	-147,379	-29.2%
I	Uncompahgre River Near Ridgway	Gunnison	126,263	101,233	-25,030	-19.8%
J	Cimarron River Near Cimarron	Gunnison	75,016	59,656	-15,360	-20.5%
K	Lake Fork At Gateview	Gunnison	170,792	153,399	-17,393	-10.2%
L	Cochetopa Creek Below Rock Creek Near Parlin	Gunnison	29,936	29,561	-375	-1.3%
		Total Gunnison	402,007	343,849	-58,158	-14.5%
M	Saguache Creek Near Saguache	Rio Grande	44,320	42,305	-2,015	-4.5%
N	Rio Grande Near Del Norte	Rio Grande	649,078	556,295	-92,783	-14.3%
O	Alamosa River Above Terrace Reservoir	Rio Grande	77,558	61,715	-15,843	-20.4%
P	Conejos River Near Magote	Rio Grande	227,798	184,396	-43,402	-19.1%
Q	Los Pinos River Near Ortiz	Rio Grande	85,894	63,869	-22,025	-25.6%
R	Rio Chama Near La Puente	Rio Grande	295,095	187,120	-107,975	-36.6%
		Total Rio Grande	1,379,743	1,095,699	-284,044	-20.6%
		Total	4,031,185	2,946,123	-1,085,063	-26.9%

* Acre Feet

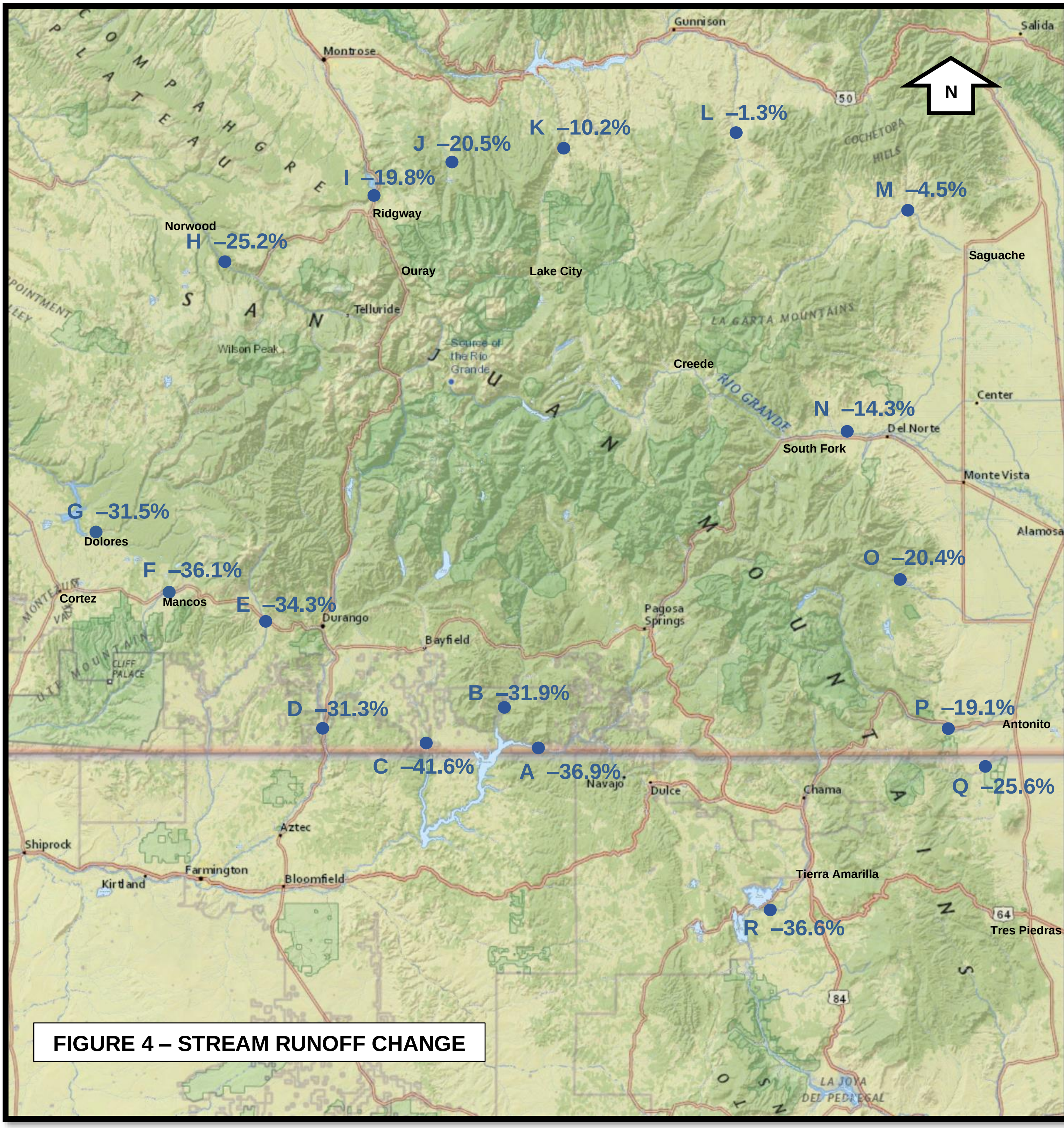
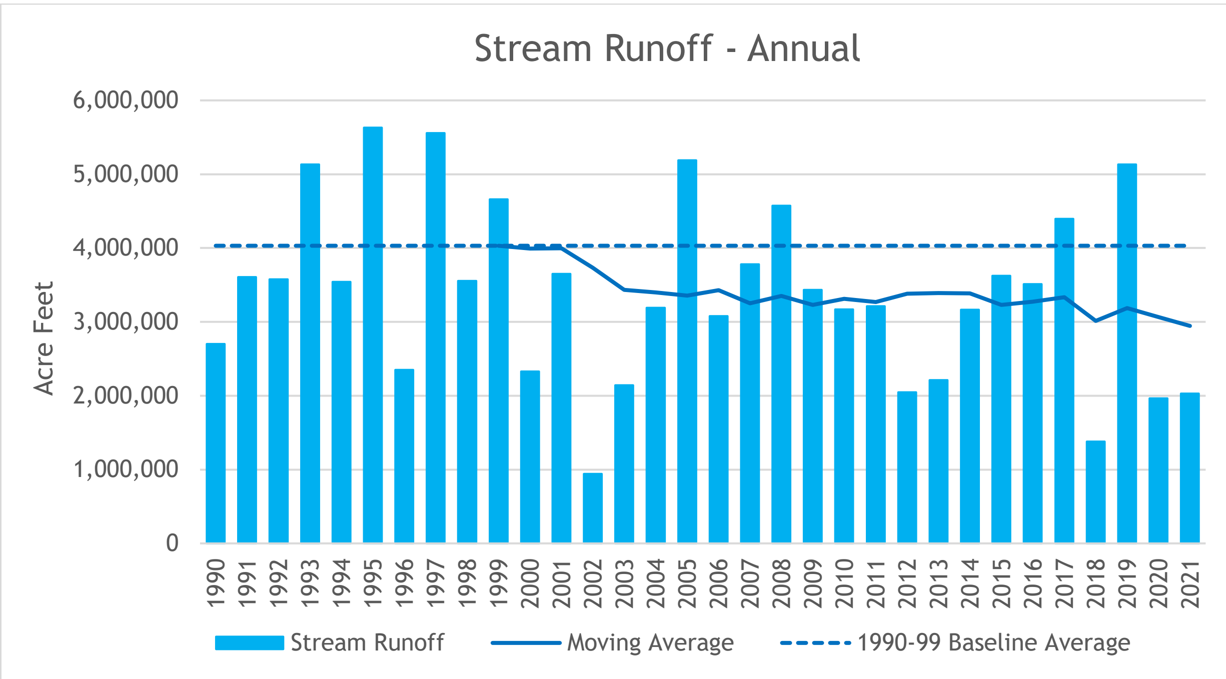
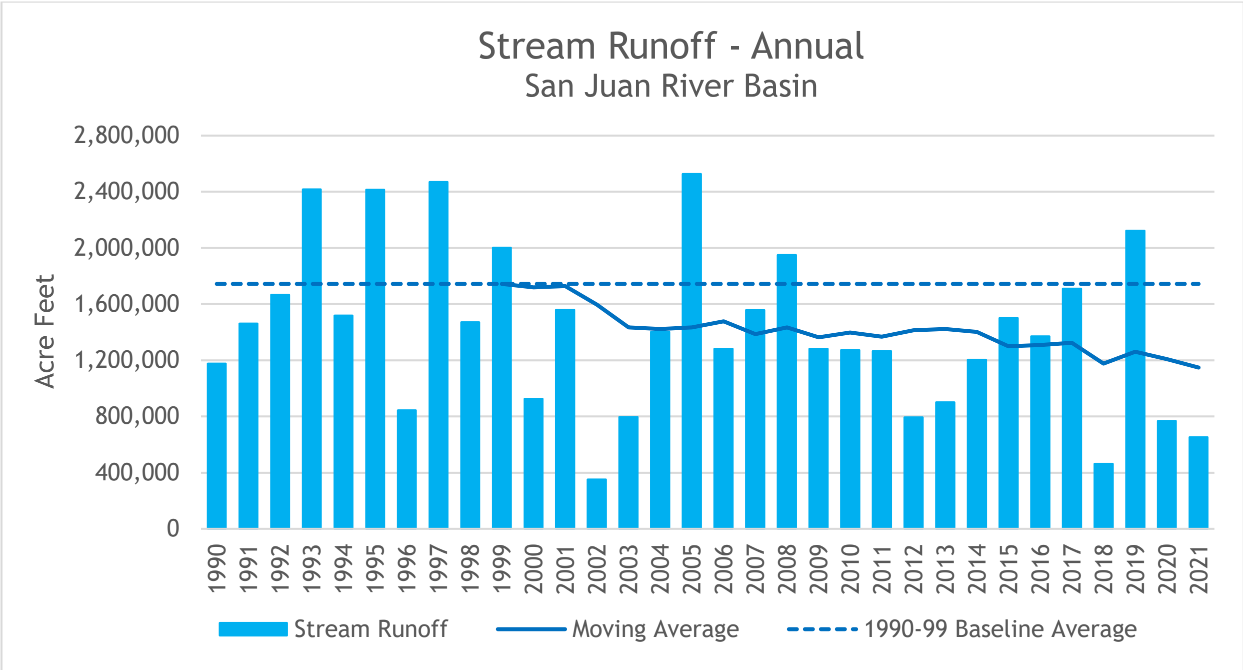
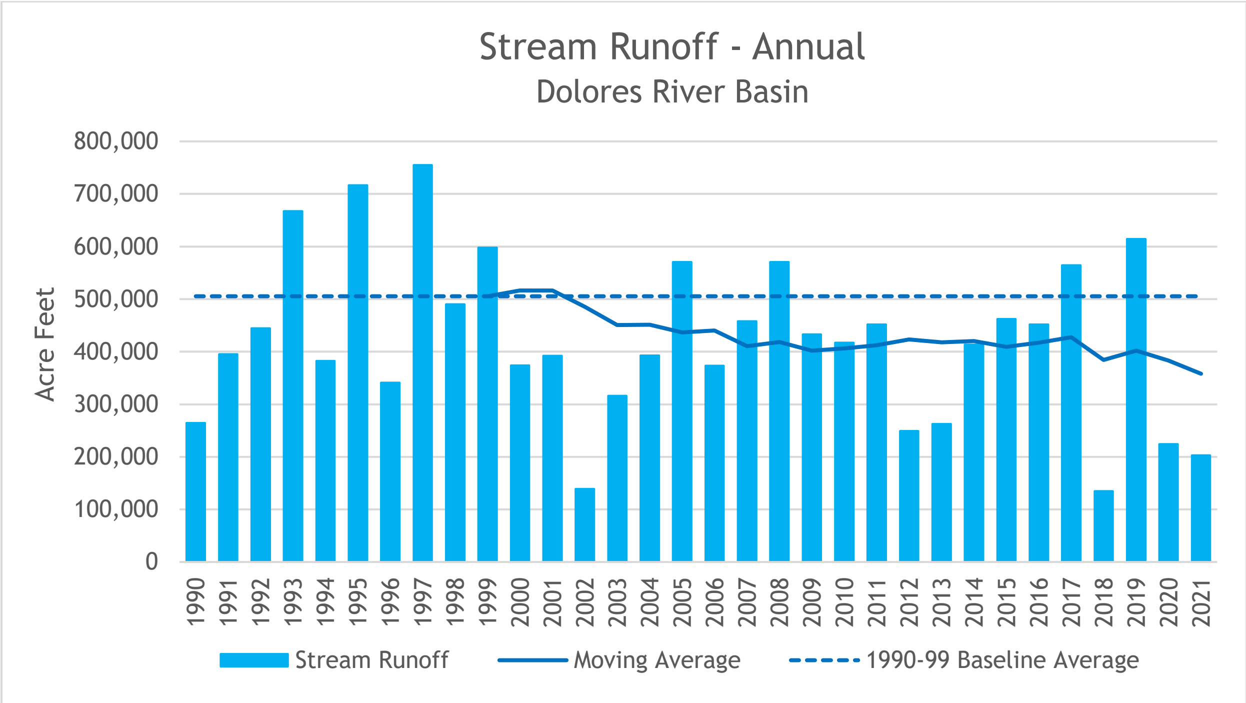
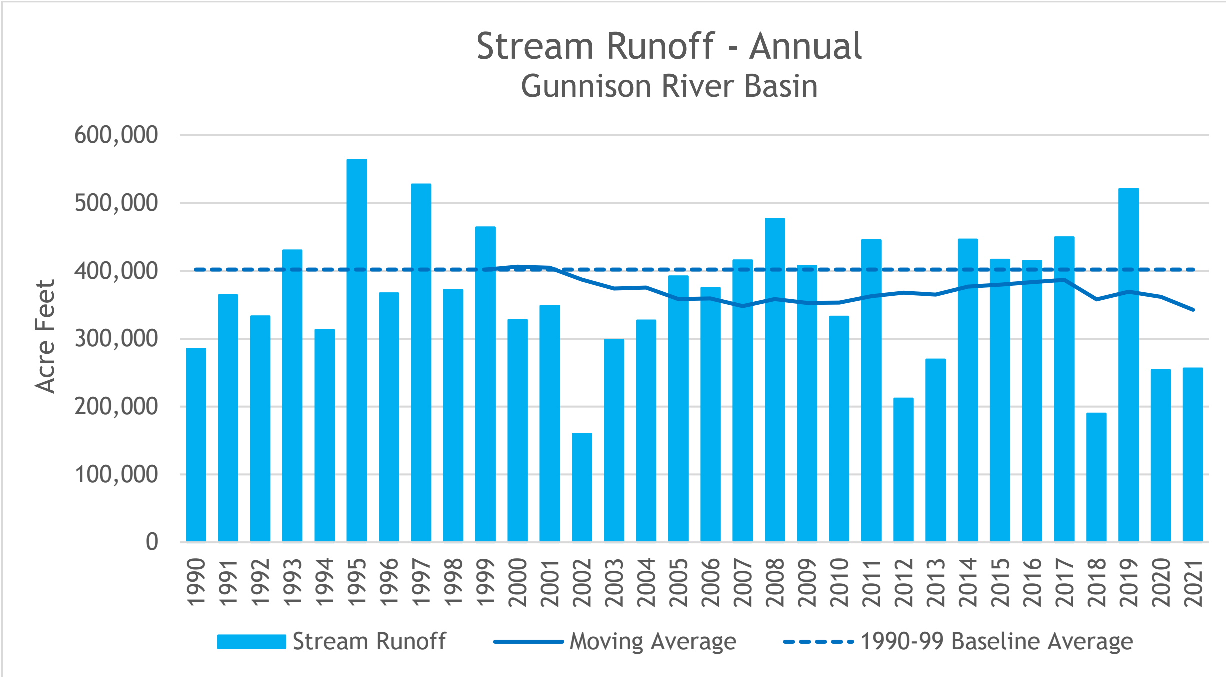


FIGURE 4 – STREAM RUNOFF CHANGE

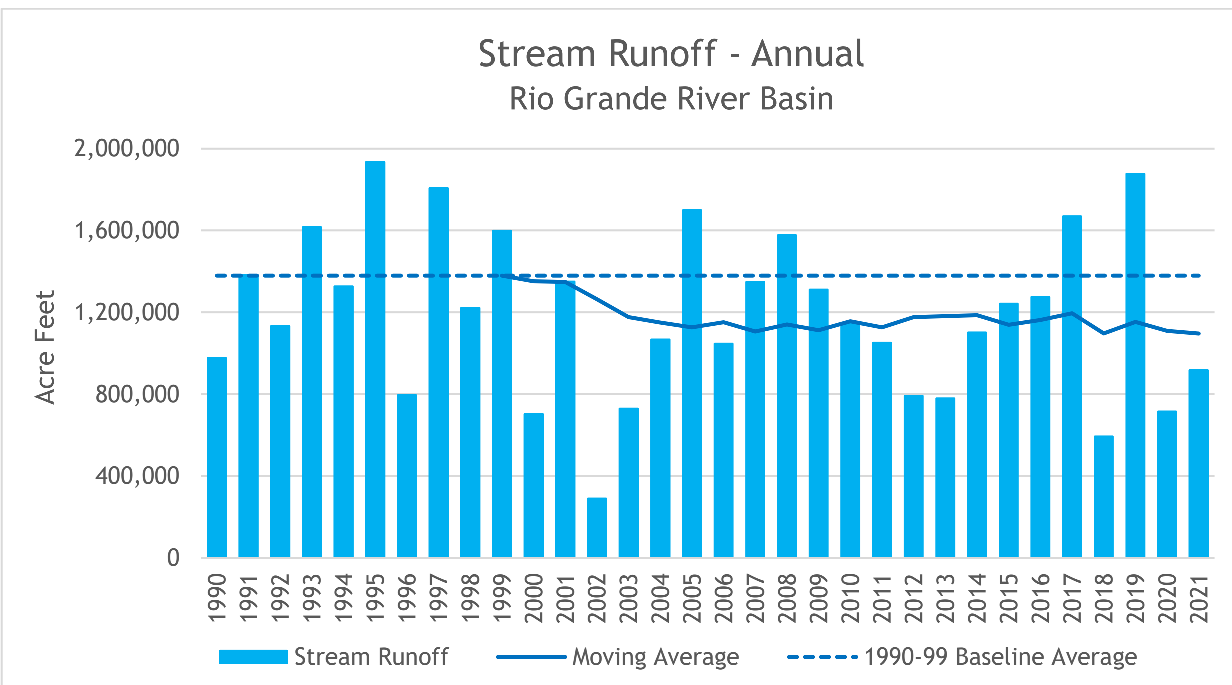

Stream Runoff - Annual
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Acre Feet
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Stream Runoff
Moving Average
1990-99 Baseline Average


Stream Runoff - Annual
San Juan River Basin
Acre Feet
2,800,000
2,400,000
2,000,000
1,600,000
1,200,000
800,000
400,000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Stream Runoff
Moving Average
1990-99 Baseline Average


Stream Runoff - Annual
Dolores River Basin
Acre Feet
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Stream Runoff
Moving Average
1990-99 Baseline Average

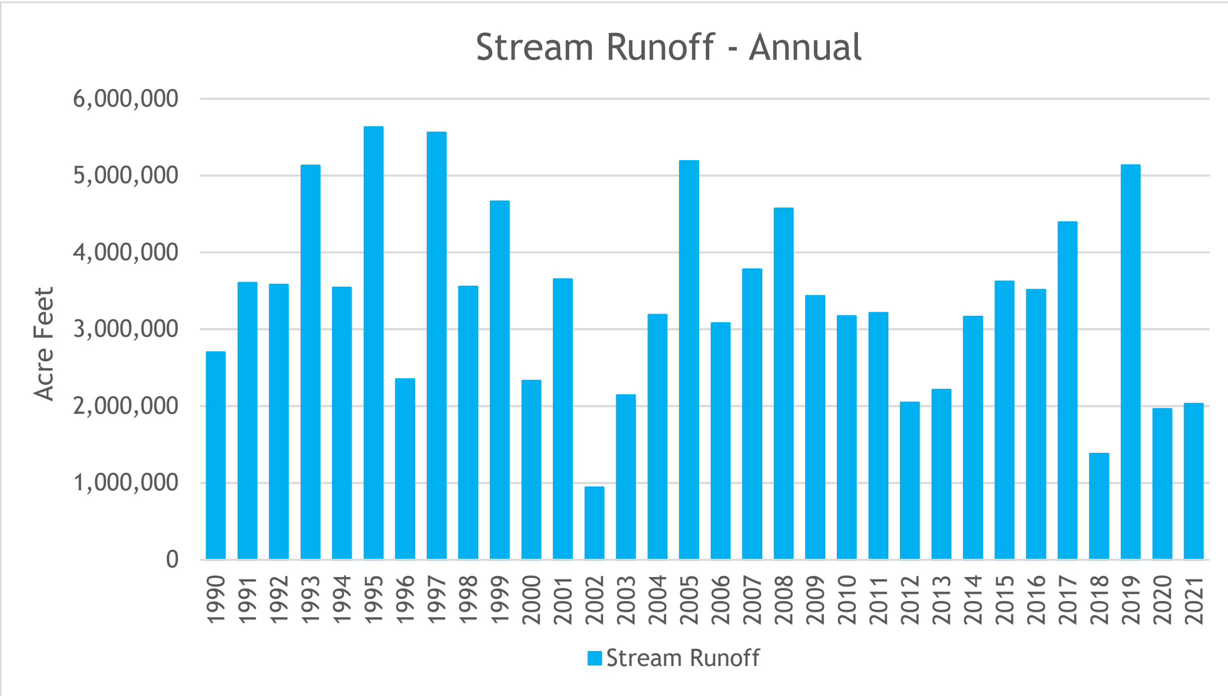


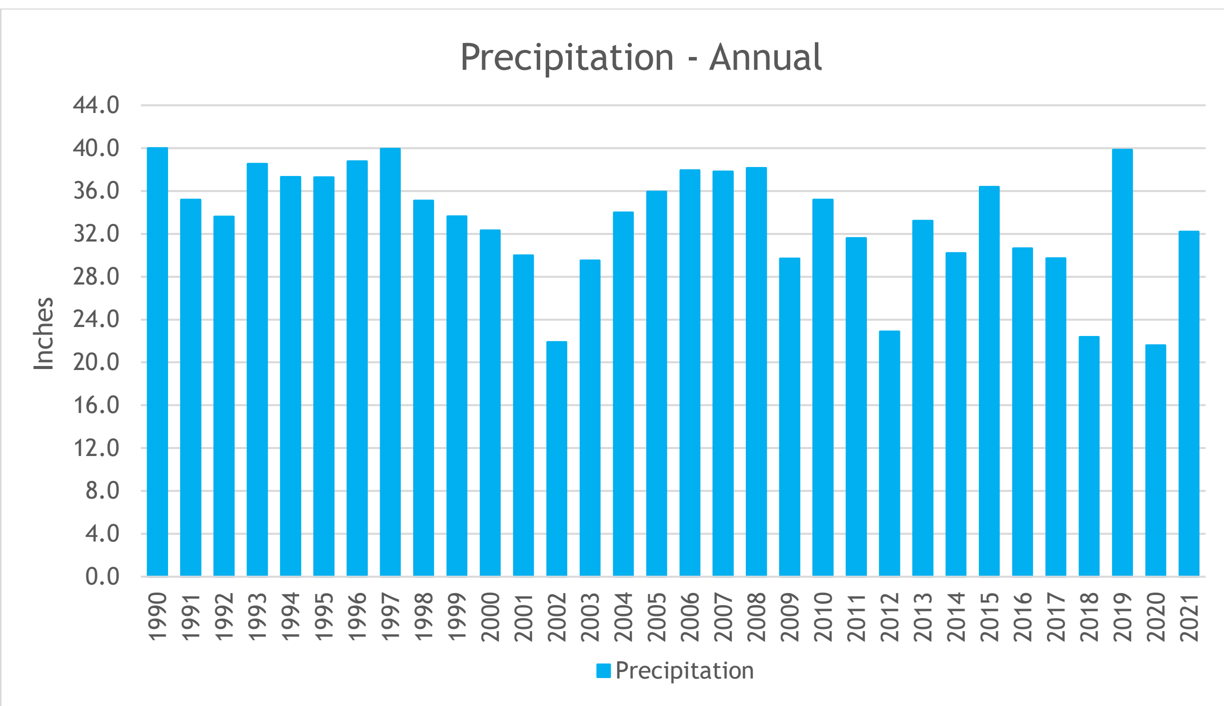
Stream Runoff - Annual
Gunnison River Basin
Acre Feet
600,000
500,000
400,000
300,000
200,000
100,000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Stream Runoff
Moving Average
1990-99 Baseline Average

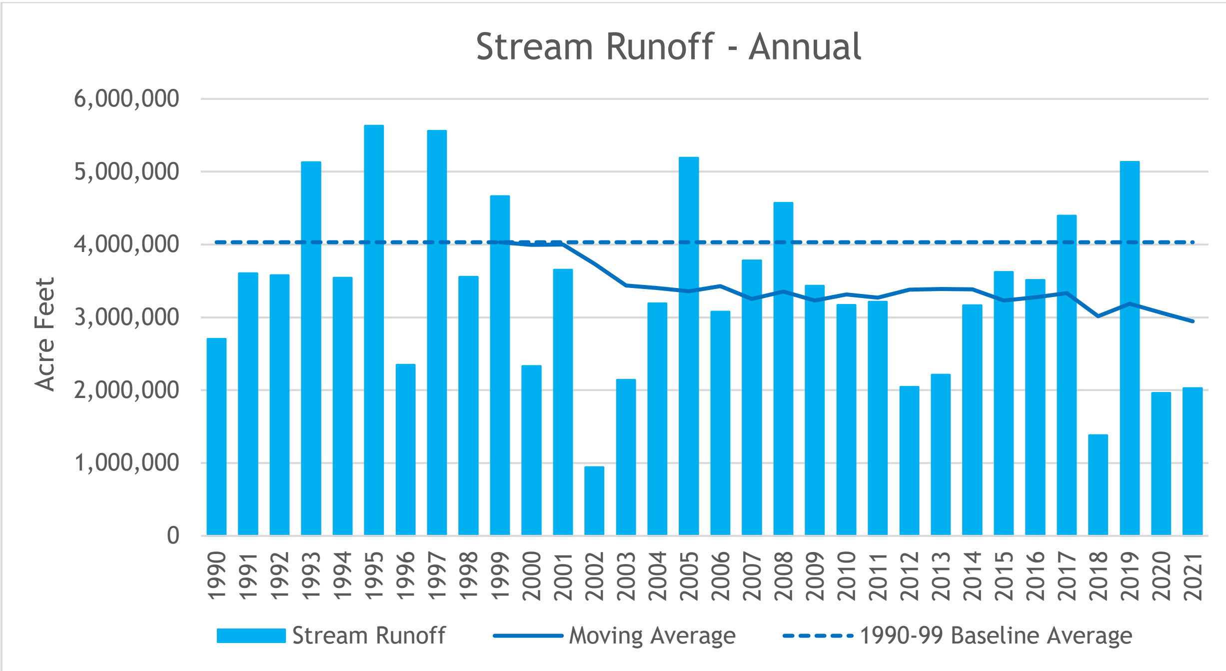


Stream Runoff - Annual
Rio Grande River Basin
Acre Feet
2,000,000
1,600,000
1,200,000
800,000
400,000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Stream Runoff
Moving Average
1990-99 Baseline Average

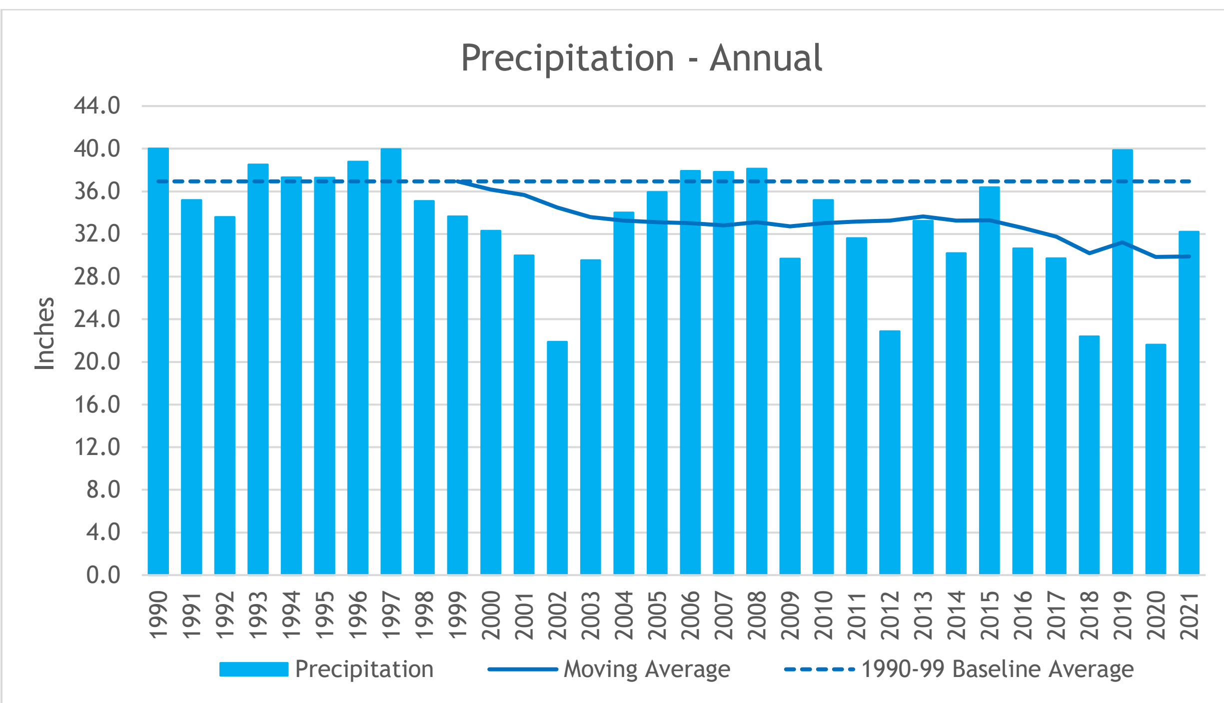
APPENDIX E


Stream Runoff - Annual
Acre Feet
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Stream Runoff

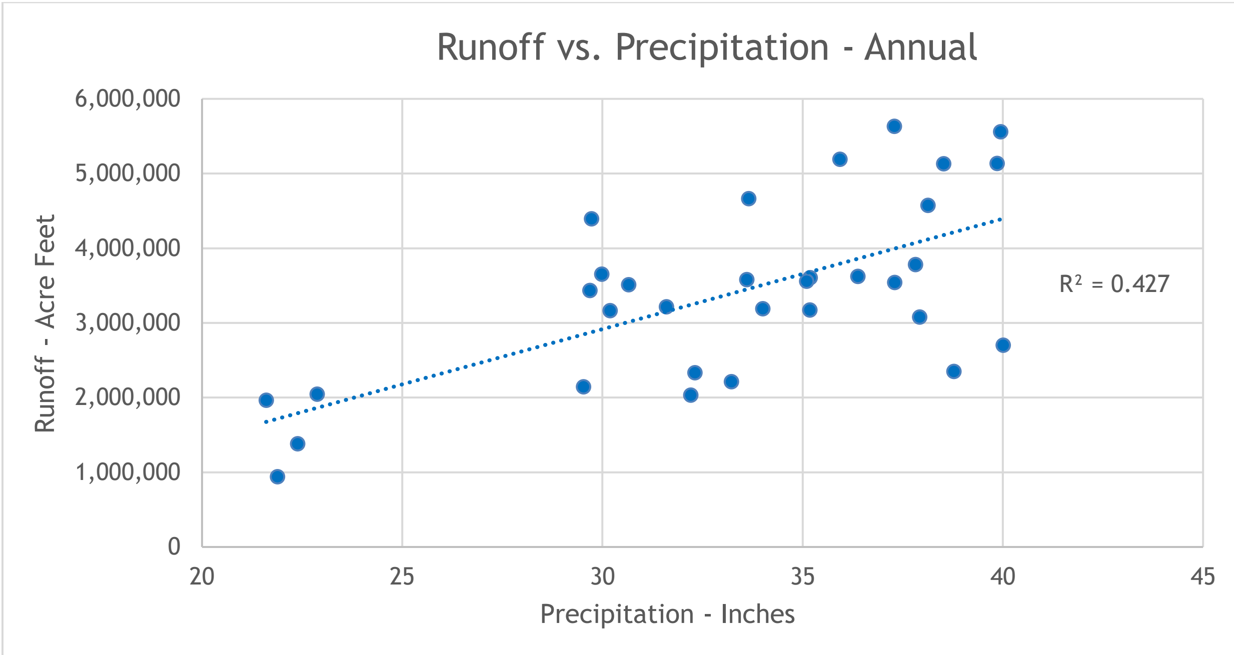

Precipitation - Annual
Inches
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation



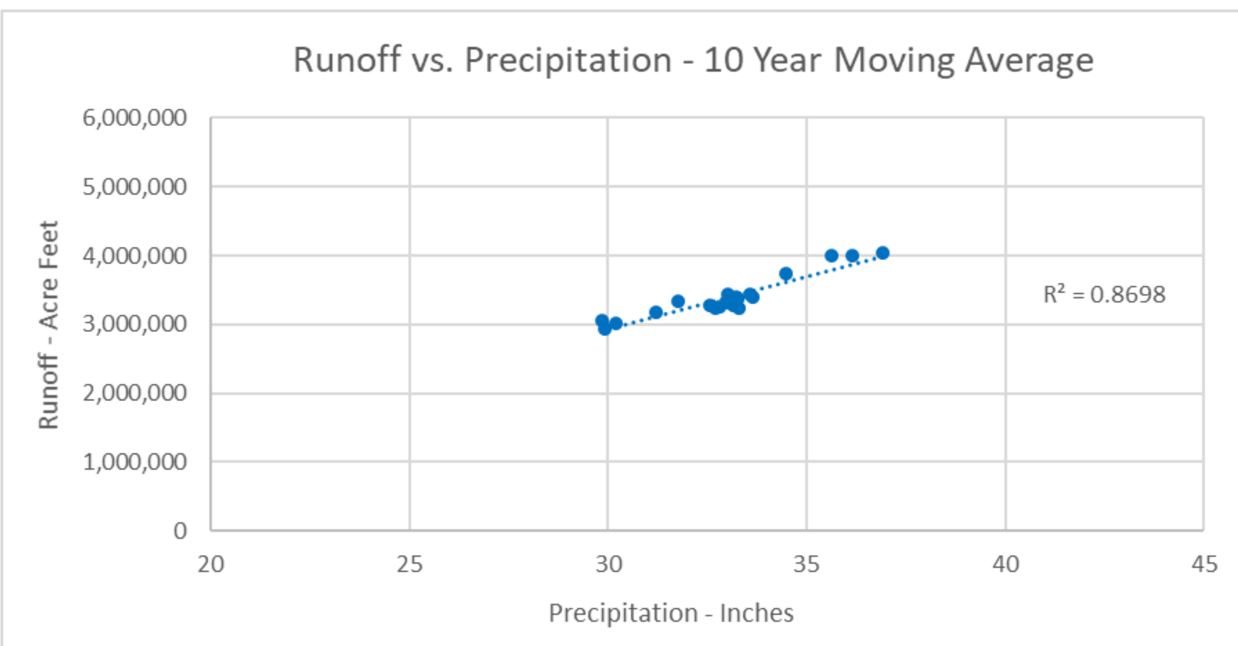
Stream Runoff - Annual
Acre Feet
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Stream Runoff
Moving Average
1990-99 Baseline Average



Precipitation - Annual
Inches
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

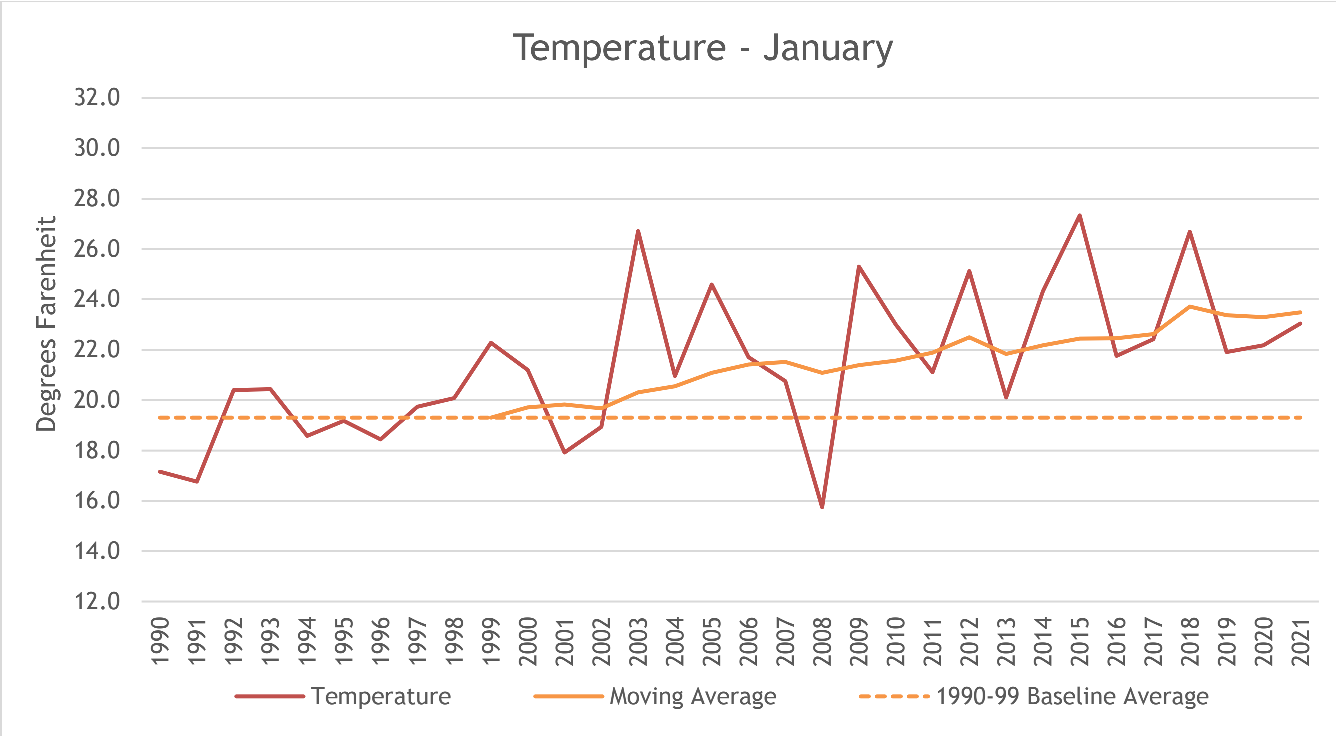


Runoff vs. Precipitation - Annual
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
20
25
30
35
40
45
Runoff - Acre Feet
Precipitation - Inches
R² = 0.427

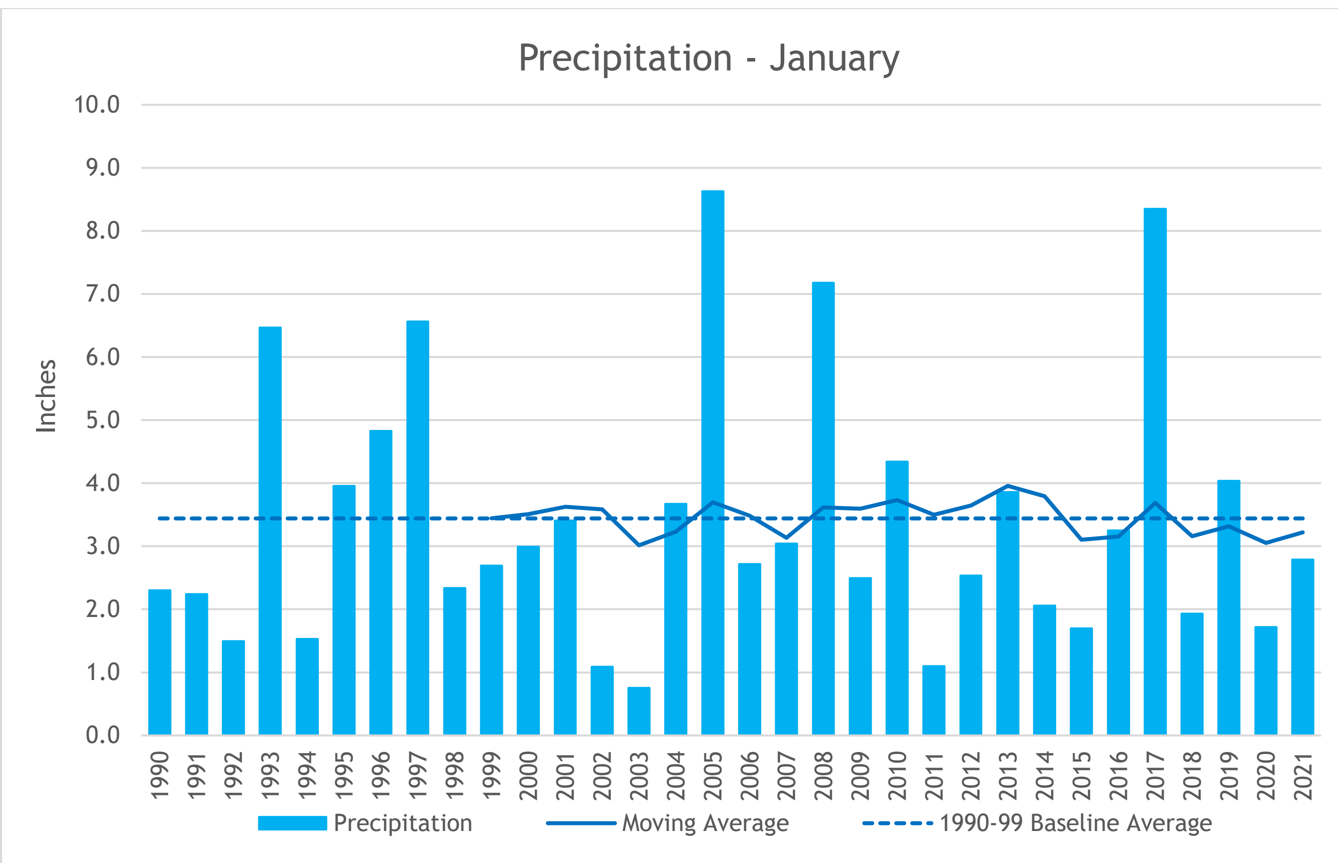


Runoff vs. Precipitation - 10 Year Moving Average
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
20
25
30
35
40
45
Runoff - Acre Feet
Precipitation - Inches
R² = 0.8698

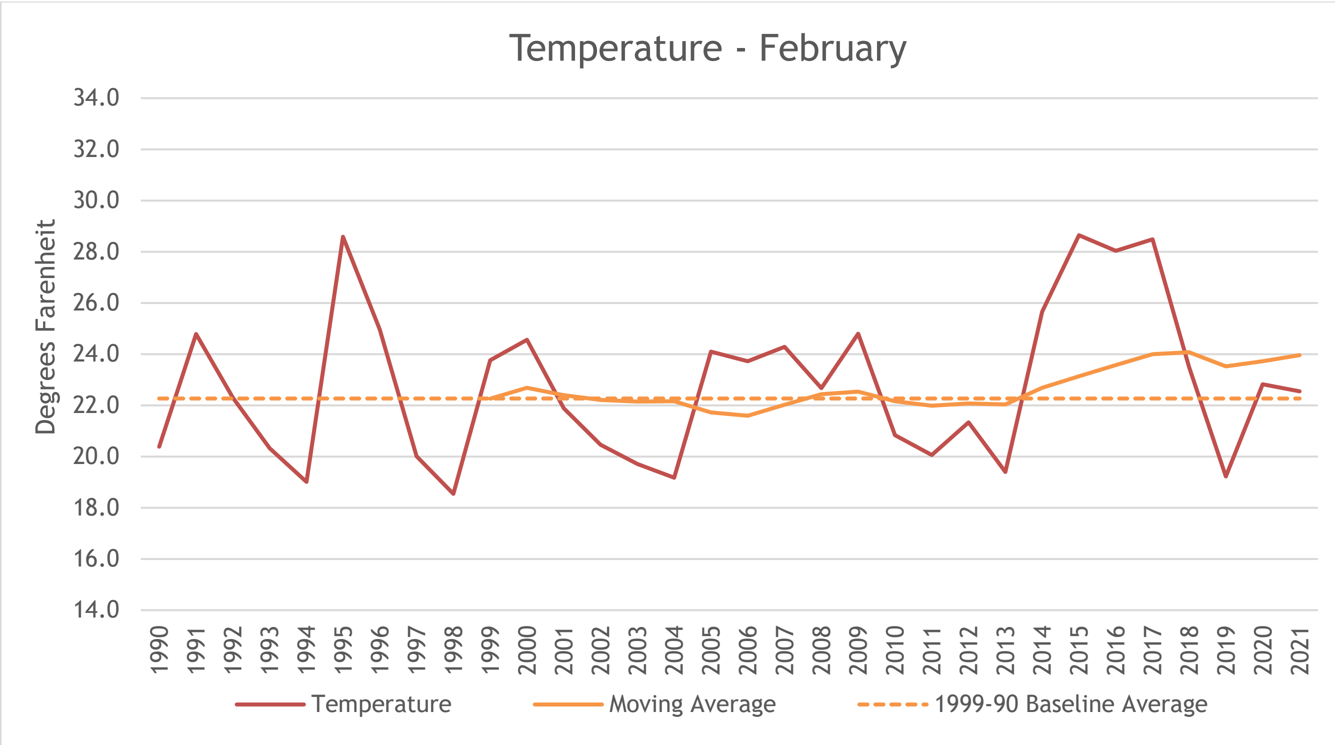
APPENDIX F

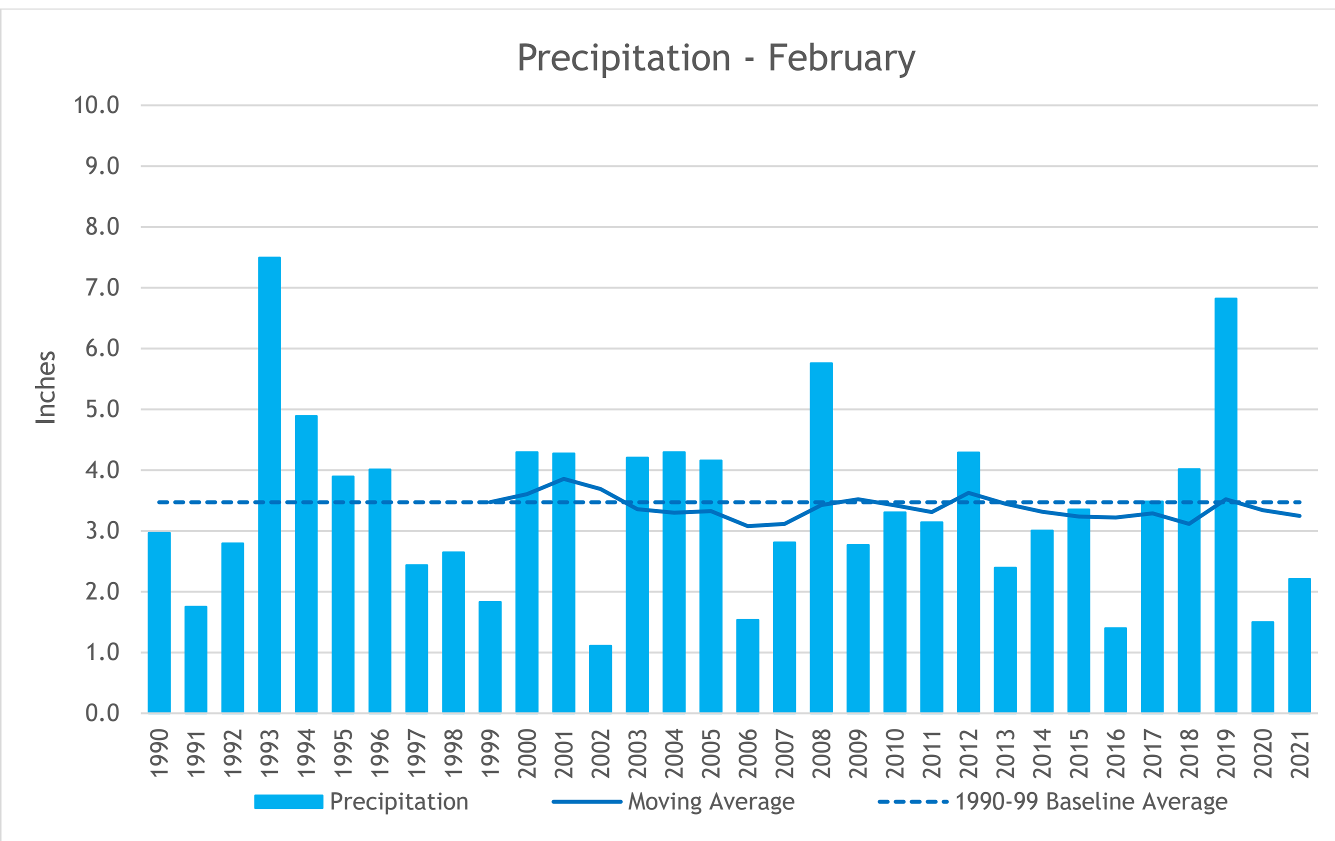


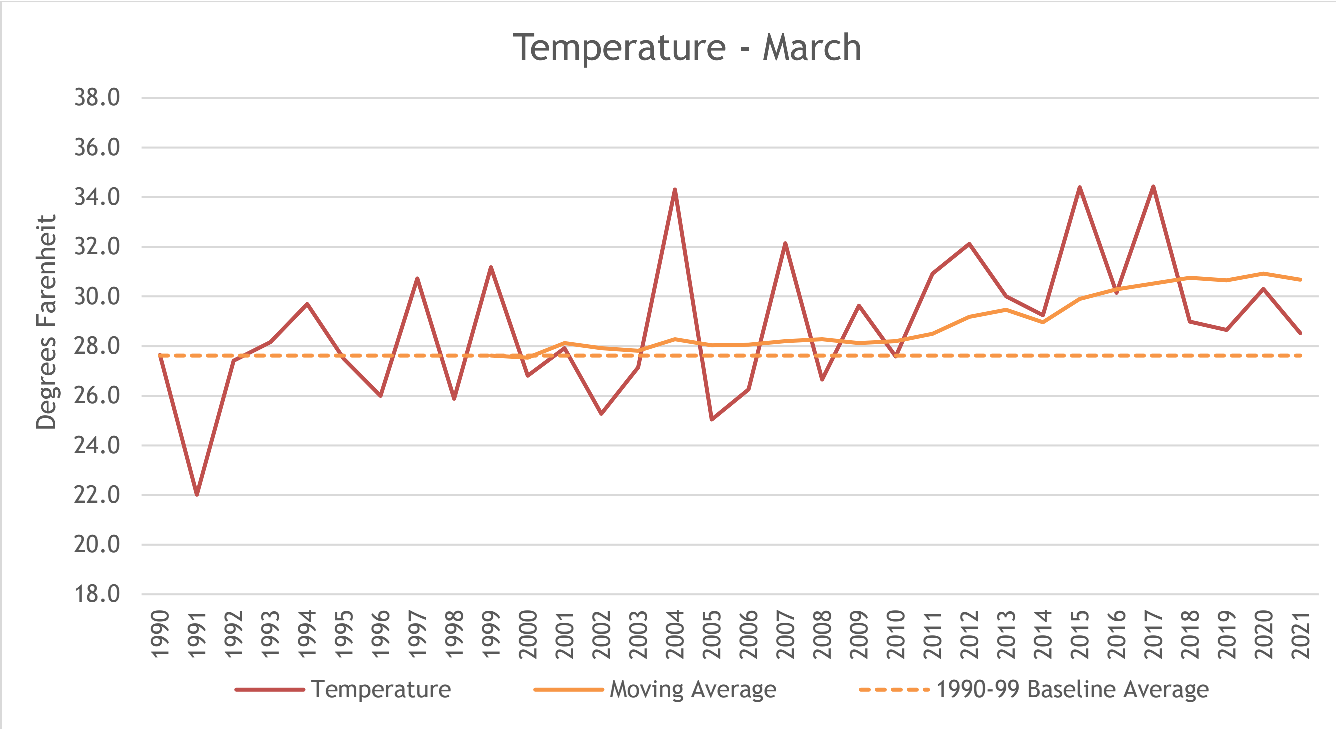
Temperature - January
Degrees Farenheit
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

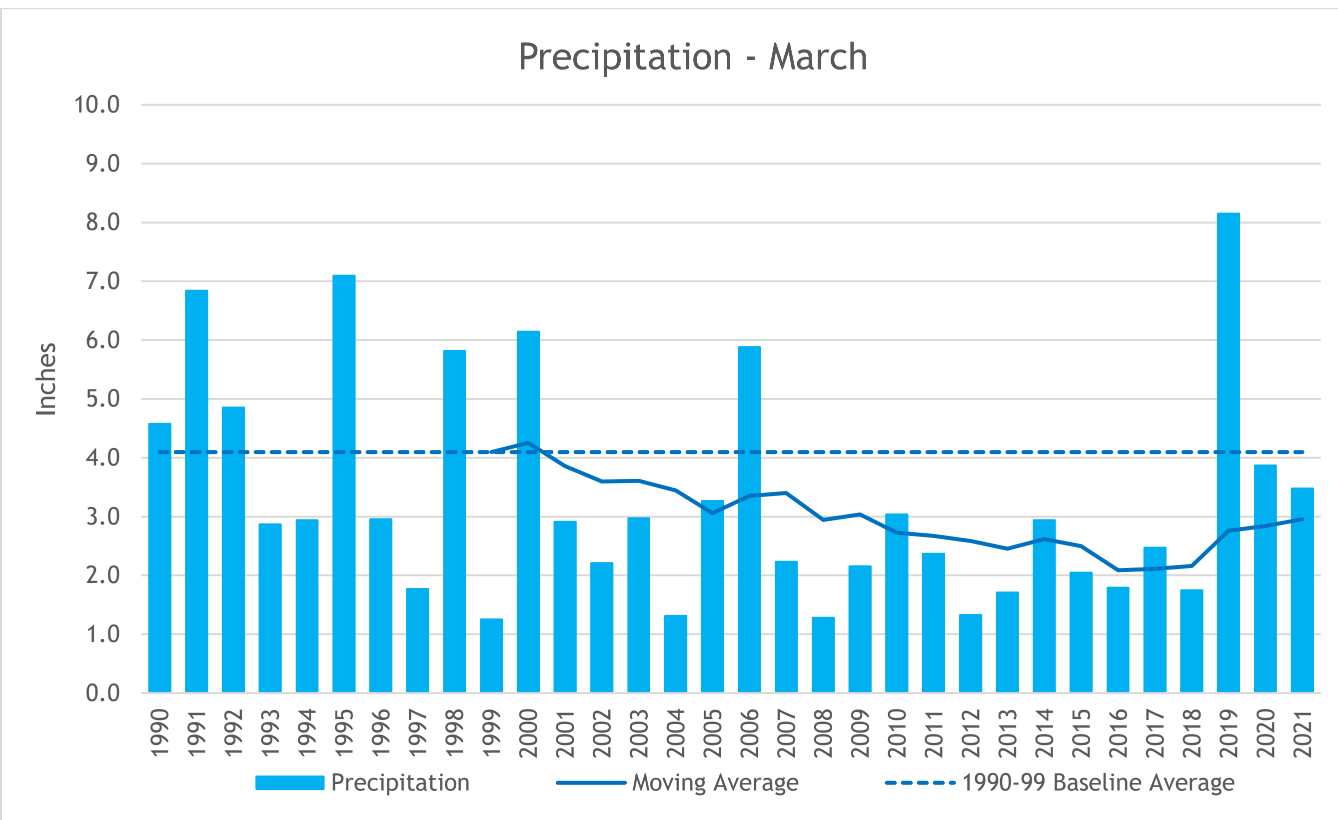


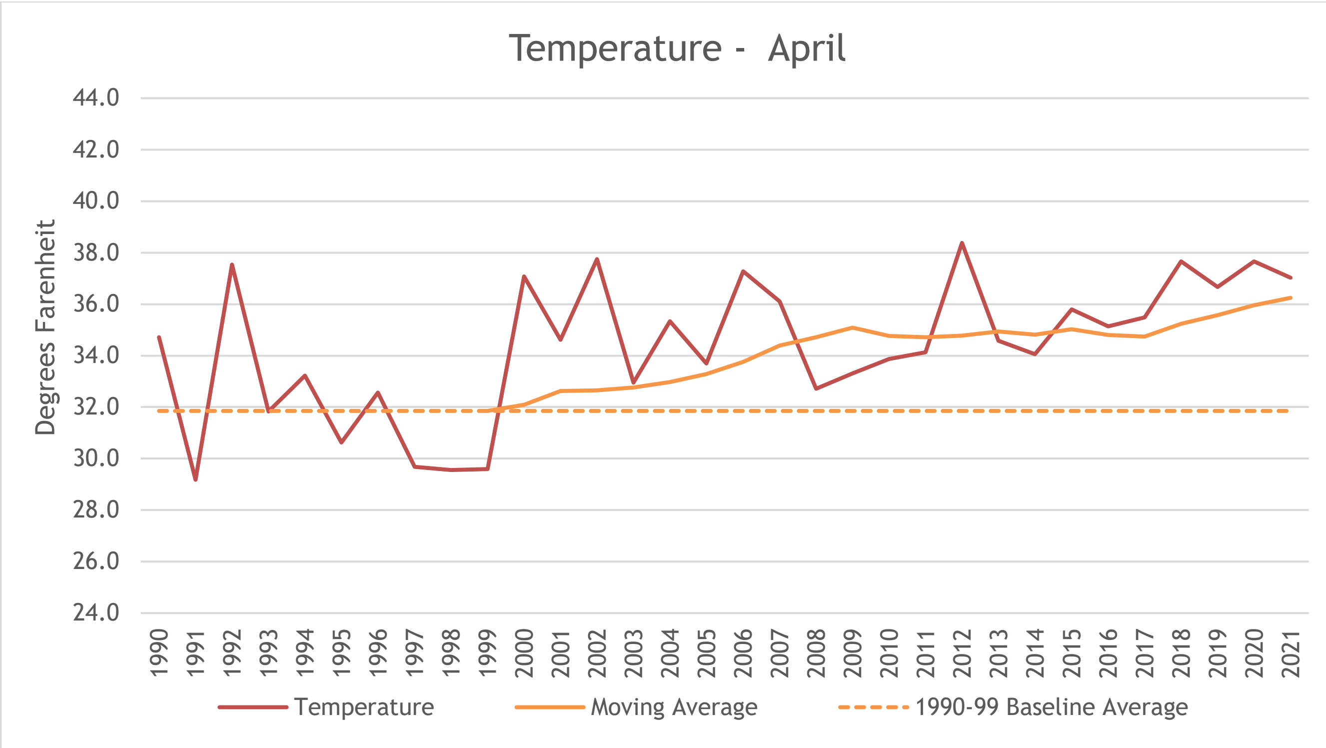
Precipitation - January
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

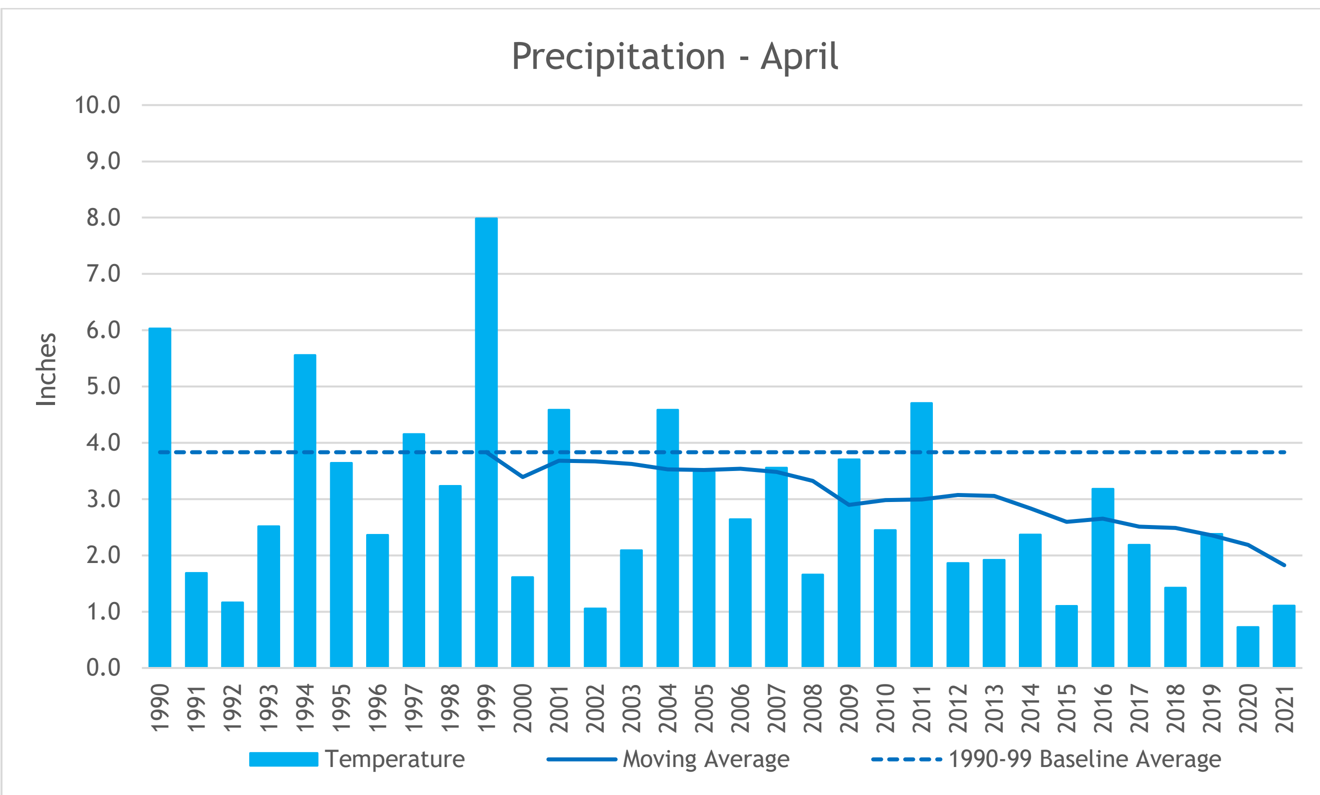

Temperature - February
Degrees Farenheit
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1999-90 Baseline Average

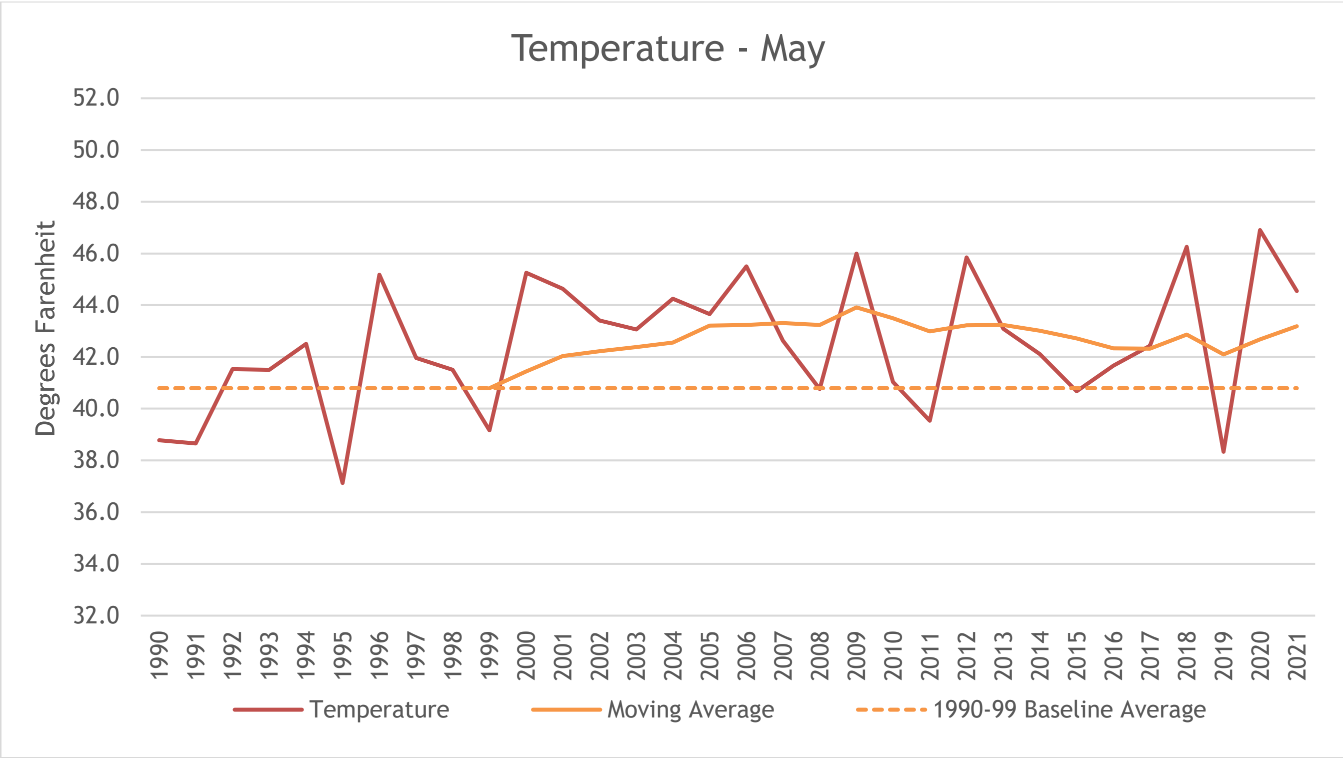

Precipitation - February
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - March
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
Degrees Farenheit
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

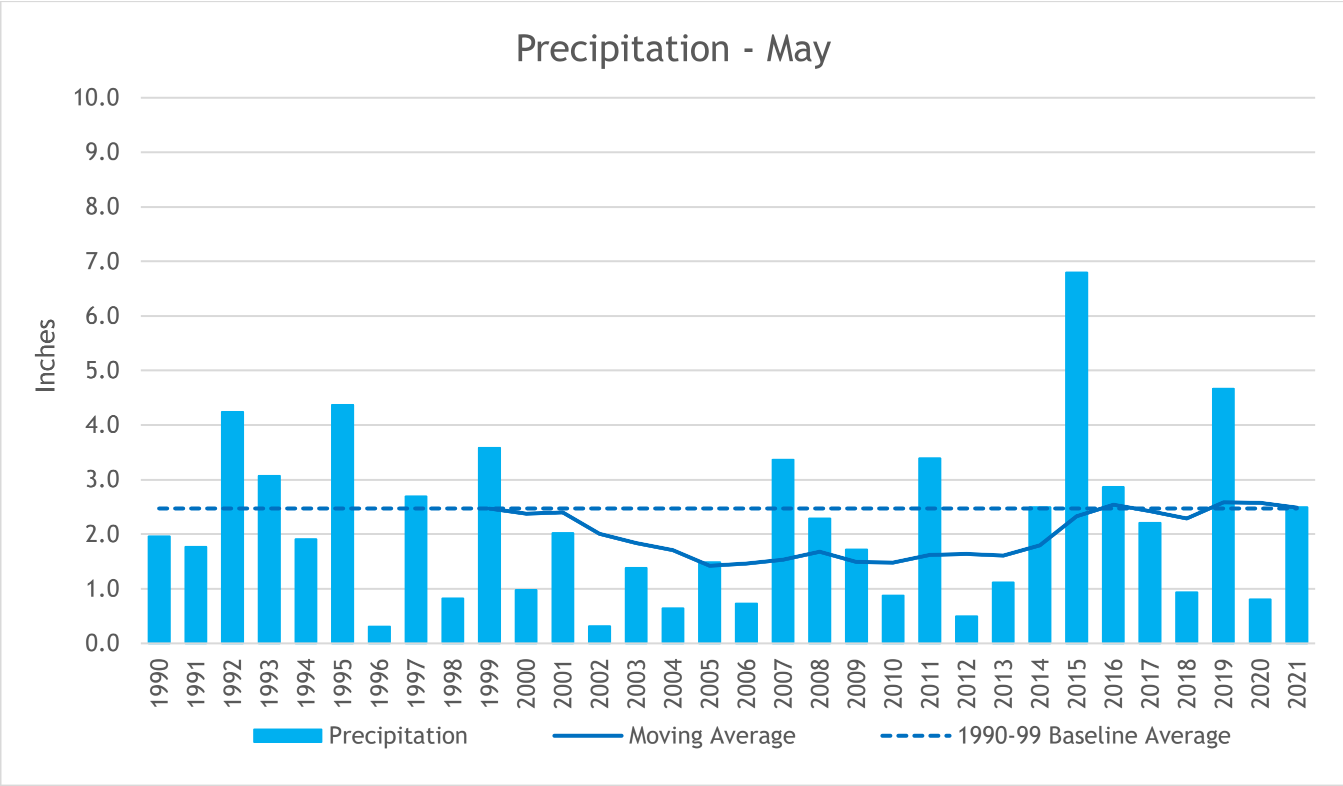

Precipitation - March
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Inches
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - April
Degrees Farenheit
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

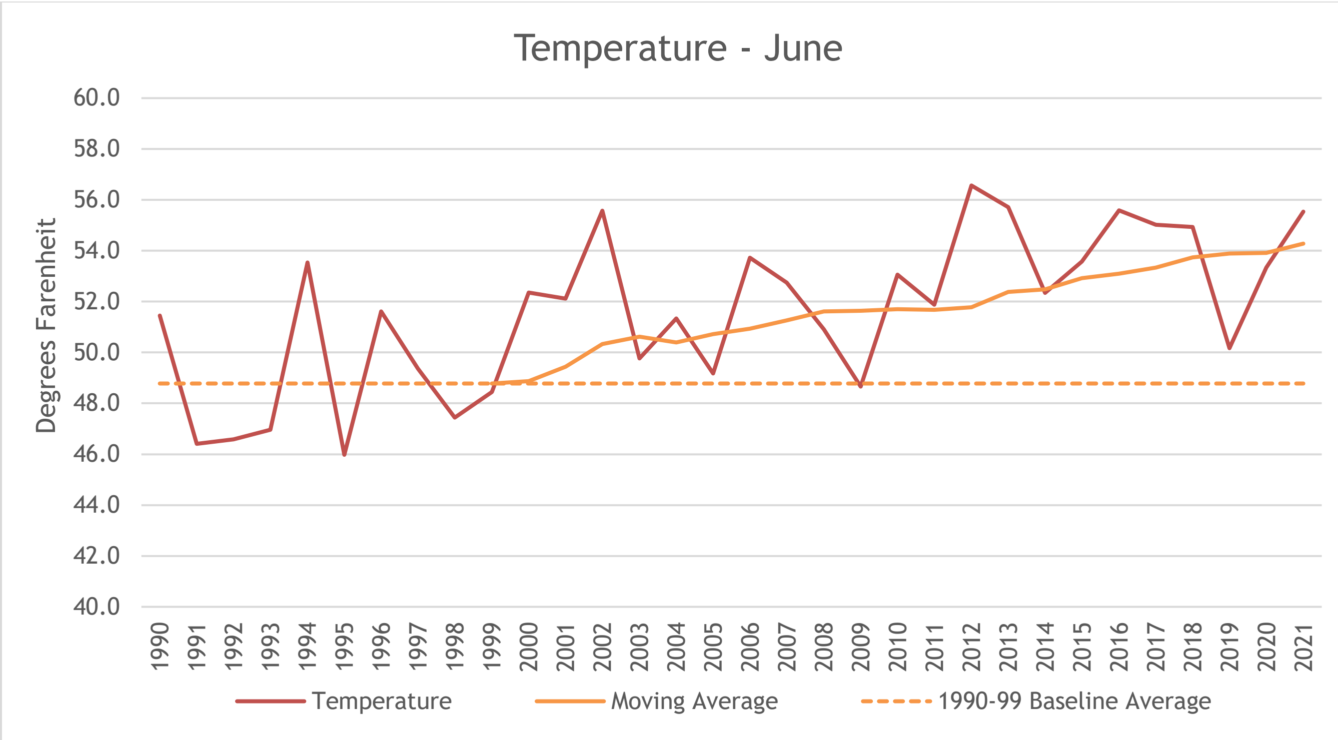

Precipitation - April
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

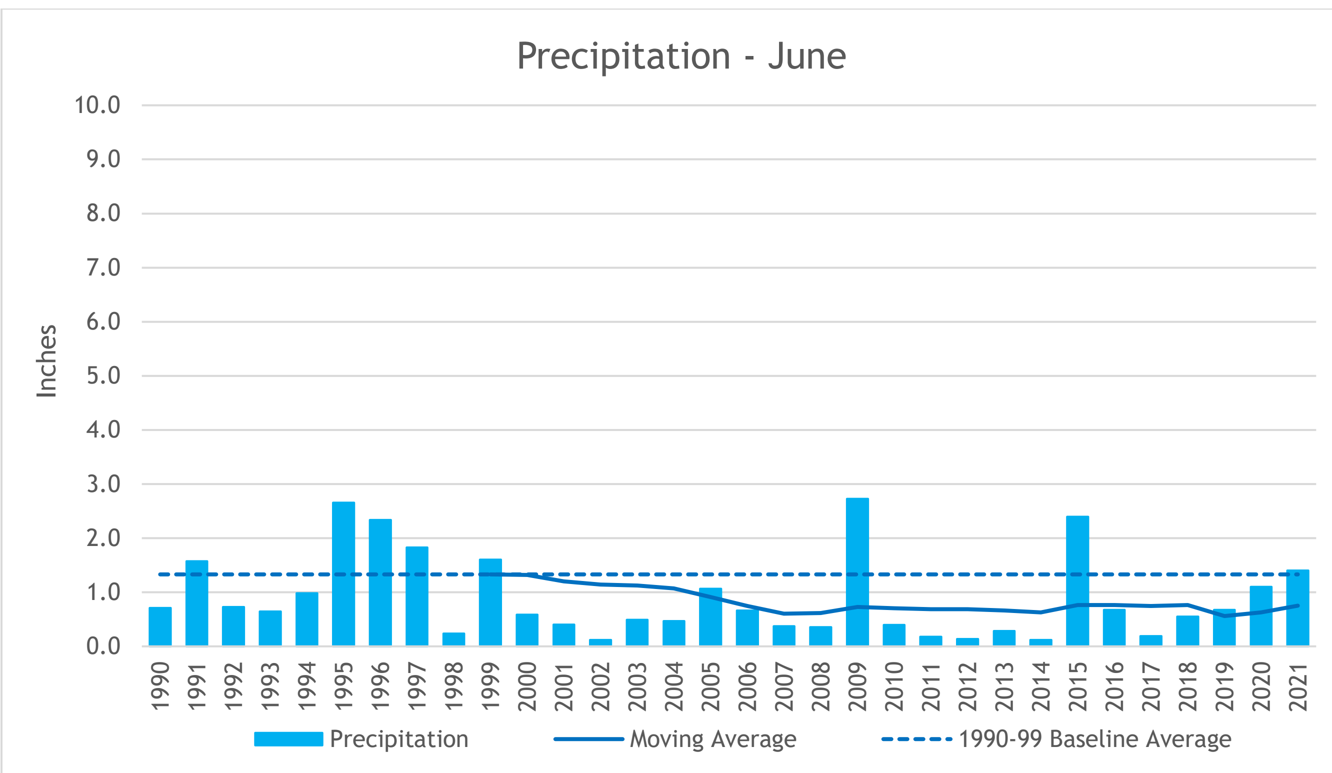


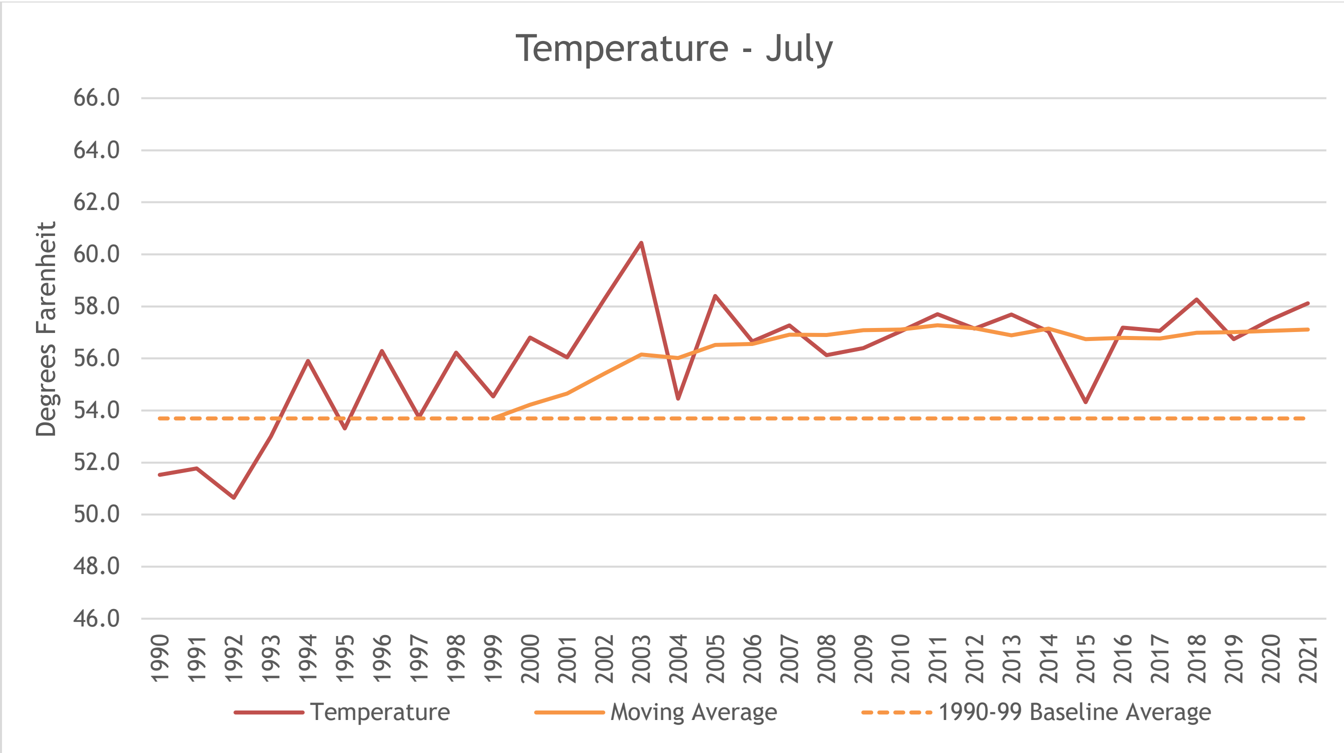
Temperature - May
Degrees Farenheit
52.0
50.0
48.0
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

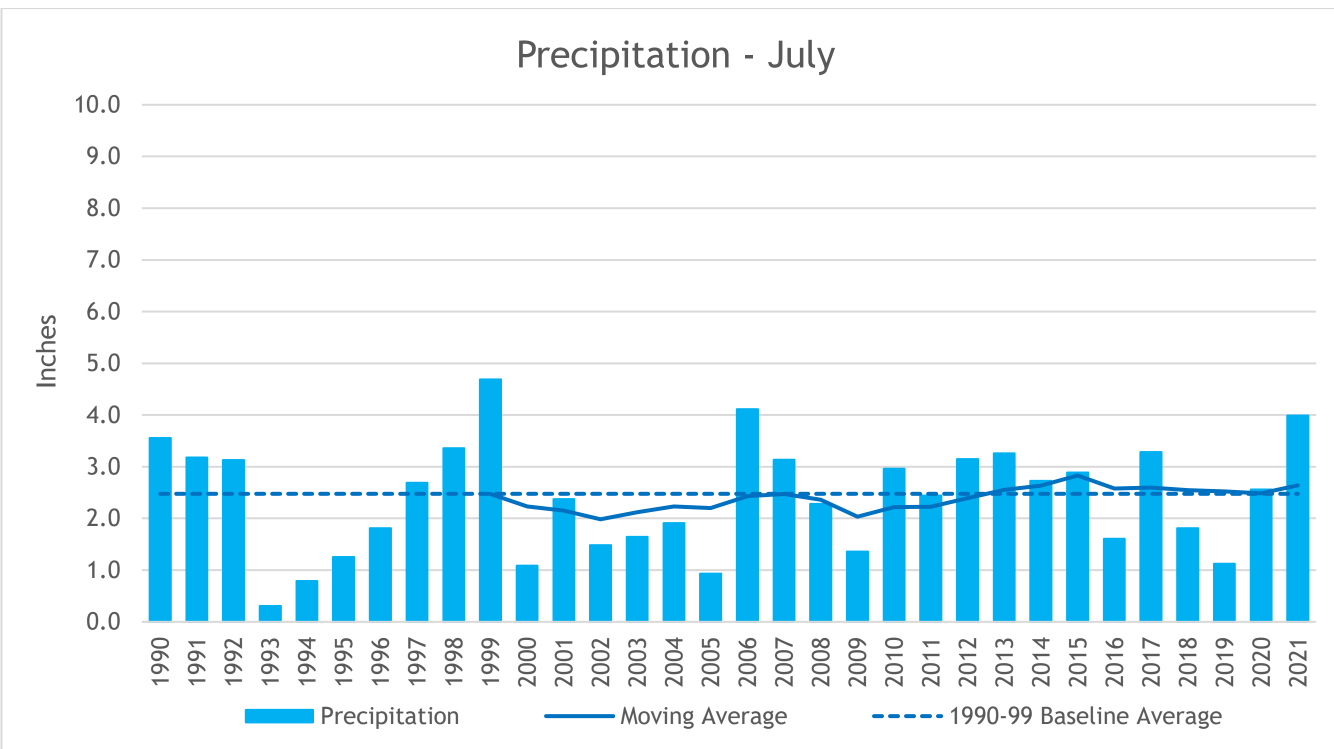


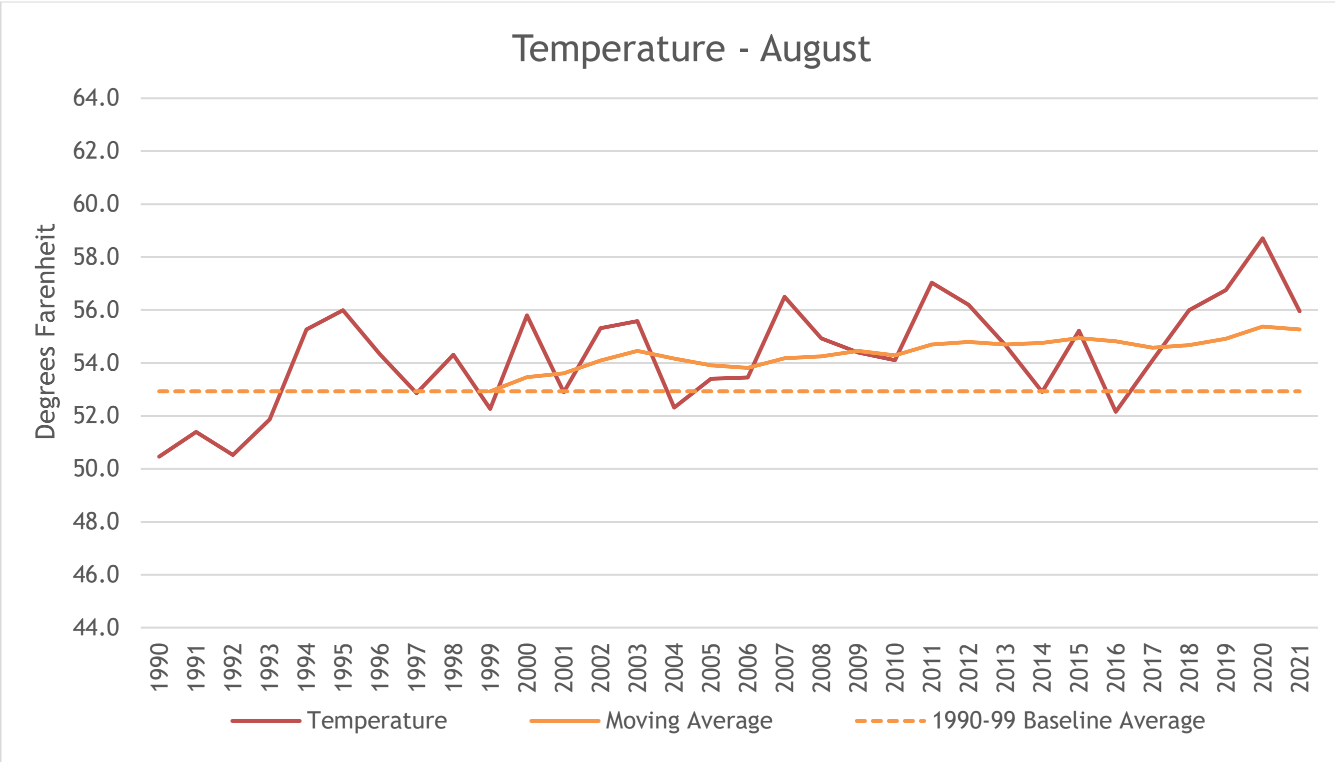
Precipitation - May
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

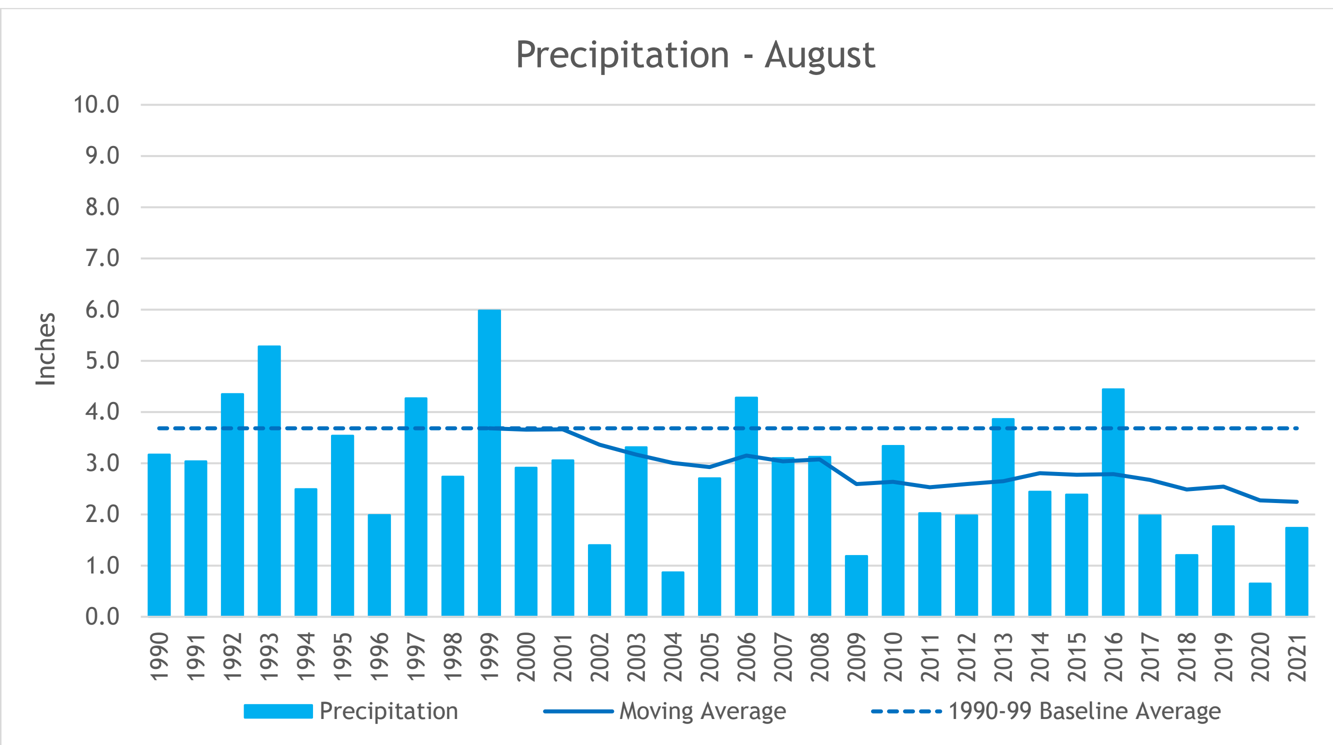

Temperature - June
60.0
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
42.0
40.0
Degrees Farenheit
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Temperature
Moving Average
1990-99 Baseline Average

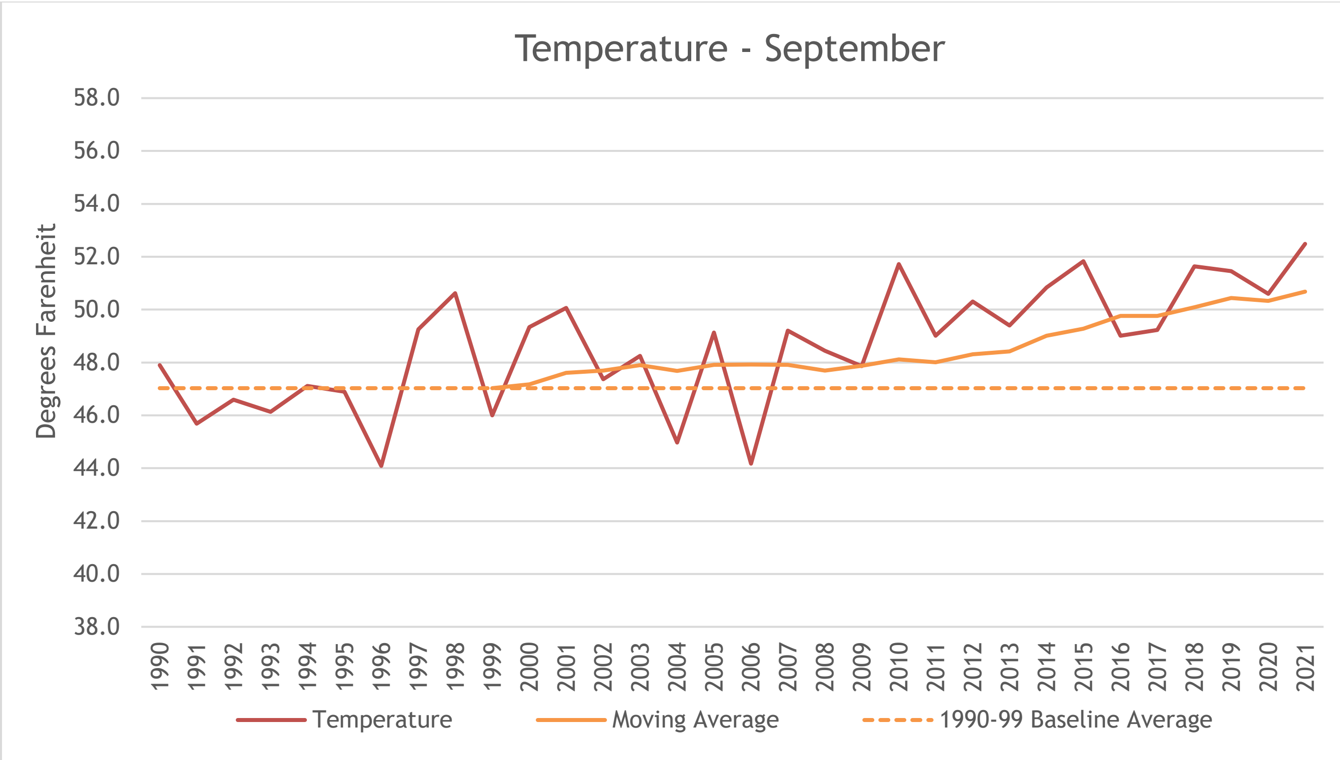

Precipitation - June
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Inches
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Precipitation
Moving Average
1990-99 Baseline Average

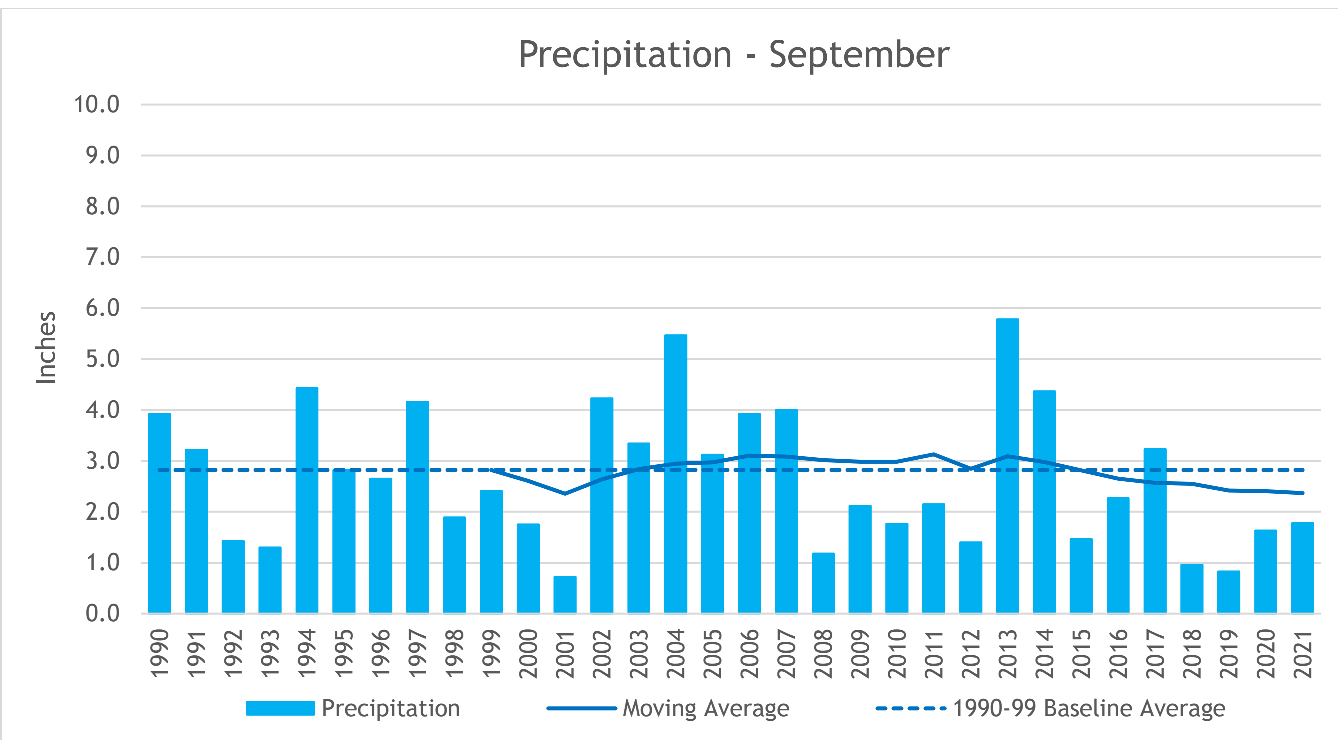

Temperature - July
Degrees Farenheit
66.0
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
48.0
46.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

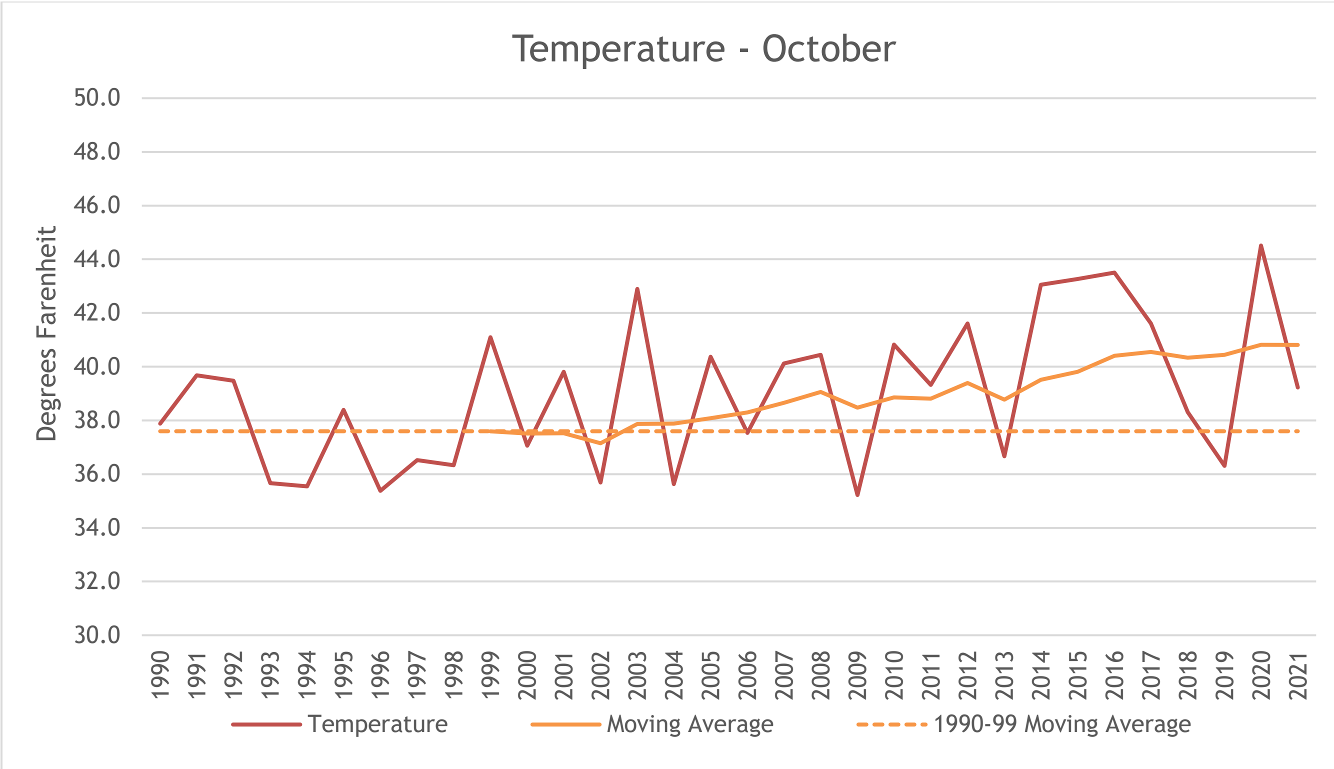

Precipitation - July
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average

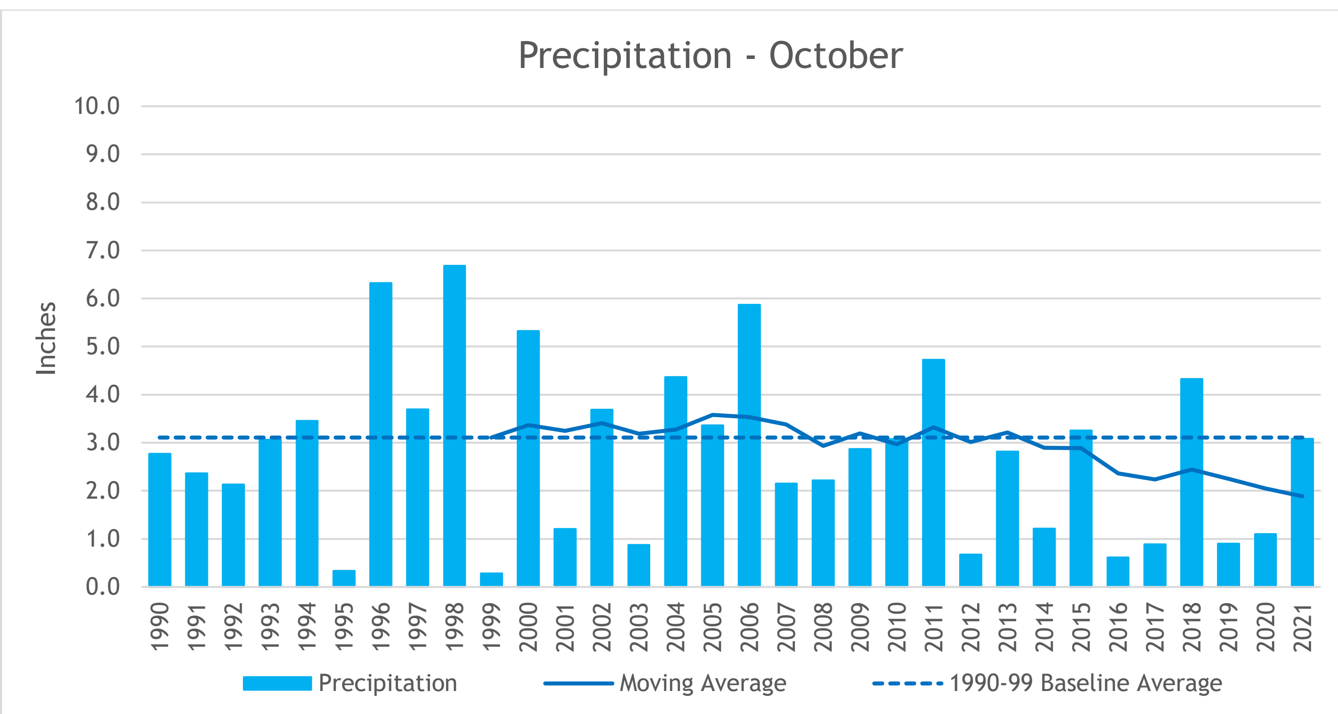

Temperature - August
Degrees Farenheit
64.0
62.0
60.0
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average

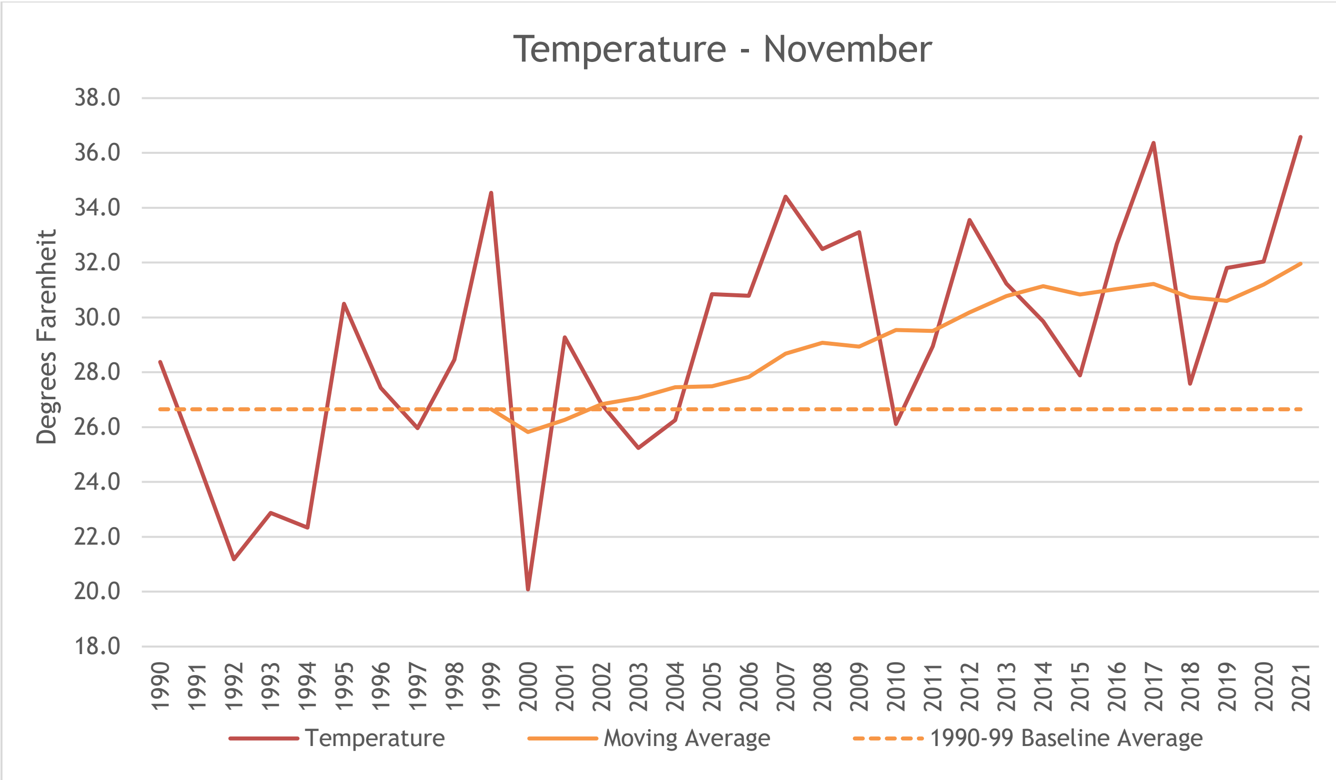

Precipitation - August
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - September
Degrees Farenheit
58.0
56.0
54.0
52.0
50.0
48.0
46.0
44.0
42.0
40.0
38.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Baseline Average


Precipitation - September
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - October
Degrees Farenheit
50.0
48.0
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Temperature
Moving Average
1990-99 Moving Average


Precipitation - October
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - November
Degrees Farenheit
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
1990
1991
1992
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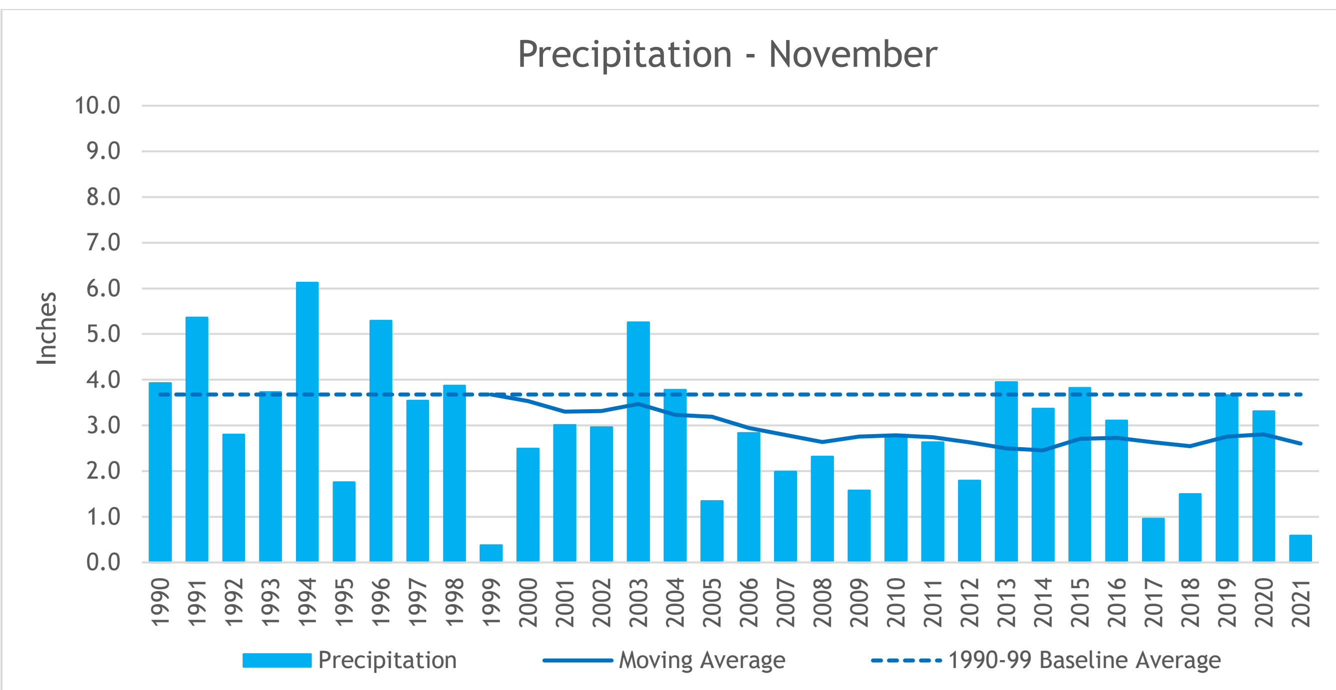
2020
2021
Temperature
Moving Average
1990-99 Baseline Average


Precipitation - November
Inches
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1990
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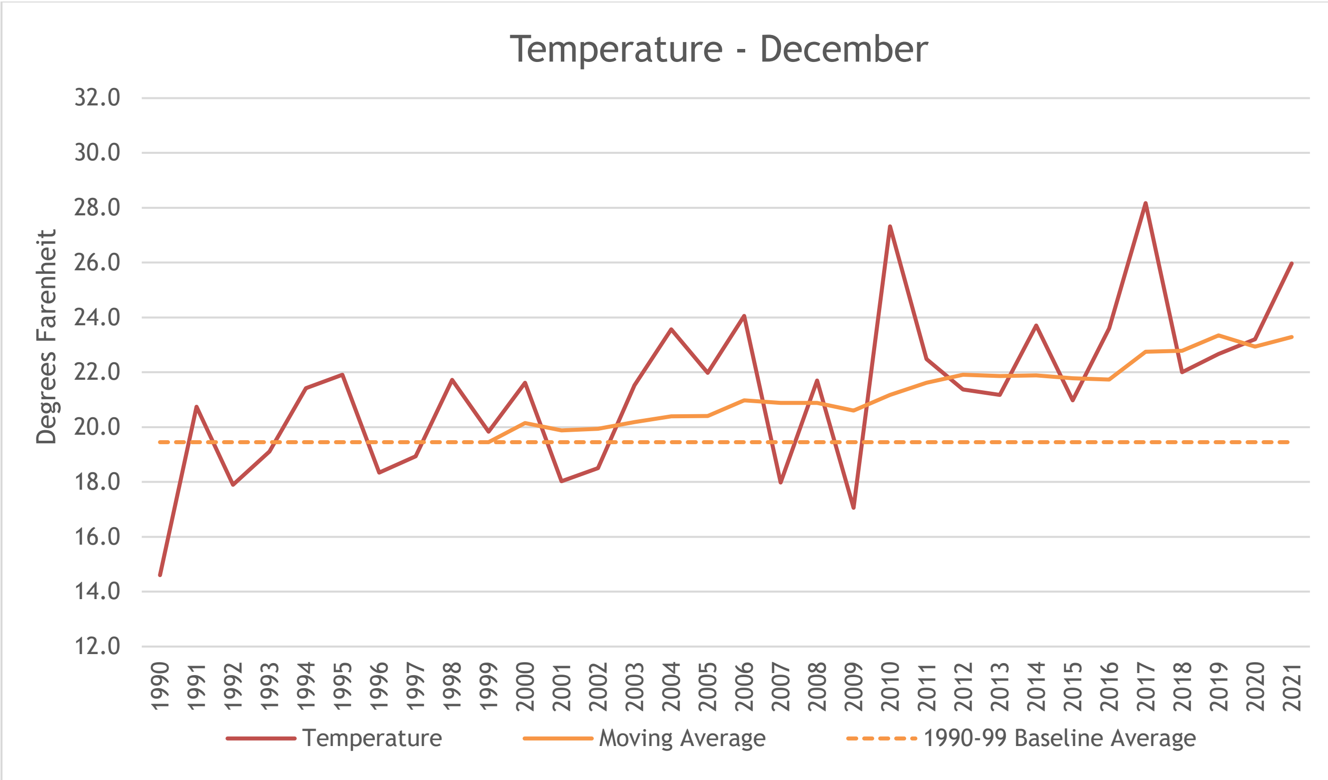
2021
Precipitation
Moving Average
1990-99 Baseline Average


Temperature - December
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
Degrees Farenheit
1990
1991
1992
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1994
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1998
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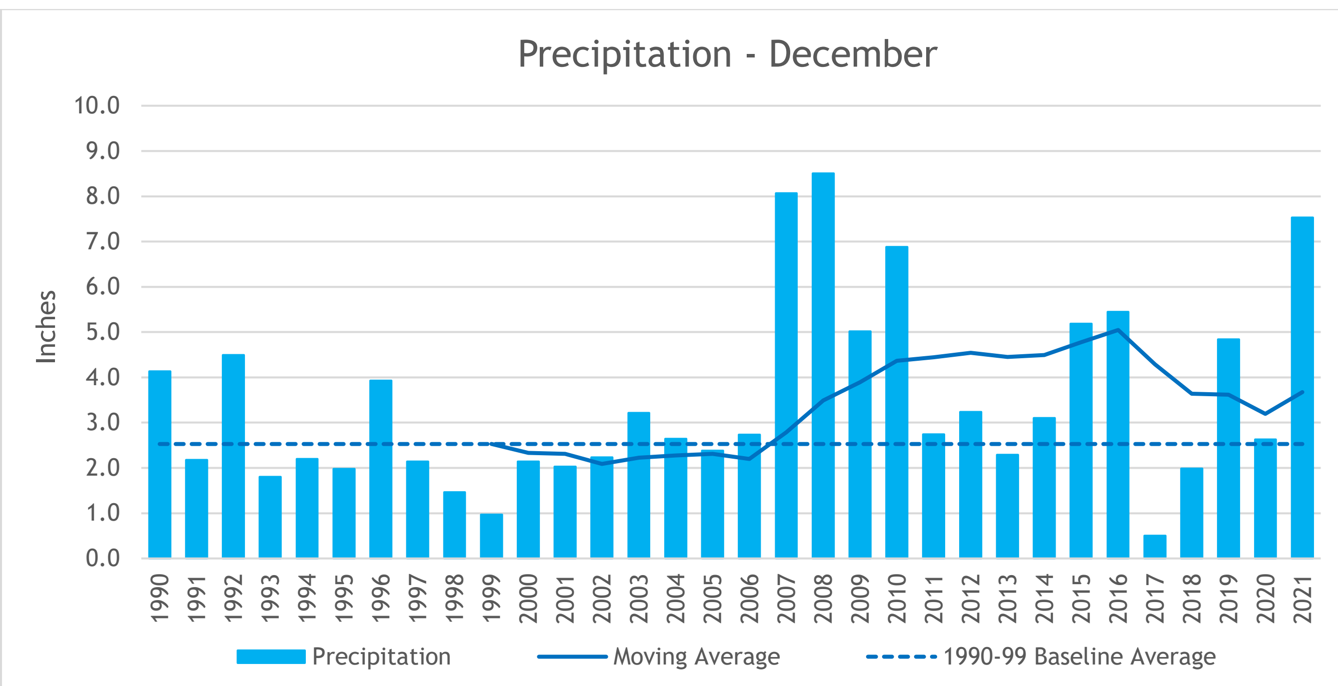
2016
2017
2018
2019
2020
2021
Temperature
Moving Average
1990-99 Baseline Average


Precipitation - December
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Inches
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2018
2019
2020
2021
Precipitation
Moving Average
1990-99 Baseline Average