Appendix A1
Climate Assessment

River Road
San Antonio, Texas
General Investigations Feasibility Study
Integrated Draft Feasibility Report and Environmental Impact Assessment

July 2020

US Army Corps
of Engineers®
Fort Worth District

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1 Introduction

The US Army Corps of Engineers (USACE) Civil Works Program and its water resources infrastructure represent a tremendous Federal investment that supports public health and safety, regional and national economic development, and national ecosystem restoration goals.

The hydrologic and coastal processes underlying this water resources management infrastructure are very sensitive to changes in climate and weather. Therefore, USACE has a compelling need to understand and adapt to climate change and variability to continue providing authorized performance despite changing conditions. The objective is to mainstream climate change adaptation in all activities to help enhance the resilience of our built and natural water-resource infrastructure and reduce its potential vulnerabilities to the effects of climate change and variability.

1.1 Climate

The city of San Antonio is located in the south-central portion of Texas on the Balcones escarpment. Northwest of the city, the terrain slopes upward to the Edwards Plateau, and to the southeast it slopes downward to the Gulf Coastal Plains. Soils are blackland clay and silty loam on the Plains and thin limestone soils on the Edwards Plateau. With its location on the northwest edge of the Gulf Coastal Plain, San Antonio experiences a modified subtropical climate. During the summer the climate becomes more tropical like with prevailing south and southeast winds. The moderating effects of the Gulf of Mexico prevent extremely high temperatures. Summers are usually long and hot with daily maximum temperatures above 90ºF more than 80 percent of the time. In many years, summer conditions continue into September and sometimes to October. The average monthly temperatures range from the 50sºF in winter to 80sºF in summer. The historic recorded high and low temperatures occurred 6 September 2000 (111ºF) and 21 January 1949 (0º F).

1.2 Precipitation

San Antonio is situated between a semi-arid area to the west and a much wetter and more humid area to the east, allowing for large variations in monthly and annual precipitation amounts. The average long-term annual precipitation for San Antonio is around 29 inches, although, it may range from as low as 10 to near 50 inches from one year to another. Precipitation extremes vary from 10.11 inches in 1917 to 52.28 inches in 1973. Most precipitation occurs in May, June, September, and October. During some of these events, rain has exceeded 5 inches in several hours and caused flash flooding. The net lake evaporation rates range from 0.08 inches per day in January to 0.29 inches per day in August. Monthly and yearly precipitation totals from 2000 to 2019 are shown in Table A-1. Yearly precipitation totals from 1934 – 2018 are shown in Figure A-1.

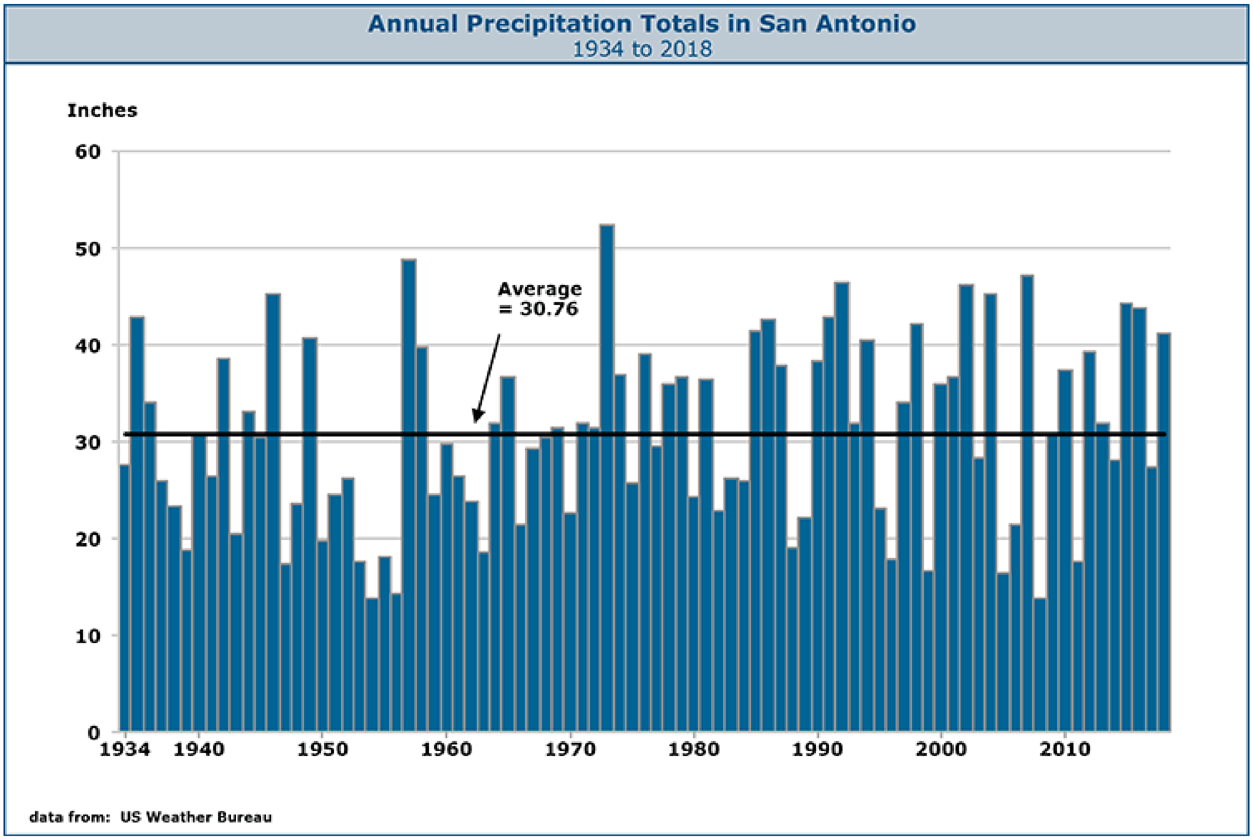


Figure A-1 Annual Precipitation in San Antonio, Texas

Table A-1. Monthly and Yearly Precipitation 2000 – 2019

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	1.40	2.20	0.91	1.22	3.59	7.61	0.34	0.16	2.65	5.62	8.58	1.57	35.85
2001	2.85	0.70	2.77	2.29	2.48	3.39	0.50	7.83	4.05	2.06	4.37	3.43	36.72
2002	0.37	0.42	1.19	3.82	2.26	1.48	16.92	0.54	7.02	7.64	2.08	2.53	46.27
2003	0.99	2.15	0.77	0.17	0.12	2.90	8.12	1.65	9.21	1.94	0.32	0.11	28.45
2004	2.31	1.73	2.35	5.02	1.80	9.47	0.61	1.10	1.92	9.47	9.46	0.08	45.32
2005	2.18	2.42	2.00	0.01	2.97	0.81	2.10	1.22	1.39	1.14	0.20	0.10	16.54
2006	0.35	0.62	1.36	1.40	3.80	1.63	1.41	0.03	4.11	3.44	0.75	2.44	21.34
2007	4.33	0.08	7.24	4.61	3.35	6.47	11.76	6.77	1.09	0.75	0.40	0.40	47.25
2008	0.42	0.20	1.82	0.83	0.66	0.01	3.86	4.98	0.46	0.26	0.01	0.25	13.76
2009	0.27	0.65	2.51	2.05	1.57	0.45	0.48	0.45	6.35	11.90	2.09	1.92	30.69
2010	4.45	4.38	2.09	3.57	4.48	4.24	3.68	0.07	9.37	0.17	0.26	0.63	37.39
2011	2.66	0.49	0.01	0.03	0.84	1.58	0.96	0.15	2.93	3.28	1.81	2.84	17.58
2012	3.99	5.63	3.24	0.04	9.84	0.11	3.79	2.41	7.31	2.40	0.27	0.37	39.40
2013	2.83	0.10	0.95	2.77	13.19	2.02	0.73	0.85	3.70	2.81	1.50	0.55	32.00
2014	0.23	0.42	1.06	0.68	4.97	5.38	3.25	0.08	1.77	1.91	7.21	1.24	28.20
2015	3.67	0.53	2.97	7.54	8.57	6.42	0.07	0.29	2.32	7.78	2.58	1.48	44.22
2016	1.38	1.55	3.56	6.19	9.14	2.39	0.33	4.91	6.30	0.16	1.79	6.22	43.92
2017	2.72	3.61	2.09	2.89	1.76	0.40	0.16	5.87	2.80	0.46	0.53	4.04	27.33
2018	0.28	1.91	4.02	0.36	0.97	0.71	4.87	0.62	16.86	6.47	1.78	2.35	41.20
2019	1.63	0.47	0.46	3.47	3.30	5.51	0.14	0.31	1.45	4.02	0.74	0.52	22.02

1.3 Technical Hydrology and Hydraulic Analysis

A technical hydrology and hydraulics analysis was performed but hydrology and hydraulics models were not developed by the Fort Worth District Water Resources Branch for this study. The majority of the technical data in this Appendix was developed by San Antonio River Authority (SARA). Pertinent technical information was extracted from these sources to develop a representative summary of the project area site conditions. Additional technical data was developed from the Fort Worth District Water Resource Branch files and the sources noted.

2 Qualitative Climate Assessment

Engineering and Construction Bulletin No. 2018-14 "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects" provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate preparedness and resilience policy and ER 1105-2-101. The objective of ECB-2018-14 is to enhance USACE climate preparedness and resilience by incorporating relevant information about observed and expected climate change impacts in hydrologic analyses for planned, new, and existing USACE projects. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant climatic and hydrologic variables. The ECB helps support a qualitative assessment of potential climate change threats and impacts, focusing on those aspects of climate and hydrology relevant to the project's problems, opportunities, and alternatives, and include consideration of both past (observed) changes as well as projected, future (modeled) changes.

2.1 Project Location and Gaging Information

The River Road project area is located within the Hydrologic Unit Code (HUC) 121003 - Central Texas Coastal. Figure A-2 shows the HUC location map for Texas and the location of the study area.

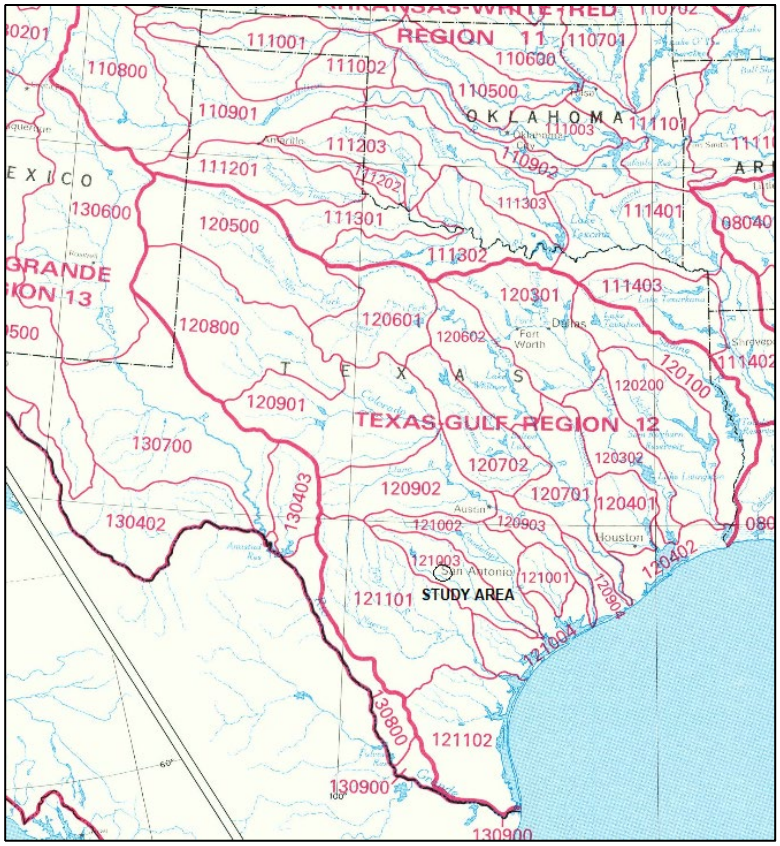


Figure A-2. HUC locations in Texas

The nearest stream gage to the project area is the USGS 08178000 San Antonio River at San Antonio, Texas. The gage is located along the San Antonio River, downstream of US 281, upstream of Interstate 10 and on the S Alamo St crossing. The gages is 3 miles downstream of the project area. Pertinent gage data is as follows:

Bexar County, Texas
Hydrologic Unit Code 12100301
Latitude 29°24'34", Longitude 98°29'41" NAD27
Drainage area 41.8 square miles
Contributing drainage area 41.8 square miles
Gage datum 605.26 feet above NGVD29
Gage installed in 1915

The gage is only slightly affected by regulation. The sole dam upstream of the project area is Olmos Reservoir located about 2.5 miles northeast. The dam is own and operated by SARA for flood control. The drainage area for the reservoir is 32 square miles and the flood capacity is 12,600 acre-feet.

Figure A-3 shows the location of the gage and its proximity to River Road.

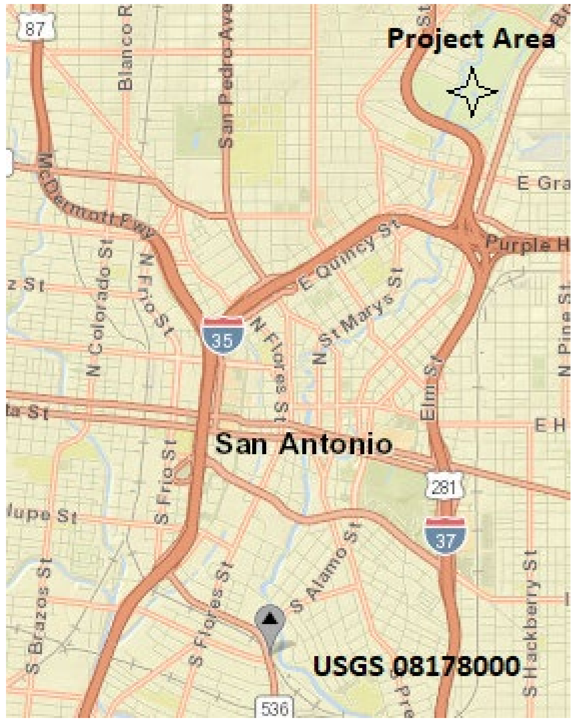


Figure A-3. USGS 08178000 San Antonio River at San Antonio, Texas

2.2 Literature Review

A literature search was conducted to locate information related to observed and projected climate trends. This USACE literature synthesis provides a summarization of reputable peer-reviewed literature focusing on a regional basis for project studies.

According to “Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Texas Gulf Region 12” the general consensus for the Texas Gulf Region is a mild increase in annual precipitation and streamflow.

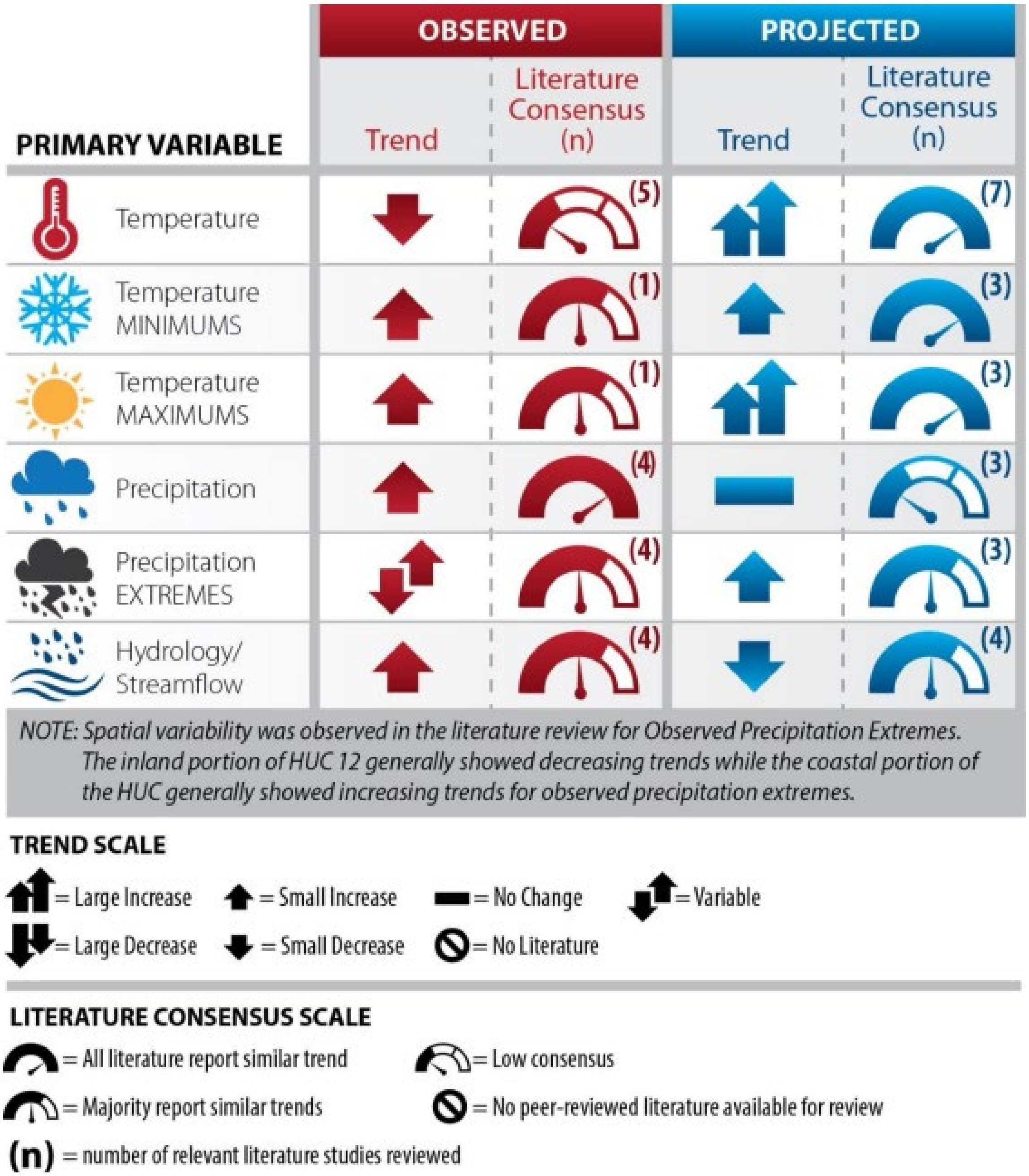


Figure A-4. Observed and Projected Climate Trends and Literary Consensus.

On a larger scale, there has been an increase in the average temperature of the contiguous United States over the past several decades. Table A-1 and Figure A-5 show the change in annual average temperature across the United States. Texas is in the Great Plains South region and is shown in comparison with the other regions in the United States. Figure A-5 shows the trend in San Antonio temperatures.

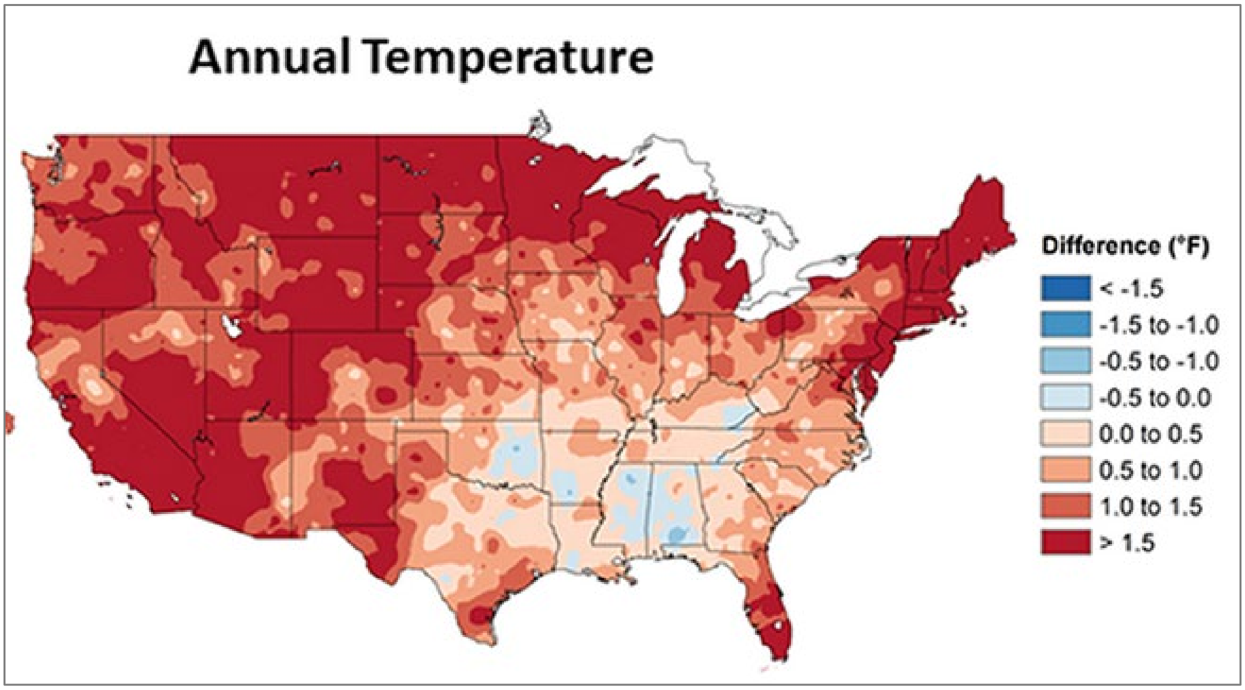


Figure A-5 Change in Average Annual Temperature United States

NCA Region	Change in Annual Average Temperature	Change in Annual Average Maximum Temperature	Change in Annual Average Minimum Temperature
Contiguous U.S.	1.23°F	1.06°F	1.41°F
Northeast	1.43°F	1.16°F	1.70°F
Southeast	0.46°F	0.16°F	0.76°F
Midwest	1.26°F	0.77°F	1.75°F
Great Plains North	1.69°F	1.66°F	1.72°F
Great Plains South	0.76°F	0.56°F	0.96°F
Southwest	1.61°F	1.61°F	1.61°F
Northwest	1.54°F	1.52°F	1.56°F
Alaska	1.67°F	1.43°F	1.91°F
Hawaii	1.26°F	1.01°F	1.49°F
Caribbean	1.35°F	1.08°F	1.60°F

Table A-2. Change in Average Annual Temperature United States[3]

Analysis of observed daily temperature and rainfall records at the San Antonio International Airport weather station shows trends that are consistent with those observed for the United

States. Table A-3 shows the monthly and yearly average temperatures from 1960 – 2019 for the San Antonio area.

Table A-3. San Antonio Monthly and Yearly Average Temperatures 1960 - 2019

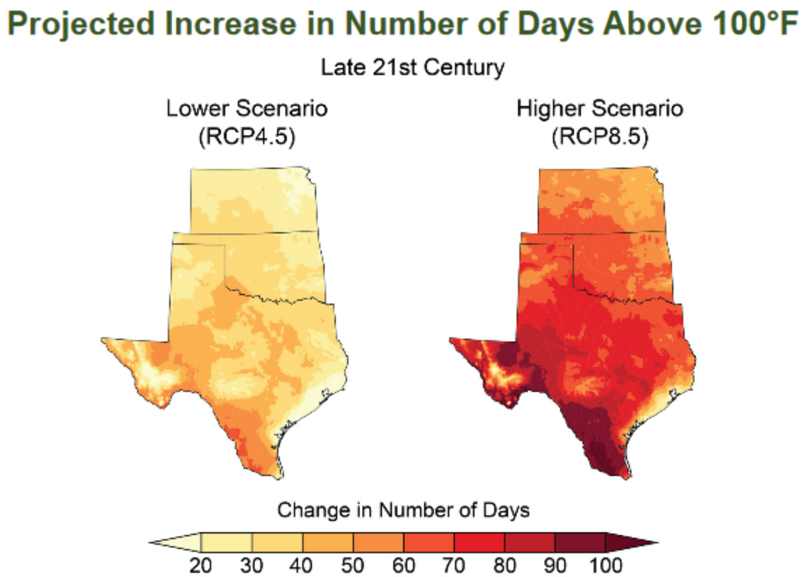
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
1960	50.0	49.8	56.0	69.7	74.0	83.2	84.2	83.5	78.6	73.2	62.2	50.1	67.9
1961	47.9	55.8	65.6	68.5	78.4	81.3	82.5	82.5	80.5	71.1	58.0	54.2	68.9
1962	45.8	62.8	59.1	69.7	77.9	82.3	86.8	87.5	80.9	75.5	60.3	52.1	70.1
1963	46.2	52.5	65.5	74.6	77.7	83.4	85.4	85.7	81.1	74.1	62.4	45.6	69.5
1964	51.0	49.8	61.5	70.5	77.6	82.4	86.3	86.2	80.0	66.3	62.6	52.2	68.9
1965	54.4	49.8	54.9	71.6	75.0	81.6	84.9	84.0	80.7	66.8	64.5	55.5	68.6
1966	45.3	49.7	60.0	68.6	73.5	78.8	84.2	81.9	77.5	66.9	63.0	50.6	66.7
1967	50.2	51.8	66.9	76.5	76.6	84.5	85.2	82.6	75.5	66.9	60.4	51.0	69.0
1968	49.8	48.2	58.0	68.1	75.3	80.5	82.7	84.1	75.9	72.2	56.4	50.7	66.8
1969	52.5	53.6	54.9	69.0	73.4	81.2	86.8	85.7	79.6	69.8	58.1	55.1	68.3
1970	45.5	54.8	56.8	70.1	72.9	80.6	83.9	85.6	81.1	67.7	58.0	60.1	68.1
1971	56.0	57.4	64.6	69.4	78.1	83.6	85.9	81.5	80.1	73.8	63.1	57.2	70.9
1972	52.8	56.7	66.2	73.7	72.8	80.3	82.2	82.1	81.9	71.9	54.0	50.2	68.7
1973	47.2	51.9	66.1	66.0	74.7	79.2	83.1	82.1	79.3	72.5	65.7	52.1	68.3
1974	51.0	56.4	67.9	69.7	77.3	79.4	83.0	81.1	72.3	68.1	57.3	50.9	67.9
1975	53.2	53.5	61.4	68.4	73.5	80.0	80.9	81.7	76.0	71.1	60.3	53.0	67.8
1976	49.6	61.2	63.8	68.9	71.3	79.8	79.8	81.6	77.5	61.0	52.1	49.8	66.4
1977	44.0	52.8	61.8	66.9	74.8	81.5	84.8	84.7	82.3	71.2	61.4	53.3	68.3
1978	43.3	46.4	59.6	68.9	77.0	82.7	86.0	83.0	78.5	69.3	62.4	51.7	67.4
1979	43.7	52.4	63.3	69.7	73.8	80.8	84.7	83.1	78.7	74.7	58.2	55.3	68.2
1980	52.6	53.6	61.4	67.5	76.1	85.1	88.1	85.3	83.6	70.7	58.3	55.0	69.8
1981	50.8	53.7	60.6	72.9	75.3	81.5	84.2	84.7	78.9	71.8	62.4	53.0	69.1
1982	50.8	49.6	63.0	66.9	74.5	81.6	85.5	86.0	80.0	69.3	59.3	52.4	68.2
1983	48.9	52.1	58.7	65.2	73.6	79.2	82.9	84.5	78.5	70.8	62.5	43.0	66.7
1984	46.6	54.1	64.2	69.7	77.0	82.7	84.9	84.7	77.6	71.2	58.7	59.6	69.3
1985	44.2	50.5	64.0	69.4	76.6	80.2	82.2	85.5	79.4	71.7	64.4	49.9	68.2
1986	53.4	58.0	62.9	72.6	74.6	81.4	85.8	85.7	83.7	69.7	59.3	51.6	69.9
1987	50.6	55.8	57.8	66.1	75.7	80.5	83.8	86.0	79.2	71.2	60.6	54.2	68.5
1988	47.5	54.2	61.3	69.0	76.1	81.1	84.6	86.4	80.7	73.2	65.1	56.0	69.6
1989	56.1	51.6	61.9	70.3	81.7	83.3	86.6	86.0	79.0	71.2	61.8	43.4	69.4
1990	56.4	58.8	61.5	69.6	79.3	87.4	83.3	85.2	80.0	69.3	63.0	51.9	70.5
1991	48.9	56.6	64.0	72.4	77.6	82.8	84.5	85.8	77.8	73.2	57.4	55.5	69.7
1992	50.7	59.1	63.3	69.0	73.7	82.5	84.7	82.1	81.7	73.4	57.2	56.2	69.5
1993	51.1	55.5	61.5	67.3	73.9	81.5	86.0	87.2	81.5	70.6	56.3	55.0	69.0
1994	52.3	56.1	63.9	69.8	76.0	84.5	87.8	86.1	78.4	72.6	64.7	56.9	70.8
1995	53.5	57.4	61.8	69.8	78.6	79.3	84.3	85.5	80.1	69.8	59.5	55.6	69.6
1996	51.0	57.9	57.6	69.5	81.9	84.1	87.3	84.4	78.4	71.0	61.3	54.5	69.9
1997	49.1	53.1	63.2	63.9	74.0	79.8	85.0	86.1	82.2	70.2	57.3	50.2	67.8
1998	56.4	55.3	59.7	66.7	79.8	86.3	88.0	83.6	80.5	71.4	62.4	52.7	70.2
1999	54.6	61.8	62.6	71.2	76.1	81.8	82.8	86.1	80.3	69.6	63.0	54.0	70.3

Figure A-22. Change in Average Annual Temperature United States

2000	55.2	62.6	67.0	70.7	78.6	81.0	85.9	86.3	80.9	73.0	56.9	46.4	70.4
2001	49.2	57.5	56.5	70.8	76.3	82.6	85.4	85.5	76.9	67.9	62.9	53.7	68.8
2002	54.0	50.8	60.3	73.2	76.8	83.4	82.5	85.3	78.7	70.7	57.8	53.8	68.9
2003	50.1	53.1	60.6	71.6	80.3	81.7	81.9	83.7	76.7	70.6	63.0	53.9	68.9
2004	54.5	52.6	65.9	67.2	76.1	80.8	82.9	83.3	80.5	76.9	61.1	53.1	69.6
2005	55.9	56.3	61.3	68.4	75.0	82.6	85.3	85.7	84.3	70.9	64.9	53.0	70.3
2006	58.2	55.9	67.5	76.7	78.7	83.6	85.7	88.3	79.7	72.4	63.8	54.4	72.1
2007	48.3	54.8	65.0	65.2	75.5	80.7	80.4	83.7	80.2	73.1	62.7	56.1	68.8
2008	51.8	61.7	64.5	70.6	80.1	86.8	84.1	84.4	79.5	71.4	63.7	55.0	71.1
2009	54.9	62.9	65.1	69.8	79.5	86.3	88.7	88.3	78.4	69.9	60.7	48.3	71.1
2010	49.7	49.4	59.3	68.6	77.5	83.5	84.0	87.5	80.1	70.2	62.1	53.8	68.8
2011	50.5	55.4	66.8	75.7	78.6	86.2	87.9	90.0	82.9	71.0	62.9	53.8	71.8
2012	56.2	57.4	66.4	73.9	78.1	84.8	85.4	87.2	79.6	70.7	63.2	57.1	71.7
2013	53.9	59.0	62.7	67.6	75.8	83.9	86.1	88.6	83.4	73.5	59.9	52.1	70.5
2014	51.1	57.4	60.6	71.3	75.7	83.1	84.9	88.1	82.0	76.3	57.3	56.7	70.4
2015	49.5	53.2	60.9	71.7	76.3	81.6	85.6	87.4	83.5	75.7	63.1	58.2	70.6
2016	51.8	59.2	65.9	69.7	75.1	82.0	86.9	83.9	81.8	74.4	66.4	55.8	71.1
2017	57.5	64.1	67.5	71.1	75.6	83.3	87.6	84.6	79.4	70.4	66.5	52.9	71.7
2018	49.3	58.4	67.0	68.0	80.5	86.4	86.1	86.6	79.3	69.8	56.7	53.7	70.2
2019	52.1	57.5	60.6	68.6	77.0	81.7	84.8	88.6	85.8	71.5	58.7	55.5	70.2

Figure A-5 shows the projected increase in the number of days above 100ºF for Texas for both the lower and higher predicted scenario. Figure A-6 shows the trend in the temperature data in graphical form.[1] The data trend to the increase of average temperature for the San Antonio area in the future. Mean temperatures are trending upward.

[1] Climate trends in San Antonio and an Overview of Climate projections for the South Central Region, Katherine Hayhoe, Ph.D., ATMOS research & Consulting, May 2015 Revised



Under both lower- and higher-scenario climate change projections, the number of days exceeding 100°F is projected to increase markedly across the Southern Great Plains by the end of the century (2070–2099 as compared to 1976–2005). *From Figure 23.4 (Sources: NOAA NCEI and CICS-NC).*

Figure A-6. Projected Increase in the Number of Days Above 100ºF

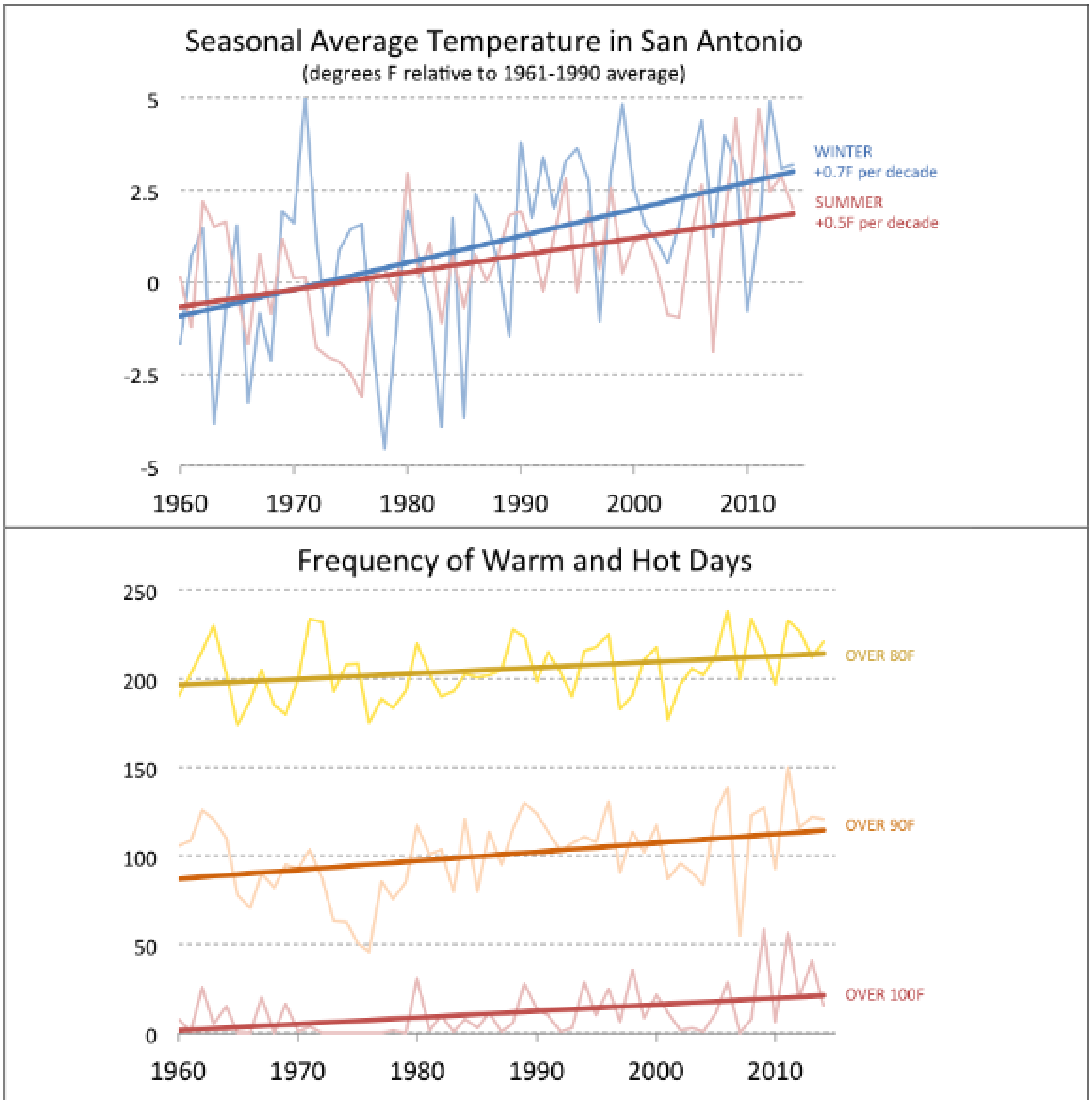


Figure 8. Observed year-to-year values (thin lines) and long-term trends (thick lines) in winter and summer mean temperature (top), and in the number of days per year with maximum temperature exceeding 80, 90, and 100°F (bottom) at the San Antonio International Airport weather station from 1960 to 2014. All trends are significant. *Source: K. Hayhoe*

Figure A-7. Trend in San Antonio Temperatures

The USACE Climate Hydrology Assessment Tool was used to enhance USACE climate preparedness and resilience. This tool aids in preparing a qualitative analysis regarding climate change impacts for projects with hydrologic based aspects. The Climate Hydrology Assessment tool allows users to access data representing past (observed) changes, as well as potential future (projected) changes to relevant hydrologic inputs. This provides qualitative information about future climate conditions, and provides a tool to develop repeatable analytical results using consistent information. The tool reduces potential error, while increasing the speed of information development so that data can be used earlier in the decision-making process.

The tool utilizes selected gage data located within the project area. The USGS 081718000 San Antonio River at San Antonio, Texas was used in the analysis based on the proximity to the project area and was evaluated for this qualitative assessment. The observed annual peak streamflow for the gage was evaluated using the Climate Hydrology Assessment Tool. A plot of the observed annual peak streamflow at the gage is shown in Figure A-8. The p-value for the annual peak instantaneous streamflow is 0.34, which is greater than the typical threshold of 0.05 for statistical significance.

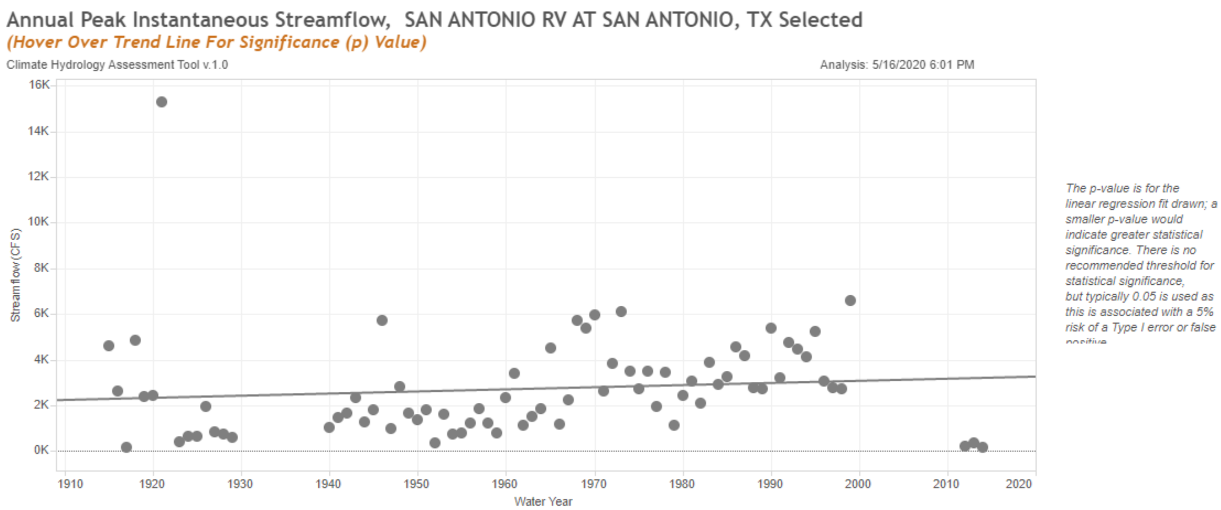


Figure A-8. Observed Annual Peak Streamflow San Antonio River at San Antonio, Texas

There are significant data concerns with at this gaging location. The USGS did not report peak streamflow from 2000 – 2011 and the majority of the streamflow measurements from gage calibration were of poor to fair condition. In 2013 additional gaging equipment was added for better accuracy. The development in the watershed has grown drastically since the gage was first installed in 1915. Due to land-use changes, an incomplete gaging record and gaging errors, this method is not as meaningful for assessing climate change as other measures such as temperature and rainfall trends and trends in streamflow records for HUC 1210 as shown in Figures A-9 and A-10.

The USACE Climate Hydrology Assessment Tool was also used to investigate potential future trends in streamflow for the San Antonio River watershed. Figure A-9 displays the range of projected annual maximum monthly streamflow computed from 93 different climate changed hydrologic model runs for the period of 1950-2099. The projected streamflow computations are based on unregulated conditions and are computed at the HUC 1210 watershed scale. As expected for this type of qualitative analysis, there is considerable, but consistent spread in the projected annual maximum monthly flows. The spread in the projected annual maximum monthly flows is indicative of the high degree of uncertainty associated with projected, climate changed hydrology.

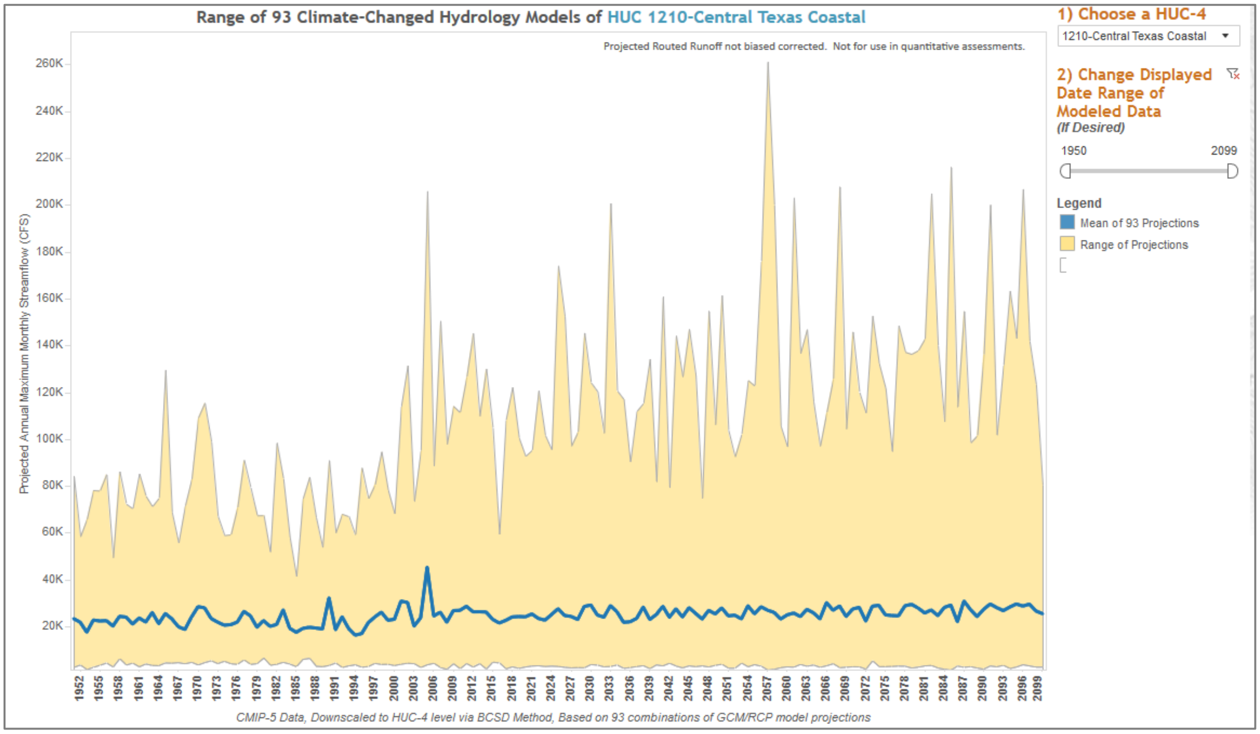


Figure A-9. Range of Projected Annual Maximum Monthly Streamflow

The overall trend in the mean projected annual maximum monthly streamflow over time and is shown in Figure A-10. The p-value is 0.094, so there is no statistical trend for the annual peak instantaneous maximum monthly streamflow data.

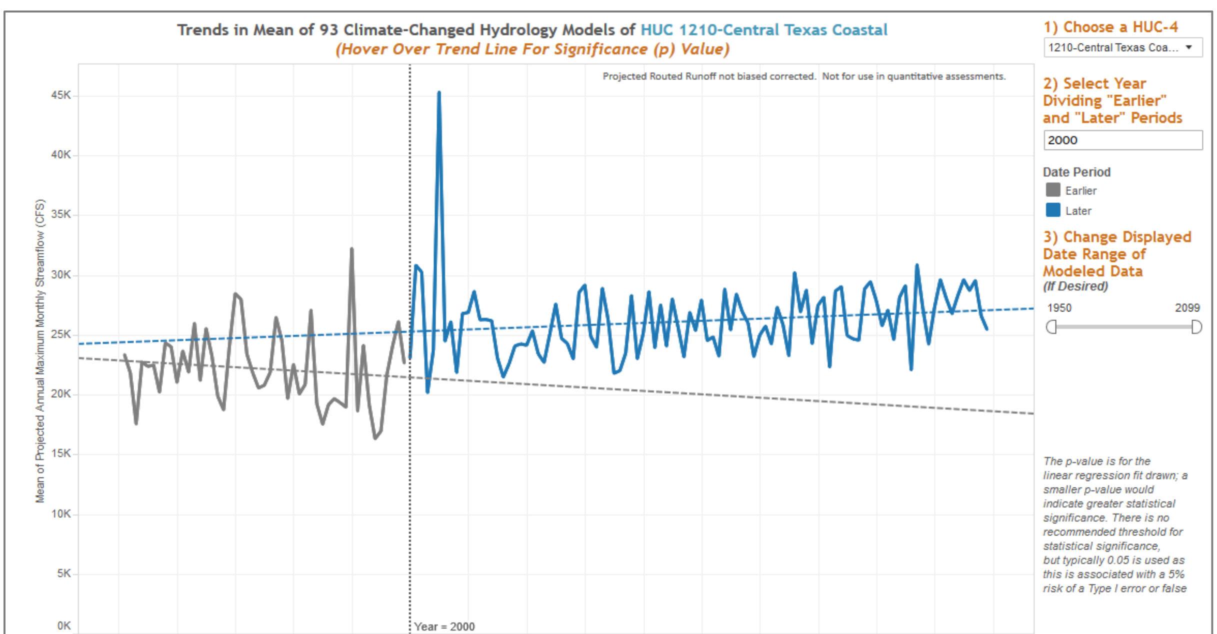


Figure A-10. Mean Projected Annual Maximum Monthly Streamflow

The USACE Nonstationarity Detection Tool was developed in conjunction with USACE Engineering Technical Letter (ETL) 1100-2-3, Guidance for Detection of Nonstationarities in Annual Maximum Discharges, to detect nonstationarities in maximum annual flow time series. This tool was also used to assess abrupt or slowly varying changes in observed peak flow data collected by the USGS gage located along the San Antonio River for the period of record spanning 1915 – 2013. Figure A-11 shows the nonstationarities detected using maximum annual flow/height analysis for the USGS 08178000 San Antonio River at San Antonio, Texas gage.

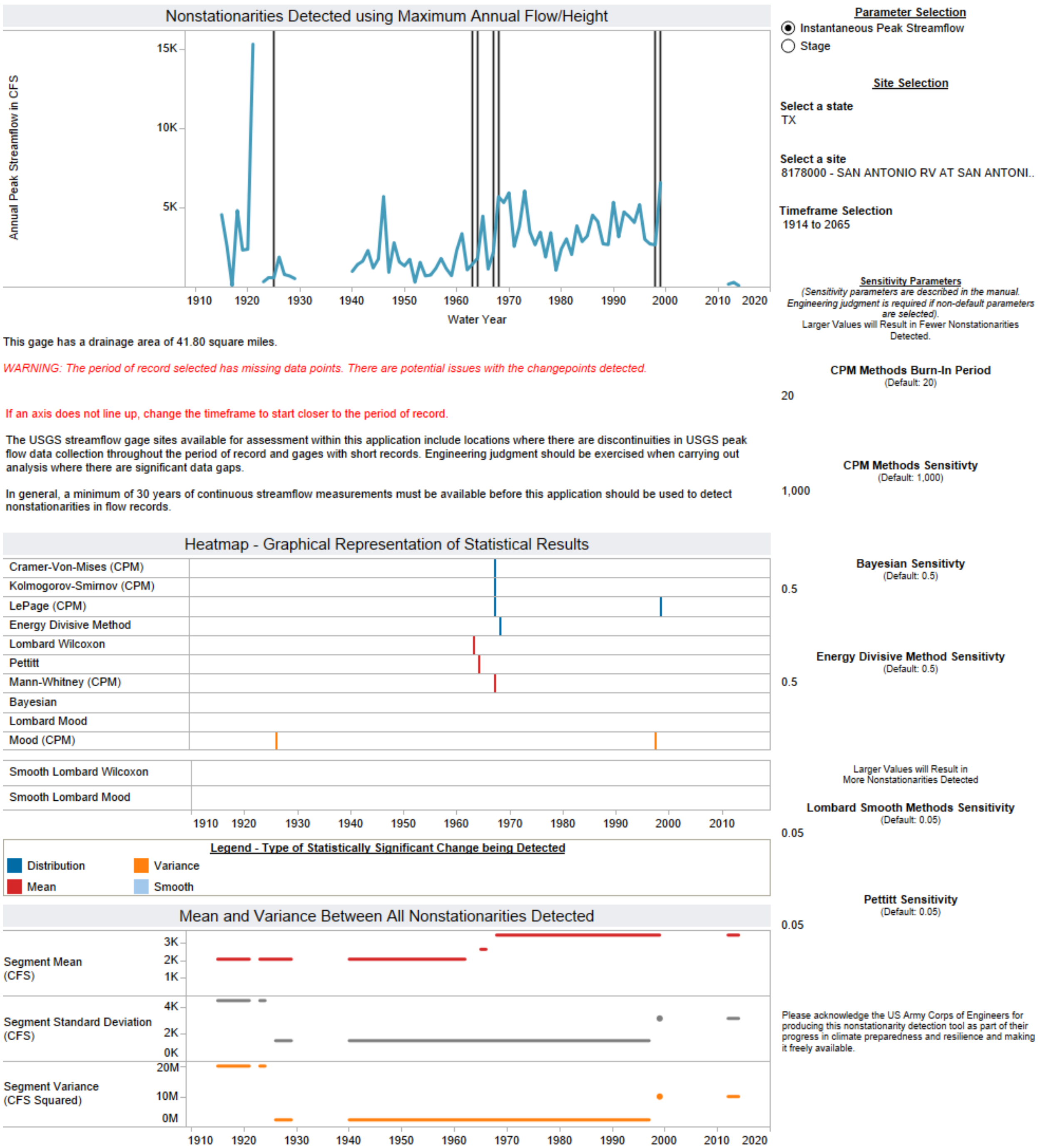


Figure A-11. Non-stationarity Detected on the San Antonio River at San Antonio, Texas

Future projected precipitation information from the Fourth National Climate Assessment for the Southern Great Plains region is shown in Figure A-12.

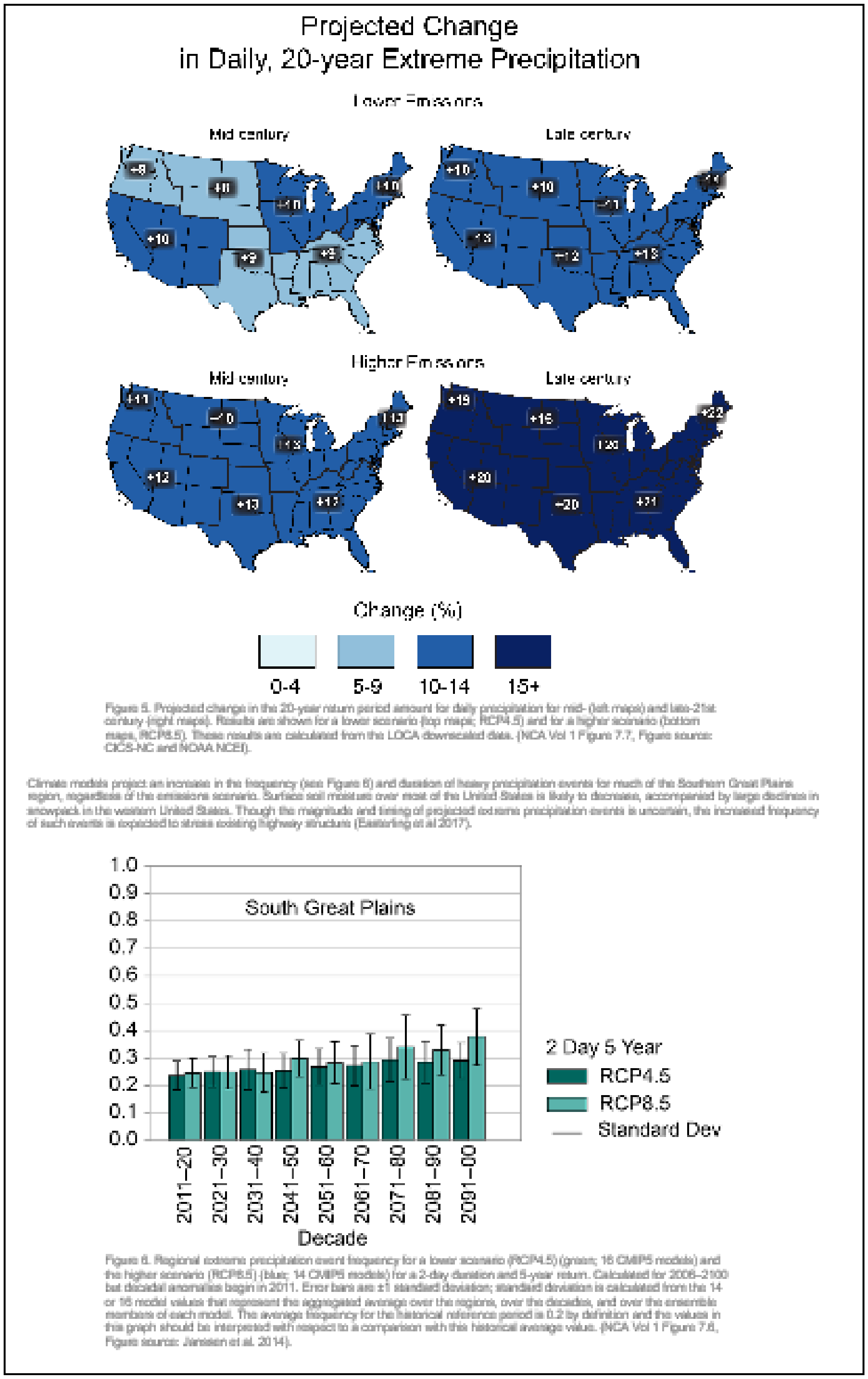


Figure A-12. Future Projected Precipitation for the Southern Great Plains Region

2.3 Vulnerability Assessment to Climate Change Impacts

The USACE Watershed Climate Vulnerability Assessment Tool was used to compare the relative vulnerability of the HUC 121003, Texas Gulf Region, to climate change to the other watersheds across the continental United States. The tool facilitates a screening level, comparative assessment of how vulnerable a given watershed is to the impacts of climate change. The Climate Vulnerability Assessment Tool is used to assess the vulnerability of the Texas Gulf Region for the USACE Ecosystem Restoration business line to projected climate change impacts relative to the effects that climate change might have on the USACE ecosystem restoration business line in the other watersheds in the continental United States. The tool uses the Weighted Order Weighted Average (WOWA) method to represent a composite index of how vulnerable a given HUC-4 watershed (Vulnerability Score) is to climate change specific to a given business line. The USACE Climate Vulnerability Assessment Tool makes an assessment for two 30-year epochs of time centered at 2050 and 2085. These two periods were selected to be consistent with many of the other national and international analyses. The tool assesses how vulnerable a given watershed is to the impacts of climate change for a given business line. The top 50% of the traces is called the "wet" subset of traces and the bottom 50% of the traces is called the "dry" subset of traces. There is a combination of four epoch subset combinations, which provide for an indication of the variability/uncertainty in the outputs. Results of the analysis are shown in Figures A-13 to A-17.

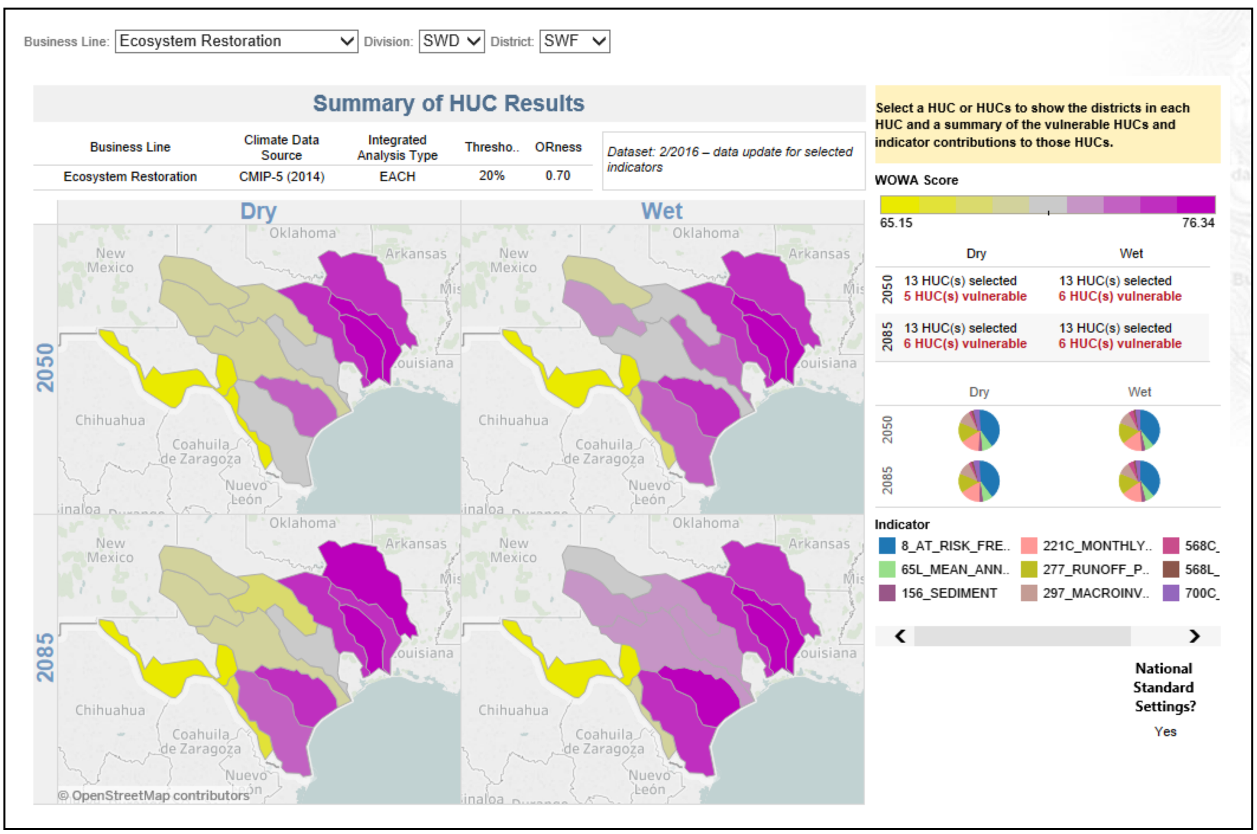


Figure A-13. Summary of HUC Results

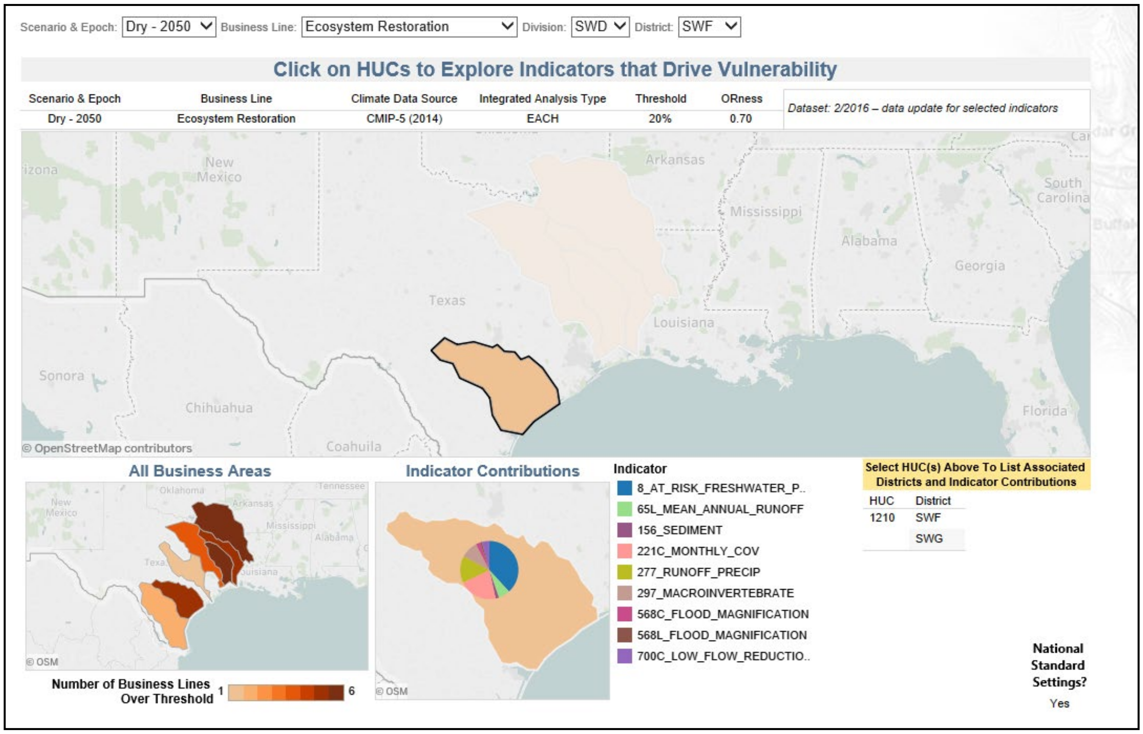


Figure A-14. Indicators that Drive Vulnerability in a Dry Forecast 2050

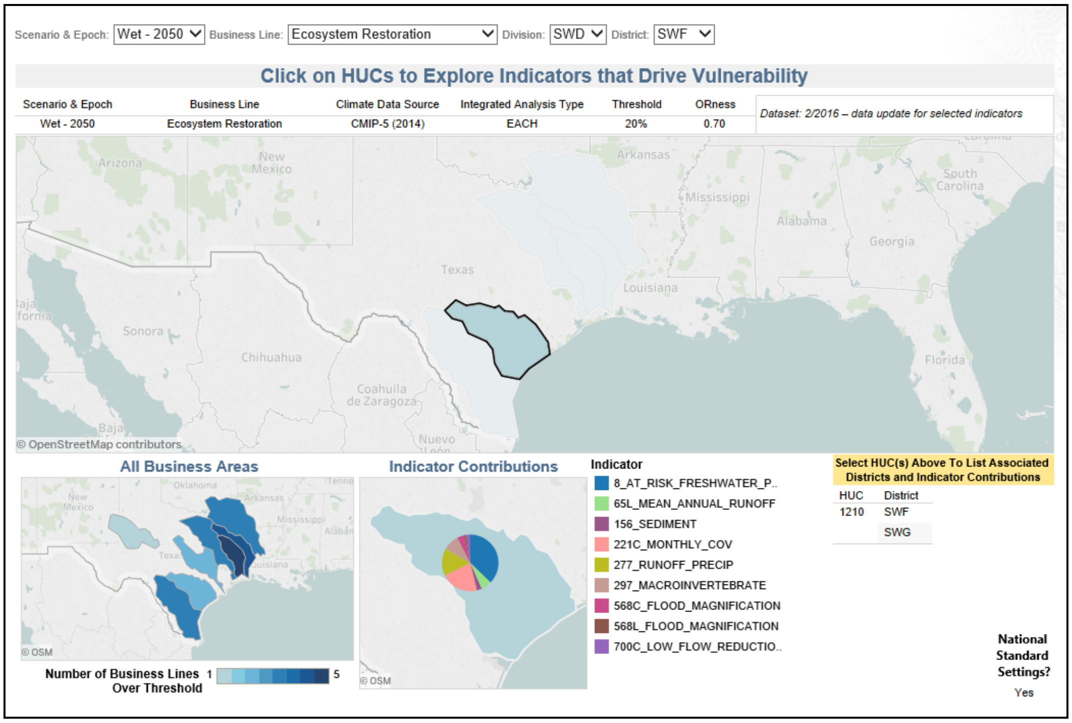


Figure A-15. Indicators that Drive Vulnerability in a Wet Forecast 2050

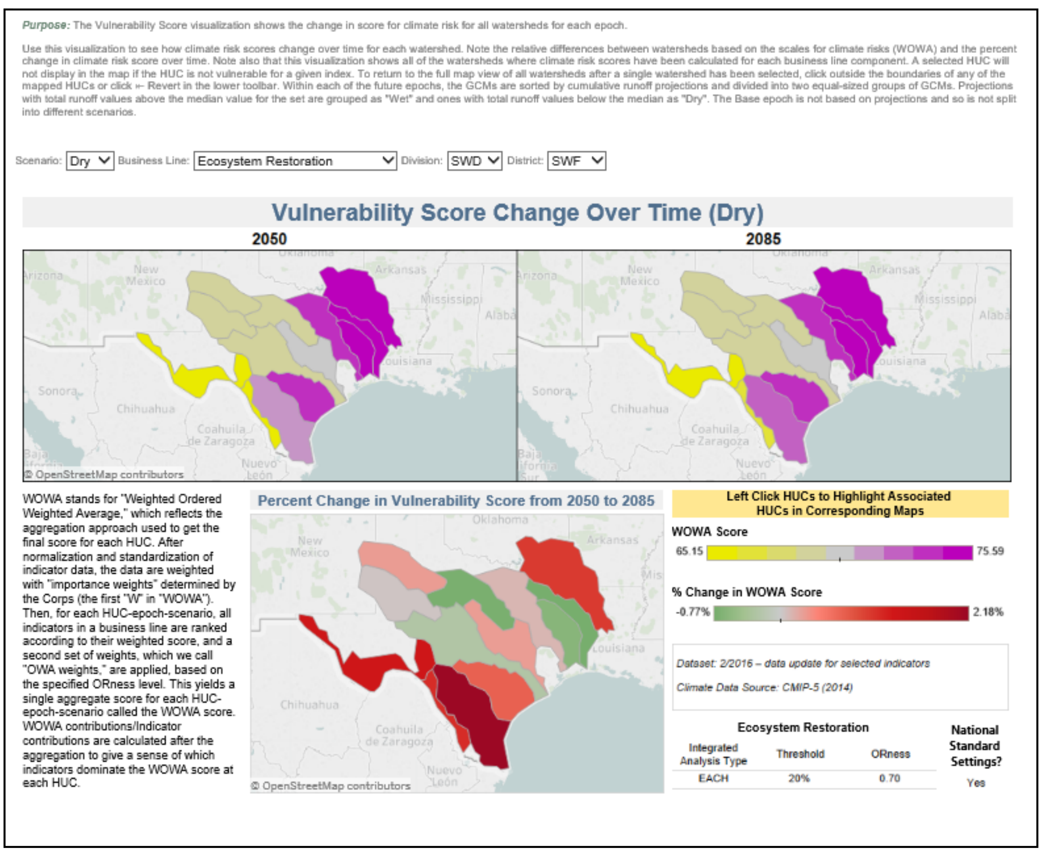


Figure A-16. Vulnerability Score Change Over Time in a Dry Forecast

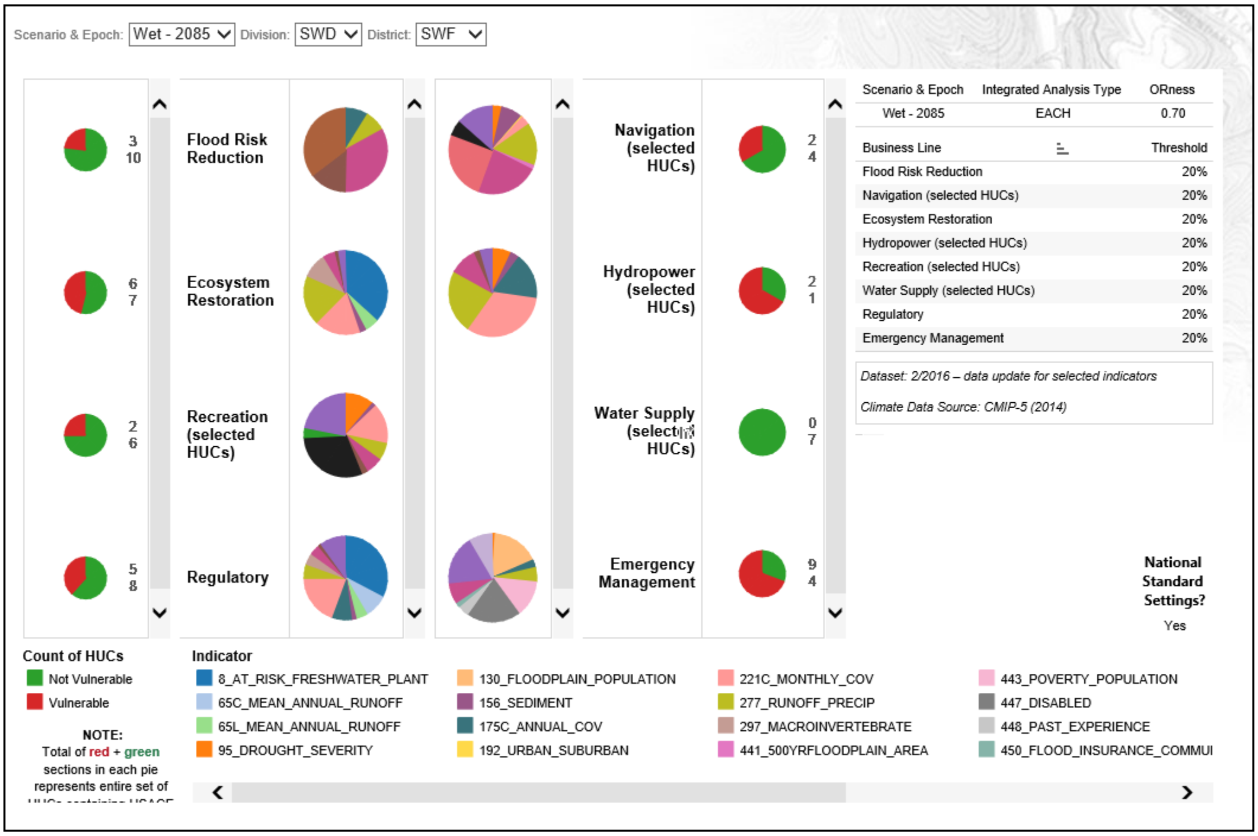


Figure A-17. Business Lines at Risk in a Wet Forecast.

The results of the USACE Watershed Climate Vulnerability Assessment Tool are presented in Table A-4. The Central Coastal Watershed is relatively more vulnerable to the impacts of climate change on Ecosystem Restoration for the 2085 Wet Epoch. The wet subsets tend to provide more water to the ecosystem, having a lesser impact on risk to freshwater plants.

Table A-4. Projected Vulnerability with Respect to Ecosystem Restoration

HUC4 Watershed	Projected Vulnerability with Respect to Ecosystem Restoration			
	Ecosystem Reduction Vulnerability Score			
Central Texas Coastal 121003	2050 Dry	2050 Wet	2085 Dry	2085 Wet
	73.34	74.66	73.87	76.34

Terrestrial and aquatic ecosystems are being directly and indirectly altered by climate change. Some species can adapt to extreme droughts, unprecedented floods, and wildfires from a changing climate, while others cannot, resulting in significant impacts to both services and people living in these ecosystems. This region is prone to periods of drought and heavy rainfall with evidence that the droughts and floods could become more frequent and more extreme. These trends would threaten native animal and plant species.

2.4 Future trends

In "Climate trends in San Antonio and an Overview of Climate Projections for the South Central Region, Katherine Hayhoe, Ph.D., ATMOS Research & Consulting, May 2015 Revised", the following conclusion were documented:

> "For projected changes occurring over climate timescales (averaging over 20 – 30 years or more), based on the observed trends analyzed here and the future projections provided in NCA3 (The Third National Climate Assessment) there is:
>
> - High confidence that average temperatures will continue to warm, with greater increases under a higher as compared to a lower future scenario.
> - High confidence that the number of hot days and warm nights occurring on average each year will continue to increase, with greater increases under a higher as compared to a lower future scenario."
> - Moderate confidence that the frequency of heavy precipitation and/or average precipitation intensity may increase across some parts of Texas, although projected increases are likely to be small and trends at individual locations, such as San Antonio, will be strongly influenced by local factors.

The report noted, "the projections presented in this report provide qualitative guidance regarding the likely direction of future trends in average climate indicators and certain temperature and precipitation extremes." And that "these projections are subject to uncertainty due to natural variability, scientific uncertainty, scenario uncertainty, and the influence of regional land use and topography on local climate."

2.5 Climate Change Impacts to the Project Study Area

One of the main purposes of the River Road Ecosystem Restoration Feasibility Study is to provide quality aquatic/wetland habitat within the study area. There are several key components to providing quality habitat for migratory Neotropical birds and waterfowl: water access and appropriate native species plantings.

The climate change analysis for this project identified that average temperatures are trending upward along with the occurrence of high intensity rainfall events. Increased rainfall intensity may increase peak streamflow through the River Road project area. The increased streamflow may help remove undesirable (woody) vegetation from encroaching upon the project areas. It could also increase erosion along the river making erosion control measures more critical.

If the average temperature continues to rise in the Central Coastal Watershed this could threaten the vegetation that is native to the area. A significant shift in climate could change the native species to plants that can thrive in higher temperatures.

3 Residual Risk of Climate Change

Climate change effects more than just ecosystems and even though ecosystem restoration is the mission of this project, this section acknowledges other threats that climate change could present to this project area.

3.1 Flood Risk

The USACE vulnerability tool indicates the dominant and most likely threat to flood risk management is flood magnification. This tool suggests that floods could be magnified by up to 20% by 2085.

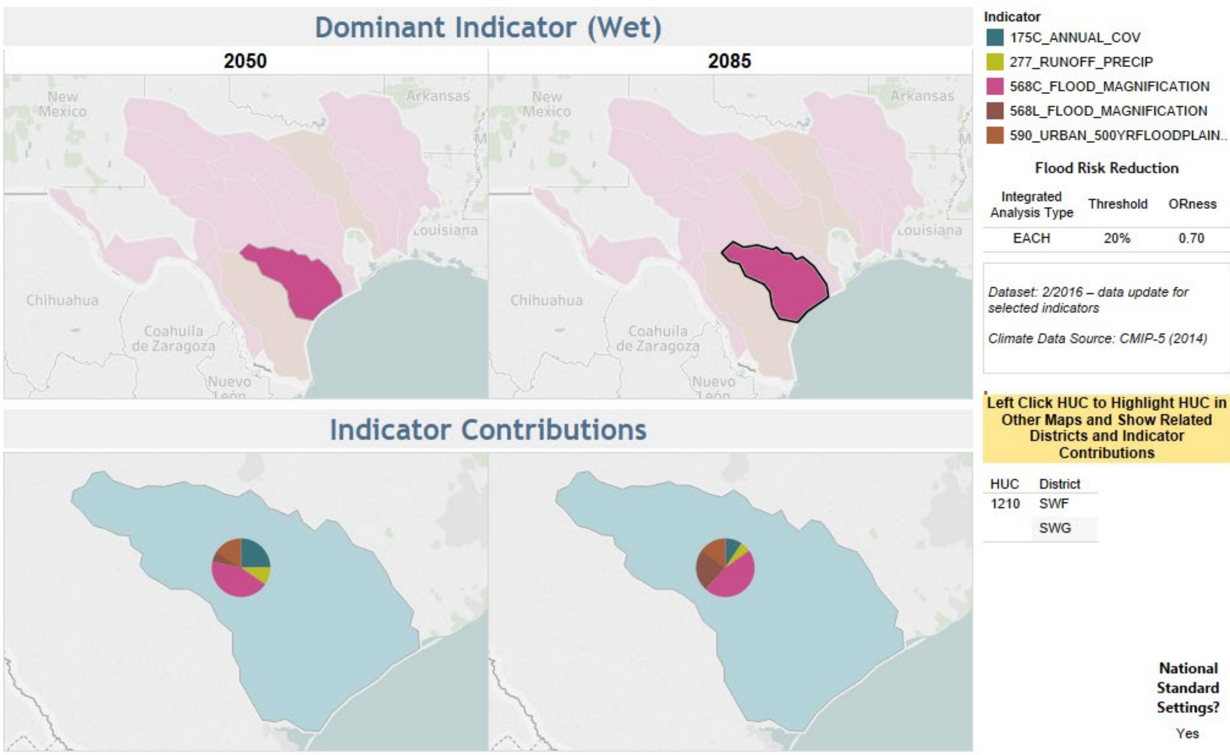


Figure A-18 Dominant Indicator for Flood Risk Reduction

While flood risk was not a mission for the project, it should be noted that an increase in flood magnitude would increase risk to the ecosystem. A flood could cause erosion or prolonged inundation and kill the vegetation that is planted as part of the project.

3.2 Sedimentation

Sedimentation is not a mission in this project, however, it should be noted that sedimentation is often caused by flooding so increased flooding would increase the amount of sediment that is deposited in the riverbed. Increased sedimentation in the river at the project area could have a negative impact on the native species being planted as part of the ecosystem restoration. Monitoring the project area in the future should not be an issue as it includes a public road and golf course. However, future maintenance may be required to keep the vegetation healthy.

4 Conclusion

While there are several concerns related to climate change with the River Road Ecosystem Restoration Project, overall the project will make the project area more resilient. This project cannot prevent a shift in average temperature or increase in flood magnitude. But by restoring native vegetation to the area, a refuge for wildlife will be provided that is near water. Increased vegetation will work to support the animals most threatened by climate change. Vegetation works to convert carbon dioxide to oxygen which is required by all animals and human life.

Overall, the ecosystem restoration project will work to combat many of the threats that climate change presents and make the area more resilient.

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