EVALUATION OF TRINITY AQUIFER GROUNDWATER AVAILABILITY IN KENDALL COUNTY

Prepared for:

Cow Creek Groundwater Conservation District

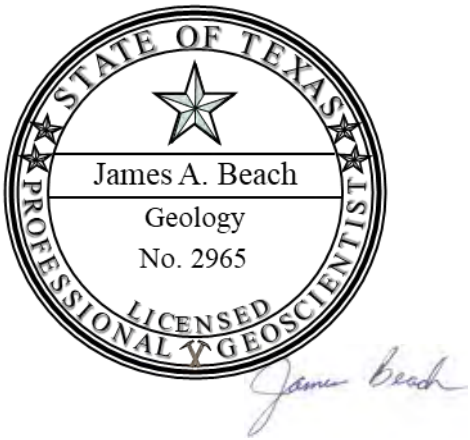
May 12, 2022

Prepared by

Advanced Groundwater Solutions, LLC

www.advancedgw.com

The seal appearing on this document was authorized by James A. Beach, P.G. #2965 on 5/12/2022.
Advanced Groundwater Solutions, LLC, TBPG Firm Registration No. 50639



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1.0 Executive Summary

Like most areas in the Texas Hill Country, the population and water demand continue to increase in Kendall County. In many areas, the water demand continues to be satisfied by groundwater development. The Cow Creek Groundwater Conservation District (CCGCD) is interested in continuing to implement an appropriate balance between the growing demands for groundwater and conservation and preservation of groundwater resources.

Significant growth in groundwater demand has occurred since the Trinity Hill Country Groundwater Availability Model (THCGAM) was completed in 2000. While the Texas Water Development Board (TWDB) made a minor change in 2009 by incorporating the Lower Trinity Aquifer into the THCGAM, there were no changes in hydraulic properties or pumping distribution in the model with that modification. The current Desired Future Condition in GMA 9 and CCGCD is based on work completed in 2010 during the joint groundwater planning process. A new conceptual model was developed for the THCGAM in 2018 (Green and others, 2018), but that data has not been incorporated into an updated THCGAM. Since 2000, many new wells have been drilled and documented, and the CCGCD has collected significant data regarding pumping and pumping distribution, water levels, and hydraulic properties of the Trinity Aquifer.

It is evident that the Middle Trinity Aquifer continues to receive recharge from precipitation in Kendall County. Water levels in the Middle Trinity Aquifer indicate water level decline is generally limited to a few areas over the past 10 to 20 years. However, some Middle Trinity wells show a continued water level decline over the past 10 to 20 years. Water levels in the Lower Trinity Aquifer indicate a more consistent water level decline. This is partially due to the concentration of the Lower Trinity monitoring wells near developing areas where pumping the Lower Trinity Aquifer has increased. Hydrographs in the Lower Trinity Aquifer indicated a more consistent pattern of water level decline in these areas. Generally, there is reasonable available drawdown in both the Middle and Lower Trinity, but the reduction in available drawdown in some areas should be monitored closely to address long-term groundwater availability.

The differences between CCGCD data and the THCGAM confirm the limitations of the THCGAM to address local management issues, especially in areas where development and groundwater pumping are increasing significantly. Consistent with that limitation, the DFC and MAG estimates should be seen as regional and long-term guidelines only. Because the THCGAM has limits in application on a local scale, the resulting DFCs and MAG estimates are also limited in application on a local scale.

The study results provide the incentive for the CCGCD to consider how local management approaches might impact the balance of production and conservation considering recent hydrologic data and development patterns. If the district adopts a policy of greater conservation, the district may consider reducing the maximum production limit per acre by up to 20%. Additionally, management zones within the district may also be considered in areas of low transmissivity and growing demand if water levels are consistently declining and available drawdown is decreasing. To the degree possible, these policy decisions should be consistent with the DFCs for Kendall County and surrounding areas.

2.0 Introduction

Starting with the well database provided by CCGCD current as of October 2021, AGS assessed the level of completeness of the data with respect to parameters important to this study: location data, completion aquifer, and well completion date. Data gaps in these parameters were filled by estimation by AGS, where possible. A map of wells after filling in location coordinate data gaps is presented in Figure 1.

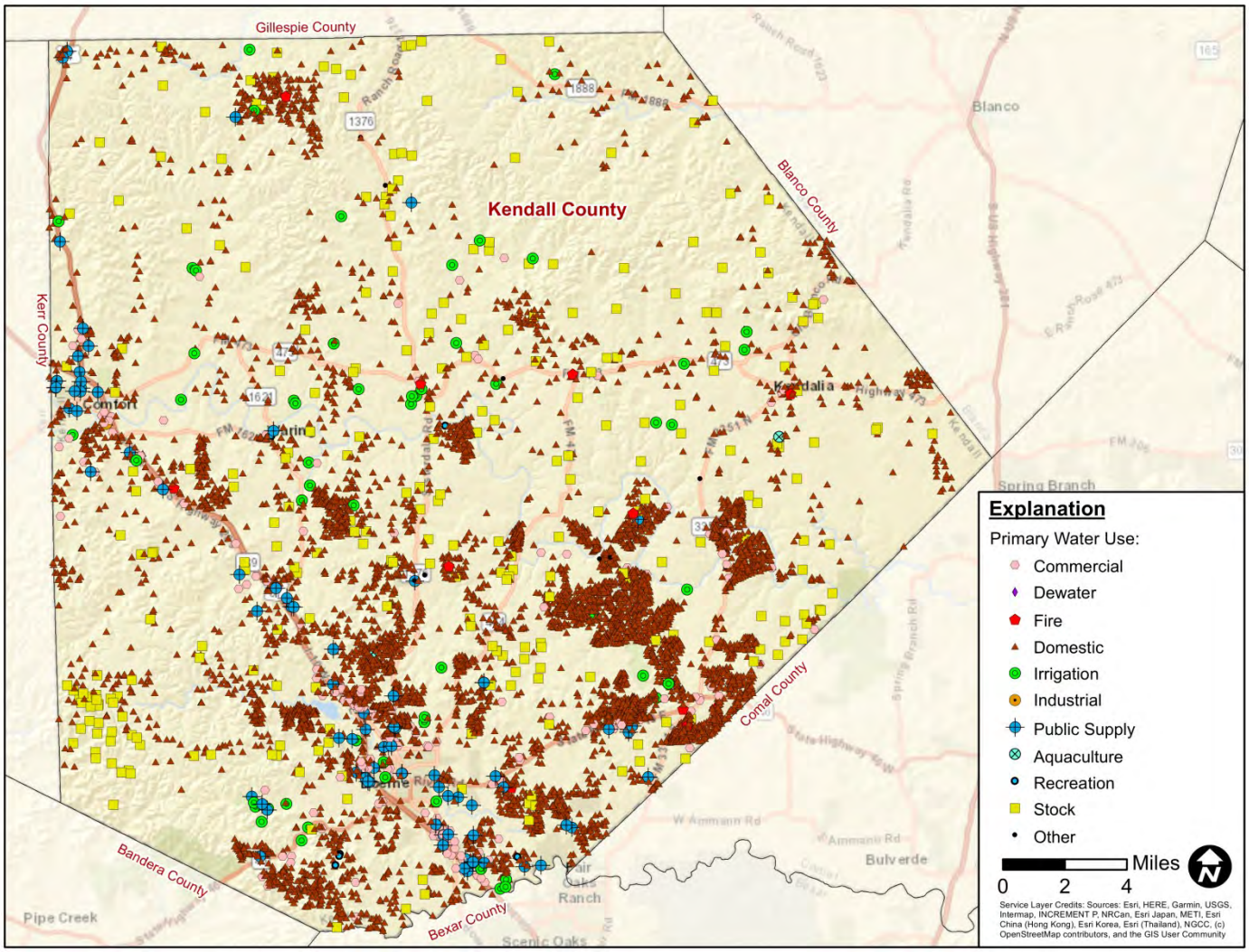


Figure 1. Cow Creek GCD Well Location Map

Location coordinate data gaps in the CCGCD database were filled by matching and/or interpolation of geocoded addresses. Most wells without coordinates in the CCGCD database are domestic wells, and street address is a reasonably accurate estimate of well location.

Many wells in the CCGCD database have a completion formation assigned by the District, using their knowledge of the formations, and using the same formation codes as are used in the TWDB groundwater database. AGS assigned the various codes to aquifer layers used in the THCGAM:

Edwards, Upper Trinity, Middle Trinity, Lower Trinity, and combinations of these layers. Mapping of completion formations to THCGAM layers is given in Table 1.

Table 1. Mapping of Formations to THCGAM Layer

GAM Layer	Member Formation(s)
Edwards	Edwards Limestone
Upper Trinity	Upper Glen Rose Limestone
Middle Trinity	Lower Glen Rose Limestone
	Hensell Sand
	Cow Creek Limestone
Lower Trinity	Sligo Limestone
	Hosston Sand

For wells in the CCGCD database lacking a CCGCD completion formation code, AGS estimated completion aquifer layer based on completion interval elevations where available, or elevation of total depth if no completion interval was available, using layer elevations in the THCGAM.

Completion date is useful to this study for estimation of pumping for exempt wells over time, as well as for assessing general trends in development over time. Where a completion date for a well was not present in the CCGCD database, the well was assumed to be an existing well with a completion date before 2000. State well reports began to be submitted electronically in 2001, and it's generally much more common for wells completed after this time to have completion dates in district databases.

Figure 2 and Figure 3 show Middle Trinity and Lower Trinity wells by completion date, respectively. Clusters of wells with similar completion dates generally align with completions of residential housing developments.

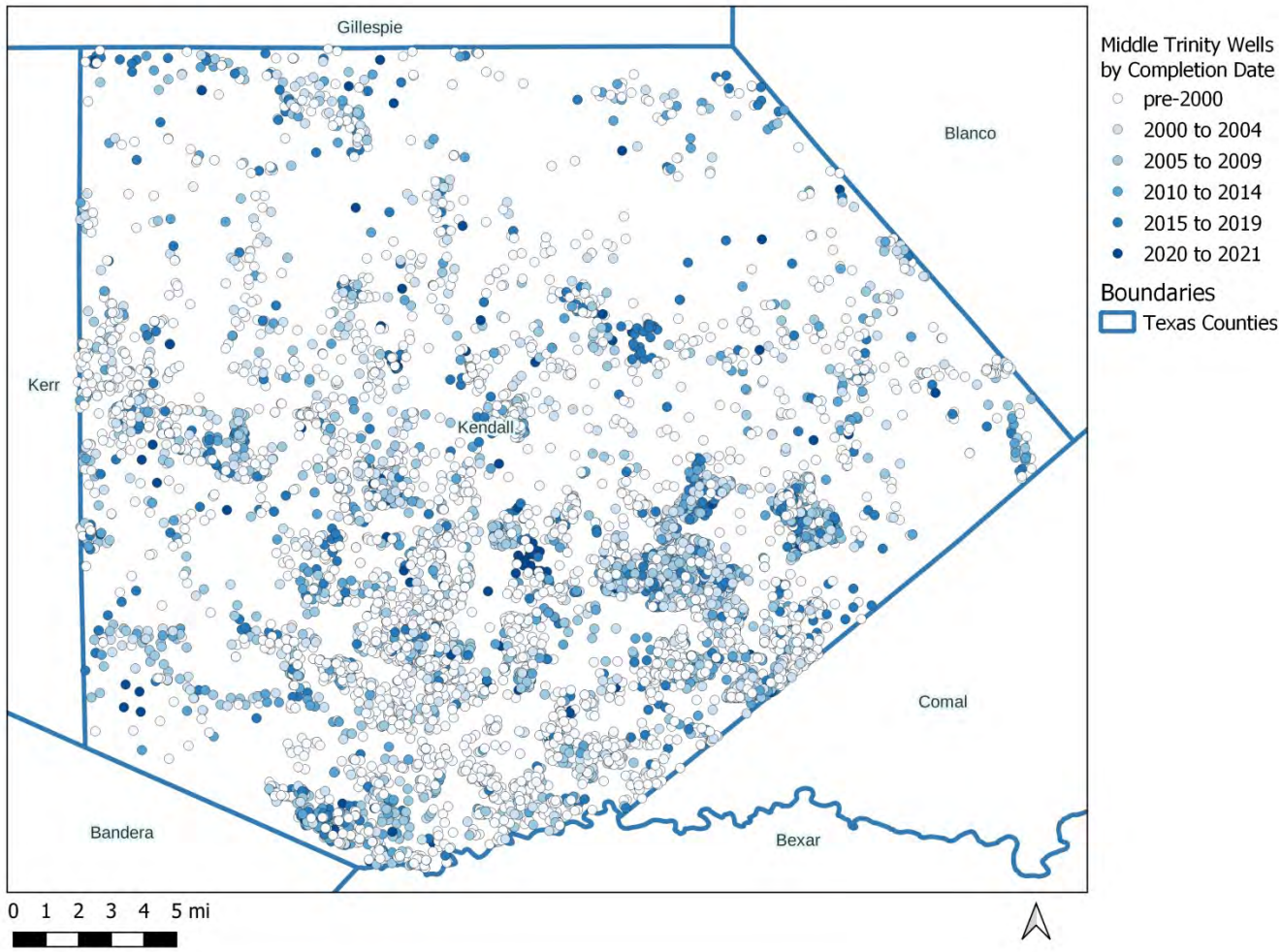


Figure 2. Middle Trinity Wells by Completion Date

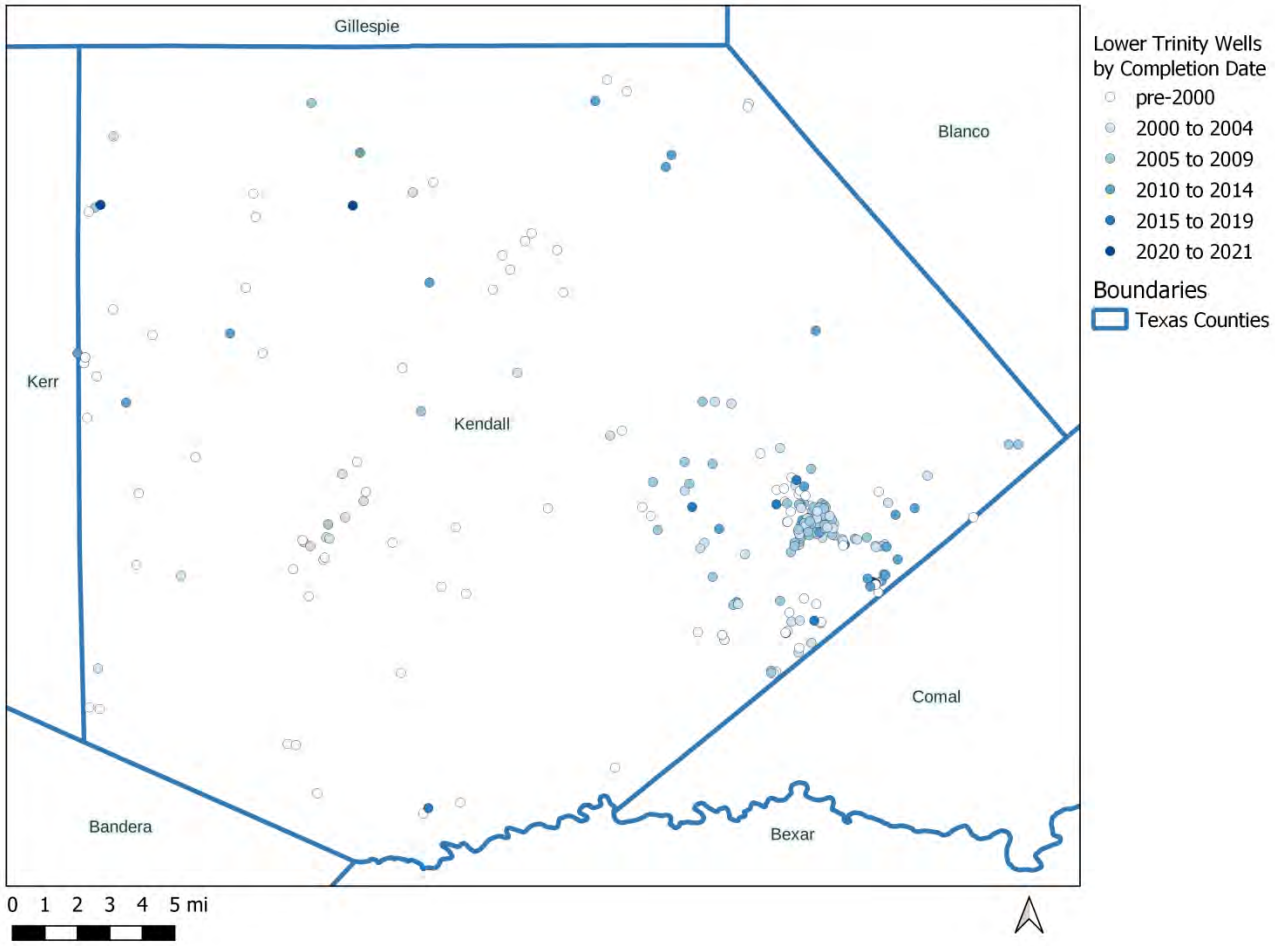


Figure 3. Lower Trinity Wells by Completion Date

3.0 Assessment of Water Level and Pumping Trends

3.1 *Water Level Trends*

To assess water level trends, AGS used a combination of water level hydrographs and estimated water level contours. This assessment was primarily based on District monitoring well data, with some additional data from Headwaters Groundwater Conservation District, Hill Country Underground Water Conservation District, and TWDB.

Hydrographs are useful for assessing trends in water levels over time, provided that the data generally represents a static level of a single aquifer (or aquifer layer), and the data record is of sufficient length. A map of locations of monitoring wells for which hydrographs were developed in this study is presented in Figure 4. As can be seen in this figure, there are more monitoring wells completed in the Middle Trinity in Kendall County than in the Lower Trinity. This is aligned with the overall distribution of wells by aquifer layer in Kendall County.

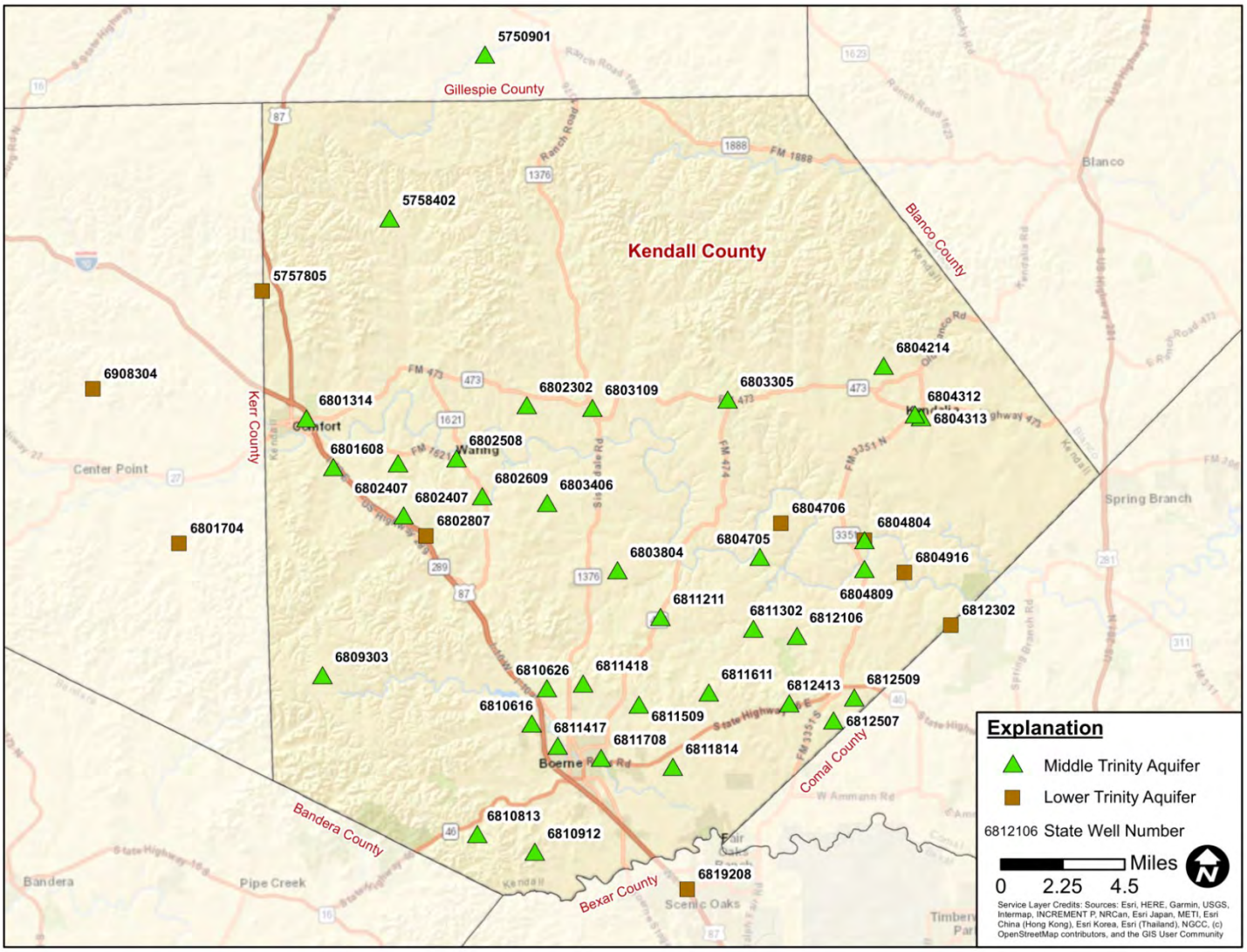


Figure 4. Hydrograph Location Map

Hydrographs developed in this study are presented in Appendix A. These hydrographs have the same time scale, from 1996 to 2021, to facilitate comparison. The elevation of the top of the formation in which the well is completed is also noted on these hydrographs (unless the information is not available). These hydrographs also include the 9-month Standardized Precipitation Index (SPI) for Kendall County. Broadly speaking, the SPI conditions represent the number of standard deviations by which precipitation deviates from the long-term mean. The SPI is therefore useful to characterize the duration and degree of both wet and dry precipitation conditions. Select hydrographs from Appendix A will be discussed in this section.

3.1.1 Middle Trinity

The first hydrograph to be discussed is that of Middle Trinity well 68-02-609 near Waring (Figure 5). This well has a complete and frequent record of water level measurements starting in 1984. Another useful feature of this well is that as a TWDB recorder well, the well is not pumped. The well also does not appear to be influenced by nearby pumping wells.

As with many wells completed in the Middle Trinity, a strong seasonal swing of about 20-30 feet from winter to summer can be seen in the water level data. This hydrograph shows levels with a mean of about 1272 ft above mean sea level (AMSL) from 1996-2005. From 2005-2011, mean annual levels decline until about 2011, when the rate of decline decreases substantially. The mean annual level in this well from 2011-2020 is 1227 ft AMSL.

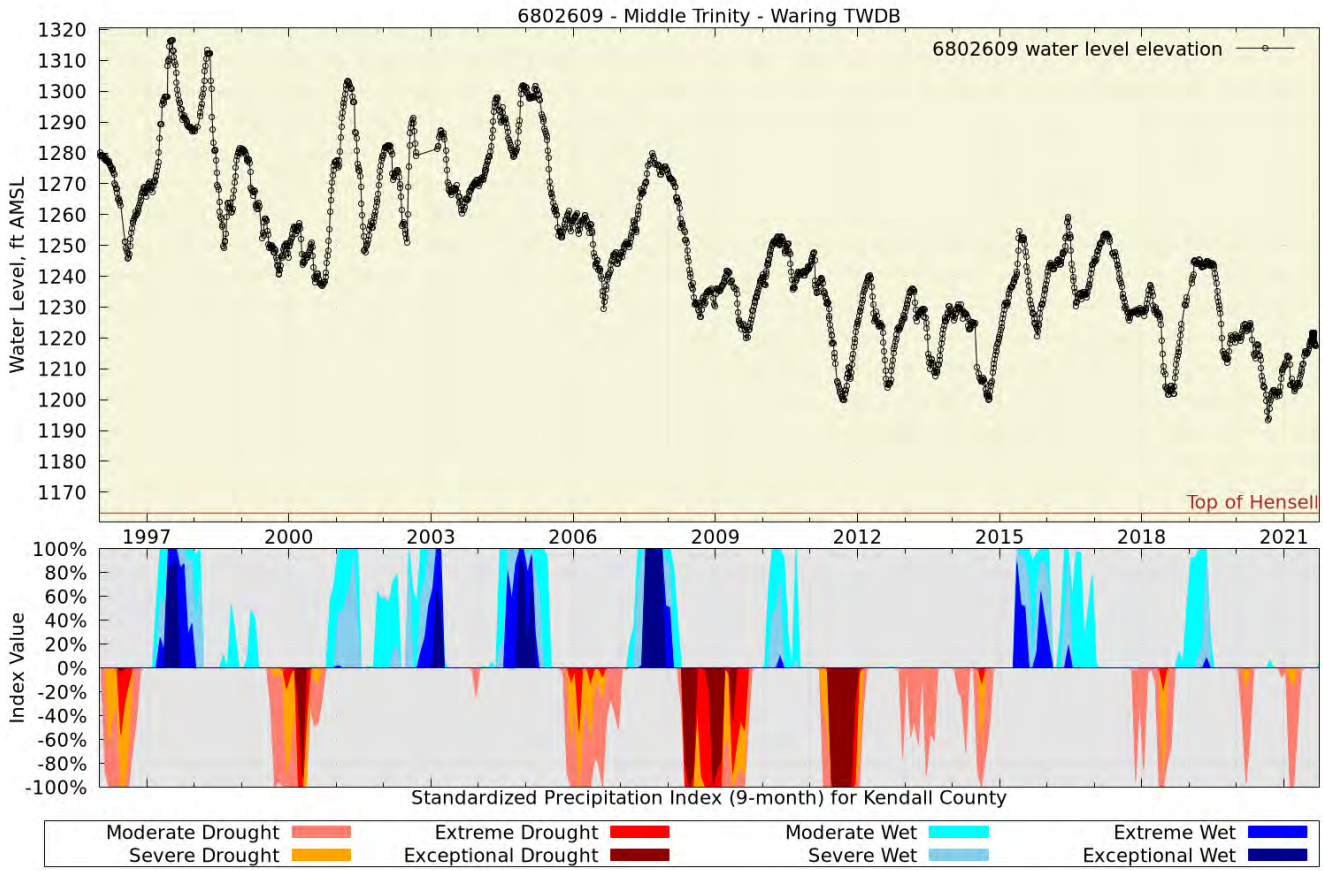


Figure 5. Long-Term Hydrograph for Middle Trinity Well 68-02-609 (Waring)

The water level in this well is currently about 50 feet above the top of the Hensell formation, which is the second-deepest formation within the Middle Trinity aquifer layer.

Other wells that show a similar pattern of water levels through this period of time in western Kendall County is well 68-01-314 near Comfort (Figure 6) and well 57-50-901 in southern Gillespie County (Appendix A). The pattern is much less apparent in the south-central portion of Kendall County.

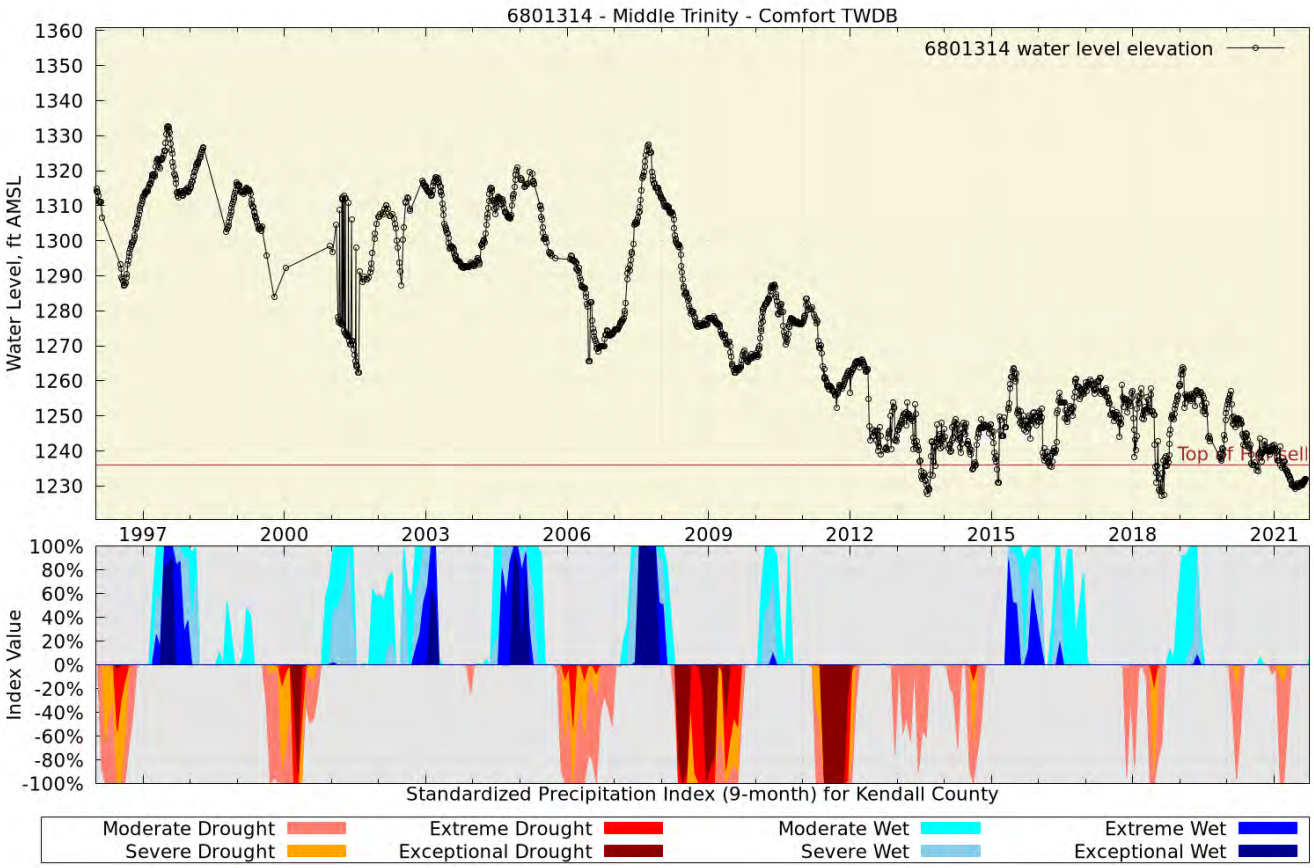


Figure 6. Long-Term Hydrograph for Middle Trinity Well 68-01-314 (Comfort)

An example of a hydrograph that is less useful is the Bergenplatz monitoring well hydrograph (Figure 7). This hydrograph features very large seasonal swings of up to 90 feet. This well is in active use, which probably explains much of the large seasonal effect in the data. District staff indicate that it is difficult to determine if the water level measurements from this well are good static measurements because the well is used regularly, and the measurements may be taken when the pump has just turned off and the water level is still recovering. Because the well is in active use and the recovery status of the water level cannot be determined or ensured to be consistent, data from this well was not included in the contour maps discussed later in this section.

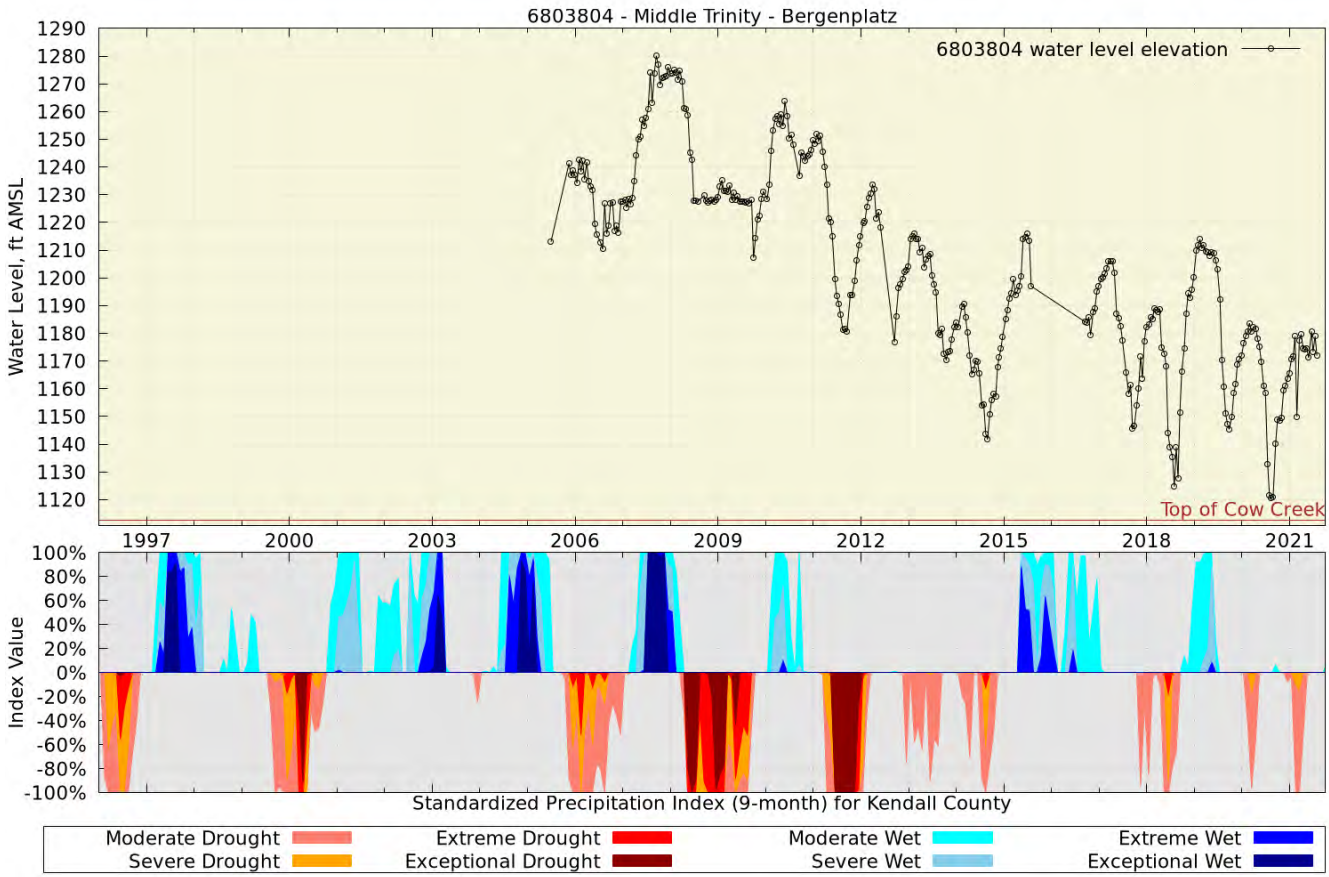


Figure 7. Hydrograph for Middle Trinity Well 68-03-804 (CCGCD Bergenplatz)

Another common way to evaluate water level trends geographically is with contour maps. These show water levels during a particular period over a given geographic area, with estimated contour lines that represent isometric levels or changes in levels, similar to topographic contour lines. These maps can suggest geographic trends and direction of groundwater flow. In aquifers with highly variable water levels (such as the Middle Trinity), these types of maps should be calculated with many data points in order to average out anomalous fluctuations in any one well.

The following several contour maps will focus on contours that illustrate water levels in 2010 and 2019 in various ways. These years were chosen because they have a large number of monitoring wells both geographically and in common, and they cover the period for which there is pumping data provided by the District.

The first contour map depicts the estimated water level contours in the Middle Trinity in 2010 (Figure 8). Water generally flows to the southeast, with some local depressions near pumping areas.

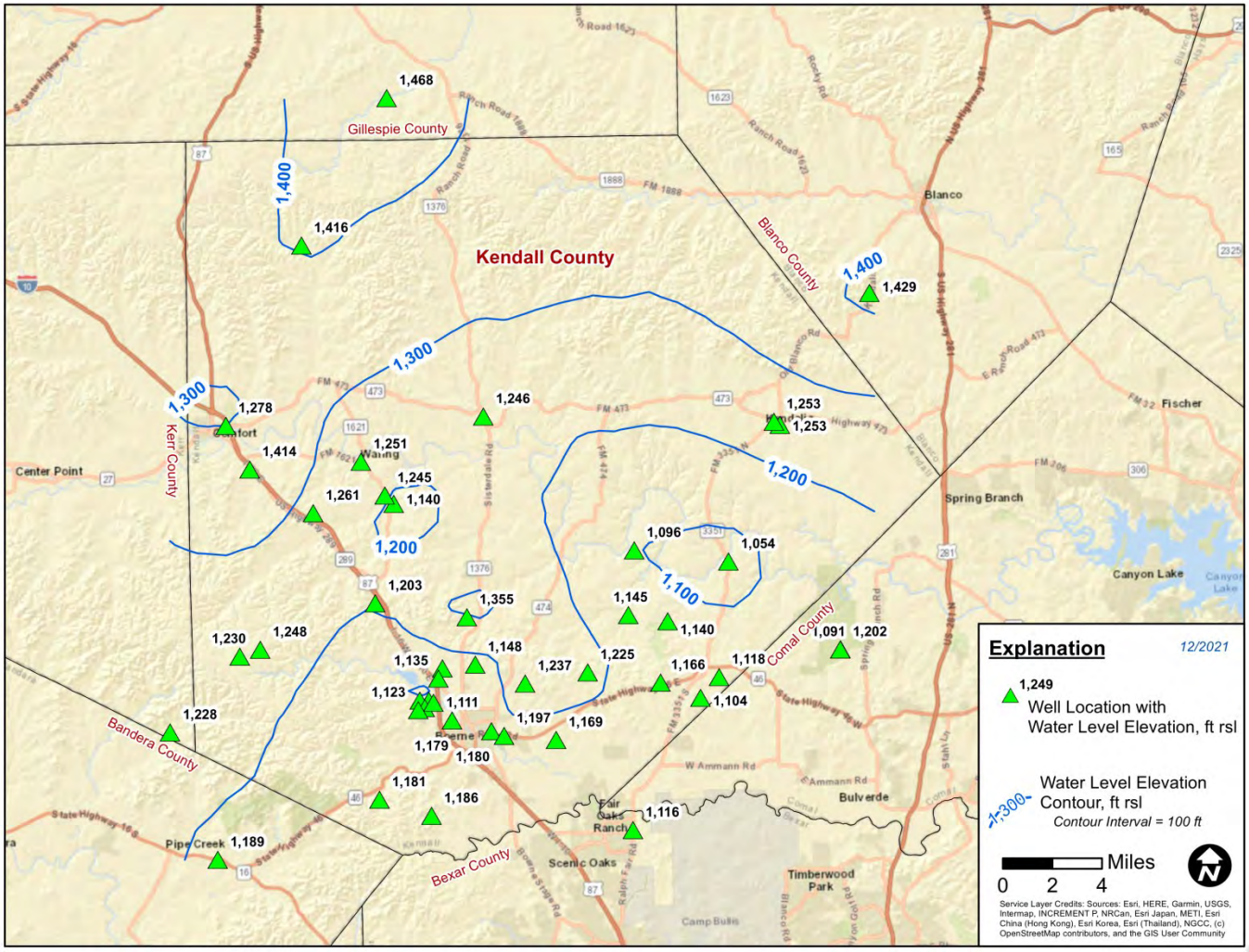


Figure 8. Estimated Water Level Elevation Contours for the Middle Trinity in 2010

The following figures (Figure 9 and Figure 10) illustrate the estimated water level contours relative to the top and base of the Middle Trinity. The elevation of the top and base at each data location are based on THCGAM surfaces. Note that the top and base of the Middle Trinity are represented by the top of the Lower Glen Rose formation and the base of the Cow Creek formation, respectively. These aquifer layer tops may not be the same as the tops of the completion formations indicated in the hydrographs in Appendix A. Negative contours indicate that the water level measurements are below the top of the Middle Trinity Aquifer as defined in the THCGAM. Positive "available drawdown" contours indicate the static depth of water above the base of the Middle Trinity Aquifer as defined in the THCGAM. Available drawdown is an estimate of the remaining depth of water for wells to capture if the wells are screened to the bottom of the aquifer.

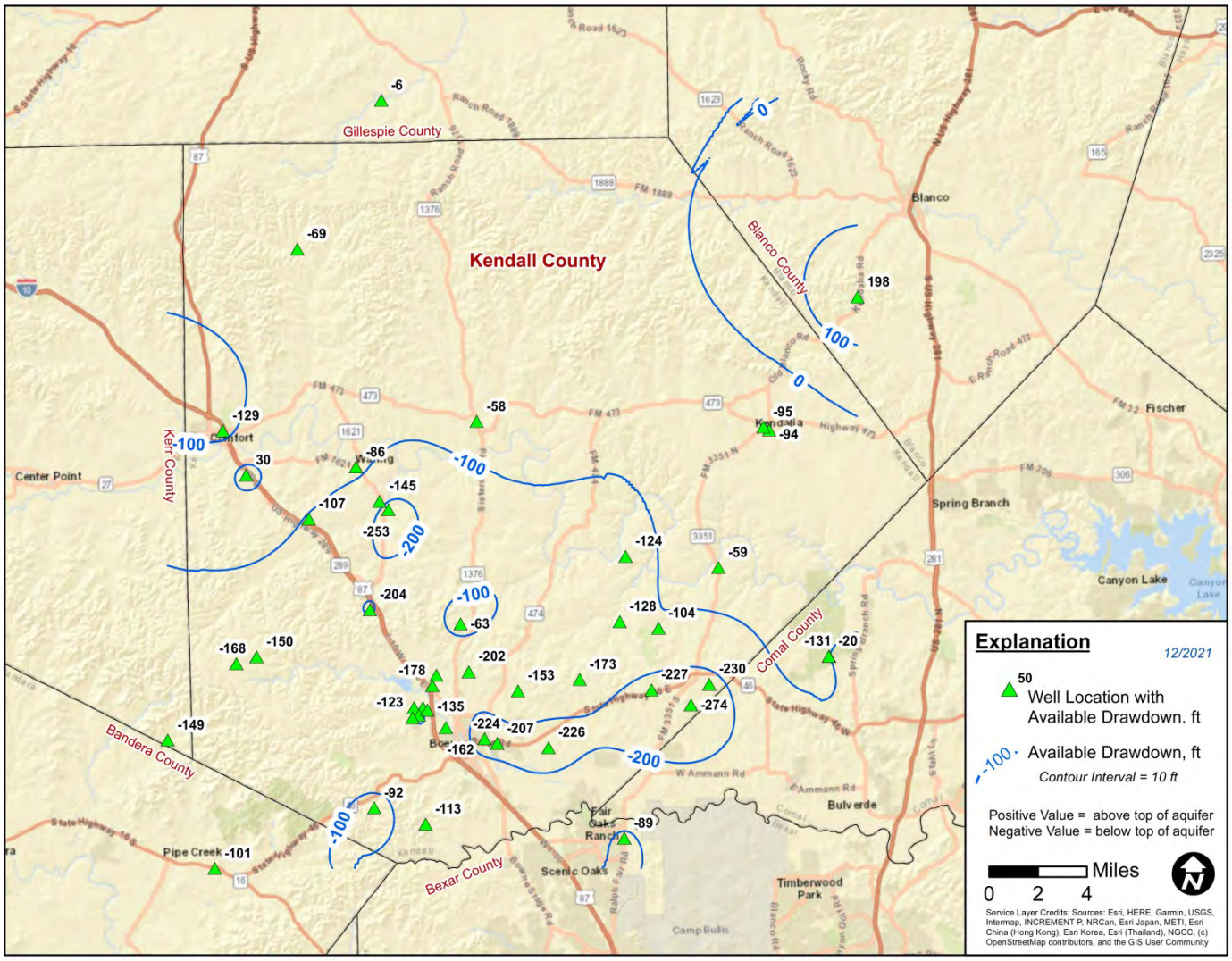


Figure 9. Estimated Vertical Distance Between Middle Trinity Water Level Measurements for 2010 and the Top of Middle Trinity Aquifer as Defined in the THCGAM

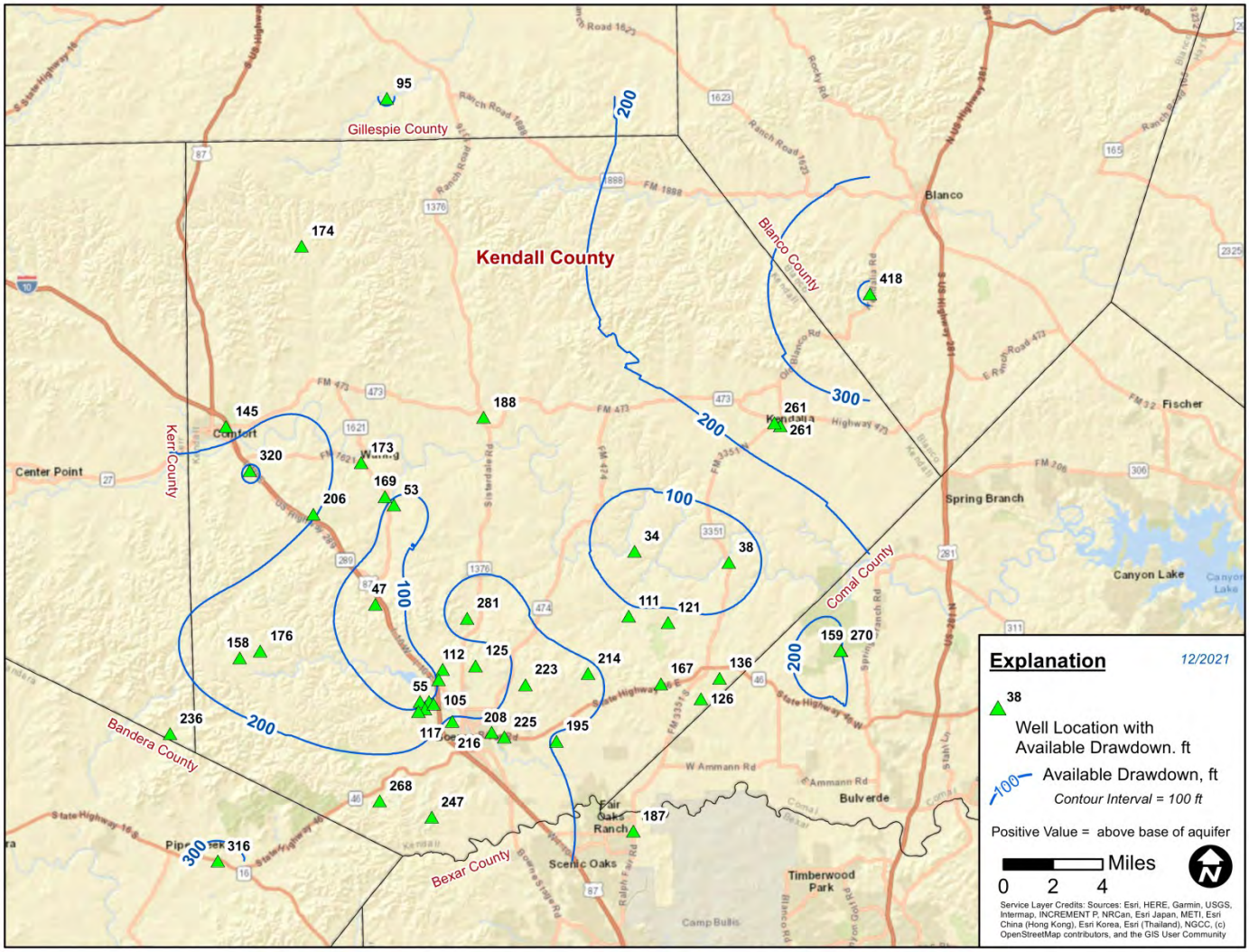


Figure 10. Estimated Middle Trinity Available Drawdown for 2010, and the Base of the Middle Trinity Aquifer Layer as Defined in the THCGAM

Estimated water level contours in the Middle Trinity in 2019 are shown in Figure 11. The contours are generally similar to those in 2010, with certain closed contours near pumping centers slightly larger.

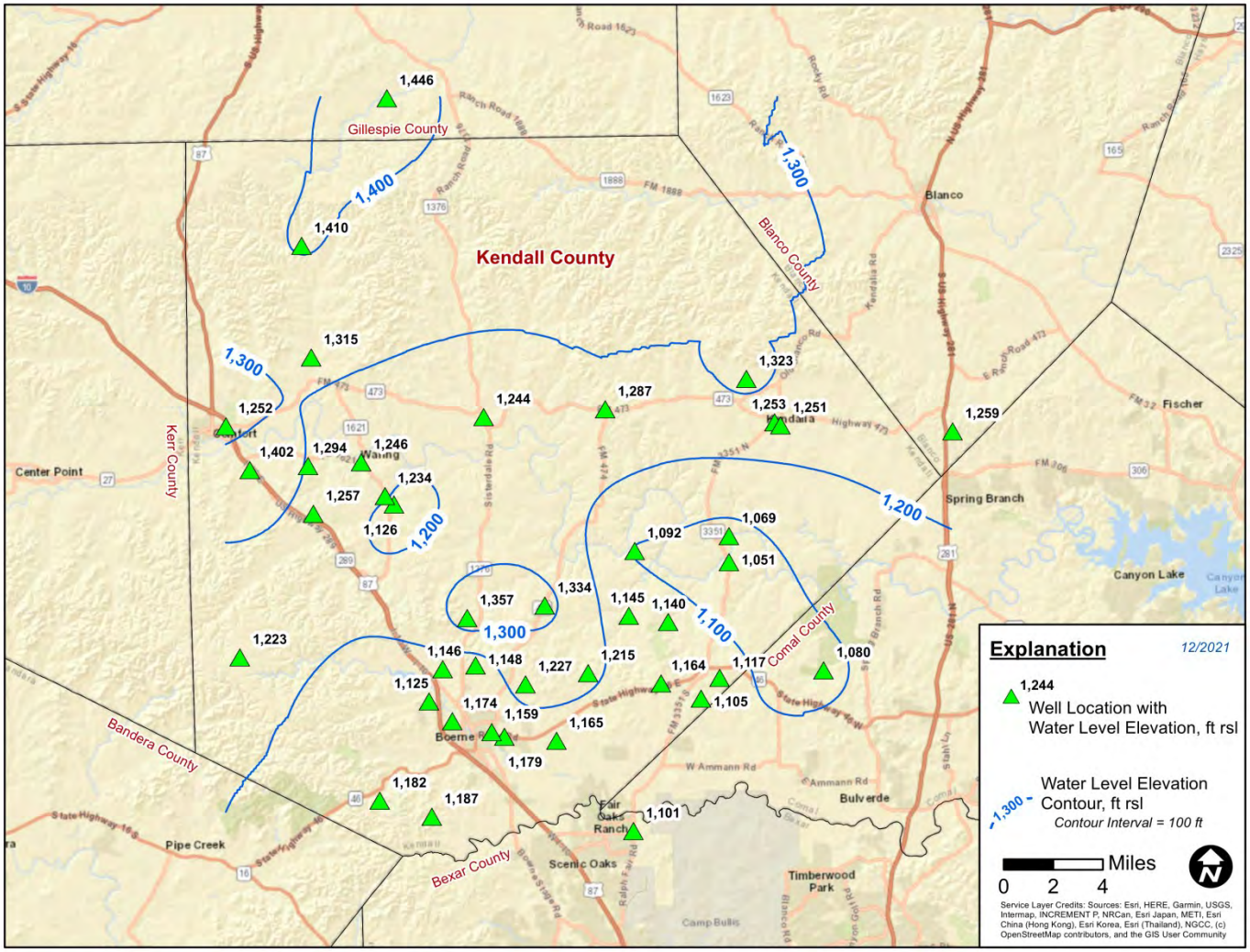


Figure 11. Estimated Water Level Elevation Contours for the Middle Trinity in 2019

Estimated available drawdown contours measured from top and base of the Middle Trinity for 2019 are presented in Figure 12 and Figure 13. As before, negative values in these figures indicate water levels below the top of the Middle Trinity. Positive values indicate water levels above the top or base of the Middle Trinity.

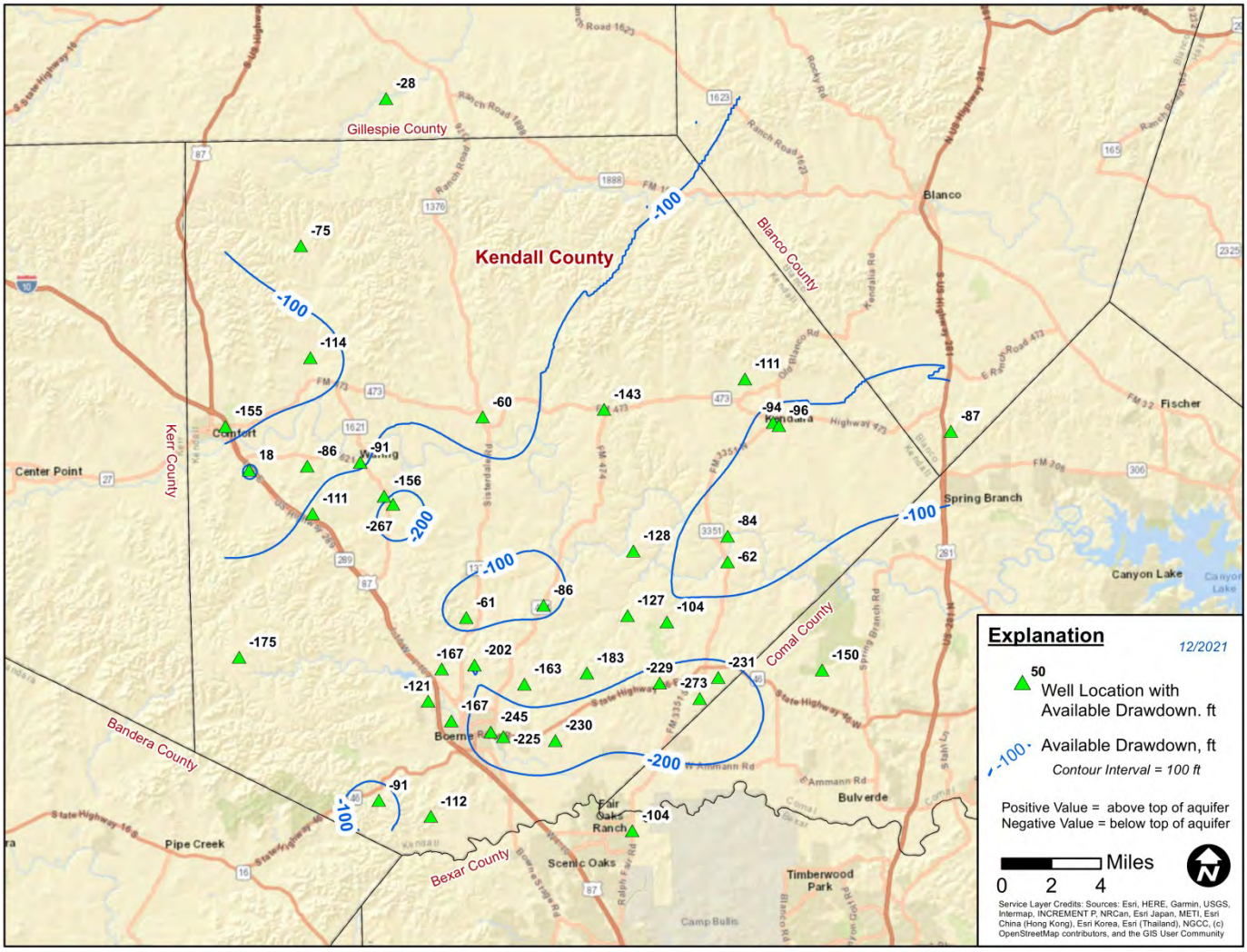


Figure 12. Estimated Vertical Distance Between Middle Trinity Water Level Measurements for 2019 and the Top of Middle Trinity Aquifer as Defined in the THCGAM

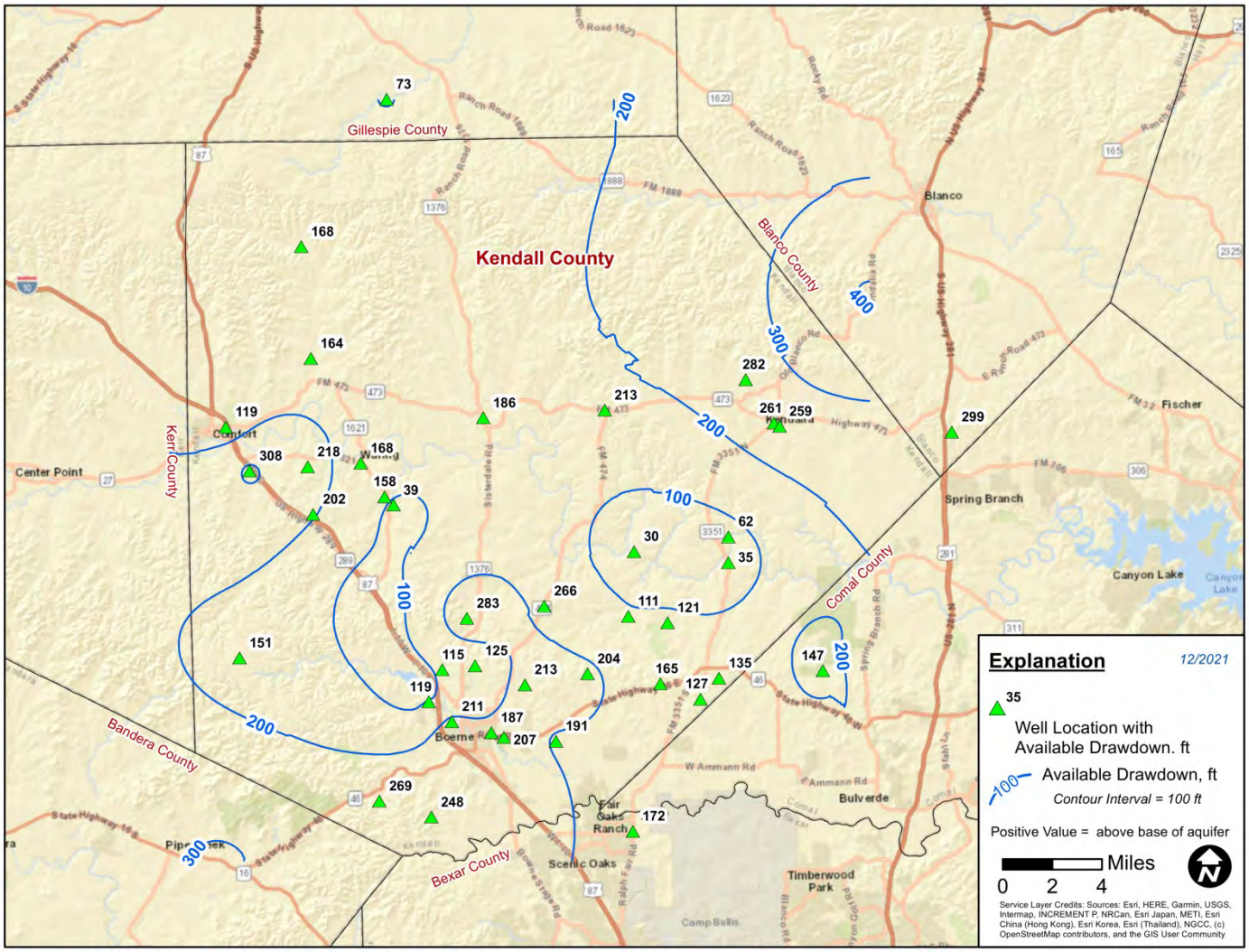


Figure 13. Estimated Vertical Distance Between Middle Trinity Water Level Measurements for 2019 and the Base of Middle Trinity Aquifer as Defined in the THCGAM

Figure 14 illustrates estimated water level change contours for the Middle Trinity between the years 2010 and 2019. The northwestern portion of the County appears to have experienced a water level decline of about 10 to 20 feet, and an area southeast of Boerne has declined about 10 feet.

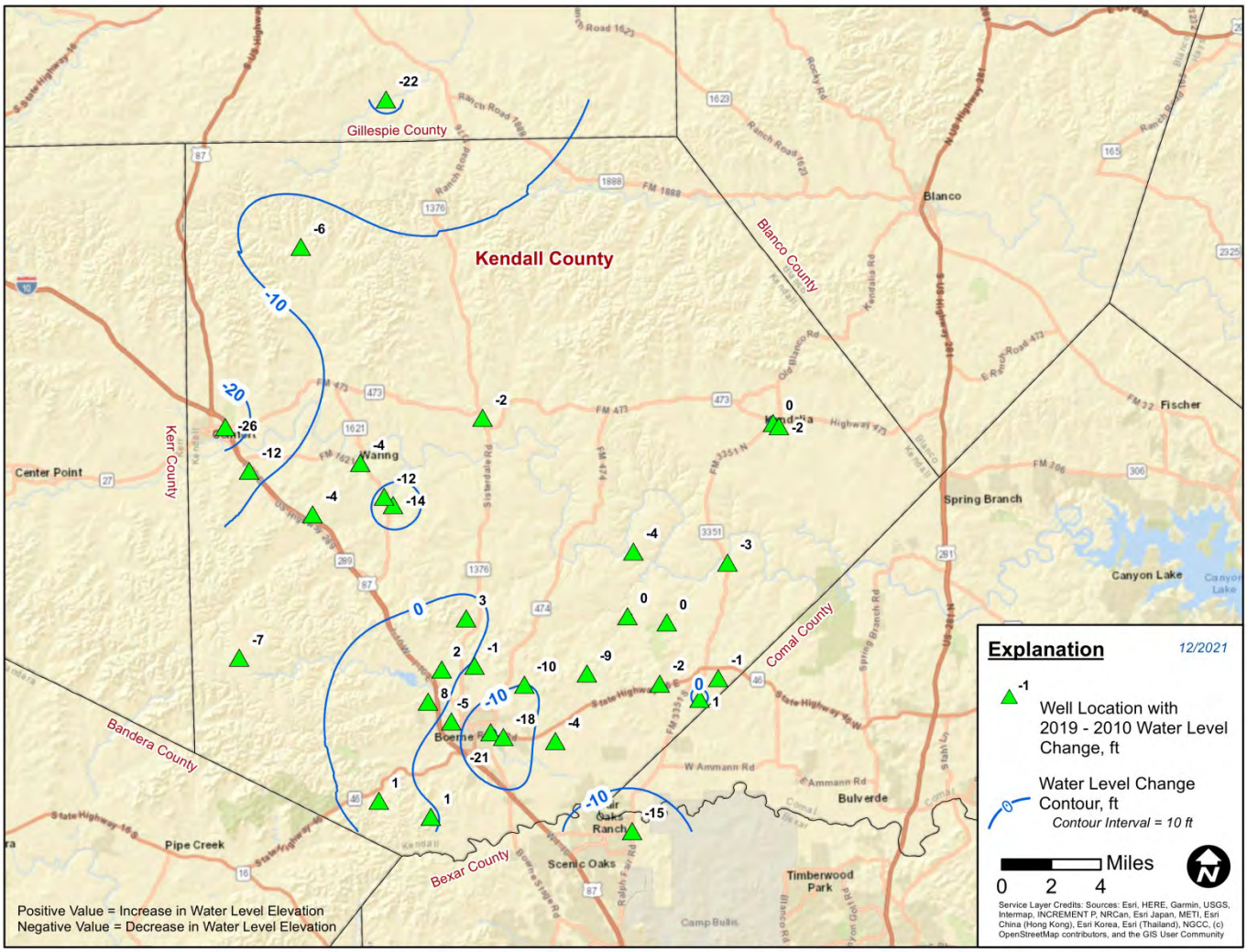


Figure 14. Estimated Water Level Change Contours for the Middle Trinity (2010 – 2019)

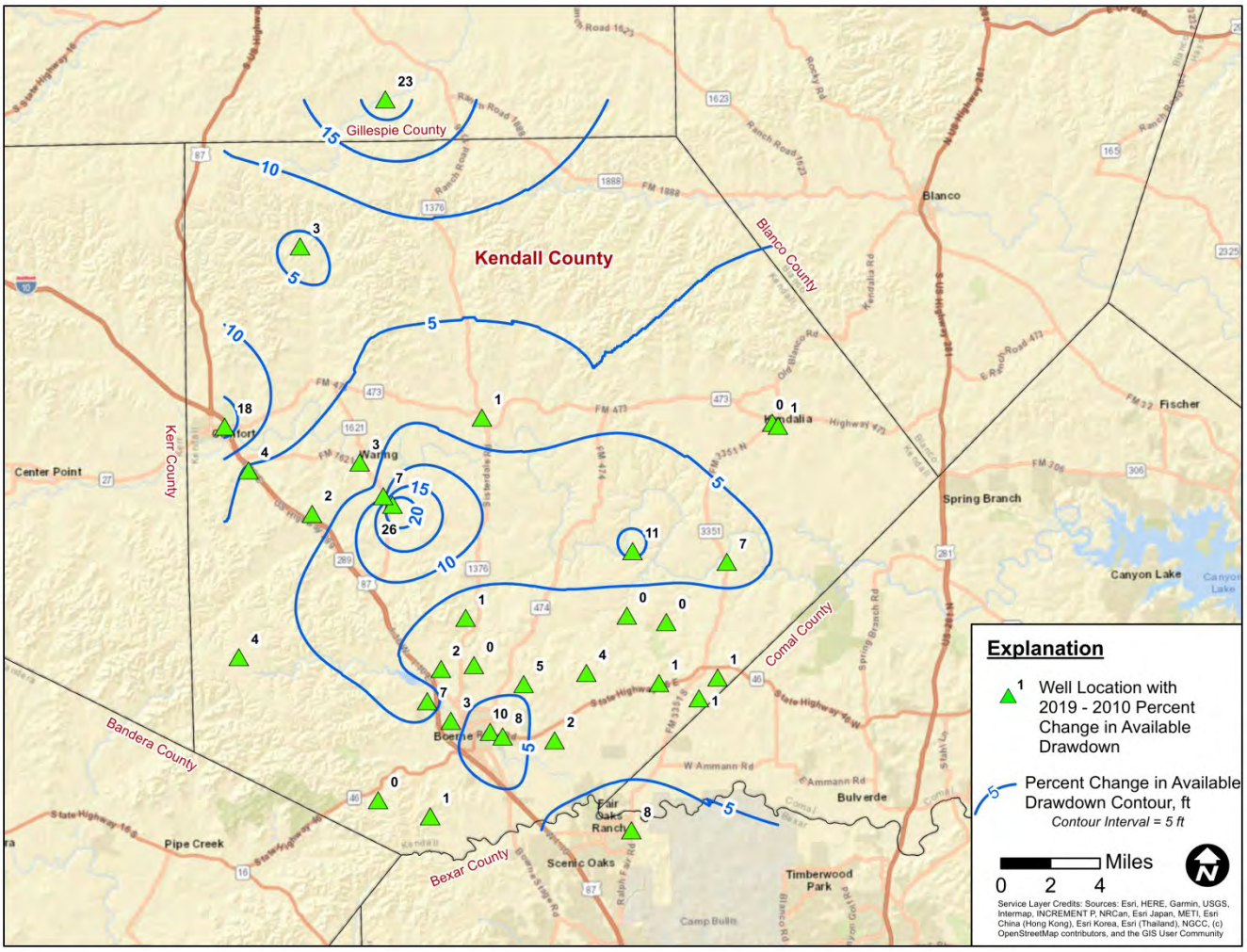


Figure 15. Percentage Decline Contours of Available Drawdown in the Middle Trinity (2010 – 2019) as Measured from the Base of the Middle Trinity

To illustrate the difference choice of year (and precipitation condition) can make on the analysis of water level decline for the Middle Trinity, Figure 16 shows estimated decline contours for the Middle Trinity for the years 2010-2021. The difference vs 2010-2019 varies by location, but in general the difference is 10-20 feet more water level decline. The estimated decline is expressed in percentage terms in Figure 17.

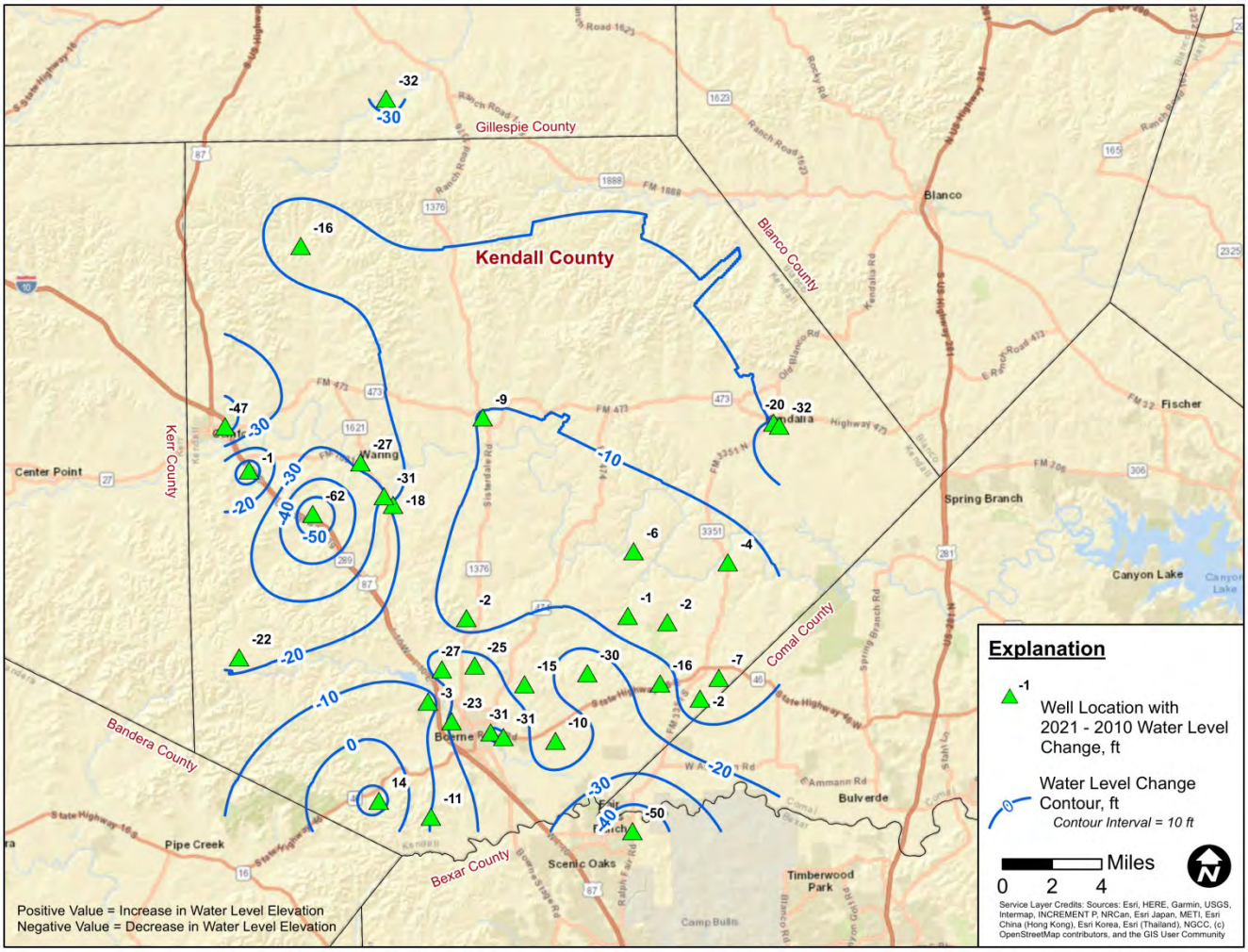


Figure 16. Estimated Water Level Change Contours for the Middle Trinity (2010 – 2021)

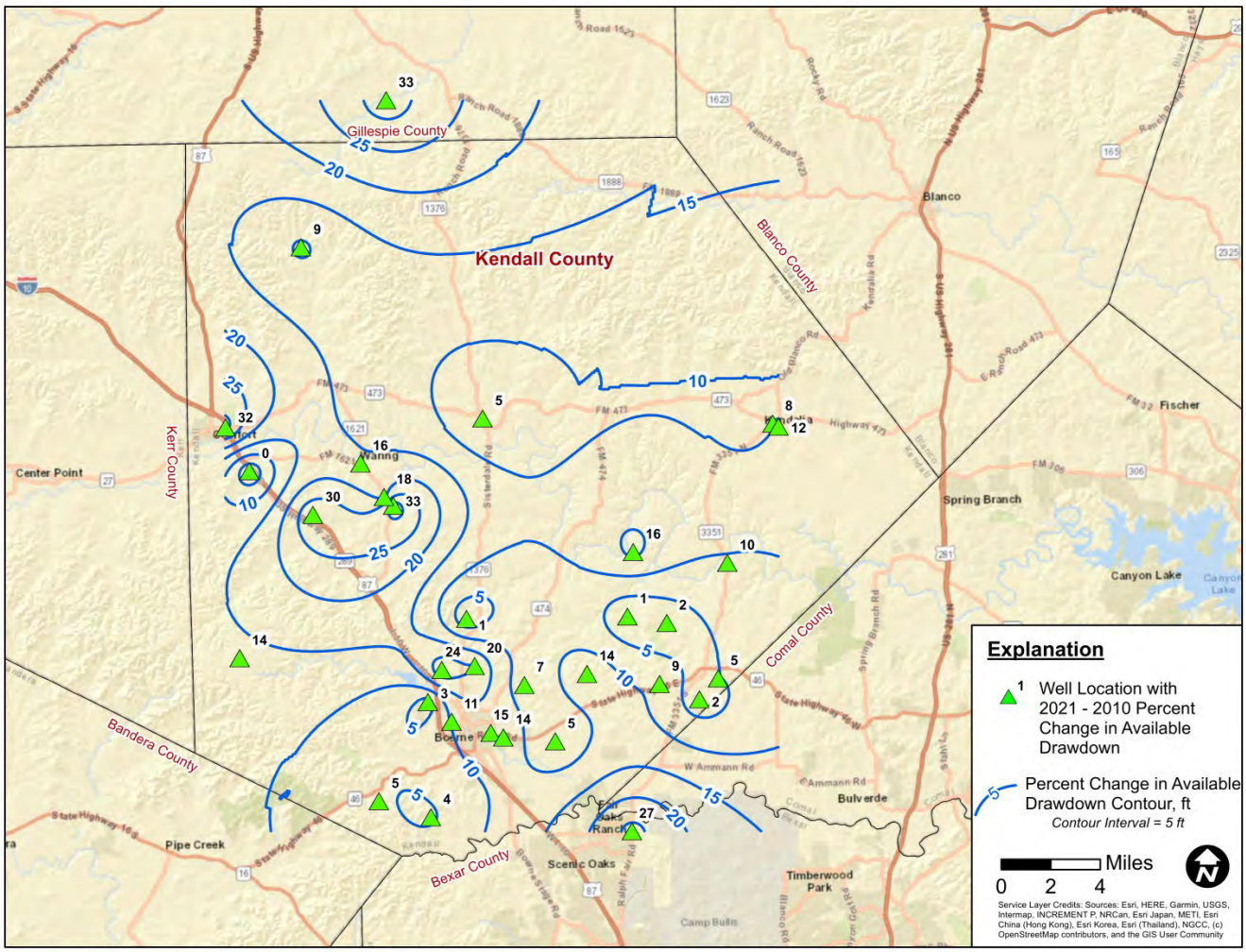


Figure 17. Percentage Decline Contours of Available Drawdown in the Middle Trinity (2010 – 2021) as Measured from the Base of the Middle Trinity

3.1.2 Lower Trinity

There are comparatively few hydrographs for wells completed in the Lower Trinity. Those that are available are included in Appendix A. Many of these are clustered in a developed area in the southeast portion of the County, where there are many domestic wells completed within the Lower Trinity. One representative example of the changes in water level in the Lower Trinity in response to pumping is shown in Figure 18.

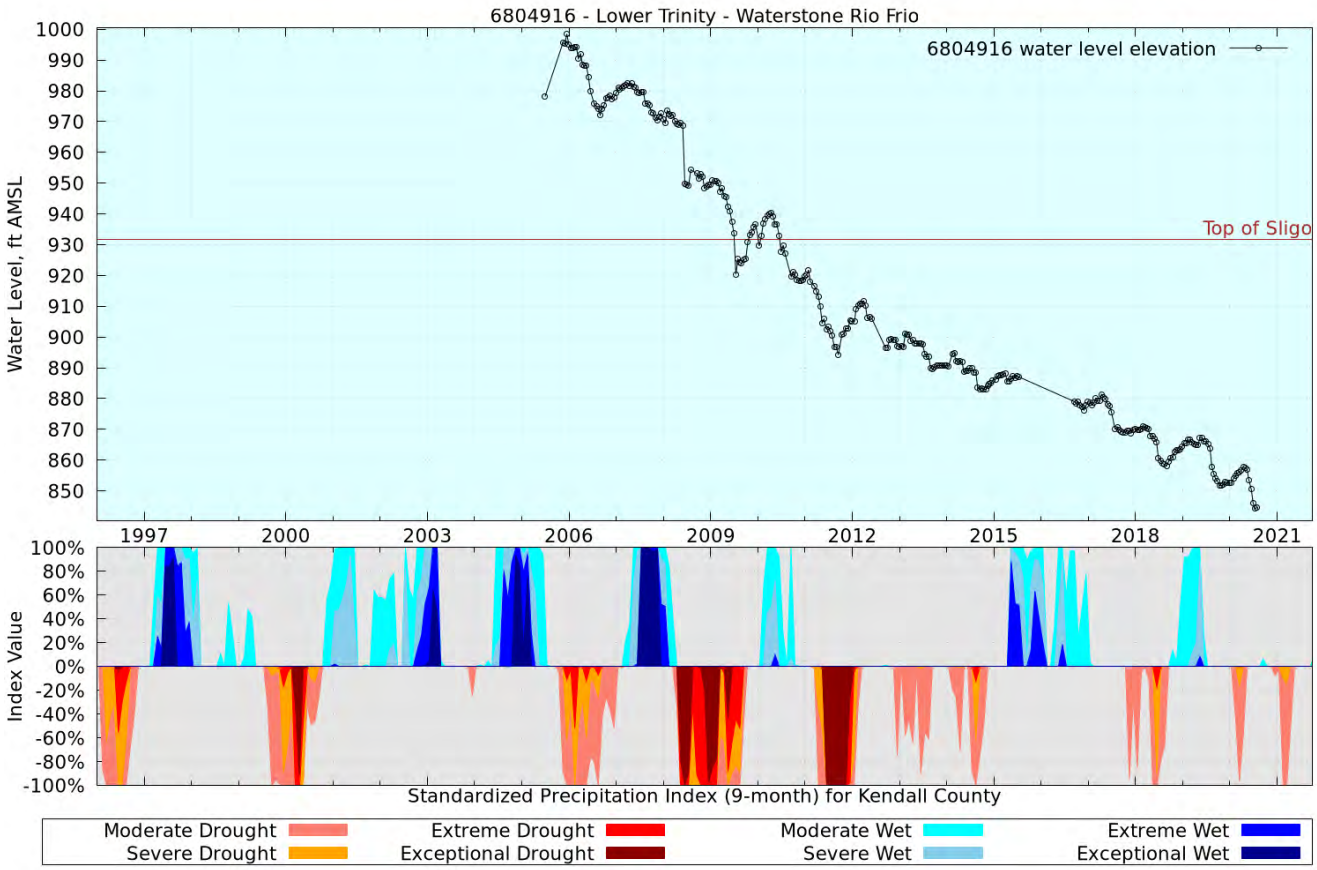


Figure 18. Long-Term Hydrograph for Lower Trinity Well 68-04-916 (Waterstone Rio Frio)

Figure 19 presents the estimated water level contours in the Lower Trinity in 2010. Water generally flows to the southeast.

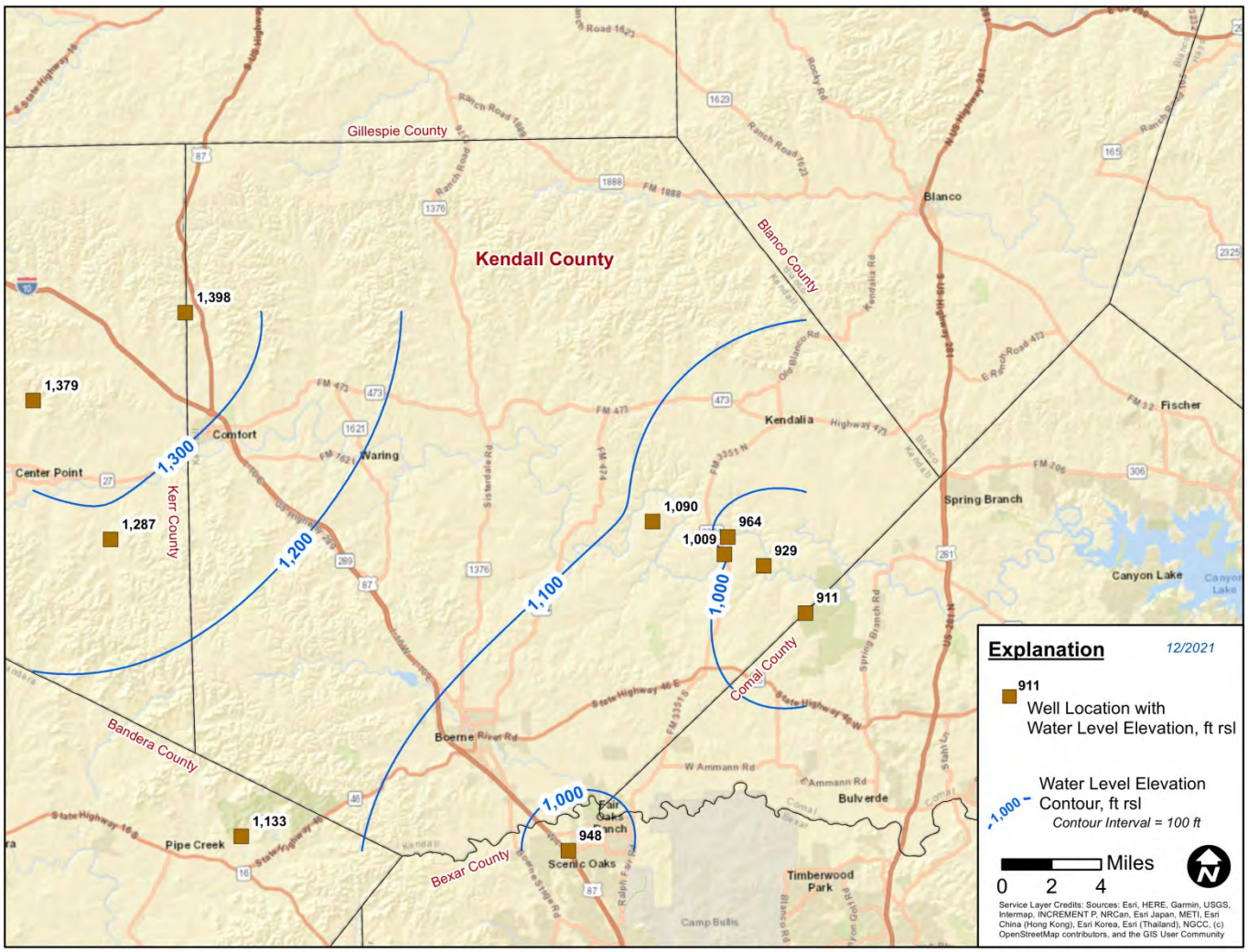


Figure 19. Estimated Water Level Elevation Contours for the Lower Trinity in 2010

Estimated available drawdown contours measured from top and base of the Lower Trinity for 2010 are presented in Figure 20 and Figure 21. As with similar figures for the Middle Trinity, negative values in these figures indicate water levels below the top of the Lower Trinity. Positive values indicate water levels above the top or base of the Lower Trinity.

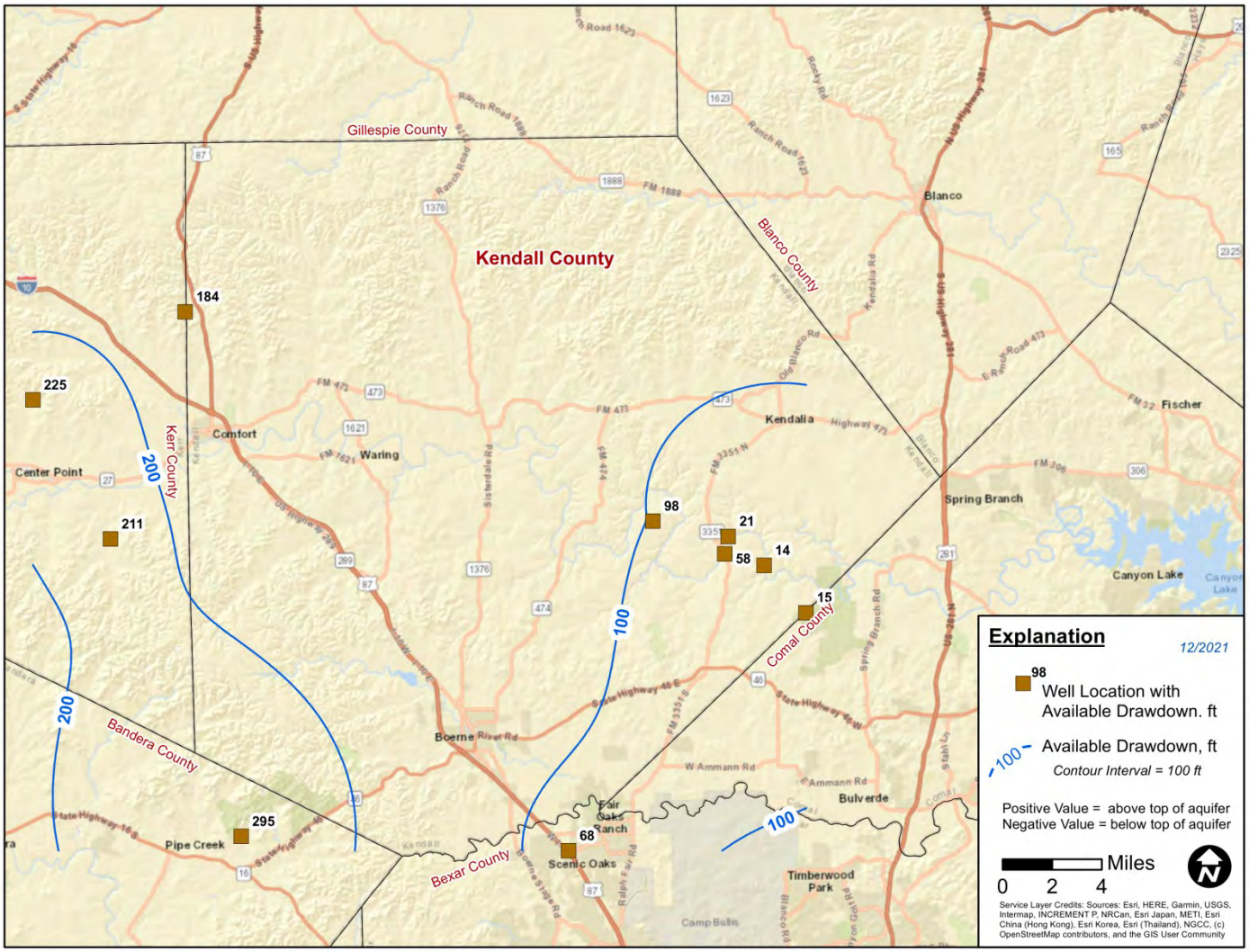


Figure 20. Estimated Vertical Distance Between Lower Trinity Water Level Measurements for 2010 and the Top of Lower Trinity Aquifer as Defined in the THCGAM

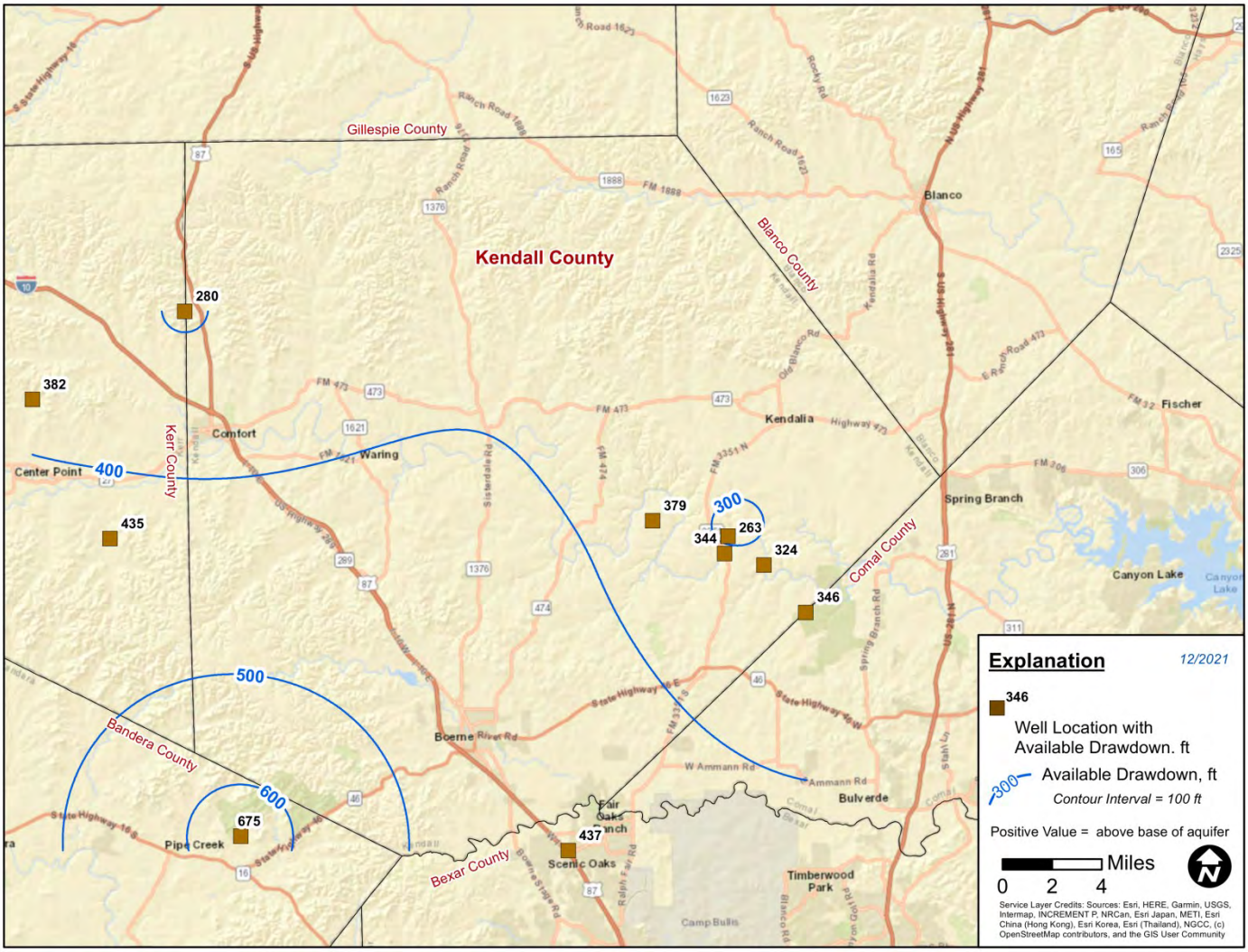


Figure 21. Estimated Vertical Distance Between Lower Trinity Water Level Measurements for 2010 and the Base of Lower Trinity Aquifer as Defined in the THCGAM

Figure 22 presents the estimated water level contours in the Lower Trinity in 2019. The elevation contour lines have a similar pattern to those in 2010, but they have generally shifted westward, indicating some amount of water level decline in the Lower Trinity in Kendall County.

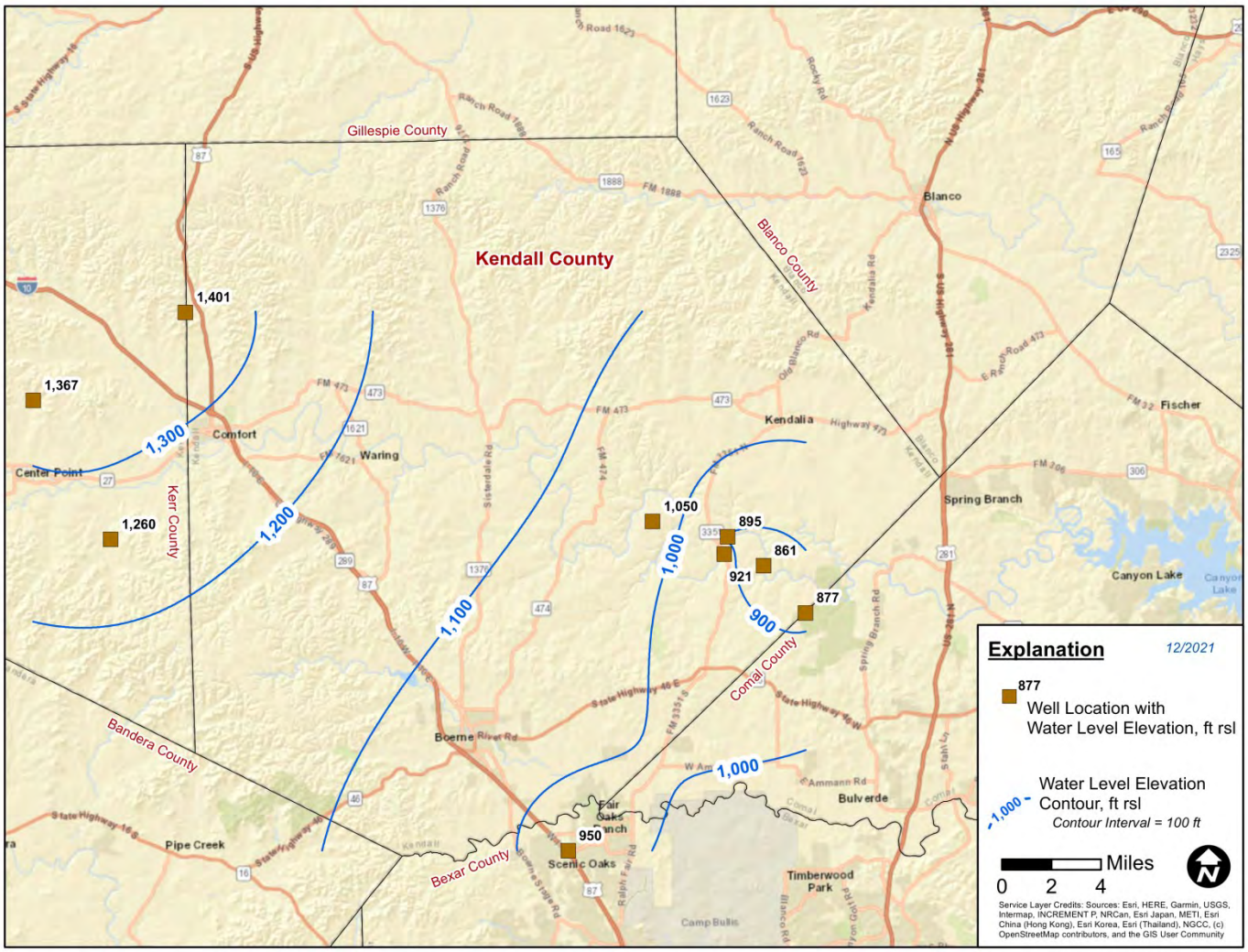


Figure 22. Estimated Water Level Elevation Contours for the Lower Trinity in 2019

Figure 23 shows the estimated available drawdown in the Lower Trinity Aquifer for 2019, as measured from the top of the Lower Trinity Aquifer as defined in the THCGAM. The zero contour indicates that there are areas where the water levels are below the top of the Lower Trinity Aquifer as defined in the THCGAM. Figure 24 provides the available drawdown measured from the base of the Lower Trinity Aquifer and these contours indicate that there is currently about 300 to 400 feet of available drawdown above the base of the Lower Trinity Aquifer. Figure 25 shows the amount of water level decline between 2010 and 2019 in the Lower Trinity. In the southeast part of the county, up to 80 feet of water level decline has occurred in the Lower Trinity in about 10 years. Eighty feet of water level decline is about 20 to 25 percent of the available drawdown in the Lower Trinity in that area (Figure 26). This finding indicates that in certain areas, significant water level decline is occurring due to increased development and pumping in recent decades. This finding indicates the need to continue to be diligent in finding an appropriate balance between maximum practicable production and conservation, especially in areas that are developing quickly and producing more groundwater.

It should also be noted that the simulated water level decline in the THCGAM is almost identical in the Middle and Lower Trinity Aquifers. However, the water level measurements in the 10-20 years indicate a divergence, especially in the southeast portion of the Kendall County. This is not unexpected given the reasonable hydraulic separation that is provided by the Hammett Shale in the area.

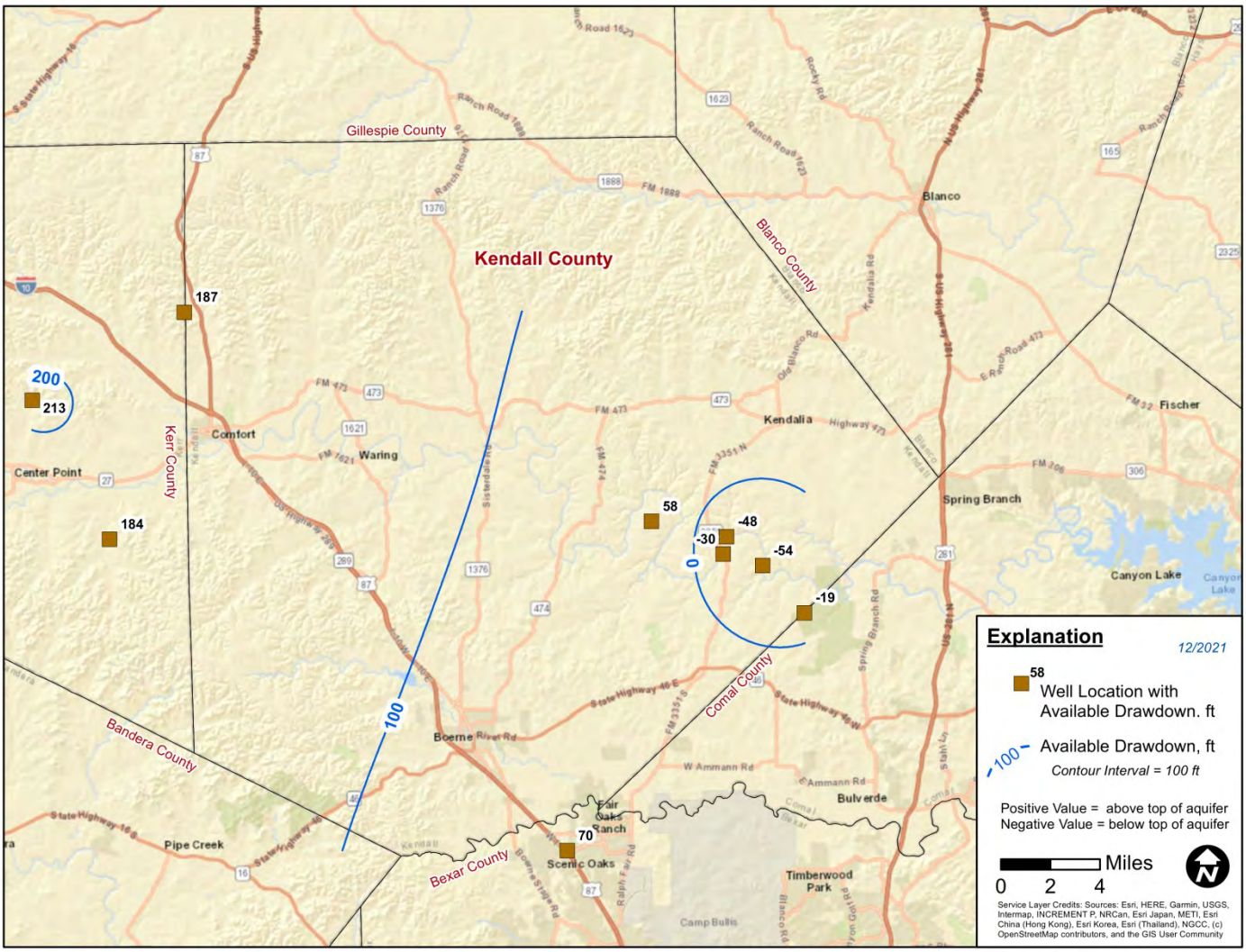


Figure 23. Estimated Vertical Distance Between Lower Trinity Water Level Measurements for 2019 and the Top of Lower Trinity Aquifer as defined in the THCGAM

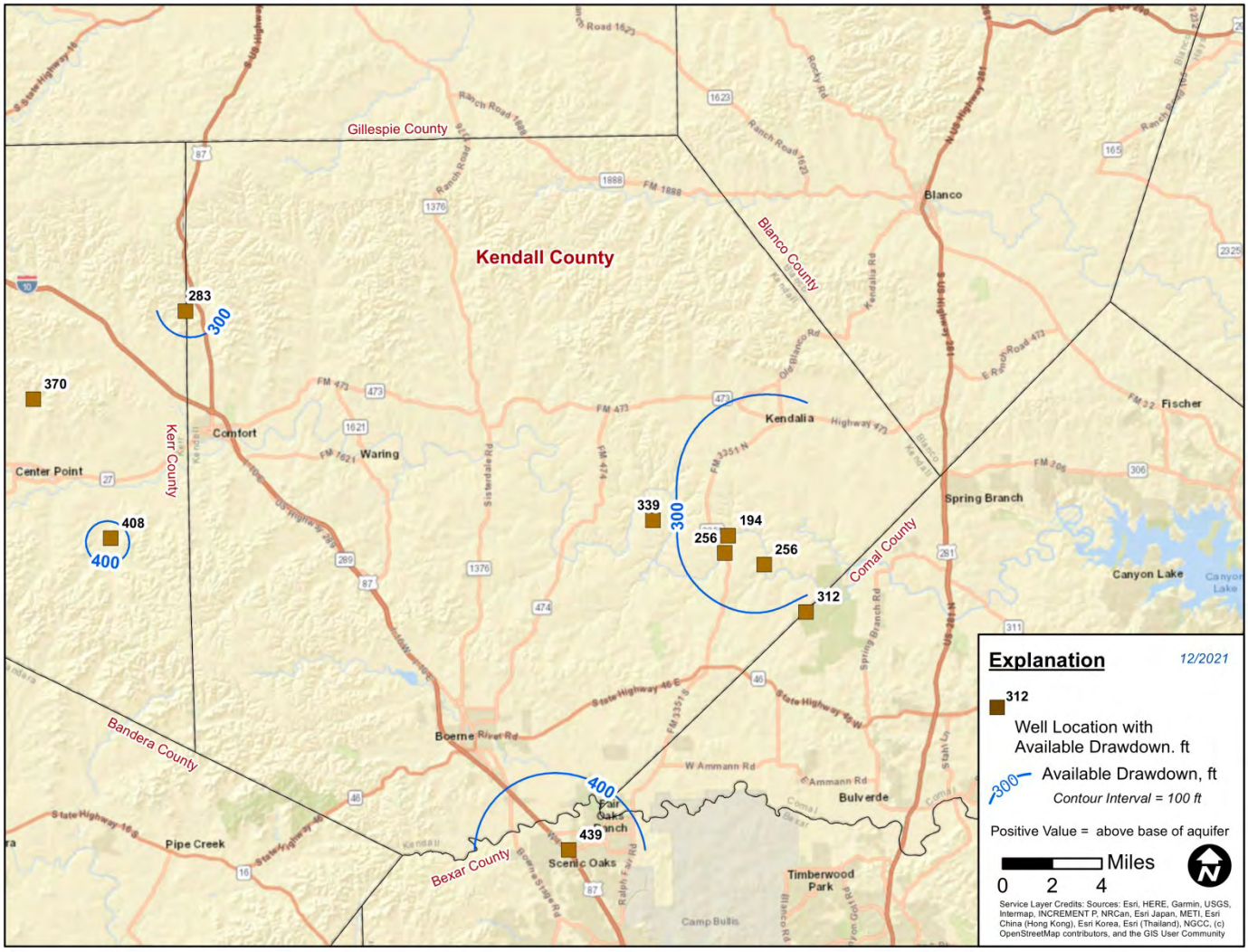


Figure 24. Estimated Vertical Distance Between Lower Trinity Water Level Measurements for 2019 and the Base of Lower Trinity Aquifer as defined in the THCGAM

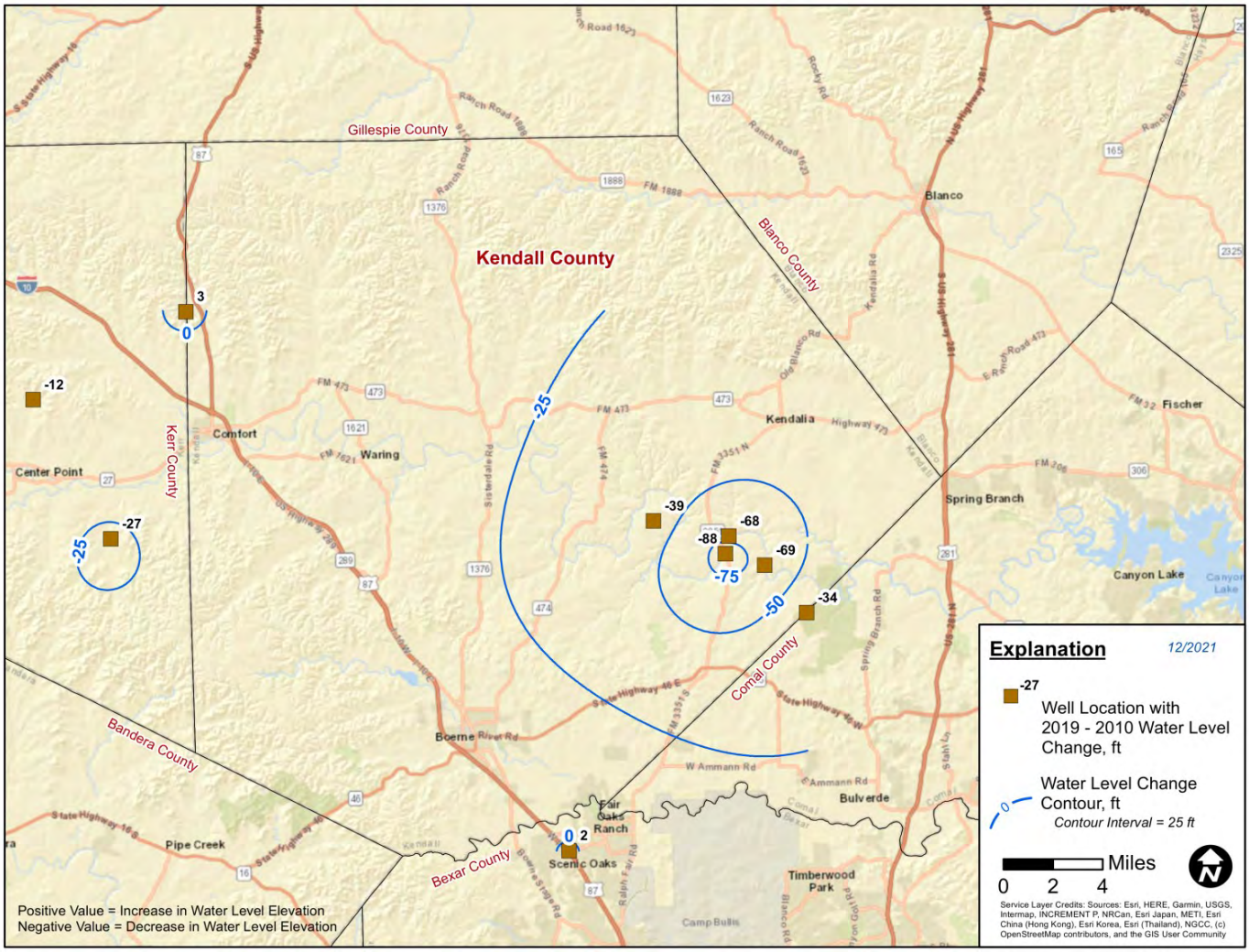


Figure 25. Estimated Water Level Change Contours for the Lower Trinity (2010 – 2019)

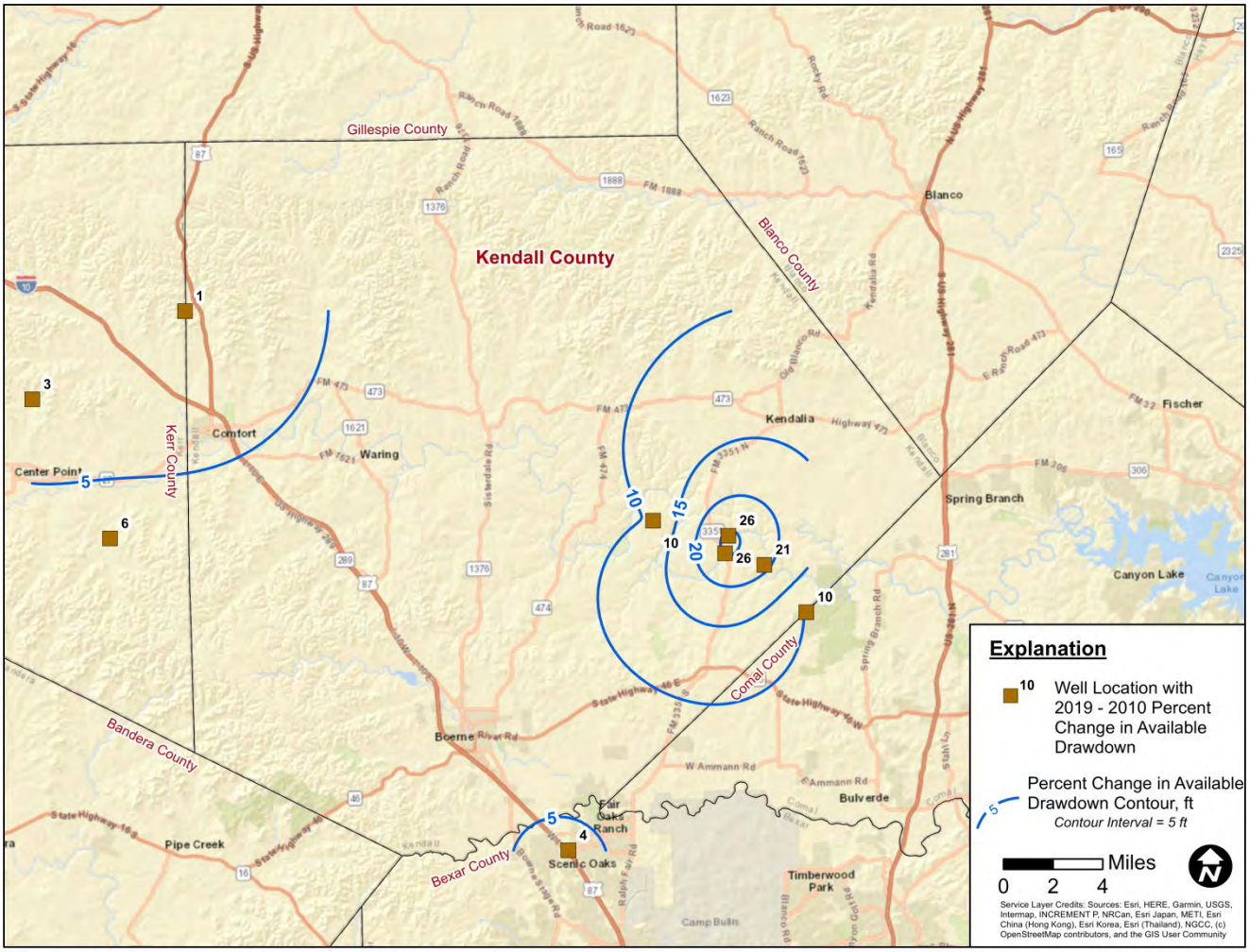


Figure 26. Percentage Decline Contours in Available Drawdown in Lower Trinity (2010 – 2019) as Measured from the Base of the Lower Trinity

To illustrate the difference choice of year can make on the analysis of water level decline, Figure 27 shows estimated decline contours for the Lower Trinity between 2010 and 2021. There are fewer data points for comparison in 2021 than there is in 2019, but in general the difference vs 2010-2019 is 10-15 feet more water level decline. The estimated decline is expressed in percentage terms in Figure 28.

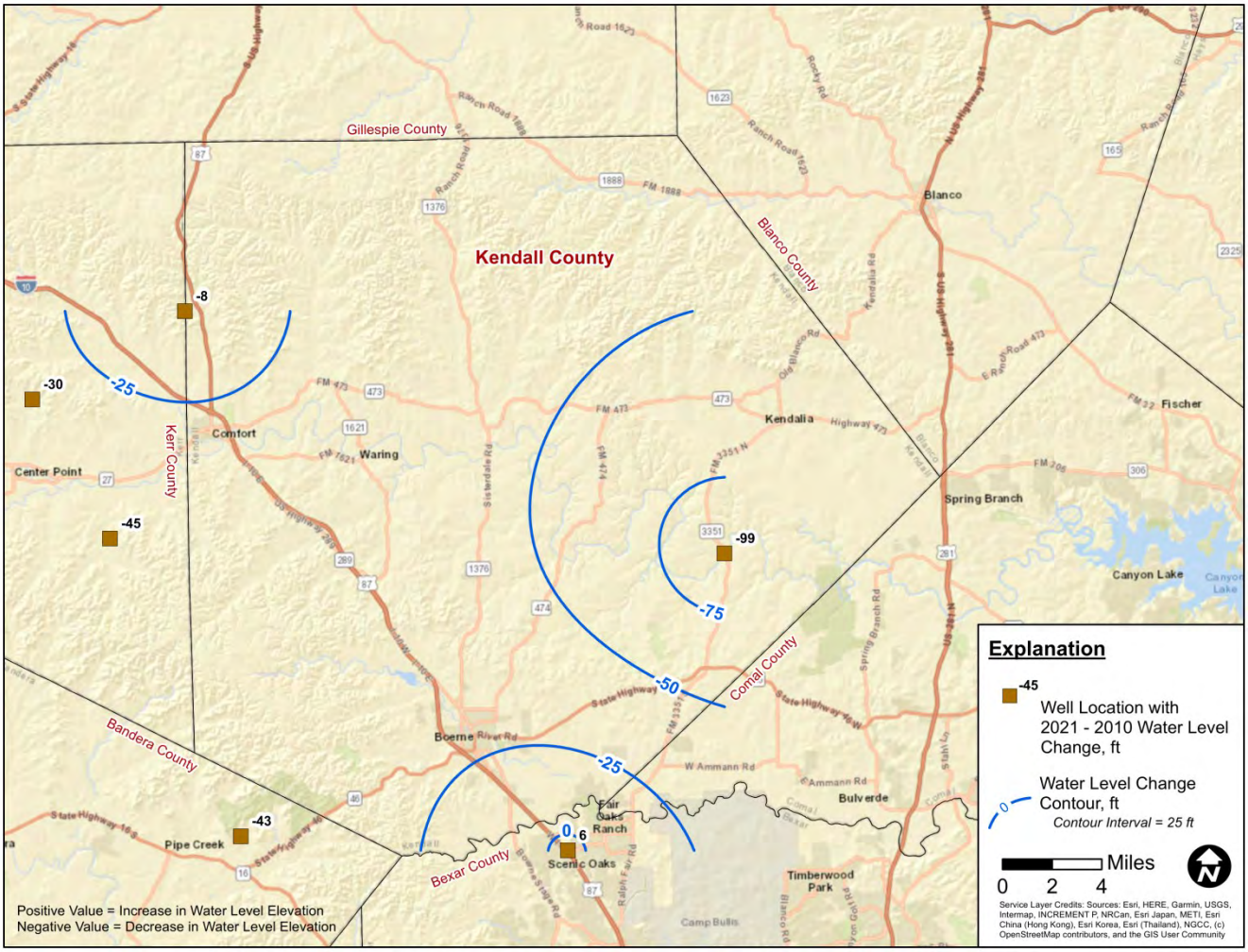


Figure 27. Estimated Water Level Change Contours for the Lower Trinity (2010 – 2021)

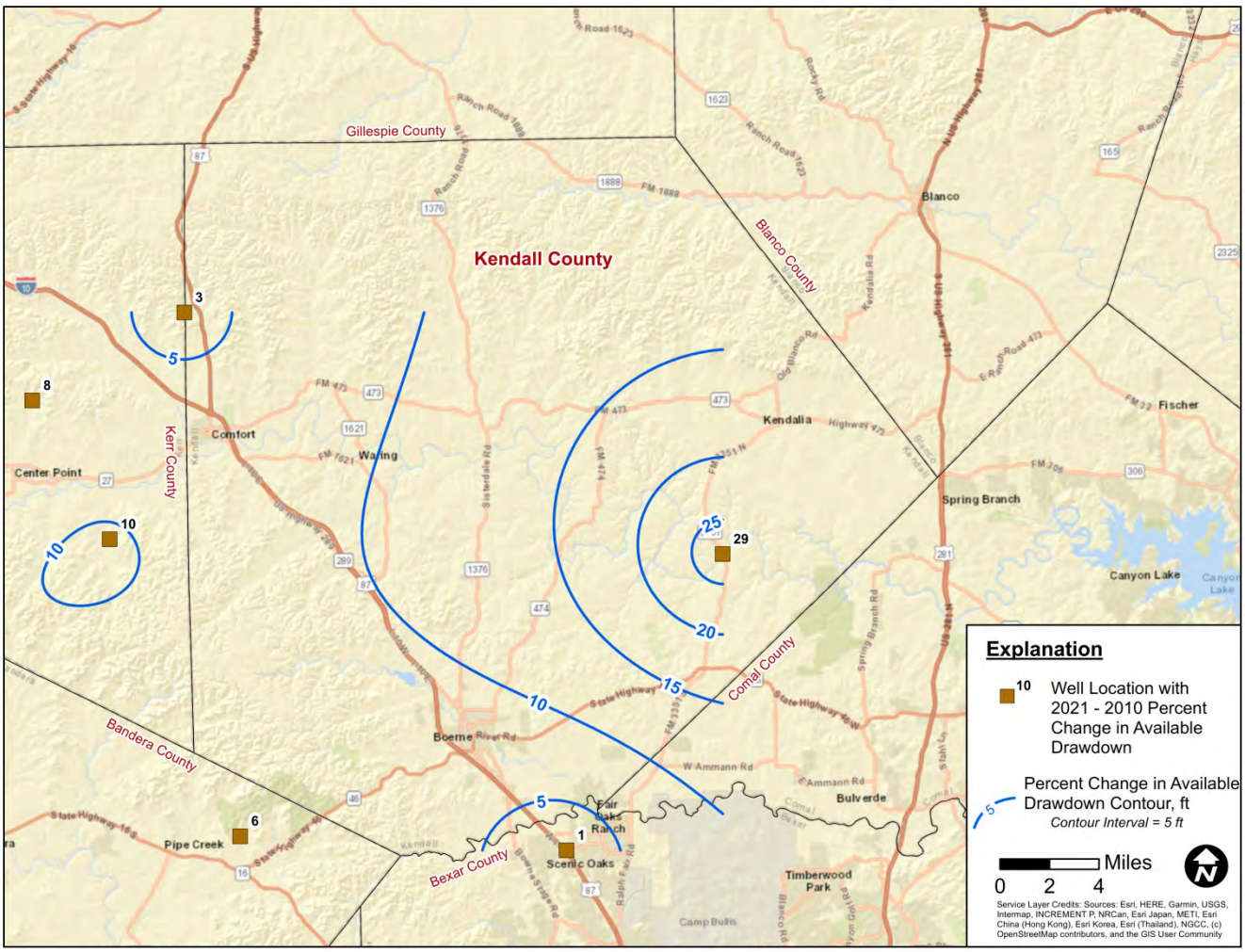


Figure 28. Percentage Decline Contours of Available Drawdown in Lower Trinity (2010 – 2021) as Measured from the Base of the Lower Trinity

3.2 *Pumping Trends*

Trends in groundwater pumping for the Middle and Lower Trinity in Kendall County have been assessed using a combination of District permitted well metered data and county-level data from TWDB and GMA 9.

The first category of historical pumping assessed was for District permitted wells. These fall into broad categories of commercial (industrial and fire were included in this category), irrigation, and public water supply. CCGCD provided monthly meter measurement data for permitted wells in individual spreadsheets. These data were combined into a single dataset and assessed for quality. Adjustments were made where meter measurements indicated a broken or new meter, and certain anomalies were investigated with the District. The annual pumping was then totaled for each permitted well. The number of permitted wells reached a level suitable for analysis by 2010, and so this date was chosen as a cut off for historical pumping estimates (Figure 29).

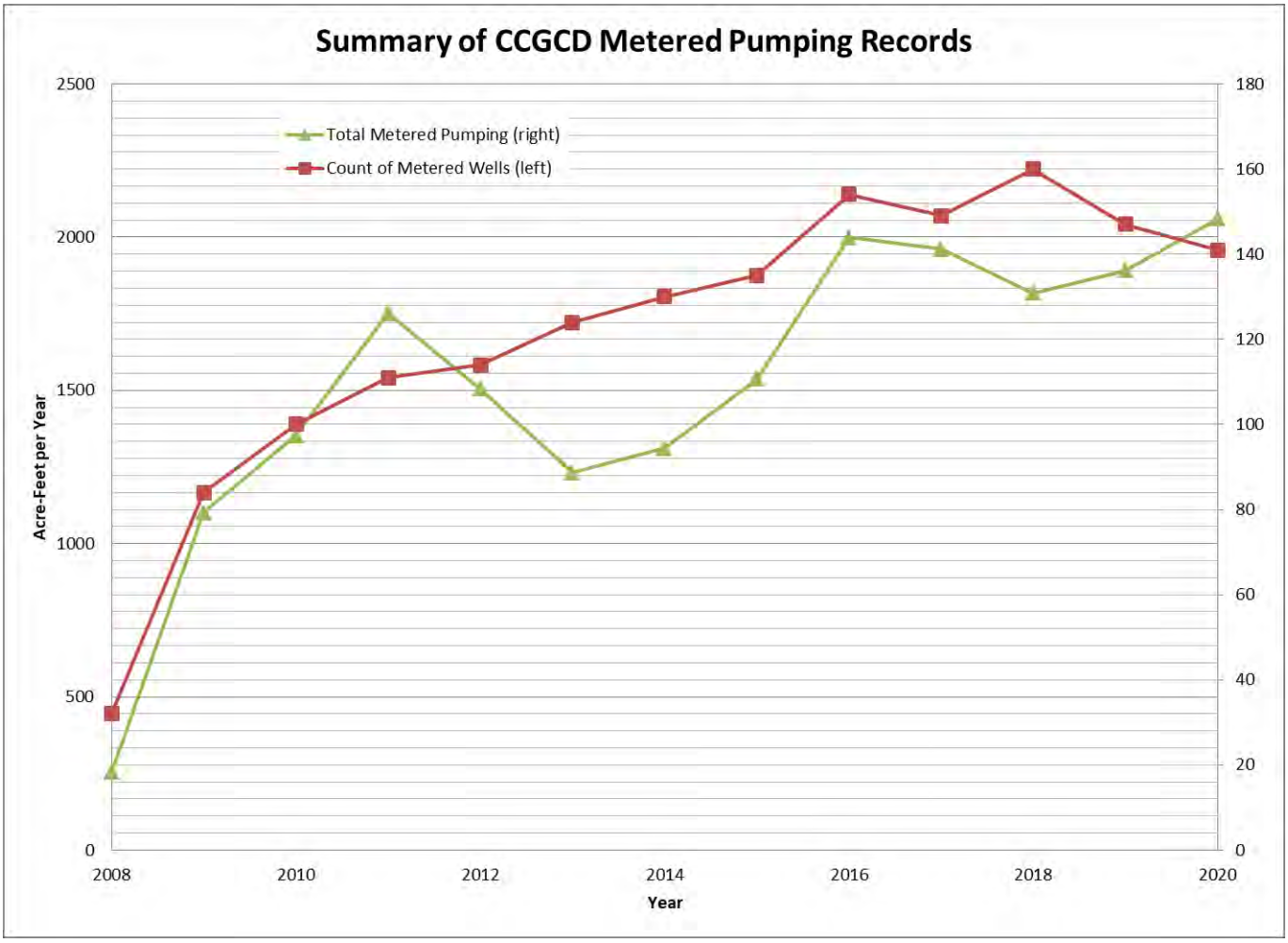


Figure 29. Summary of CCGCD Metered Pumping Records 2008-2020

The second broad category of historical pumping to be assessed is exempt wells. By their nature, exempt wells have no well-specific pumping records, unlike permitted wells. Our approach to assessing this pumping was to use county-level pumping estimates and distribute that pumping to each exempt well in existence in the District data for the years 2010-2020.

For livestock pumping, the TWDB provides historical groundwater use estimates on an annual basis. These estimates are based on agricultural census data for Kendall County, combined with water use estimates for each class of livestock. The amount of pumping estimated by TWDB for a given year in Kendall County was distributed to each well present in the District data for that year, for the years 2010-2020.

For domestic pumping, GMA 9 estimates of Kendall County domestic pumping for 2020 (2,973 AFY) were used to derive an estimate of the number of gallons per connection per day for each registered domestic well. These county-level estimates are based on census population data. For the number of domestic wells present in District data this estimate was 406 gallons per connection per day. This amount is somewhat higher than average connection usage throughout the state, but this is likely

due to the effect of unregistered domestic wells not present in District data. This estimate was applied to all domestic wells present in each year in District data to arrive at an annual pumping for each of the years 2010-2020.

For all wells, pumping was assigned based on completion aquifer. In the case of dual-completed wells (e.g. Middle and Lower Trinity), assigned pumping was split between the two aquifers.

A summary of Middle Trinity annual pumping in each use category for the years 2010-2020 is given in Figure 30. The scale for the pumping volume is variable in this figure, as the amount of pumping for each category varies considerably.

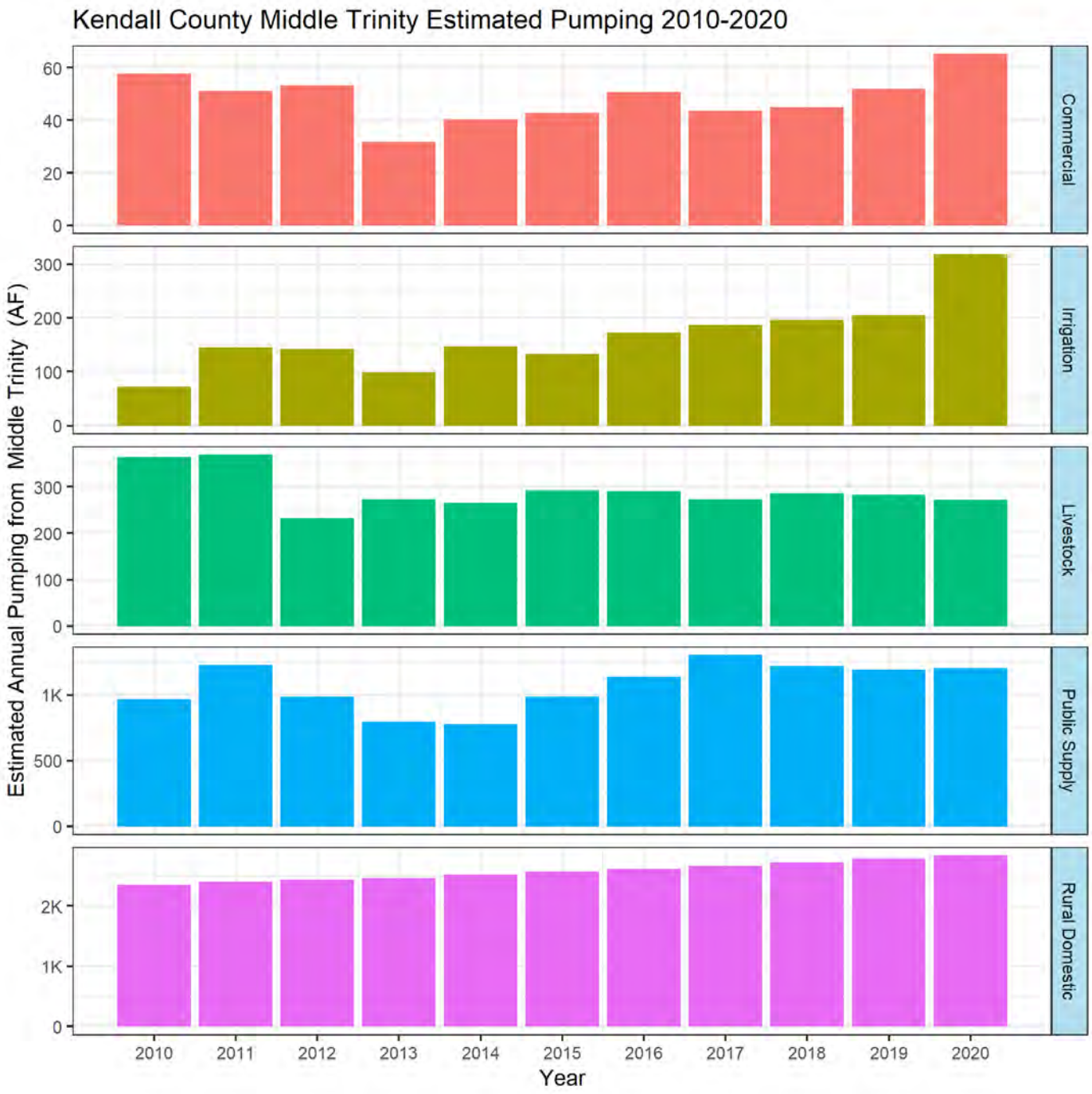


Figure 30. Estimated Pumping from the Middle Trinity by Usage Groups 2010-2019

A comparison of the Middle Trinity estimated annual total pumping, and for the pumping in the layer representing the Middle Trinity in the THCGAM is given in Figure 31. Because the pumping in the GAM is representative of pumping for Modeled Available Groundwater (MAG), it is much higher than actual estimated pumping. The MAG estimate for CCGCD and all of GMA 9 was based on an increase in future pumping of about 66 percent. Specifically, the estimated pumping in GAM 9 in 2008 was about 60,000 AFY, and the Desired Future Condition selected by GMA 9 yielded a MAG of about

100,000 AFY. Therefore, it is not surprising that the MAG pumping in CCGCD is greater than the current pumping.

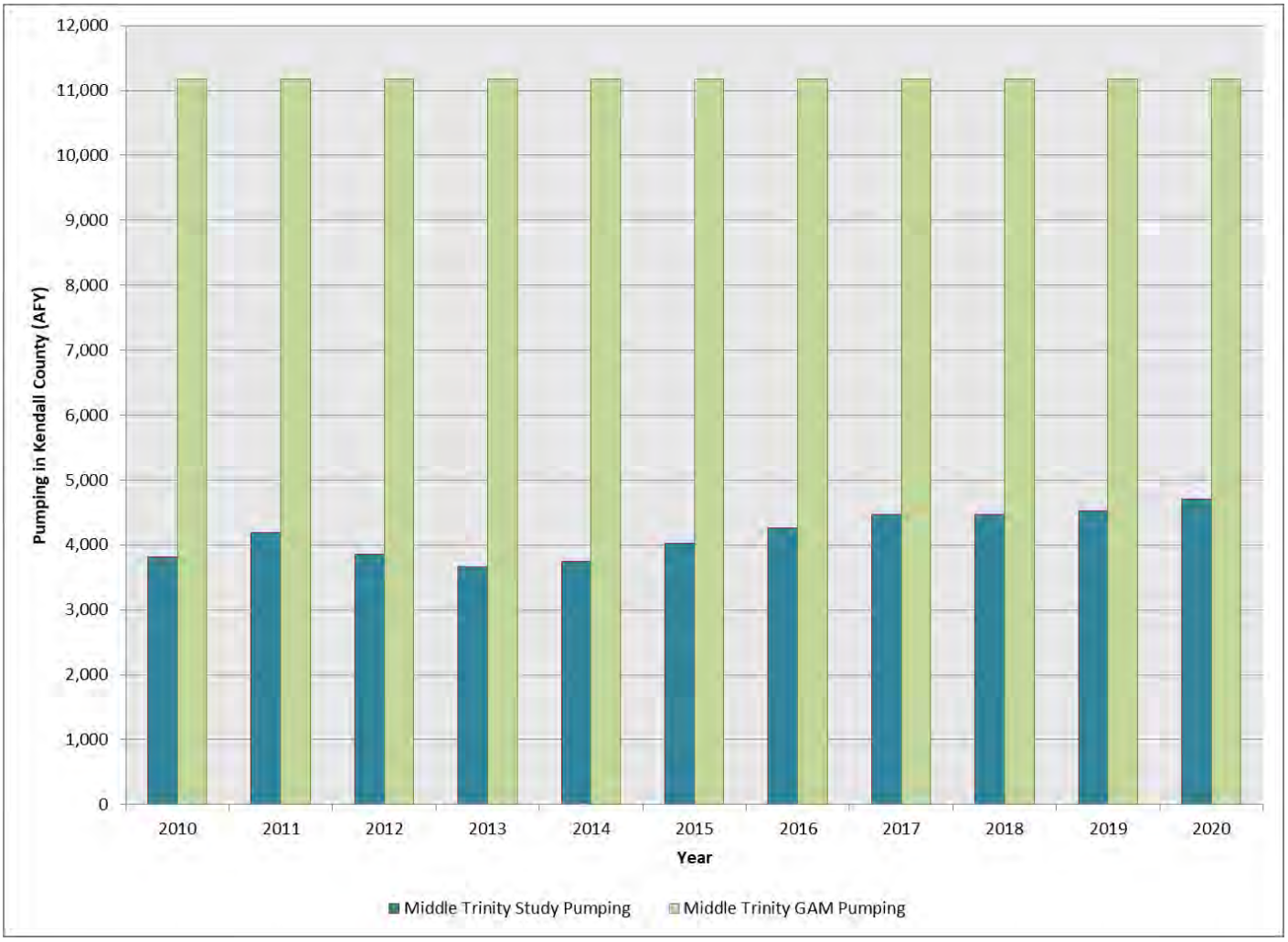


Figure 31. Comparison of Estimated Total Pumping from the Middle Trinity Aquifer and MAG Pumping in the GAM

A summary of Lower Trinity annual pumping in each use category for the years 2010-2020 is given in Figure 30Figure 32.

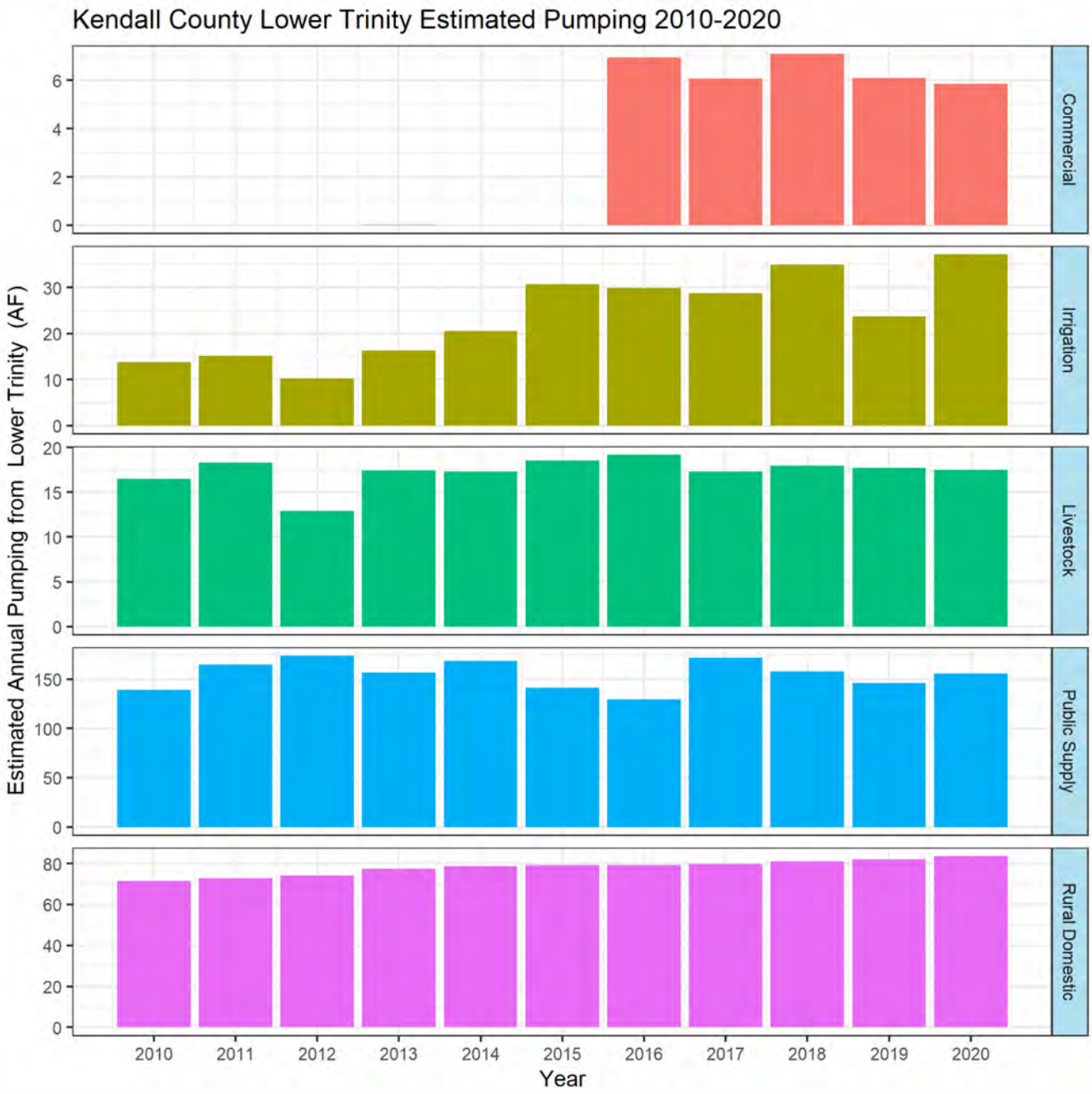


Figure 32. Estimated Pumping from the Lower Trinity by Usage Groups 2010-2019

A comparison of the Lower Trinity estimated annual total pumping, and for the pumping in the layer representing the Lower Trinity in the THCGAM is given in Figure 33. Again, the GAM pumping is much larger than the estimated actual pumping, as it represents a level close to the MAG.

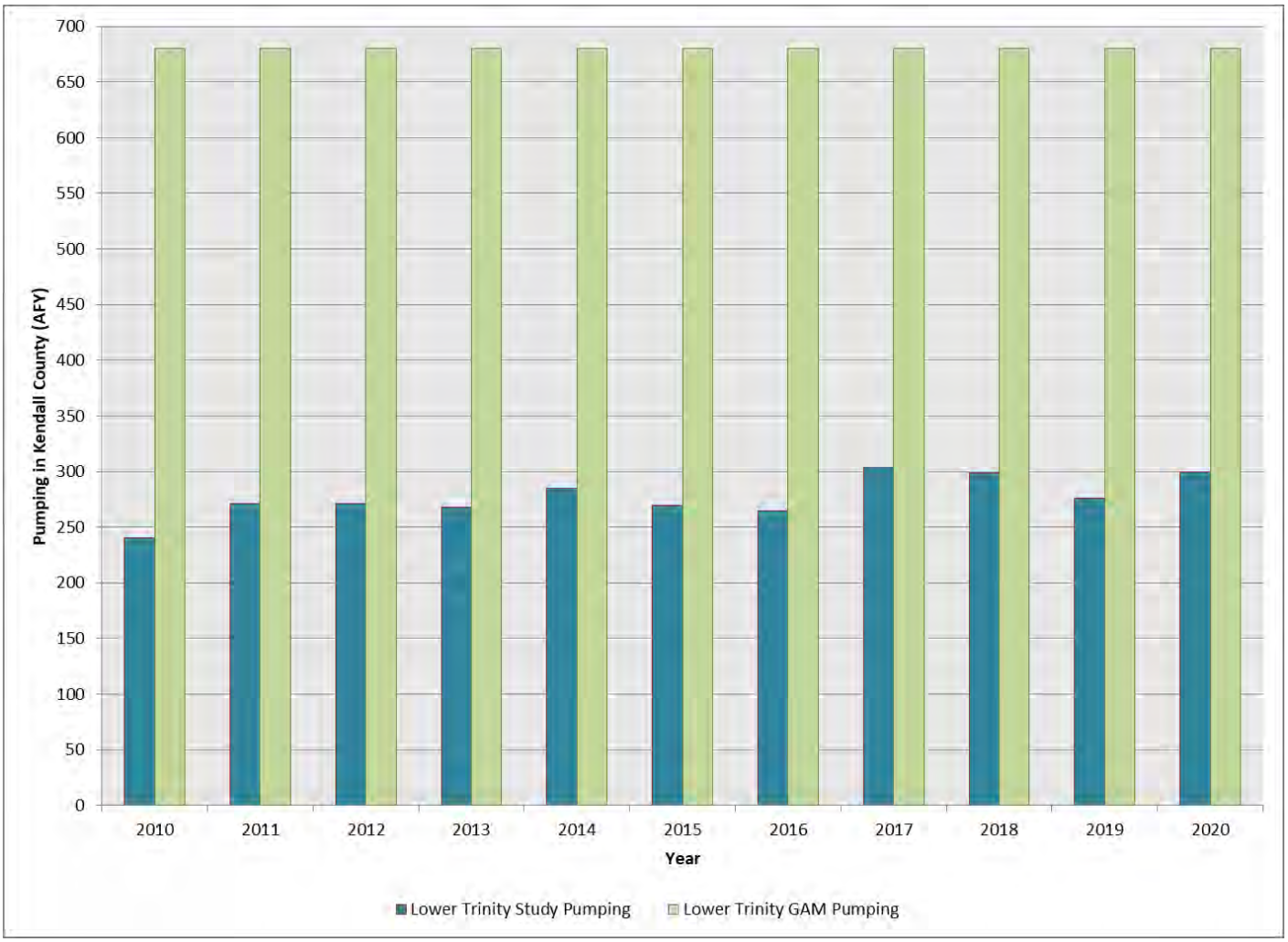


Figure 33. Comparison of Estimated Total Pumping from the Lower Trinity Aquifer and MAG pumping in the GAM

The total estimated annual pumping for the year 2020 was assigned to GAM grids according to pumped well location for both the Middle Trinity (Figure 34). Actual estimated grid totals have been assigned to discrete pumping bins in this figure for ease of illustration. Areas without grid cells in this figure have no estimated pumping for the year 2020. Usually this is a case of no wells being present in that gridblock. In some cases a non-exempt well is present in a gridblock, but did not have metered records for the year 2020.

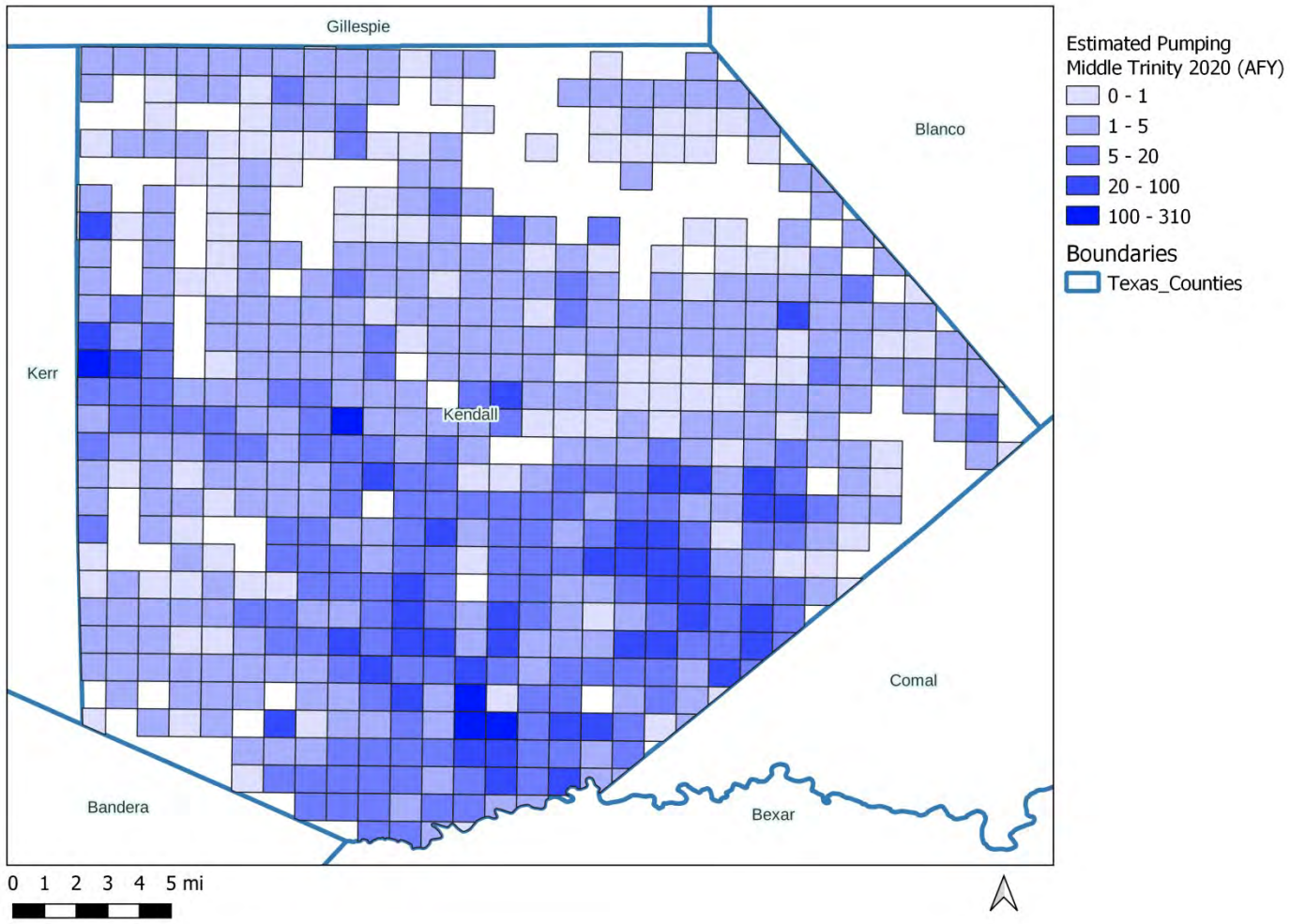


Figure 34. Estimated Middle Trinity Study Pumping Distribution for 2020

The difference between the estimated actual 2020 pumping and the THCGAM pumping is shown in Figure 35. The difference in pumping is illustrated within each gridblock in the THCGAM. Each gridblock measures 1-mile x 1-mile. In this figure, red colors indicate the THCGAM pumping was higher, and green colors indicate the actual estimated pumping was higher.

This figure illustrates that several developed areas have had more actual pumping than is in the MAG estimate in the THCGAM, while less-developed areas of Kendall County have had less actual pumping than is in the MAG estimate in the THCGAM. This is caused in part by different approaches used to distribute pumping in the GAM and the detailed approach used in this study which incorporated the location of specific well locations and permitted production values.

Gridblocks with large public water supply wells also generally have had less actual pumping than is in the GAM. This is likely due to the “ramp up” of pumping that was used in the joint planning process to assess the DFC and MAG. In the ramp up process, the 2008 estimated pumping in every model gridblock was simply multiplied by a factor to estimate the future pumping. For GMA 9, the factor

was about 1.66, which is the factor required to increase the entire pumping in GMA 9 from 60,000 AFY to about 100,000 AFY. With this approach, gridblocks that contain the majority of the pumping in a county (such as municipal wellfields) are "ramped up" to even larger pumping in relatively small areas. This method of increasing pumping maintained the same distribution of pumping that was estimated when the THCGAM was developed in the mid-1990s. This explains why the future pumping contained in the MAG is underpredicted in high growth areas of the county as illustrated in the green gridblocks.

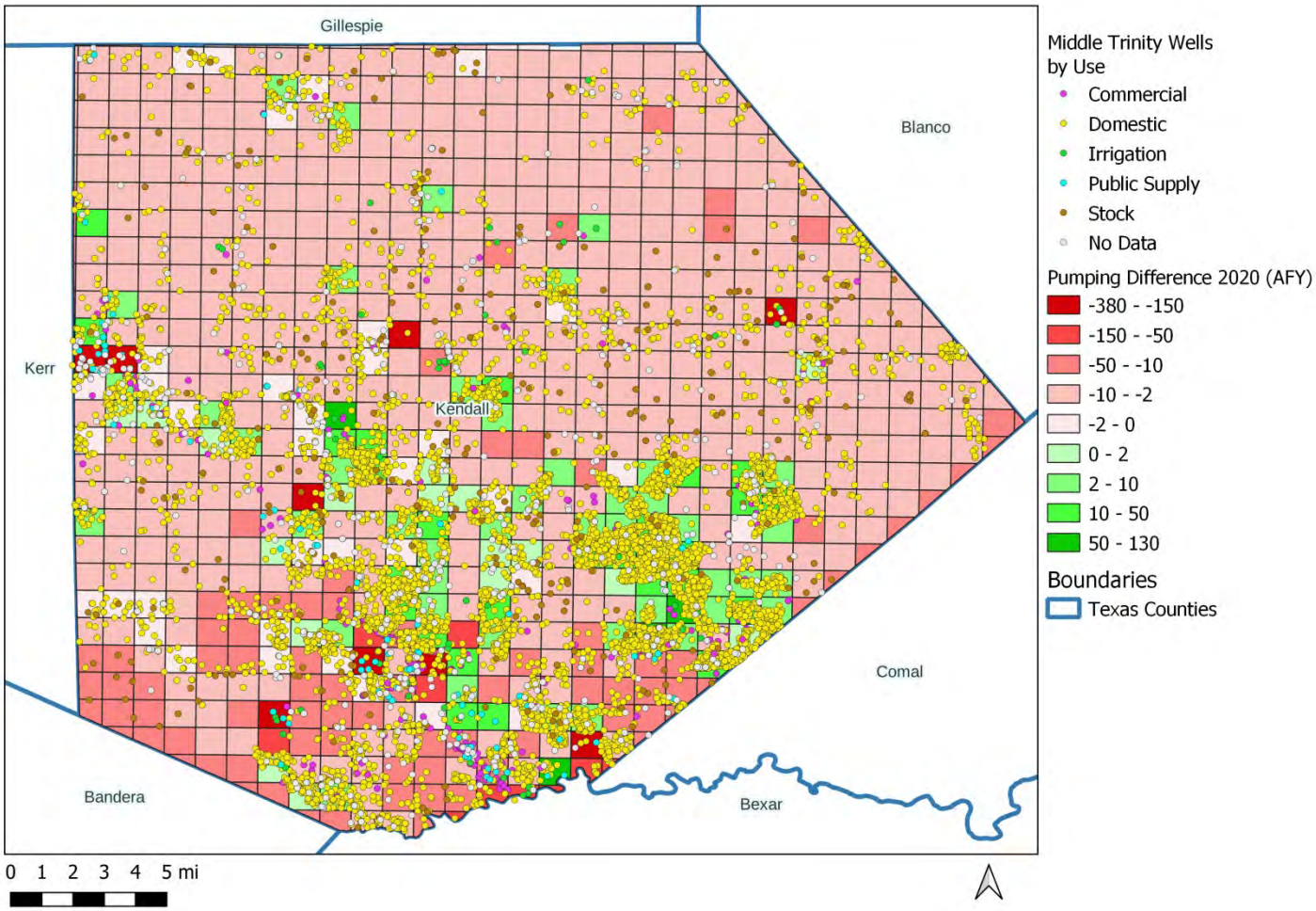


Figure 35. Middle Trinity Difference in Pumping in Acre-Feet for 2020 Between Estimated Actual Pumping and GAM

The total estimated annual pumping for the year 2020 on a per-grid basis according to pumped well location for the Lower Trinity is given in Figure 36. As in Figure 34, actual estimated grid totals have been assigned to discrete pumping bins in this figure for ease of illustration. As before, areas with no grids have no 2020 estimated pumping in the Lower Trinity.

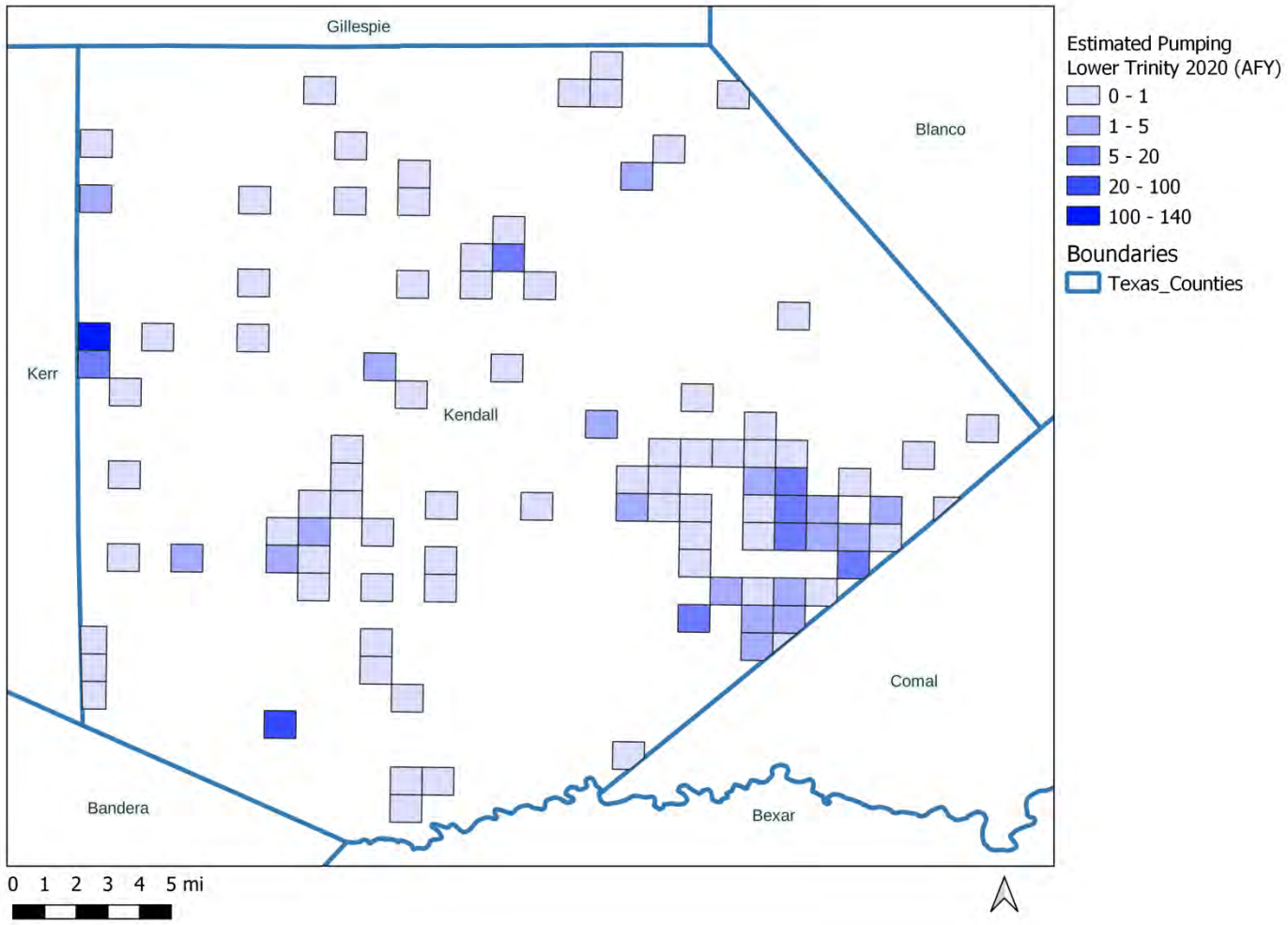


Figure 36. Estimated Lower Trinity Study Pumping Distribution for 2020

The difference in per-gridblock pumping between the estimated actual 2020 pumping and the THCGAM pumping is shown in Figure 37. As before, red colors in this figure indicate the THCGAM pumping was higher.

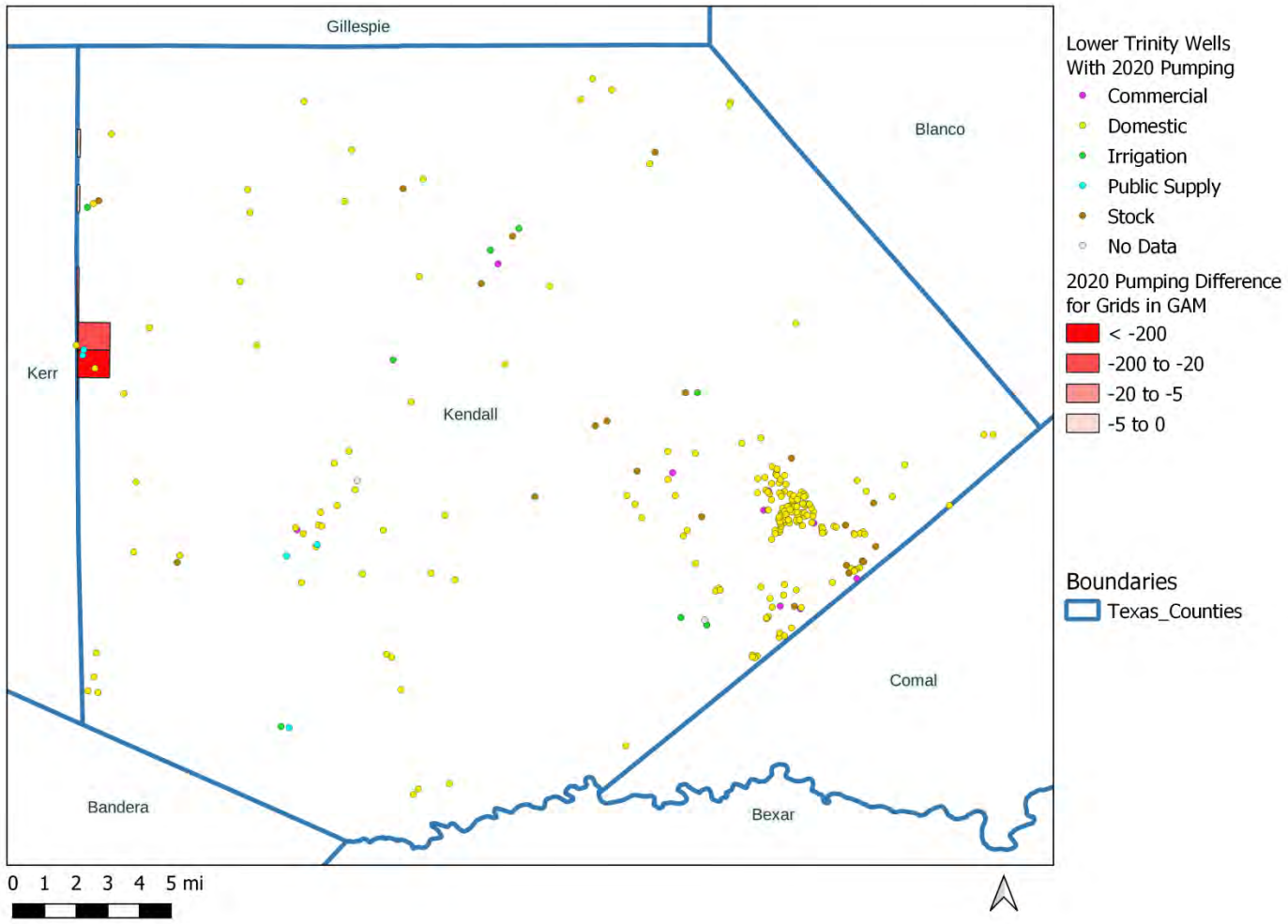


Figure 37. Lower Trinity Difference in Pumping for 2020 Between Estimated Actual Pumping and GAM (Acre-Feet)

Note that only two complete grids near Comfort have Lower Trinity pumping for the THCGAM in Kendall County, so only two complete grids can be directly compared in Figure 37. To illustrate where actual estimated pumping is occurring in the Lower Trinity, actual estimated pumping grids from Figure 36 have been added, resulting in Figure 38.

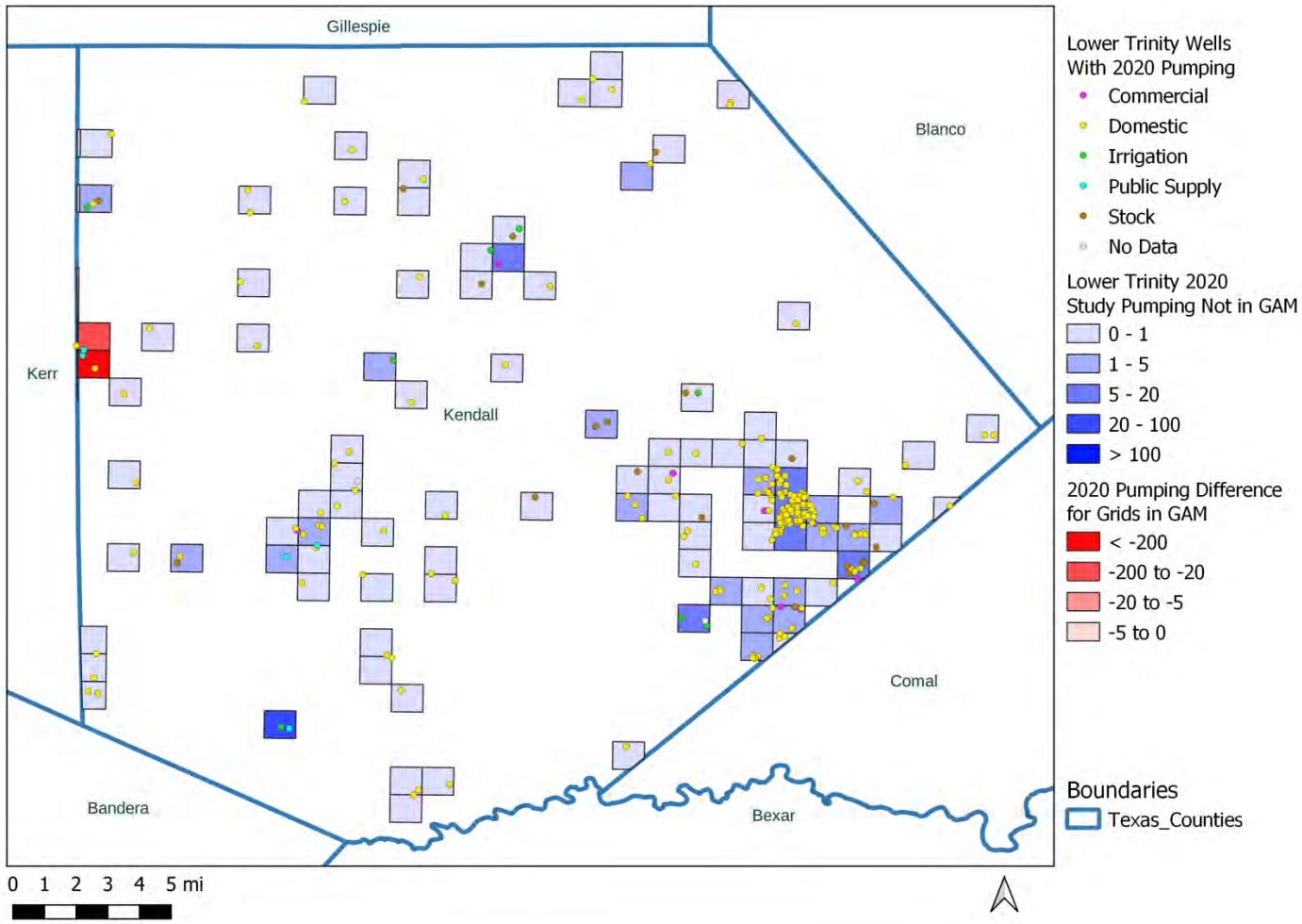


Figure 38. Lower Trinity Difference in Pumping for 2020 Between Estimated Actual Pumping and GAM (Acre-Feet). Also includes estimated actual pumping (blue squares) not included in GAM.

3.3 *Aquifer Parameters*

AGS compiled a summary of aquifer parameters contained in pumping tests results submitted to CCGCD. The summary of these reports is included as Appendix B. One of the most important aquifer characteristics in determining groundwater availability and well production is hydraulic conductivity. Hydraulic conductivity and aquifer transmissivity (hydraulic conductivity times saturated thickness) the general measure of the ability of an aquifer to transmit groundwater. Aquifers exhibiting low transmissivity transmit groundwater slowly and generally have wells that produce less water. Aquifers exhibiting high transmissivity transmit groundwater relatively faster and have wells that produce more water with less drawdown in the well and aquifer. Groundwater availability studies generally require an aquifer pumping test that measures drawdown as a well is pumped. From this data, the aquifer transmissivity can be estimated near the well. In certain types of consolidated

aquifers, such as the Trinity Aquifer, transmissivity can vary significantly, even between points in relatively close proximity. This is due in part to the effects of secondary porosity (e.g., voids, fractures) present near the well that is being tested.

When the estimate of transmissivity is divided by the aquifer thickness, an estimate of hydraulic conductivity can be obtained. Aquifer models like the THCGAM contain estimates of hydraulic conductivity to help define the aquifer flow system and productivity of aquifers represented in the model.

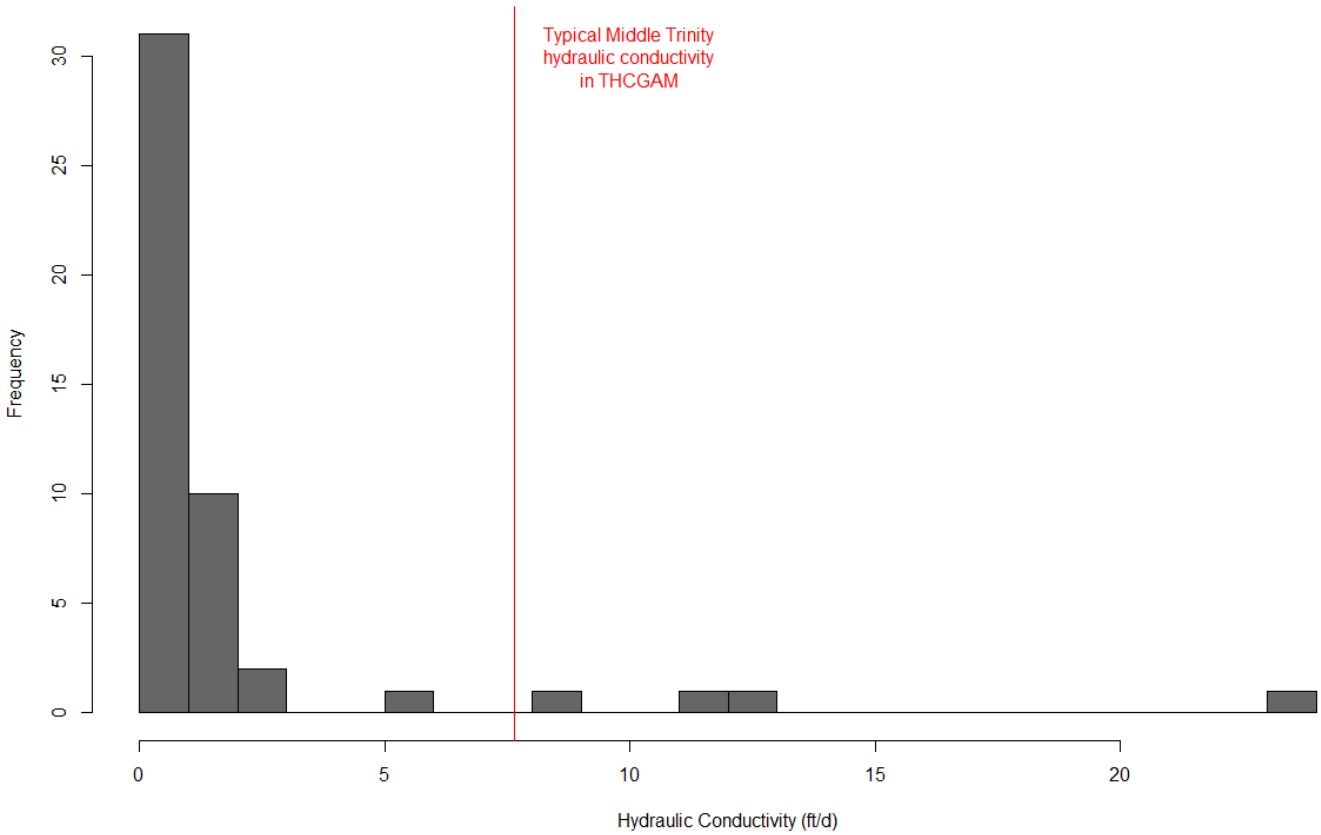


Figure 39. Histogram of Middle Trinity Hydraulic Conductivity From Water Availability Studies

Figure 39 shows the histogram of hydraulic conductivity estimates from CCGCD pumping tests in the Middle Trinity Aquifer throughout Kendall County. A histogram illustrates the frequency and distribution of hydraulic conductivity values from lower to higher. Figure 39 shows that most hydraulic conductivity estimates are below 2 feet/day. The leftmost bar of the histogram indicates that the 31 of 48 (65%) of hydraulic conductivity estimates are less than 1 feet/day. The red line indicates the value of hydraulic conductivity contained in the THCGAM for the Middle Trinity Aquifer. Only 4 of 48 (8%) of the hydraulic conductivity measurements are higher than the THCGAM estimate.

This finding indicates that the THCGAM may be generally overestimating the hydraulic conductivity and transmissivity of the Middle Trinity Aquifer in Kendall County. The data show that the transmissivity can vary significantly over short distances in the Trinity Aquifer, and this conclusion

supports numerous previous studies of the Trinity Aquifer. The finding is significant because it indicates that combinations of relatively low aquifer transmissivity and relatively higher demands may create situations where local water level decline can be greater than the typical average declines from the regional THCGAM simulations used to assess the water level decline in GMA 9.

Figure 40 shows the histogram of hydraulic conductivity estimates from CCGCD water availability studies in the Lower Trinity Aquifer in Kendall County. Figure 40 shows that all the estimates of hydraulic conductivity from CCGCD water availability studies in the Lower Trinity Aquifer range from 0.01 feet/day to 0.04 feet/day, which is significantly lower than the estimate of 1.7 feet/day ($\log_{10}$ = 0.223 shown) used in the THCGAM. Evaluation of the hydraulic conductivity estimates in the summary table in Appendix B shows that the Lower Trinity estimates from the pumping tests in Kendall County are typically about 100 times lower than the estimate in the THCGAM.

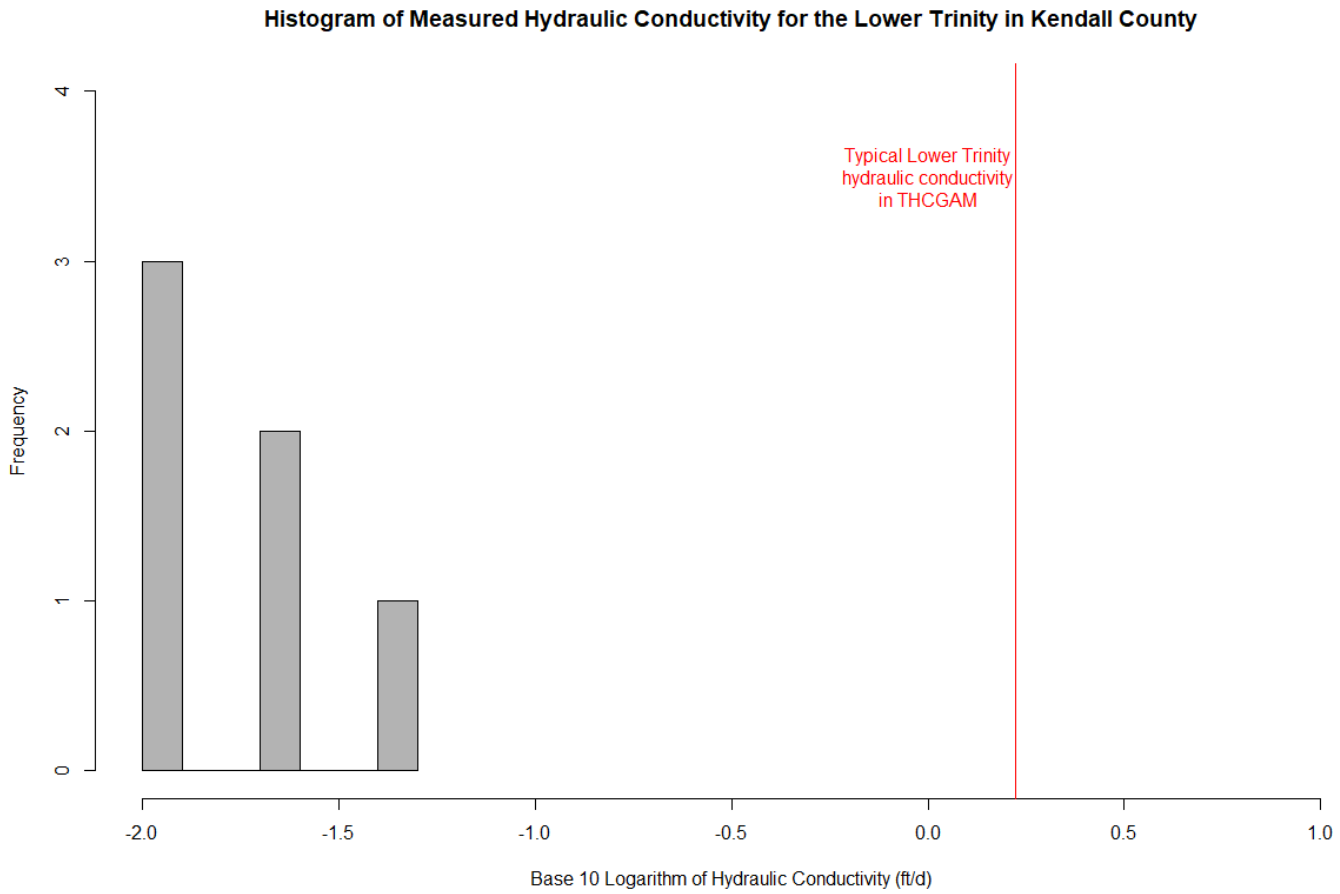


Figure 40. Histogram of Lower Trinity Hydraulic Conductivity From Pumping Tests

4.0 Groundwater Availability

Figure 41 shows the locations where pumping in the Middle Trinity Aquifer is higher than the MAG estimate in the THCGAM. It is important to remember that the differences are not necessarily problematic because all the white areas have estimated pumping that is lower than the MAG pumping in the THCGAM. It is not unusual for future (i.e. predictive) pumping distributions to be different than actual pumping for many reasons. However, Figure 41 does indicate areas where pumping is growing over the past 20 years, and where it might be necessary to review groundwater availability regularly.

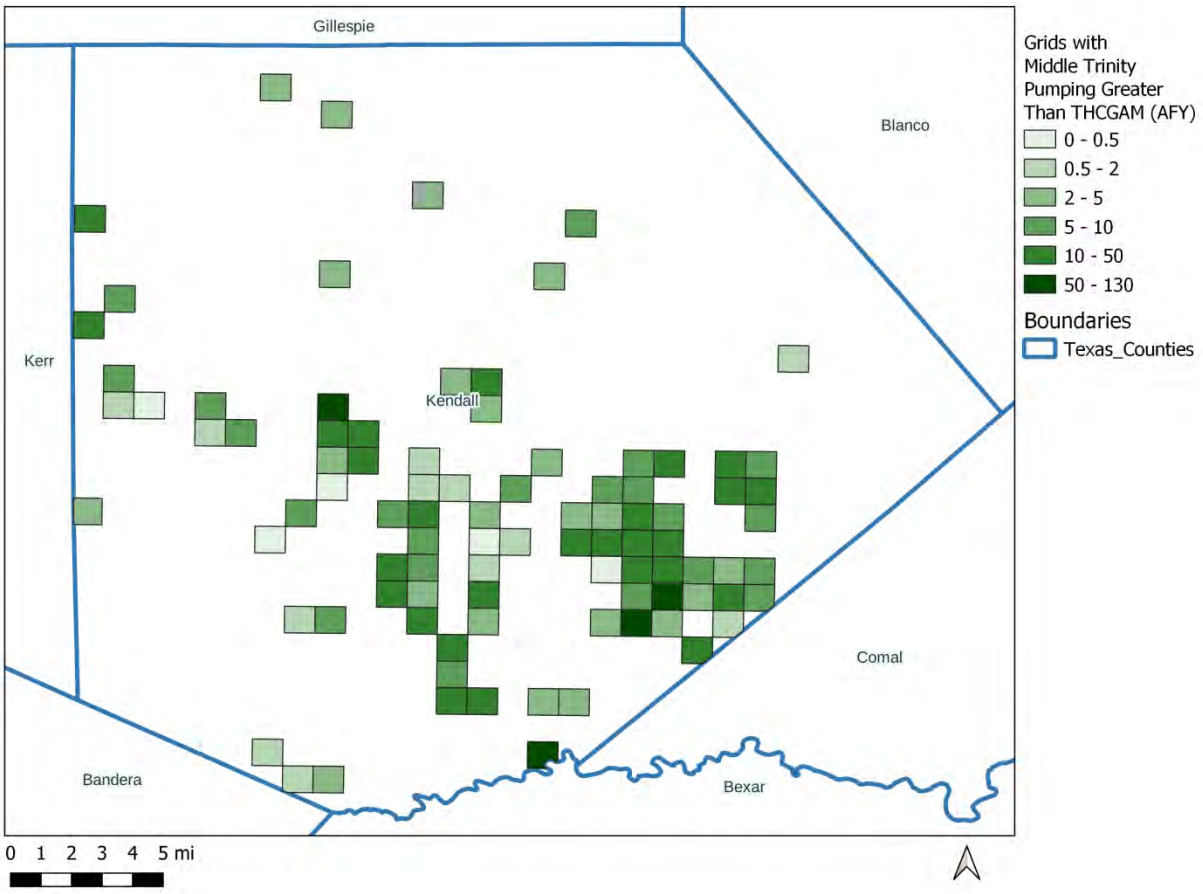


Figure 41. Estimated Pumping Greater than the THCGAM for Middle Trinity 2020

Figure 42 shows the locations of hydraulic conductivity estimates (from GWAS pumping tests) in relation to areas where estimated pumping is greater than the THCGAM in the Middle Trinity Aquifer. Water levels should be monitored closely in areas where production continues to increase in areas where hydraulic conductivity is relatively low.

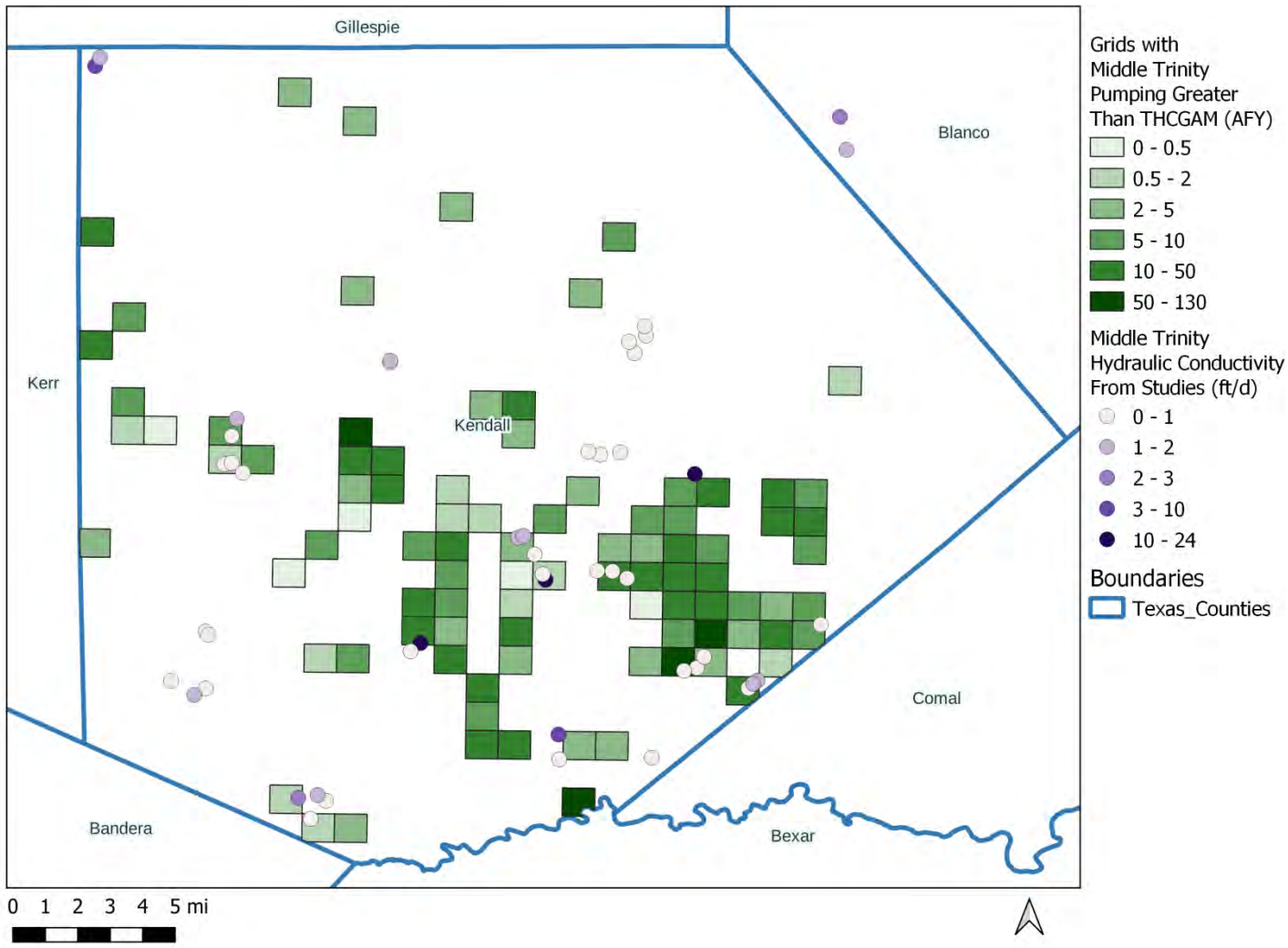


Figure 42. Estimated Pumping Greater Than THCGAM for 2020 with Hydraulic Conductivity from Water Availability Studies

5.0 Conclusions and Recommendations

This detailed evaluation of pumping and water level measurements in this study provides an updated review of the status of groundwater conditions in Kendall County. Significant findings include the following:

1. Pumping continues to grow in the Middle and Lower Trinity Aquifers, and as expected, is growing fastest and is most concentrated in developing areas in the southern half of the county. The large majority of pumping in the county is still from the Middle Trinity, but Lower Trinity pumping is increasing in the southeast portion of county.

2. Water level measurements in the Middle Trinity Aquifer indicate water level decline is generally limited to a few areas over the past 10 to 20 years. However, some Middle Trinity Aquifer wells shows a continued water level decline over the past 10 to 20 years.

3. Water level measurements in the Lower Trinity Aquifer indicate a more consistent water level decline. This is partially due to the location of the Lower Trinity wells near developing areas where pumping the Lower Trinity Aquifer has increased. Hydrographs in the Lower Trinity Aquifer indicated a more consistent pattern of water level decline, which is not unexpected as pumping increases over time due to the confinement and reduced recharge afforded by the Hammett Shale.

4. It is evident that the Middle Trinity Aquifer continues to receive significant recharge in Kendall County. However, it is also clear from the hydrographs that dry periods such as 2009 and 2011 do cause consistent water level decline in the Middle Trinity Aquifer in Kendall County. Very wet seasons like the latter half of 2018 also show that significant recharge can occur in the Middle Trinity Aquifer in Kendall County that can replenish the aquifer. This dynamic was consistent with water level increases across other counties in GMA 9 in the Middle Trinity Aquifer.

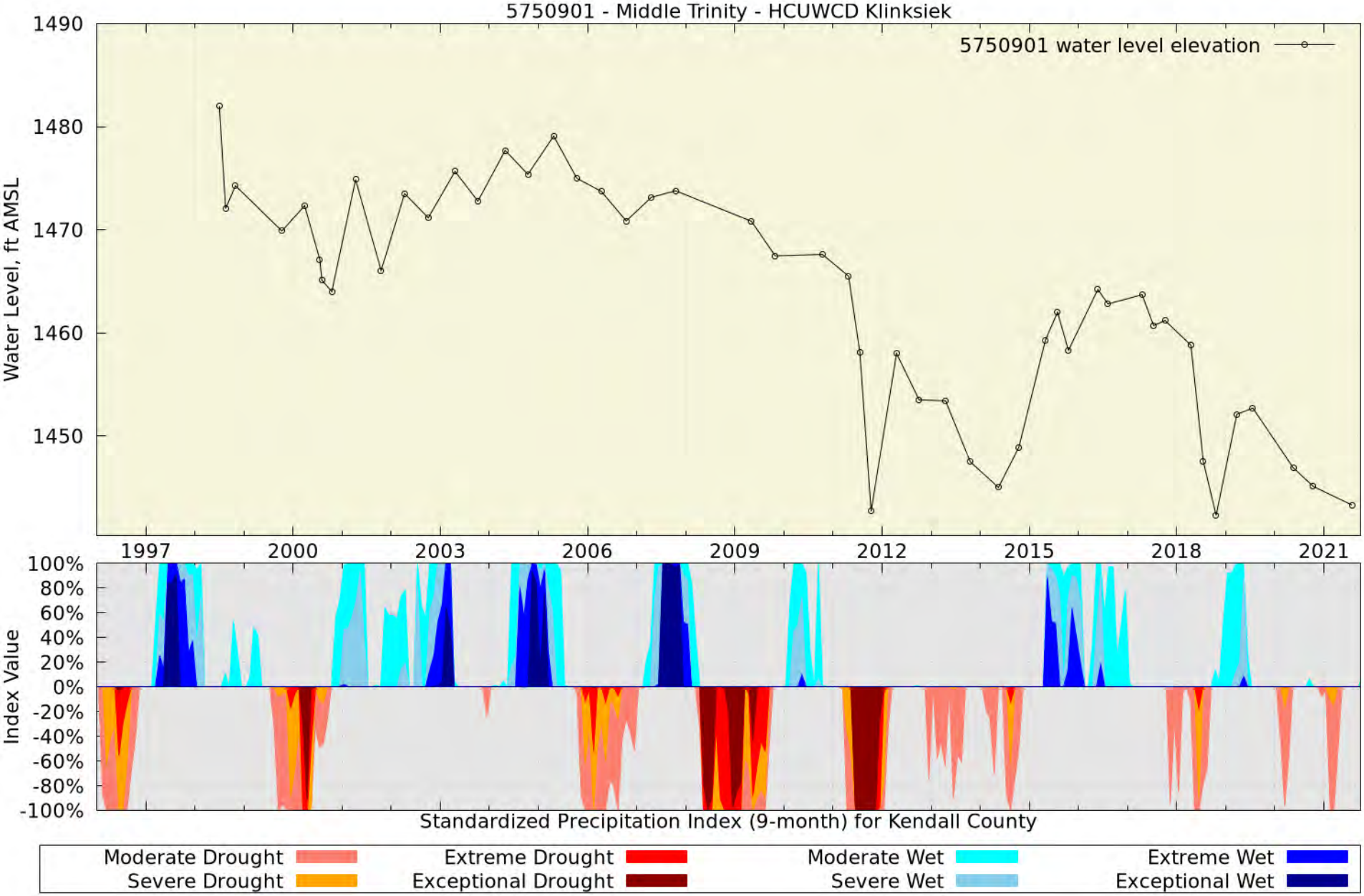
5. The THCGAM has been used as a tool to assess regional impacts of increased pumping on future water levels in the joint groundwater planning process to assess DFCs and estimate MAGs. As is indicated in the THCGAM report, the model is not intended to assess aquifer conditions on a local basis. This study reveals some of the differences between the hydraulic properties and pumping distribution estimated from CCGCD data and the THCGAM.

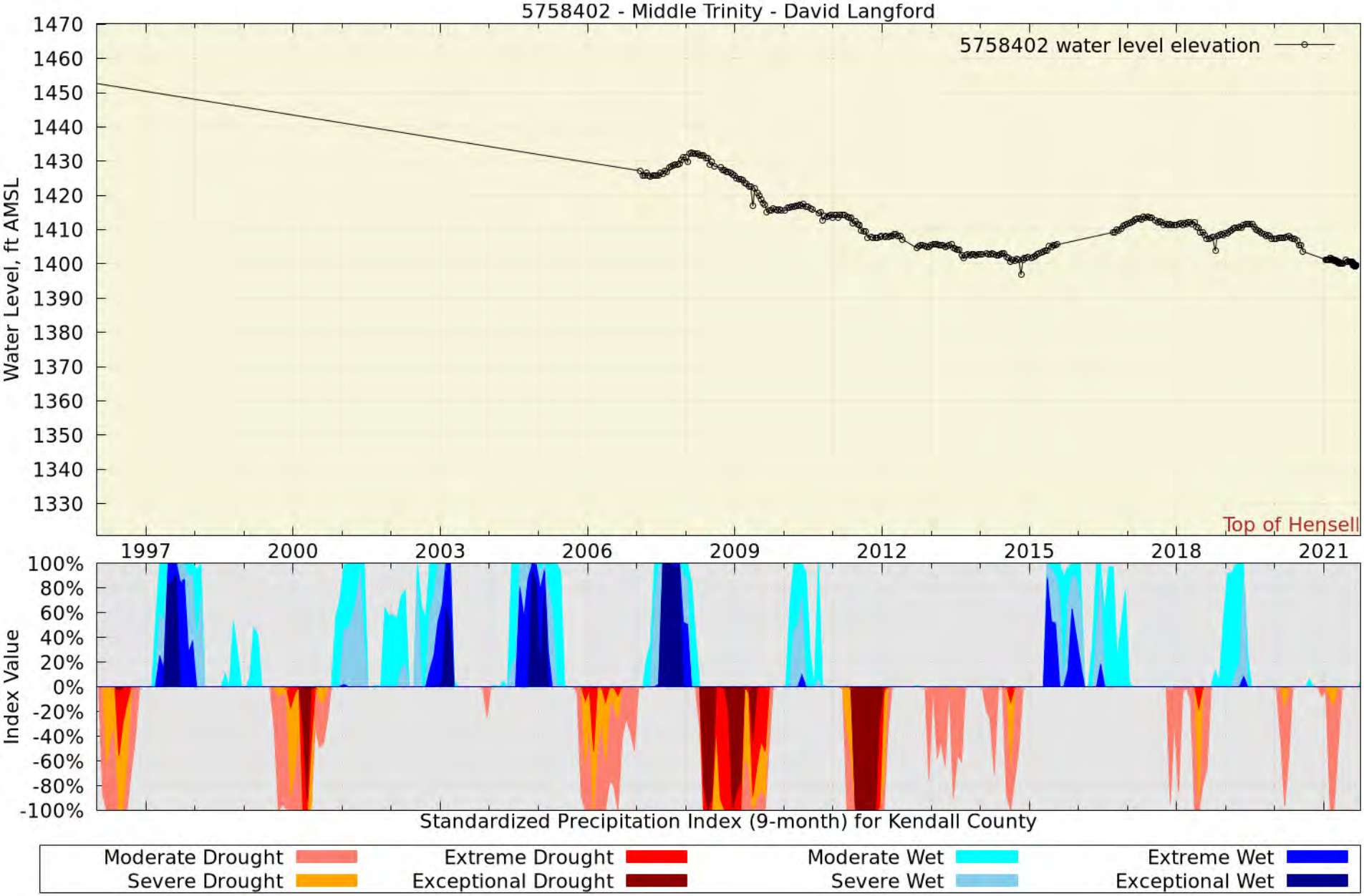
6. The differences between local data and the THCGAM confirm the limitations of the THCGAM to address local management issues, especially in areas where development and groundwater pumping are increasing significantly. Consistent with that limitation, the DFC and MAG estimates should be seen as regional and long term guidelines only. Because the THCGAM has limits in application on a local scale, the resulting DFCs and MAG estimates are also limited in application on a local scale.

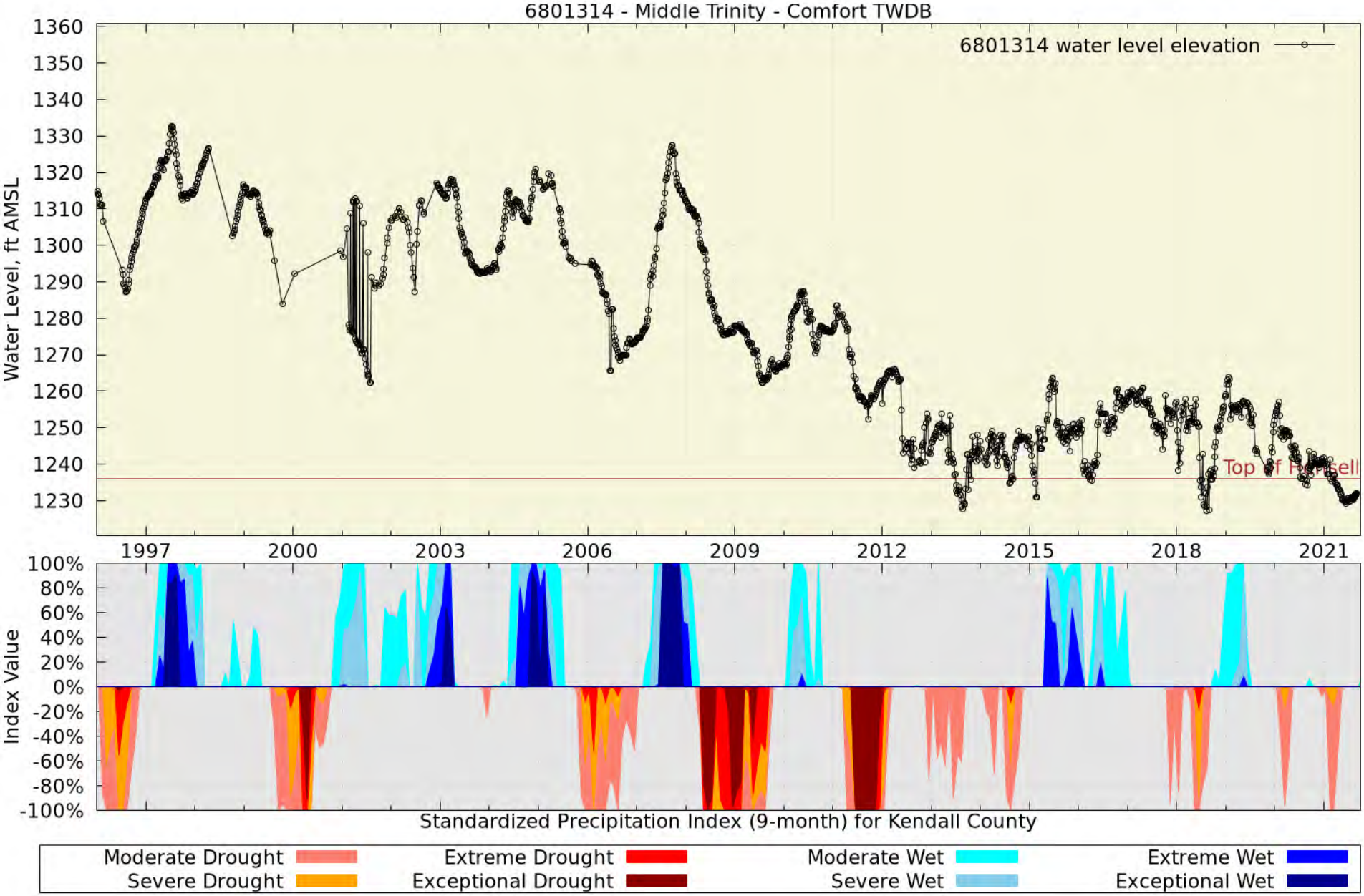
7. The study results provide the incentive for the CCGCD to consider how local management approaches might impact the balance of production and conservation considering recent hydrologic data and development patterns. If the district adopts a policy of greater conservation, the district may consider reducing the maximum production limit per acre by up to 20%. Additionally, management zones within the district may also be considered in areas of low transmissivity and growing demand if water levels are consistently declining and available drawdown is decreasing. To the degree possible, these policy decisions should be consistent with the DFCs for Kendall County and surrounding areas.

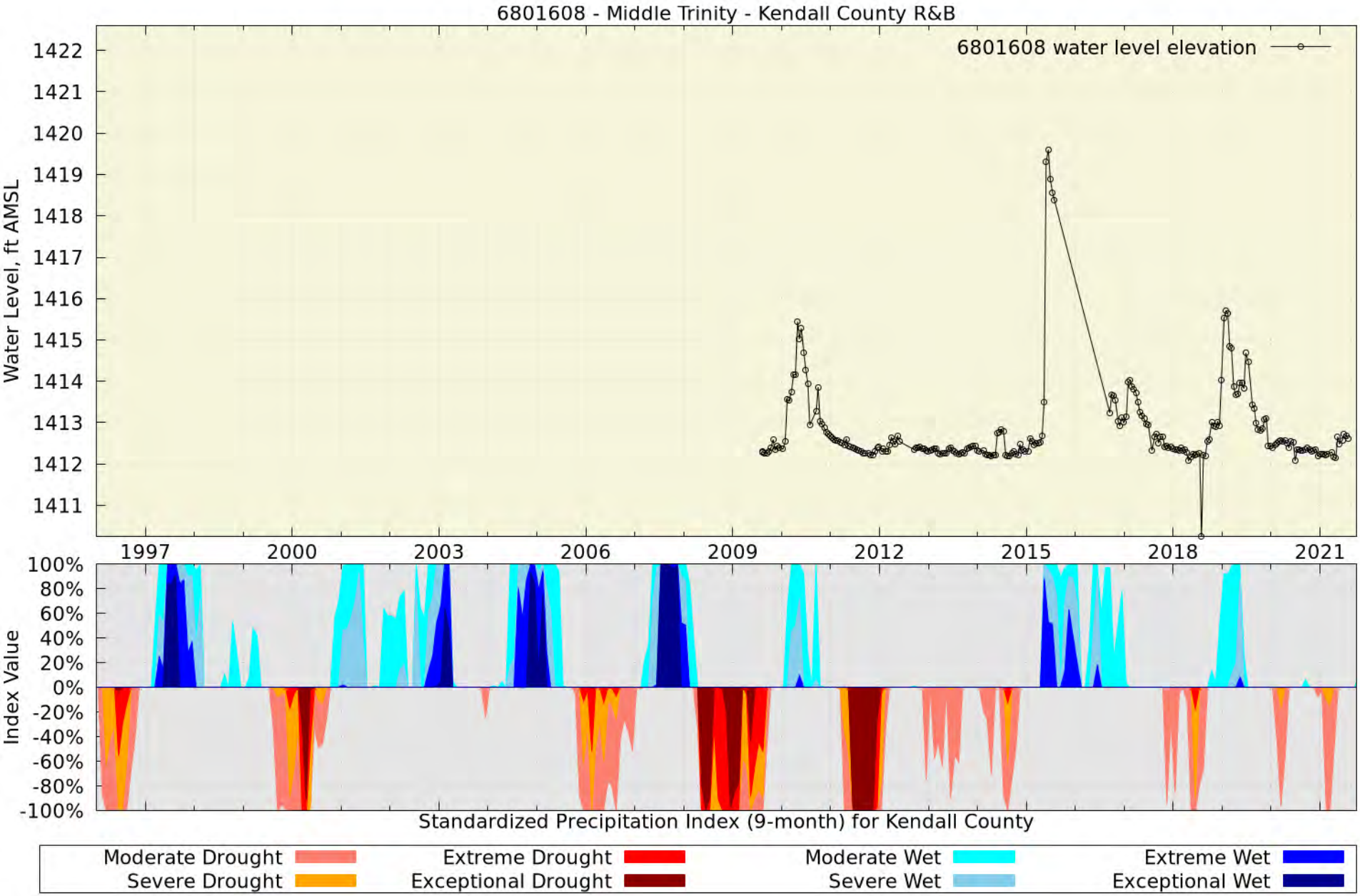
Appendix A

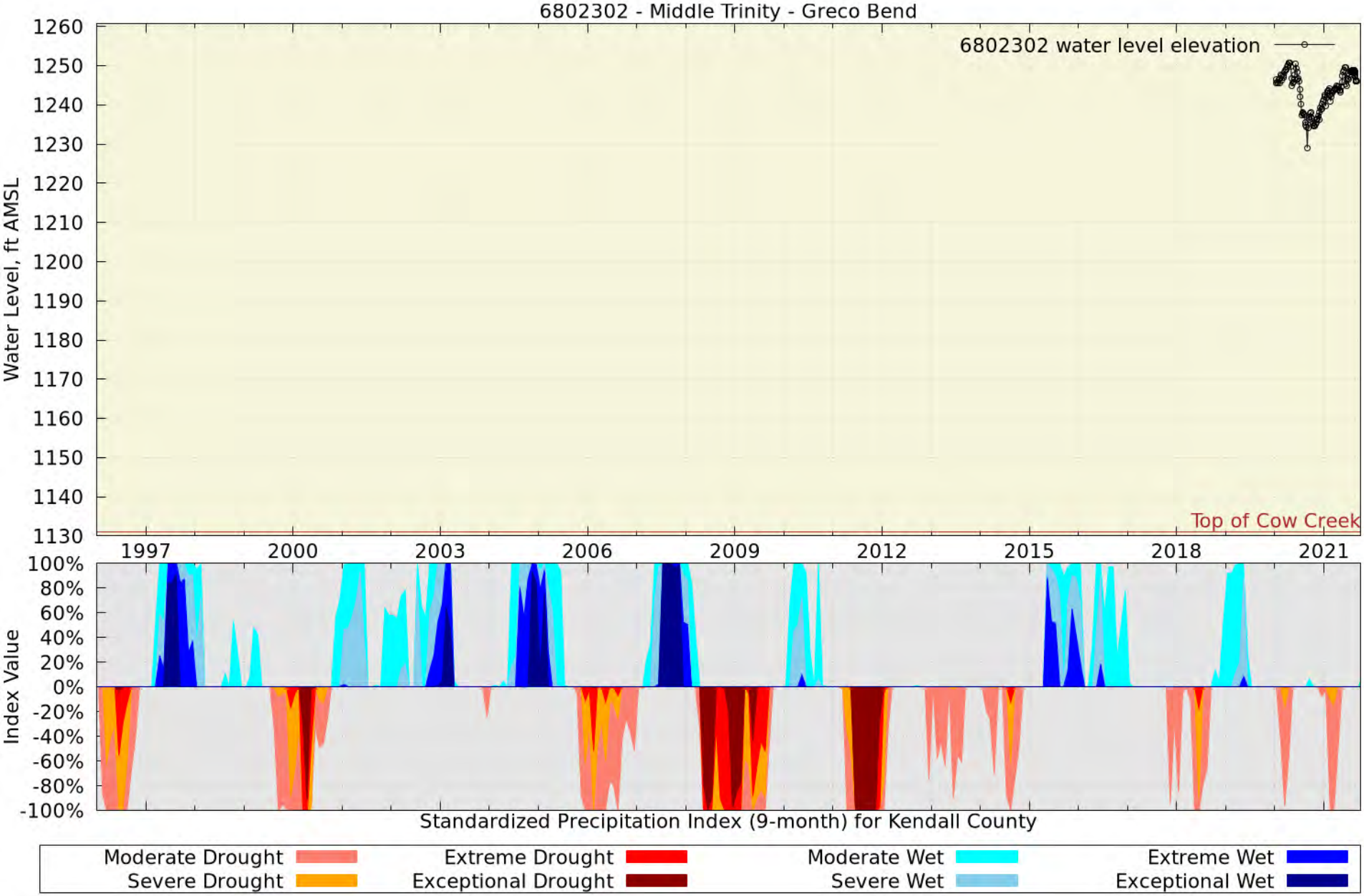
Hydrographs

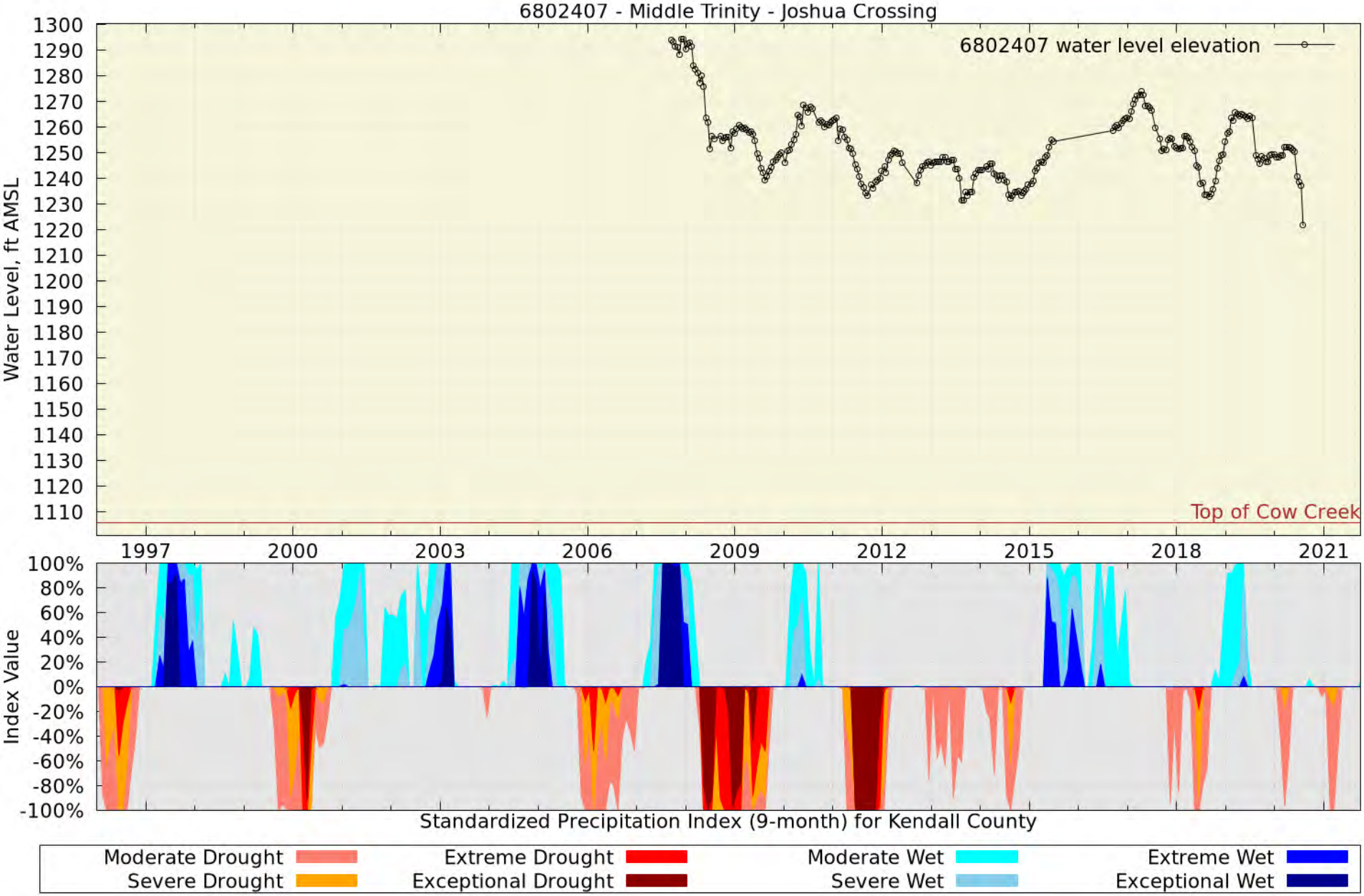

5750901 - Middle Trinity - HCUWCD Klinksiek
5750901 water level elevation
Water Level, ft AMSL
1490
1480
1470
1460
1450
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

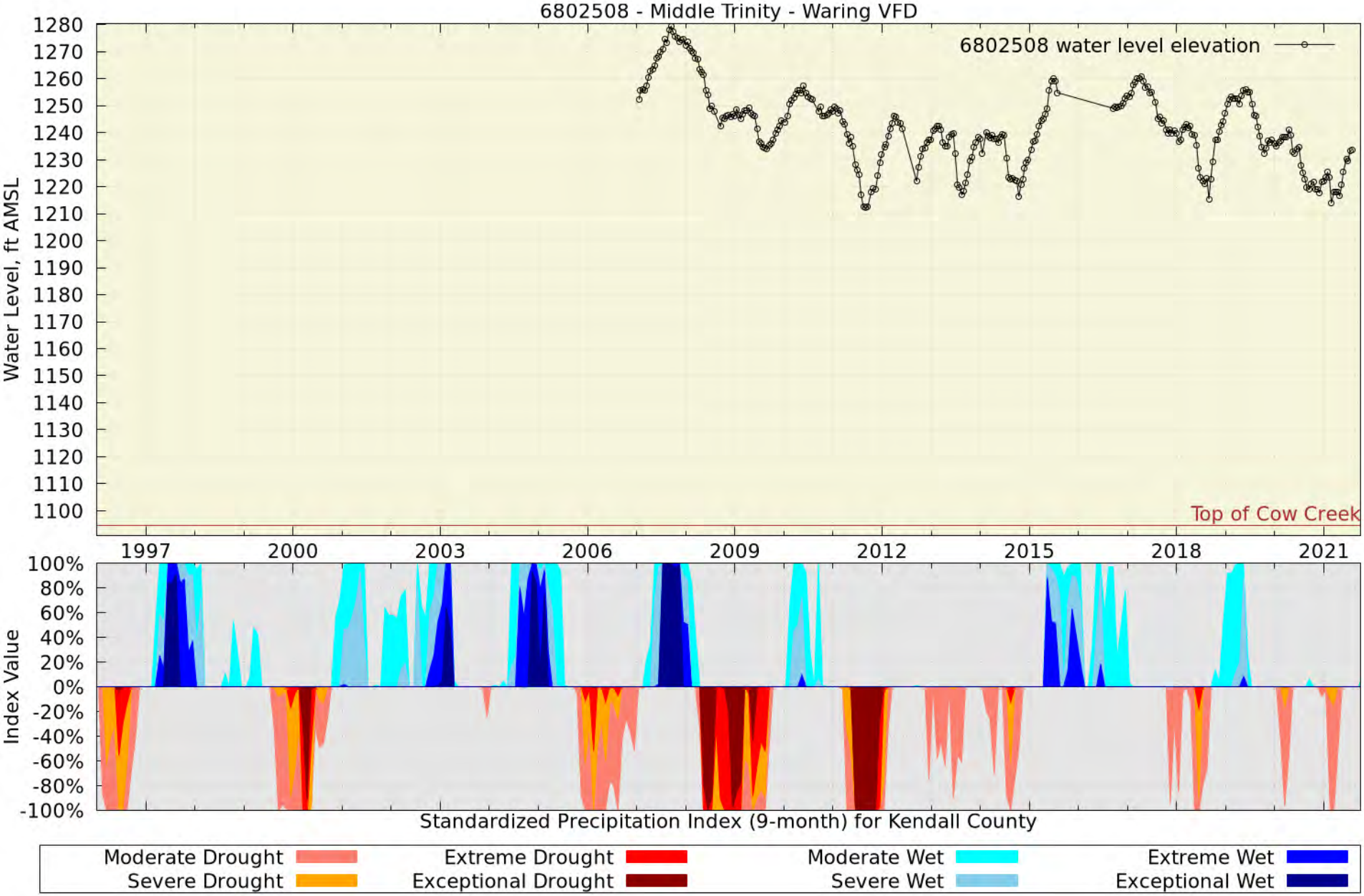

5758402 - Middle Trinity - David Langford
5758402 water level elevation
Water Level, ft AMSL
1470
1460
1450
1440
1430
1420
1410
1400
1390
1380
1370
1360
1350
1340
1330
Top of Hensell
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

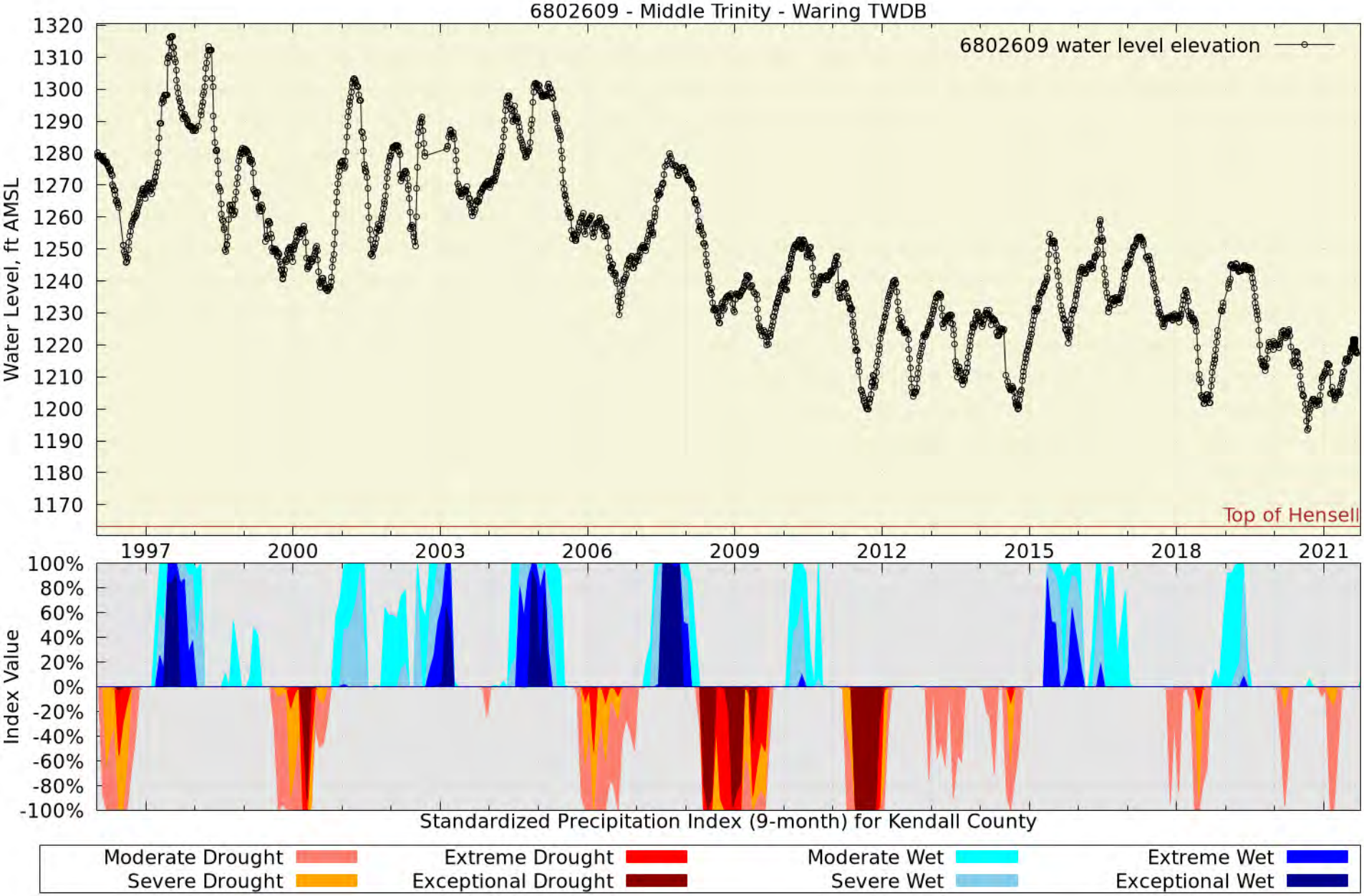

6801314 - Middle Trinity - Comfort TWDB
6801314 water level elevation
Water Level, ft AMSL
1360
1350
1340
1330
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
Top of Hensell
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

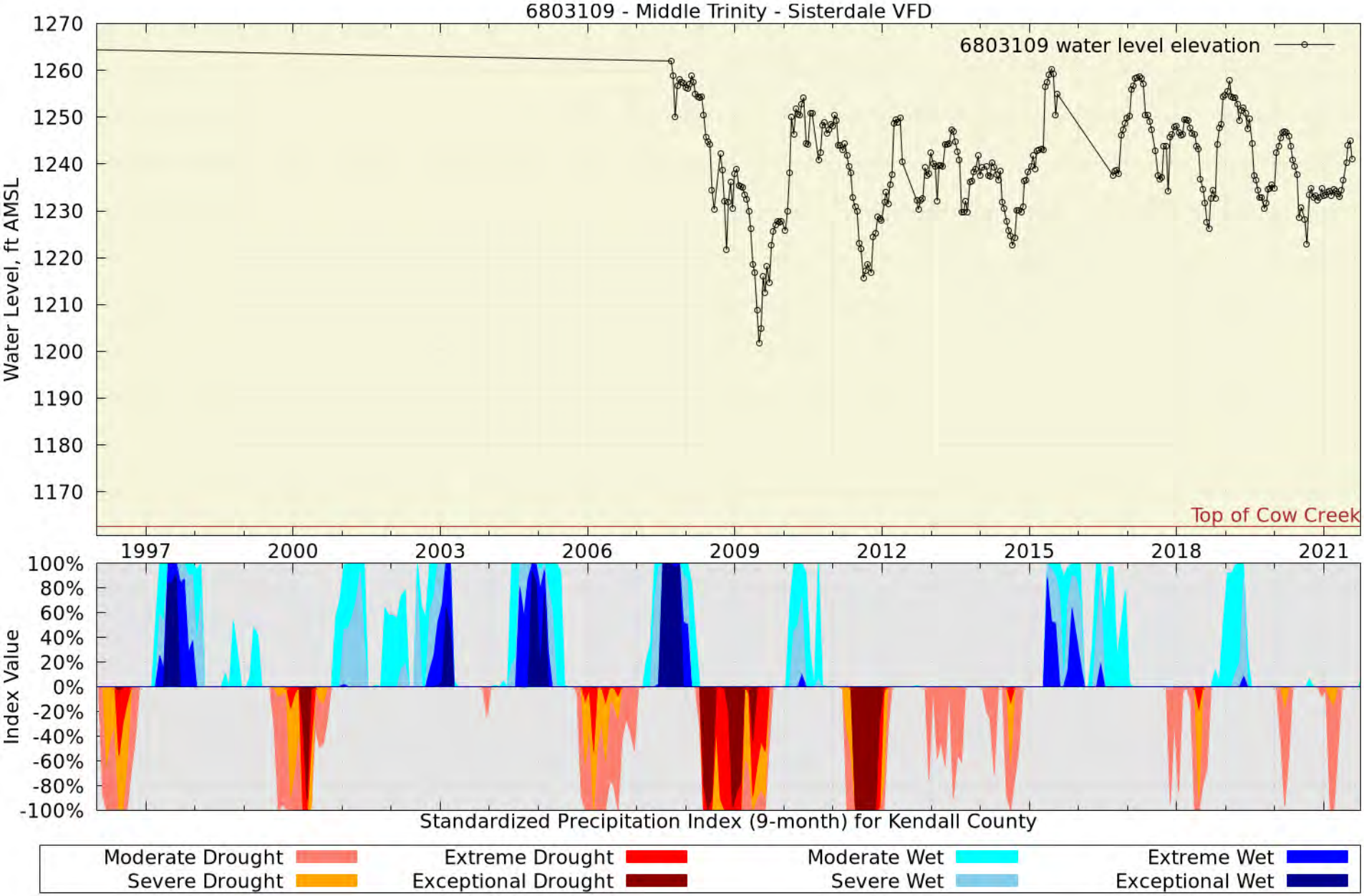

6801608 - Middle Trinity - Kendall County R&B
6801608 water level elevation
Water Level, ft AMSL
1422
1421
1420
1419
1418
1417
1416
1415
1414
1413
1412
1411
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

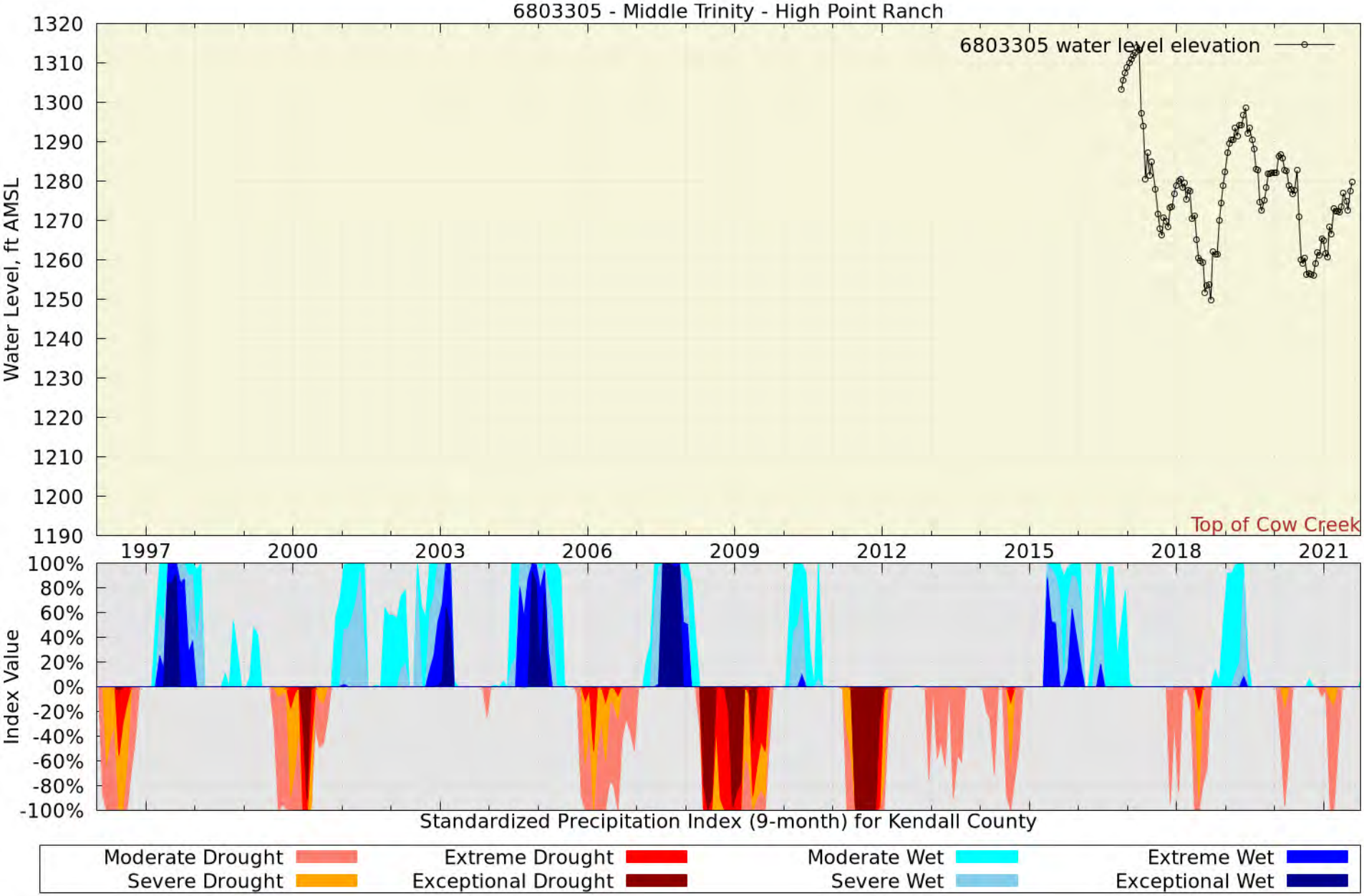

6802302 - Middle Trinity - Greco Bend
6802302 water level elevation
Water Level, ft AMSL
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

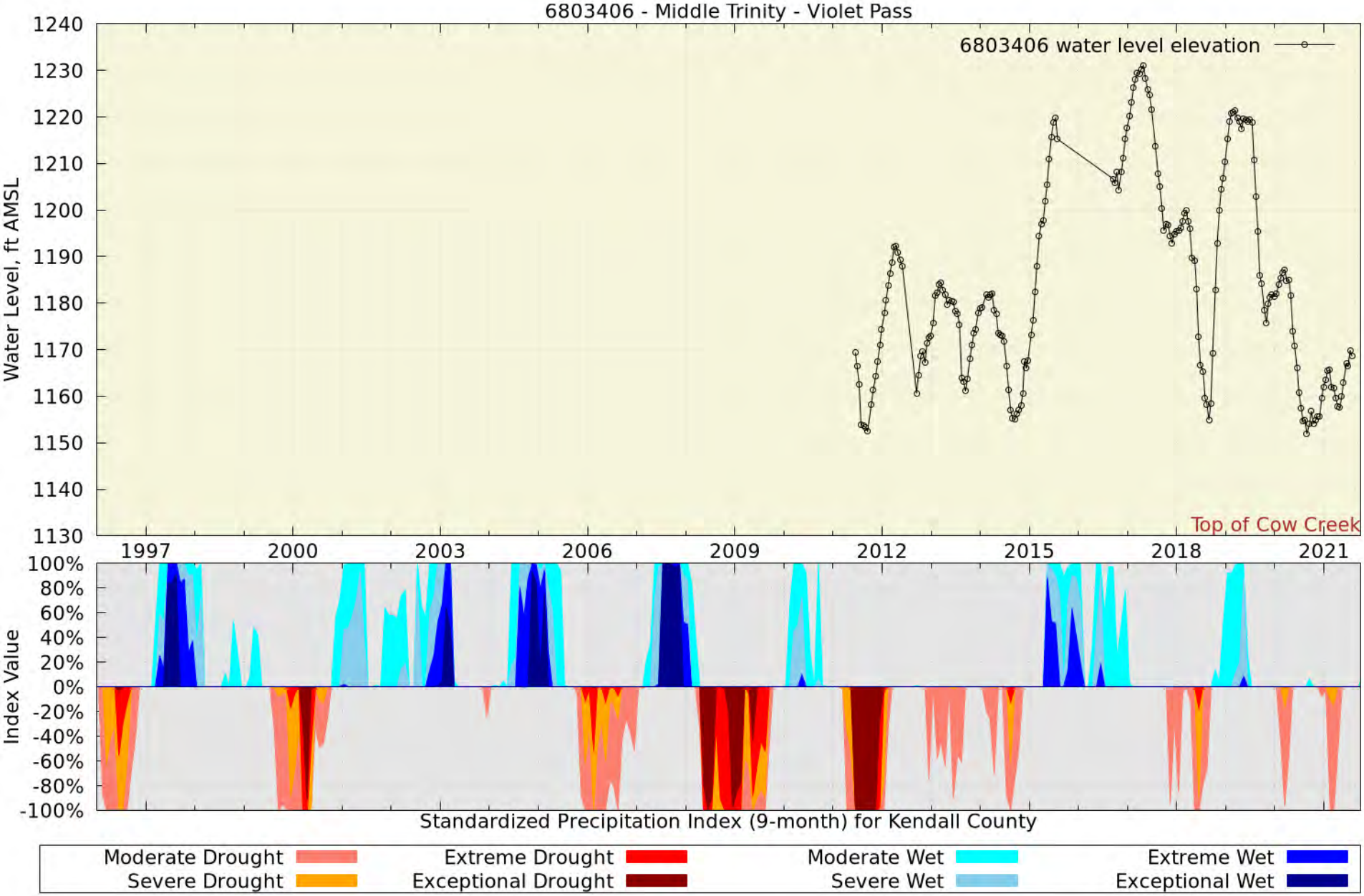

6802407 - Middle Trinity - Joshua Crossing
6802407 water level elevation
Water Level, ft AMSL
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

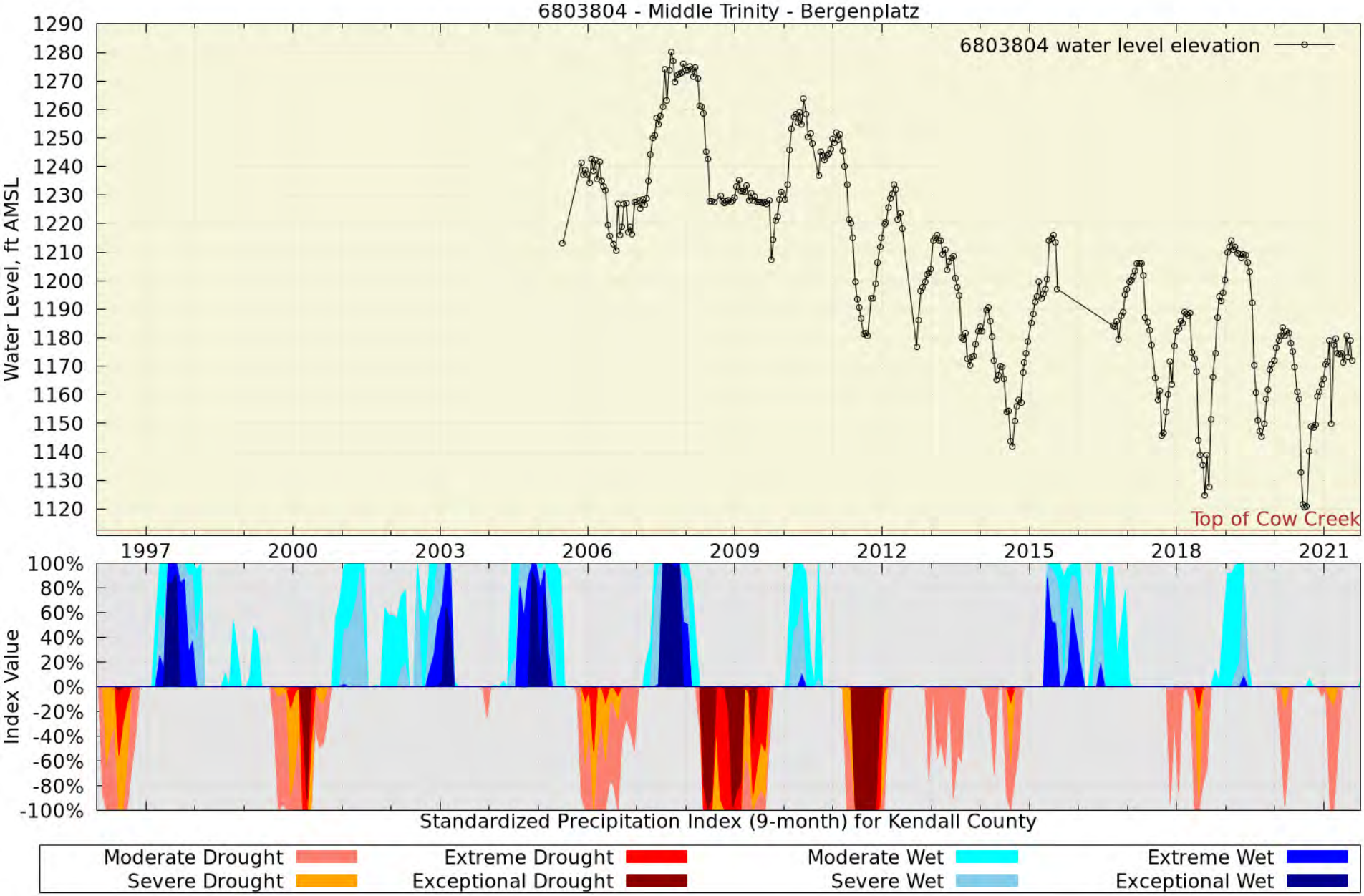

6802508 - Middle Trinity - Waring VFD
6802508 water level elevation
Water Level, ft AMSL
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

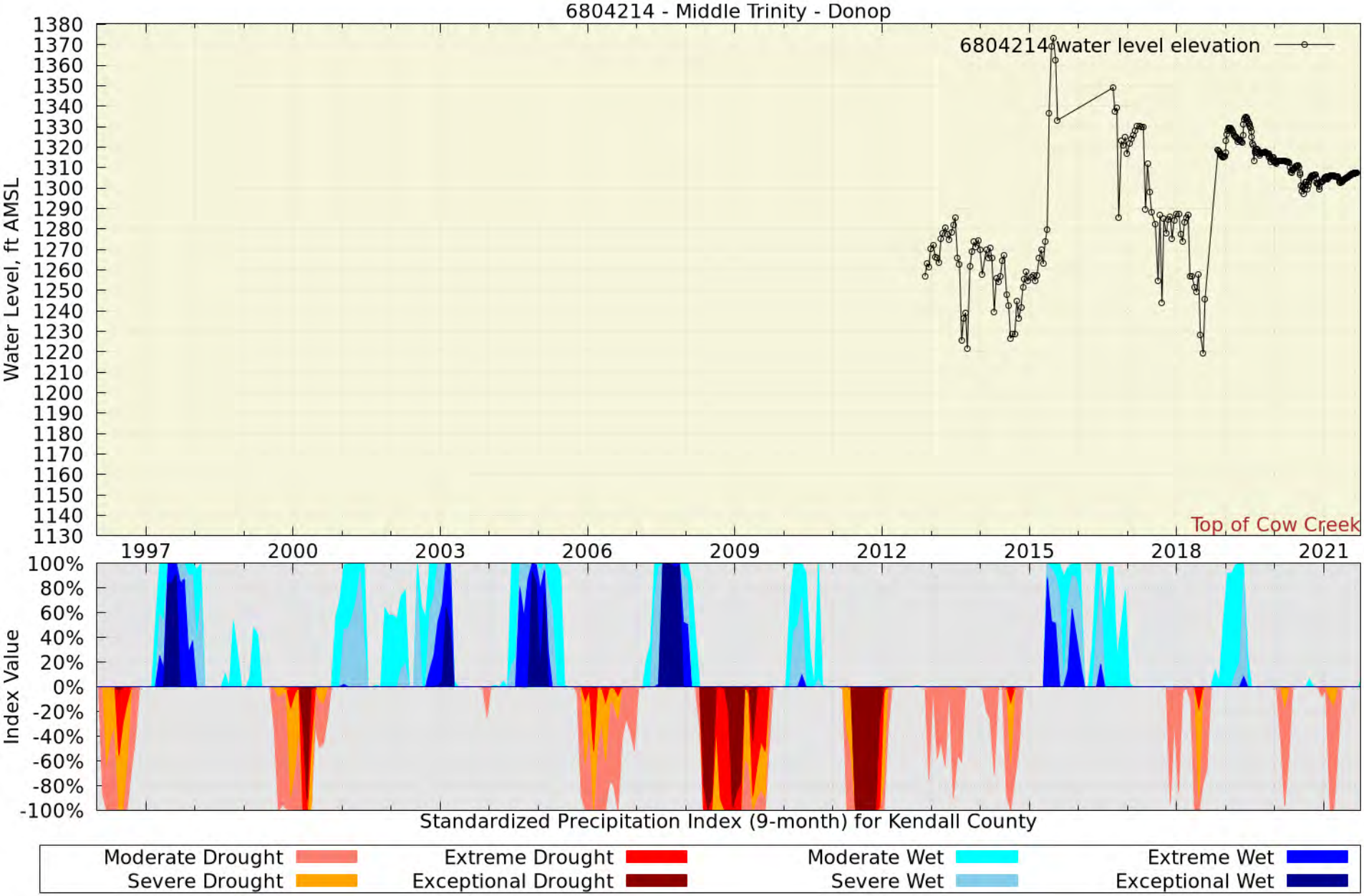

6802609 - Middle Trinity - Waring TWDB
6802609 water level elevation
Water Level, ft AMSL
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
Top of Hensell
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

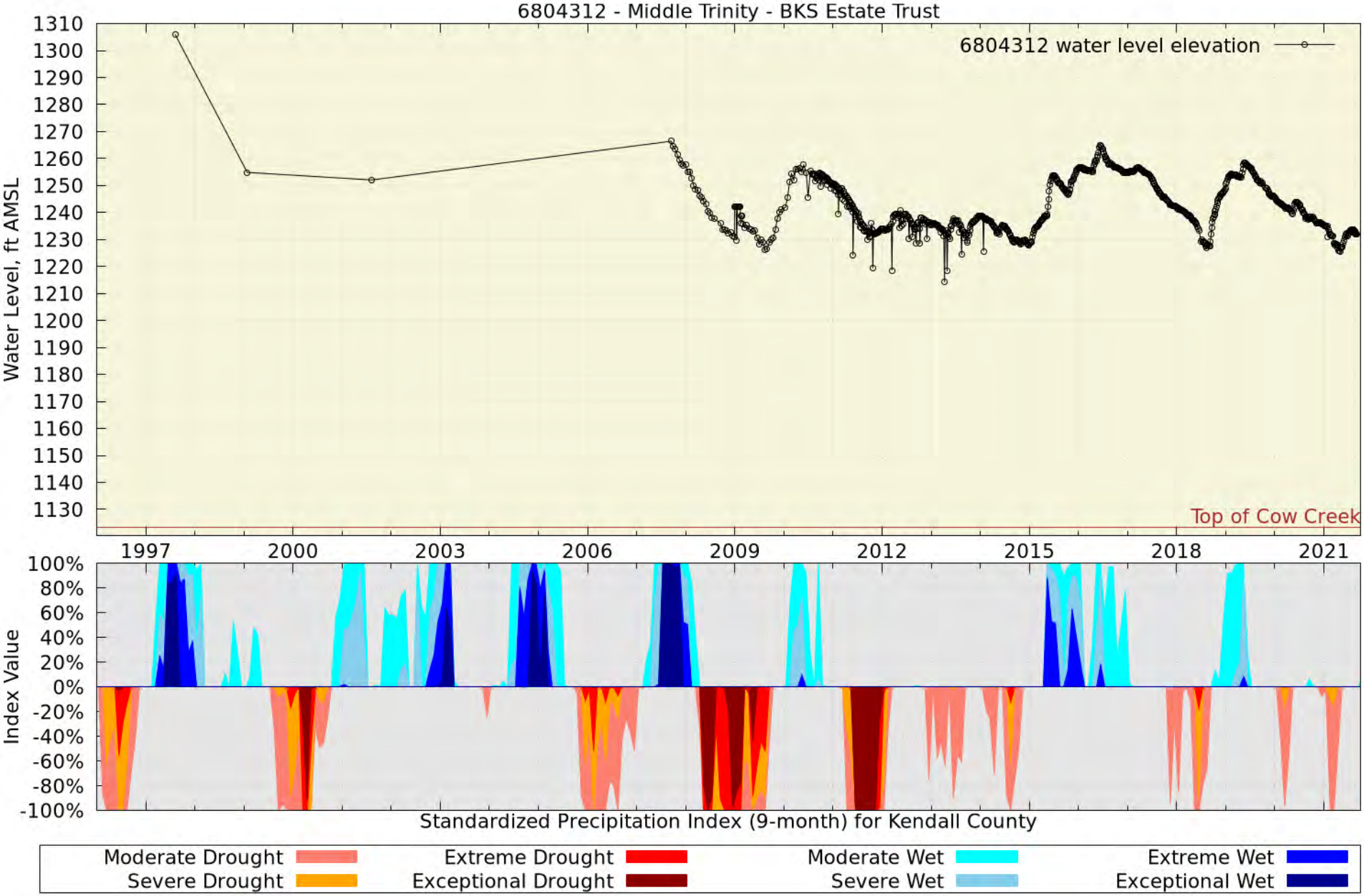

6803109 - Middle Trinity - Sisterdale VFD
6803109 water level elevation
Water Level, ft AMSL
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

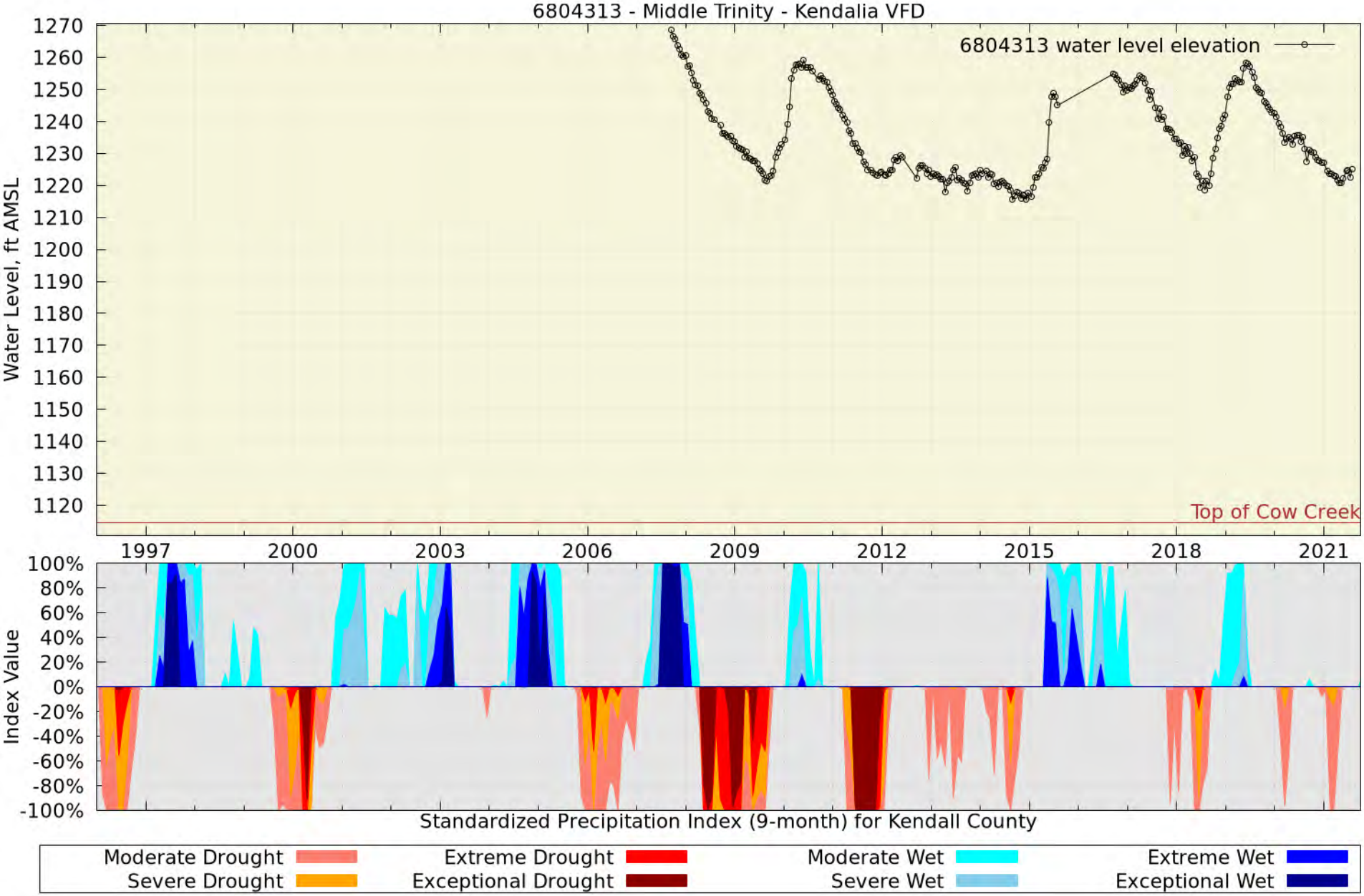

6803305 - Middle Trinity - High Point Ranch
6803305 water level elevation
Water Level, ft AMSL
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

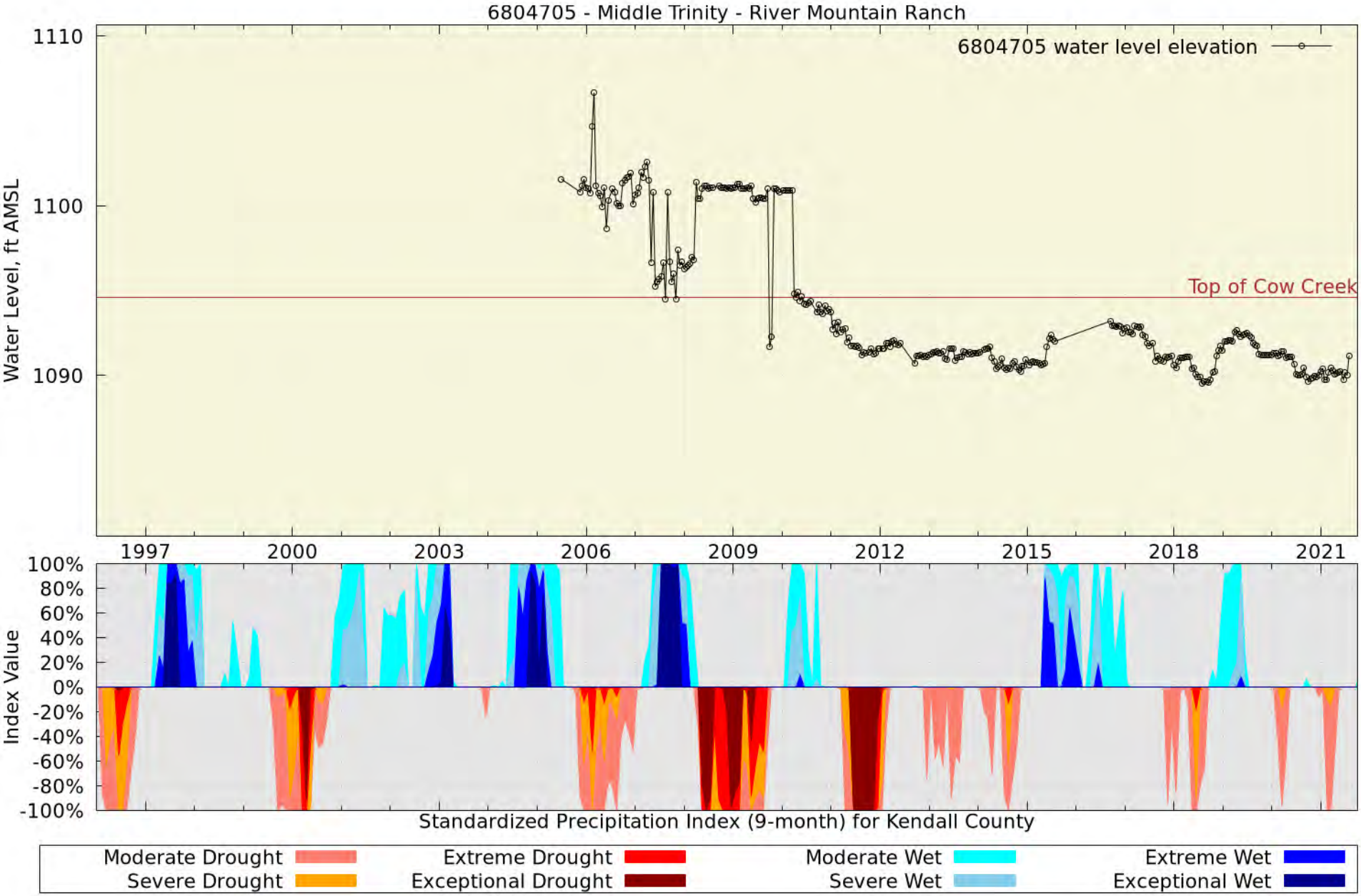

6803406 - Middle Trinity - Violet Pass
6803406 water level elevation
Water Level, ft AMSL
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

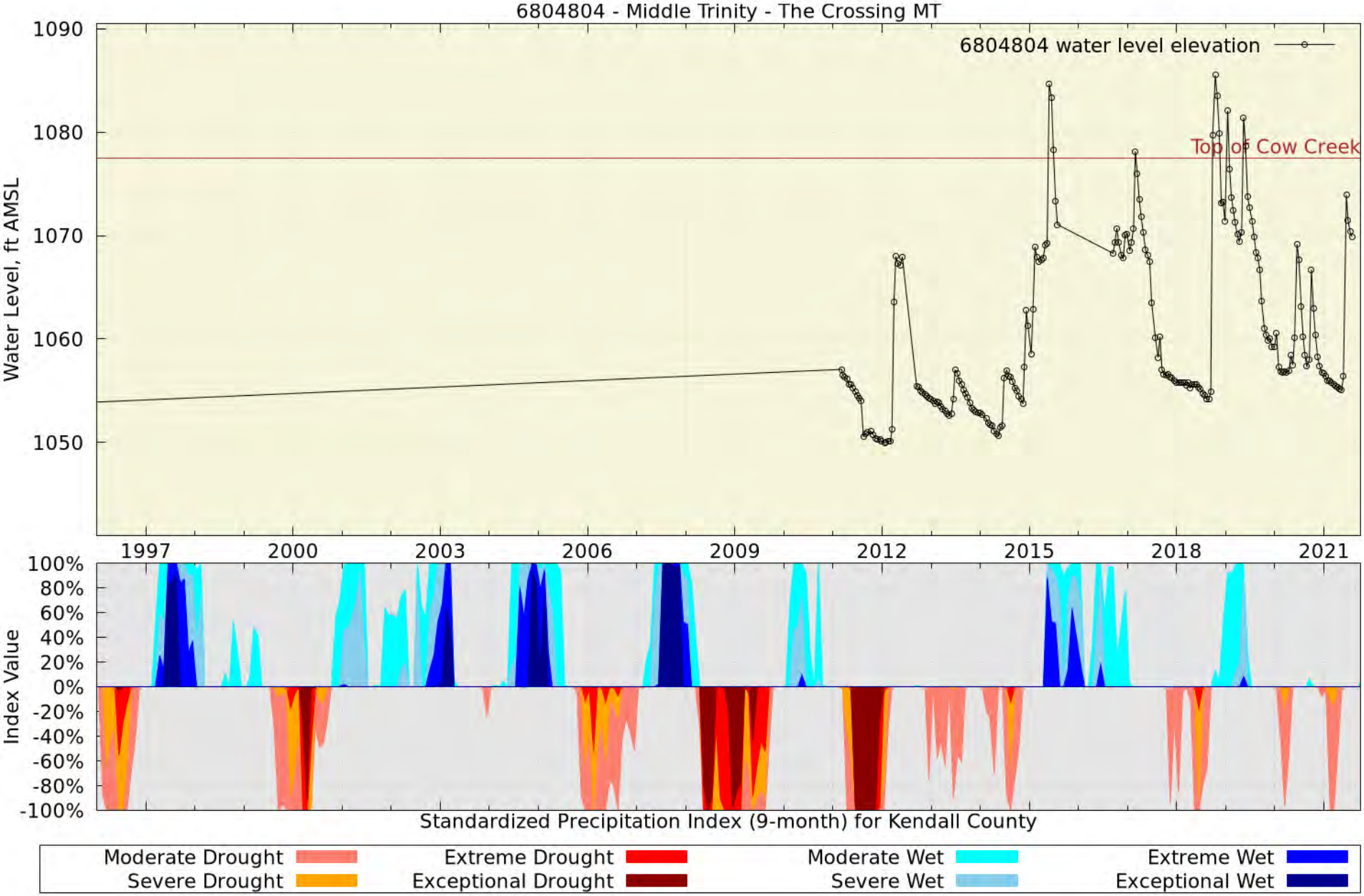

6803804 - Middle Trinity - Bergenplatz
6803804 water level elevation
Water Level, ft AMSL
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

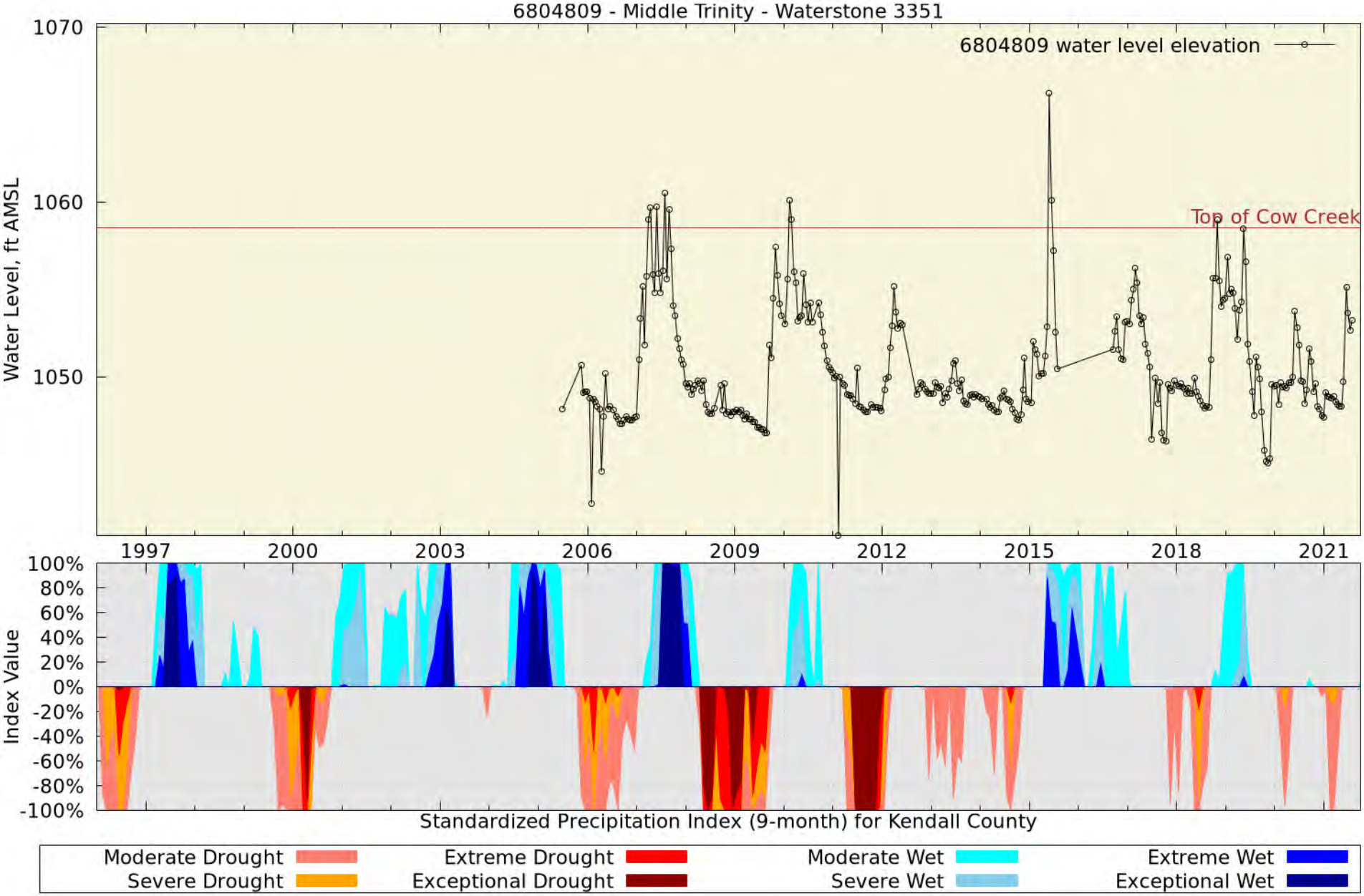

6804214 - Middle Trinity - Donop
6804214 water level elevation
Water Level, ft AMSL
1380
1370
1360
1350
1340
1330
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

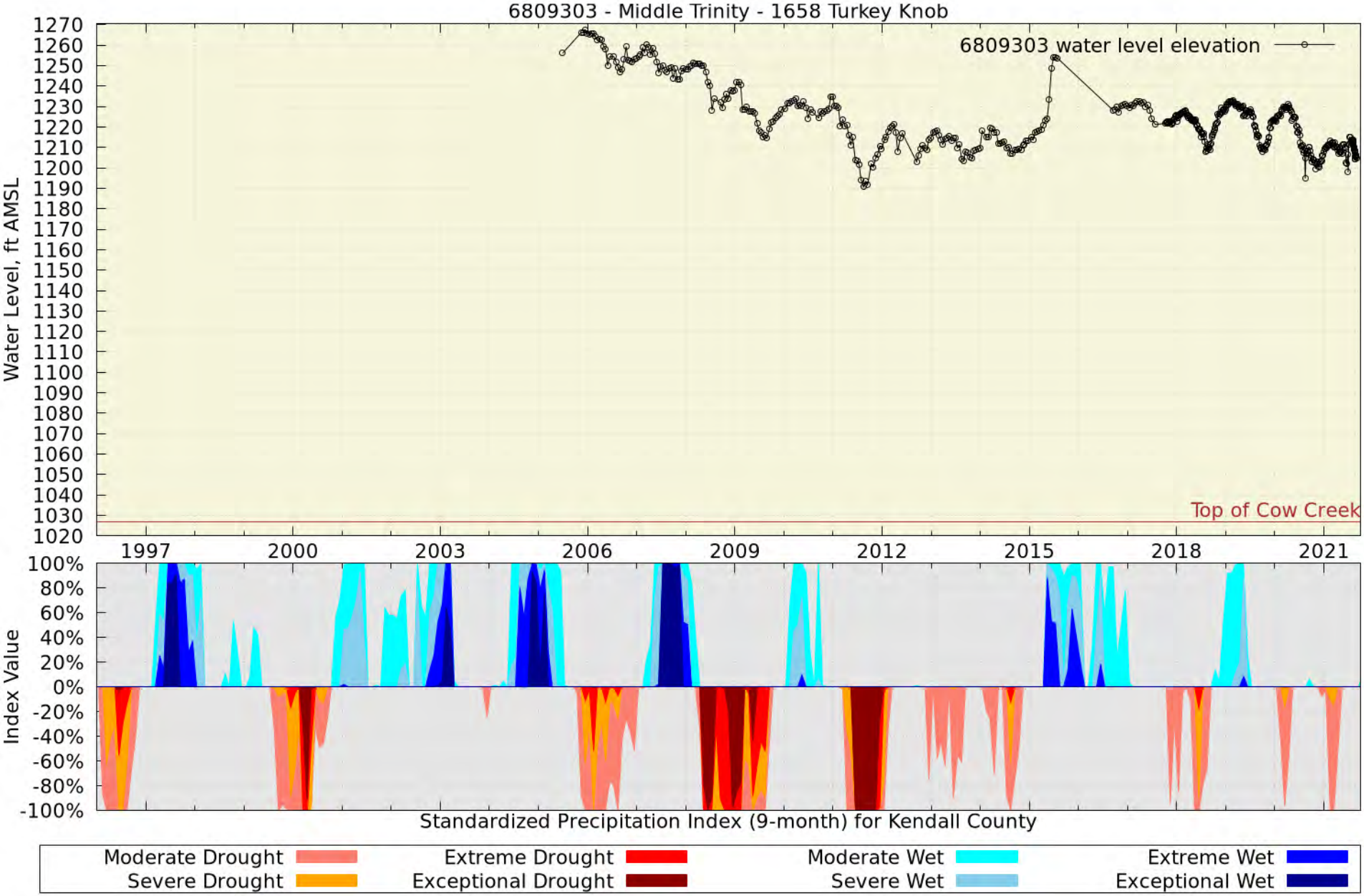

6804312 - Middle Trinity - BKS Estate Trust
6804312 water level elevation
Water Level, ft AMSL
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

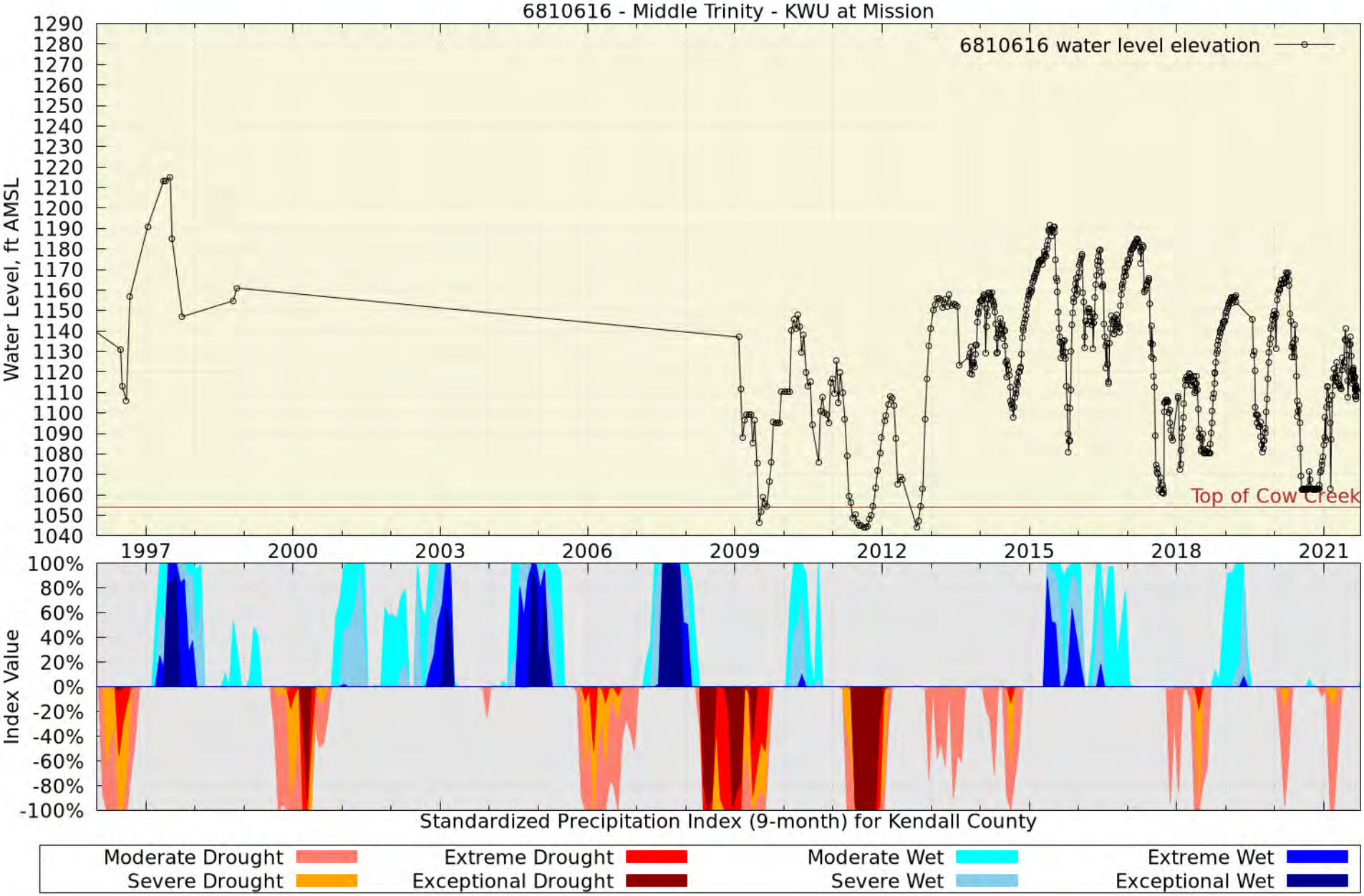

6804313 - Middle Trinity - Kendalia VFD
6804313 water level elevation
Water Level, ft AMSL
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

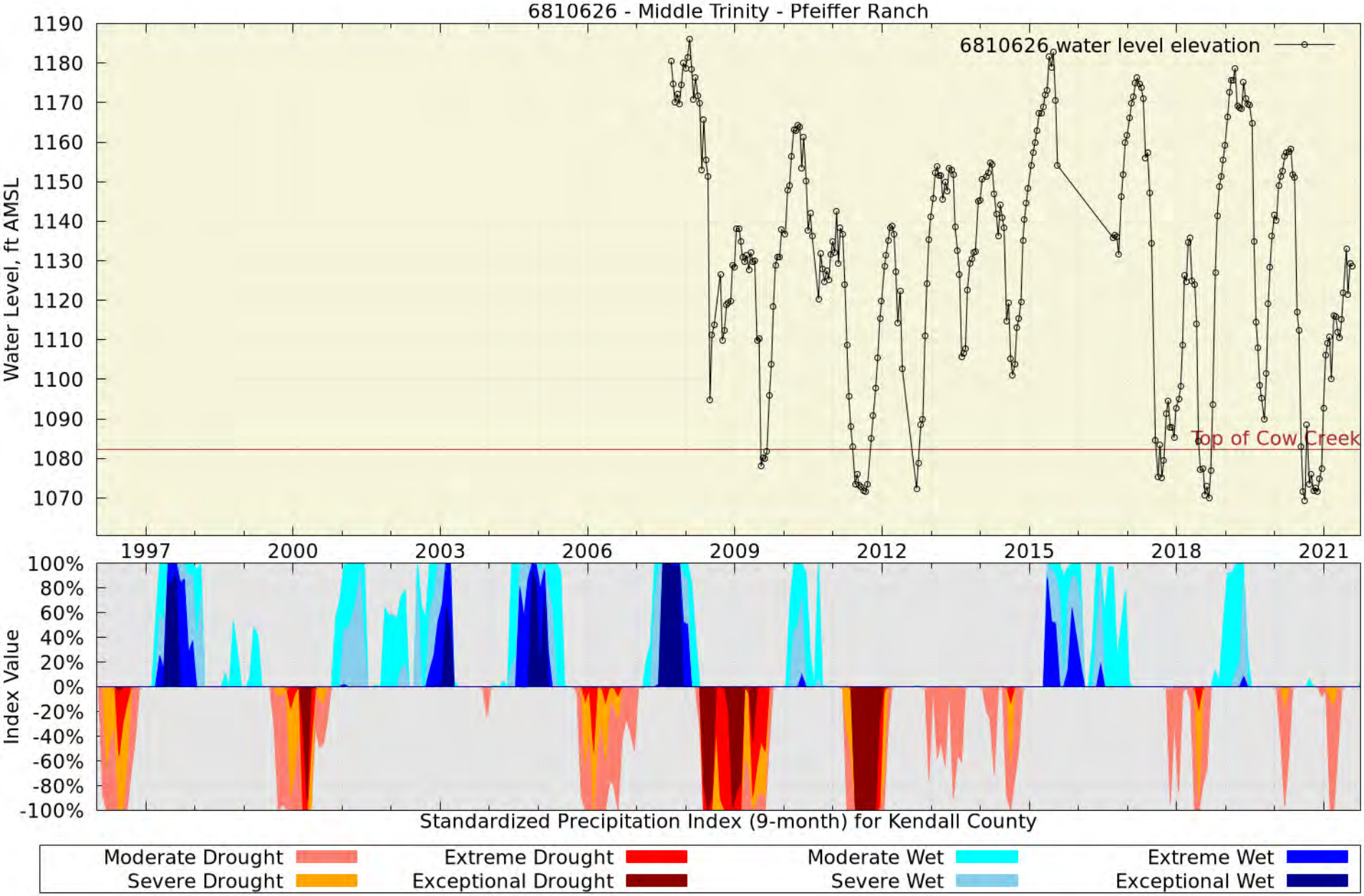

6804705 - Middle Trinity - River Mountain Ranch
6804705 water level elevation
Top of Cow Creek
Water Level, ft AMSL
1110
1100
1090
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

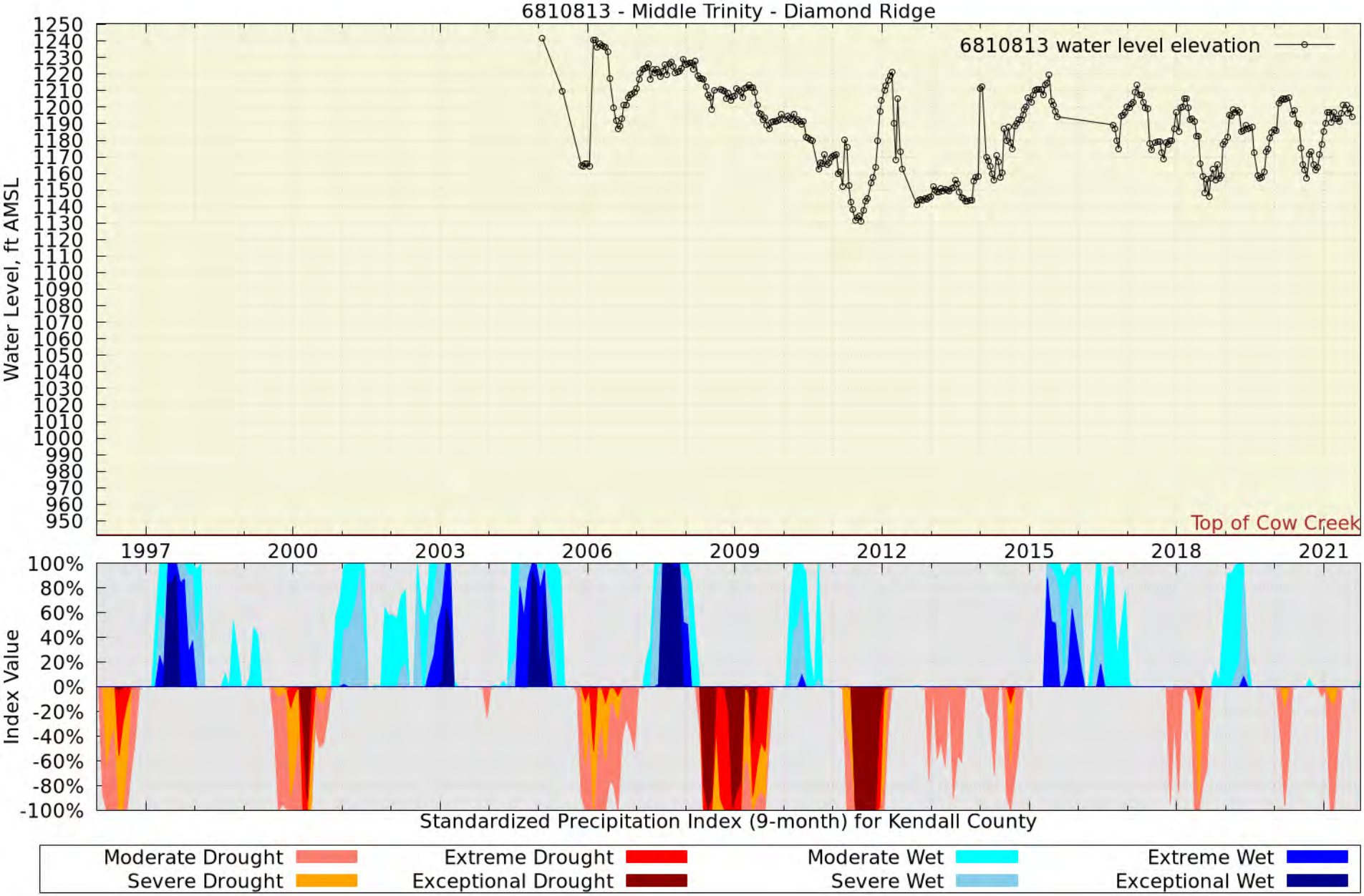

6804804 - Middle Trinity - The Crossing MT
6804804 water level elevation
Top of Cow Creek
Water Level, ft AMSL
1090
1080
1070
1060
1050
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

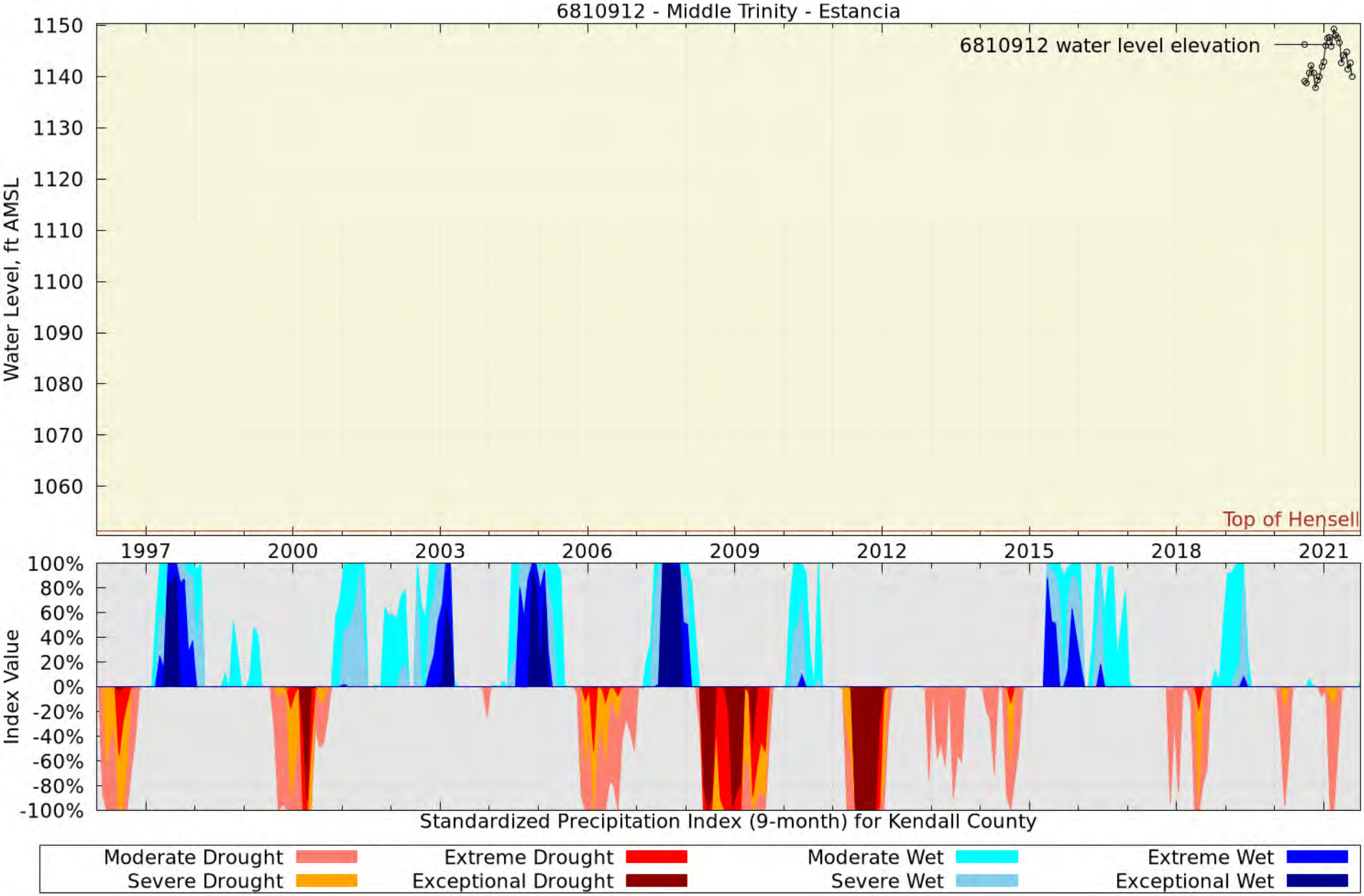

6804809 - Middle Trinity - Waterstone 3351
6804809 water level elevation
Top of Cow Creek
Water Level, ft AMSL
1070
1060
1050
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

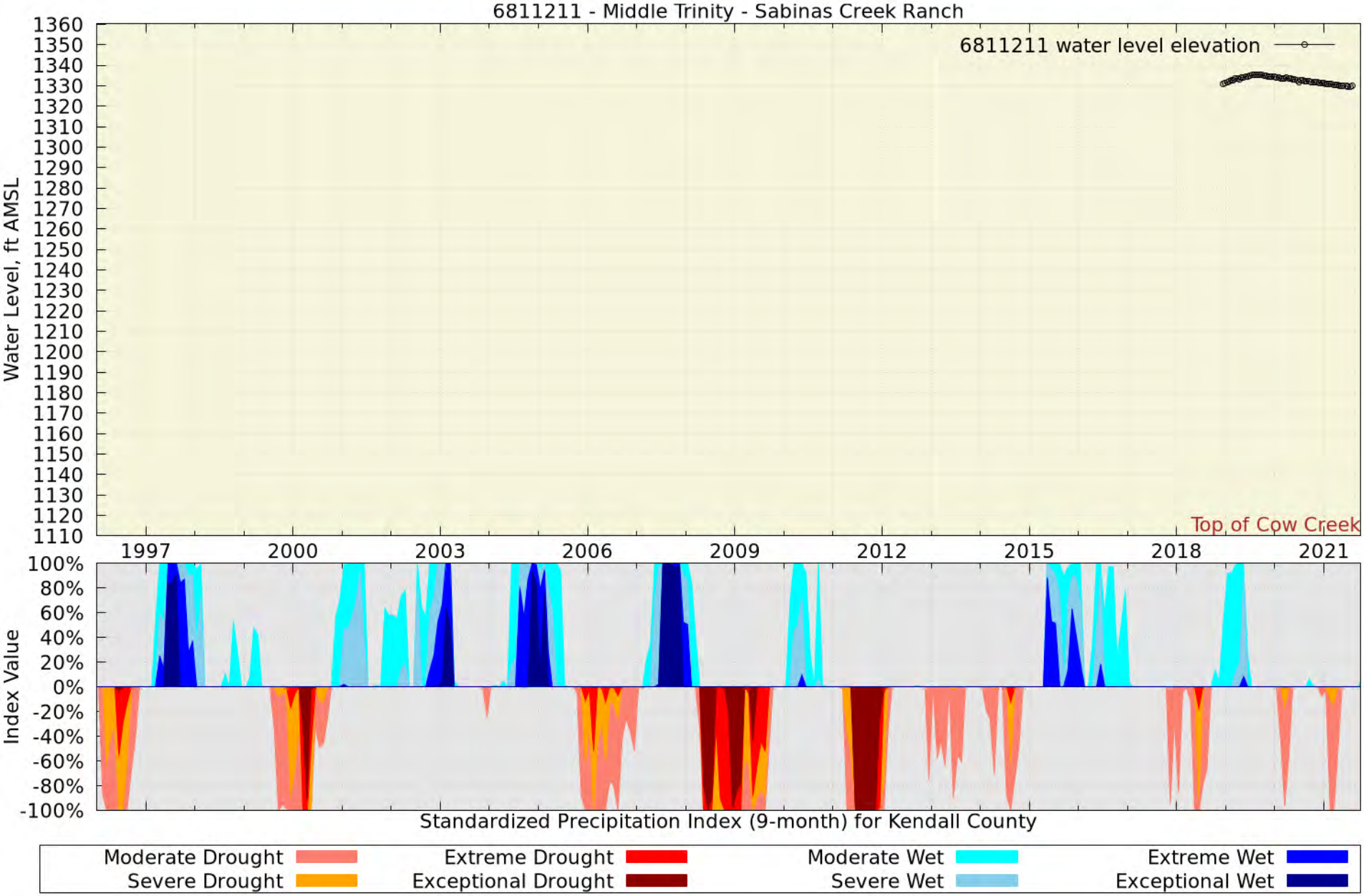

6809303 - Middle Trinity - 1658 Turkey Knob
6809303 water level elevation
Water Level, ft AMSL
Top of Cow Creek
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

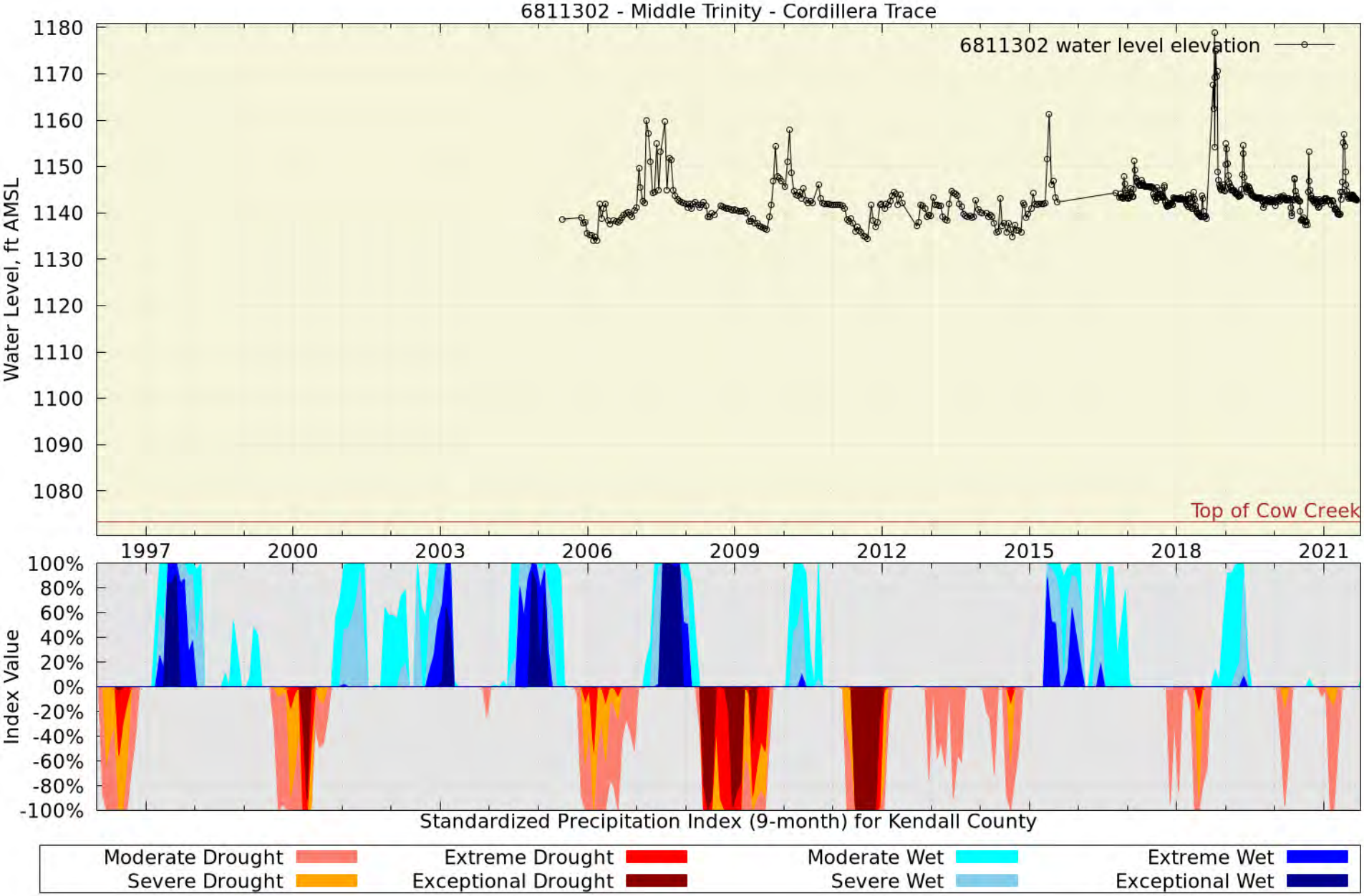

6810616 - Middle Trinity - KWU at Mission
6810616 water level elevation
Water Level, ft AMSL
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

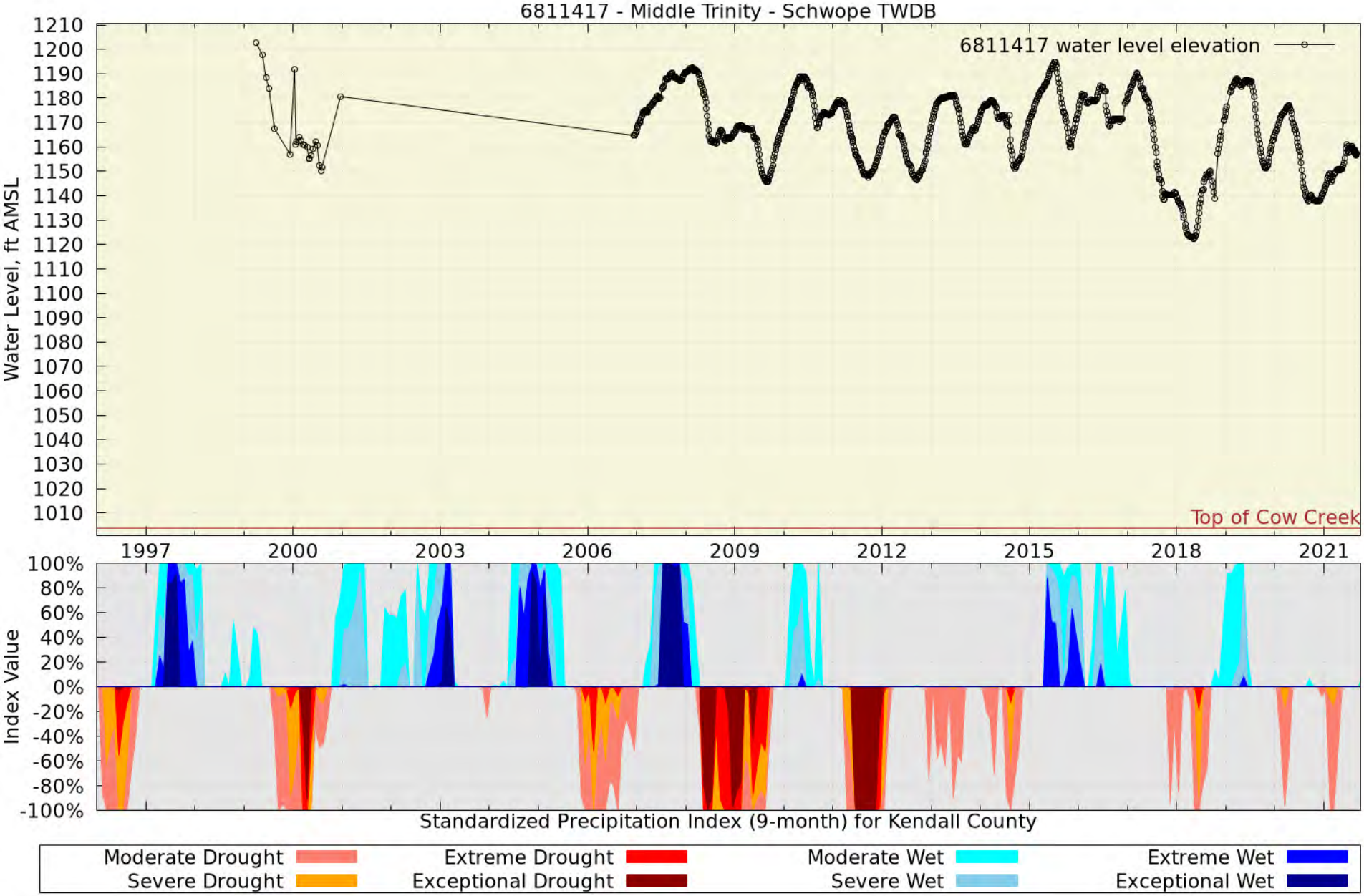

6810626 - Middle Trinity - Pfeiffer Ranch
6810626 water level elevation
Top of Cow Creek
Water Level, ft AMSL
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

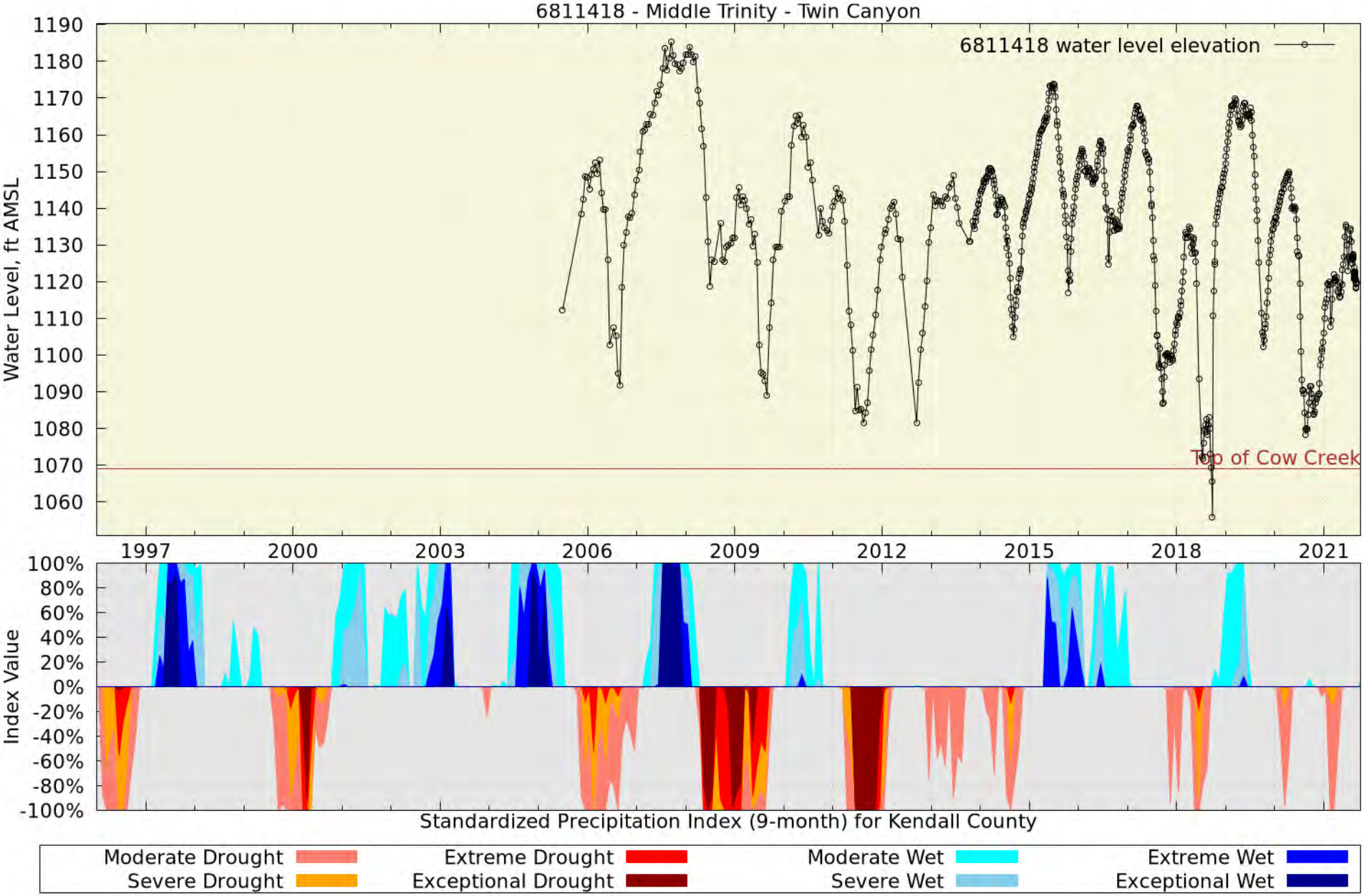

6810813 - Middle Trinity - Diamond Ridge
6810813 water level elevation
Water Level, ft AMSL
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
1010
1000
990
980
970
960
950
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

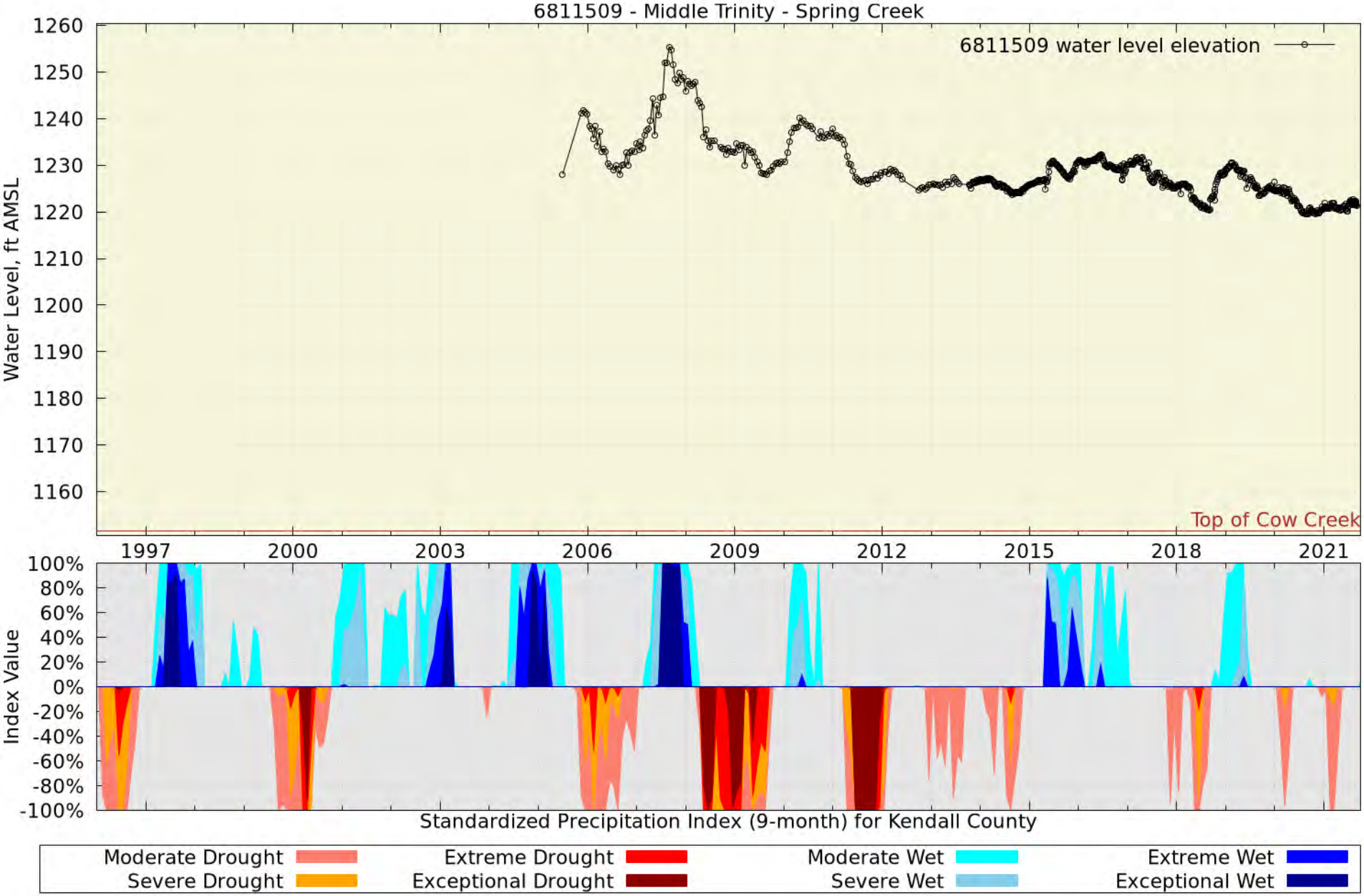

6810912 - Middle Trinity - Estancia
6810912 water level elevation
Water Level, ft AMSL
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
Top of Hensell
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

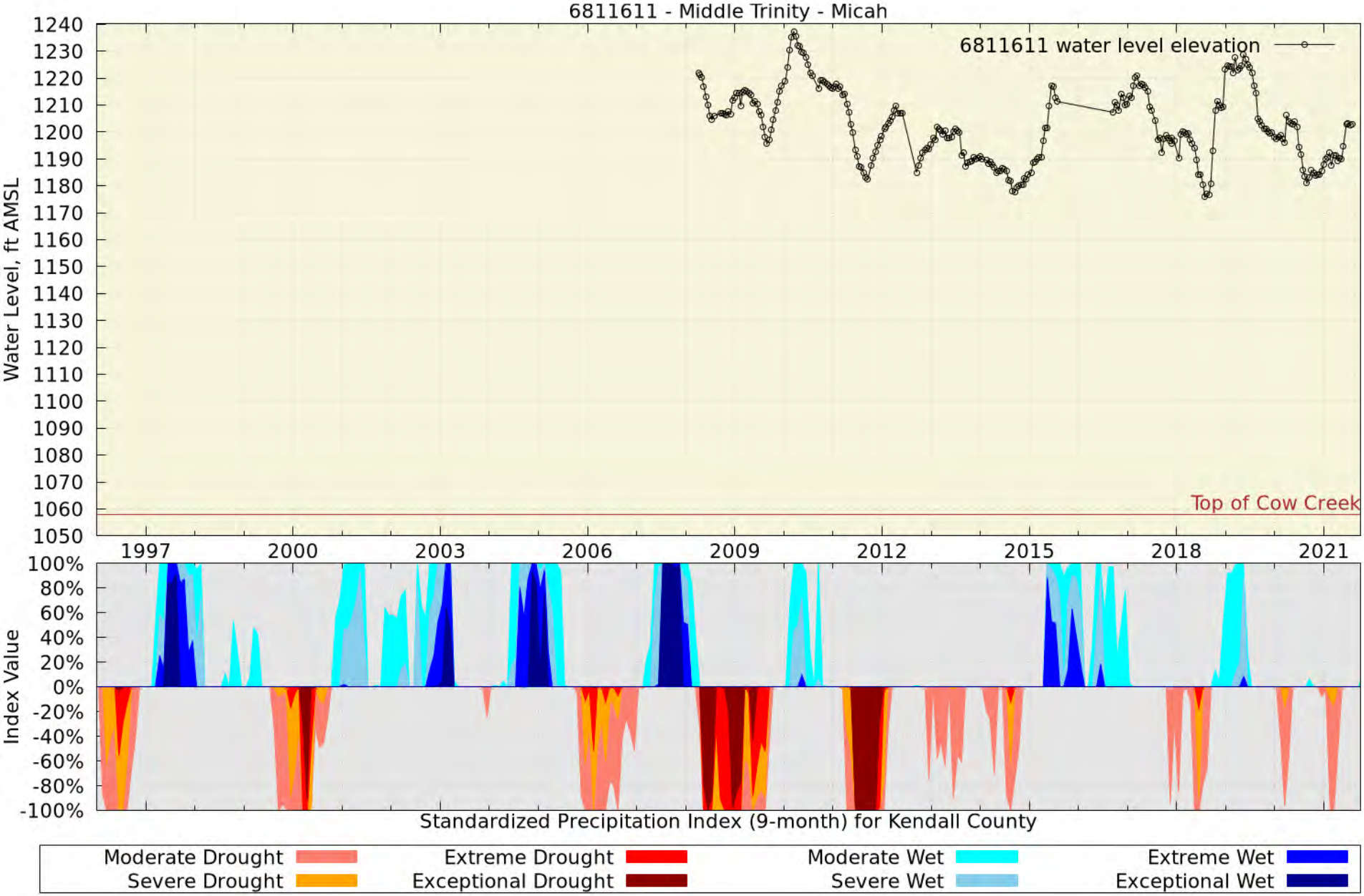

6811211 - Middle Trinity - Sabinas Creek Ranch
6811211 water level elevation
Water Level, ft AMSL
1360
1350
1340
1330
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

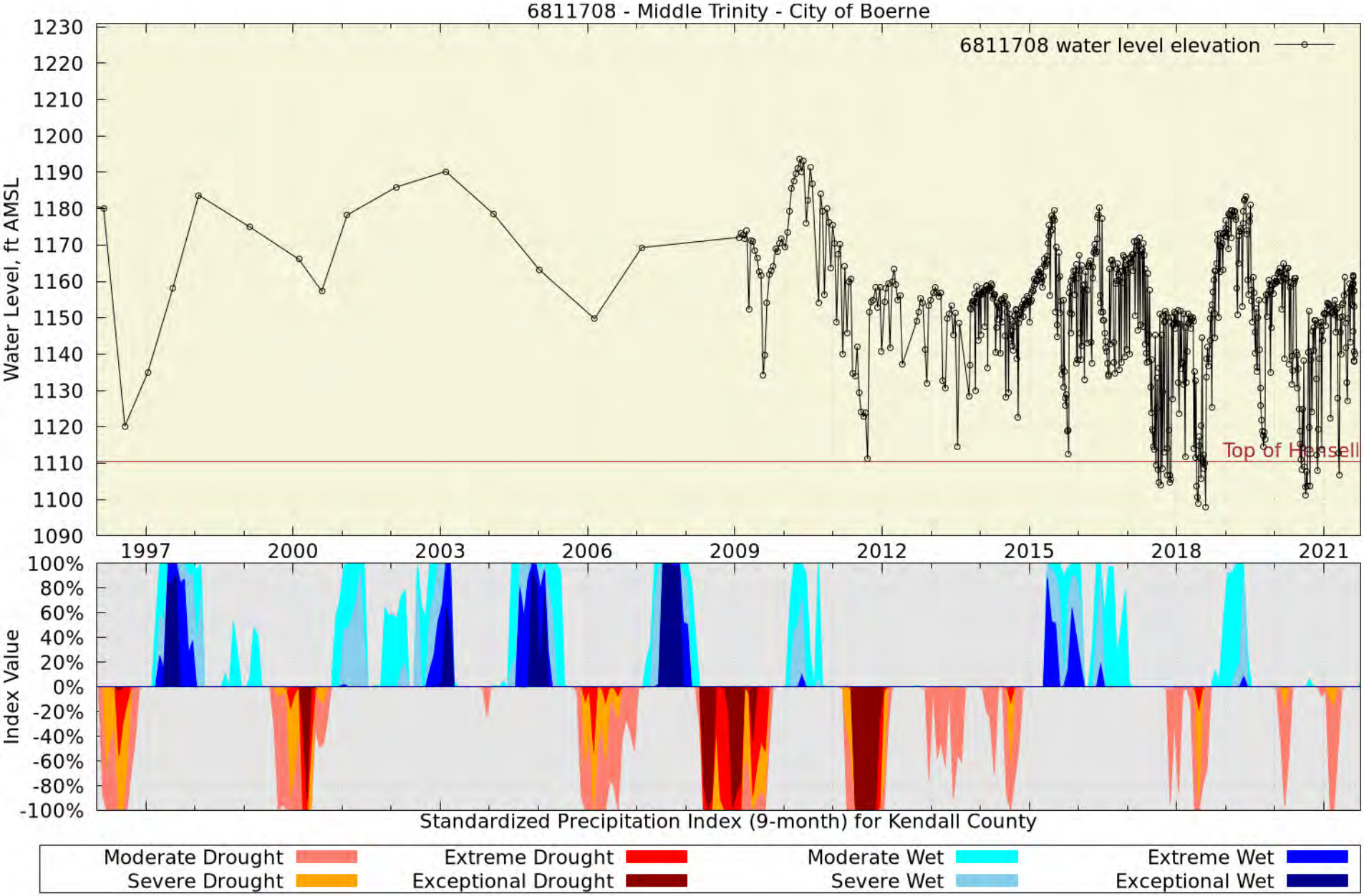

6811302 - Middle Trinity - Cordillera Trace
6811302 water level elevation
Water Level, ft AMSL
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

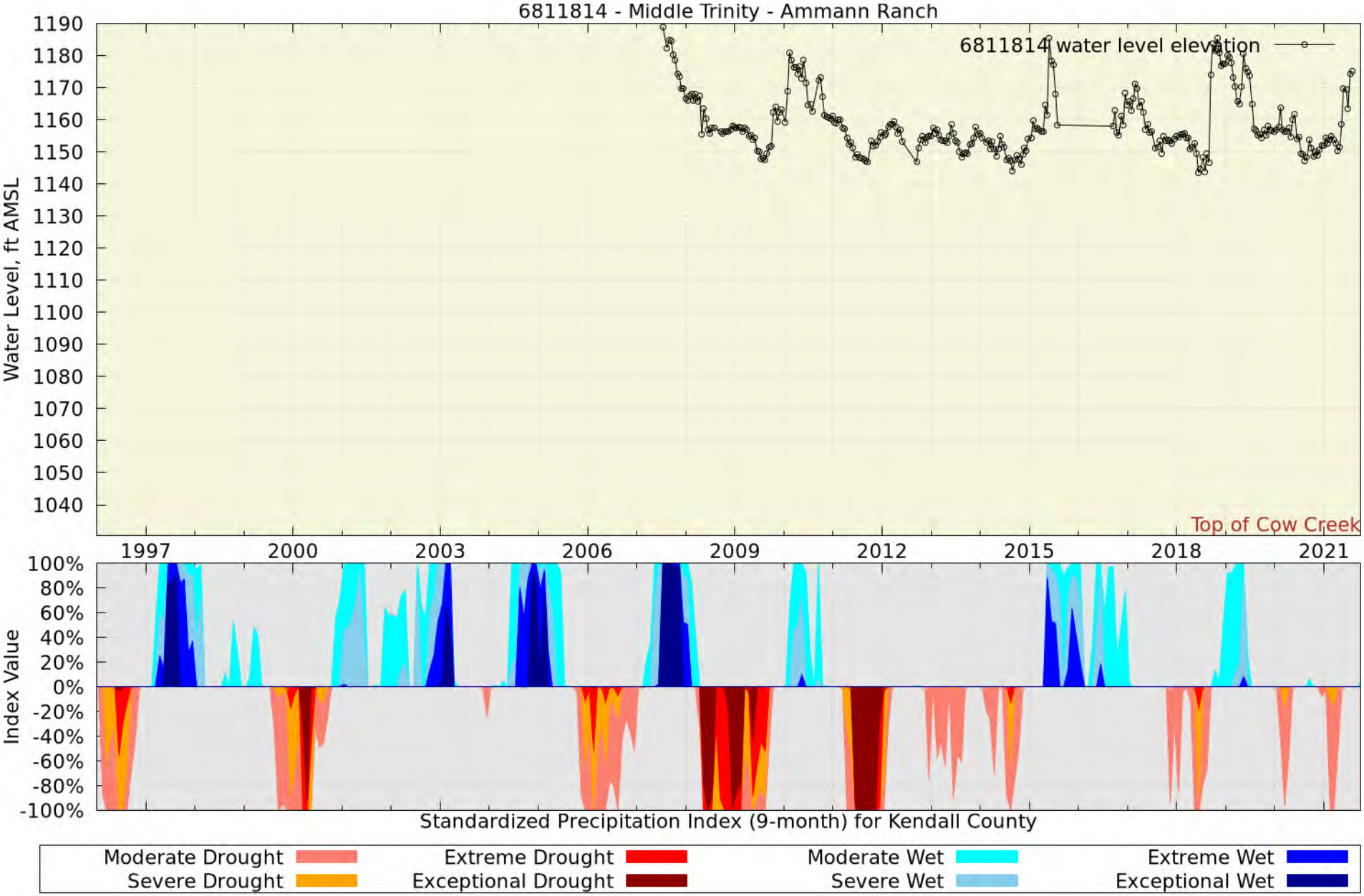

6811417 - Middle Trinity - Schwope TWDB
6811417 water level elevation
Water Level, ft AMSL
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
1010
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

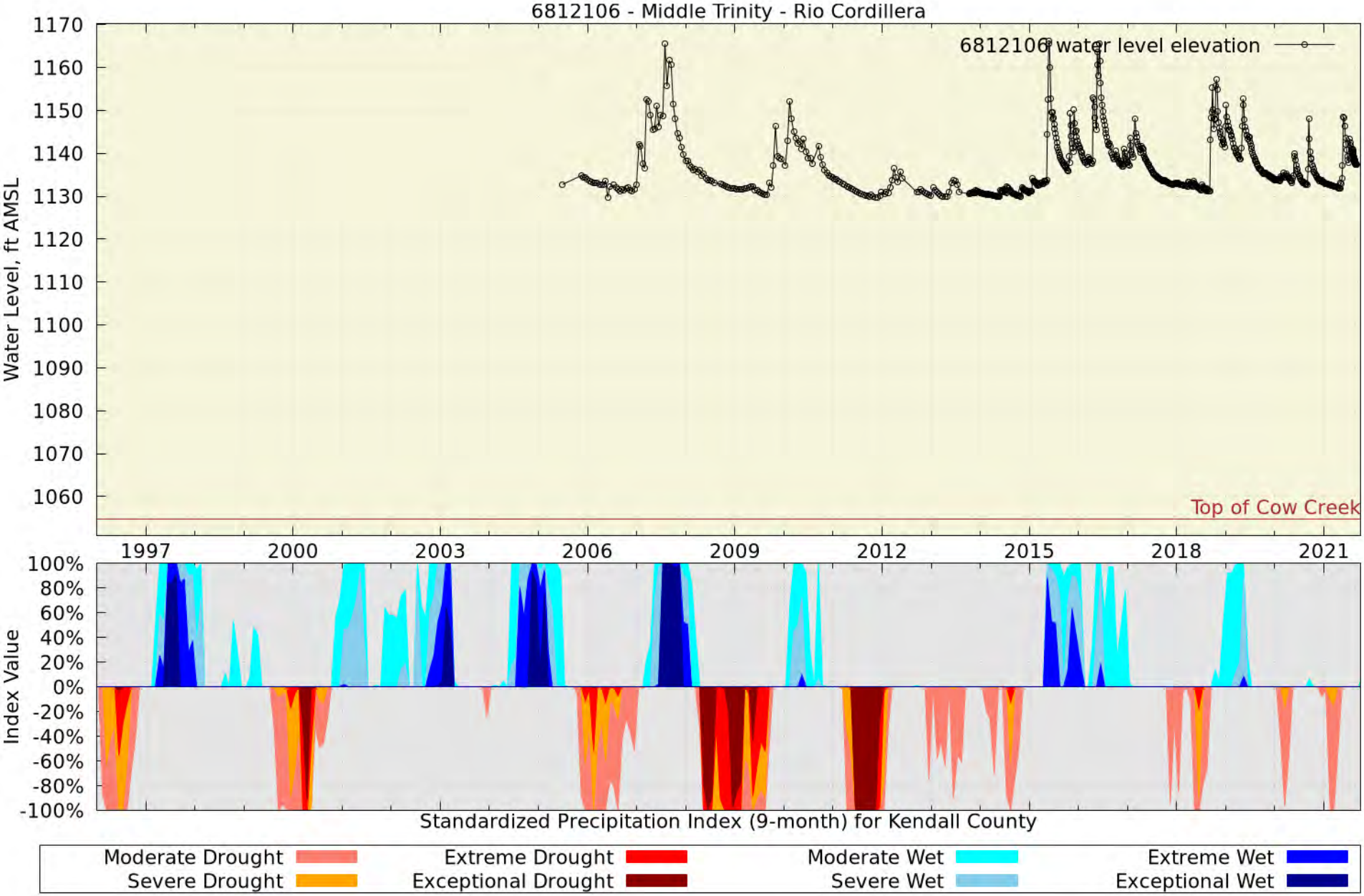

6811418 - Middle Trinity - Twin Canyon
6811418 water level elevation
Water Level, ft AMSL
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

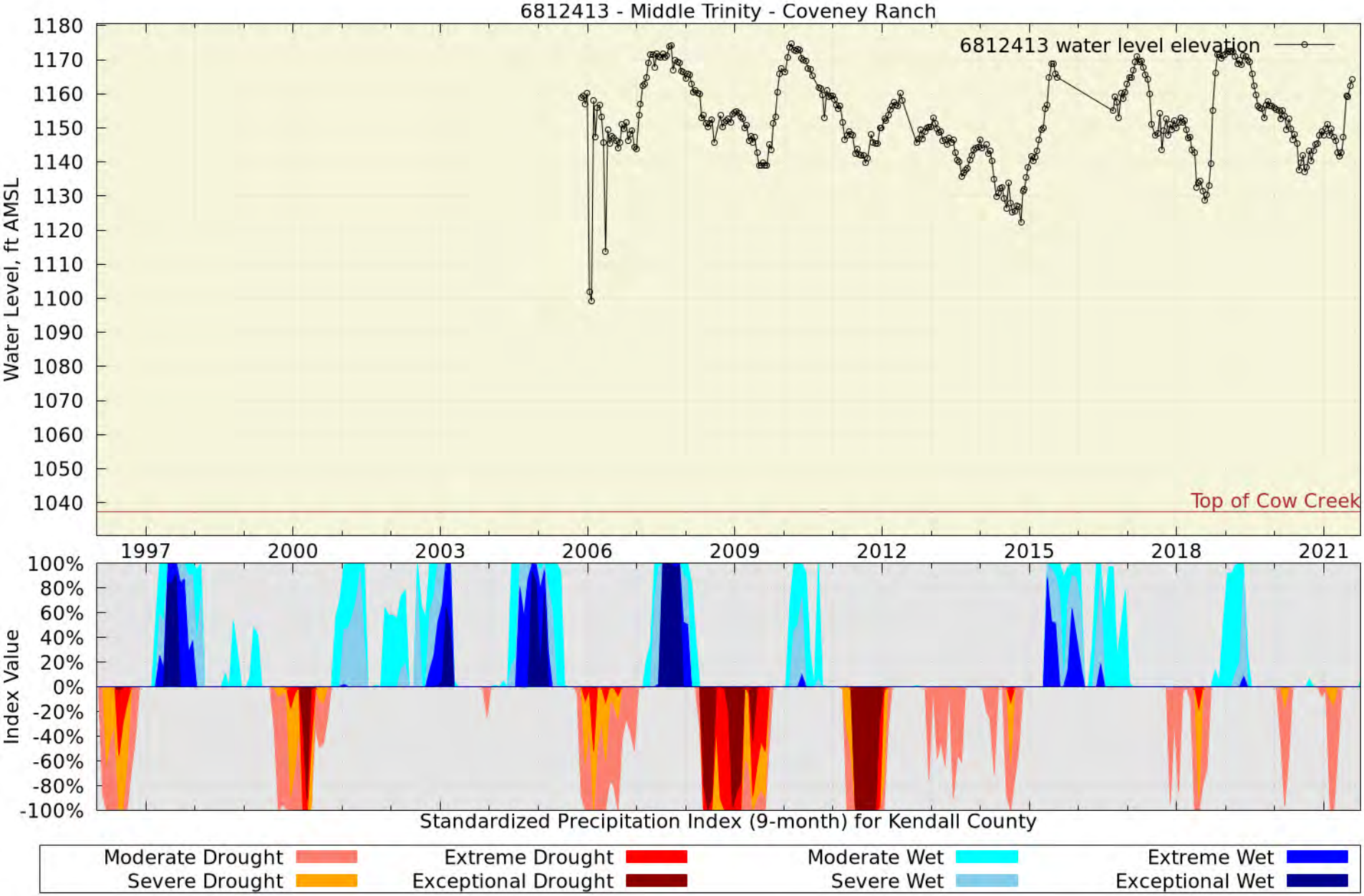

6811509 - Middle Trinity - Spring Creek
6811509 water level elevation
Water Level, ft AMSL
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

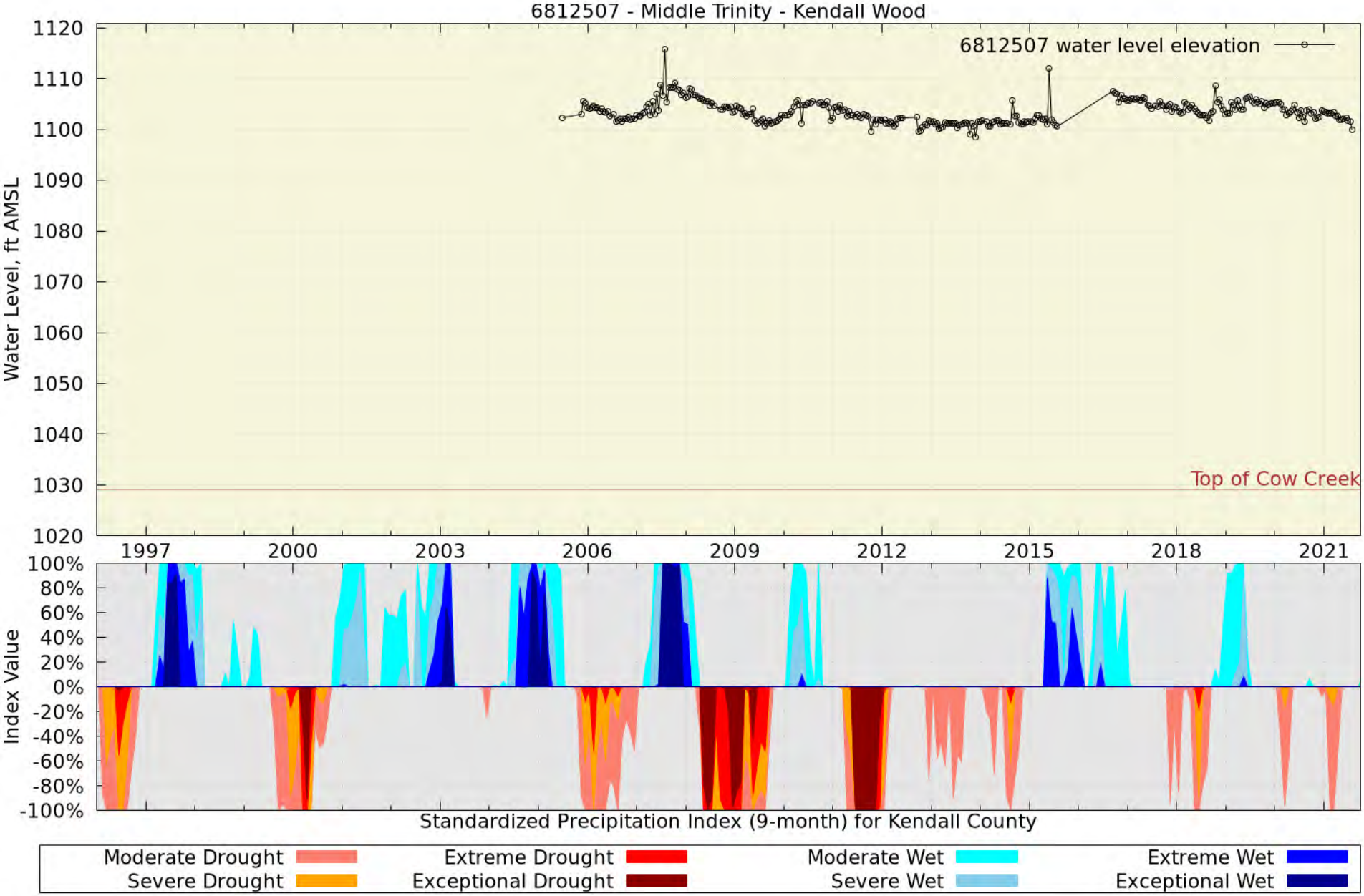

6811611 - Middle Trinity - Micah
6811611 water level elevation
Water Level, ft AMSL
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

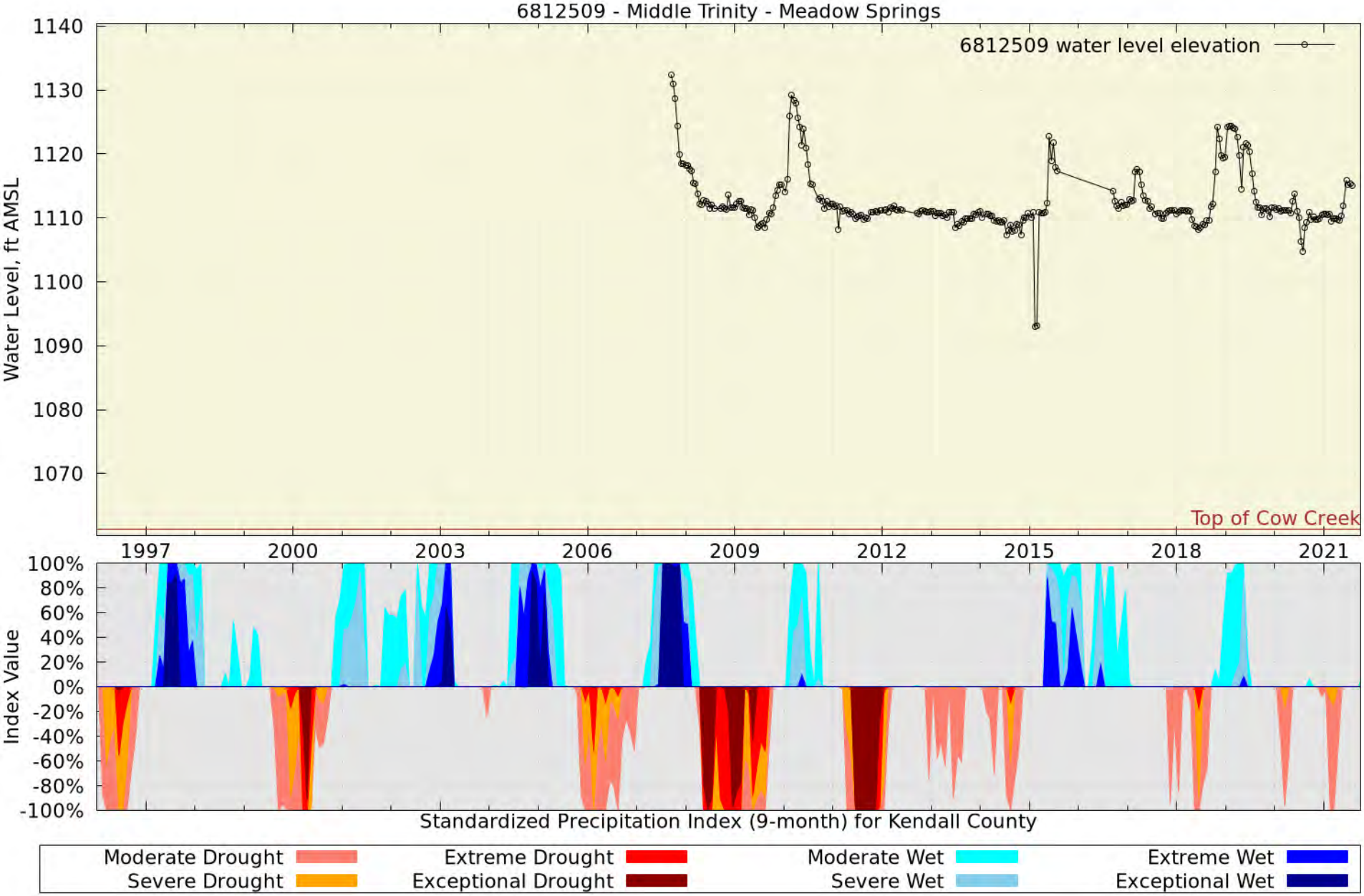

6811708 - Middle Trinity - City of Boerne
6811708 water level elevation
Water Level, ft AMSL
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
Top of Hensell
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

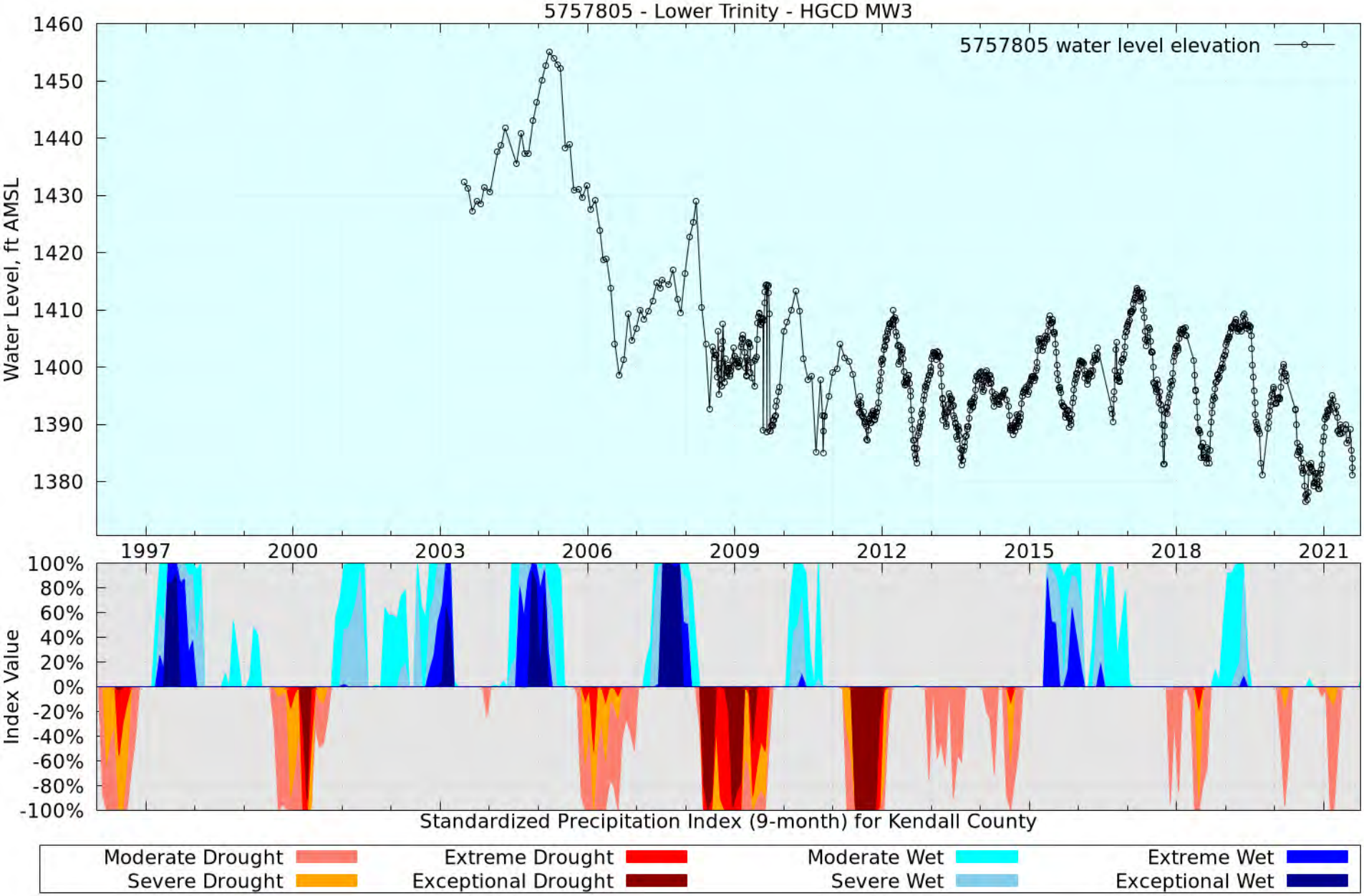

6811814 - Middle Trinity - Ammann Ranch
6811814 water level elevation
Water Level, ft AMSL
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

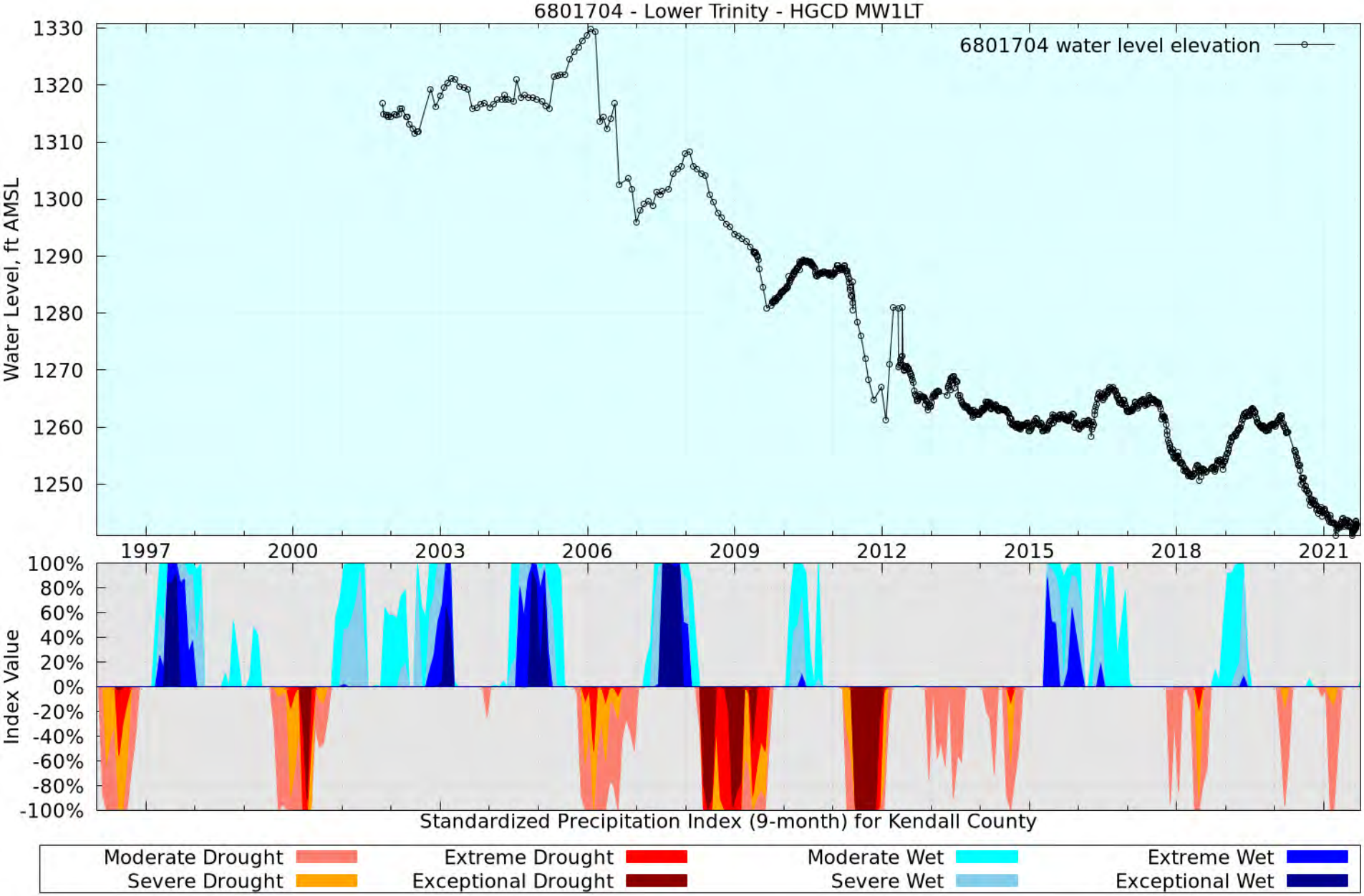

6812106 - Middle Trinity - Rio Cordillera
6812106 water level elevation
Water Level, ft AMSL
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

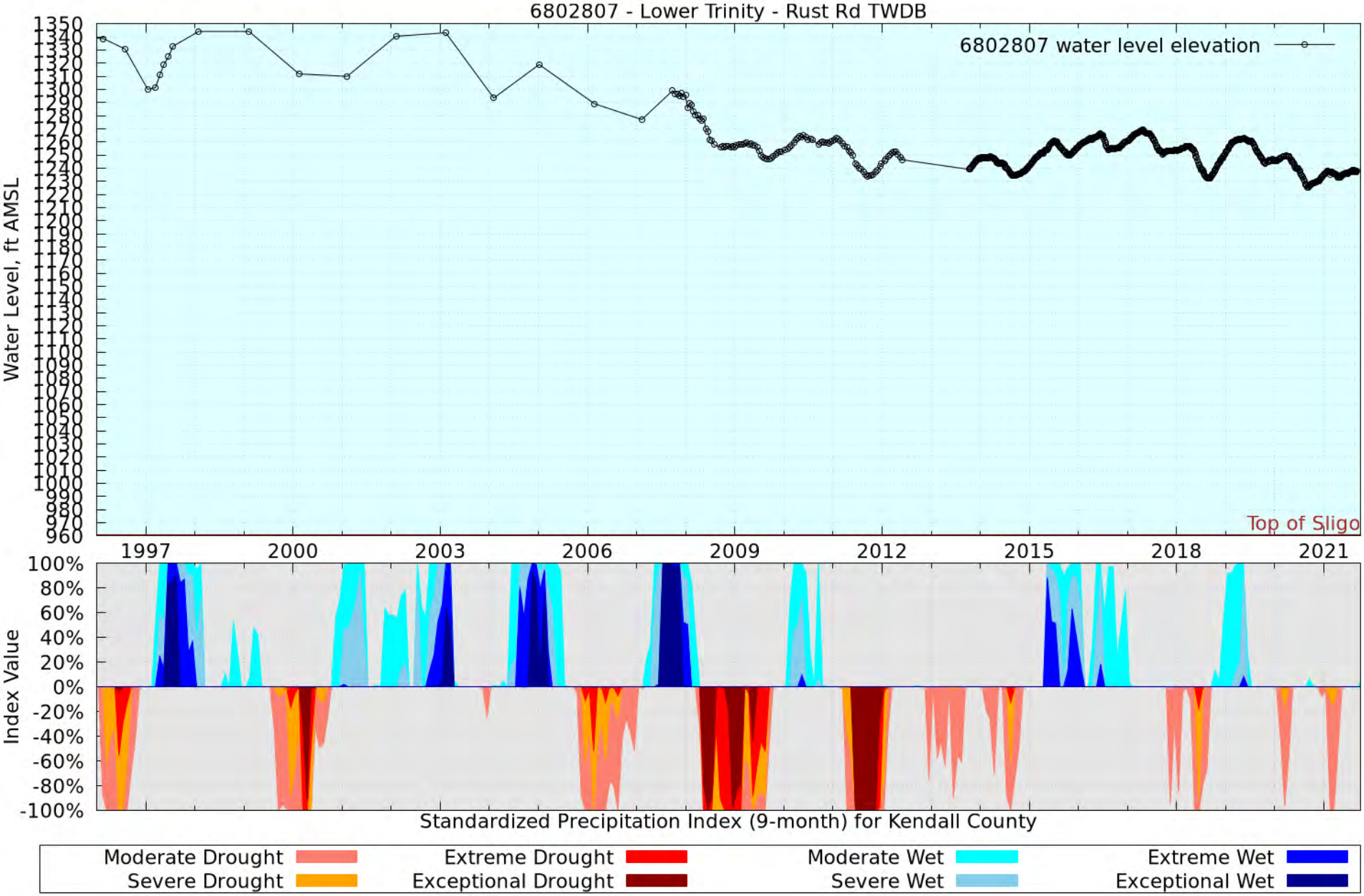

6812413 - Middle Trinity - Coveney Ranch
6812413 water level elevation
Water Level, ft AMSL
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

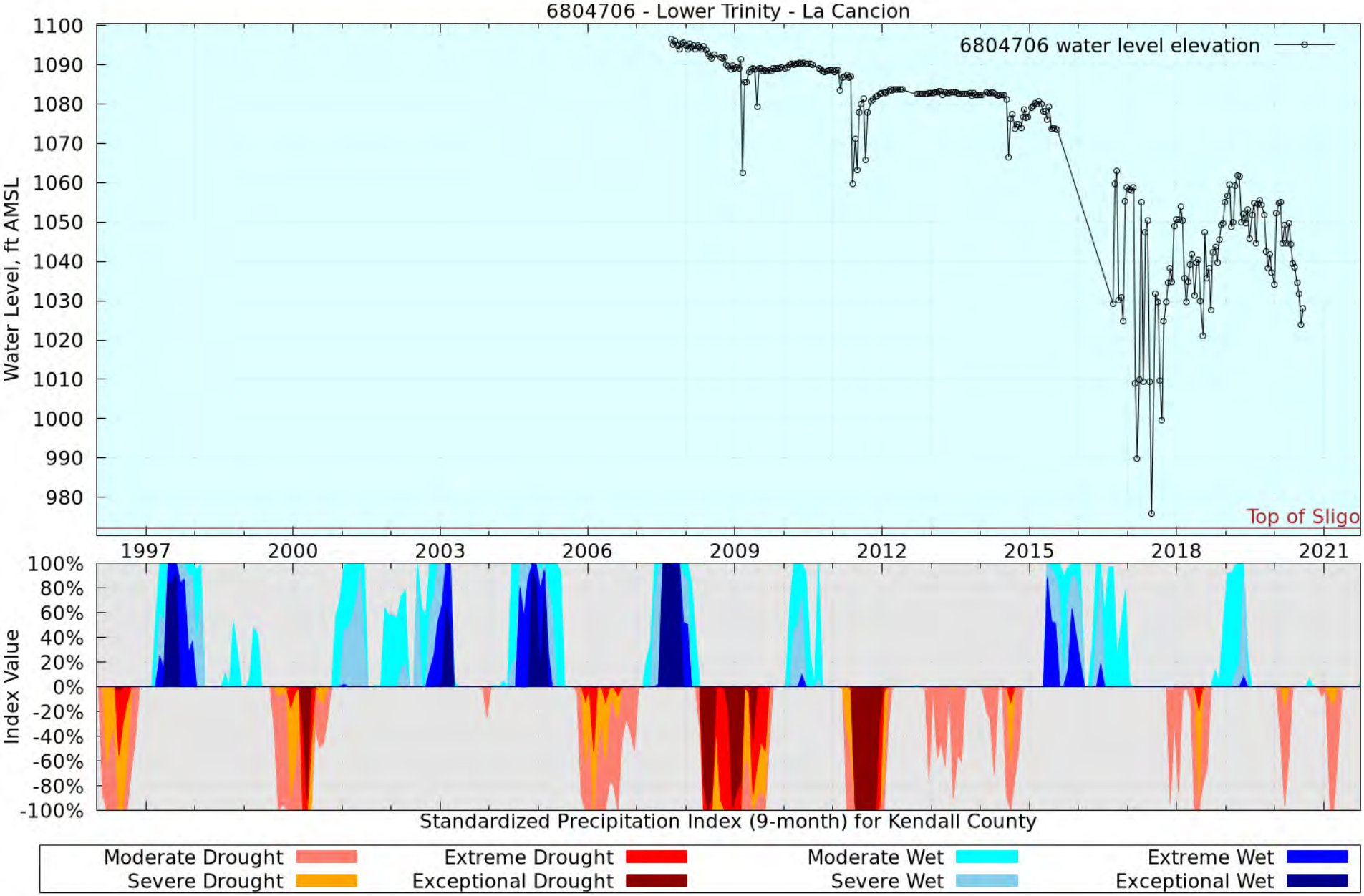

6812507 - Middle Trinity - Kendall Wood
6812507 water level elevation
Water Level, ft AMSL
1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

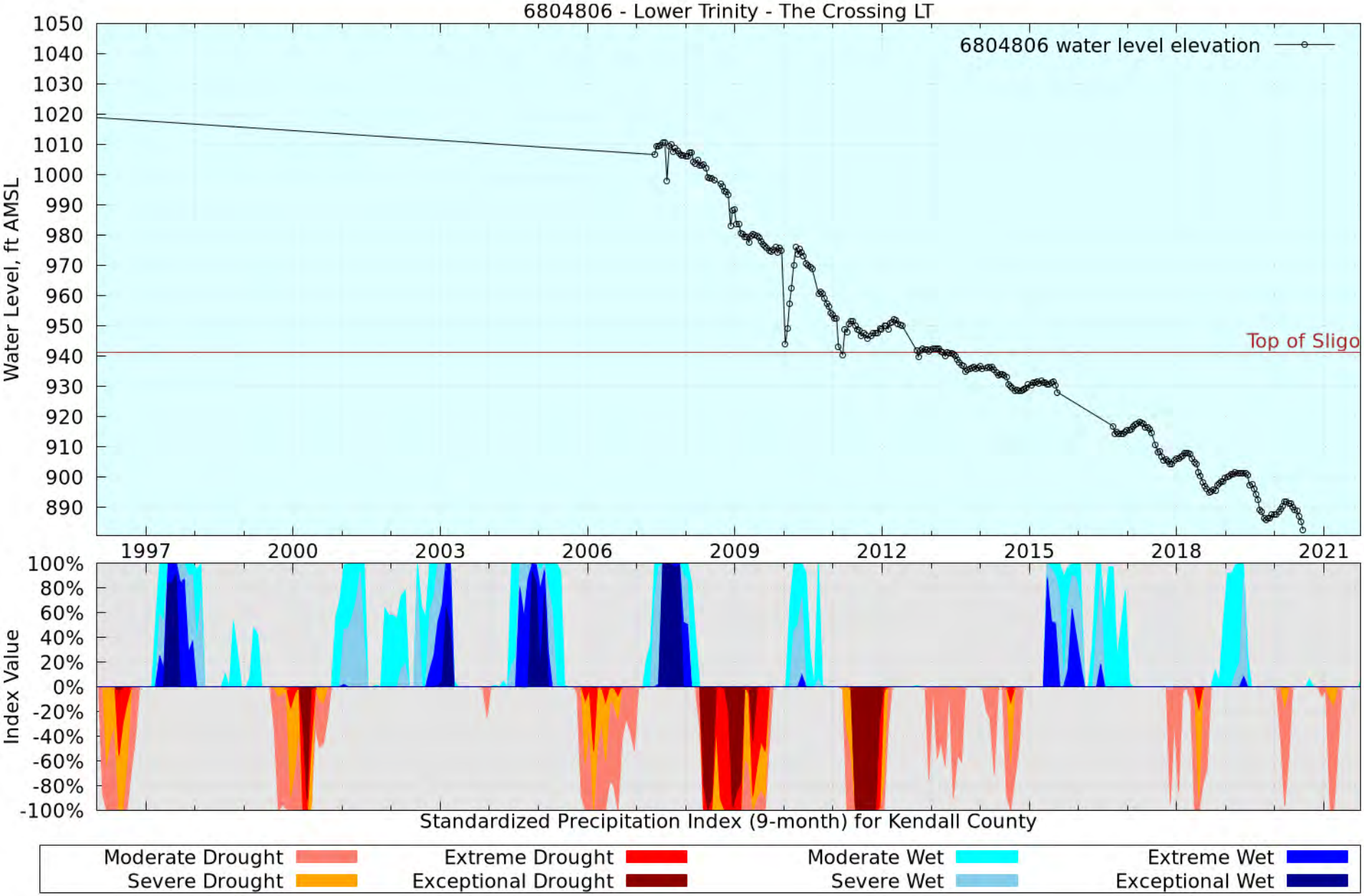

6812509 - Middle Trinity - Meadow Springs
6812509 water level elevation
Water Level, ft AMSL
1140
1130
1120
1110
1100
1090
1080
1070
Top of Cow Creek
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

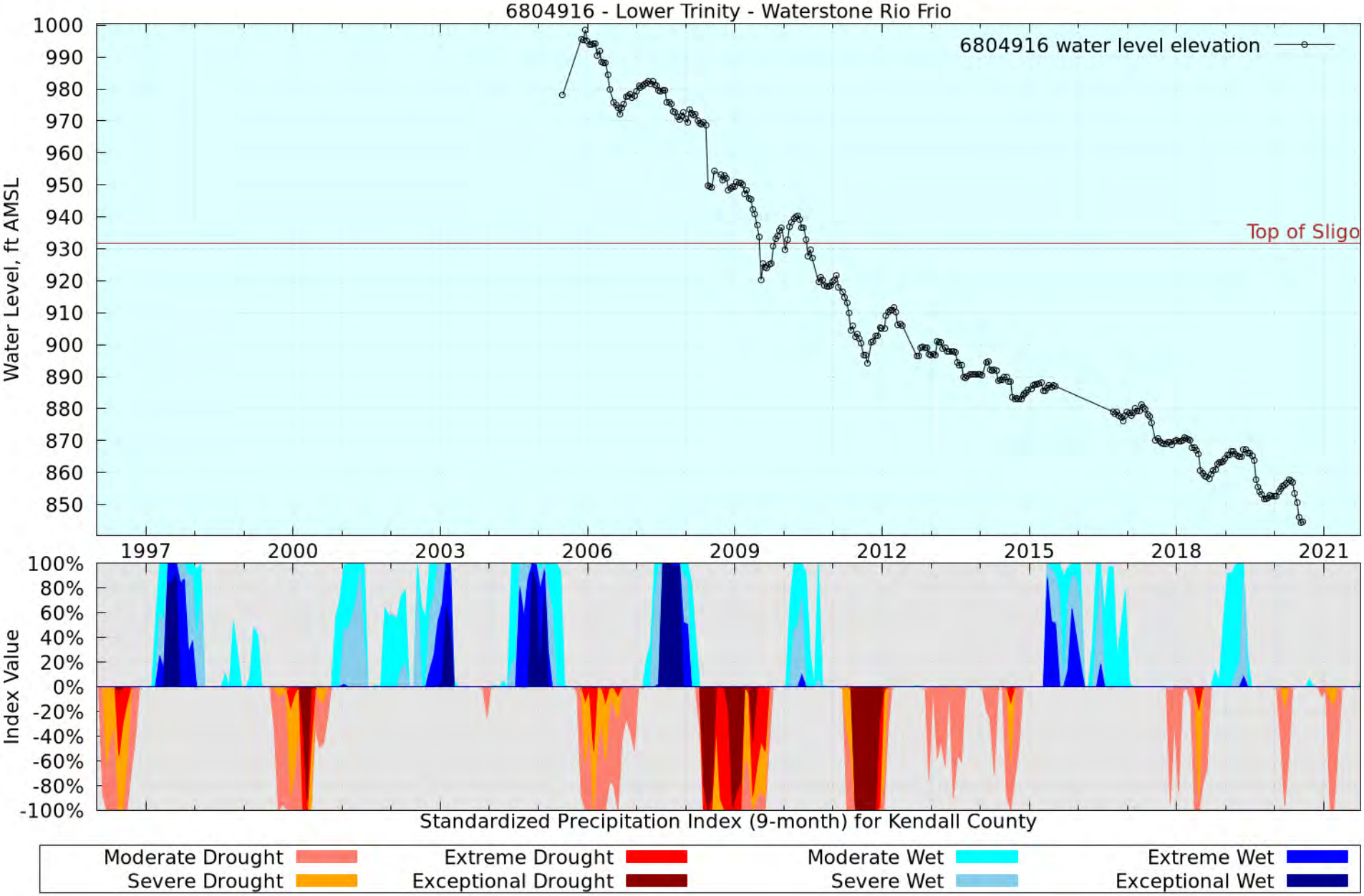

5757805 - Lower Trinity - HGCD MW3
5757805 water level elevation
Water Level, ft AMSL
1460
1450
1440
1430
1420
1410
1400
1390
1380
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

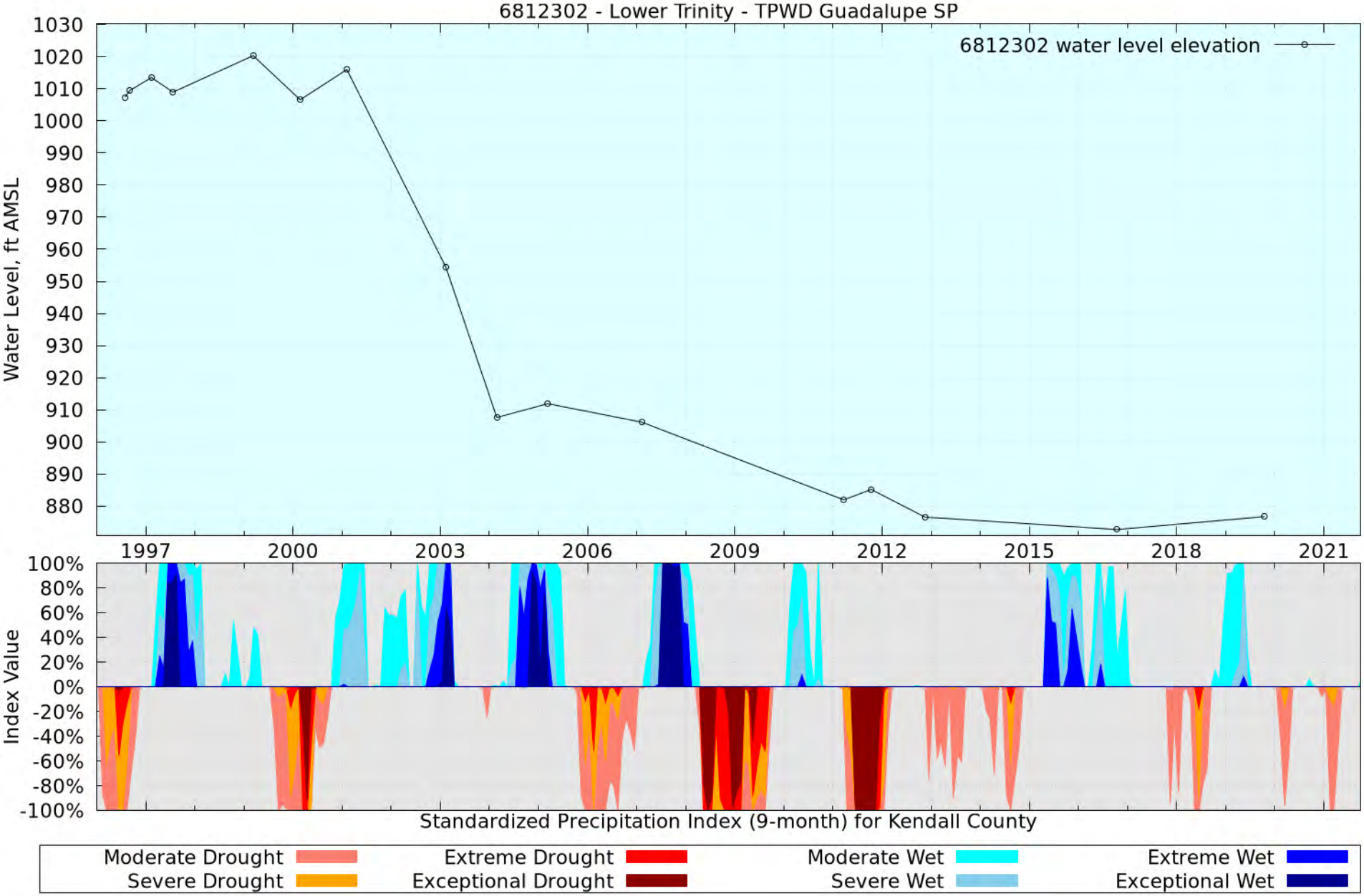

6801704 - Lower Trinity - HGCD MW1LT
6801704 water level elevation
Water Level, ft AMSL
1330
1320
1310
1300
1290
1280
1270
1260
1250
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

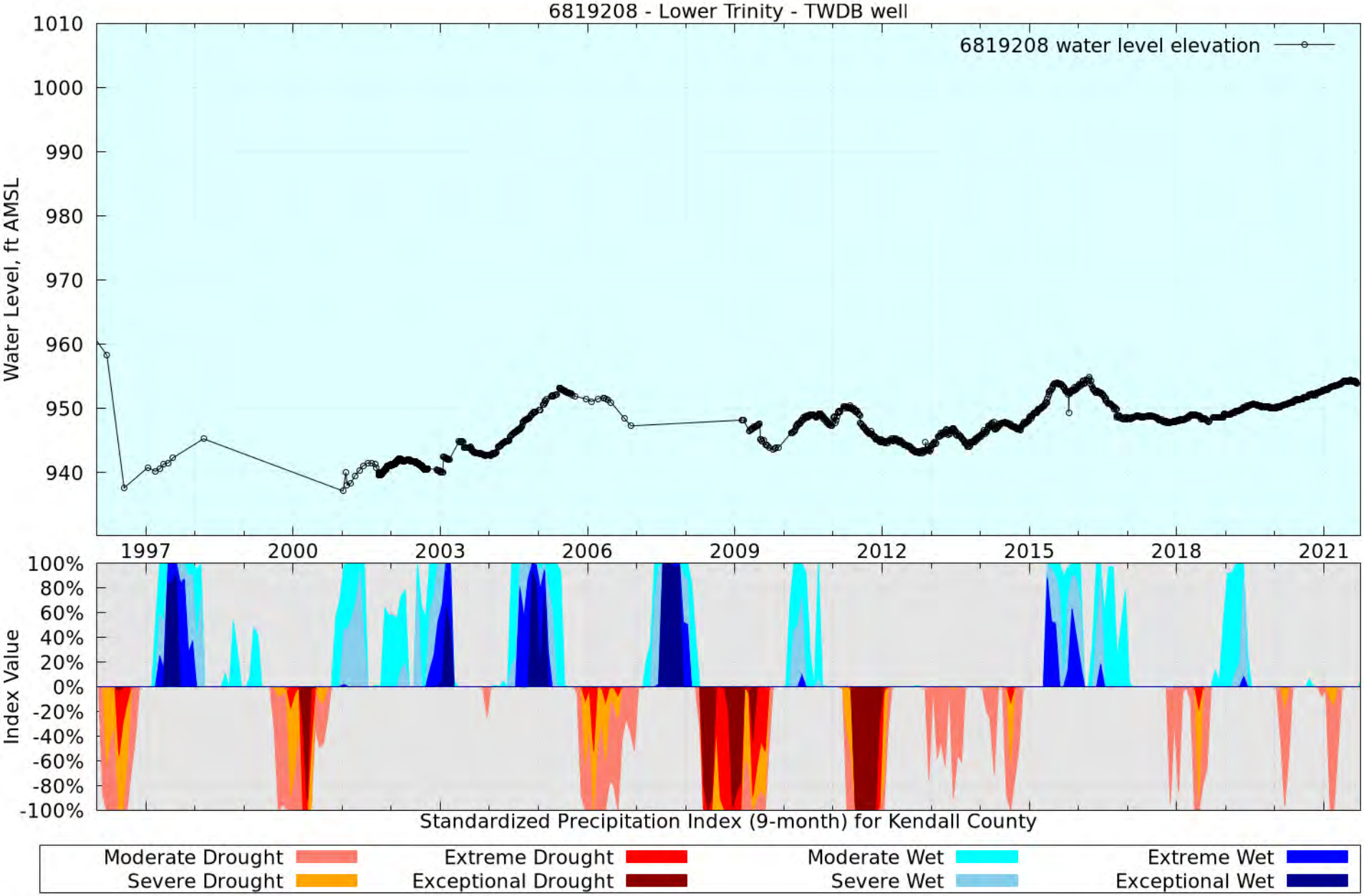

6802807 - Lower Trinity - Rust Rd TWDB
6802807 water level elevation
Water Level, ft AMSL
Top of Sligo
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

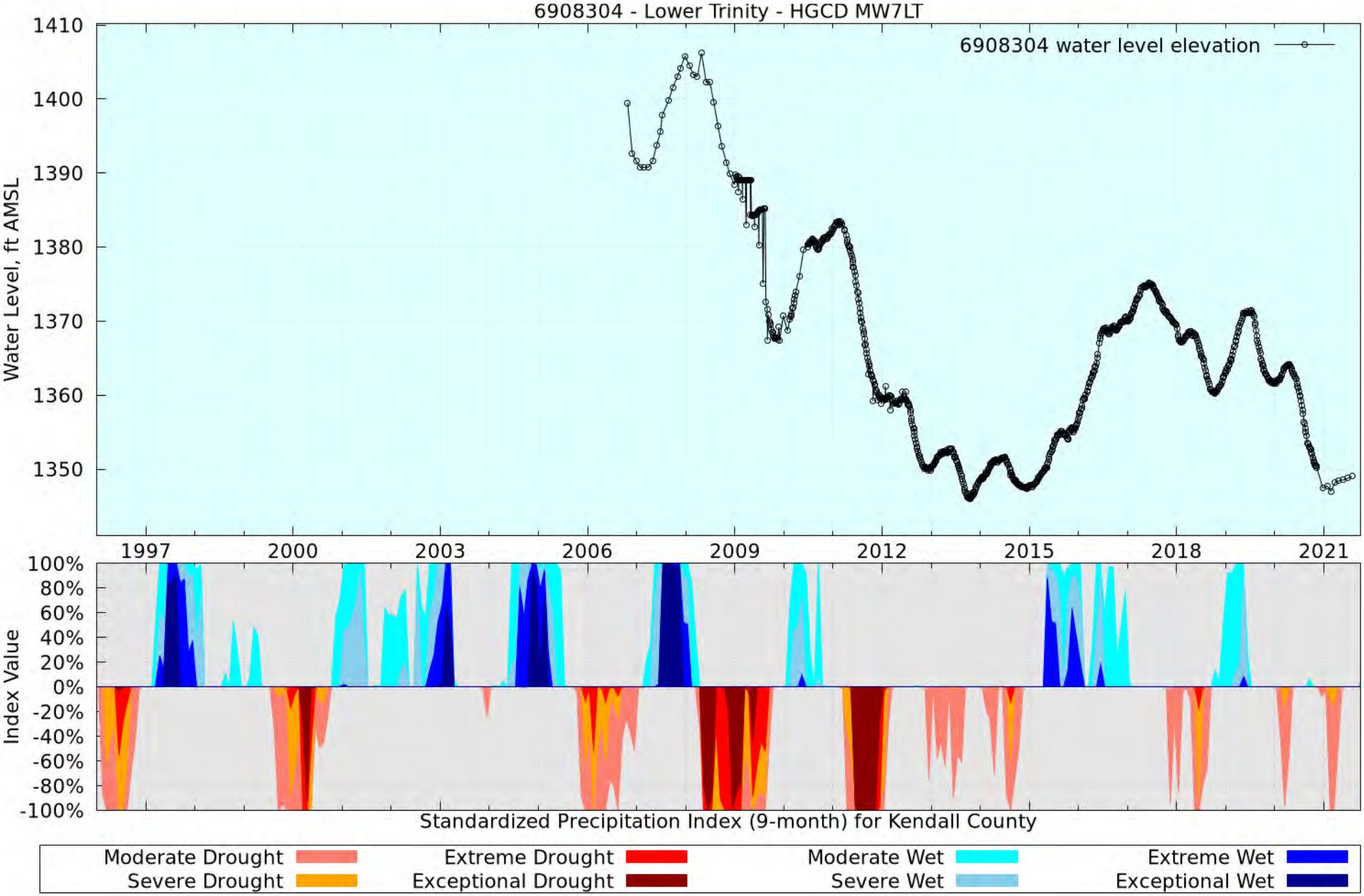

6804706 - Lower Trinity - La Cancion
6804706 water level elevation
Water Level, ft AMSL
1100
1090
1080
1070
1060
1050
1040
1030
1020
1010
1000
990
980
Top of Sligo
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet


6804806 - Lower Trinity - The Crossing LT
6804806 water level elevation
Water Level, ft AMSL
Top of Sligo
1050
1040
1030
1020
1010
1000
990
980
970
960
950
940
930
920
910
900
890
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet


6804916 - Lower Trinity - Waterstone Rio Frio
6804916 water level elevation
Top of Sligo
Water Level, ft AMSL
1000
990
980
970
960
950
940
930
920
910
900
890
880
870
860
850
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

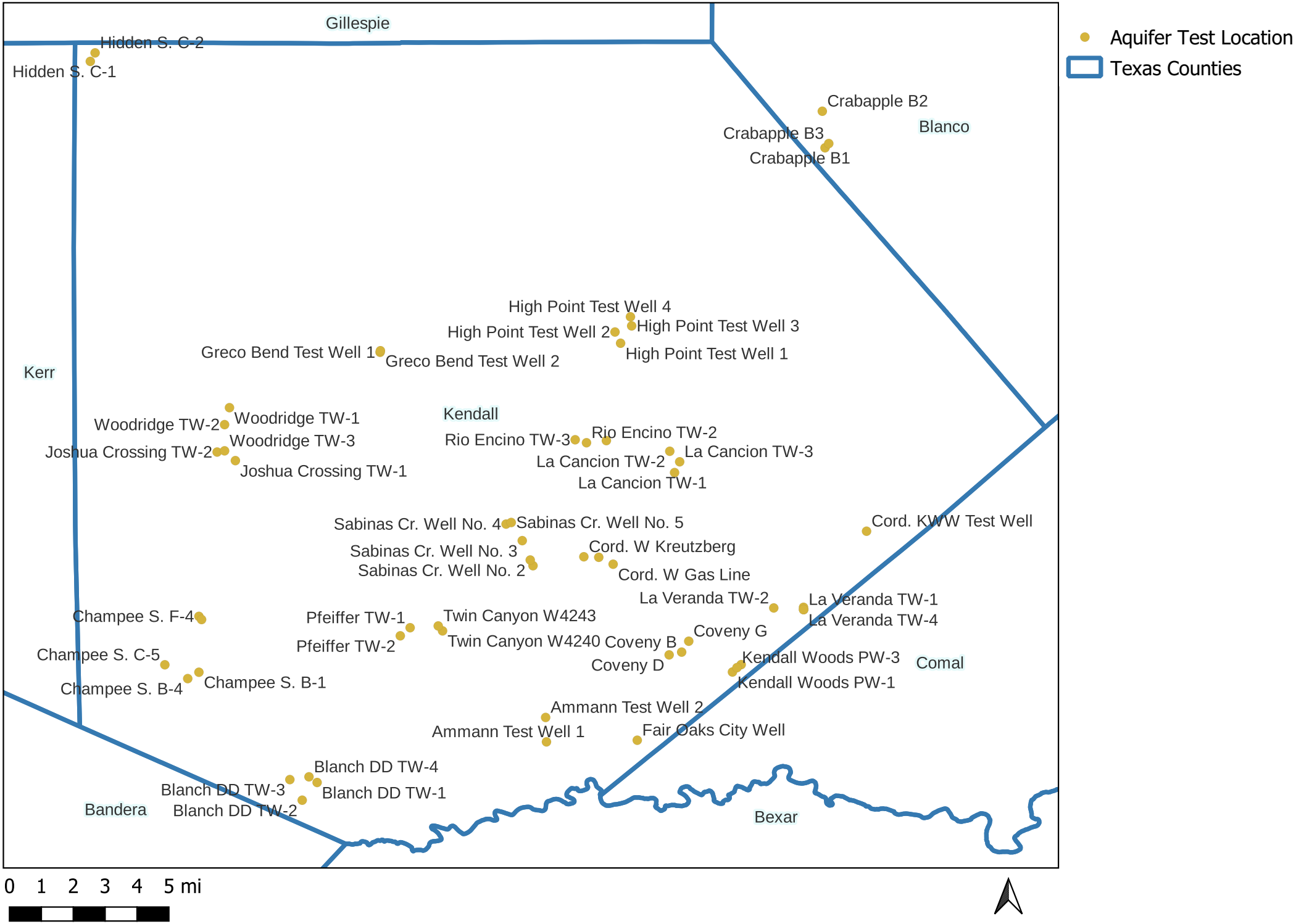

6812302 - Lower Trinity - TPWD Guadalupe SP
6812302 water level elevation
Water Level, ft AMSL
1030
1020
1010
1000
990
980
970
960
950
940
930
920
910
900
890
880
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet


6819208 - Lower Trinity - TWDB well
6819208 water level elevation
Water Level, ft AMSL
1010
1000
990
980
970
960
950
940
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet


6908304 - Lower Trinity - HGCD MW7LT
6908304 water level elevation
Water Level, ft AMSL
1410
1400
1390
1380
1370
1360
1350
1997
2000
2003
2006
2009
2012
2015
2018
2021
Index Value
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Standardized Precipitation Index (9-month) for Kendall County
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
Moderate Wet
Severe Wet
Extreme Wet
Exceptional Wet

Appendix B

Summary of Aquifer Parameters from Water Availability Studies


Aquifer Test Location
Texas Counties
Gillespie
Hidden S. C-2
Hidden S. C-1
Crabapple B2
Crabapple B3
Crabapple B1
Blanco
High Point Test Well 4
High Point Test Well 2
High Point Test Well 3
High Point Test Well 1
Greco Bend Test Well 1
Greco Bend Test Well 2
Kerr
Kendall
Woodridge TW-2
Woodridge TW-1
Woodridge TW-3
Joshua Crossing TW-2
Joshua Crossing TW-1
Rio Encino TW-3
Rio Encino TW-2
La Cancion TW-2
La Cancion TW-3
La Cancion TW-1
Sabinas Cr. Well No. 4
Sabinas Cr. Well No. 5
Sabinas Cr. Well No. 3
Sabinas Cr. Well No. 2
Cord. W Kreutzberg
Cord. W Gas Line
Cord. KWW Test Well
La Veranda TW-2
La Veranda TW-1
La Veranda TW-4
Champee S. F-4
Pfeiffer TW-1
Pfeiffer TW-2
Twin Canyon W4243
Twin Canyon W4240
Coveny B
Coveny G
Coveny D
Champee S. C-5
Champee S. B-4
Champee S. B-1
Kendall Woods PW-3
Kendall Woods PW-1
Comal
Ammann Test Well 2
Ammann Test Well 1
Fair Oaks City Well
Blanch DD TW-4
Blanch DD TW-3
Blanch DD TW-1
Blanch DD TW-2
Bandera
Bexar
0 1 2 3 4 5 mi

Well	Latitude	Longitude	Aquifer	Transmissivity (ft2/d)	Aquifer Thickness (ft)	K (ft/d)	Storage Coefficient
Crabapple							
B1	30.0835000	-98.528889	Middle Trinity/Ellenburger (Cow Creek-Ellenburger)	494.65	15	32.98	0.0000315
B2	30.1025833	-98.530306	Middle Trinity (Cow Creek)	60.16	25	2.41	0.0000525
B3	30.0857222	-98.526944	Middle Trinity (Cow Creek)	29.41	20	1.47	0.000042
Hidden Springs							
C-1	30.1286111	-98.912222	Middle Trinity (Hensell)	504.68	95	5.31	0.000022
C-2	30.1330556	-98.909722	Middle Trinity (Hensell)	364.97	220	1.66	0.000023
Coveney							
B	29.8202222	-98.603694	Middle (LGR)	100.94	73	0.60	0.0000173
			Middle (LGR&CC)	124.17	130	0.46	0.0000128
D	29.8187778	-98.610222	Middle (LGR)	48.00	80	0.60	0.0000868
			Middle (LGR&CC)	50.77	110	0.96	0.00004659
G	29.8259167	-98.600000	Middle (LGR)	18.94	73		0.0000226
			Middle (LGR&CC)	47.32	130	0.36	0.0000173
Champee Springs Ranches							
B-1	29.8097222	-98.855556	Middle (CC)	36.63	51	0.72	0.0028
B-4	29.8063889	-98.861389	Middle (CC)	97.59	60	1.63	0.00058
C-5	29.8136111	-98.873333	Middle (CC)	32.89	82	0.40	0.0001
F-4	29.8388889	-98.855556	Middle (CC)	27.01	47	0.57	0.001
E-3	29.8372222	-98.854167	Middle (CC)	9.09	38	0.24	0.0001
Blanch Double Diamond							
TW-1	29.7521667	-98.793889	Middle (1/2LGR&CC)	52.94	75	0.71	
TW-2	29.7429167	-98.801667	Middle (1/2LGR&CC)	46.52	62	0.75	
TW-3	29.7536667	-98.808111	Middle (1/2LGR&CC)	186.90	64	2.92	
TW-4	29.7551111	-98.798139	Middle (1/2LGR&CC)	131.15	89	1.47	
Twin Canyon Ranch							
W4240	29.8313056	-98.728444	Middle (CC)	625.67			0.000006
W4243	29.8338889	-98.730694	Middle (CC)	70.19			0.000006
Ammann Ranch Estates							
Test Well 1	29.7733611	-98.674222	Middle (LGR&CC)	167.11	220	0.76	0.006096
Test Well 2	29.7861111	-98.674667	Middle (LGR&CC)	1624.33	193	8.42	
High Point Ranch							
Test Well 1	29.9814722	-98.635556	Middle (LGR&CC)	33.56	80	0.42	0.0002
Test Well 2	29.9873333	-98.638472	Middle (LGR&CC)	6.15	100	0.06	0.06
Test Well 3	29.9905278	-98.629778	Middle (LGR&CC)	14.71	80	0.18	0.008
Test Well 4	29.9952778	-98.630417	Middle (LGR&CC)	56.55	100	0.57	0.0004

Well	Latitude	Longitude	Aquifer	Transmissivity (ft2/d)	Aquifer Thickness (ft)	K (ft/d)	Storage Coefficient
Kendall Woods Estates							
PW-1	29.8098333	-98.577194	Middle (LGR&CC)	36.10	135	0.27	0.2
PW-2	29.8136944	-98.572639	Middle (LGR)	441.18	15	29.41	0.03
			Middle (LGR&CC)	213.90	122	1.75	0.04
PW-3	29.8121111	-98.574833	Middle (LGR)	668.45	22	30.38	0.01
			Middle (LGR&CC)	129.68	123	1.05	0.003
La Cancion							
TW-1	29.9139444	-98.607389	Lower Trinity	3.21	220	0.01	0.04
TW-2	29.9250833	-98.609889	Lower Trinity	2.81	210	0.01	0.01
TW-3	29.9195833	-98.604722	Middle Trinity (CC)	334.22	30	11.14	1
La Veranda							
TW-1	29.8423889	-98.540028	Lower Trinity	1.87	210	0.01	0.07
TW-2	29.8432778	-98.555639	Lower Trinity	4.68	250	0.02	0.05
TW-3	29.8436111	-98.540111	Lower Trinity	4.41	230	0.02	0.05
TW-4	29.8424167	-98.540111	Middle Trinity (CC)	3.48	100	0.03	0.1
TW-5	29.8460556	-98.546833	Middle Trinity (LGR)		30		--
Pfeiffer Ranch							
TW-1	29.8329611	-98.745361	Middle (LGR&CC)	3877.01	302	12.84	0.001
TW-2	29.8287306	-98.750494	Middle (LGR&CC)	157.75	262	0.60	0.01
Joshua Crossing							
TW-1	29.9201944	-98.836528	Middle (LGR&CC)	70.19	80	0.88	0.09
TW-2	29.9246667	-98.846056	Middle (LGR&CC)	70.19	80	0.88	0.05
Rio Encino							
TW-1	29.9306389	-98.642972	Middle (LGR&CC)	58.82	138	0.43	0.007
TW-2	29.9295278	-98.653333	Middle (LGR&CC)	14.71	132	0.11	0.03
TW-3	29.9310833	-98.659250	Middle (LGR&CC)	8.69	128	0.07	0.06
Woodridge							
TW-1	29.9478333	-98.839611	Middle (LGR&CC)	147.06	100	1.47	0.00001
TW-2	29.9389722	-98.842167	Middle (LGR&CC)	37.70	100	0.38	0.00001
TW-3	29.9253056	-98.842167	Middle (LGR&CC)	53.21	100	0.53	0.00001
Fair Oaks Reserve							
City Well	29.7742222	-98.626861	Middle (LGR&CC)	115.64	190	0.61	--
Cordillera West							
Kreutzberg	29.8700000	-98.654722	Middle (Hensell&CC)	30.48	110	0.28	0.00026
Horseshoe B	29.8697222	-98.646944	Middle (Hensell&CC)	50.53	113	0.45	0.00032
Gas Line	29.8661111	-98.639444	Middle (Hensell&CC)	19.25	92	0.21	0.00031
Cordillera KWW							
Test Well	29.8833333	-98.507222	Lower Trinity (Sligo)	6.42	160	0.04	--
Greco Bend							
Test Well 1	29.9767500	-98.761030	Middle (Hensell&CC)	56.15	130	0.43	0.00006
Test Well 2	29.9775700	-98.760860	Middle (Hensell&CC)	73.53	60	1.23	0.00006
Sabinas Creek							
Well No. 1	29.8653167	-98.681253	Middle (LGR&CC)	1851.60	80	23.15	--
Well No. 2	29.8683056	-98.682694	Middle (LGR&CC)	54.89	80	0.69	--

Well	Latitude	Longitude	Aquifer	Transmissivity (ft2/d)	Aquifer Thickness (ft)	K (ft/d)	Storage Coefficient
Well No. 3	29.8784167	-98.686861	Middle (Hensell&CC)	16.48	80	0.21	--
Well No. 4	29.8870556	-98.695306	Middle (Hensell&CC)	82.96	60	1.38	0.00000974
Well No. 5	29.8878889	-98.692611	Middle (Hensell&CC)	59.16	40	1.48	0.00000995
Champee Springs							
Day Well	29.8385556	-98.879000	Upper Trinity (Ed&UGR	308.59	100	3.09	1.06